
PER AMPLIORA AD ALTIORA

Dr Holmes
with the authors Complts

ON THE

HUMAN SKELETON.

Cambridge:
PRINTED BY C. J. CLAY, M.A.
AT THE UNIVERSITY PRESS.

A TREATISE

ON THE

HUMAN SKELETON

(INCLUDING THE JOINTS).

BY

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Cambridge:

MACMILLAN AND CO.

AND 23, HENRIETTA STREET, COVENT GARDEN, LONDON.

1858.

PREFACE.

In lecturing on the Skeleton my practice has been, instead of giving a detailed account of the several parts, to request the members of the class, each day, to get up the descriptive anatomy of certain bones, with the aid of some work on osteology. On the subsequent day, I tested their acquirements by *vivâ voce* examination, and endeavoured to supply deficiencies and to correct errors. I also added such information—physical, physiological, pathological, and practical—as I had been able to gather, from my own observation and researches, and which was likely to be useful and to excite an interest in the subject.

The additional information, thus collected, forms, in great part, the material of the present volume; which does not profess to give a regular description of the bones, and is not, therefore, intended as a substitute for any of the existing manuals of anatomy; but is, rather, supplementary to them.

The description of the joints has been made more complete than that of the bones; because it is less fully given in other works; and because an accurate knowledge of the structure and peculiar forms of the joints is essential to a correct knowledge of their movements.

To hear the study of the human skeleton complained of as dry and tedious is always, to me, a matter of regret. It really may be, and ought to be, one of the most interesting of studies. To the practical Surgeon it is essential. To the philosophical anatomist the human skeleton is most instructive, being related to the intelligent will of man on the one hand, and to the various members of the animal kingdom on the other. It is, moreover, the framework of nature's masterpiece, the most perfect piece of mechanism, replete with fearful and wonderful manifestations of creative skill. The contemplation of such a work is one of the noblest exercises of the mind, not merely on account of the many physical and other problems which it suggests, but, still more, because it tends to give additional force to the conviction, derived from more direct revelation, of the infinite wisdom, power and goodness of the Creator.

The illustrations were all drawn, upon stone, from nature, by my wife; and, in most instances, from specimens prepared, for the purpose, by myself.

To my friend and former pupil, Dr William Ogle, fellow of St Catharine's College, I am much indebted for valuable assistance which he has kindly rendered by sharing with me the labour of correcting for the press.

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ON

THE SKELETON.

Chemical composition of bone.

THE substance of bone has been repeatedly subjected to analysis by eminent chemists, and by none with greater care and labour than by Dr Stark[1] and Von Bibra[2], whose experiments embrace the osseous system of nearly the whole of the vertebrate kingdom. That there should in many instances have been some difference in the results of the quantitative analysis of different chemists, is not surprising when we consider how difficult it is to divest the osseous structure of the fat, vessels, membranous and other ingredients, that enter into the bones, traversing their canals, tubes and cavities, and even, according to the supposition of Hoppe and others, lining the very bone-cells and their prolongations. Some of these ingredients must necessarily be left adherent to the osseous tissue after the most complete maceration and drying, and must, in a slight degree, affect the accuracy of the results of the respective analyses, which will vary a little according to the measures that are taken to get rid of these appurtenances. There is, however, a sufficiently close agreement among several recent and accurate observers to enable us to arrive at tolerably exact conclusions respecting the more important points.

[1] *Edinburgh Medical and Surgical Journal*, LXIII.

[2] Simon's *Chemistry*, by Day, II. 399.

The composition of compact osseous tissue as deduced by Lehmann[1] from the best analyses is as follows:

Phosphate of Lime	57
Carbonate of Lime	8
Fluoride of Calcium	1
Phosphate of Magnesia	1
Mineral constituents	67
Cartilage	33
	100

To this is added, by most chemists, a small quantity (about 1 per cent.) of fat.

Animal basis.

The animal basis, therefore, forms nearly an exact third of the clean dry bone. It is often called *cartilage;* though incorrectly, inasmuch as it differs, both chemically and structurally, from cartilage. When boiled it yields gelatine, which is identical with the gluten obtained from tendons and connective tissue. It preserves its characters in a remarkable manner, having been found unaltered in bones which have lain more than three thousand years.

Changed during development.

During the process of development the animal substance undergoes a change. So long as the structure continues in the state of fœtal cartilage it contains a substance yielding chondrin; but concurrently with the subsequent infiltration of earthy matter into its texture it is converted into a material from which only gluten can be extracted. Ossified true cartilage is, however, said by Dr Sharpey to be found in the articular ends of adult long bones, lying underneath the natural cartilage of the joint, both in the moveable articulations and in symphyses, and to be in fact the deeper part of the cartilage which has been encroached upon by the calcifying process. The animal basis is here of a totally different nature from that of the bone elsewhere; for on extracting the earthy matter by means of an acid the tissue which remains has all the characters of cartilage. Cartilage also is stated to form the animal basis of the bone in a few other parts of the

[1] *Physiological Chemistry,* translated by Dr Day, III. 18.

skeleton, but only in very limited portions; according to Tomes and De Morgan it occurs in the petrous portion of the temporal bone[1].

Earthy constituents.

The phosphate of lime, which forms the chief part of the mineral constituents, is sometimes called "bone-earth phosphate," being rather a peculiar salt. It is regarded as a tribasic phosphate, consisting of 8 equivalents of lime, 1 of water, and 3 of phosphoric acid. The great predominance of this salt over the carbonate is a striking feature in the composition of bone, as compared with that of shell, in which the phosphate is either absent altogether, or exists only in very small quantities. The carbonate is a simpler salt, much more abundant in the inorganic world, and answers the purpose of the earthy material of shell sufficiently well, being in it united with only a small quantity of animal matter. But in true bone, the greater proportion of animal substance rendered necessary for the purposes of growth, &c. requires the substitution of the phosphate, which is capable of forming a harder compound with animal substance than the carbonate. In the hardest part of the skeleton—the enamel of the teeth—it is present in still greater quantity, forming more than 80 per cent. It possesses the same property as the animal matter of preserving its characters and composition for a great length of time, having been found unaltered in fossil bones. The salts of phosphorus exist in small quantities in the inorganic world, but form a very important ingredient in some vegetables, particularly those vegetables which are most nutritious, such as bread-corn, &c. Hence bone-powder is so valuable an article of manure.

Modes of combination.

The union of the animal and the earthy constituents of bone is evidently very intimate, though the precise nature of it is not well understood. The variable proportions in which they are combined to form bone, and the facility with which they can be separated, or partially separated, without destroying the shape of the bone, proves that if it be a chemical union, it is not quite of the ordinary kind.

[1] Quain's *Anatomy*, 1856, I. p. cxxvi.

Variations in the proportions slight in different bones,

Instances of slight variations in the proportions in which the animal and earthy constituents are combined are furnished by the different bones of the human skeleton. Dr Owen Rees[1], whose results are in great measure confirmed by Bibra, has shewn that the long bones of the extremities contain more earthy matter than those of the trunk; that the bones of the upper extremities contain somewhat more than the corresponding bones of the lower extremities; that the humerus contains more than the radius and ulna, and the femur more than the tibia and fibula. The vertebræ, ribs and clavicle are nearly identical as regards the proportion of earthy matter contained in them. The bones of the head contain considerably more than those of the trunk, somewhat more even than the humerus. The quantity of carbonate of lime appears to be regulated by that of the phosphate, at least the two exist in the same proportions in the most diversely constituted bones. Among mammals the bones of herbivora contain the greatest quantity of earthy matter; and human bones are said to contain the most water, the spongy bones containing more than the shafts of the cylindrical bones. The bones of birds, the granivorous more particularly, are said to contain more earthy matter, some silica and more water than those of mammals, though the experiments of Bibra and Stark are not altogether confirmatory of this. The bones of reptiles contain according to Bibra's analyses, rather less, and those of fishes decidedly less, of saline ingredients than the bones of mammals; and they further differ from them in containing some sulphate of soda and a larger proportion of water. In this respect Stark's analyses do not altogether coincide with Bibra's, inasmuch as they shew that there is no difference between the perfectly ossified bones of some fish, such as those which surround the mouth of the sturgeon, and the bones of birds or of mammals.

These differences in the proportionate quantity of the animal and earthy constituents are less than might have been expected, judging from the varying appearance and density of the several

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[1] *Medico-Chirurgical Transactions*, XXI. 406.

bones. It is probable also[1] that some of these differences, those more especially which have been pointed out between the bones in the human skeleton, may, in part, depend upon the variable proportions of the membranous and other matters remaining in the minute channels and cavities of the bones, and separable with more difficulty in some bones than others. It appears, moreover, that the *hardness* of one bone in comparison with another does not depend upon the amount of earthy matter it contains so much as on its physical structure; a cancellated bone differing in chemical composition very little from a solid bone[2]. Dr Stark concludes from his numerous experiments, "that the amount of earthy matter in healthy bones is nearly uniform over the whole animal kingdom; and that neither the solidity or sponginess, the rigidity or flexibility, the opacity or transparency of bones, depends on an increased or diminished amount of the earthy matters in their composition."

and at different ages;

It is usually stated on the authority of Davy, Schreger and others, that there is a progressive and considerable increase in the earthy constituents of the bones with advancing years. This, however, would seem to be by no means universally true. Dr Rees finds it to be the case with regard to the long bones and the bones of the head; those in the fœtus not containing the excess of earthy matter which he discovers in those of the adult. But the bones of the trunk in the fœtal skeleton appear from his analyses to be as rich in the proportion of earthy matter as those of the adult. Stark's tables shew that age does not increase the amount of earthy matter; the solid shaft of the radius of a child under six years and that of an adult above forty containing exactly the same amount of earthy matter even to a fraction. This is partly confirmed by the experiments of Bibra; the proportions of animal and earthy matter given by him being nearly the same in the fœtus of 7 months, in the man of 30 and in the woman of 78. It is supposed that those chemists who have arrived at an opposite conclusion may have included in their analyses the soft layer of cartilage which exists between the epiphysis and the shaft of

[1] Quain's *Anatomy*, I. p. cxi.

[2] Dr Rees finds rather less earthy matter in cancellated bones. Berzelius and Stark state that there is no difference.

the bone. Whether this be so or not there can be no question that fœtal bones are very hard and dense in their shafts; these being nearly as difficult to cut with the knife or saw as the corresponding parts in the adult.

In morbid conditions. In almost all the diseased states of bones (in all indeed with the solitary exception of sclerosis) and in new bone-formations, including callus, it appears that the earthy matter is deficient in quantity. This is especially the case in Rachitis and Osteomalacia, in each of which both the phosphate and the carbonate of lime are often reduced to less than a quarter of their usual quantities. It would seem in some of the instances of these diseases that the salts of lime, not being properly attracted by the animal constituents of the bone, the blood and urine become surcharged with them. The latter fluid at least has often been found in such cases to contain an excessive amount of earthy phosphates. In caries the earthy constituents disappear before the animal matter, rendering the bone around the ulcer soft and easily penetrated by a knife.

The attention of the chemist has generally been confined to the examination of the mineral elements, and we are not supplied with many particulars respecting the composition of the animal matter in morbid conditions of the bones; where mention is made of it, it is generally said to be unchanged. In one case of Osteomalacia, however, in a child, Marchand found that the "cartilage", which constituted 70 per cent. of the bones, yielded neither gluten nor chondrin. Although the quantity of animal matter is relatively great in these cases, there is no evidence that an actual increase—a true hypertrophy—of it takes place. Little also has been determined with reference to the changes in the *relative proportions of the mineral constituents*, or whether, when one is removed, it is replaced by some other. Lehmann gleans from the analyses in our possession that the carbonate of lime is first diminished and subsequently again increased in a corresponding proportion with the phosphate, in diseases of the bones; it being only in osteophytes and other new formations of bone that we find the carbonate exceeding the normal standard.

Oil in bones. A small quantity of oil, varying from $\frac{1}{2}$ to 2 per cent., is found in bones from which the marrow has been cleaned and macerated away as completely as possible. It is supposed therefore to form a natural constituent of the osseous matrix, just as it forms a constant if not an essential ingredient in the ultimate tissue of muscle, nerve, gland, and other elementary structures. It is rather more abundant in fat animals than in lean ones, and the bones of hybernating animals contain more oil before than after their winter sleep. It is increased in most diseased bones, especially in Rachitis and Osteomalacia, though the increased quantity of oil forms a less important feature in those diseases than does the deficiency of the earthy matter.

Strength and elasticity of bone,

The constituents of bone are blended in such proportions as to produce a structure admirably adapted for the purposes required. It is exceedingly strong, capable of bearing great weight and resisting great force of muscular contraction. It has been proved by experiment to possess twice the resisting property of solid oak. It is also elastic, as is shewn by the resiliency of the fibula when its shaft is pressed against the tibia, and by Mr Ward's experiment of placing the clavicle at right angles against a hard body and striking the free end a smart blow with a hammer, when the bone will rebound a distance of two feet. This elasticity is a very important quality, breaking the shocks from falls and blows and contributing very materially to preserve from injury the delicate nervous and other structures that are connected with the skeleton.

proportionate to force of muscles.

We learn, from the experiments of Rees and Bibra, quoted above, that the proportion of earthy matter is, on the whole, greatest where the bones are subject to the greatest mechanical stress, as in the shafts of the long bones of the extremities. The bones are at those parts also very dense. The density and strength of the bones varies a good deal in different persons, being, as we might expect, generally proportioned with nicety to the weight of the body and the strength of the muscles. In early life they are, relatively as well as actually, small, light and flexible, well suited to the nimble, almost incessant movements of the child, and well suited for escaping the numerous accidents to which they are then exposed. In the adult, when muscular force is the greatest, they attain their greatest size, density, and strength, being hardest in those who are strongest and most active. It has been calculated that at the age of 21 the weight of the skeleton is to that of the whole body in the ratio of 10.5 to 100 in man, and that of 8.5 to 100 in woman (the average weight of the body being about 125 or 130 lbs.)[1]. In old age, when the muscular and other powers are failing, and when the movements are consequently slow and cautious, the bones become lighter and more porous and, consequently, more fragile. These changes in the characters of the bones, whereby they are adapted to the varying conditions of the muscular system at different periods of life and under different circumstances, are brought about, not so much by an alteration in the *chemical composition* of the bone substance, as by an alteration in the *amount* of the bone substance employed; in other words, by alterations in the size and density, and consequently in the weight of the bones.

Spontaneous fracture rare.

So well is the balance preserved between the resisting power of the bones and the contractile force of the muscles, that a fracture is very rarely occasioned by the mere effort of muscular contraction. Such an accident may, however, occur under unusual exertion. Thus the arm has been broken in throwing a ball, or lifting a weight; and the patella is sometimes snapped by the sudden action of the quadriceps muscle. My colleague, Mr Hammond, was called to a strong man whose thigh-bone had been broken across the middle by the severe spasmodic contractions of the muscles of the thigh, which ushered in a fit of cholera. I attended an old man who fractured his humerus when pulling himself upstairs by the aid of the hand-rail. Instances are also related in which a hereditary fragility of the bones has been observed, leading to fractures from contractions of the muscles and other slight causes. In by far the greater number of cases of spontaneous fracture, however, some disease—commonly rickets[2], mollities or cancer—has proved to be the cause of the lesion. It may be added, as a remarkable fact, that in many of the instances of spontaneous fracture resulting from some change

[1] Lehmann's *Physiological Chemistry*, III. 35.
[2] Virchow's *Archiv*, V. 463.

in the bone, whatever be the cause of that change, whether it be old age or mollities, or even cancer, reunion has taken place in the ordinary period, or has occupied a shorter time than usual.

The Laminæ.

The laminated arrangement of the structure of bone is faintly perceived in the sections of the dry shafts of the long bones. It is still better seen when the earthy matter has been removed by steeping in dilute hydrochloric acid, after which a succession of thin layers of the remaining animal substance may be peeled off. The delicate layers into which the animal basis of bone is thus capable of being separated, are described by Dr Sharpey[1] to consist of transparent fibres decussating each other in the form of an exceedingly fine network. By reversing the experiment and driving off the animal matter through the medium of heat the calcined laminæ may be sometimes seen separated from one another. They are also not unfrequently exhibited in the clearest manner in inflamed states of the bone, when the osseous tissue has been softened by the morbid process and the laminæ have been pressed asunder by the effusion of new products between them[2]. The laminæ are most marked near the exterior of the shafts of the long bones, where they are disposed circularly, that is to say, concentrically with regard to the medullary canals. In this latter situation they are said by Messrs Tomes and De Morgan to be less numerous than is generally supposed, to be most marked in bones of full growth, and to afford a means of determining the age at which a bone has arrived. In the interiors of bones the laminæ surround the haversian canals and the cells of the cancellated portions. The laminæ visible with the naked eye and separable with the forceps are composed of more delicate lamellæ similarly arranged, and depending, not as was formerly supposed upon any particular arrangement of the bone corpuscles, but, according to the observations of Tomes and De Morgan, upon a linear disposition of the granules or granular cells imbedded in the more clear, homogeneous, or slightly granular matrix, each lamella presenting a more transparent and a more opaque portion.

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[1] Quain's *Anatomy*, 1856, I. p. cxx.

[2] This is well represented in Lobstein's *Traité d'Anatomie pathologique*, Pl. III. fig. 6.

This lamellated arrangement of osseous tissue has been compared with that seen in the sections of many urinary calculi, and may be compared also with that found in the trunks of exogenous trees, in most shells, in phleboliths, in certain coagula, and in many other structures. Indeed the tendency to a disposition in laminæ is a very remarkable feature in organized solids. Such disposition must depend upon partial intermissions in the deposition of the particles which compose those solids, or upon variations in the manner of their deposition, and would seem to indicate that a greater or less periodicity in the activity of its processes is a common occurrence in nutrition; so common that it probably deserves to be regarded as a law of nutrition. The periods of alternation, so to speak, may vary greatly in different bodies and in different textures; but general analogy would lead us to suppose that they are like those of the solar system—regular—and that they take place in the softer structures, in which their impressions cannot be traced, no less than in the bones. It need scarcely be added that periodicity is a well-established fact in many diseases, as well as in many natural processes; a fact of which no explanation can be given unless it results from some such law of nutrition as that just alluded to as a probable cause of the lamination of bone.

THE SHAPE OF THE BONES

Shape conformed to archetype.

is in each particular case moulded in adaptation to the position the bone occupies and the purposes it has to serve. Nevertheless there are certain general principles observed in the construction of the skeleton. Thus each bone is, in a greater or less degree, conformed to the corresponding bone in other animals, or rather to the archetypal plan upon which that bone is constructed in the whole animal series. For instance, a general resemblance is easily traceable in the humerus of the reptile, to that of the bird, and of man; and there is a similar resemblance between the corresponding bones of the two extremities in the several classes of animals.

Exteriors dense, interiors spongy.

Secondly, the exterior of a bone is always dense in comparison with the interior; the latter being either cancellous or hollowed out into a cavity. By this arrangement the bones are rendered much lighter than they would otherwise be with little loss of strength. This principle is carried to great perfection in birds, the interior of the bones being in them (in many of them at least) filled with air. In the delicacy, the abundance, and exquisite arrangement of its cancellated structure, however, the human skeleton exceeds that of any other animal.

Shafts and extremities.

Thirdly, the middle parts or "shafts" of the long bones are small in circumference and dense in structure, so as to make room for the fleshy bellies of the muscles which occupy the interspaces between the joints. The extremities of the same bones are expanded by a cancellated disposition of the osseous laminæ in their interior, so as to render the joints more secure, and to afford better leverage to the muscles and more room for their attachment. The wide surface of contact thus provided also serves to distribute the forces communicated from one bone to another over a large space, and prevents their operating injuriously upon any one point.

It is interesting to observe the manner in which the cancelli are arranged near the extremities of the bones so that the direction of their plates is chiefly perpendicular to the articular surface, and therefore in the line of the pressure the bone has to bear; thus affording the most effective support. This is well seen in the representations of sections of the femur and tibia. In some parts they form a dense network beneath the articular surface which serves the same purpose. (See the astragalus in plate of section of the bones of the foot.)

Although there is great difference in size between the shafts and the extremities of the long bones, there is not so much difference in the actual amount of osseous matter contained in them as might be supposed; for portions of equal length cut from both parts weigh nearly the same. In the shafts, the density of the osseous structure, through the mutual support afforded by the close contact of its particles, nearly makes amends for the smaller area upon which the weight is borne by them, and for the greater disadvantages of leverage against which they have to contend—it being always easier to break a cylinder at the middle than near either end—as well as for their more or less curved form. I say, nearly makes amends, for it does not do so completely. Hence the shafts are in the adult weaker and more liable to fracture than the extremities. Some assistance is furnished to them by ridges and processes thrown out at the parts where they are most needed, as along the concavities of the curves. These projections result in great measure from an actual thickening of the walls of the shafts; the medullary cavities not deviating to an equal extent from their cylindrical form (see plate of sections of thigh-bones). The latter, therefore, do not correspond closely, though they do in a general manner, with the shape of the exterior of the shafts.

It may be remarked, that, as a general rule, the parts at which the shafts are narrowest are not exactly at the middle of the bone; but either a little above or a little below the middle. They are the hardest parts, often the most curved parts, and the parts at which the ridges just mentioned stand out most prominently. One might suppose they would indicate the point at which ossification of the shaft had commenced; but this is not always the case, inasmuch as they do not always coincide with the canal for the medullary artery; and the latter marks the spot at which the osseous nucleus was first formed.

Curves and Twists.

The bones are in very few, or in no instances, found to be straight. The variety of curves and twists which they present gives a slight obliquity to all the movements, which has a great influence in imparting ease and grace to the carriage. Take any of the bones; it will be found that its articular surfaces do not lie in parallel planes, and the planes in which it moves upon the contiguous bones do not coincide with one another or with its own axis. Hence none of the movements of the limbs are in truly perpendicular planes; and they are, consequently, less stiff and awkward than they would otherwise be. Moreover, these curves and twists, by imparting greater elasticity to the bones, have much influence in preventing the communication of jars from one part to another, thus lessening the liability to fractures, dislocations, and other injuries of the skeleton as well as that to concussion and laceration of the soft parts. By the direction which they take they afford additional space and leverage to the muscles where those are most required; the concavity of the curve being generally on the side on which the most powerful muscles are situated, e.g. on the back part of the thigh and leg, and on the fore part of the arm and forearm. As a general rule, these flexures are more marked in short persons than in the tall; and the greater proportionate muscular strength of the former, constituting a sort of compensation for the deficiency of their stature, is, in part, attributable to the greater curvature of their bones.

Roughnesses and Processes. Besides the ridges above mentioned, which are intended to strengthen the shafts, there are many roughnesses and projecting processes which have relation to the attachment of muscles, ligaments, and other ministers of locomotion. They are found, not along the length of the bones where the muscular fibres chiefly arise, so much as near the ends of the bones where the tendinous prolongations of the muscles and the ligaments are implanted. They serve the purpose of increasing the extent of surface and connexion between the tendons and the bones, thereby strengthening that connexion to such a degree that it rarely or never gives way. Either the tendon itself may be snapped, or the process of bone into which it is implanted may be torn off; but the bond of union between the two is very rarely severed, provided the force be applied in the direction in which the tendon or ligament is intended to resist. It is necessary to add the latter proviso because, when a fibrous structure is pulled in an opposite direction to that in which it is calculated to resist traction, it may sometimes be torn away from the bone without much difficulty. Such great strength is rendered necessary by the fact that each tendinous fibre is the cord by which many muscular fibres are attached to the bone, and it has, therefore, to bear a considerable pull during the contractions of the muscle. It results from this, that a rough spot on a bone indicates it to be a point of attachment not of muscular but of tendinous or ligamentous fibres. For instance, the fleshy fibres of the subscapularis muscle are attached, not to the rough ridges on the under surface of the scapula, but to the smooth interspaces which the bone presents; the ridges being reserved for the tendinous intersecting bands of the muscle and for the processes of the subscapular fascia.

give increased leverage to muscles,

The projecting processes serve the further purpose of increasing the leverage of the muscles connected with them. They do this, of course, by distancing the point of attachment of the muscle from the centre of motion in the joint; but in proportion as power is gained in this way so must velocity of movement be sacrificed. Hence we find that where quick motion is of much importance these processes are suppressed; and it is only where great strength is required that they are thrown into much relief. Compare for instance the skeleton of the stag with that of the rhinoceros. In the latter the various processes for attachment of muscles are of huge size; in the former they are small. Compare also the insignificant tubercles at the upper extremity of man's humerus with the enormous corresponding processes of pachydermatous and many graminivorous animals. It is obvious that the fact of these processes and roughnesses for the attachment of tendons being, for the most part, situated near to the joints upon which the muscles act, must be attended with a considerable loss of power; but it is in the same degree favourable to that rapidity of movement which is, in the human frame at any rate, of far more importance. It is so because the space through which the muscles draw their respective points of insertion is many times multiplied at the other end of the bone. For instance, the space through which the tubercle of the radius is drawn by a given amount of contraction of the biceps flexor of the forearm, is many times multiplied in the hand; it is multiplied in proportion as the segment of the circle which the hand describes around the lower end of the humerus is greater than that described by the tubercle of the radius, and the loss of power is necessarily in a similar ratio. It is in consequence of this attachment of the flexor and extensor tendons near to the centre of motion of the elbow, that we acquire that rapidity of movement of the forearm which is essential to the striking a blow, the driving a nail, and the performance of a multitude of useful offices.

proportioned to the strength of the muscles.

From the relations already shewn to exist between the bones and the muscles, it will be readily supposed that these processes and roughnesses are most strongly marked in the skeletons of those persons whose muscles are the most powerful. We need not on that account necessarily infer that they owe their existence and their size directly to the traction exerted upon them by the tendons; though it is not improbable that they do so in some measure. In this and many other points in the formation of the skeleton the direct relation between cause and effect is not very obvious, often we cannot specify the proximate cause at all. That the origin of these prominences is not entirely owing to the pull of the muscles upon them, but is due, in part at least, like the curves in the shafts, &c., to the same developmental forces which call the bone into existence, is proved by their being modelled in the fœtal cartilage and by their not unfrequently possessing an independent centre of ossification, as in the case of the trochanters of the femur and the tubercle of the radius. In some parts also, where there is neither a separate osseous nucleus nor a jutting out of the fœtal cartilage, there is, in the position of the future projection, a bed of fibrous tissue upon the surface of the shaft. This is well marked along the line of attachment of the glutæus maximus to the femur[1]; and it is by the progressive ossification of this fibrous tissue, in the same manner as by the ossification of the cartilage in other parts, that the projection of the bone is effected. The tendency to a continuance of the ossifying processes at these parts goes on with advancing years so strongly, that in many instances it involves the tendons and fasciæ where they are implanted into the bones, and is the cause of the somewhat anomalous fact, that the projections, ridges and other asperities, are often more pronounced in the skeletons of the aged than in those of young persons.

The same developmental powers which originate and give expression to the ridges and processes, must be regarded as being, in some measure, the cause of the various *grooves* in which the tendons play, and still more of the *pits* into which they are here and there implanted. The latter, of which one is found on the inside of the great trochanter of the femur, and another on the forepart of the condyle of the lower jaw, serve, like the processes, the purpose of increasing the extent of surface for the attachment of the tendinous

[1] See this projection in representation of section of Femur at Birth, Pl. I. fig. 3. p. 35.

and ligamentous fibres. They are made use of where projections would be inconvenient, or where the leverage afforded by them would be useless. In the instances mentioned, the fibres of the short rotators in the one case, and of the *pterygoideus externus* in the other, run at right angles to the surfaces of the trochanter and the condyle into which they are implanted, and would consequently have gained nothing by the jutting out of the bones at the points of their attachment.

Term "duality," not applicable to the skeleton.

We hear sometimes the expression "duality" applied to the nervous system; and theories with regard to the duality of the mind have been based upon that construction of the brain in two halves, which has suggested the phrase. With as much propriety might we speak of the duality of the skeleton, or of any body whose parts are disposed symmetrically about a centre. The skeleton originally consists of a linear axis corresponding with the bodies of the vertebræ, and lying in the long axis of the embryo. From this processes jut out in pairs, forwards, backwards and on either side. Certain lateral processes projected from the trunk, extend a considerable distance and form the limbs. The several processes are almost exactly symmetrical in their shape and growth, and, as might be expected, are symmetrical also in the liability of their component parts to disease. Hence we so often find the same parts of corresponding bones affected with syphilis, rickets, ulceration, &c.[1] This mode of symmetrical development about a linear axis obtains also in the nervous, the vascular, and the mucous systems of the embryo, although as development goes on the symmetrical arrangement of some of the great circulatory and digestive organs is departed from.

So generally are the bones of the skeleton disposed in pairs, as to suggest the probability that those which occupy the median line, such as the bodies and spinous processes of the vertebræ, the vomer, occipital bone and sternum, are composed also of lateral portions

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[1] Attention was first especially directed to the relation between symmetry and disease by Dr Budd and Mr Paget in the 25th volume of the *Medico-Chirurgical Transactions*.

united together. Several circumstances tend to confirm that view; and in most of the bones mentioned it can be proved to be so by observing the manner of their development. In the case of the bodies of the vertebræ, however, this has not yet been clearly made out. Whether they are so or not—that is, whether the axial centre of the vertebrate system is resolvable into two halves or not—matters little, inasmuch as the disposition of the parts of a body symmetrically about an axis, whether that axis is real or an imaginary line, cannot constitute duality in the body itself. The term may be properly applied to the component *parts* of the nervous system and to the several bones, but not to either the nervous system or the skeleton as a *whole*.

Number of separate bones.

There are about 220 bones in the skeleton. That is to say, 220 separate bones in the adult skeleton, namely, in the skull, 24; in the upper extremities (34 in each, including the clavicle and scapula) 68; in the lower extremities (32 in each) 64; in the trunk, 56. This is exclusive of the teeth and the ossicula auditus. The number varies at different periods of life. In the child and young person they are more numerous, owing to the segments in which most of the bones are formed not having grown together. Many of these segments are the representatives of separate bones in some of the lower animals. After the adult period the number is further diminished by the union of some of the bones of the skull; for instance, of the sphenoid and occipital, and it may be also of the frontal, parietal and occipital, causing an obliteration of the sutures.

THE PERIOSTEUM.

A barrier against the extension of disease.

The bones are all surrounded by a tough fibrous membrane, the periosteum, which corresponds with the fibrous capsules of other organs. Besides other offices presently to be mentioned, the periosteum serves the very important purpose of isolating the bone from surrounding tissues, and preventing the spread of disease from them to it. Any one who has watched the progress of disease—of inflammatory disease particularly — cannot have failed to observe how very frequently it is confined to a certain stratum of tissue, spreading along that tissue for a considerable distance without encroaching, it may be at all, upon the adjacent strata above and below it. Thus an inflammation often travels over the skin covering a whole limb, or it may remain for some time fixed at any one part of the skin, without ever affecting the subcutaneous cellular tissue. So again it is no uncommon thing for suppuration and other results of inflammation to take place over a large tract of the last-named structure, without spreading to the skin on the one side or the subjacent fascia and muscles on the other. How often does pleurisy run its course without involving the pulmonary tissue; and conjunctivitis may go on for weeks or months without any detriment to the internal tunics of the eye. In this way the several strata of tissue intervening between the skin and the internal organs form a vast protection to the latter, constituting so many barriers against the invasion of disease from the exterior. Were it not for this arrangement how fraught with danger would each skin-wound prove; as there would be nothing to arrest the spread of inflammation from it to the vital organs within. That the periosteum affords this protection to the bones there can be no doubt; and the shin-bone is most deeply indebted to it for its comparative immunity in cases of ulcer of the leg. Now and then, it is true, the long continuance of an ulcer upon the skin covering the bone leads to inflammation of the periosteum and thickening of the bone immediately beneath; but this is a comparatively rare occurrence. The advantage afforded by this isolation of bone through the medium of the periosteum is most forcibly presented to us by the manner in which those bones fare, where the periosteum does not form so complete and distinct a sheet between the bone and the surrounding parts. Thus the terminal phalanges of the fingers and toes are connected with the skin by means of tough fibrous threads which run from the deeper layers of the cutis into the bone itself, blending, as it were, the skin and intervening tissue, through which they pass, with the phalanges; and cases are every day coming under our notice in which these bones, or the distal ends of them, perish in consequence of inflammation extending to them from the surrounding cellular tissue. The other bones of the hand and foot are, to some extent, circumstanced in a similar manner and are subject, though in a much less degree, to a like extension of the morbid process. This is probably the cause of our, now and then, finding the bones and joints of the carpus and tarsus involved in cases of phlegmonous erysipelas of the hand and foot.

It supplies vessels and ossifying blastema.

The periosteum is vascular, and is the means by which the external layers of the shafts and the greater part of the spongy portions of the bones are supplied with blood. The vessels form plexuses in its substance, and pass from it through the numerous foramina that are visible on the exterior of the bone, carrying with them delicate sheaths of fibrous tissue which assist in binding the membrane to the bone. From the internal surface of the periosteum also is produced a layer of soft blastema, by means of which additions are made to the exterior of the growing bones. The process of ossification going on in the inner part of this blastema contributes to the thickness of the bone; while a fresh supply is continually being added to the exterior of the blastema through the medium of the vessels of the periosteum.

Connection with shafts slight in young bones,

In fœtal and young bones the periosteum is thick and vascular, and, in consequence of the presence of a considerable quantity of this soft growing blastema, is very easily separable from the bone, particularly from the shafts of the bones. So that blows are likely to cause an effusion of blood beneath the periosteum which may induce suppuration, leading to further loosening of the membrane, and perhaps necrosis. In the operation of amputation also, unless care be taken in sawing the bone and in the subsequent sponging and other manipulations, the periosteum is very likely to be detached to a considerable distance from the cut end of the bone. The periosteum is closely connected with the epiphysial cartilages, and, passing from them upon the shafts, constitutes an important bond of union between the two. If the periosteum be dissected off, the epiphysis is easily separated with it[1]; the direct medium of union between it and the shaft,

[1] The manner in which the epiphyses are connected with the periosteum and the ease with which they may be detached together from the shaft, led Du Hamel to regard the epiphyses, as well as the intermediate and articular cartilage, as formed by a thickening of the periosteum.—*Mémoires de l'Académie Royale*, 1743, p. 143.

which is soft and blastematous, easily giving way. This is so even after ossification has taken place in the epiphysis. Hence we not unfrequently meet with instances in which the epiphysis has been accidentally detached from the shaft, but remains bound to it by the periosteum; the continuity of the latter preventing displacement, and masking the nature of the injury. In like manner, fractures of the shafts in young persons, particularly in the instance of the clavicle, are often unattended with laceration of the periosteum; and are, consequently, liable to escape detection. There may be no crepitus discoverable, the only definite indication of fracture being furnished by the facility with which the bone can be bent at the injured part.

closer in the adult and aged.

As years roll on the periosteum becomes less thick and vascular, and its connection with the bone becomes closer, the quantity of soft intervening blastema being less. At the same time the periosteum ceases to be the chief bond of connection between the epiphyses and the shafts; for the direct uniting medium between the two becomes firmer, and, gradually ossifying, holds them so strongly together, that after early childhood the line of union is capable of offering as much resistance as any part of the bone. In old persons the periosteum is very thin and its vessels are scanty. The blastema has disappeared, the process of ossification seems to encroach upon the inner layers of the periosteum itself, and the membrane is with difficulty separable from the bone. It follows, that in adults and old persons separation of the periosteum is less likely to follow from blows; and when fracture occurs, the periosteum is almost invariably torn through,—in the adult, it may be, at some part only, in the aged it is generally rent in its whole circumference.

Where closely attached.

To the spongy bones and to the long bones, near their articular ends, where it would be likely to be disturbed by the movements of the joints, the periosteum is closely connected with the surface of the bone; also, wherever it covers a prominent and exposed portion of bone, as the patella, olecranon, great trochanter, &c., also where tendinous fibres are implanted into the bone. In the latter case the periosteum is commonly absent, the tendons being implanted directly into the bone itself. In all these situations, indeed at whatever parts the union between the bone and the periosteum is close, the latter is torn through when the former is broken. It is simply torn through without being detached from the surfaces contiguous to the fracture; and there is, accordingly, little external callus formed in the reunion of the fracture. Along the shafts of long bones, and on the concave sides of flat bones, on the other hand, where the exposure to injury from similar causes is comparatively slight, and where muscular fibres for the most part arise, the periosteum is less closely united to the bones, is consequently more easily detached from them when fracture occurs, and there is usually a greater quantity of external callus produced.

By "external" callus I mean that which is often called "temporary" or "provisional" callus. It surrounds the fracture and runs up alongside the bone beneath the periosteum where the latter has been detached from the bone. The amount of it is, therefore, generally proportionate to the extent of separation of the periosteum. It is a happy provision that the periosteum is most easily detached, and the external callus is most abundantly formed, about the shafts of bones; because the dense, bloodless quality of the bone there is ill-adapted to supply the medium of reparation, and because the consolidation of the fracture is there more likely to be disturbed by movement. Near the extremities, where the periosteum is less easily separated, external callus is less required, for the bone itself is more vascular and therefore better able to supply the reparative medium, the surfaces of contact are greater and the liability to displacement is less.

Periosteal vessels supply means of nutrition and reparation.

This leads me to the remark that the periosteal vessels afford not only the means by which the bones grow at their circumference, but the chief means also by which their nutrition is maintained and by which they are repaired or reproduced when injured or destroyed. Hence, whenever we find that the periosteum has been detached by suppurative disease, or in the case of a wound, we apprehend that the exposed portion of bone will perish, except in the instance of the skull, which derives its chief supply from the dura mater. Nevertheless this is not quite so necessary a sequence as it is commonly supposed to be. Thus the end of the bone in a stump, though it may be bared of periosteum for some distance, does not always necrose. In excising the bones of an elbow-joint crushed between the buffers of railway carriages, I left the humerus bare for nearly an inch above the sawn end; but the wound healed up without any further loss of bone. In a little boy the periosteum was detached from the fibula to a considerable extent by suppuration; yet no necrosis took place. A gentleman received a severe contused wound on the shin; subsequent events proved the tibia to be exposed and necrosis was confidently predicted; but he escaped without it.

That the periosteum has much to do with the reproduction of bone is proved by experiments, which show that if a portion of bone be removed its place is supplied with much more certainty and expedition, provided its periosteum has been left, than when it has been taken away. The results of these experiments suggested to Mr Jordan[1] the plan of dissecting up and reflecting the periosteum from the ends of an ununited fracture, previously to refreshing the surfaces of the bone with the saw. I tried this in a case of fracture of the femur where bony union had not taken place 18 months after the accident, and found it no easy matter to succeed in doing it effectually, because the periosteum was so closely united to the bone at and near the fracture. The patient, a middle-aged man, died of erysipelas.

In the nasal and tympanic cavities, where a mucous membrane rests upon the periosteum, the two are so closely united together as to form one membrane. A similar cohesion also exists between the dura mater of the brain and the periosteum of the interior of the skull.

It has been already mentioned that the periosteum is commonly interrupted at the parts where tendons and ligaments are implanted into the bones; the tendinous fibres being attached directly to the elevations and depressions on the surface of the bone. Some of these tendons are found by Kölliker to contain, close to the bones, delicate isolated cartilage cells between their fibres, which, probably, accounts for the fact that ossification occasionally spreads from the

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[1] *Medical Times and Gazette*, 1854.

bone and involves a considerable portion of the tendon. In some instances the periosteum is not interrupted, but its fibres are continuous with those of the tendon. The same author describes the periosteum to consist in most places of two layers; an outer layer, composed of fibrous tissue with fat-cells, in which the vessels and nerves take their course, and an inner one, consisting of elastic tissue arranged in one or more sheets. The vessels and nerves run through this latter in their course to the bone. It was the opinion of Du Hamel and Havers that the periosteum is composed of a series of laminæ separable by maceration; and the former observer held the view, which modern anatomy[1] has shown to be partly true, that the bones increase in thickness by the addition and ossification of successive laminæ of periosteum on their exterior[2].

THE VESSELS OF BONE.

Periosteal arteries

Consistently with what has been just stated respecting the importance of the periosteum to the formation, maintenance and reproduction of bone, it is found that the osseous tissue derives its vessels chiefly from the periosteum. The arteries enter the bones at many points, through the pores seen on their surfaces, which are comparatively few and of small size in their shafts, in some places so small as to be scarcely visible with the naked eye, but are larger and more numerous in their extremities. They are accompanied by some connective tissue, and, in young bones, by some blastema. In the denser portions of the bone they are distributed in the haversian canals, losing their muscular coat, yet scarcely reduced to a capillary condition. Of the larger and more numerous vessels which enter the spongy portions a few pass into haversian canals to supply the bone; the greater number, however, break up into capillary plexuses and ramify in the marrow occupying the cancelli. We have thus both haversian and medullary

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[1] Virchow, *Archiv*, v. 409.

[2] *Mémoires de l'Académie Royale*, 1743.

systems of vessels supplied from the periosteum; the latter preponderating, even in the long bones; and the blood supplied by both is carried away by veins which return to the periosteum.

and veins. These veins pass through the larger foramina seen on the surface of the bone, not always in company with the arteries, but separately, the arteries traversing the smaller holes. The distinction between the two is well seen in the skull, where the veins occupy considerable channels hollowed out in the substance of the diplöe and pass out through distinct foramina[1]. It is said that so long as they lie in the bone the veins are deprived of their outer coats; but are still provided with valves. On a bone which has been thickened by osseous deposit in consequence of inflammation, these vascular foramina and the grooves connected with the veins, are very apparent, rendering the surface coarse and uneven.

Medullary arteries, The "medullary artery," specially so named, runs through an oblique canal in the wall of the shaft of each of the long bones, and, having reached the medullary canal, divides into an ascending and a descending branch. The blood contained in it is distributed almost entirely in capillary plexuses in the medullary tissue. In the well-injected bone of a young child its offsets may be seen taking the direction of the laminæ of the spongy tissue, and occupying the interspaces between them: thus in the lower end of the femur they take a nearly parallel direction towards the articular surface. A few of its branches, however, reach the innermost of the haversian canals and anastomose there with the periosteal vessels, so that the periosteum may be injected from the medullary artery. A vein accompanies the medullary artery, and returns the chief part of the blood supplied by it.

point of entrance and direction, The point at which the medullary artery enters is not quite constant in the same bone. Thus in the femur it may be near the upper or lower part of the shaft, or at some intermediate point; or there may be two openings, one above and the other below. The direction which it takes, however, though different in different bones, is very constant in the same bone; it has a uniform relation to the mode of ossification of

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[1] See the Plates in Breschet's work, *Sur le Système Veineux.*

the bone, and is invariably slanted towards that end at which the epiphysis is first united to the shaft. Thus it slants towards the upper end of the femur and the lower end of the tibia and fibula (Plate I. figs. 2 and 3); the reverse being the case in the upper extremity, viz. towards the lower end of the humerus and the upper ends of the radius and ulna. When there is only one epiphysis the canal for the medullary artery is directed towards that end where the epiphysis does not exist. Thus it slants towards the acromial end of the clavicle (Plate I. fig. 1), towards the distal end of the metacarpal bone of the thumb and great toe, and towards the proximal end of the other metacarpal bones. This fact was observed by Berard[1], who attributes the earlier union of the one epiphysis to the better supply of blood furnished to it in consequence of the artery taking that direction. The orifice of the canal for the medullary artery marks the spot at which the osseous nucleus first appeared in the fœtal cartilage, and the direction of the canal marks the direction in which ossification first advanced; the prelude to the conversion of cartilage into bone being usually the appearance of a blood-vessel, around which the process begins.

I believe, too, it is a general rule, though there are some exceptions, as in the ulna and the four smaller metatarsal and metacarpal bones, that the canal for the medullary artery takes the direction in which the shaft is hardest and smallest, and in which the medullary canal is most marked and reaches nearest to the end of the bone. We might anticipate that this would be the case, because the marrow is there most abundant and is peculiarly dependent upon the medullary artery for its supply of blood, in consequence of the density of the wall of the shaft at this part precluding the entrance of many vessels from the periosteum.

to be found in flat and short bones as well as in the long.

These canals for the medullary arteries are not peculiar to the shafts of long bones. They exist also in most of the flat bones; and in the short spongy bones there are commonly to be discovered certain canals for vessels larger than others, which run towards some part in the interior where the cancelli are thinnest and the cells between them largest. These parts

[1] *Archives Gén. de Médecine,* Vol. VII.

correspond with the medullary canals of the long bones; and the vessels which run to them correspond with the medullary arteries. Thus a well-marked vascular canal enters the middle of the hinder part, and runs forwards through the spongy substance occupying the middle of the body of each of the vertebræ[1]. Again, on the under side of the astragalus, in the groove between the articular surfaces, and at the corresponding upper side of the os calcis, are the openings of vascular canals which run into the adjacent cancellous texture of the respective bones, the texture there being more spongy than at any other part (see Plate of section of foot-bones). These are the points at which ossification commences in the respective bones, and I have several times seen the delicate vessels, the preludes to ossification, entering the fœtal cartilage at these spots and ramifying in these parts.

One remark which springs out of these observations is this, that the part of each bone at which ossification begins in the fœtus is that which becomes the medullary canal, or, what corresponds to it, the most spongy portion in the adult. At first it is made into solid bone, and subsequently, as development and growth go on, it becomes cancellous. Why was it not made cancellous at once, instead of being formed dense in the first instance, and afterwards altered? This apparent defect in contrivance is explained by the fact that bone is first formed at that part of the fœtal cartilage at which strength is most wanted, viz. about the middle, and, being of small size, it is made solid. Afterwards, as the bone enlarges, this central part becomes included within the layers produced around it; so that if it remained solid it would increase the weight without adding to the strength of the bone. It is, therefore, removed altogether, or reduced to an extremely spongy condition.

Anastomosing vessels.

The two systems of vessels springing, one from the periosteal and the other from the medullary trunks, anastomose, as has been mentioned, in the innermost haversian

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[1] The analogy thus suggested between the body of a vertebra and the long bones is further carried out by the former being at its middle narrower and denser on the exterior than it is at the upper and lower ends, as well as by the epiphyses next to the intervertebral substance which ossify late, and are joined to the rest of the body later still.

canals; and instances have occurred in which, the medullary artery having been obliterated, a supply of blood, sufficient for the interior of the bone, has been drawn through these anastomosing branches from the periosteal vessels.

In the twentieth volume of the *Medico-Chirurgical Transactions* is a paper by Mr Curling showing that when, in cases of fracture, the medullary artery has been torn the portion of bone supplied by it, above or below the fracture, as the case may be, undergoes atrophy, for the most part, in a greater or less degree. Such an effect may be sometimes traceable; but not in most instances with sufficient certainty to be a matter of much importance. As a general rule, it would seem that the anastomosing periosteal branches are sufficient to maintain the supply to the interior of the bone, when the medullary artery is interrupted by fracture or by any other cause.

Direction of vessels.

The vascular canals of bones form plexuses resembling the plexuses of vessels in soft structures, and like them take different, though determined, directions in different parts. In the compact substance of the long bones they run, for the most part, parallel with the axis of the shaft, and are connected by cross branches so as to form elongated meshes, like those of muscle, nerve, &c. In the flat bones they are generally parallel with the surface, sometimes radiating from a point in a stellate manner towards one or several sides. Even in the short bones there is usually one predominant direction in which the canals run, as vertical in the vertebræ, that of the long axis of the extremity in the carpal and tarsal bones, &c.[1]

Some few bones—the delicate plates of the æthmoid, palate, and lachrymal bones—have neither haversian canals nor cancelli. Consequently they have no vessels, but draw their nourishment from the periosteal plexuses which are not far removed from any part of them.

Enlargement of vessels.

The diameter of the vascular canals being greater than that of the vessels, the latter are capable of undergoing dilatation and congestion, the effects of which, giving a red colour to the bone, are seen in inflammation of its substance, and

[1] Kölliker's *Manual*, I. 291.

under other circumstances. Cases have been recorded[1] in which the medullary artery becoming enlarged in consequence of the growth of tumours, the canal has enlarged also, even acquiring such size as to admit the little finger. This capability of enlarging, possessed both by the arteries and their containing canals, explains the fact of pulsation having been so often observed in tumours of bones, particularly in those of an encephaloid character: the pulsation being evinced in certain directions more distinctly in consequence of the resistance which is offered to it in others by the unyielding framework of the bone. The cancellated structure of the lower end of the femur and of the upper end of the tibia seems to be particularly favourable to the formation of growths of this kind, which pass under the names of "erectile" tumours, "blood" tumours, "pulsating" and "encephaloid" tumours.

NERVES AND LYMPHATICS OF BONE.

Few nerves required in bone.

Nerves are supplied rather liberally to the periosteum; and a sufficient number enter the several vascular canals and ramify with the vessels, both the medullary vessels and the fine vessels derived from the periosteum, to confer on bones that low amount of sensibility which is all that is requisite, or even desirable, for the performance of their mechanical offices and for the purposes of nutrition. Indeed, the use of their nerves would seem to be displayed when any diseases or accidents befall the bones rather than in the healthy state. Under those circumstances the scantiness of their number is compensated by their being enclosed in rigid channels, and being consequently subjected to compression by the swelling of the vessels and the effusions into the canals in which they run. The peculiar dull, aching, heavy, intolerable pain experienced on these occasions rather indicates this to be its cause. It is often very intense when the nerves passing between the bone and periosteum are being stretched by the formation of a quickly growing tumour—encephaloid for instance—in this situation. Many

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[1] Stanley *On the Bones*, p. 203.

diseases of bone, however, such as some forms of ulceration, and destruction by scirrhous and epithelial cancer, may go on to a great extent without much pain. Judging, too, from the slight constitutional disturbance that commonly follows even severe and protracted operations on the bones, we may infer that the sympathies of the system are not very easily excited through their medium.

In considering the question of the nervous supply to a part, it is well to remember that, as the nutritive and circulatory processes are by no means restricted to the blood-vessels and their immediate vicinity, so the nervous functions may be, and probably are, extended to some, and that a variable, distance beyond the exact course of the nerve-fibres. Were this not so, the bundles of nerve-fibres would be quite insufficient to communicate sensory and volitional impressions to the different parts of the body. We must not, therefore, suppose that a part is entirely destitute of nervous influence because few or no nerves can be traced into it. Moreover, the solid structure of the skeleton, as we find in the instance of the teeth and nails, is capable of transmitting impressions to nerves through a greater distance than is possible in the soft parts, which renders a smaller number of nerves necessary to confer the requisite amount of sensation. That a certain amount of nervous energy is necessary to the maintenance of perfect nutrition, or at any rate to the reparation of bone, has been inferred from a few instances in which the reunion of the broken bones of paralysed limbs has been delayed beyond the usual period: though it is probable that in these instances other causes, besides the mere loss of nervous supply, may have interfered with the processes of repair, especially as in other cases of a similar kind reunion has taken place very well.

Lymphatics.

Lymphatics have not, according to Kölliker, been traced with certainty either into periosteum or bone. By other anatomists they are described as being visible on the surface of the bone and in the periosteum; and Cruikshank, after a successful injection, saw them ramifying in the substance of a dorsal vertebra[1].

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[1] *Anatomy of Absorbing Vessels*, 1790, p. 198.

THE MARROW.

When first formed, the bones, like the cartilages that preceded them, are solid. At birth they are nearly solid, with merely a narrow canal for the medullary artery and minute vacuities in the parts where cancellated structure is subsequently formed. (Pl. I. figs. 2 and 3.) As they increase in size their interiors become hollowed out and reduced to a spongy condition; or, by a further continuance of the same process of resorption, larger cavities are formed in them. By this means they are rendered much lighter with very little loss of strength. The cells and cavities thus formed are filled by a substance of low specific gravity called "marrow," which varies in its composition in different bones and at different periods of life.

Watery marrow.

In some of the short bones—the bodies of the vertebræ, the basis of the skull and the sternum more particularly—the marrow has a reddish colour and consists of connective tissue enclosing an albuminous fluid in its areolæ, with but very little oil, which accounts for the fact that these bones are soon cleaned by maceration. According to Kölliker, it contains minute, roundish nucleated cells like those which he finds in young medulla[1]. It is found on analysis that 75 parts consist of water, and the remainder of albuminous and fibrinous matter with some salts and a mere trace of oil.

Oily marrow.

In the long bones of the well-nourished adult the marrow consists of a yellow oily fluid contained in vesicles, like those of common fat, which are imbedded in the areolæ of a highly vascular membrane—the medullary membrane. It differs greatly from the marrow of the bones just mentioned in its composition, consisting of 96 parts oil and only 4 water, connective tissue and vessels. This rich oily compound is confined to the long bones of the adult, and in them, according to the

[1] The similarity of the constituents of certain tumours to these cells has induced Mr Paget to apply to them the term "myeloid" (μυελωδής, marrow-like). *Lectures on Surgical Pathology*, II. 212.

observations of the most careful histologists, does not pass into the haversian canals of the compact osseous substance. The younger the individual the less marrow do the bones contain, and the proportion of oil in it diminishes, till we come to the fœtal bones and cartilages in which there are neither medullary spaces nor marrow. In emaciated and rickety persons also, and, it is said likewise in the very aged, though probably it is not so in those who continue fat, the marrow becomes thin and watery, containing in some only a third or a fourth part of the normal proportion of oil, the other constituents consisting of water with some albumen. Hence it appears that the quantity of oil in the bones affords, as a general rule, a measure of the vigour with which the work of nutrition is conducted throughout the body, and we perceive the force of the expression of Job who, speaking of a man in full strength, says his "bones are moistened with marrow."

Composition and uses.

The oily matter of the marrow is, in its natural state, composed of the same materials as common fat, in somewhat different proportions; the oleine being in rather greater quantity in relation to the other constituents. Being of comparatively low specific gravity it is well suited to fill the cavities of the bones, forming an advantageous substitute for the bony matter which preceded it and which was cleared away in the course of development and growth. In this respect it is second only to air which fills the corresponding cavities in the bones of many birds, and which fills also the sinuses about the nose and ear in man. It cannot fulfil two of the uses commonly assigned to fat, that, namely, of retaining the heat of the body and that of giving rotundity to the frame; but it may perform the same functions in relation to nutrition, whatever they be, which the fat stored in other parts would seem to subserve. The precise nature of these functions it yet remains for physiological chemists to point out, our views respecting them being, at present, scarcely satisfactory. The marrow is well supplied with blood, by far the greater part of that which enters the bone by the periosteal as well as by the medullary vessels being distributed to it; whence we may infer, with tolerable certainty, that the changes going on in its composition are greater than those in the osseous structure itself. These changes must have reference to some purpose useful to the economy; for, were it not so, the bones would scarcely have been filled by so vascular a material.

Removed in diseases of bone. Not only does the marrow lose its perfect composition when the general nutritive powers fail; but it often becomes removed altogether when disease attacks the bone. Thus, in an early stage of inflammation, the marrow is cleared away leaving the cancelli clean and white; and in sequestra of the shafts of bones separated after necrosis, not only is the marrow gone but the cancellous structure has commonly been removed with it from the interior of the bone. After fracture the marrow disappears from the neighbourhood of the broken part and does not reappear till some time after reunion. After amputations also the oily matter is removed, and a cellulo-vascular substance is formed at the truncated end of the bone, till the medullary canal is closed up by the growth of bone over its extremity. In the case of cancer attacking a bone the marrow retains its natural oily character; at least it has appeared so in the instances I have seen. This accords with what we find when cancer affects other organs; the fatty matter in them, and indeed in the system generally, being often rather increased, relatively if not actually.

Medullary membrane. The medullary membrane is the membranous tissue in which the oil vesicles of the marrow are imbedded, in which the blood-vessels ramify, and which lines the cells of the osseous cancelli. It ministers, therefore, both to the marrow and the interior of the bone, and may be called either "medullary" or "endosteal."

Medulla in animals. The bones of fishes are solid, though very spongy, and those of the slow, heavy reptiles, like those of the human fœtus, contain no medullary cavities; except in the instance of crocodiles and some of the large land-lizards, in which they are of considerable size. Neither in fishes does the cancellated structure contain oily matter, with the exception of that of the vertebræ and a few bones of the head. In the other bones the cellular spaces are filled with a watery fluid holding a small quantity of saline matter in solution or some albumino-gelatinous substance; and in many, owing to an incompleteness of the ossifying processes, the structure is partly made up of cartilage. Hence the bones of these animals lose more than three quarters of their weight in drying, and are more transparent than other bones. Birds, when young, have an imperfect medulla (an oleo-albuminous fluid) in their bones. This is said to remain while the bones are growing. After they have attained their full size, when the bird gets upon the wing, their medullary cavities are enlarged and contain air, the principle of lightness being in them carried out to the fullest extent. The number of bones into which air is admitted is proportionate to the powers of flight of the bird. Thus in the Swift it finds its way into most of the bones; whereas, in the Ostrich and its allies the shafts of the long bones are partly occupied by medullary cancelli, and in the Apteryx none of the bones receive any air at all; these conditions represent arrested stages of the development through which the bones of the flying birds have passed. In some of the mammals which approach nearest to reptiles in their sluggish movements, the Sloths, for instance, and in Whales and Seals, which are adapted to the condition of fishes, there are no distinct medullary canals.

THE FORMATION OF THE BONES

has at all times received a very large share of attention from physiologists; and the different statements that have been made respecting it sufficiently prove the difficulty of acquiring an accurate knowledge of the several steps of the process. One thing seems certain; namely, that the bones are not in any instance a primary formation, but always result from the transformation and earthy impregnation of some pre-existing tissue, which may be cartilage, nucleated blastema, or some other.

Commencement of process.

At a very early period of fœtal life, as soon as any structure at all is perceptible, the embryonic material, from which the bones are to be formed, becomes mapped out, as a soft gelatinous substance contained, perhaps, in a delicate membrane. It may be distinguished from the other tissues by being rather less transparent; but at this early period the elementary cells and amorphous matter of which it is composed resemble very much those of the other embryonic structures. Soon it acquires a slight increase of density; perhaps from the formative cells accumulating in greater numbers in its substance. From this beginning the bones are formed in two ways. Either the formative tissue is converted into cartilage, which in course of time is replaced by bone; and bones produced in this way are sometimes called *primary* bones: or a membrane is formed upon which a soft blastema is developed, and the ossifying process takes place in this blastema, giving rise to what are called *secondary* bones.

continuance by means of Cartilage or of Blastema.

I think the terms "primary" and "secondary" are not well chosen, being likely to lead to misconceptions respecting the formation of the bones, and that they had, therefore, better be discontinued. Indeed, it does not appear to be desirable that any classification of the bones should be based upon this difference in the mode of their development. For, first, the difference between the two processes is not essentially very great, and, secondly, they are combined together in the formation and growth of by far the larger proportion of the skeleton. Thus all the long bones, if not in the very first instance formed through the medium of cartilage, are, at any rate, in great measure so produced during fœtal life; and their increase in length during the whole period of growth is mainly attributable to the ossification of the continually increasing cartilage that lies between their shafts and their epiphyses. These, therefore, if any, would properly deserve to be called "primary" bones. Yet, from a very early period, their increase in thickness is almost entirely effected, not by means of the formation and ossification of cartilage, but by the deposition of ossifying blastema upon their exterior. Again, the lower jaw would seem to be formed primarily and chiefly by the latter method, i. e. by the ossifying blastema, and should, therefore, be called a "secondary" bone, yet it is increased in the direction of its condyle, through the addition of cartilage.

Ossification in Blastema.

The process by ossifying blastema is the more simple and expeditious mode of forming bone. The blastema appears to resemble very much that of common connective tissue; it consists, that is to say, of an indistinctly fibrillated matrix with small, round, simple cells scattered through it. When ossification commences the matrix becomes rather more opaque, and its fibrous character becomes more distinct; the component fibres are collected into bundles not unlike those of fibrous or connective tissue, which are arranged, more or less, in a reticulated manner. Gradually they become more and more opaque and granular from impregnation with earthy matter, and are converted into the homogeneous matrix of bone[1], while the cells which are involved with them are supposed to shoot out into the irregularly shaped bone-corpuscles, from which the canaliculi are extended by resorption of the surrounding bone substance, or in some unknown way. The bone thus formed is from the first areolar. The interstitial spaces contain vessels and blastema, and by the progressive ossification of the latter the walls of the areolæ are thickened, and the bony tissue is rendered more solid. Nevertheless there is at the same time in many places a resorption of portions of this newly formed osseous tissue, by which the areolæ are enlarged and thrown into one another, and a regular cancellated structure is produced. By the combination of these two processes—the addition of freshly ossified layers to the areolar walls in some spots, and an absorption of them at others—a kind of internal growth is maintained, and we can thus understand how it is that the enlargement of the areolæ goes on simultaneously with the thickening of their walls.

It is now generally admitted that the facial and cranial bones, with the exception of those at the base of the skull where cartilage is required to give strength, are formed in this way by the direct ossification of a sort of connective tissue derived from blastema, without the intervention of any cartilage whatever. The blastema is formed upon, or in the substance of the membranous envelopes of the brain.

Ossification in Cartilage.

The process of ossification in cartilage is more complex and difficult to follow. In the first place, the cells of the cartilage (each containing a nucleus or nuclei) are collected

[1] Though the matrix of bone is called homogeneous, and appears to be so when seen in the usual way, it exhibits a finely granular structure under high magnifying power, and, as before mentioned, it is capable of being resolved into delicate lamellæ, which again are made up of transparent decussating fibres. It seems probable that these fibres are the resultants of the fibrous structure of the primitive blastema, and that the granular appearance is the result of its earthy impregnation.

into oblong groups, which are separated by the homogeneous, transparent, cartilaginous matrix; and calcification first takes place in this matrix, bone shooting up between the groups of cells, and forming oblong areolæ. The tissue is by this rendered opaque, and the subsequent changes in the cells are obscured. It seems that the cells become enlarged, and encroach upon the intervening matrix in which calcification is commencing, causing it to disappear more or less, and bringing the groups of cells into closer contact. According to Baur[1], each cartilage-cell now becomes the seat of an endogenous cell-formation; in place of the single vesicular nucleus, which may already be regarded as a secondary cell, several vesicles of the same kind make their appearance; and this brood of cells becomes the starting-point of all the subsequent changes. For, the cavities of the parent cells being thrown together by the disappearance of their septa, part of this new generation of cells is transformed into blood-vessels, fat-cells, or medulla-cells; and those lying nearest the periphera, in each group, are converted into blastema, in which the process of ossification goes on in the same manner as in the blastema formed from membrane. There is now, therefore, a calcified matrix of cartilage forming oblong areolæ in which are enclosed ossifying blastema, blood-vessels, &c. This cartilaginous matrix has already been greatly reduced by the enlargement of the cartilage-cells, which has taken place at its expense; and it is believed that, in process of time, it is entirely absorbed, as well as the walls of the cartilage-cells, to make way for the new bone substance formed from the blastema. The enlargement of the areolæ by the absorption of their walls at some parts, and the thickening of those walls at other parts by the ossification of successive strata of the blastema, probably takes place just as if the cartilage had never existed.

A complete replacement of one tissue by the other takes place,

It appears, therefore, from what has been stated, that when ossification is carried on in cartilage, a complete molecular replacement of one substance by the other takes place; and that the organic basis of bone is no more anatomically than it is chemically identical

[1] Zur Lehre von der Verknöcherung des primordialen Knorpels—von Albert Baur in Tübingen. Müller's *Archiv*, 1857, s. 347.

with the matrix of hyaline cartilage. The latter is incapable of true ossification; its calcification is a process accompanying ossification, it is true, but one of an essentially different nature. The osseous substance which makes its appearance in cartilage is a new formation in the cartilage cavities, being preceded by the formation of a kind of connective tissue, which is evolved in this instance by the aid of the cartilage-cells just as in other instances (the calvarial bones, &c.) it is formed by the aid of a membrane. Connective tissue is thus, in the opinion of Baur, the only foundation of the formation of bone.

or a transformation.

The exact identity of bone which has been preceded by cartilage with that formed from membrane favours this opinion. Other observers, however, think that more or less of the cartilaginous matrix remains, and becomes impregnated with earthy matter, at the same time that gelatine is substituted for its chondrine. They think also that the cartilage-cells or their nuclei in some way undergo transformation into bone-corpuscles, and that the cavities and canals of bone are hollowed out in its substance by the resorption of the newly formed osseous tissue. Kölliker and Virchow[1] find that the cartilage-cells undergo an irregular thickening and calcification of their wall, with the simultaneous formation of canalicular vacuities in it. This thickening of the cell-walls takes place, in part, at the expense of the cavities of the cells, which become indented and gradually reduced in size, and finally are converted into the bone-corpuscles, a communication having been already established between them and the canaliculi formed in the substance of the thickened and calcified cell-wall.

All the bones of the human body, except those of the head and face just mentioned, are at first formed, in part at any rate, from cartilage, and are said to originate in cartilage. Some of them are

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[1] The metamorphoses of the cartilage-cells and of the cells of ossifying blastema have been traced by Virchow (*Das normale knochenwachsthum und die rachitische Störung desselben*, Virchow's *Archiv*, v. 409) in rachitic bones, where they are not so much obscured as in the healthy state by the infiltration of earthy matter; this latter part of the process of ossification being imperfect and delayed in those bones, although the changes in the cells take place with nearly their usual rapidity. Kölliker also formed his views in part from observations made on rachitic bones.

osseous at so early a period of fœtal life, and ossification goes on so quickly through nearly their whole extent, for instance the clavicle, the ribs, and the shafts of the long bones, that it would seem not improbable they may be developed in the first instance from blastema, instead of from cartilage as generally supposed; but I have not been able by careful examination to assure myself that this is the case. Whether the ossification be commenced in blastema or not in these bones, it is certainly carried on by means of cartilage in the direction of the length of the shafts and in the epiphyses. The generally received opinion that the shafts are evolved from cartilage gains confirmation from the observation of Dr Sharpey, "In the tibia of a sheep, at a time when the whole embryo is not more than an inch and a quarter in length, we can plainly see that the substance consists of cartilage-cells embedded in a pellucid matrix[1]."

The time at which the process of ossification commences does not at all follow the order in which the primordial cartilage is laid down at the various parts of the skeleton. Thus the cartilage of the vertebræ appears before there is any trace of the clavicle, yet the ossification in the latter commences at a much earlier period than it does in the former.

Ossification in femur.

Let us trace briefly the process of ossification in the human femur. At first the position of the bone is occupied by a hyaline substance, as it is called, consisting of common formative cells. These become gradually, in greater part at any rate, converted into cartilage, which, being composed of cells embedded in a strong, though transparent and structureless, intercellular matrix, gives sufficient firmness to the part to enable it to resist the slight forces that the rudimentary fœtal muscles are able to exert upon it; at the same time it is capable of being formed and shaped more easily and quickly than solid bone, whilst it is lighter, more in harmony with the muscular and other structures, and more flexible. In the second month, ossification begins about the middle of the shaft and quickly travels upwards and downwards along its entire

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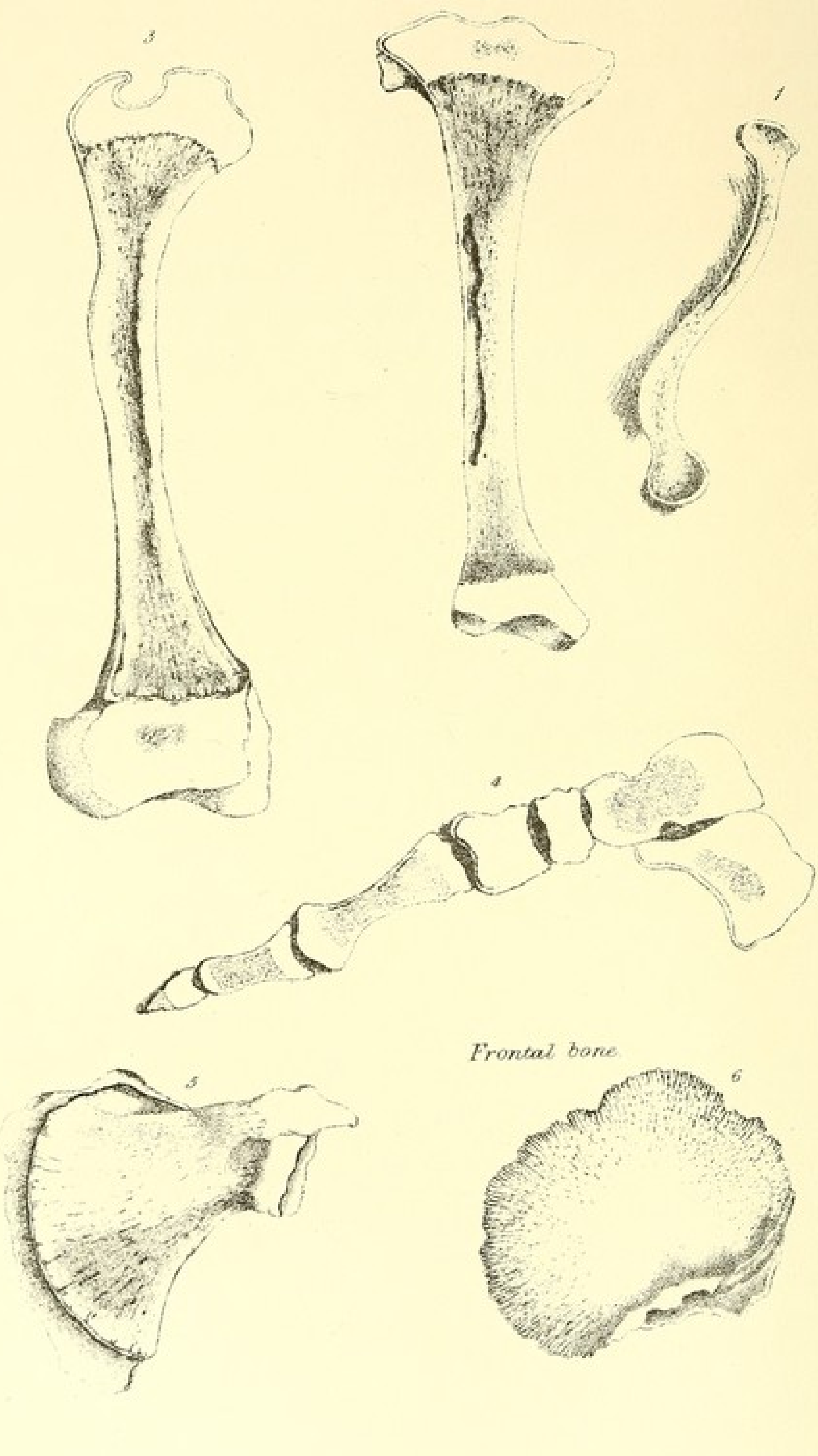
[1] Quain's *Anatomy*, 1856, Vol. I. p. cxxx.

Plate I.



length. Still the upper and lower ends are cartilaginous, and remain so for a long period after the complete ossification of the shaft. Not till some time in the last month of fœtal life does an ossific nucleus appear in the lower extremity.

Resorption of osseous tissue.

The bone is at first made solid or nearly so, the canals and cancellated spaces being subsequently caused by the resorption of the newly formed osseous tissue. Hence we have in ossifying bone, at the same time and almost in immediate contiguity, two processes going on—a formation of bone and a resorption of its substance; the latter scarcely less energetic than the former. It is by the continuance of this process of resorption that not only the haversian canals and the cells of the cancellated texture, but the larger cavities—the medullary and others—are formed. The spaces so formed are at first occupied by blastema, of which part becomes converted into vessels, medulla-cells, fat-cells, and areolar membrane, while the part lying nearest to the bone-wall in each cavity and canal is (as described at page 36) transformed into connective tissue, by the stratiform ossification of which subsequent additions are made to the bone-wall, and the process of internal growth is maintained.

DESCRIPTION OF PLATE I.

Bones at the time of Birth.

Fig. 1. Section of the Clavicle, shewing the narrow stratum of cartilage at either end of it. In the lower which represents the sternal end an osseous nucleus is subsequently developed. The narrow channel for the medullary artery is seen running from near the middle towards the acromial end (page 25).

Fig. 2. Section of Tibia. Osseous nucleus in the upper epiphysial cartilage. Narrow channel for medullary artery running obliquely downwards (page 25).

Fig. 3. Section of Femur. Osseous nucleus in lower epiphysial cartilage. Narrow channel for medullary artery running obliquely upwards (page 25). The shaft bulges outwards at attachment of glutæus maximus (page 15).

There is but little cancellous tissue in these bones, the shafts being of nearly uniform density throughout.

Fig. 4. Section of inner part of foot and great toe. Osseous nucleus in os calcis, astragalus, metatarsal bone, and both phalanges.

Fig. 5. Scapula. The acromial and glenoid parts are quite cartilaginous. The circumference of the bone is furnished with a cartilaginous border, except along inferior costa.

Resorption an active process in fœtal life.

The cotemporaneous working of these two processes—formation and resorption—in the fœtal state is not by any means confined to the bones. The latter is in operation with scarcely less activity than the former in many other parts. By it the various cavities and canals of the body, as well as their external orifices, are hollowed out in the soft parts; and the failure of this agency in development leads to a variety of malformations, such as an imperforate state of canals, what is called "atresia" of orifices, the persistence of fœtal structures, to wit the membrana pupillaris and the omphalo-mesenteric cord, &c. To the same cause may probably be attributed some of the so-called adhesions of membranes. Thus we not uncommonly find complete adhesion of the pleura or pericardium, in young subjects, and in persons in whom there has been no sign of inflammatory affection or other disease; in some of these cases it is quite probable that the process of resorption, by which the serous surfaces should have been separated and the cavity formed, has never been carried out, and that they are, therefore, examples rather of imperfection of development than of subsequent disease.

Epiphyses and apophyses.

To proceed, however, with the formation of the thigh-bone. Near the end of the first year after birth a third centre of ossification appears in its upper end. The bone now, accordingly, consists of two extremities, or *epiphyses*, with an intermediate shaft, or *diaphysis*. These remain separate, that is to say, united only by intervening cartilage, for many years, indeed

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DESCRIPTION OF PLATE II.

Sections of long bones from young subject (æt. about 10), shewing the epiphyses and the line of cartilage between them and the shafts.

Fig. 1. Upper and lower extremities of Femur.
2. Do. of Tibia and Fibula.
3. Metatarsal bone of second toe.
4. Metatarsal bone of great toe.
5. Phalanx of one of the toes.
6. Upper and lower ends of Humerus. A, B, C, separate nuclei for outer and inner parts of the lower articular portion, and for the inner condyle.
7. Upper and lower ends of Radius and Ulna.

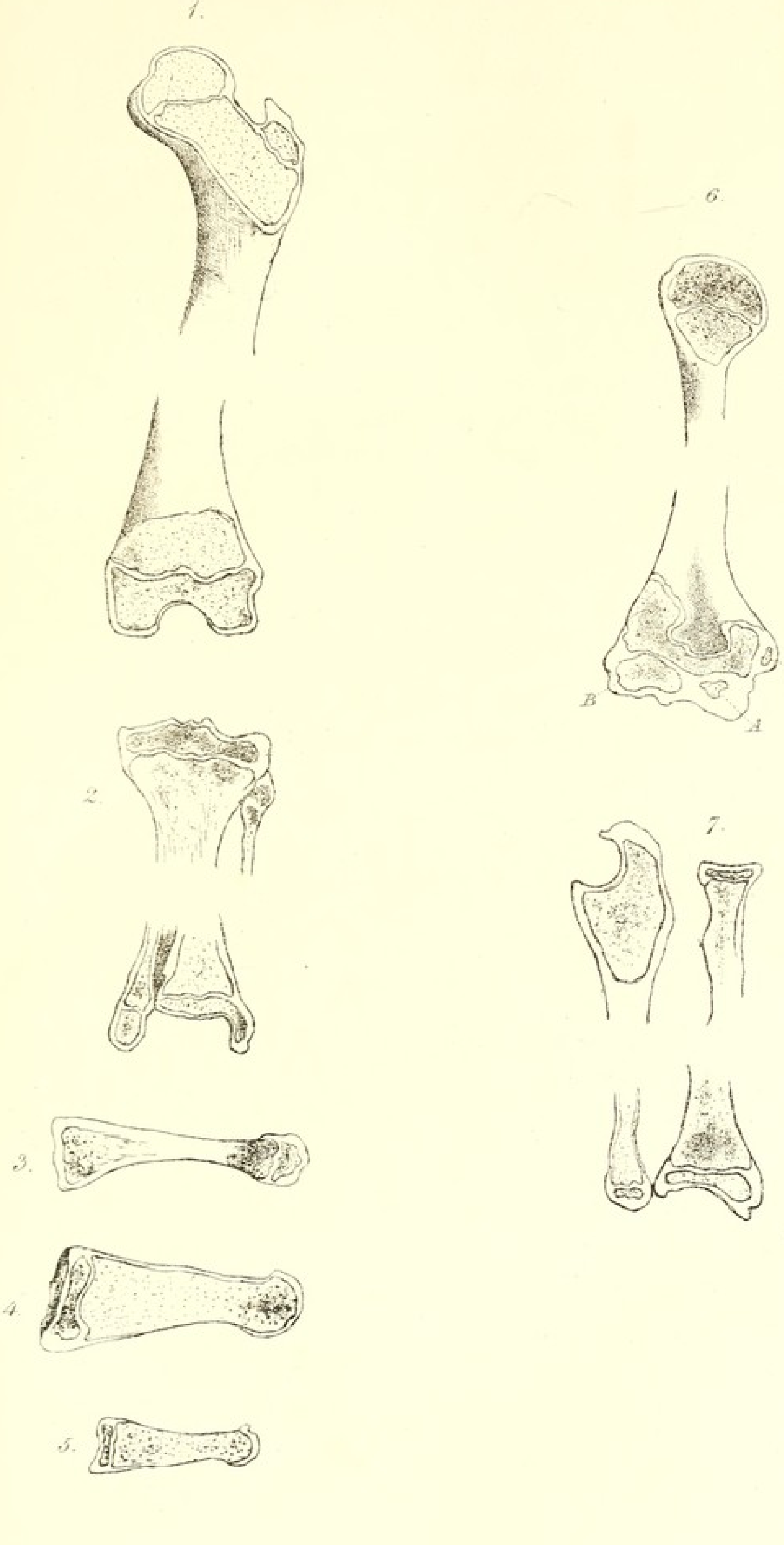

Plate II.

throughout the whole period of growth; the superior epiphysis is ossified to the shaft at about the eighteenth and the inferior not till after the twentieth year. At about the fifth year a fourth ossific centre is developed in the cartilage of the great trochanter, and a fifth centre makes its appearance in the lesser trochanter at about the fourteenth year. These latter are sometimes called *apophyses*.

Most of the long bones are developed in this way, consisting at first of a diaphysis with two epiphyses (the clavicle and the long bones of the hand and foot have only one), and, in some instances, one or more apophyses.

The epiphysis first ossified is the last to be united to the shaft.

It is a curious fact, that the union of the various apophyses to the epiphyses and of the epiphyses to the shaft takes place in the inverse order to that in which their ossification began. Thus the lesser trochanter of the femur obtains an osseous union to the rest of the bone first; the great trochanter next; then the upper epiphysis, and last of all the lower epiphysis is joined to the shaft. So many other instances of a similar relation between early ossification and late coalescence of parts are to be observed in the skeleton of man and in the lower animals, that it may be regarded as a law in the development and growth of the bones. A few instances have occurred, in which the union of the epiphyses with the shafts has been delayed much beyond the ordinary period. Otto[1] observed all the epiphyses separate in the skeleton of a man æt. 27, and in others æt. 22 and 23.

Articular cartilage not ossified.

The ossification in the cartilage of the epiphyses not only commences later but proceeds more slowly than in the shafts. It is remarkable that, although the cartilage of an epiphysis presents throughout the same characters, ossification takes place in a part of it only; a thin portion next the surface of the joint remains unossified, and forms the *articular cartilage*. This becomes in course of time somewhat more opaque and more dense; but I am not aware that it has ever been known to be converted into true bone, even in morbid states or in old age.

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[1] *Path. Anat.* by South, p. 126.

It has already been mentioned, that the canal for the medullary artery is directed towards the epiphysis last formed; and, therefore, towards the one first united to the shaft. These relations are almost invariable, though I do not know what especial purpose is served by them.

Connection of epiphyses with shaft comparatively slight.

The medium connecting the epiphysis and the shaft, where the work of ossification is going on, is softer than any other part of the bone; and separation of the two is no uncommon thing in children. When this accident occurs, a thin layer of the calcifying cartilage generally remains with the epiphysis, and may cause a crepitus to be perceived if the parts be moved upon one another. This will also be found to be the case when the epiphysis is torn away from the shaft of a fœtal bone after death. The soft connecting medium may, during childhood, be the seat of acute ulceration, leading to separation of the epiphysis from the shaft; a fact which has not received the attention demanded by its importance and the frequency of its occurrence. It must not be forgotten, however, that advantages, more than outweighing these inconveniences, accrue to the young skeleton from this subdivision of its skeleton and the interposition of cartilaginous plates between its segments. Besides the greater facilities for growth thus afforded, its flexibility is thereby greatly increased; and its escape from injury during the many falls incidental to this time of life is, in no small degree, attributable to this cause. With reference to this latter point it may be remarked, that in the reptiles which crawl and push themselves along the ground, and whose skeletons are accordingly not subjected to sudden jars—the crocodile and tortoise for instance—there are no epiphyses at the ends of the long bones; the growth continuing at their extremities through the medium of layers of ossifying cartilage, retained between the articular cartilage and the ends of the bones, in the same manner as at the condyle of the lower jaw and at the acromial end of the clavicle in the human skeleton. Whereas in the leaping frog the extremities of the humeri and femora long remain as separate epiphyses[1].

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[1] Owen's *Homologies*, p. 105.

Uses of apophysial nuclei.

There are probably also some additional reasons for the development of separate osseous centres in the epiphyses of the long bones, a knowledge of which will give some more satisfactory explanation than we are at present able to find of the absence of such centres in some situations; for instance, at the acromial end of the clavicle, and at one or other end of each of the long bones of the hand and foot. There must be also some especial reason for the frequent formation of apophyses or separate osseous nuclei at the extremities of most of the projecting processes in the skeleton. They are so common in these situations that we may search with confidence for an epiphysis as the normal appendage to every prominence which stands out in a marked manner from its bone, such as the trochanters of the thigh-bone, the spinous processes of the vertebræ, &c. This led me to look for an epiphysial nucleus at the summit of the odontoid process of the axis (see Plate VII. fig. 4). These nuclei are often very thin, situated at the very extremities of the processes, not formed till late, till the ossification of the processes is nearly completed, and they do not long remain separate. They cannot, therefore, contribute much assistance in building up the processes, and one is rather at a loss to discover their use. To say that they correspond with similar separate portions in the lower animals helps very little; as the question still presents itself, "what purpose do they serve in them?" inasmuch as in them also these apophyses soon become united with their processes, very few if any of those nuclei to which I now refer remaining as permanently separate bones in any animal skeleton.

Growth of bones in length.

We have next to consider the mode of growth of the bones. It must be remembered that the present remarks apply to the femur and other bones of the like kind. They grow in length, and they grow in thickness; but the increase in the two directions is not effected in the same manner. The growth in length takes place chiefly through the medium of the cartilage interposed between the shaft and each of the extremities, which is continually receiving additions to its thickness, and as continually undergoing ossification, in the part next the shaft. That the length of the shaft is thus increased by additions to its ends, instead of by interstitial growth, was shown long ago by the experiments of Hales and John Hunter. The latter bored two holes in the tibia of a young pig and put a shot into each, measuring on a card the distance between them; when the pig was full grown the holes were found at exactly the same distance from each other as at the first.

A series of preparations illustrative of the same fact are to be found in St Bartholomew's Museum. The experiments have been repeated in the tibia by Flourens[1] with the like result. It appeared from these that the growth at the upper extremity of the shafts exceeds that at the lower. This probably has relation to the fact that, in the tibia, the upper epiphysis remains separate from the shaft to a later period than the lower, permitting the ossifying process to go on longer at that end of the shaft.

Growth after excision of the knee.

The fact that, the growth of a bone in length takes place chiefly through the medium connecting the epiphyses with the shaft, has of late assumed a greater practical importance since the successful revival of the operation of excision of the knee. It is maintained by some, that if the operation be performed in children the limb will not grow in like proportion with its fellow, and will, therefore, be comparatively useless. This has not been found to be so in all cases; and it is highly probable that the subsequent proper growth of the limb will depend, in a great measure, upon the quantity of bone which is sawn away. If the epiphyses were completely removed and the shaft of the femur became directly united with that of the tibia, we should have much reason to fear that the objection urged against the operation might prove valid. But if care be taken to leave a thin slice of the epiphysis in connection with each of the bones, and if the case proceeds favourably, it is probable—indeed experience has proved it to be pretty certain—that the growth will go on with little interruption and a useful limb be retained. It should be borne in mind, in reference to this point, that as the growth in length takes place almost entirely by addition at the ends of the *shafts*, and ossification advances from them into the cartilage, which is in continual process of formation between them and the epiphyses, the epiphyses do not increase much in depth, and do not, therefore, as growth advances,

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[1] *Théorie Expérimentale de la Formation des Os*, p. 19.

maintain the same relative size with regard to the shafts which they had in the fœtal and infantile periods. Hence it is advisable, especially in the case of the tibia, where the epiphysis is thin, to carry the saw as near to the articular surface as possible.

Growth in thickness. The increase of the bones in thickness is effected, not through the medium of cartilage, but by the formation of ossifying blastema between the periosteum and the bone. This blastema corresponds with that which is produced in the cavities and canals in the interior of the bone, and ossification takes place in it in precisely the same manner. At the periods when growth is most rapid the blastema on the exterior of the bones is most abundant, and the connection between the periosteum and the bone is slight, which accounts for the fact, already mentioned, that the periosteum may be easily torn away in fœtuses and young persons.

The new-formed subperiosteal bone, being at first porous and rather rough in consequence of its incomplete formation, and in consequence of the large size of the cavities and spaces for vessels and unossified blastema in its substance, has been called by Virchow "pumice-stone-like" osseous matter. Gradually it becomes condensed by the ossification of the blastema contained in its pores and canals, and is rendered smoother and harder. The rough pumice-stone-like condition of the exterior of the bones is very remarkable in some cases of rickets where the ossifying processes go on hastily and imperfectly. The bones in such instances sometimes acquire double their natural size, but long remain light, rough, and crumbling. In course of time, however, even in these the crevices may be filled up, a smooth surface produced and greater solidity given.

In the adult the blastema ceases to form. There is consequently a cessation of growth on the exterior of the bone, and the connection of the bone with the periosteum becomes more firm. In the old person the ossifying process often recommences. It does not appear, however, then to take place through the medium of a blastema, but rather to extend slowly from the bone into the structure of the periosteum and of the tendinous structures implanted with it into the bone. This gives rise to those nodules and spicules which so often roughen the exterior of the bones of the aged, and accounts for the close adhesion and thinness of the periosteum commonly observed in them.

Formation of the medullary cavity.

It has already been stated that the bones are originally solid, and that a process of resorption of the osseous substance follows very quickly upon its formation, giving rise to the various cavities and canals. At birth the cancellous spaces are few and the medullary cavities very small, mere canals containing the medullary arteries and a small quantity of fœtal marrow. As the child grows, and more particularly as the bone is thickened by new deposit on its exterior, the medullary cavity is enlarged and the cancellous spaces are increased. So that here again, as in the longitudinal increase, there is no need for interstitial growth; the bone receives continual additions on the exterior, and undergoes continual absorption at the interior. The two processes—the external addition, and the internal absorption—are proportionate to one another, and are carried on in such due relation as is required to bring the bone to its proper adult size and weight[1]. After these have been obtained, the hollowing out of the interior ceases, as well as the growth of the exterior; and a considerable period elapses during which the bone remains stationary, or nearly so. Again, in old age the two processes come into activity: the medullary cavities and the cancelli become enlarged, and ossification receives a new impulse on the exterior. The proportion between the two processes is, however, now the reverse of what it was before. During the ascent to the adult state, addition was greater than absorption, so that the bones gained in weight. In the decline to old age, absorption is greater than addition, the

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[1] Flourens believes the medullary membrane and the periosteum to be identical, and that the former is the agent in the resorption of the interior, as is the latter in the formation of the exterior. His experiments, however, do not appear conclusive on these points. *Théorie Expérimentale de la Formation des Os*, Paris, 1847, p. 34. By varying his experiments he finds that the functions of the two membranes may be reversed, the medullary membrane being made the agent in reproducing and the periosteum in absorbing the bone (p. 42). The small bones of one animal introduced into the interior of the larger ones of another become gradually absorbed, just as the ivory pegs inserted into the bones in cases of ununited fracture, in process of time, become roughened, and finally disappear.

hollowing out of the interior is more marked than the ossification on the exterior; indeed the latter can sometimes scarcely be perceived; and there is consequently a loss of weight.

Modelling process on the exterior.

The association of absorption with deposition, remarked by Hunter and called by him the "modelling process," is not entirely confined to the interior of the bones. It takes place sometimes on the exterior, contributing to their shape and to their lightness. Thus the flat cranial bones, when fully formed, are thinnest near their centres, the very parts where they were thickest at an earlier period; and in the scapula the laminæ which form the middle of the infraspinal space become gradually thinner and more transparent as the edge of the bone becomes thicker. Occasionally they are entirely removed, leaving an aperture or apertures which are closed by fibrous tissue. Thus it happens that in old age, and in some cases of mollities, the flat bones are rendered thinner and the shafts of bones are rendered smaller, and, at the same time, it may be, more compact, by the approximation of their laminæ.

Interstitial growth.

These statements respecting the growth of bone are, doubtless, on the whole, true; and a bone may therefore be placed, as regards the manner of its increase, if we leave the process of absorption out of the question, nearly on a level with a shell, inasmuch as, like a shell, it grows by the addition of fresh laminæ deposited upon it through the vessels of an external membrane. It is difficult to divest oneself entirely of the idea of interstitial growth taking place to some extent in the bones, even if it be only as an adjunct to the other means above described; but the more our knowledge of the changes that take place in bones becomes extended, so much the more do we find the processes resolved into mere addition at one part and subtraction from another. The quantity of animal matter in the bones, however, and the analogy of other tissues are suggestive of a certain amount of interstitial growth, and lead us to the conclusion that this question must be regarded as not being at present quite satisfactorily determined.

Ossification of short bones.

The ossification of the short bones takes place on much the same plan as that of the long bones; except that they are formed in greater proportion from cartilage than from periosteal blastema. There being also no great increase of size in any one direction they do not require epiphyses. Accordingly the os calcis and the bodies of the vertebræ are the only ones furnished with them.

For a detailed account of the formation of bone, the results of experiments with madder, &c. I must refer to other books, such as the last edition of Quain's *Anatomy*, or Kölliker's *Manual of Human Histology*. There are, however, a few additional points of a more general character to which I would direct attention.

Pressure influencing the shape of bones,

The shape of the bones (and here it may be remarked that the uniformity with which they acquire their proper shape is truly marvellous) must be due chiefly to those same developmental forces whereby the shape of the body generally is determined. Future investigation may point out the proximate causes by which shape is evolved; at present we have little or no clue to them. There are, however, some few secondary agents—assistants as they may be termed to the primary developmental processes—whose influence we can trace in moulding the shape, &c. of the bones: one of the chief of these is Pressure. The effect of its operation may be observed in a variety of ways. Thus the modelling of the cranial, thoracic, and other bones upon the parts enveloped by them must be, in some measure at least, a result of the pressure of those parts upon the osseous material in its soft growing state. The furrows and channels of the bones are, in like manner, partly originated and preserved by the pressure of the tendons, nerves, and vessels upon them. They do not exist when these are absent; and they disappear, becoming filled up, when these are removed. The curvatures of the bones, though chiefly attributable to the forces of development (page 15), may also, in some slight degree, be owing to the influence of pressure; some to the pressure of adjacent organs; some to pressure caused by the action of the muscles pulling upon them in the fœtal state, or by the weight of the body compressing them afterwards. It has been before remarked, and may be again mentioned in connection with this subject, that the bones are, as a general rule, most curved in those persons whose muscular strength is greatest, that is to say, where the pressure upon them resulting from muscular action is greatest; weak persons, on the contrary, provided they be not rickety, have, for the most part, comparatively straight bones.

and the growth. Another interesting point, connected with the influence of pressure upon the shape and size of the bones, is the fact, that the growth of one bone is very commonly arrested by its meeting with another; the tendency of both to increase being checked by their mutual pressure. Thus the spreading of the cranial bones beyond their proper limits is, in the natural state, prevented when their edges meet. The want of this check is observable in cases of hydrocephalus, where the bones go on growing beyond their natural size because their edges are kept apart by the increasing fluid of the ventricles. A still better example of the same thing is afforded by the palate. The alveolar and palatine processes of the opposite maxillary and palate bones ordinarily coalesce with one another and with the vomer in the median line, and put a stop to one another's growth. Supposing, however, that in consequence of an imperfection of development, the maxillary and palate bones fail to reach the middle, then, as may be seen in a specimen preserved in the Cambridge museum, the vomer and intermaxillary bones grow on beyond their proper level, and project in front of the line of the alveolar arch. In a case where the zygomatic process of the temporal bone was extremely short the deficiency was supplied by a compensatory elongation of the malar bone[1]. In congenital deficiency of the nasal and lachrymal bones their place has been supplied by the maxillary bone, and in that of the frontal bone the parietal has become preternaturally enlarged[2]. Cases of congenital dislocation of the joints sometimes furnish illustrations of the same thing. Thus the deficiency of the external condyle of the humerus, which is an attendant on this malformation at the elbow, is usually found to be associated with such preternatural elongation of the neck of the radius, that the

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[1] *Treatise on Fractures, &c.* by R. W. Smith, p. 280. This anomaly reminds us of the natural condition of the kangaroo, in which the malar bone extends to and forms part of the glenoid cavity for the lower jaw.

[2] Otto's *Path. Anat.* by South, p. 129.

extremity of that bone reaches to the same level with the olecranon process of the ulna[1].

Effect of removal of pressure.

An illustration of the effect of the *restraining* influence of habitual pressure upon the growth of bones is afforded by the instances in which it has been removed. When the biceps tendon has been ruptured or torn away from its groove in the humerus the groove soon becomes choked up by bony growths in the interval between the condyles. In cases of unreduced dislocation of the humerus and femur the glenoid cavity and the acetabulum become filled up with knotty growths of bone, to a greater or less extent, the cartilages lining them having been previously replaced by a sort of fibrous structure through which the ossification extends from the bottom of the cups. At the same time it is to be remarked that the edges of the cups become absorbed, and the displaced bones adapted in shape to their new position; this being partly, if not entirely, a result of the unusual pressure to which they are subjected in consequence of the altered relation of the parts. Similar changes follow the removal of the teeth; the bottoms of the sockets being filled up, and the edges absorbed. It has been noticed that contraction of the optic foramen from growth of its margins sometimes follows wasting of the nerve; and thickening of the skull, by growth of its internal table and diplöe, is a well-known attendant upon some forms of wasting of the brain.

Pressure promoting absorption.

The influence of pressure also in promoting the *absorption* of bone is abundantly illustrated in all pathological collections. It is found, indeed, that bone yields to pressure more readily than some other textures. Thus a tumour upon the exterior of the dura mater will make its way through the skull, whereas a similar tumour upon the inner surface of that membrane grows inwards, encroaching upon the brain; and in cases of aneurism of the aorta the intervertebral substances remain intact, standing out in strong relief, while the bodies of the vertebræ may have been destroyed, even to the exposing of the spinal cord.

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[1] Adams in *Cycl. Anat.* II. 77.

Relation between the development of the soft parts and the bones.

The formation of the bones is, as one might anticipate, very closely connected with that of the adjacent soft parts, both of those which lie upon their surface and of those which they cover. I cannot call to mind any instance of a decided failure in the development of a portion of the skeleton without its being attended by a proportionate, or nearly proportionate, failure in the development of the contiguous over and underlying soft parts. Thus in the several varieties and degrees of acephalous monstrosity, the failure in the formation of the brain is about equal to that of the skull; and the hairy scalp, the dura mater, and the intervening tissues are blended in a homogeneous membranous envelope at the line where the development of the skull ceases. The same thing may be observed in the corresponding condition of the spinal column, called *spina bifida*. In it the deficiency in the vertebral arches is always associated with some deficiency or aberration in the cord, the skin being also generally imperfect. In the worst cases, where the vertebral arches are wanting, the cord and the rudimentary skin are fused and expanded together in the form of a common membranous envelope. A fissure in the alveolar processes of the upper jaw is usually (always if it be a complete cleft) associated with hare-lip. A deficiency in the body and symphysis of the pubes is always accompanied with an imperfect formation of the corresponding part of the abdominal wall and the fore side of the bladder, leaving the posterior surface of the latter and the openings of the ureters exposed, and giving rise to the malformation called *ectopia vesicæ*. The like deformity in the chest, called *ectopia cordis*, consists in a partial or complete absence of the sternum and ribs, with more or less deficiency in the pericardium, pleura, heart, and lungs[1].

[1] In spina bifida though the vertebral canal is incomplete the vertebral arches are not always defective. They are sometimes found to have acquired nearly or quite their natural length; but appear to have been pressed outwards by the protruding sac of the neural membranes, instead of approaching each other from opposite sides and coalescing in the middle line. In a pelvis, which I lately had an opportunity of examining, taken from a young person with ectopia vesicæ, the pubic bones presented a somewhat similar condition. They were formed naturally or nearly so; if anything

Relation between bones and muscles.

This relation between the development of the bones and that of the soft parts extends also to the adaptation of the structure of their respective tissues to one another. The bones of the thoroughbred, corresponding with the hard, wiry, active nature of its muscles, are smaller and denser than those of the cart-horse; and in the muscular energetic man they are hard, well-formed, with well-marked processes. They grow in strength with the increasing power of his muscles; and diminish in weight and strength, when, from old age, the force and activity of the muscles is on the wane. Not only do the bones and muscles thus become formed, grow, and waste in relation to one another in the ordinary course of nature at the different periods of life, but the relation is preserved when by any accidental circumstance the condition of either is subjected to alteration. Thus the muscles waste when the bones or joints are impaired; and, in like manner, the bones undergo a slow but sure atrophy, when, from paralysis or other cause, the muscular force abates.

It does not necessarily follow from all this that the development, growth and nutrition of one tissue depends in a direct manner upon the other; though it is far from improbable that some more intimate relationship exists between the several structures in their formation and nutrition than we are at present aware of. It may be that the abstraction of certain materials from the blood for the production of one tissue, by altering the relative proportion of the constituents of that fluid, renders it better adapted to the formation of others. But of this and other mutual influences of a similar kind that imagination may suggest we know very little. Suffice it to say, that all the several tissues of each part being under the impulse of one common developmental force, any cause which disturbs that force with regard to one tissue will be found to operate in a more or less deleterious manner upon the others.

When once the bones have been formed, I am not aware that any especial sympathetic relation can be very clearly traced between

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they were rather short; but the chief deformity consisted in their being directed forwards instead of forwards and inwards, so that what should have been their symphysial edges were three inches asunder.

them and the adjacent soft parts, even in the case of the viscera contained in the cavities enclosed by them; though the instances in which suppuration of the brain has ensued upon necrosis of the tables of the skull, and the frequent association of disease in the lungs with caries of the ribs, may be suggestive of something of this kind.

The symmetry of the skeleton.

The symmetry of *development* in the corresponding parts of the two halves of the skeleton is carried out with singular uniformity. We now and then find it interfered with, by the absence of a part or a whole limb on one side. It is, however, more frequently maintained even in cases of aberration from the ordinary standard, the same or similar deviations being commonly observed in the opposite members. Still less frequently is there any deviation from symmetry in *growth*, the parity of length in the corresponding limbs being remarkably uniform. It is maintained in dwarfs, and generally in rickets[1], the arrest of growth in both instances being commonly symmetrical. It is not often interfered with even by disease, unless the effects of the disease have been sufficient to impair the limb to such a degree as to render it almost useless, in which case the loss of function may exert so deleterious an influence upon nutrition as even to interfere with growth. Thus, in a man whose left arm and fore arm were grievously distorted by the cicatrix of a burn which had occurred in childhood, I found this extremity two inches shorter than the other, the difference being chiefly caused by want of

[1] In the Musée Dupuytren are five rickety skeletons, in each of which one femur is shorter, from one to three inches, than the other. (See *Atlas* of Musée Dupuytren, where some of these are represented, Pl. XX. and XXI. also *Catalogue*, No. 516, &c.) There is nothing to account for this disparity in any, and the pelvis retains its proper level in them all. In one, the leg-bones of that side are longer than those of the opposite, so as in part to make amends for the deficiency of the femur. In none of the others has this occurred, and there is, consequently, a difference in the length of the two extremities. In a rickety female skeleton in St Bartholomew's museum, the right femur measures nearly 12 inches, and the left $9\frac{1}{2}$. The leg-bones are longer than the thigh-bones, and a slight compensation is afforded by the left tibia measuring $12\frac{5}{8}$ inches, the right measuring $12\frac{1}{8}$. I have not observed this disparity of growth as an attendant on rickets in any other bones than the thigh-bones, except in the instance of the leg just mentioned, or where there has been disease in the bone or a contiguous joint.

growth in the fore arm. In a case of long-standing disease of one knee the affected limb was an inch and a half shorter than the other; the difference being chiefly in the thigh. In an infant brought to Addenbrooke's Hospital without the right thumb, with contraction of the fingers and other imperfections in the hand, no difference in the length of the two limbs was observed at birth; but as the child grew, though the arm and hand maintained nearly their proper symmetrical proportions, the fore arm scarcely grew at all.

The examples of bones *exceeding* their proper symmetrical proportions in any marked degree are very rare. In the 28th volume of the *Medico-Chirurgical Transactions* Mr Curling relates cases where one or more fingers or toes greatly exceeded the others in size. The difference existed at birth and continued relatively the same with the growth of the children.

The most remarkable instance of the kind that I have met with is that of the skeleton of a young man in the museum at Bonn, where the right upper and lower extremities are, in each of their parts, longer than the left. It is so curious that I think it worth while to give the measurements in inches:

Height, 58.	Length of Spine, 19.	
Circumference of head, 19.2.		
Right Humerus, 12.	Ulna, 9.4.	Hand, 7.
Left ditto . . 11.3.	Do. 8.6.	
Right Femur . 17.2.	Tibia, 17.	Foot, 9.
Left ditto . . 16.3.	Do. 14.3.	Do. 8.6.

It will be observed by a comparison with Tables I. and IV. given further on, that the right extremities have acquired a length disproportionate, not only to that of the left, but to that of the height of the skeleton and of the spine in particular. The disproportion is most marked in the leg-bones, which is in some measure accounted for, by those of the right side having been the seat of inflammation, as shown by their thickened nodulated condition. There are, however, no traces of any inflammatory action in the other bones[1].

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[1] Doubtless this is the instance of hypertrophy of the tibia and fibula mentioned by Mr Stanley (*Diseases of the Bones*, p. 1). It is described in the catalogue of the

THE SENILE SKELETON.

Conditions of the bones vary in different persons.

A few words more may be added respecting the changes that take place in the bones of old persons, about which many conflicting statements have been made. One thing, I think, is clear, and it is the only thing which seems to reconcile the various opinions that have been given upon the matter, viz. that the bones of the aged differ a good deal in different individuals. The writer in the *Cyclopædia of Anatomy* says, that his experiments on the condition of the bones of old persons, though instituted during several years, were entirely unsatisfactory. The thigh-bone of a woman, who must have been 70 or 80, was thicker, stronger, and contained more, both of animal and earthy materials, than that of any adult with which it was compared. I have repeatedly observed nearly the same thing. Only recently I had occasion to remove parts of the thigh-bones from the body of a woman æt. 75, from a man æt. nearly 80, and from another man æt. nearly 90. In neither could I, without close examination, have distinguished the section of the shaft from that of the healthy adult. It was always believed, and the belief rested upon the analyses of many competent chemists, that the proportion of earthy matter underwent a progressive increase from the beginning to the end of life, the bones of the old person containing a greater quantity than those of the young or even of the adult; but the experiments of Stark and Von Bibra, already quoted, are in opposition to this, showing that the constituents of old bone and young bone are relatively the same.

It is probably in the varying relations in which the two processes of absorption and deposit, described at page 46, stand to one another in different persons, that an explanation is to be found of the want of uniformity in the characters of the bones in old people. In one class of persons the progressive absorption and deposition, proceeding slowly, are nearly balanced, so that the weight of the bone remains much the same, differing very little from that of the

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museum as "the skeleton of a young man with diseased condition of bones of the right leg." The left hand and radius have been removed.

adult; the only alteration is that the cancellous parts are somewhat more rarefied, the medullary cavities somewhat larger, and the external walls somewhat denser than they were. In another class the tendency to bony deposit, exceeding the tendency to absorption, may not only evidence itself by causing greater hardness of the outer walls, but may even supersede the process of resorption in the interior, and, encroaching upon and consolidating the cancellous structure, may actually increase the weight and solidity of the bones. This is not a common occurrence in the skeleton. The most frequent, if not the only well-marked, examples of it are to be found in the cranium, which often becomes preternaturally dense and heavy, as well as thick, in the aged, its tables being thickened and its diplöe becoming consolidated. Numerous specimens of this senile change in the skull are preserved in pathological collections; and I shall again revert to it when treating of that part of the skeleton.

They may become harder and heavier.

Generally become lighter.

The third class of persons consists of those in whom the progressive absorption goes on in a greater ratio than the osseous deposition. This is much the more numerous class, as might be expected. Indeed, if the alteration be not excessive, this may be regarded as the regular and natural course of events. The effects of this increasing ratio of absorption are first and most felt in the cancellous parts of the bones; such as the spongy extremities of the long bones; and as a consequence of these parts becoming relatively weakened, they are proportionately more liable to sustain injury in the aged than in younger persons. Fractures of the shafts and dislocations, so common in the adult, are comparatively rare in the aged, because in the latter the atrophied extremities of the bones give way more easily. An old man falls upon his shoulder and breaks the upper end of his humerus by a blow, which, in his earlier life, would have dislocated the bone into the axilla;—or he falls upon his thigh and breaks the neck of his femur, a part of the bone which, in the adult, would have withstood a shock sufficient to fracture the shaft or rend the strong capsule of the hip;—or he falls upon his hand, and the lower end of the radius gives way, an accident, common, it is true, in young persons, but proportionately more frequent in the aged. When this progressive absorption proceeds beyond due limits, or occurs at a preternaturally early period of life, it leads to that form of atrophy of the bones which is called *mollities*.

Condensation by approximation of laminæ.

Associated with this thinning and absorption of the osseous plates of the cancelli there is commonly an approximation of the tables of the bone, which adds to the condensation of the harder parts of the structure. This is best appreciated in some of the flat bones, the scapula and the ilium for instance, where the outer and inner tables may coalesce at parts so as to form but one plate, which may be reduced to the thinness of writing-paper. Its effects are also sometimes well seen in the skull.

Tendency to osseous growths on exterior.

Associated with these changes, in some instances, is also a slight tendency to osseous growths on the exterior of the bones, particularly about their extremities; these growths for the most part taking place at the expense of the periosteum and of the tendinous and fibrous tissues implanted there. This accounts, in some measure, for the stiffness and lessened range of movements of the joints of old people; and this activity of the ossific processes on the surfaces of the bones accounts also for the fact, that fractures at this time of life unite, if they unite at all, as quickly or even more quickly than in adults[1].

Fatty and calcareous degeneration.

Not only may the quantity of fat contained in the marrow of the bones be increased as a consequence of the enlargement of the cells of the cancelli and the medullary cavities; but there is also in the bones of many old persons a good deal of free fluid fat not enclosed in cells, which has become soaked into the bone substance. This renders the thin laminæ more opaque and gives to the bones a yellowish colour and a greasy feel, incapable of being removed by long maceration and repeated boiling. Wedl[2] speaks of the presence of *calcareous granules* in the cancelli of old individuals, due to the deposition of amorphous, calcareous salts, no longer capable of entering into an organic union with the osseous tissue.

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[1] See *Association Medical Journal*, 1856, p. 610.

[2] *Pathological Histology*, translated for the Sydenham Society, by George Busk, F.R.S., page 141.

Changes of shape.

The changes of shape in the bones which take place in advancing years (with the exception of those in the jaws, the neck of the thigh-bone and the spine, which will be described when we come to speak of those bones) are few and unimportant. I have seen nothing to warrant the belief that the bones become more bent with advancing years. The loss of height which is experienced as a man grows older, amounting, according to Quetelet, from $1\frac{1}{2}$ to 2 inches between the ages of 50 and 90, results, not from any increased flexures in the bones, but partly from a diminution of the elasticity of the cartilages, the intervertebral fibro-cartilages especially, and partly from the erect posture not being maintained; for the joints, even when the old man attempts to stand most upright, are all, or most of them, a little bent. This incomplete state of extension of the joints is not without its good effect in preventing the communication of jars from one part to another.

Ossification of costal cartilages.

The ossification of the cartilages of the ribs is commonly regarded as being simply a senile change, and the instance of Old Parr, noted by Dr Harvey, in which they remained soft and easily cut, is quoted as a marvellous exception to the general rule. My own observation has furnished many exceptions, not so striking of course, but sufficiently marked and sufficiently numerous to make me question the rule. In almost all the old persons on whom I have had the opportunity of making a post mortem examination, I have observed the cartilages of the ribs to be discoloured and yellowish, but soft, so as to yield easily to the knife and render the saw unnecessary; and in the skeleton of a person æt. 100, in the Berlin Museum, the costal cartilages are still unossified; whereas they are commonly ossified and requiring to be sawn through in adults who have been addicted to drinking and have become unhealthy. I am on the whole, therefore, disposed to regard the ossification of the costal cartilages as a sign of disease rather than of age. The morbid condition which induces it in the adult may induce it also in the aged, though I have not remarked that it does so; and I suspect, that those in whom it occurs do not often attain to great age.

PATHOLOGICAL CONSIDERATIONS.

It is not my intention to enter at any length, or in a systematic manner, upon the wide field of the pathology of the human skeleton, but merely to offer a few remarks which connect themselves with the account above given, of the formation, shape, &c. of the bones.

Relation between order of development and liability to disease.

It might seem probable, that those parts of the skeleton which are latest in their development would be the weakest in their nutritive powers, and would give evidence of that weakness by a greater liability to disease than other parts. Certainly the analogy furnished by the teeth is in favour of that view. They are the last of the solid structures of the body evolved, and they are the first to decay and be removed. Moreover, they decay pretty much in the inverse order of their appearance. The "wisdom" teeth first, the "incisors" last. I do not find, however, that such a rule holds good with regard to the other bones of the skeleton, in a sufficiently constant manner to render it of any practical value. True, the lines of union of the epiphyses are not unfrequently the seat of inflammation and ulceration, that of the lower end of the femur more often than any other; but this takes place before the union is complete, while the part is in a soft state. When once bony union has taken place, these are not more liable to disease than other parts of the skeleton, indeed not so much as the shafts of the long bones. The clavicle, I grant, is not often the seat of disease, though it takes the lead in ossification; but the shafts of the long bones of the extremities, which, in their ossification, follow very quickly upon the clavicle, are endowed with no such immunity. Though formed very early they are very often the seat of disease; inflammation, syphilis and cancer attacking them more frequently than they do the epiphyses or the short bones, in which ossification is later.

Several parts of skeleton often affected by same disease.

The liability of corresponding parts of the skeleton to suffer in a similar manner—their symmetrical tendency to disease, as it is called—has already been noticed (p. 16). It is most marked when the disease depends upon some morbid condition of the blood; for instance, when it is of a syphilitic character. Besides this symmetry in its diseases, there can be no question that there is a harmony in the pathological relations of the various parts of the same skeleton, as there is in the case of the other tissues, several bones being often associated in similar morbid conditions. Thus, scrofulous inflammation frequently affects several parts of the skeleton in the same individual, or shifts from one bone to another, without extending to any other structure. The same is true of certain forms or stages of syphilis. There have also been remarkable instances of exostoses springing from many bones of the same skeleton; and the appearance of mollities or cancer in one bone, suggests a well-grounded apprehension that others are or soon will be involved.

Parts most subject to sclerosis,

The shafts of the long bones are the parts in which, more than in others, the process of addition to the exterior, by means of ossific blastema, takes place during growth, and they are also the parts in which consolidation of the structure, by deposit in the haversian system, proceeds to the greatest extent, and from which the periosteum is most easily detached. We cannot but associate these peculiarities with the facts, that they are also the parts in which reunion of fractures takes place most quickly, and that they are most subject to necrosis and that morbid thickening and condensation which is called *hyperostosis* or *sclerosis*. The latter is an affection of an inflammatory kind, and does not commonly extend to the epiphyses, though it usually affects the whole length of the shaft; in the worst cases it involves the interior of the bone, solidifies the cancellated structure and blocks up the medullary canal, as well as causes deposit upon the exterior. At the extremities of the bones, on the other hand, where

ulceration,

the structure is more spongy and the periosteum more closely attached, inflammation is commonly more localized, and leads to ulceration, much more frequently than to necrosis or sclerosis.

and tumours. Of the several varieties of tumours that grow upon the bones, the "fibrous" affect chiefly the extremities of the bones where the periosteum is rather coarse, and a good deal of fibrous tissue passes from it to the bone. They affect also the jaws, where the fibrous tissue is vascular and dips into the sockets for the teeth. The "cartilaginous" are most frequent in the first and second phalanges of the fingers, beginning in their shafts. Sometimes they are found growing around the pubes, the ribs, and the shafts of the long bones. The "osseous" are almost exclusively confined to the jaws, the æthmoid and frontal bones. Occasionally they extend to the parietal and occipital bones. I include under this term the dense, ivory-like, knotty growths, which are regarded by some pathologists as originating in the ossification of enchondromatous tumours. They form a distinct class from "exostoses," which are found upon almost every part of the skeleton. The "cancerous" tumours ("scirrhous" and "encephaloid" at least) attack all parts indiscriminately, and originate sometimes in the interiors, but more frequently on the exteriors of the bones. I am not aware that "colloid" cancer has been found affecting the bones, and "epithelial" cancer attacks them only by extending into them from other structures.

Reparation. The work of reparation and reproduction goes on most quickly and abundantly in the shafts of the long bones, in the ribs and lower jaw; in those parts, that is to say, where the periosteum is easily detached, and where it most contributes to the growth of the bone. The cancellous parts are repaired somewhat more slowly, and with less amount of callus; so, that if by any cause their fractured surfaces are kept apart, reunion is likely to fail altogether, or is effected only by fibrous tissue, as in the case of the patella, olecranon, os calcis, and neck of the femur. The reparative processes are also carried on very slowly in the skull. Even a simple fissure does not usually become quite closed; and if a small portion has been taken away, the gap is commonly found not to have been quite filled up after many years, though the integrity of the dura mater may have been preserved. In such cases the new bone is formed slowly upon the cut edges of the skull, with scarce any formation of callus upon either its outer or its inner surface; from this we may infer, that neither the dura mater nor the pericranium have much to do with the production of the reparative ossific medium, which proceeds, perhaps exclusively, from the surface of the bone itself. We may connect this mode of reparation, as well as the recoveries which take place, without necrosis, after a considerable extent of the skull has been deprived of its pericranium, with the abundant supply of blood which the cranial bones receive, and which is distributed through large canals in their diplöe.

RICKETS.

Result from defective structural development

Many interesting points in relation to the structure and formation of the bones, are presented in cases of "Rickets," which is essentially a disease of the developmental and growing period. The leading peculiarity in the bones affected by it, consists in a deficiency of earthy matter; analyses made by various chemists combine to show, that rickety bones often do not contain above 20 or 25 per cent. of phosphate and carbonate of lime, instead of about 70. This deficiency probably results, not so much from the earthy matter being absorbed after it has been once deposited, as from its never having been added in the right proportions. It would seem, therefore, to be owing to a defect in the ossifying process, the calcareous granules not being, according to the observations of Kölliker and Virchow, supplied in their proper quantities to the cartilage or blastema, during the period in which the various changes requisite for the conversion into bone are going on in the cells and other constituents of these structures. The bones, in consequence of this failure, do not acquire their proper degree of hardness, that hardness which is requisite to enable them to bear the weight of the body. They, therefore, yield under its weight and under the contractile force of the muscles, and become misshapen in various ways. The disease may show itself in the first formative periods; the bones not being made of sufficient strength to bear the pressure of the muscular contractions during fœtal life. Accordingly in a few cases the child has been born more or less distorted in consequence of rickets. These cases are not, however, very common.

The age at which its effects are most frequently witnessed, is from about the first to the third year; that is to say, at the time when the limbs are first called upon to sustain the weight of the trunk. Dr Merei observes: "In the immense majority of instances, the age at which rachitism shows its first symptoms, in my experience, ranges between the first nine and eighteen months; and the children afflicted with it are almost invariably such as are late in their dentition, closure of the fontanelle, and walking[1]." Associated with the deficiency in the quantity of earthy matter is usually a preternatural amount of oil in the bone substance; and in some instances, as in the case quoted before from Marchand, a morbid condition of the animal basis has been found. There may be, besides, preternatural vascularity, a spongy or cellular condition of the structure, owing to too great activity of the processes of absorption, or actual cavities of considerable size, filled with serous or gelatinous fluid, pale or stained with blood: all which shows that though the failure in the calcification of the animal matrix may be the most obvious, it is by no means the only, perhaps not even the most important feature, in this disease.

and growth.

Associated also with the failure in the structural development of the bones is commonly more or less failure in their growth. The child is undersized; the deficiency of size being most marked in the limbs that are most affected, that is, in the lower limbs, and in the parts in which, during the later periods of fœtal life and after birth, growth has to take place most quickly, so as to bring the body into its proper proportions; that is, in the face and in the shafts of the long bones, particularly those of the humerus and femur. Hence in the rickety person the face is sometimes small in comparison with the cranium; the limbs are short in comparison with the trunk; the shafts of the bones are small in comparison with their epiphysial extremities; and it is interesting to observe, in connection with what is said at a future page on the relative growth of the thigh and arm after birth, that the femur and humerus, in many of these cases, do not attain to nearly

[1] *Disorders of Infantile Development*, 1855.

their proper proportionate length. This point is well exemplified in specimens preserved in the College of Surgeons (Nos. 9, 12, and others). Some of these illustrate also the fact, which I have observed in other instances, that the feet and hands may attain and preserve their proper shape and size, where the other parts of the limbs are small and sadly distorted[1].

Another illustration of the imperfect development and growth of the bones in rickets is furnished by transverse sections of them, which, in some of the worst cases, have been found to exhibit a greater degree of compactness in the osseous structure lying towards the interior of the bone than on the exterior; wherein they resemble fœtal bones; that transfer, as it were, of osseous material from the inside to the exterior of the bone, which is one of the results of the processes that should go on in growing bones, not having taken place as it ought to have done. This feature of rickety bones is partly a consequence of the sub-periosteal, pumice-stone-like, osseous matter of Virchow, which may be present in greater quantity than is natural, not having undergone its proper condensation, and is partly also due to the circumstance that the internal structure has not undergone its proper rarefaction. Meyer[2] remarks that rickety bones are thicker than ordinary bones, especially at their articular ends; a section shows the medullary cavity smaller and shorter than natural; the periosteum is thick and the surface of the bone under it is thicker and more porous than usual. The component sheets, he says, are no more or fewer than natural, but thicker and more separate. According to Rokitansky, the apophyses also remain separate longer than usual. A remarkable specimen of rickety

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[1] Dr Stern (Muller's *Archiv*, 1834, p. 225) found that in cases of curvature of the spine, although the long bones of the extremities were short in comparison with those of the healthy skeleton, they bore their proper proportion to those of the trunk, with the exception of the thigh-bones, which were relatively as well as actually short. In a young woman, æt. 20, who had from childhood suffered paralysis of the left arm, Otto (*Seltene Beobachtungen*, II. 32,) found the bones exceedingly thin and short, and the humerus and ulna were of nearly equal length, the former measuring 7½ inches, and the latter 7 inches and 3 lines.

In some rickety skeletons I have found the shafts of the bones very short but not much bent.

[2] Muller's *Archiv*, 1849. Virchow's account given in his *Archiv*, v. 409, agrees generally with that of Meyer.

fœtus, in which the bones are singularly short and thick, is in the Musée Dupuytren[1].

Curvatures in rickets.

The curvatures that take place in rickets, in consequence of the want of proper hardness of the bones, are commonly observed in those parts of the skeleton which are narrowest and most dependent on the density of their structure for their strength, such as the shafts of the long bones, those especially of the lower limbs which have to bear the weight of the body. They are observed to take place a little above the ankle more frequently than at any other part, because the tibia and fibula there have to sustain a greater weight, in proportion to their diameter, than falls to the share of any other portion of the skeleton. They generally take the direction of the natural curves of the bones, being exaggerations of them. In the most severe cases, where the disease begins early, the preternatural flexure is commonly an exaggeration of the chief or primary curve of the bone. The femur and tibia, for instance, are simply arched forwards; or the former bone is bent forwards and outwards, and the latter forwards and inwards. Occasionally they are so much curved as to form nearly a half-circle. In less severe cases, where the evidences of the disease do not appear quite so soon, the slighter or secondary curves are increased; thus the femur is bent outwards at the upper part, inwards below, and the shaft of the tibia, in accordance with the curves of its spine, is bent inwards above and outwards below. The neck of the femur approaches more nearly, or quite, to a right angle with the shaft. In severe cases only are the bones of the upper extremities much bent. In them the humerus is curved a little outwards, as if the action of the deltoid had pulled the part of the shaft to which it is attached in that direction. Or it may assume that shape in consequence of the manner in which the child supports itself in the sitting posture by the aid of its hands; this

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[1] See *Catalogue of Musée Dupuytren*, p. 691, and *Atlas*, Pl. XX. No. 514. The affection is there called "hypertrophie rachitique." The fœtal type is also in this specimen perpetuated in some other peculiarities, such as the maintenance of a disproportionate prominence of the occipital and parietal protuberances. I have seen several similar specimens in other museums.

would seem to be the cause of the deformity in those cases where the lower parts of the arm-bones and the elbows are bowed outwards. The radius and ulna exhibit merely a slight increase of their ordinary curves, that with the concavity towards the palmar aspect being deepened, and the interval between the two bones is widened. For information respecting the changes of shape that take place in the pelvis, spine, and other bones, I must refer to what is said respecting those bones in subsequent parts of the work.

Flattening at the sides.

If this bending of the bones were a mere mechanical process in the course of the disease, resulting simply from the imperfectly hardened shafts being unable to bear the required amount of pressure made upon their ends, we should then find that the bones would be flattened on their concave and convex sides, and would be widened transversely, as takes place when a quill or a stick is bent. But such is not the case. Indeed precisely the reverse of this is usually the result. The bones are commonly flattened at the sides, and thickened in a corresponding manner towards the convexities and concavities of the curves, forming what has been called sabre-shaped curvatures. This shows that a modelling or growing process is at work during the progress of the disease, adapting the diameters of the shaft to its unnatural shape, and heaping up bone where it is most required. It seems, when a section is examined, as though the layers of the bone were spread out on the concave side, so as to project into the middle, where the medullary cavity should be, and to project also on the other side in the arc of the curve. Generally the curves are gradual. In a few instances they are sharp. In the Dupuytren Museum there are the bones of the lower extremities in which this is remarkably the case, so much so as to simulate fracture. In the Berlin Museum also the two thigh-bones of a rickety child are bent to a right angle at the middle. Some of these sharp curves may be the result of fractures which have united, and instances now and then occur in which such fractures have taken place in the uterus[1].

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[1] See a paper by Dr Barker in the *British Medical Journal*, Sept. 26, 1857.

Virchow[1] seems inclined to attribute many of the flexures in rickety bones to fracture. The direction and symmetrical disposition of the curves, however, would indicate such a cause to be the exception rather than the rule.

Subsequent hardening.

At a subsequent period ample amends are made for that deficiency of ossifying force in early life which is the prime cause of the disease. The bones become actually harder and stronger than those of the healthy adult; and the exuberance of the ossifying processes is further evidenced by growths, in the form of ridges and knotty projections, which often shoot out from the shafts and extremities. This unwonted hardness and strength are rendered necessary by the peculiar shapes which the bones have assumed, their preternatural curves being unfavourable for bearing weight and resisting muscular action. At the same time they afford a better leverage to the muscles. This very condition, which originates in weakness, becomes thus a source of strength, and accordingly some of these bent-limbed rickety persons, presenting, as they do, a resemblance to the lower animals in the conformation of their bones, have, when arrived at mature age, like them, been endued with remarkable muscular power.

Other changes in rickety bones.

The imperfection of structure from a want of proper proportion of earthy salts, associated with deficiency of growth and alteration of shape, constitutes the chief feature of rickety bones. But to it may be superadded other morbid conditions which are rather of a secondary nature, and which depend in some measure upon a liability in the weak and imperfect structure to be the seat of low inflammatory processes. These lead to a further softening with a preternatural expansion of the osseous tissue, to absorption of the bone-substance nearly allied to ulceration and, it may be, to fracture. In some cases they engender an enlargement of the bones by causing the formation of soft crumbling osseous deposit upon their exterior. Enlargement from this cause is often seen in the bones of monkeys dying in this country. In the human skeleton it is seen in its most marked forms in the skull. It affects most frequently the frontal bone on either side, but sometimes involves all the bones both of the face

[1] *Archiv*, v. 461.

and the cranium[1]. Many of the enormously thickened skulls to be found in our museums are attributable to this cause. It is also a very common thing to find the articular ends of some of the bones, particularly those of the radius and ulna, enlarged in rickety children; sometimes in young children who present no other signs of an abnormal condition of the bony system. Mr Brayne, of Banbury, has related, in the third volume of the *Transactions of the Provincial Medical and Surgical Association*, a remarkable case of enlargement of the epiphyses of the bones of the leg and fore-arm, as well as of the lower epiphyses of the femur and humerus, in an undersized lad æt. 7 years, the shafts of the bones remaining straight. This enlargement results from a preternatural growth of the epiphysial cartilages; but it is difficult to account for its being so common in the lower ends of the radius and ulna in comparison with the other epiphyses. In the case of a little girl under my care, where there was no other sign of rickets, suppuration took place in connection with the enlarged lower ends of the radius in both arms.

Mollities ossium. The disease commonly called "mollities ossium" differs from rickets in occurring at a later period, after the skeleton has been properly formed, and in resulting, not from an imperfection in the work of ossification, but from an alteration and absorption of the osseous texture after that process has been completed. It is most frequent in women, and has in several instances occurred in the intervals between confinements, causing distortion of the pelvis and rendering delivery difficult or impracticable. It occurs most frequently and progresses with greatest rapidity during pregnancy, in consequence, it has been fancied, of the phosphate of lime being then absorbed from the mother's skeleton for the purposes of contributing to the formation of the fœtal bones. It is usually attended with pain, and would seem to be somewhat inflam-

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[1] As a general rule, the cranial bones affected in this manner are light and porous as well as thick, consisting in great measure of diplöe with a thin sieve-like outer and inner table. After a time, they may, like other rickety bones, become very dense and heavy. In a few instances the foramina at the base, the carotid and jugular, and even the foramen magnum, have been found reduced in size by the bony deposit; the former so much, that it was difficult to understand how they could have transmitted a sufficient supply of blood to the brain. Otto, *Neue Beobachtungen zur Anat. Phys. und Path.* § 3.

matory in its nature. I have lately met with a case[1] of the kind in the person of a woman, æt. 30, who had been five years previously, and again after an interval of two years, delivered of a healthy child. Since the last confinement she had suffered pains about her back and hips, and had become gradually very lame. She had been in labour eighteen hours when I saw her, and the child was dead. It being quite clear that the pelvis was so distorted as to render delivery through the natural passage impossible by any means, I at once performed the cæsarian operation, not, however, the event proved, till after the uterus had given way. The pelvis exhibited the effects of excessive atrophy; an exaggerated condition of that state which often occurs in senile atrophy. The entire structure was light and spongy, with the exception of a delicate external lamina. In the middle of the ala of the ilium, the outer and inner plates had coalesced, and the delicate resultant lamina had, to a considerable extent, disappeared, leaving wide perforations. In most cases where an analysis of the bone has been made under similar circumstances, the earthy matter has been found deficient, and in this case it amounted to only 47.8 per cent. The large areolæ were filled with apparently healthy medulla. The distortion resembled that which usually occurs in such cases, consisting of a folding up of the pubic bones, so that the middle of the linea ilio-pectinea on either side formed an angle directed towards the middle of the brim of the pelvis, and the sacrum had advanced forwards towards the same point. The thigh-bones and vertebræ were involved in the disease, the latter being easily cut with a knife. In some of these cases the patients' urine has contained phosphate of lime. Upon what this premature and excessive atrophy depends we cannot tell; and no instance has yet been related in which the disease has failed to proceed to a fatal termination.

It was interesting to observe in this case that, although the bones were in so extremely atrophied a condition, yet they were in many parts encrusted with osseous deposit, which had recently taken place upon their exterior, affording an additional illustration

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[1] *Association Medical Journal*, 1856, p. 779.

of the fact that osseous deposition on the exterior of bones is often coincident with (perhaps it may be in some measure a resultant of) osseous absorption in their interior. The occurrence of the same thing has been remarked in senile atrophy (page 57); it is not an unfrequent accompaniment of cancer and some other diseases, which are attended with absorption or destruction of bone[1].

Wasting of bones from disease.

If a limb be not used, the bones usually waste. They may become smaller, that is thinner, without very great alteration in their texture; or they may undergo interstitial absorption without much alteration of size; or they may undergo both changes—diminution of size and interstitial absorption—at the same time. These points are well illustrated by the conditions which the bones of stumps present where the limbs have been long amputated. In some the bones are cleared of their cancelli and reduced to a mere porous shell, the size remaining unaltered. In others they become much reduced in circumference, their walls retaining their proper density. In a third class the bones are small, and are also light and porous. In a case recorded by Larrey of a man who died forty-one years after amputation of the arm near the shoulder the scapula was as thin as paper, and the clavicle no thicker than that of an infant. I am not aware that a bone is ever reduced in length as a consequence of atrophy. If a part be disused by reason of paralysis or other cause, the bones may fail to attain their proper length; but, having attained it, I do not know that they ever lose it.

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[1] For an account of the changes observed microscopically in a case of *osteomalacia* see Wedl's *Pathological Histology* (edited by the Sydenham Society), p. 237.

THE JOINTS.

THE various points of interest of a mechanical kind displayed in the construction and shape of the bones are secondary only to those which may be observed in the manner of the connection of the several bones with one another. The long words that have been used by different anatomists in their classifications of the several joints, whatever good they may have done, have, I think, had an evil influence in rendering this branch of anatomy somewhat distasteful to the student. It will be my endeavour, therefore, to avoid them.

Suture with intervening membrane,

The several bones of the head and face, where no movement is required between them, are joined together by direct apposition of their edges. At least there is interposed between them only an exceedingly thin membranous streak composed of connective tissue, and extending in short parallel fasciculi from the border of one bone to that of the other[1]. In some instances, where the mechanism of the parts is sufficient to hold the bones together, their edges are simply placed in apposition. This is the case also where the bones are very thin, as in those forming the septum of the nose (Pl. XII. fig. 1. C, D). In some instances the edges overlap one another, for the purpose of giving support in a particular direction, as in the suture of the temporal with the parietal; or the one bone may be let into a

[1] "This *sutural ligament*, as it may be termed, is very evident as long as the cranial bones are still growing. When the growth of the cranium approaches its completion, this tissue gradually disappears, becomes firmer, and, in old age, seems, in many places, especially on the inner part of the sutures, and even before their complete obliteration, to be entirely removed." Kölliker's *Manual*, I. 311.

superficial groove in the other, as in the suture of the sphenoid with the vomer. Most frequently the bones have grown somewhat into each other, and become interlocked or dove-tailed together, so as to constitute a very strong and intimate union. This is the most prevalent form of suture in the cranium. The bones are so closely and firmly joined together by this means, that separation of them by external force is a rare occurrence; and fractures and fissures are less frequent in the lines of the sutures than in other directions.

with intervening cartilage.

In a few exceptional instances at the base of the cranium, where the primordial structure was cartilage instead of membrane, the contiguous edges of the bones are connected by a thin layer of intervening cartilage which has remained unossified. In this manner the basilar process of the occipital is joined to the sphenoid, and its jugular processes are united to the temporal bones. This mode of union is the one which prevails between the shafts of the long bones and their epiphyses. (See Plate II. page 40.) The surfaces so connected are less serrated than those which enter into the formation of the ordinary sutures; and they are, in most instances, cemented together by bone at an earlier period. There are, however, in other parts of the skeleton, examples of the same kind of joint in which the uniting cartilage remains unossified to a late date, as in the case of the costal cartilages and the cartilages of the sacro-iliac joints.

Union by fibro-cartilage,

Where a slight amount of movement of one bone upon another is required to be combined with great strength for the purpose of supporting weight, &c. the apposed surfaces of the bones, which are usually broad in such case, are united by a tolerably thick and very strong layer of fibro-cartilage, in which there is disposed a variable amount of elastic tissue. This material is found between the bodies of the vertebræ, and will be described more particularly when treating of the spinal column. It is of greater strength even than the bones themselves, and very rarely becomes ossified.

by synovial joints.

Lastly, where a greater amount of movement being required, it is necessary that the apposed surfaces of the bones should slide upon one another, a regular joint is provided, with a synovial capsule; and the bones are held together by fibrous tissue disposed in bundles or sheets which pass from one to the other in such a manner as to permit, and, to some extent, direct the movements within a certain range, and at the same time to prevent their exceeding it. We shall find that the chief office of these fibrous ligaments is, as I have said, to regulate and limit the movements of the joints: and the precise mode in which each one is intended to perform that duty may commonly be learned, with tolerable certainty, by examining the course of its fibres, and the direction which they take at the point of insertion into the respective bones. In addition to this, their primary office, the ligaments contribute to prevent the displacement or dislocation of the bones, which is further provided against by the influence of atmospheric pressure, and by the contractions of the surrounding muscles. Such accident is, indeed, *chiefly* provided against by the contractions of the muscles; for, although no complete dislocation of any joint can take place without rupture of some of its ligaments, yet slight displacements—subluxations as they are called—can in a few instances, that of the thumb for example in some persons, be effected during life with the assent of the muscles. Moreover the comparative facility with which sprains and dislocations occur when the muscles are unprepared to support the joints, as in making a false step, &c. clearly shews that the latter are the chief agents in preventing those accidents. In the ordinary healthy state the ready contractions of the muscles of a limb scarcely permit its ligaments to be even put on the stretch by external forces, which accounts for the surprising escapes of tumblers, wrestlers, and other devotees to the gymnasium. It is not that their ligaments have acquired unusual strength, so much as that their joints are braced by the increased vigour and activity of their muscles.

Influence of atmospheric pressure.

In many joints—the ball and socket joints for instance—though the ligaments assist, as just mentioned, in preventing dislocation, it is quite clear that the articular surfaces cannot, under ordinary circumstances, be directly held in apposition by them, inasmuch as they must be loose in the whole circumference to permit the movements of the joint in every direction. If the ligament were sufficiently tight at any one part to hold the bones together, it must of necessity prevent the movement in one direction, which we know is not the case. The experiments of Weber upon the hip-joint were, I believe, the first to prove the fact, that atmospheric pressure is the real power by which the head of the femur is held in the acetabulum when the muscles are at rest. One convincing experiment is easily repeated; that namely of holding up a side of the pelvis, with its appended lower extremity, the joint not having been opened, and then boring a hole through the acetabulum, so as to admit air into the hip-joint, when the weight of the limb will cause it to drop from half an inch to an inch, the head of the thigh-bone being pulled out of the acetabulum as soon as the air is permitted to pass between the articular surfaces. In the unopened state of the joint, therefore, the weight of the limb is entirely borne by atmospheric pressure, so that both ligaments and muscles, the latter especially, are relieved in a corresponding manner. The same fact may be shewn with regard to the shoulder, and other joints, in a greater or less degree, though the illustration is, for obvious reasons, most easy in the hip and shoulder. The advantages of this construction, and the facilities it affords for easy movement by leaving all the muscles free to act upon the joint, need no demonstration. We have only to remember that this power is in continual operation to appreciate the amount of animal force which is economized by it.

Bones not held together by the shape of their articular surfaces,

While upon this subject, I may remark that there is in the body no single example of a moveable joint in which the shape of the bones is, of itself, such as to prevent their separation from one another. They all fall asunder when the soft parts are cut or macerated away. In none of the ball and socket joints, for instance, does the cup form so much as a half circle. The acetabulum, which is the nearest approach to it, falls short of it by some degrees, and cannot, therefore, without assistance, retain the head of the femur in its cavity. Neither in any of the hinge-joints is there an example of what is called by mechanicians "a centre-pin and angel," so complete that the latter embraces the former sufficiently to hold it in place.

nor movements stopped. We may go further than this and assert, that there is not any instance in which the movements of a joint are stopped or limited by the shape of the bones, that is, by the edges of the bones coming in contact. If the several joints be examined in the recent state with reference to this point, it will be found in each that either the tension of the ligaments, or the compression of the soft parts, arrests the movements before the margins of the bones touch one another. Take the elbow-joint for example. In flexion and extension the coronoid process and the olecranon enter their respective fossæ on the anterior and posterior sides of the humerus; but they are not permitted to go quite to the bottom of those fossæ. Just before the point at which this would happen, the movement in each direction is limited by the ligaments and the other soft parts. The effect of this arrangement is to prevent any sudden jarring limitation of the range of movement of the several joints. So that although the muscles fail to perform the restrictive duties assigned to them, still the movement of each joint in any particular direction is not brought to a sudden stop by the contact of the edges of the bones, which would be likely to cause frequent damage to the articular surfaces; but the check, instituted in the soft parts, is brought to bear gradually, and the result is thus attained with safety.

Obliquity of movements. It has been said that nature abhors a vacuum. It may be said with equal truth that, in the construction of the skeleton, she has shewn her abhorrence of a straight line. Not only are the bones curved and twisted, each in more than one direction; but the joints are so made that the movements of the limbs on the two sides of the body are rarely in parallel planes. They are commonly a little oblique with regard to one another. Thus each forearm moves in a plane oblique with regard to that of the other forearm, and oblique also with regard to the arm; and the same thing may be said of the leg, and of the other segments of the two members. An easy graceful style is thus communicated to the movements, and awkwardness of gait is prevented. (This has been before alluded to, page 12.)

Articular ends.

The articular ends of the bones, expanded for the purpose of giving security to the joints and leverage to the muscles inserted into them, are cancellous in their interior, the larger plates and fibres of the cancellated structure being arranged perpendicularly with regard to the surface of the joint so as to support it in the most effectual manner. Near to the surface this arrangement is lost. The bone is there more dense, the walls of the cancelli being much thicker and coarser and the interspaces between them much smaller. Still it does not usually present the same dense smooth structure as the exterior of the shafts. Close to the articular cartilage is said to be a thin layer of incompletely-formed bone-substance, containing elongated corpuscles without canaliculi, without haversian canals and without cancellated excavations; the animal basis presenting a nearer resemblance to fœtal cartilage than does that of true bone (page 2). This "articular bone" can have, therefore, no vessels; and it constitutes an imperfectly ossified stratum—a sort of intermediate structure—between the true bone of the epiphysis on the one side and the articular cartilage, which shows no capacity for ossification at all, on the other. Nevertheless, in diseased states, it is often penetrated by vessels passing to the cartilage and to the soft vascular granulation-like substance which forms between the cartilage and the bone. In certain rheumatic and other morbid conditions, when the cartilaginous covering has been removed, this articular bone becomes rubbed down by the friction incurred during the movements of the joint, and acquires a density and polish that reminds us of porcelain.

Articular cartilage.

Articular cartilage is a material admirably adapted to its purpose; so smooth, that, when it is lubricated by synovia, the friction between the surfaces is reduced to a minimum quantity not worthy of being taken in computation; so elastic, that it prevents any jarring of the bones upon one another; and so far devoid of sensation, that the movements of the joints, during which the cartilages are subjected to a good deal of pressure by the contraction of the muscles and the tension of the ligaments, take place without any pain. Its elasticity is increased by the arrangement of its components in fibres, or in such a manner as to present a fibrous appearance, the fibres being perpendicular to the surface of the bone on which they rest. Its insensibility, due to the absence of nerves in its substance, is not so complete as to prevent its giving warning when a foreign body, as a loose cartilage, is in the way, or when it is affected with ulceration. The severe starting pains waking up the patient as he drops to sleep, so characteristic of ulceration of the cartilages, may depend in part on the compression of that soft granulation-like substance which commonly forms in these cases between the cartilage and the bones, but it would seem to depend in part also upon the sensation excited in the cartilage itself. (See remarks on nerves in bone, p. 29.)

It is worthy of remark in a practical point of view how quickly the muscles that act upon the joint fall away, when disease attacks its cartilages. A year of simple synovial disease will not produce so much effect upon the adjacent muscles as a month or even a week of ulceration of the cartilages. Hence this wasting of the muscles becomes a symptom of great importance in assisting us to arrive at a diagnosis as to which of these two structures is involved, as well as in enabling us to decide whether disease, which commenced in the synovial membrane, has extended to the cartilages.

It is only in certain morbid conditions that vessels have been traced in the articular cartilages, and reparation after any loss of their substance is only effected through the medium of connective tissue, true cartilage never being reproduced. Cartilage is capable, however, of being the seat of certain morbid processes by which its tissue may become loosened into a sort of filamentous or fibrous condition, or it may be destroyed by ulceration and absorption, commencing upon either the free or the attached surface; and adhesions, by means of connective, areolar, or fibrous tissue, are not uncommonly established between the opposite cartilaginous surfaces of joints where disease has long existed.

The cartilages are thickest where they have to bear the greatest pressure; that is, commonly, about the middle of the articular surface. They decrease in thickness towards their edges, and terminate abruptly, extending upon the bones no further than their friction upon one another, or upon the adjacent ligaments and tendons requires. Near their circumference they are covered by synovial membrane, which extends a little way upon them. In the rest of their extent the surface of the cartilages is uncovered and is moistened with synovial fluid; in the fœtal state it is covered by delicate scales of epithelium. These, however, soon disappear.

Synovial membranes. Their vascular folds.

Except in situations where the cartilages are naked and exposed in the manner just described, the surfaces of the joints are lined by synovial membranes, which, in the natural state, are very thin, yet, in certain morbid states of common occurrence, acquire great thickness. They cover the edges of the cartilages and extend beyond them upon the adjacent bones. They are vascular, and are particularly so near the margins of the cartilages, where, in some places, they form delicate folds lying flat upon the edge of the cartilage. These folds, containing looped vessels, somewhat resemble the choroid plexuses of the cerebral ventricles in their structure, as well probably as in the function of regulating the amount of fluid in the joints. They are furnished with little processes, like villi, which contain a small quantity of fat and occasionally one or two cartilage cells. These processes are often seen enlarged in joints, particularly in shoulder-joints, which have been the subject of chronic, perhaps rheumatic, inflammation, or inflammation consequent on an injury. They then form polypous bodies, overhanging the cartilages, and may exist in considerable numbers and attain a considerable size. This change is generally associated with a gradual thinning and removal of the cartilages of the joint. The formation of *loose cartilages* in the joints has been attributed to a hypertrophied state of the cartilaginous element of these processes. If that be the true mode of formation of these bodies, and it is highly probable that it is so in some cases, it is remarkable that they should be so generally single, and that there should so rarely be a recurrence when one has been removed[1].

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[1] A remarkable instance in which the pointed end of a needle was found in a "pendulous osseo-cartilaginous body excised from the knee-joint" of a young woman

Liability to disease.

Being the most vascular as well as the most extensively disposed of all the articular structures, the synovial membranes are much more frequently the seat of disease than either of the others. In the ordinary cases of disease of a joint, whether it be scrofulous or not, the inflammation begins in the synovial membrane. It may remain long confined to that membrane, or it may spread from it to the cartilages and bones. Even after a sprain, it seems to suffer more than the ligaments, the immediate as well as the subsequent effects of the injury being evinced chiefly in the synovial membrane.

Their fatty appendages.

Appended to the synovial membranes and situated on their exterior are, in many joints, masses of soft fat. These were formerly thought to be glands which secreted the synovial fluid. Such a notion has been disproved by the fact that they are found on microscopical examination to consist simply of fat. Their office is to fill up the spaces between the bones, and between the bones and ligaments, in the movements of the joints; for which purpose they usually project more or less into the articular cavity, carrying the synovial membrane before them, at the intervals between the bones (see representations of elbow, ankle, and other joints). They are of large size on the fore part of the knee, may be found of greater or less size in most joints, and evidently perform an important office in facilitating the movements of the joints. The one which, from its conspicuous appearance, has attracted most attention is that at the bottom of the acetabulum. It serves a somewhat different purpose from the same structure in other joints, that, namely, of permitting the play of the ligamentum teres and the slightly prominent extremity of the head of the femur. It is obvious that were there not

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is related in the *Trans. of the Path. Soc.* VI. 328. The foreign body must have been the exciting cause of the growth, and it is a unique case of the kind. Both the cartilage and the osseous nucleus presented the normal characters of those tissues under the microscope. In a case where several bodies of the like kind hung into a knee-joint which was greatly altered by chronic rheumatic disease, I found the *quasi* "cartilage" in them to be composed only of compact fibrous structure, and the "bone" of concreted carbonate of lime.

some provision of that kind the ligament would be squeezed between the articular surfaces during the movements of the joint. These *fatty appendages*, like the *folds* just mentioned, are highly vascular, and it is probable that inflammatory affections of the synovial membrane not uncommonly begin and are most obstinately maintained in or near one or other of them.

Fat round the articular edges.

In addition to these fatty appendages to the synovial membrane there are other accumulations of fat about the joints, lying upon the hollows or depressions of the bones in the immediate neighbourhood of the articular surfaces. It very commonly happens that the articular surface, especially that forming the convex head of a bone, about which a more or less concave socket plays, is extended, or spread out, for the purpose of increasing the security and range of movement of the joint, and projects beyond the adjacent surface of the extremity of the bone. Under these circumstances, the depression, or obtuse retiring angle, so formed around the edge, is filled up by fat. Thus a layer of fat lies upon the fore part of the lower end of the femur behind the edges of the articular surfaces of the condyles. In some diseased states, which have prevented the free movements of the joint, this layer acquires considerable thickness. Similar accumulations of fat may be found about the head of the femur, the heads of the metacarpal bones, especially on their palmar sides, and in many other parts. In some instances, as on the upper surface of the neck of the astragalus, they form soft cushions for the reception of the edge of the contiguous bone in certain positions of the joints. When the foot, for instance, is bent up towards the leg, the anterior edge of the articular surface of the tibia is received and supported by this fatty cushion upon the astragalus.

The joints are formed very early in fœtal life, the synovial cavities being distinct as soon as the limbs are sufficiently formed for movement of one part to take place upon another. They were quite distinct in the hip and shoulder in a fœtus under three months which I examined, and they may probably be found at an earlier period. It is very seldom that the development of a joint fails entirely. Even malformations are not very common.

A few instances are recorded where the bones were found congenitally united—the calcaneum and cuboid; the calcaneum and scaphoid; the humerus and radius[1]. These anomalies have no especial relation to the ordinary mode of development of the parts in man, or to their natural condition in other animals. The case occasionally quoted from the *Histoire de l'Académie des Sciences*, 1716, as one of congenital union of the bones, is not detailed with sufficient minuteness to enable us to form an opinion of its real nature.

Gliding or arthrodial joints.

The movements of these synovial joints vary a good deal. In the most simple, the surfaces are nearly flat, and merely glide a little upon one another, remaining in the same plane, or nearly so. Such are the joints between the arches of the vertebræ, and some of the joints of the foot and hand.

Hinge-joints.

Secondly; one bone may revolve upon the other, the articular surfaces being adapted to the direction and extent of the movement required. When the movement takes place in only one direction, there being only one axis of motion, as in the elbow, it is called a hinge-joint. Such a joint is usually furnished with *lateral ligaments* which are connected with one of the bones about the ends of the imaginary axial line round which the other revolves. Thus the axial line of the motion of the radius and ulna at the elbow passes through the lower end of the humerus, from the point of attachment of one lateral ligament to that of the other, or thereabouts; and the ligaments are, consequently, about equally tight in all positions of the joint.

Ball-and-socket-joints.

When the movement takes place in many directions, and there are, consequently, many axes of motion, it is called a ball-and-socket-joint. Such joints are usually provided with circular ligaments, like muffs, embracing the edges of the opposed articular surfaces. Unlike the *lateral* ligaments, these *capsular* ligaments vary in their degree of tension according to the position of the joints. When the latter are in a position of ease,

[1] I found one specimen of congenital union of the humerus, radius and ulna in the Musée Dupuytren.

the ligaments are relaxed in their whole circumference; and it is only in some forced posture that any part of them becomes quite tight. They may be so arranged that a great number of their fibres are rendered tense by certain postures of the joint, as is the case with the capsule of the hip. It is tightened in almost every part when the thigh is extended upon the pelvis; but if the limb be bent a little, the ligament is relaxed. Some joints present combinations of the hinge and the ball-and-socket conformation; the joint, for instance, of the thumb with the carpus. When a bone rotates upon its own axis, or, what comes to the same thing, when one bone revolves round the axis of another bone, it may be called a rotatory joint. Such are the movements of the upper end of the radius upon the ulna, and of the atlas upon the tooth-like process of the second vertebra.

Combination of sliding and hinge-joints.

Occasionally the sliding is combined with the hinge-like movement, that is to say, the axis of motion is altered, describing a curve during the movement; as in the temporo-maxillary and the knee-joints. In each of these instances an interarticular fibro-cartilage is inserted between the bones, which serves a double purpose. In the *first* place it lessens the amount of friction between the two bones, which, in consequence of this combination of the sliding with the revolving movement, would be more than what ordinarily takes place between articular surfaces. It does this in consequence of the parts being so arranged that the one movement—the hinge-like movement—takes place, in great part at least, between the interarticular cartilage and the one bone; while the other, or sliding movement, is chiefly effected between the interarticular cartilage and the other bone. Thus in the case of the temporo-maxillary joint, the hinge-like movement—the opening and shutting the mouth—takes place, chiefly, between the condyle of the jaw and the fibro-cartilage; whereas, the sliding movement—the advancing and withdrawing of the teeth—is conducted, in great measure, between the fibro-cartilage and the glenoid cavity. In the *second* place, the fibro-cartilage, being flexible and being more closely connected with one of the bones, follows it in its movements, and adapts its surface to the shape of the articulating surface of the other bone, which varies in different parts of its extent. Thus, to revert to the temporo-maxillary joint for illustration, the condyle of the lower jaw is enabled at one time to rest upon the convex glenoid ridge, and at another in the concave glenoid cavity, by the aid of the interposed fibro-cartilage. The interarticular fibro-cartilage of the sterno-clavicular joint does not quite correspond with those of the knee and jaw, being rather a ligament of retention, passing from one bone to the other, firmly connected with both, and forming a very powerful bond of union between them.

Combination of two or more joints.

In some instances, where a variety of movements are required to be associated with great strength, the end is attained, not by a combination of the movements in one joint, but by a double joint, or rather by the employment in juxtaposition of two or more joints, the bones of which play in *different* directions upon one another. Thus, the movements of the head upon the neck are distributed between the occiput and the atlas, and between the atlas and the dentata; the nodding power being derived from the joint between the two former, the rotatory action chiefly from the joint between the two latter. The same may be noted of the movements between the foot and leg; flexion and extension taking place at the ankle, and rotation at the joint of the astragalus with the os calcis, and of the latter with the scaphoid bone. Occasionally also two or more joints combine to effect the *same* movement, as in the case of the wrist, where flexion and extension are effected partly by the rolling of the carpal-bones upon the radius, and partly by the rolling of one row of carpal-bones upon the other. This arrangement also is for the purpose of combining freedom of movement with strength; for it will be found as a general rule that, wherever the movement between any two bones is free, the joint is proportionately weak. The shoulder and elbow are examples of this. In the knee, which forms an exception to the rule, compensation is afforded by the great extent of the articular surfaces, by the strength of the ligaments, and by the number of powerful muscles and closely attached tendons and fasciæ that invest it. An illustration of the combination of two joints of different kinds to effect, or rather to give security to one movement, is afforded by the articulation of the first vertebra with the second. The lateral joints between these two vertebræ are arthrodial, and serve to support the atlas and steady it in the revolving movement that takes place in the median line around the odontoid process, which, surrounded by the arch of the atlas and the transverse ligament, stands to them in the relation of the "centre-pin" to the "angel" of a hinge-joint.

THE PROPORTIONS

OF

THE HUMAN FIGURE[1].

THAT in the human frame, no less than in the most regular constructions of architecture, certain definite proportions are observed between the several component parts does not admit of a doubt, and scarcely needs to be asserted. Those proportions in the well-developed frame are consonant with our ideas of beauty, and the eye of every one is more or less cognisant of a certain law of proportions, to which it behoves the artist to pay scrupulous attention if he desires success. To give pleasure by his representations of the human frame he must aim first at truthfulness in proportions, and secondly at accuracy of detail and exquisiteness of touch, for even the untutored eye will be sure to discover an error in the former, though it may fail to discriminate with respect to the latter. Hence the proportions of the human figure have formed a subject of study from very early times. The Egyptians (the Assyrians doubtless also) and the Greeks had their respective rules by which they were guided in the formation of their statues. Both the former and the latter took the foot as their standard, and regulated the length of the figure accordingly. The former, by dividing the body into six feet, gave an appearance of heaviness to their figures, which might accord well with the general character of their architecture; but which made them certainly less graceful

[1] Read before the Cambridge Philosophical Society in April, 1857.

and less consonant with our ideas of beauty than the statues of the Greeks, whose better taste and more accurate measurement led them to adopt a lighter style both in architecture and statuary, and who gave as a rule seven feet for the length of the figure. The great artists of more modern times are said by those who have investigated the matter to have been careful to follow this rule; making, at the same time, the head an eighth and the face a tenth of the figure, giving to the lower extremities one half of the length of the body, and making the measurement of the extended arms equal to that of the height from the sole to the crown. If they have detracted at all from the length of the figure, it has been sure to give a heaviness to their productions. This, remarks Camper[1], is exemplified by a comparison of the pictures of Watteau with those of Rubens. The figures of the former, having eight heads instead of seven, are more graceful than those of the latter, notwithstanding the wonderful power of execution and colouring exhibited by that great master. A consciousness of the bad effect of this error has induced some to exaggerate a little in length, which is certainly less displeasing. Thus the Pythian Apollo has a length of eight heads and a half; and in some of Michael Angelo's figures the size is equal to nine, ten, nay twelve heads, in order to communicate more grace to a stooping attitude.

In like manner the height of the columns in the various styles of architecture, and the dimensions of their capitals, were regulated in certain definite proportions to the diameter of the several columns. The radius of the base was usually taken as the standard of measurement and called the "module." Thus the Tuscan column measured 16 modules, the Ionic 18, and the Corinthian 20. Gradually as the science of architecture made progress, the columns were rendered lighter and more graceful; and it is interesting to observe that the several parts were elongated until the column, with its capital and base, acquired nearly the proportions of the human frame. Considering the capital as in the place of the head, the whole length of a Corinthian pillar is $8\frac{1}{2}$ heads.

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[1] *On the Connexion between the science of Anatomy and the Arts of Drawing, Painting, Statuary*, &c. Translated from the Dutch by T. Cogan, M.D. 1794.

The "module" proposed by Carus.

With the view of obtaining a more satisfactory and scientific "module" or standard for determining the proportions of the human figure than has heretofore been adopted, C. G. Carus[1] selects the spinal column as being at once the most important, the earliest formed, and the least varying part of the body; and, dividing it into three, takes one of these portions as the module of the whole skeleton. His investigations, conducted with all the assiduity and accuracy which characterize the German anatomists, appear to justify the selection, for he found the various parts of the frame to correspond in a remarkable manner with this standard. Thus the length of the skull, from the forehead to the occiput, equals one "module," or a third part of the length of the spine. The height from the vertex to the lower margin of the upper jaw is the same. The circumference of the skull is three modules, or the whole length of the spine. The length of the breast-bone and of the shoulder-blade is in each case one module. The width of the chest from the extremity of one clavicle to that of the other is two modules. In the pelvis each of the measurements from the highest point of the ilium to the symphysis pubis, from the anterior superior spine to the tuber ischii, and from one anterior inferior spine to the other, corresponds with one module. The arm and fore-arm give three modules and the hand one. The thigh-bone gives two and a half; the tibia two, and the foot, from the ankle to the tip of the toes, one. The height of the whole body is 9½ modules. The module measures 18 centimeters, or rather more than 7 inches, making the entire figure 5 feet 6½ inches, or 5 feet 7.

These are the ideal proportions of the well-developed European, deduced from the measurements of numerous skeletons. They represent the mean between the male and female, and are stated by Carus to be generally true, though not applicable with mathematical accuracy to any one person; slight deviations from the standard being essential to the endless varieties of individual form. The measurements which I have myself made for the purpose of testing

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[1] *Die Proportionslehre der menschlichen Gestalt.* Leipzig, 1854. See table reduced from this work at page 112.

the value of this means of determining the scale of the proportions of the figure, though in a general manner confirmative of the results obtained by Carus, have proved that the exceptions to the rules laid down by him are very numerous.

Sufficient, however, has been said to give a general idea of the proportions of the body. Further information may be quickly obtained by reference to the tables at p. 106, and will be culled as we pass along in the more interesting task of instituting various comparisons, to which we now proceed.

Comparison of human figure with that of lower animals.

First, let us briefly compare the human figure, in its proportions, with that of some of the lower animals, particularly the animals which present the nearest resemblance to man. To avoid prolixity I will allude only to some of the more prominent and important differences between them; such as the eye will quickly detect in examining the respective skeletons, or such as are indicated by the accompanying tables.

Size of brain-case,

In making this comparison, the first thing which strikes us is, the great proportionate size of the human brain-case, an indication not merely of the superior intellectual capacity of man, but also of the greater predominance and control of the mental or volitional over the vegetative and physical parts of his system. I make the latter remark, because in dwelling so much on the offices of the brain as an organ of the mind, we are sometimes apt to under-estimate its importance as an organ of the body, to forget that it is the intervening link between the mind and the body, and that it has, therefore, its relations to both.

of face,

The next peculiarity which attracts attention, is the small comparative size, and the suppression or thrusting back, of the face and jaws, so that they are situate beneath the cranium instead of being protruded in front of it. This has relation, first, to the fact, that the mouth is no longer an organ of prehension. The hands are free to do this work, and the office of the mouth is altogether subservient to the digestive system and the voice. Secondly, this thrusting back of the mouth makes the opening of the orbits more vertical, and gives to the eye a more complete command over the frame, particularly over the lower extremities. In most of the inferior animals these limbs are not much under the guidance of the eye. The hind-feet follow the front and need no especial direction. Whereas in man, each movement of the legs, as well as of the arms, is regulated by sight.

of extremities.

Another peculiarity in the human frame is, the great proportionate size of the lower extremities. The length of these regulates very much the middle point of the body, which in man, is at or near the symphysis pubis. In the most nearly allied animals the lower extremities are much shorter and, accordingly, the middle point of the body is higher. In the Chimpanzee I found it to be 3, in the Orang 3½, and in the Gorilla 4 inches above the symphysis[1]. Thus an ample development of leg, no less than of brain-case, is one of the attributes of man, and it is no empty vanity which leads him to be proud of the former as well as of the latter. A still more marked peculiarity, though of an opposite kind, is observable in the upper extremities of man, as compared with the fore-limbs of these animals. They are not only relatively but actually much shorter, although the whole human figure is considerably higher. The reason of this obviously is, that the human arm is used, not as an agent in progression, but as a minister to the various requirements of an intelligent will, for which, its higher purpose, it is better fitted by a shortening of its component parts, whereby it is brought more readily under the dominion of the sensorium. And it is for the sake of setting this member free to execute the behests of the will, that the lower extremity is developed of sufficient length, strength and compactness, to bear unaided the weight of the body and to perform the whole work of progression.

Proportions of component parts of extremities.

With regard to the proportions of the parts which compose the extremities, it is to be remarked, that in man the segments nearest to the trunk are comparatively lengthy; the more distal ones being comparatively short. Thus, the thigh and arm are respectively longer than the leg and fore-arm; the leg is much longer than the foot; and the fore-arm is longer than the hand. The inferior animals, on the contrary, are

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[1] See Table I. page 106.

remarkable for the comparatively greater length and strength of the more distal segments.

In the Chimpanzee and Orang the leg and fore-arm are respectively nearly equal to the thigh and arm. In the latter animal indeed, the fore-arm commonly rather exceeds the arm in length. In each of the three, particularly in the Orang, the hand and foot are from 1 to 3 inches longer than in man, although the entire stature of the animal is from 10 to 20 inches less, and the excessive development of the phalanges is especially remarkable. It will be seen from Table I. that the great proportionate length of the thigh is one of the characteristics of the human figure; it being to the rest of the frame nearly as 1 to 3½, and to the leg as 17.88 to 14.4. In the Chimpanzee, Orang and Gorilla, it is to the rest of the body about as 1 to 4, and to the leg as 12 to 10. (Tables I. and IV. pp. 106 and 108.) In most other animals the difference is still more marked. There are, however, some exceptions; and the Mylodon preserved in the Museum of the College of Surgeons forms a striking one. In it the femur measures 18 inches, the tibia being only 7½ inches. The humerus in the same animal measures 14 and the radius 10 inches.

Purpose attained by shortening distal segments.

We naturally inquire, what are the purposes served in man and the lower animals by these differences in the relative proportions between the component parts of their extremities. Why in man should the difference be in favour of the proximal, and in the animals of the distal segments. I can only suggest, that the shortening of the distal parts of the extremities is one of the many instances in the human skeleton, in which strength is sacrificed to celerity and nicety of movement, as well as to a ready subservience to the will. It is obviously of the first importance that these latter qualities should exist in the human hand and fore-arm in the most perfect manner; and to effect this the bones are reduced in size, while the length of the extremity is, to a sufficient extent, maintained by the preponderating size of the humerus. In the foot also, which is a no less marvellous structure and little less important as a ready minister of the will, variety, celerity and nicety of movement are combined in a wonderful manner with strength. The shortening of the bones, whereby a number can be gathered within a small space and the part is rendered compact and strong, contributes to these results; at the same time the requisite length of the limb is preserved by the great size of the femur. In the monkeys, on the contrary, all four extremities being used chiefly for prehension and climbing, nicety of movement in the upper limbs and stability in the lower, are of less importance than in man. In these animals, accordingly, extent and strength of grasp is secured by the extension of the distal at the expence of the proximal segments of the limbs.

Comparison with inferior races of mankind.

The inferior races of mankind exhibit proportions which are, in many respects, intermediate between the higher or European orders and the monkeys. In the Negro, for instance, the stature is less than in the European. The cranium, as is well-known, bears a smaller proportion to the face. Of the extremities the upper are proportionately longer, and there is in both upper and lower a less marked preponderance of the proximal over the distal segments. For instance, in the Negro the thigh and arm are rather shorter than in the European; the leg is actually of equal length in both races, and is, therefore, relatively, a little longer in the Negro; the fore-arm in the latter is actually, as well as relatively, a little longer; the foot is an 8th and the hand a 12th longer than in the European. It is well-known that the foot is less well-formed in the Negro than in the European. The arch of the instep, the perfect conformation of which is essential to steadiness and ease of gait, is less elevated in the former than in the latter. The foot is thereby rendered flatter, as well as longer, more nearly resembling the monkey's, between which and the European there is a marked difference in this particular. In Australians and in the Polynesian tribes the difference is less, though there is still a greater proportionate length of the leg and fore-arm. The feeling, therefore, which is prevalent in favour of a small proportionate size of hand and foot, and which compels civilized and uncivilized nations alike to submit to varieties of torture in accommodation to it, has a foundation deeper than mere fancy. It is based upon one of the characteristic differences between the higher and lower races of mankind, as well as between man and the lower animals.

As a general rule, I believe, in their attempts to modify the proportions of the human form by mechanical appliances, each nation endeavours to give more forcible expression to that which may happen to be a national peculiarity. Thus the Chinese, who are distinguished by the smallness of their hands and feet, as well as by the sparseness of their hair, endeavour still further to cramp the former whilst they reduce the latter to a pig-tail. And certain of the South American Indians, regarding as a beauty that prognathous conformation of the cranium which exists among the inferior races of mankind, endeavour to promote it by compressing the foreheads of their children, with what surprising results may be seen in specimens preserved in the Museum of the College of Surgeons[1].

Conformation of the trunk.

With regard to the conformation of the trunk, we find that, both in the shape of the chest and the pelvis, the human figure is characterized by its width; the transverse diameter being in greater proportion to the antero-posterior diameter than in the lower animals. In this respect again the negro occupies an intermediate position. The chest and pelvis are not only both smaller than in the European, but the transverse diameter of both is diminished in a greater degree than the antero-posterior diameter. It is said by Carus that the transverse diameter of the Negro's chest is a sixth less than that of the European, and that the antero-posterior diameter measures nearly the same in both; and it will be found by reference to the table at p. 106, that the transverse diameter of the pelvis in the Negro measures nearly an inch less than in the European, whereas there is very little difference observable in the antero-posterior diameter[2].

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[1] This disposition is very remarkable, especially if it be found to exist in cases where there may, perhaps, not have been the opportunity of comparison so as to create the pride of difference.

[2] I found great varieties in the measurements of different specimens of the negro pelvis, and that the difference in size between the male and the female was commonly more pronounced than in the European, the male being very small.

A fine frame the natural associate of a powerful intellect.

It has been sufficiently proved by the observations of others, that the negro cranium is, in its capacity as well as in its relation to the face, inferior in size to that of the European, but Table IV. shews, that in its relation to the rest of the skeleton this is not the case. The cranium of the Negro is there seen to bear a slightly, and that of the Bosjesman, a considerably greater proportion to the rest of his skeleton than does that of the European; which is a remarkable and, I think, an unexpected fact. It is, however, to some extent in accordance with a conclusion which forces itself upon us in reviewing this comparison of the European skeleton with that of the Negro, and of both with that of the monkey, and which is confirmed by a more extensive survey than I am able here to give; namely, that in the ascent from the lower animals to the higher orders of mankind there is a gradual increase, not only in the actual size and capacity of the cranium, but also in the size of the whole frame, and more particularly in the size, strength, and excellence of conformation of the lower extremities. The dimensions of the cranium are, on the whole, a fair criterion of the dimensions of the brain, and, consequently, of the nervous and intellectual powers of the individual. It follows then, from the comparisons of different nations of mankind and of the animals nearest approaching them, that the size of the frame is, on the whole, proportionate to that of the nervous centres. This led me, in a former paper which I had the honour to read before this society, to observe, that the mental and corporeal capacities are, to a certain extent, an expression of one another, and that a fine and well-developed frame is the natural associate of a powerful intellect. We should, *à priori*, expect that it would be so, and, though numerous exceptions may be adduced, the result of all the many causes which, particularly in civilized life, contribute to modify the normal development and growth of the frame, I have no question that the rule does, on the whole, stand good.

Proportions at different ages.

Let us now proceed to observe briefly the changes that take place in the proportions of the body as it passes through the various phases of development and growth on the way to manhood. The most striking feature in these changes is, the great relative size of the head during the early periods of existence, in comparison with the more advanced periods. In the second month of fœtal life the head measures a half, or more than a half, of the whole length of the embryo. At about three months it measures an inch, the length of the embryo being from 2½ to 3 inches. The rest of the body goes on growing at a greater rate than the head, and the length of the fœtus receives considerable addition from the outgrowth of the extremities, so that by the seventh month it measures 13 inches, the head being now only 3½ inches. At birth the head forms about a fourth of the length of the child[1]. The relative decrease continues more slowly as growth proceeds, till the adult period, when the head measures about an eighth of the length of the body or less. Thus, from birth to adolescence, the relative size of the head is reduced at least one half.

Reason of disproportionate size of brain in infancy.

We are here struck with the remarkable and apparently inconsistent fact that the cranium, and consequently the brain, should have so great size, relatively to the face and the rest of the body, during the periods of intra-uterine and infantile life, when the cerebral faculties can scarcely be said to be in existence, when they are at any rate very feebly exerted: and, further, that as the latter come into play and acquire an increase of power and a greater command over the rest of the body, the relative size of the brain should undergo a continually progressive decrease. Or, to put the case in a somewhat more correct way; it seems very strange that the brain and skull should be so much in advance of the rest of the body during that very period of life in which the cerebral functions are least active and have least influence over the other organs; and that, subsequently, when the intellectual faculties are becoming developed, and the will is gaining the ascendancy over the organism, the growth of the

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[1] The measurements given by Carus correspond very nearly with the above. He states that at the commencement of the second month of fœtal life the length of the head is to that of the vertebral column as 1 to 1; at the beginning of the third month it is as 1 to 2. By the beginning of the fifth month it is as 2 to 3, the relations being about the same as at birth. At birth he finds that the face forms a third instead of a half, of the vertical depth of the skull, the orbits being of great proportionate size, whereas the nose bears about the same proportion as in the adult.

face, trunk and limbs, should proceed at so much greater rate than does the brain. The explanation of this apparent anomaly is afforded by the conditions under which the brain is placed. It is, for the purposes of protection, shut up in a case of bone which becomes hard and unyielding soon after the child enters the world; and that case admits only of a slight and slow increase of size, because bone possesses very little power of interstitial growth, and because the bones of the skull cannot grow much at their edges in consequence of the manner in which they are interlocked at the sutures. To avoid the difficulties which must necessarily have resulted from anything like a proportionate rate of growth under such circumstances, the brain is, at an early period, while the skull is still partly membranous and yielding, made large, but at the same time soft, pulpy, with much fluid in its texture. Subsequently, when the skull has become consolidated, when the intellect is ripening and volition is strengthening, the brain increases, not so much in size as in the density and quality of its texture, and in the number and depth of its convolutions. Thus in infancy the brain is large, flaccid, feeble, and quickly growing. In adolescence its growth is slower; but it is gradually becoming denser and more powerful, and is acquiring, by virtue of the increase of its convolutions, a greater amount of that vesicular structure upon which its higher properties seem more particularly to depend.

It has been suggested that the proportions of the head in infancy have reference to parturition; that the head of the fœtus is of large size compared with the rest of the body, that it may gravitate in the liquor amnii to the os uteri, and, by closing that orifice, prevent the presentation of the hands and feet[1]. Those who take that view seem to have forgotten that if the weight of the head were the cause of its presenting in the erect posture of the woman, it would have rather a contrary effect when she was recumbent. Yet head-presentations are not said to be less frequent in women who keep their bed than in those who move about. Not long ago I found the head presenting in a patient who had long been confined to bed, and who died under the effects of premature

[1] Shaw, *Medico-Chirurgical Transactions*, XXVI. 338.

labour. There can be little doubt, I think, that the presentation of the head in so large a proportion of cases is due to the fact that the contractions and pressure of the walls of the uterus bring the long axis of the child into correspondence with its own; and, aided by the movements of the lower extremities, direct the latter and the nates into the fundus or more roomy part of the organ, which causes the opposite or cranial end to occupy the pelvis.

Skull large in short persons.

It is a curious fact that when, from any cause, the growth of the rest of the body is stunted, the head not only remains disproportionately large, but it often becomes actually larger than in other persons. Thus short persons and persons with imperfectly developed lower extremities, are not uncommonly remarkable for the size of their heads. The same may be observed in rickety and hump-backed persons. Whereas those who grow quickly and become unusually tall have, for the most part, rather small heads. As though the expenditure of growing force being too great in one direction, other parts are ill-cared for.

Relative growth of face.

Although the skull is, at birth, of great size proportionately to the rest of the body, it is not so in all its parts. It is to the cerebral portion, developed so as to contain the large brain, that the size of the skull is chiefly due. The base of the skull and the face bear but a small proportion to the cranium. Had they been developed during the fœtal state in the same ratio with the upper part of the brain-case, a greater diameter of the mother's pelvis would have been necessary to permit delivery. After birth, especially during the periods of dentition, compensation is made by the growth of the face and of the base proceeding at a greater rate than does that of the rest of the skull. Supposing therefore any cause to occur, such as rickets, which arrests the growth of the whole body, then we find, not only that the limbs are small in comparison with the skull, but that the face also is small in comparison with the cranium. In short, the infantile type remains perpetuated in both instances. Attention was first particularly directed to this point by Mr Shaw[1], who finds "the relative size of the cranium to

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[1] *Medico-Chirurgical Transactions,* Vol. XVII. 26. The observations of Mr Shaw are on the whole confirmed by the measurements of five skeletons with curvature of

that of the face, in the child, to be as 8 to 1; in the adult as 6 to 1; while in the adult whose growth has been interrupted by rickets it is as $7\frac{1}{13}$ to 1; that is, the ratio in such individuals is intermediate between what it is in the child and the adult." In those persons who exceed the ordinary standard of height, he finds the impulse of growth to be shared by the face and extremities in a greater degree than by the cranium. Thus the relation of the skull to the face of the giant was only 5 to 1. These results, though generally true, are liable to some exceptions. I have remarked that not unfrequently in short persons, and occasionally in rickety skeletons, the face has borne its proper relative size to the cranium, both being in an equal, or nearly equal, degree out of proportion to the rest of the body. It must be remembered that in some rickety subjects the brain exceeds the ordinary size; in others the skull is morbidly thickened; and both these conditions are sources of fallacy in estimating the usual relations of the face and cranium in that class of persons.

Proportions of extremities during development.

The limbs may be distinguished in the second month of fœtal life as small processes budding out from the sides of the trunk; the upper ones a little sooner than the lower: and the feet and hands are the parts first formed. At 3 months the upper limbs measure rather more, the lower rather less, than $\frac{3}{4}$ inch. The shape of the feet and hands is distinct; though the thumb is at that time nearly parallel with the fingers, not divergent from them as it subsequently becomes. At 7 months the upper extremities measure $5\frac{1}{2}$ inches, and are exceeded by the lower which measure 6 inches: the division into upper arm, fore-arm, and hand, into thigh, leg, and foot, has also become apparent.

At the 7th month the nails are better developed in the fingers than in the toes; and ossification has commenced in all the terminal phalanges of the fingers, whereas in the toes it is confined to the terminal phalanx of the pollex. Thus the fingers are a little in advance of the toes in their development at this period. Not so, however, the

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the spine, made by Dr M. Stern (Müller's *Archiv*, 1834, p. 225). These show the face to be small, actually as well as relatively to the cranium. He found the same with regard to all the other bones of the skeleton with the exception of the brain-case which was large.

carpus. In it ossification has not begun, whereas there is already a bony nucleus in the heel-bone. At birth the lower extremities have gained some other points in advance: a distinct bony nucleus is present in the astragalus, in the lower epiphysis of the femur, and in the upper epiphysis of the tibia, (see Pl. I.); and ossification has made considerable progress in all the phalanges. It appears, therefore, that the extremities proceed *pari passu* in their development more nearly than might be supposed from the statements generally made. The upper extremities have a little the advantage in the earlier periods of fœtal life; but they are overtaken subsequently by the lower limbs, which, at the time of birth, are somewhat in advance of them.

Proximal segments at first shortest.

With regard to the proportions of the different *segments* of the extremities; in the earliest periods the arm and thigh are respectively shorter than the fore-arm and leg, and the latter are respectively shorter than the hand and foot. During development and growth these proportions gradually become reversed; but the final relations between the several segments are not established till after puberty (Tables VII. and VIII.). At birth it will be seen by reference to the tables, that the arm, leg, and foot are of about equal length; and that the hand is a little longer than the fore-arm.

Fœtal proportions show some approximation to those of Negro and quadrumana.

These facts are interesting as clearly showing that in its earlier conditions the most perfect human form presents more numerous approximations to the permanent type of the Negro, and likewise to that of the quadrumanous animal, than at subsequent periods. They show also that it is during the work of development and growth that the lower extremities attain their greater relative dimensions, and that the proximal segments of both upper and lower extremities come to bear that large proportion to their distal parts whereby the European type is characterized. By thus reducing the difference in type between the Negro and the European to a mere matter of growth, and showing that, so far as the extremities are concerned, a transient condition of the one corresponds with a permanent condition of the other —the one being only a further development of the other, or, rather, a degree of development in advance of the other—some countenance is given to the opinion entertained by Pritchard and others, that the human family are all derived from one stock, which has become modified by a variety of external circumstances, and that the type of that stock is preserved in the Negro. The same remark applies also to the dimensions of the trunk. Till the period of puberty the European and the Negro more nearly correspond. It is not till after that period that the greater proportionate breadth of chest and pelvis is attained in the former.

That inferences of this sort must, however, be drawn with much caution, is sufficiently illustrated by the view which has been taken from the same line of argument pressed a little further, or rather I should say a good deal further: namely, that not only is the European a result of an advanced development of the negro type, but that both are in like manner merely the product of an advanced development of the monkey. This fanciful notion, derived from exaggerated ideas of similarities that exist, and of the changes which take place in fœtal life, as well as from an imperfect knowledge of the real differences between the human and the quadrumanous classes, has been so amply refuted by Professors Clark and Owen, that it needs no further comment.

Middle point of figure.

The small size of the pelvis and lower limbs, in comparison with that of the head during the first months of fœtal life, causes the *middle point* of the body to be situated higher at that period than afterwards. At about 3 months it is a little above the lower end of the sternum. Before this it is higher still. At 7 months it is just below the lower end of the sternum. At birth it is a little above the umbilicus. After birth to adolescence it is between the umbilicus and the pubes; being for the most part a little lower in tall persons than in the short. In a man who was only 4 feet 2 in. in height, the middle point was at the umbilicus. In the well-formed adult it is, as before said, at the symphysis pubis; the length of the lower extremities being equal to that of the rest of the body. In the position of the middle point of the body we find, therefore, another point of similarity between the fœtal and the quadrumanous skeleton.

It appears from the measurements of Carus, that the age of 15 offers, in some respects, a contrast to the proportions of fœtal life;

forasmuch as at that time the extremities have acquired a greater relative length than at any former period; which is, to a certain extent, lost in the further accomplishment of growth. This, he remarks, gives the lengthiness of limb and slenderness of figure which is characteristic of that period of life. Some corroboration of this statement is furnished by the measurements given in Tables VII. and VIII. pp. 110, 111.

Arrested development.

Examples of arrested development and growth, as already mentioned, are occasionally met with, in which the fœtal proportions are perpetuated in the adult frame. The most marked instances are those in which the earliest condition is permanent, a hand or foot only being appended to the trunk, and all the rest of the limb being wanting. In rickety persons whose growth is usually defective, the limbs are commonly short; and it is interesting to observe, that the failure of growth is most marked in the arms and thighs; more particularly in the latter. I have measured some examples in which the fore-arm was longer than the arm, and several in which the leg was longer than the thigh. In some of these the trunk is also small; but in most of them the head has its normal size, or more than its normal size, giving a remarkable preponderance to this part of the figure.

Peculiarities of rickety and short persons.

In persons of this class the limbs are generally curved, even when there is no other evidence of a rickety diathesis. Indeed I think it may be stated that as a general rule the bones are curved in proportion to the shortness of stature of the individual, the tallest persons having the straightest bones. This may be for the purpose of redeeming by their greater curvature some of the elasticity which has been lost by want of length in the bones, so that the delicate internal organs may be alike defended from jars, whether the bones are long or short. Be this so or not it is certain that, owing to the leverage which these curves afford to their muscles, very short persons are commonly very strong.

Dwarfs on the whole well proportioned.

It is to be remarked that short persons, in whom the deficiency of height is due to a want of proper proportionate growth in certain parts, are to be distinguished from *dwarfs* strictly so called, although they are often confounded with them. In the true dwarf, so far as I have been able to ascertain, the proportions between the several parts of the frame are good, corresponding or nearly corresponding with those of the normal adult; and the diminutive stature depends, accordingly, not upon the relatively imperfect growth of any particular segments, or even upon the permanence of a fœtal or childlike condition; but upon the whole frame being undersized. The various phases of development and growth go on, and go on correctly, but upon a small scale. This was the case in Nicholas Perry—*alias* Bœbe—æt. 23, a celebrated Polish dwarf, under 3 feet high, whose skeleton, preserved in the museum of the *Jardin des Plantes*, shows a fair proportion between head, trunk and extremities, (Tables III. and VI. pp. 108, 9,) and in a dwarf æt. 26, under 4 feet high, the measurements of which are given by Carus[1]; it was so too, if my memory is correct, in the instance of General Tom Thumb. Indeed in Carus' case, far from the infantile type being retained, as it would have been from a mere imperfection of growth, it is most remarkable that the extremities are somewhat longer than they should be, the preternatural length depending, in great measure, upon a disproportionate growth of the thigh and arm. In Bœbe also, though the leg and fore-arm are short, the arm is long in proportion to the whole figure and the thigh is long in proportion to the leg. It would seem, therefore, that the stature of these dwarfs is somewhat higher than its module would indicate that it should be; and if the same proportions be found in other instances the paradox would be rendered tenable, that dwarfs, though undersized, are in reality rather overgrown persons[2].

Their extremities rather lengthy.

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[1] *Die Proportionslehre*, s. 12, and Table X. given at p. 112.

[2] The Sicilian dwarf preserved in the College of Surgeons, whose measurements are given in Table III., is not a fair example, inasmuch as she was only ten years old, and the processes of development as well as growth are remarkably backward, being advanced very little beyond what is usual at the time of birth. Most of the epiphyses, as well as most of the carpal and tarsal bones, remain cartilaginous, and the skull is very large. In Bœbe I observed the head and face to be rather small in proportion to the rest of the body, and decidedly small in comparison with the head and face of a four-year-old skeleton which stands close by it, and which exceeds it in height by two inches.

It may be objected that this conclusion is not warranted, and that instead of saying the extremities are disproportionately long in these dwarfs, it would be more correct, or at any rate equally correct, to say, that the other parts are disproportionately small. To this I would answer, that forasmuch as the central parts of the skeleton are those first formed, are the most important, and are in close relation with the various important internal organs, being, in fact, in great measure, moulded upon those organs, they may be most fitly selected as affording the standard of the proper dimensions of the whole skeleton. We are therefore more likely to arrive at correct conclusions respecting the normal height of the skeleton in any particular instance by data derived from them than from the extremities. The latter are subject to greater varieties, and must be considered long or short in accordance with their relation to the central parts.

Tall persons.

Having made these observations with reference to dwarfs I naturally turned with some interest to examine the proportions of those who are oversized. The measurements of several persons who were somewhat above the ordinary standard of height showed that there was considerable variety. In some the height depended chiefly upon length of trunk, in others more upon length of extremities; and in many both trunk and extremities were elongated in an equal degree. In short, no particular results were obtained.

In giants the extremities short in relation to the stature.

The only *Giant's* skeleton I have had an opportunity of measuring is that of O'Byrne in the museum of the College of Surgeons. His height was 8 feet 2 inches. He died at the age of 22. The measurements given in Table II. indicate proportions in many respects the reverse of those of the dwarf. The extremities are by no means long. Indeed they are in every particular shorter in relation to the stature than they are in the normal European. The middle point of the body is an inch above the symphysis, and it is interesting to observe that the length of the lower extremities is greatly dependent upon the leg-bones, which exceed their proper relative proportions to the thigh-bones, and that in like manner the fore-arm is long in proportion to the arm. In other words, the thighs and arms have not grown up to their proper length either in relation to the legs and arms or to the trunk; and, if these proportions obtain in giants generally, the same process of reasoning which led me to speak of dwarfs as rather overgrown, though undersized individuals, seems to warrant the conclusion that giants though oversized are rather undergrown.

The inferences drawn from O'Byrne's skeleton are confirmed by the measurements of several other giants given in Tables II. and V. These were made since the above was first written.

It appears that in all these giants, with one exception, the cranium is small in proportion to the rest of the skeleton, and that the spine is the only part in which the due proportions are exceeded. It may be objected that this opens a source of fallacy because measurements of the spine are less to be relied on than those of other parts, in consequence of artificial intervertebral substances being added when the skeleton was articulated, and there would be a temptation to increase the height of a giant's skeleton by making them thicker than they ought to be. I could not perceive that this had been done in any instance; and in the cases where the height of the giant, when living, was given it exceeded that of the articulated skeleton.

Proportions of female.

With regard to the differences between the figure of man and woman.—The latter is smaller in most of its dimensions. In the proportions of its several parts it presents in some respects an approach to the infantile type. The brain-case and the brain, though actually smaller, are, relatively to the rest of the body, larger than in man[1]. The face is smaller. The extremities are shorter, both thigh and foot being proportionately small. The transverse diameter of the chest is less, but that of the pelvis is greater. Although, therefore, man presents in some respects a

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[1] Carus finds the size of woman's brain to that of man's is as 44½ to 50. Nevertheless, the size of woman's brain to that of the body is as 1 : 35; that of man's being as 1 : 37½. The brain of a woman weighed 46 oz. 6 drachms, and the spinal cord 1 oz. 6 drachms; whereas in a man with a very small head whose brain weighed 41 oz. 4 drachms the spinal cord weighed still 1 oz. 6 drachms.

The skull of the female is said to be, relatively to the rest of the skeleton, heavier than that of the male; the proportion in the former being as 1 to 6, and in the latter as 1 to 8. Jourdan's *Encyl. Anat.* II. 18.

wider departure from the brute creation—as in his greater stature, the width of his chest, and the length of his thigh and arm; yet the balance is restored and the attributes of the human figure are preserved to woman by the large proportionate size of her cranium, the small proportionate size of her feet and hands, and by the width of her pelvis.

Results. The chief results of all these details are:—1. That certain tolerably definite proportions between its several parts are uniformly observed in the construction of the human frame. 2. That these proportions differ in a regular and distinct manner from the proportions of the nearest allied members of the animal kingdom. 3. That the proportions of the inferior races of mankind, in their differences from the higher ones, present some approach to the animal type. 4. That in the progress of the development and growth of the trunk and extremities the human frame passes through phases of similarity to the animal and the negro type on its way to the European or perfect standard. 5. The remarkable fact has been elicited that, in some of those persons who are of unusually low stature, these specific proportions, if I may so call them, are rather exceeded in the extremities, while in those of excessively high stature they appear to be scarcely attained.

It will perhaps be asked, are there no other results? Is there nothing further, nothing of a higher character to follow from this sort of study of the human frame? Are there no great and important laws involved in all this; laws having relation to the better part of man? If the material world be in any way, as has been supposed, an expression or representative, a sort of cast as it were, of the immaterial, ought we not, in the contemplation of the human form, the highest and noblest work in creation, which is so essentially a minister of the spiritual, to be able to penetrate a little beyond the husk and outward form, and to base upon that outward form some, at least obscure, notion of the nature and qualities of man's inward essence? It has been attempted at various periods in the history of science and in various ways to do something of the kind. The efforts have been made chiefly by those in whom the imaginative have predominated rather than the inductive faculties of the mind, and they have not come to much practical result.

They have served only to convince us that there is between the material and immaterial a gap which no power of human reason can bridge over. We may observe the mode in which the human frame, as distinguished from that of animals, is fitted to carry out the purposes of an intelligent will; but we are unable to go further, and can discover in the physical construction of man nothing to guide us to a knowledge, even to an idea, of his more important and essential peculiarities and of the high destinies that are associated with them. The consciousness of this makes us the more deeply thankful that, for all needful information on these points, which are, after all, by far the most important, we are not left to uncertain deductions from the book of science, but are able to rely upon the sure word of revelation.

The measurements given in the tables appended and those from which the averages were derived, were taken by myself from skeletons or separate bones contained in various museums in England, in Paris, and in Germany, except that of the Irish giant, for which I am indebted to Mr Butcher of Dublin. In Tables IV. V. and VI. the several measurements given in I. II. and III. are, for convenience of observation, reduced to a scale of proportion to 100, which is taken to represent the height of the skeleton in each instance. The tables are not quite perfect, because in some cases the skeletons were imperfect; and because in others it was difficult to estimate correctly the length of the spine, foot, and hand, in consequence of the manner in which the bones were put together. Difficulties were also often experienced in taking the measurements of the bones of young persons, owing to the greater or less shrinking of the cartilages of the epiphyses.

TABLE I.

MEASUREMENTS OF SKELETONS.

(IN INCHES.)

	Height.	Middle, point of.	Spine, length of.	Circumference of Skull.	Humerus.	Radius.	Hand.	Femur.	Tibia.	Foot.	Pelvis. Trans. diameter.	Pelvis. Ant-post diameter.
European (average of 25) ...	65	Symphysis pubis.	22.2	20.5	12.7	9.2	7.3	17.88	14.4	10.6	5.2	4.3
Negro (average of 25)	62	1 inch below Symphysis.	19.3	19.8	12.1	9.4	7.7	17	14.4	11.11	4.6	4.1
Bosjesman (average of 3) ...	54	Symphysis.	17	19.6	10.8	8.3	6	15	12.9	7.5	4.4	3.5
Idiot (in Berlin Museum) ...	57		19.5	13.5	12	8.8	7	16	12.5	8.5	5	3.8
Chimpanzee (average of 4)...	50	3 inches above Symphysis.	17		12.2	11	9	12.4	10	10.5	4	5.5
Orang (average of 2)..........	44	3½ inches above Symphysis.	18		14	14	10	10.6	9.2	12	3.8	4.5
Gorilla (average of 3).........	58	4 inches above Symphysis.	21		16.6	12.9	9	13.9	11.3	12	5.7	7.3

TABLE II.

GIANTS.

	Height.	Middle, point of.	Spine, length of.	Circumference of Skull.	Humerus.	Radius.	Hand.	Femur.	Tibia.	Foot.	Pelvis. Trans. diameter.	Pelvis. Ant-post diameter.
O'Byrne	8 ft. 2 in.	1 inch above Symphysis.	30	23.5	17	13	10	24.2	21	12.5	6.8	6.2
Irish Giant in Trinity College, Dublin	8 ft. 6 in.	4 inches above Symphysis.	33.7	34.5	17.2	13.5	10.3	25.2	20.5	11.8	8.5	4.5
Models in Musée Orfila ...	7 ft. 9 in.							24	22			
Prussian Giant in Museum at Bonn	8 ft.							21				
Ditto, ditto	7 ft. 6 in.							20.8				
Skeleton in College of Surgeons	7 ft.	½ inch below Symphysis.	25.2	21.5	16	11.8	9.2	22.8	19	12.3	5.8	5.3
Skeleton in Museum at Berlin	7 ft. 3 in.		28	20.3	17	11.7	9	24.3	25	11	6.1	5.6
Ditto, ditto	7 ft.		29.5	28	15.4	12	10	22	18.6	11	6.2	6
Separate bones in College of Surgeons								22	20			
English female	6 ft. 1 in.				13	10.4		19.8	16.5			

TABLE III.

DWARFS.

	Height.	Middle, point of.	Spine, length of.	Circumference of Skull.	Humerus.	Radius.	Hand.	Femur.	Tibia.	Foot.	Pelvis. Trans. diameter.	Pelvis. Ant-post diameter.
Sicilian female, æt. 10, in College of Surgeons ...	20 in.	¾ inch above Symphysis.	6.2	14	3.5	2.6	2.2	5	3.5	2.8	1.4	1.5
Nicholas Perry, alias Bœbe, æt. 23, in Jardin des Plantes	3 ft.				8	4.9		9.5	7		3.1	2.4

TABLE IV.

TABLE I. REDUCED TO A SCALE.

	Height.	Middle, point of.	Spine, length of.	Circumference of Skull.	Humerus.	Radius.	Hand.	Femur.	Tibia.	Foot.	Pelvis. Trans. diameter.	Pelvis. Ant-post diameter.
European	100.00		34.15	31.54	19.54	14.15	11.23	27.51	22.15	16.03	8	6.61
Negro	100.00		31.13	31.94	19.52	15.16	12.42	27.40	23.23	17.90	7.42	6.61
Bosjesman	100.00		31.48	36.29	20	15.37	11.11	27.78	23.89	13.78	8.15	6.48
Idiot	100.00		34.21	23.68	21.05	15.43	12.28	28.07	21.92	14.96	8.94	6.66
Chimpanzee......................	100.00		34		24.40	22	18	24.80	20	21	8	11.11
Orang	100.00		37.50		29.17	29.17	20.83	22.08	19.17	25	7.91	9.37
Gorilla	100.00		36.21		28.62	22.24	15.54	23.97	19.48	20.69	9.83	12.59

TABLE V.

TABLE II. REDUCED TO A SCALE.

	Height.	Middle, point of.	Spine, length of.	Circumference of Skull.	Humerus.	Radius.	Hand.	Femur.	Tibia.	Foot.	Pelvis. Trans. diameter.	Pelvis. Ant-post diameter.
O'Byrne	100.00		30.61	23.98	17.35	13.26	10.41	24.69	21.43	12.75	6.94	6.33
Irish Giant	100.00		33.04	33.83	16.86	13.23	10.1	24.70	20.90	11.57	8.33	4.45
Models	100.00							25.81	23.66			
Prussian Giant	100.00							21.87				
Ditto	100.00							23.11				
Skeleton in College of Surgeons	100.00		30	25.59	19.05	14.50	10.95	27.14	22.62	14.16	6.90	6.31
Ditto in Berlin	100.00		32.18	23.33	19.53	13.44	10.34	27.93	23.56	12.64	7.01	6.43
Ditto	100.00		33.92	33.33	18.80	14.28	11.90	26.19	22.14	13.09	7.38	7.14
English female	100.00				17.81	14.25		27.12	22.60			

TABLE VI.

TABLE III. REDUCED TO A SCALE.

	Height.	Middle, point of.	Spine, length of.	Circumference of Skull.	Humerus.	Radius.	Hand.	Femur.	Tibia.	Foot.	Pelvis. Trans. diameter.	Pelvis. Ant-post diameter.
Sicilian	100.00		31	70	17.50	13	11	25	17.50	14	7	7.5
Bœbe	100.00				22.23	13.6		26.39	19.45		8.6	6.67

TABLE VII.

MEASUREMENTS AT DIFFERENT AGES.

Age.	Height.	Spine.	Circumference of Skull.	Humerus.	Radius.	Hand.	Femur.	Tibia.	Foot.	Pelvis. Trans. diameter.	Pelvis. Ant-post diameter.
At birth	19	7	15	3.5	2.5	3.1	4.3	3.5	3.5	1.3	1.3
2 yrs.	25	8	17.5	4.5	3.3	3	5.5	4.5	3.5	2.2	2.2
	29	9	18	5	4	3.2	7	5.8	3.7	2.2	2.2
Average	27	8.5	17.7	4.7	3.6	3.1	6.2	5.1	3.6	2.2	2.2
4 to 6	31	10.5	16.2	5	3.4	3.3	6.7	5.3	3.7	2	2.2
M.	36	11.3	20.2	6.7	5.2	4	8.5	7	5.3	2.2	2.3
F.	35.5	12	18.2	6.7	4.5	4	9.3	7	5	2.5	2.5
	35	12	18	6.2	5	4.2	8.5	6.5	5	2.3	2.3
	34	11	19	6.3	5	4.2	8.5	7	5	2.5	2.3
				6.6	4.9		9	6.9		2.6	2.8
M.	34.5	13.2	16	7.5	5.5	4.2	11.5	8.5	6	2.9	2.6
	37	12.5	18.6	6.6	5.2	4.5	9.6	7.6	5.5	2.4	2.8
	38	12.5	17.5	7	5.3	4.8	9.4	8	5.4	2.7	2.8
F.	35	11.6	18.3	7.5	4.6	4	9	7	5.4	2.5	2.6
M.				6.7	4.9		9.9	7.4		3	2.6
Average	35	11.8	18	6.6	4.8	4.1	9.1	7.1	5.1	2.5	2.5
8 to 12 M.	45	14.2	19	8.5	6.2	5	12	9.5	6.5	3.2	3.3
M.	48	15.2	20.5	9	6.4	5.3	13	9.8	7.3	3.4	3.4
	49	16	19	9.2	7	5.4	13.5	11.3	7		
F.	39.5	12	18.5	8	5.6	4.6	10.5	8.5	5.6	3	3
M.	45	14	15.7	8	5.5	5	11.5	9	6.5	3	3.2
M.	40.5	13	18.4	7.2	5.2	4.5	9.6	8	5.7	2.7	2.9
F.	43	12	19.2	8.8	6	5	11.5	9.3	6.5	3	2.8
M.	46	15.2	20	9	7	5.4	12.5	11	7	3.5	3.3
F.	30	13	19.5	7	5.5	6	10.5	8	6		
Average	43	12.8	18.8	8.3	6	5.1	11.4	9.4	6.4	3.1	3.1
15 M.	52	16	20	10.5	7.8	6.5	14.5	12	8.4	3.7	3.5
M.	55	17	19	10.5	7.5	5.8	14.8	12	8	3.7	3.7
F.	55	17	19	10.3	7	5.6	14.8	11	7.8	4	3.6
M.	54	16.5		10.5	7.5		15	11.5			
Average	54	16.6	19.3	10.4	7.4	5.7	14.8	11.6	8	3.8	3.6
18 to 19 F.	62	19	19.5	12.4	9	7	16.5	14.2	9	5.1	5
F.	59	19	19.5	11	8.2	6.5	16	12.8	8	5	4.8
M.	59	17.5	20.4	11	8.5	6.3	15	13	8	3.9	3.8
Average	60	18.5	19.8	11.4	8.6	6.6	15.8	13.3	8.3	4.7	4.5

TABLE VIII.

AVERAGE MEASUREMENTS AT DIFFERENT AGES REDUCED TO A SCALE.

Age.	Height.	Spine.	Circumference of Skull.	Humerus.	Radius.	Hand.	Femur.	Tibia.	Foot.	Pelvis.	
										Trans. diameter.	Ant-post diameter.
2	100.00	31.48	65.55	17.40	13.33	11.48	22.94	18.88	13.33	8.14	8.14
4 to 6	100.00	33.71	51.42	18.85	13.71	11.71	26.00	20.28	14.57	7.14	7.14
8 to 12	100.00	29.76	43.72	19.30	14.09	11.86	26.51	21.86	14.65	7.21	7.21
15	100.00	30.74	35.70	19.25	13.70	10.55	27.40	21.48	14.81	7.03	6.66
18 to 19	100.00	30.83	33.00	19.00	14.33	11.11	26.33	22.16	13.83	7.83	7.50
Adult	100.00	34.15	31.54	19.54	14.15	11.23	27.51	22.15	16.03	8	6.61

TABLE IX.

The following measurements are given by M. Sue in the *Memoires de l'Académie Royale des Sciences,* 1755, Tome II. p. 574:

Fœtus of	Total length.	Trunk.	Upper extremities.	Lower extremities.
6 weeks.	16 lin.	1 in.	5 lin.	4 lin.
2½ months.	2 in. 3 lin.	1 ,, 8 lin.	9 ,,	7 ,,
3 ,,	3 in.	2 ,, 1 ,,	13 ,,	11 ,,
4 ,,	4 in. 4½ lin.	2 ,, 11 ,,	1 in. 9 ,,	1 in. 5½ ,,
5 ,,	6½ in.	4 ,, 4 ,,	2 ,, 6 ,,	2 ,, 2 ,,
6 ,,	9 in.	5 ,, 8 ,,	3 ,, 7 ,,	3 ,, 4 ,,
7 ,,	1 ft. some lin.	6 ,, 5½ ,,	5 ,, 10 ,,	5 ,, 9 ,,
8 ,,	14 in. 9 lin.	8 ,, 3½ ,,	6 ,, 8 ,,	6 ,, 6 ,,
9 ,,	18 in.	10 ,,	8 ,,	8 ,,
1 year.	1 ft. 10½ in.	13 ,, 6 ,,	9 ,,	9 ,,
3 years.	2 ft. 9 in. some lin.	19 ,,	14 ,,	14 ,, some lin.
10 ,,	3 ft. 8 in. 6 lin.	2 ft.	19 ,,	20 ,, 6 lin.
14 ,,	4 ft. 7 in.	2 ft. 4 in.	24 ,, 6 ,,	27 ,,
25 ,,	5 ft. 4 in.	2 ft. 8 in.	30 ,,	32 ,,

TABLE X.

IDEAL PROPORTIONS OF HUMAN FIGURE AT DIFFERENT PERIODS OF LIFE, ETC. (*Reduced from* CARUS' *Work.*)

	At Birth. Module = 9 Centimeters, or 3.53 in.		At 3 Years. Module = 10 Centimeters, or 3.93 in.		At 6 Years. Module = 13 Centimeters, or 5.11 in.		At 15 Years. Module = 16 Centimeters, or 6.29 in.		Full-grown. Module = 18 Centimeters, or 7.07 in.		Dwarf, æt. 26. Module = 12 Centimeters, or 4.71 in.		Female.		Negro.	
	Modul.	Min.[1]	Modul.	Min.	Modul.	Min.	Modul.	Min.	Modul.	Min.	Modul.	Min.	Modul.	Min.	Modul.	Min.
Length of skull from forehead to occiput	2		1	10	1	8	1	5	1		1	4				
Circumference of skull	5	12	3	22	3	12	3	6	3							
Height from lower margin of upper-jaw to crown	1	12	1	3	1	3	1	2	1		1	2		22		22
,, root of nose to crown	1			17		16		14		12				12½		
,, ,, to lower margin of upper-jaw		12		10		11		12		12				10		22
Breadth of face between malar bones	1	6	1			23		20		18						
Each orbital cavity (width of)		12		9		8		6½		6						
Length of nose		8		8		8		8		8						7
Height of skull from foramen magnum to crown	1	6	1	3	1			20		18						
Depth of fore part of lower-jaw		5		6		6		6		6						
Length of arch of lower-jaw	1	12			1	6			1							
,, vertebral column	3		3		3		3		3							
,, neck from chin to upper edge of sternum		8		8		9		11		12						
From upper edge of sternum to pit of stomach	1		1		1		1		1		1					
,, pit of stomach to navel	1		1		1		1	2	1		1					
,, navel to upper edge of pubes	1		1		1		1		1		1					
,, middle of upper edge of breast-bone to tip of shoulder	1			22	1		1		1					20		22
Between iliac crests	1	6	1	12	1	14	1	15	1	16	1	16				21
,, anterior inferior iliac spines	1								1				1	4		
Height of os innominatum		18						22	1							
Length of head		18						22	1							
Height of scapula		18		20		22		23	1							
Length of arm	2	12	2	16	2	18	3	2	3		3	5				
,, upper-arm	1	7	1	10	1	11	1	16	1	15	1	20			1	18
,, fore-arm	1	5	1	6	1	7	1	10	1	9					1	11
,, hand		20		20		22	1		1			23		21½	1	2
From last lumbar vertebra to acetabulum		14		14		14		15		18						
Length of thigh	1	12	1	18	2	1	2	13	2	12	2	14	2	7	2	11
,, leg	1	6	1	18	1	23	2	2	2		2	1			2	2
Height of foot from sole to ankle		8		8		8		8		10						7
Length of foot from heel to point of toes	1		1	4	1	8	1	13	1	12			1	9	1	13
,, ankle to point of toes		17		20		22	1		1							
Height of figure from crown to sole	8		8	12	9		9	12	9	12	10		9		9	6

THE SPINE

is the most distinguishing and important part of the skeleton of a large, and that the highest, class of the animal kingdom[1]. It preserves its chief characteristics in all the members of that class. In each of the Fishes, the Reptiles, the Birds and the Mammals, it is composed of a series of bones, placed one above, or in front of, the other, called *vertebræ*. Hence the whole of these, the highest orders of animals, are included under the name VERTEBRATE[2]. The several components of the spine—the vertebræ—vary greatly in their number in different animals, even in members of the same subdivision: the comparison of an ophidian (a boa constrictor for instance) with a chelonian reptile (a turtle) at once shows this; and the number in each have, apparently, no relation to the other organs or members of the animal. They differ also in their shape, even in different parts of the same spine. What can be more unlike a dorsal vertebra than the last bone of the coccyx? Nevertheless they present certain marked characteristics, which are, with few exceptions, constant in this great division of the animal series. Each one consists of a short, thick mass of bone, in shape, more or less, approaching to a cylinder, which is connected with a similarly shaped bone above and below by a softer intervertebral substance. This bony mass constitutes a fundamental or central portion—*centrum*—from which other parts seem to emanate as processes[3]. The processes vary in number in the different vertebræ.

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[1] It is the part first formed in the embryo, and is very rarely wanting; the instances in which it has been so being those of the most imperfect monsters. (Otto's *Path. Anat.* by South, p. 194.)

[2] The skeletons of invertebrate animals are composed of horny, or shelly, or calcareous matter, but never of true bone. Wherever in the animal kingdom true bone exists, the skeleton is arranged in vertebræ, and has an intimate relation to the nervous system.

[3] I say, seem to emanate, because the other components of the vertebræ do not, in reality, radiate from the centra; in some instances they are formed independently, and

They are all absent in the lower bones of the coccyx. The centrum is constant in man, and nearly so in other animals. Even the atlas has ceased to be considered an exception to the rule, since we have been taught that its body forms the odontoid process of the dentata. There is every probability that each of the *centra* corresponds with, and is developed in connexion with, one of the primitive *central* ganglia of the nervous system; though, as growth proceeds, their topical relation to one another may be altered. This has occurred with regard to nearly all the vertebræ of the human spine; the lumbar, sacral, and coccygeal centra are not in juxtaposition with the cord at all, and those of the dorsal and lower cervical portions are not in juxtaposition with the same segments of the cord as they were at their first formation.

Homologies of the skeleton not here discussed.

These *centra*, which are also called the *bodies* of the vertebræ, with the intervertebral substances between them, are arranged in a row in the axis of the skeleton, forming a line around which all other parts are arranged, and from which they all appear to radiate. The limbs, no less than the more closely connected organs, may all be regarded as appendages to this spinal axis; and the attention of anatomists has been long and closely directed to the study of the relation which the various pieces of the skeleton bear to the different segments of the spine and to one another. Into the results of that highly interesting but difficult study I do not propose now to enter, but proceed at once to consider the mode of

DEVELOPMENT OF THE VERTEBRAL COLUMN.

Changes in Chorda dorsalis.

The first indications of the spine are given by the appearance of the "Chorda dorsalis" in the investing membrane of the ovum. It has a gelatinous appearance, consists entirely of cells, is of cylindrical form, and lies in the

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some of them, the "arches" or "neural processes," are ossified before the "centra." Though the fundamental and most constant part of a vertebra, the centrum is not the most certain in its ossification; in some animals (the Lepidosiren) it does not become ossified at all.

long axis of the embryo. Soon it becomes enclosed in a membranous sheath, which assumes a fibrous structure; and it corresponds at this time with the permanent condition of the "Lancelet[1]." In this membranous sheath the cartilaginous bodies of the vertebræ are soon formed, while the chorda dorsalis itself gradually shrinks and disappears, with the exception of the portions left between the vertebral bodies, which are converted into the intervertebral substances. In some fishes it is persistent, being continued from end to end of the column through the centres of the bodies of the vertebræ, which in them are ring-shaped, instead of being solid cylinders as in other vertebrates.

The "chorda dorsalis" appears first in the germinal membrane as a line; by the elevation of the membrane on either side the line becomes a groove with the chorda dorsalis at the bottom: gradually the groove becomes deeper, and nervous elements—the "neural laminæ"—are developed at the sides and bottom of the groove, and constitute the rudiments of the spinal cord. The outer membranous sheath of the chorda dorsalis, which is in the middle line situated beneath the nervous structure, is prolonged into the sides of the groove, external to the neural laminæ, and forms the rudimentary "vertebral plates" or "laminæ." These two structures—the neural and vertebral laminæ—growing up together from either side of the groove and bending in towards the middle line, coalesce with those of the opposite side so as to form a nervous tube included in a vertebral tube. As the two structures grow and assume their respective characters they become distinct, and, to a certain extent, detached or separated from one another. The separation takes place latest in the part of the canal last formed; that is, along the median line behind, or, more properly, above. (These processes are partly illustrated by the diagrams in Plate III. figs. 1, 2, 3, 4.)

Formation of the vertebræ.

Thus the nervous canal and the vertebral canal are formed together. In about a month the rudiments of the individual vertebræ are visible, their several formation being the result of the conversion of the vertebral laminæ into cartilage

[1] Owen's *Lectures on Comparative Anatomy*, II. 45.

at certain points on either side, and in front, of the canal[1]. Fig. 6, in Plate III. is a drawing of the spine of a human fœtus of about a month. The median white line is the spinal cord. The broad oblong white spots or streaks, arranged in a row on either side, having their long diameter at right angles to the cord, I clearly made out to be the rudimentary vertebral arches. This view was taken from behind. The anterior aspect given at fig. 5 shows, along the median line, a row of spots (represented dark, though in the specimen they had a transparent, slightly bluish appearance, with dark lines between them). These are the rudimentary bodies; and the arches can be seen on either side approaching to meet them. Each vertebra is thus formed of three primitive cartilaginous portions; one in the situation of the original "chorda dorsalis" for its body, and one on either side for the arch. In each of these cartilaginous

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DESCRIPTION OF PLATE III.

Development of the Spine.

Figs. 1, 2, 3, 4, (from Reichert, *Das Entwickelungsleben im Wirbelthier-Reich*. 1840), are diagrammatic representations of transverse sections of the ovum of a frog showing the development of the rudimentary nervous and vertebral systems. *Y* is the yolk, *I* the investing membrane, *Ch.* the chorda dorsalis, *V* the vertebral plates with their upward and downward prolongations; the latter are in close relation with *N*, the rudimentary nervous centres. They grow up together, and in Fig. 3 have covered in the neural canal, but remain united at the uppermost part. In Fig. 4 they are more nearly separated, and the nervous centres are separated from the chorda dorsalis by the growth of the vertebral bodies around the latter. *C* is the cutaneous system, *A* the depression in the yolk beneath the germinal part.

Fig. 5. Spine of a human fœtus æt. a month, seen from the front. The row of dark spots in the median line represents the vertebral bodies, and the parallel broad white lines on either side the vertebral arches.

Fig. 6. The same viewed from behind. The median white line is the nervous centre, the broad streaks on either side are the vertebral arches.

Fig. 7. Longitudinal section through spine of a human fœtus æt. under three months, showing the square cartilaginous vertebral bodies separated by distinct lines which are the invertebral spaces. There are minute specks of ossification in the vertebral bodies of the dorsum.

Fig. 8. Back view of the same fœtus; the arches have nearly or quite coalesced in the dorsal region, are still separated by a considerable interval above and below that part.

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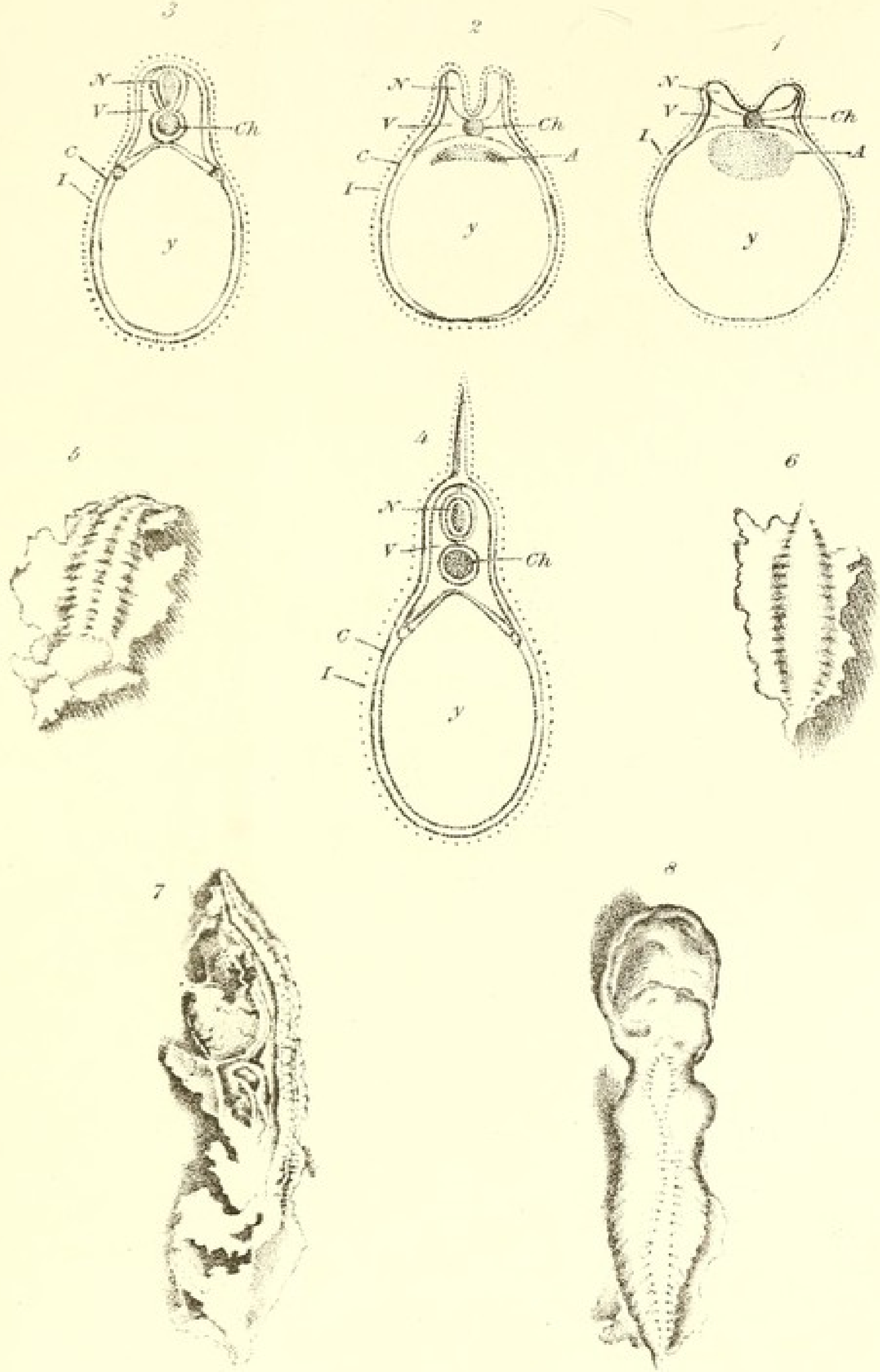
[1] Rathke, *Entwickelungsgeschichte der Natter*, Taf. I. fig. 3. Reichert, *Das Entwickelungsleben in Wirbelthier-Reich*. Taf. III. and V.


3
2
1
N
V
Ch
C
I
A
y
5
4
6
7
8

elements a centre of ossification appears about the third month or earlier; those in the arches generally preceding those in the bodies: though they do not invariably do so at every part of the column, as is proved by the drawing at fig. 7, which represents a section of a human fœtus, under three months, where there were faint traces of incipient ossification, in the form of minute opaque specks in the middle of the bodies of the lower dorsal vertebræ, the arches remaining cartilaginous[1]. It will be perceived that at this time the cartilages forming the bodies of the vertebræ are well formed, with squared edges, and the intervertebral spaces, though mere lines, are quite distinct. The dorsal view of the same fœtus given in figure 8, shows that the vertebral arches have reached the middle line in the back, becoming quite or nearly united together; whereas in the cervical, lumbar, and sacral regions, there is a considerable interspace between them. The last vertebra in which they meet is the upper sacral, which, it may be remarked, is the most frequent seat of spina bifida.

Spine at 8 months.

Fig. 1 in Pl. IV. shows the ossification in a much more advanced state. It represents a section of the spine of a fœtus of about 8 months. In the middle of each body, surrounded entirely by cartilage, is a lens-shaped mass of bone, which is traversed, from behind forwards, near the middle, by

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[1] It appears as a general rule that the vertebral bodies are formed into cartilage at an earlier period than the arches, but that the ossification of the latter precedes that of the former. Hildebrandt's *Anatomie*, II. 162. According to Beclard (Meckel's *Archiv*, VI. 408,) ossification begins in the arches between the fortieth and forty-fifth day, in the bodies a few days later; in the former commencing in the atlas and travelling downwards; in the latter commencing at the lower part of the back, about the ninth or tenth dorsal vertebræ, and travelling upwards and downwards. Thus at three months the nucleus of the last dorsal body is the largest; at the fourth month that of the first lumbar has outgrown it; at five months and a half that of the third lumbar body, and at birth the fourth exceeds the others. The same anatomist says, that at birth the upper six dorsal arches are united behind; that a year after birth all the arches are united behind, except those of the upper two cervical, the lower lumbar, and the sacrum; at two years and a half the upper sacral arch alone remains unclosed; and at four and a half all the arches have coalesced. The arches unite together before they unite with the bodies.

The commencement of ossification in the lower part of the back in the human fœtus reminds us that in some of the inferior animals, when full grown, the vertebræ of this region equal in size or exceed those of the loins.

canals for blood-vessels. Some of these are seen in the lumbar vertebræ, where the section has passed through them. In the back the antero-posterior diameter of the osseous nucleus is rather greater, and the upper and lower surfaces are rather flatter than in the loins, where the nucleus has a more spherical shape. In the neck the shape is intermediate between that in the loins and in the back. The nucleus for the odontoid process of the second vertebra is prolonged a little towards the skull. In other respects it resembles the nuclei of the bodies of the other vertebræ. At present

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DESCRIPTION OF PLATE IV.

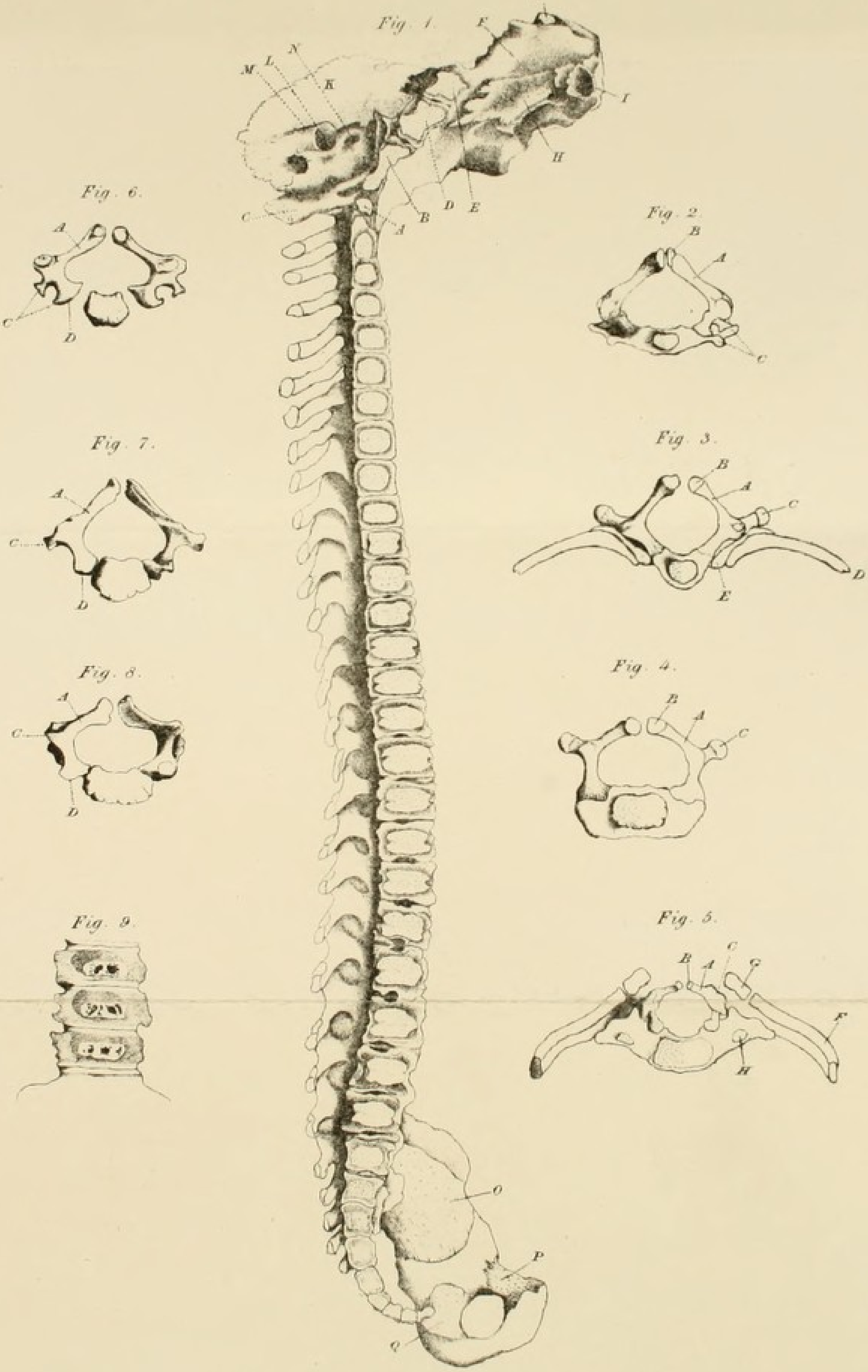
Fig. 1. Section, from before backwards down the middle, of the spine of a fœtus of 8 months, with the side of the base of the skull and the pelvis. It shows the shapes of the ossified portions of the bodies at that time, and of the arches, which are tipped with cartilage. The curve, which is seen in the dorsal portion, has been acquired since the suspension of the preparation in spirit. *A* is the fore part of the ring of the atlas, *B* the basilar part of the occipital bone, *C* the ring surrounding the foramen magnum, *D* the hinder part of the body of the sphenoid, *E* the fore part of the body of the sphenoid. These three osseous nuclei for the occipital and sphenoid bones are imbedded in square pieces of cartilage, resembling those of the vertebræ, and separated by linear spaces resembling the intervertebral spaces. The cartilage of the fore part of the sphenoid is continuous with *F* the cartilage of the median plate of the æthmoid. *G* is the nasal bone, *H* the vomer, *I* the intermaxillary bone, *K* the squamous part of the temporal bone, *L* the vacancy in the petrous bone between *M* the superior semicircular canal and *N* the internal auditory meatus. *O*, *P*, *Q*, are the osseous centres of the ilium, pubes, and ischium.

Figs. 2, 3, 4, 5. Transverse sections through (2) a cervical, (3) a dorsal, (4) a lumbar, and (5) a sacral vertebra of an eight-month fœtus, showing the relations between the nuclei of the arches and those of the bodies. They are connected by the cartilage in which they are imbedded. *A* one side of the arch, *B* its hinder cartilaginous tip, *C* the transverse process tipped with cartilage, *D* the rib, with *E* its cartilaginous terminal portion, which separates it from the body and transverse process of the vertebra, *F* the ala of the ilium with *G* its cartilaginous hinder extremity, *H* the nucleus in the ala of the sacrum.

Figs. 6, 7, 8. The osseous parts of (6) a cervical, (7) a dorsal, and (8) a lumbar vertebra of a child at birth. The shapes of the central nuclei foreshadow the future shapes of the bodies, and have reference to the future curves of the spine. *A* the arch, *C* the transverse process, *D* the pedicle of the arch. In Fig. 6 the arches are placed rather further from the centre than natural, to show the size of the anterior extremities of their pedicles in the neck.

Fig. 9. A vertical section from side to side through the bodies of three lumbar vertebræ before the time of birth, showing the osseous nuclei imbedded in the cartilage, and perforated by a large irregular channel on either side of the median line.

See description on preceding page.



the shape of the bodies is dependent entirely upon the cartilage in which each osseous nucleus is embedded. Between the several cartilages are linear spaces—the intervertebral spaces. These contain at their middle only fluid, or, at most, a delicate areolar tissue, which is enclosed at their circumference by dense, fibrous structure, binding together the marginal parts of the cartilages. The osseous nucleus is well marked in the upper three, and is perceptible in the lower two, bones of the sacrum. It has not appeared in either of the cartilages of the coccyx.

The arches are osseous, in a considerable part of their extent, all the way down, except in the lower part of the sacrum. In the middle line they are all cartilaginous. Each arch is made up of two lateral portions—neural processes as they are called—which in front are connected with the sides of the cartilage of the centrum, and behind are united to one another by a piece of cartilage, into which the spinous process subsequently grows and bears one or two separate nuclei at its extremity. From each of the lateral portions project the two articulating processes and one or two transverse processes. The former have not usually separate centres of ossification. The latter are at present cartilaginous; but osseous nuclei are subsequently developed in their extremities. Figs. 6, 7, 8 in Pl. IV. show the shapes of the arches, and the osseous nuclei of the bodies from different parts of the column after they have been dried and macerated. The nucleus of the body of the lumbar vertebra (fig. 8) is large and elongated transversely into an ovoid form. It is also slightly curved with the convexity in front. That of the dorsal vertebra is flat and heart-shaped, with the apex directed forwards. The cervical nucleus presents an intermediate form. Each is composed of a thick, dense, upper and lower lamina, with a cancellous portion between them. The latter is very evident in front causing quite a deep transverse notch in the dried bone: it is also conspicuous behind where the large vessels enter.

Spine of young child.

In Plate V. drawn from the vertebral column of a young child, the osseous nuclei of the vertebral bodies have attained considerable size; but each still consists of a dense lamina above and below, with a more cancellous structure in the middle. They are imbedded in cartilage which partially obscures them and separates them from the intervertebral substances and from the anterior extremities of the arches. The latter are advancing to meet them and are in close contact with them behind, though there is still a considerable thickness of intervening cartilage in front. The transverse processes have shot out to a considerable length. They are continuous with the arches at one end and have cartilaginous prolongations at the other.

The hinder view of the same preparation shows well the direction of the several neural processes. Those in the cervical region are nearly cylindrical and almost horizontal. Their approximated extremities nearly touch one another in the middle line, and run on a little way together, side by side, so that a slight further prolongation of them would make the bifid spinous processes. Each one is tipped with cartilage. In the back the neural processes are broader and directed more obliquely downwards. Their upper edges approach one another in the median line, but do not quite touch; and the angular interval between their extremities is occupied by a lozenge-shaped piece of cartilage. This cartilage is continued along the inferior border of the neural processes, which grow by deposition

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DESCRIPTION OF PLATE V.

Fig. 1. Anterior view of spine of a child æt. about nine months. The atlas has been removed. It appears as though there were three nuclei in the fore part of the dentata, viz. one (*A*) for the odontoid process on either side, and one (*B*) in the middle line for the lower part of the body. It is probable, however, that the two former are blended behind, the nucleus for the odontoid being commonly single at a much earlier period, if not from the first. The nuclei for the bodies of the several vertebræ (*B*) are still imbedded in cartilage, and are separated by it from the neural pedicles (*C*). The anterior wall of the several foramina in the cervical transverse processes (*D*) are cartilaginous, except that of the seventh (*E*), where it is formed by a separate osseous bar. *F* the osseous nuclei for the ala of the first sacral bone; *G* ditto of the second.

Fig. 2. Hinder view of the same, showing the shape and direction of the arches in different parts of the column. *A* the cartilaginous extremities of the arches. In the neck those of either side are separate; in the back they are united into a triangular piece; and in the lower part of the back and loins they are continuous with a rim of cartilage upon the under edges of the laminæ of the arches. At the upper part of the sacrum the ossification of the arches is very incomplete, and at the lower part the arches are scarcely formed at all even in cartilage.

See description on preceding page

Plate V.

Fig. 2.

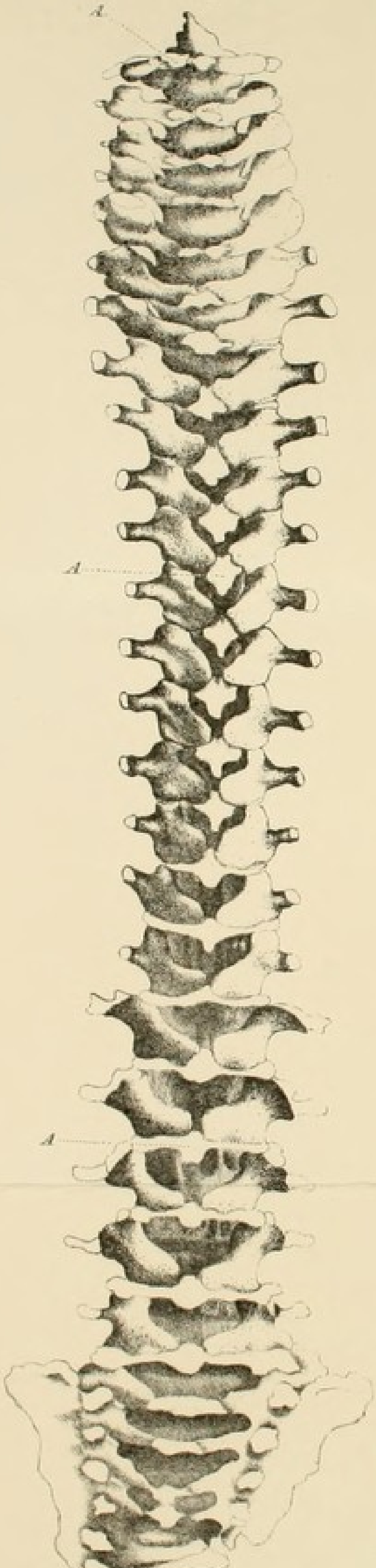
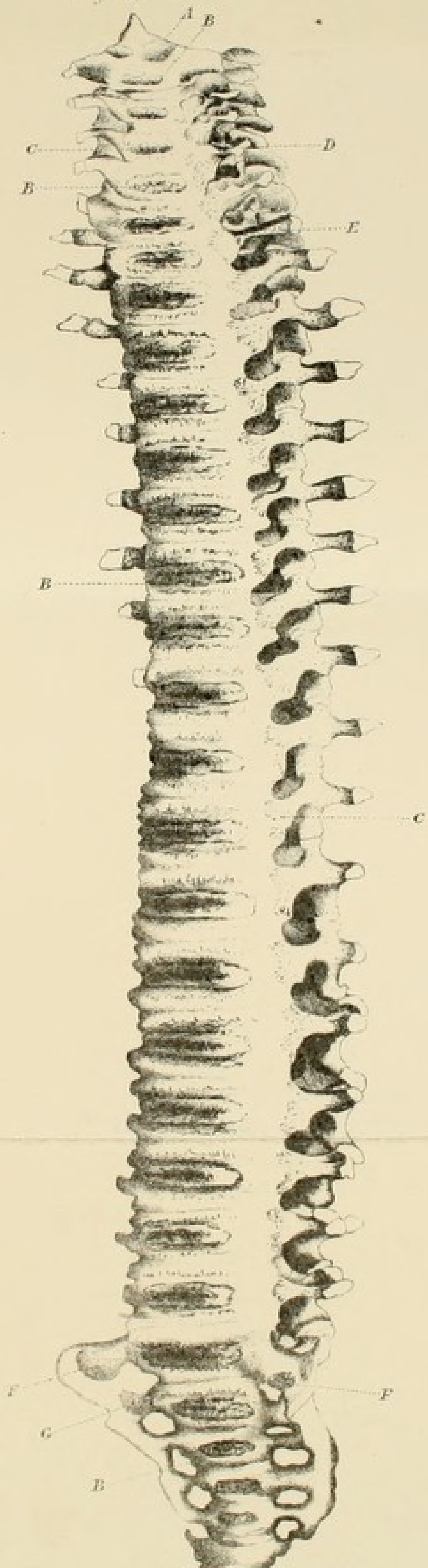


Fig. 1.



on the lower edge, rather than on the upper, where there is no cartilage. The arches are thus continually deepened from below, and overlap those beneath more and more[1]. The lumbar neural processes are wider than those in the back, but less oblique, their extremities present a deeper surface to one another, and the interval between them is filled up by square plates of cartilage, which project horizontally backwards. The sacral neural processes are still less oblique than the lumbar. They are not so much developed; the upper one extending not much more than half way towards the middle line; the second and third reach nearly two-thirds across; the fourth and fifth not so far. They are united by narrow bands of cartilage extending transversely between them.

Eight osseous nuclei in a vertebra.

There are, accordingly, three *primary* osseous nuclei in each vertebra, which appear soon after the first month; one in the median line, in front, for the body; and one on either side, more behind, for each lateral portion of the arch. The latter are joined to one another, and complete the bony arch behind at about a year after birth; and the spinous, transverse and articulating processes are only growths from them. These lateral portions, or arches, are not united to the nucleus of the bodies till the age of four or five[2]. To these three primary centres are superadded certain *secondary* "epiphysial" points of ossification some time after puberty. One for the end of the spinous process appears, a little before the others, in the tip of the cartilage connected with the united extremities of the neural processes[3]. Near the extremity

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[1] In Plate IV. Fig. 1, the section has in some parts gone a little to one side of the median line, and the divided laminæ of the arches are there seen to consist of bone in their upper, and cartilage in their lower parts.

[2] Rosenmuller is said to have described a lateral bifidity of the column, owing to a want of union of the lateral portions with the bodies of the vertebræ.

[3] Meckel states that he has never been able to find a separate ossifying nucleus for the spinous processes of the human vertebra, except in the instance of the atlas, though he has found them in some animals. Cuvier also says that the spinous process is, in man, an outgrowth from the united arches, not derived from a separate nucleus. Sœmmering describes separate nuclei at the extremities of the spinous processes in the neck and loins, and one at each point of the bifid cervical spines. Flamm and Albinus describe two nuclei in the back and loins, one at the base, and the other near the extremity of the spinous process (Hildebrant's *Anatomie*, II. 164). Separate ossicles

of each transverse process a nucleus appears at about the age of 18. In the loins these are sometimes of considerable size, and remain for a few years separate, resembling the hinder ribs of the crocodile. At about 18 also a nucleus appears in the cartilaginous laminæ above and below the body of each vertebra, between it and the intervertebral substance. The one above is thicker than that beneath. They are not united to the body till after 20. They are much more distinct and remain separate in some animals,—whales for instance. The protracted separation of these epiphyses of the vertebral bodies is supposed to serve for the purpose of affording a provision for the lengthening of the spinal column, and so permitting the growth of the trunk to take place till a late period[1]. The articulating processes have no independent centres of ossification, with the exception of the upper ones of the lumbar and one or two of the adjacent dorsal vertebræ, in which the projections corresponding with the upper tubercles of the dorsal transverse processes (see page 140) are sometimes developed from separate nuclei. Beclard speaks of these articulating processes as if they were *prolonged* by means of epiphysial nuclei. This I have not found to be the case. It appears, therefore, that to the 3 primary centres of ossification 5 additional or epiphysial nuclei are commonly added, making the proper complement in each vertebra

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have also been found by Otto (*Seltene Beobachtungen*, § 200,) at the extremities of the spinous processes of the seventh cervical and some of the lumbar vertebræ: whether these were independent sesamoid bones or the unattached nuclei of the parts, does not appear. In a specimen in the museum at Prague, I found the separate nuclei at the extremities of the lumbar and dorsal spinous processes quite distinct. They were not so clear in the neck, though I judged from the appearance that there was a nucleus at the extremity of each spinous tubercle. There were also in this specimen distinct nuclei for the extremities of the dorsal and lumbar transverse processes, and for the upper tubercles on the superior articulating processes of the lumbar vertebræ, but not for the articulating processes themselves.

[1] Prof. Luschka (Virchow's *Archiv*, IX. 312) does not admit the existence of separate epiphysial nuclei above and below the bodies of the vertebræ; but says that the body is completed by outgrowth from its one primary nucleus into the cartilage which forms its upper and lower surface. They may however be seen distinctly in a specimen in the Cambridge Museum, and are found in many animals; in some, the whale for instance, as stated above, they are permanently separate from the rest of the body of the vertebra.

to amount to 8; viz. 3 for the body, 2 for the arch, 1 upon the spinous and 1 upon each transverse process. In the neck there may be two upon the spinous process, and in the loins there may be one upon each upper articulating process.

Number of nuclei in the body of a vertebra.

There can be no doubt that, as a rule, the primary osseous nucleus of the vertebral body is single. It may be seen to be so as soon as it is visible to the naked eye. I have examined many fœtal spines with great care without ever finding two nuclei, and Meckel, in spite of diligent search, could never find more than one nucleus in the body of each vertebra. Nevertheless there are several things which suggest that in the complete or "typical" vertebra two nuclei should be allowed to this part, one on either side of the median line. For instance, two nuclei are said to exist in the odontoid part of the axis and in each division of the sphenoid. There are usually two foramina for vessels, one on either side of the middle line behind; and a superficial notch or longitudinal groove may be sometimes found on the fore part of the vertebral bodies. Instances are related by Rokitansky of the deficiency of one half of a vertebra, and of "angular curvature produced by the 12th dorsal vertebra consisting of two divided lateral halves." An interesting example of deficiency of the left half of the 11th dorsal vertebra is given by Otto[1]; and a still more remarkable specimen of congenital malformation in the neck and upper part of the back is represented by Sandifort[2]. In it one half of the body of each of the 7th cervical, the 9th and 11th dorsal vertebræ, is absent, the remaining half being wedge-shaped. In some of the bodies lower down there are two distinct nuclei, one on either side of the middle line. In the Museum of the College of Surgeons is a specimen of malformed fœtus with the lower part of the spine cleft in twain, each half connected with a side of the pelvis and a lower extremity.

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[1] *Seltene Beobachtungen*, 2te Sammlung, § 15. In the 11th dorsal vertebra the left half was absent; the right half of the body with the arch and processes of that side were natural, except that the former was wedge-shaped, and the spinous process had become fused with the left side of the arch of the 12th vertebra. The spine was bent at the part. In other respects the skeleton was natural.

[2] Tab. CLXXVIII. figs. 2 and 3.

The bodies appear to be divided in two, but this cannot be seen quite clearly. In a specimen of cervical spina bifida in the museum at Berlin, I found several vertebral bodies consisting of two halves, with an opening between the two, through which a communication was established with the space in front of the column. In another specimen there was a similar condition of the vertebral bodies in the back. Another instance is given by Albers, (*Atlas der Path. Anat.* Bonn, 1847). So that there is sufficient evidence of the occasional development of the vertebral bodies from two nuclei laterally disposed. Muller[1] says, "the form of the centre of ossification of the body of a vertebra is bilobed, only in the sacral vertebræ of a bird have I ever seen it in the form of two distinct ossifying points."

Neural pedicles contribute to formation of bodies.

The amount contributed to the formation of the several vertebræ by the central and lateral portions respectively, differs in different parts of the column. In all parts the anterior pedicles of the lateral or "neural" portions advance forwards beyond the intervertebral foramina, and assist to form the lateral and posterior parts of the bodies. Hence the bodies are derived in their median parts only from their own nuclei; their lateral portions are contributed by the osseous nuclei of the arches, and the amount so contributed increases as we trace the bones upwards from the lower part of the column. Thus in the coccyx and sacrum the bodies are formed almost entirely from the central nuclei. In the lumbar vertebræ the lateral and hinder parts of the bodies are formed from the pedicles of the arches. In the back the pedicles extend as far forwards as the heads of the ribs, these being entirely supported by them. In the neck the middle level portion of each body is the only part formed from its own nucleus; the sides, which are shifted a little upwards, so as to overlap those above and be overlapped by those below, are derived from the arches. (Pl. IV. figs. 2 to 8, and Pl. VI. figs. 2, 3, 4.) In the axis the pedicles advance on either side nearly half-way to the middle line (Pl. VII. fig. 5); and in the atlas the prolonged pedicles, advancing quite in front

[1] *Physiology*, by Baly, p. 1613.

of its body and constituting the fore part of its arch, are united together in the middle line. (Pl. VIII.)

Transverse processes in the different regions:

A few other points of peculiarity in the mode of development of the vertebræ in different regions remain to be mentioned. They relate more particularly to the transverse processes. We have observed (page, 121) that these are merely *outgrowths* from the sides of the arches, and that they are tipped with cartilage, in which are developed epiphysial nuclei; and we must be careful to bear in mind the distinction between the transverse processes themselves and their epiphysial nuclei; the former are mere projections from the arch, the latter are independent osseous centres. In the neck there are two transverse processes on either side, one in front of the other. (Pl. IV. figs. 2 and 6 c.) One—the posterior—springs from the neural process, where its pedicle bends inward from its articulating portion. The other—the anterior—springs from near the anterior extremity of the neural pedicle. They enclose between them the foramen for the vertebral artery, and are at first united at their extremities, or near their extremities, by cartilage, which subsequently becomes ossified, owing to an extension of ossification into it from the processes, without there being usually any separate nucleus[1]. Of these two transverse processes the hinder one is the more developed in the upper three vertebræ; in the 4th, 5th and 6th, the anterior ones become more prominent. In the 7th the anterior scarcely projects at all.

in the Neck,

in the Back,

In the back the "transverse process" corresponds with and springs from the same part of the arch as the posterior transverse process in the neck. (Pl. IV. figs. 3 and 7 c.) At its extremity a separate osseous nucleus is superadded, from which the part of the process that bears the articulating facet for the rib is developed. The analogue of the anterior transverse process of the neck is, however, suppressed. The articulating facet for the rib upon the side of the body—or rather upon the extremity

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[1] In the crocodile there is a separate nucleus, from which the extremities of both transverse processes and the intervening outer margin of the foramen are formed.

of the neural pedicle—is its representative. Its place is occupied by the rib, which may be the representative of its epiphysial nucleus; and the interval between the neck of the rib and the transverse process corresponds, or nearly corresponds, with the foramen for the vertebral artery.

in the Loins,

In the loins there is no trace of the anterior transverse process. The posterior transverse process (Pl. IV. figs. 4 and 8 C) retains the same position as in the neck and back; and, as if to make amends for the absence of any anterior transverse process or any rib, it bears a more constant and larger nucleus in the cartilage at its extremity. This occasionally remains separate and exceeds its ordinary dimensions, forming a sort of supernumerary rib.

in the Sacrum,

In the sacrum the analogue of the posterior transverse process (Pl. IV. fig. 5 C) occupies nearly the same relative position as in other parts of the column. It becomes united with those of the other component vertebræ of this bone above and below. There is no anterior transverse process. But in each of the upper two bones a separate nucleus is formed on either side of the ala; and this seems to answer to the epiphysial nucleus of the anterior transverse process, that is to say, to a rib. (Pl. IV. fig. 5 H, and Pl. V. fig. 1 F, G.) In the lower three bones of the sacrum there is no such representative present. The ilium, which overlaps the exterior of the bone (Pl. IV. fig. 5 F), is quite a separate structure; it corresponds with the scapula of the upper extremity.

in 7th cervical vertebra,

In the 7th cervical vertebra the transverse processes indicate an intermediate condition between the transverse processes of the neck and those of the back. The hinder process corresponds with those above and below. But the anterior one, though much resembling those of the other vertebræ of the neck, and, in the adult, like them, forming one with the rest of the bone, is developed from a separate nucleus (see Pl. V. fig. 1 E), which corresponds with the head and neck of a rib. It appears, according to Beclard, at about the third month of fœtal life, and unites with the rest of the vertebra at about the 5th year. It does not always form the anterior wall of the foramen for the vertebral vein[1], being sometimes separated from it by a thin lamina of bone. (Pl. VI. fig. 1 D.)[2].

Cervical ribs,

It now and then happens that this nucleus, remaining separate from its vertebra, shoots beyond its ordinary dimensions, runs parallel, or nearly so, with the first rib, and forms what is called a "supernumerary," or "cervical rib." It does not commonly run more than half way to the sternum. Its extremity may either remain free—"floating"—resembling the "asternal" ribs of birds, or it may be joined to the first true rib. In the preparation represented in Pl. VI. fig. 1, which I took from a young woman, the left cervical rib is floating, the right is swollen out at its extremity into a broad uneven surface, which was united by fibrous tissue to an outgrowth from the upper and inner surface of the first true rib. It will be observed that on the left side the cervical rib covers in the foramen for the vertebral vein, completing its anterior wall; whereas on the right side it is separated from the foramen by a distinct lamina of bone, which is the diminutive correspondent of the *true* anterior transverse process of the other cervical vertebræ, that is to say, of the transverse process, which is an *outgrowth* from the extremity of the neural pedicle[3].

usually found in the three-toed sloth.

The lower two of the nine cervical vertebræ of the three-toed sloth usually bear ribs. In the specimen in the Cambridge Museum they are connected only with the extremities of the posterior transverse processes, like many of the ribs in the crocodile, and like those which are occasionally found upon the lumbar transverse processes in man.

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[1] I call it "foramen for the vertebral vein," though it is often traversed by neither the artery nor the vein.

[2] The presence of a separate nucleus at this part is not always confined to the lowest cervical vertebra. Meckel (*Archiv*, I. Taf. VI. Figs. 10—13) found, in a child æt. 9 months, separate nuclei for the fore part of the transverse processes of the seventh, fifth, sixth, and second cervical vertebræ. These were small, and did not in each instance form part of the foramen for the vertebral artery. Blandin (*Nouveaux Élémens d'Anatomie*, I. 37) found these "costiform epiphyses" in the third, fifth, and sixth cervical vertebræ of each of three fœtuses at the third, fourth, and fifth months respectively.

[3] Dr Knox has described several examples resembling the above in the *London Medical Gazette*, Vol. XXXIII.

Cervical ribs always moveable upon their vertebræ.

We cannot fail to be struck by the curious coincidence which these cervical ribs present in the preternatural development of the osseous nucleus in which they originate, and its want of coalescence with the parent vertebra. When the nucleus retains only its proper dimensions it acquires a bony connexion with its vertebra; when it exceeds them and sprouts into a rib, it invariably, so far as I know, remains separate. I have not met with or read of an exception to this rule either in the neck or in the loins. It probably results from its being necessary for the part to be moveable when it exceeds the usual size, rather than from any general law of relation in a nucleus between its size and its remaining separate from the parent bones; such relation not being generally observable in other parts of the skeleton of man or animals.

Formation of two upper vertebræ.

It remains to consider the formation of the uppermost two vertebræ, which differ in some particulars from those beneath them, especially in the very remarkable point, that the centrum of the first is united with that of the second to form its odontoid process. The atlas is accordingly separate from this element. That such is the true view of the case is rendered quite certain by the fact, that in some reptiles (tortoises and perhaps others) the odontoid process remains separate from the axis, and retains, accordingly, nearly the same relations to the atlas, which the centra do to their respective vertebræ in other parts of the column.

DESCRIPTION OF PLATE VI.

Fig. 1. Representation of cervical ribs. *A* Transverse process of seventh cervical vertebra, *B* ditto of first dorsal. The former on the right side is perforated by a foramen which is enclosed in front and separated from the rib (*C*) by a lamina of bone (*D*). The end of the left cervical rib is free; that of the right rests upon a tuberculated process (*E*), which has grown up from the first dorsal rib (*F*).

Fig. 2. Cervical vertebra from a young subject, showing *AA* the lines of union between the lateral and central portions.

Fig. 3, a cervical, and Fig. 4, a dorsal vertebra from a young rabbit. *AA* the same as in Fig. 2.

Plate VI.

Fig. 1.

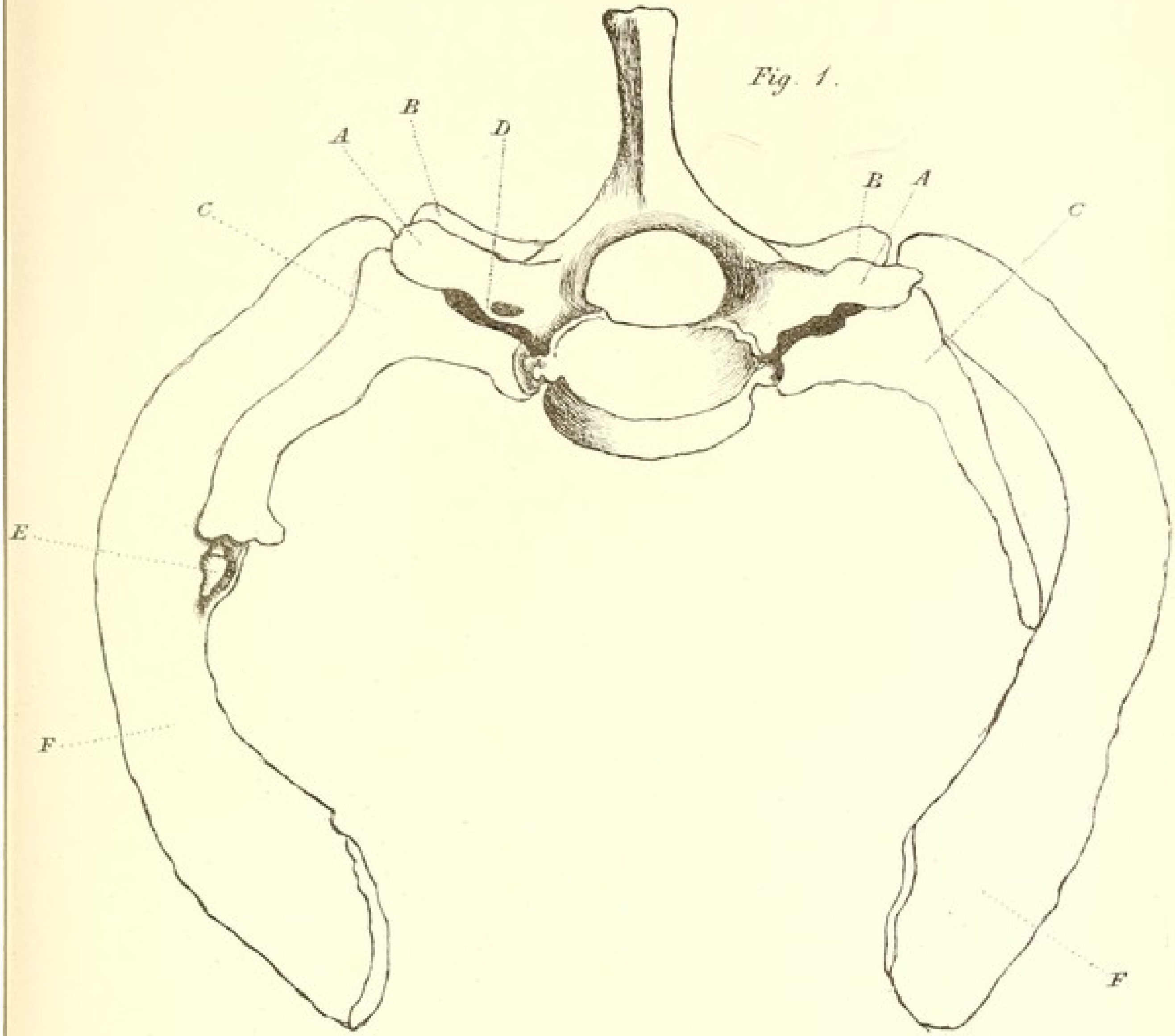


Fig. 2.

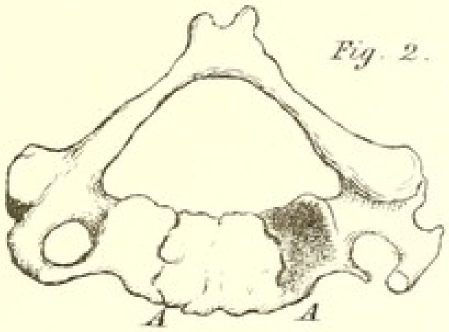


Fig. 4.

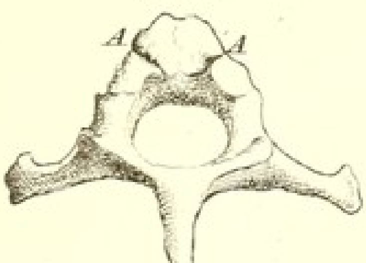


Fig. 3.

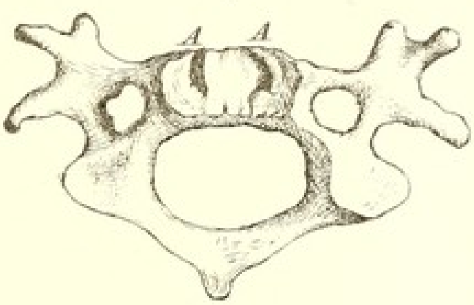


Fig. 1.

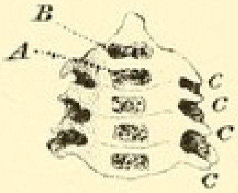


Fig. 2.

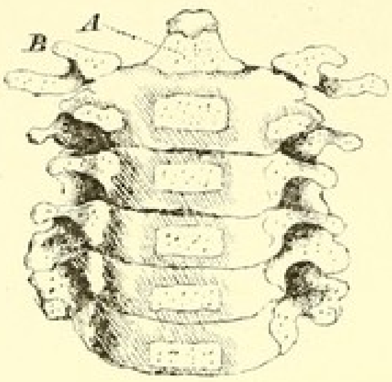


Fig. 3.

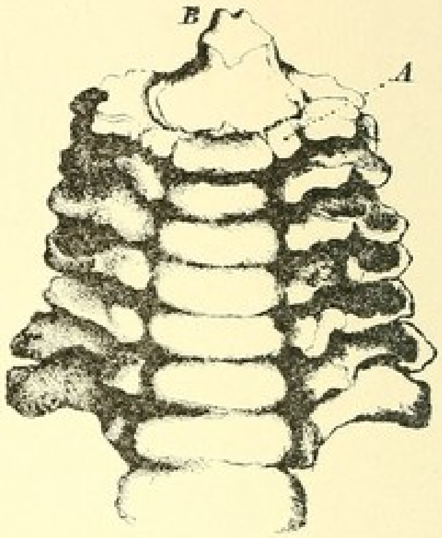


Fig. 4.

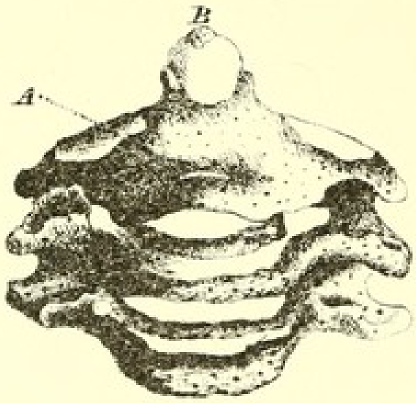


Fig. 5.

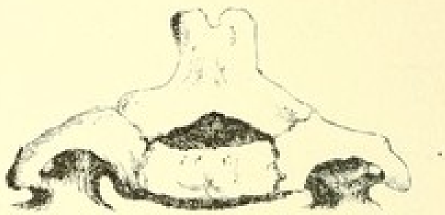


Fig. 6.

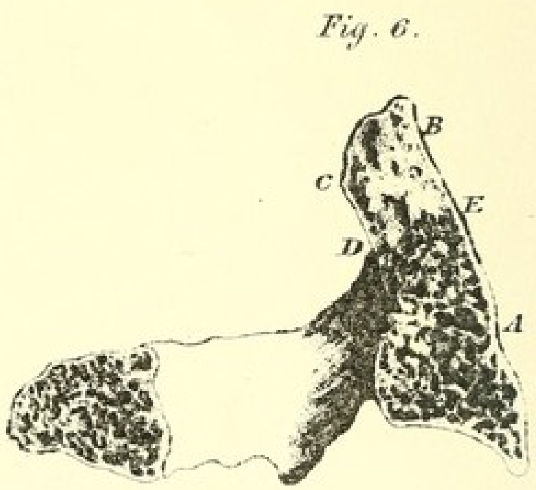
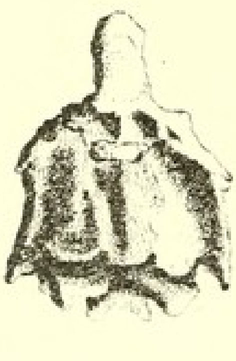


Fig. 7.



of the axis: The arch and body of the axis agree in the mode of their development with the corresponding parts of the vertebræ beneath it; except that the body is situate on rather a lower plane with regard to the neural pedicles, which advance somewhat nearer to the median line, and curve downwards at their anterior extremities to embrace and support it. (Pl. VII. fig. 5.) These prolonged anterior extremities of the neural pedicles are sometimes developed from separate nuclei which appear

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DESCRIPTION OF PLATE VII.

Fig. 1. The axis and next three cervical vertebræ at about the fifth month, or earlier, with the fore part of their bodies cut away so as to show the square shape of their nuclei. Those of the axis (*A* and *B*) are rather larger than those of the two next below, that for the odontoid process (*B*) being the largest. It is also slightly bilobed; but even at this early period it is single. *CCCC* the fore parts of the transverse processes.

Fig. 2. The upper six cervical vertebræ at the time of birth. They have been treated as in the preceding instance, the section having been made a little further back. The bilobed nucleus of the axis (*A*) bears a piece of cartilage upon its notched summit. Its relation to the sides of the atlas (*B*) is seen to resemble that of the nuclei of the other vertebral bodies to their respective lateral portions.

Fig. 3. The fore part of the axis and six vertebræ below it, from a young child. The odontoid nucleus is separated from the nucleus of the body by a line of cartilage. A separate nucleus (*A*) is seen between the anterior part of the arch and the body of the axis on either side. *B* the cartilaginous top of the odontoid process. The line of contact of the arches with the bodies of the several vertebræ is well seen.

Fig. 4. Front view of the second, third, fourth, and part of the fifth cervical vertebræ, in a rather more advanced stage. There is only a narrow cartilaginous interval (*A*) near the middle, between the odontoid process and the body of the axis. The arches are united with the bodies in this and in the other vertebræ. There is a distinct osseous nucleus (*B*) in the top of the cartilage that forms the uppermost part of the odontoid process. (Drawn from a specimen in the Museum at Berlin.)

Fig. 5. Axis, in an earlier stage of development than in the preceding instance, macerated and dried. It shows the forked summit of the odontoid process (which in the recent state is occupied by cartilage), the interval between the odontoid portion and the body of the axis in the middle, and the line of union of the odontoid portion and the remainder of the body with the lateral parts of the vertebra.

Fig. 6. Section of an adult axis. *A* an interval in the middle of the bone between the odontoid portion and the rest of the body, like that between the component portions of the sphenoid bone and of the sacrum. The dense portion of the odontoid between *BC*, *DE* is the part between the articulating facets upon its anterior and posterior surfaces. The more cancellous portion above *BC* is the part produced from the separate nucleus represented in Fig. 4 at *B*.

Fig. 7. Axis from a young rabbit, shewing a separate osseous nucleus in the middle line between the odontoid portion and the rest of the body of the vertebra.

during the first year, and are joined to the other parts in the third or fourth year. (Pl. VII. fig. 3.)[1] This is an interesting fact in relation to the development of the corresponding parts of the atlas.

its odontoid process. The cartilage in which the body of the axis is formed is prolonged upwards into the odontoid process without any line of demarcation, similar to those which are found in the cartilages between the bodies of the vertebræ lower down (Pl. IV. fig. 1), and which are indicative of intervertebral spaces. At about the fourth month a nucleus appears in the base of the odontoid process. It is bilobed (Pl. VII. fig. 1), either being originally made so, or being formed from two nuclei, one on either side of the middle line, which are in close contact, and which coalesce very early. It becomes dense and soon grows upwards in the middle, acquiring the shape of a cone which is deeply cleft from before backwards at the summit (fig. 2), and which is surmounted by a diamond-shaped piece of cartilage (figs. 3 and 4). It is supported on either side by the pedicles of the neural arches, and becomes united with them about the fourth or fifth year; a cartilaginous interval still remaining between it and the body of the vertebra. In this interval a separate nucleus has been developed in the axis of a rabbit represented in Pl. VII. fig. 7. This nucleus may perhaps be thought to correspond with one or more of the epiphysial laminæ of the other vertebræ. At about puberty the interval is obliterated by ossification of the fore and hinder parts of the cartilage that occupies it; but in the middle a space still remains (fig. 6) resembling the intervertebral spaces seen in a section of the sacrum. The line of union is also often indicated on the fore part by a transverse ridge extending between the articular surfaces on either side.

Gradually the ossification fills up the cleft at the top of the odontoid nucleus and proceeds into the cartilage that covers it, so that about puberty the whole is converted into bone. The section of the fully formed bone (Pl. VII. fig. 6) shows a distinct opaque

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[1] Meckel also describes this, *Handbuch der Menschlichen Anatomie,* II. 45, and *Archiv,* I. Taf. VI. figs. 6—9; and Nesbitt is said to have observed the same at birth, *Osteog.* s. 66.

Fig. 1.

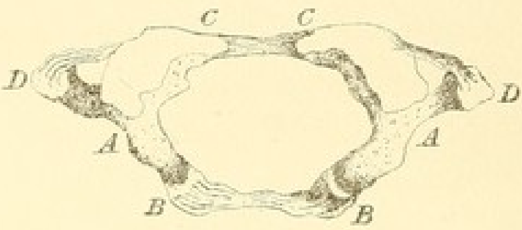


Fig. 2.

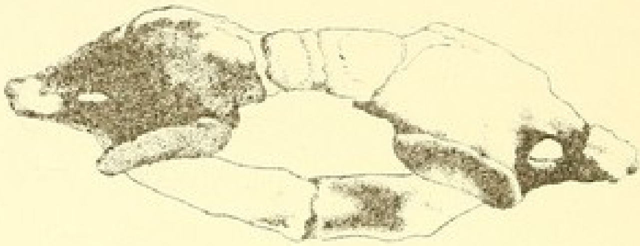


Fig. 3.

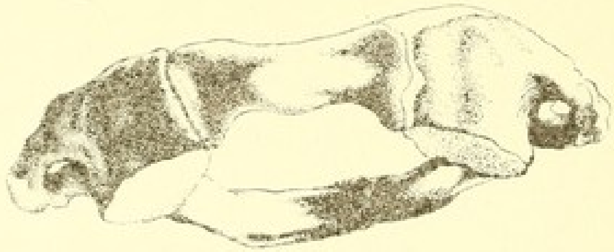
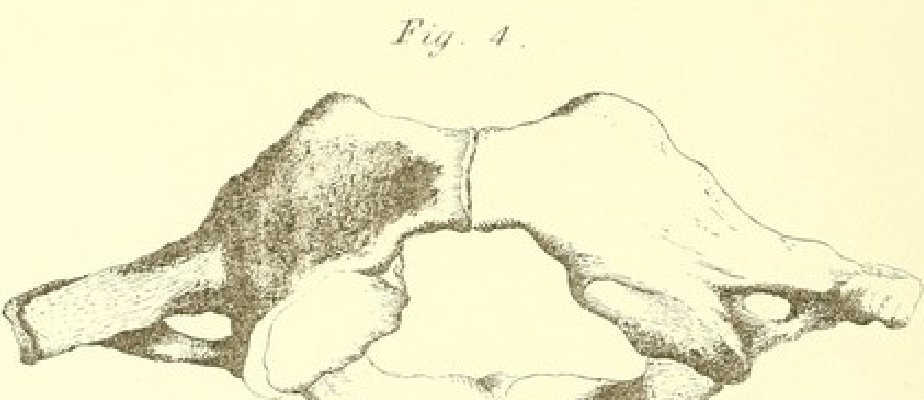


Fig. 4.



horizontal line of dense osseous structure lying between the articulating surface on its anterior aspect (*BE*) for the arch of the atlas and the surface behind (*CD*), which is in contact with the transverse ligament. This denser part forms a division between the more cancellous apex and the rest of the process; the appearances are suggestive of a separate epiphysial nucleus at the summit, corresponding with that occasionally found below the odontoid process (fig. 7). Thinking it highly probable that a nucleus is sometimes developed at the top of this process, though it has not been described by either of the many careful investigators of the development of the spine, I made frequent search for it; but without success, till I met with it in the specimen represented in Pl. VII. fig. 4, and in another in the Museum at Prague.

Nucleus at the summit of the odontoid process.

Development of the atlas.

The atlas is composed entirely of lateral or neural portions which shoot forwards to a greater extent than

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DESCRIPTION OF PLATE VIII.

Fig. 1. The atlas at birth. *AA* the ossified lateral portions terminating behind in blunt extremities (*BB*), which are tipped with cartilage and united together by a fibrous band extending transversely between them. *CC* the anterior extremities of the same, extending a little in front of the superior cartilaginous facets; they are also united by a fibrous band. The extremities of the transverse processes (*DD*) are tipped with cartilage; and a fibrous band extending from them to the fore part of the vertebra encloses the foramen in front.

Fig. 2. Atlas from a child æt. 4. There are two osseous nuclei of unequal size in the fore part of the arch, united together in the median line by cartilage, and united to the lateral parts of the vertebra also by cartilage. The arch behind is interrupted in its middle by a thin plate of cartilage which constitutes the bond of union of its lateral portions. Viewed from behind, the specimen showed, at and near the junction of the laminæ, a depression which was occupied by cartilage forming a rudimentary spinous process. The extremities of the transverse processes are cartilaginous.

Fig. 3. Atlas from a child æt. 5. The anterior part of the arch is formed of one piece, which is united to the lateral portions, close to the articular facets, by a plate of cartilage on either side. There is a prominence in the median line forming the anterior tubercle. Behind, the lateral portions are united by bone; but there is a depression on the posterior surface occupied, as in the former specimen, by cartilage. The tips of the transverse processes are cartilaginous.

Fig. 4. Atlas from a youth æt. about 17. There is a fissure in the median line in front which was occupied by cartilage. The posterior arch is complete. The spinous process is slightly bifid and entirely osseous. The transverse processes have also attained their full size and structure.

the corresponding parts of any other vertebra, and which, either directly, or by means of epiphysial nuclei developed in connection with their anterior extremities, meet in the median line, and form the anterior part of the ring. The centrum is detached and placed behind them, forming the odontoid process of the axis. Ossification commences in the sides of the atlas near its articulating surfaces at an early period; earlier, it would seem from Beclard's observations, than at any other part of the column; it shoots backwards, and at birth the arches, which form the *hinder* part of the ring of the bone, are osseous in rather more than two-thirds of their extent. They are of cylindrical shape and terminate abruptly in thick ends, which are united to one another by a band of fibrous tissue and cartilage extending transversely between them (Pl. VIII. fig. 1, *B*, *B*). Usually ossification extends from them till they meet in the median line (as represented in fig. 2). I found them firmly united together at the age of 5 (fig. 3). Occasionally, however, a small separate nucleus is developed in the cartilage at the point of their junction[1].

The *fore* part of the ring of the atlas consists at birth of a fibrous band extending between the cartilaginous anterior extremities of the neural processes, which project very little in front of the facets for the condyles (fig. 1). These anterior prolongations of the neural processes may gradually grow on, as do the posterior, till they meet in the middle line; where they become united, first by cartilage, subsequently by bone (Pl. VIII. fig. 4). In some cases an osseous nucleus is developed in the uniting cartilaginous medium, on either side of the middle line (Pl. VIII. fig. 2). These nuclei joined together may form a central portion, which becomes united to the lateral parts a little in front of the articulating surfaces (Pl. VIII. fig. 3); or a nucleus may be formed in the middle line and extend laterally till it encounters the lateral portions at the same point; or there may be a central nucleus and a distinct nucleus in the cartilage on either side of it. The period at which these nuclei are united with one another and with the lateral portions varies; commonly it is before 12. In a lad, æt. 12, I could

[1] Meckel's *Archiv*, I. Taf. VI. fig. I.

find no line of separation between the several parts; indeed the ossification of the atlas was quite completed. In another, æt. 7, the line of separation was obliterated on one side, though easily seen on the other. In the Musée Orfila is an adult atlas with the fore part of the arch still separate from the sides of the bone; in fig. 4 is represented a fissure in the middle of the anterior arch at the age of 17; and in Guy's Museum is a specimen of an adult atlas in which union has entirely failed both before and behind, so that the vertebra remains divided into its two primitive lateral portions[1].

The transverse processes resemble those of the other cervical vertebræ. At birth the hinder one has grown out to a considerable distance from the neural arch (Pl. VIII. fig. 1). It is tipped with cartilage; and the anterior process is represented by a fibrous or cartilaginous band extending from this cartilaginous summit to the articulating portion. Gradually ossification extends into the band; and at the age of 4 or 5 it has reached the same level as in the hinder process. The two are then united by an interposed piece of cartilage, which is subsequently converted into bone by a further extension of the ossification. Sometimes the ossification of the anterior process is incomplete, and the foramen remains open in front.

Relative proportions of spine vary with growth.

Beclard gives the following relative measurements of the vertebral column at different periods of fœtal life. At three weeks it is to the whole body as 3 : 4; at from 30th to 35th day as 3 : 5; at from 40th to 45th day as 1 : 2; at 4 months and a half as 4 : 9; at 6 months as

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[1] Blandin (*Nouveaux Élémens d'Anatomie*, 1838, I. p. 39) suggests that the odontoid process of the axis is the body of the atlas, and that the anterior arch of the latter, developed from two points, is the representative of the marginal epiphyses of its body. I think, however, that the mode of development of this anterior arch and a comparison with the vertebræ below clearly show that it is, as stated in the text, formed by an extension of the fore part of the lateral or neural portions, which is effected in some instances through the medium of epiphysial nuclei, and in others by the continued growth of the lateral parts themselves without any such epiphysial aids.

5 : 12; at $7\frac{1}{2}$ months as $6\frac{1}{2}$: 15; at the full time as $7\frac{3}{4}$: 18. The relative proportions at different periods after birth are given in the Table at page 110.

In the early periods of fœtal life the size of the column is greatest near the middle of the back, where ossification of the bodies is observed first to take place. In this respect it resembles the permanent condition of the spine of many quadrupeds. As development and growth proceed, the lumbar vertebræ gradually obtain the predominance required to enable them to bear the weight that is imposed upon them. While the child is within the uterus the spine is bent a little forwards, and there is then no other curve. Nevertheless, the shapes of the osseous nuclei represented in Pl. IV. (figs. 6, 7, 8) indicate that preparation is already being made for those flexures which exist in the adult, and which begin to be formed soon after birth.

Relations of the vertebræ to the cord.

Mention has already been made of the intimate relation which exists between the vertebral column and the included spinal cord. We have seen the two, in process of formation, developed and growing together in the dorsal groove of the embryo; both being, at first, of the same length, and combining to inclose the same canal which traverses them from end to end. I have also alluded to the probability that each vertebra corresponds to one of the primitive ganglia which make up the spinal cord. Subsequently, however, the relations of the two become altered by the growth of the column exceeding that of the cord, partly in consequence of the latter undergoing a process of concentration, which is most marked about the regions of the attachment of the brachial and lumbar plexuses of nerves, more particularly of the latter, that is, at the lowermost portion of the cord. At the third month of intra-uterine life the spinal cord reaches as low as the last bone of the sacrum, if not to the coccyx. In the adult it extends only to the second lumbar vertebra at the furthest. It has been stated by some observers that, at the former period, the coccyx consists of seven portions, the number being subsequently reduced to four or five; and that if anything occurs to interfere with the ascent of the cord, the diminution in the number of the coccygeal bones does not take place, and the child is born with a tail. That this is not a necessary sequence is proved by cases of spina bifida, in which, although the ascent of the cord is prevented, the coccyx does not present anything unusual. In the lower animals there is a direct proportion between the length of the cord and that of the tail.

Relations of vertebræ to the nerves.

The alteration in the relative position of the several parts of the cord with regard to the vertebræ makes no difference in the relation between the nerves and the vertebræ. Each interspace between the several vertebræ along the whole length of the column transmits a pair of nerves, the ganglia of which lie either in the intervertebral foramina or just within side them. From the intervertebral foramina the nerves ascend in their course to the cord with a degree of obliquity increasing from the first or uppermost to the last. The point at which each nerve enters the cord indicates the point of the latter which was originally opposite to the foramen from which the nerve proceeded, and the distance between that point and the foramen is the measure of the ascent of that region of the cord. In consequence of the constancy of this relation between the vertebræ and the roots of the nerves, a vertebra has been defined to be a bone, or axial segment of the skeleton, included between two pairs of nerves; and it was considered that the observation of the points at which the nerves traverse the bony envelopes of the cerebro-spinal system would furnish a ready guide to distinguish the several vertebræ. As a general rule it does so: though there are some few exceptions; thus in some fishes and in some animals, e. g. the buffalo, the nerves do not pass between the vertebræ, but through them, perforating the neural pedicles; and in the skull some of the nerves perforate the pedicles of the cranial vertebræ, while others pass between them, which has contributed not a little to the difficulty of deciding on the number of the component vertebræ of this part of the skeleton, and of grouping the several bones with reference to them.

THE VERTEBRÆ.

Number of vertebræ.

The number of vertebræ in the spinal column—viz. 7 in the neck, 12 in the back, 5 in the loins, 5 in the sacrum, and 4 or 5 in the coccyx—is remarkably constant. Occasionally there are 13 dorsal, or 7 lumbar; there may be also a supernumerary vertebra in the sacrum or coccyx, but I am not aware that the regular number in the neck has been known to be exceeded. When there is a deficiency in either region, it is not uncommonly supplied by an excess in one of the others. Thus, if there are only 4 lumbar vertebræ, it is usually found that there are 6 in the sacrum or 13 in the back. It is singular that the number of cervical vertebræ should be so uniform throughout the mammalian classes, although there are great varieties in the length of the neck. The only known exceptions to the number 7, are presented by the three-toed sloth, which has 9, and by the sea-cow, which has 6. In other cetaceans, although the neck is very short and the bones are often more or less united together, the regular number can be discerned. In the other regions of the spine the number varies a good deal in different animals, without having

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DESCRIPTION OF PLATE IX.

Sections of adult vertebræ, showing the shape and structure of their bodies.

Fig. 1. Vertical section from before backwards of the 4th cervical vertebra.

Fig. 2. Ditto of 4th dorsal vertebra. A bristle has been passed from the median through one of the lateral vascular canals, proving the communication between them.

Fig. 3. Ditto of 5th lumbar vertebra.

Fig. 4. Horizontal section of 4th cervical vertebra. It is more cancellous at the middle and close to the sides than elsewhere.

Fig. 5. Ditto of 4th dorsal vertebra.

Fig. 6. Ditto of 5th lumbar vertebra. A channel is seen, on either side of the middle line, passing from the vertebral canal to the middle of the vertebral body, where the two unite. A channel also passes from either side towards this middle point. The cancelli are larger in the vicinity of these several channels than elsewhere.

Fig. 7. Vertical section from side to side through the body of the 4th cervical vertebra.

Fig. 8. Ditto of the 4th dorsal vertebra.

Fig. 9. Ditto of the 5th lumbar vertebra.


Fig. 1.
2.
3.
4.
5.
6.
7.
8.
9.

any obvious reference to the size of the adjacent organs or of the limbs.

Bodies of the vertebræ—their structure;

The *bodies* of the vertebræ are composed of very light, spongy structure, which is surrounded by a thin wall of moderately compact tissue; I say moderately compact, for it is perforated by so many large and small holes that it presents a spongy appearance in comparison with the exterior of most other bones. The cancelli increase in size towards the middle of each vertebra, where there is a sort of irregularly shaped cavity or canal (or two canals, one on either side the middle line) traversing the bone, more or less completely, from behind forwards, simulating the medullary canals of the long bones, and transmitting an artery and large vein, or more commonly two arteries and two large veins, which enter through a single or double foramen from the vertebral canal. Two other considerable channels for vessels pass through foramina on the exterior, one on either side, at a variable distance from the middle line. They run towards the centre of the bone, and communicate more or less directly with the channels which run backwards to the vertebral canal. They do not, however, always lie on the same level with them or with one another, and are not, therefore, in each instance, exposed together in one horizontal section. The cancelli are occupied by vascular areolar tissue, in the meshes of which is an albuminous fluid with but little oily matter. Hence these bones are easily cleaned by maceration. The central most cancellous part is the spot at which ossification commenced (Pl. III. fig. 7). At first it was solid, but was very early reduced to a spongy state. Each of the vertebral bodies may be observed in Pl. IX. to present a very spongy structure on either side, near the part where the lateral vessels just mentioned enter and are distributed, as well as at the middle. The chief direction of their cancelli is vertical; in some parts it is more horizontal, as near the lower surface of the last lumbar vertebra (fig. 3). The cells of the cancellated tissue are wider in proportion as the bodies of the vertebræ are large. Thus in the neck they are small, their septa are thick, and the bone is consequently dense; in the back they are larger, the septa are thinner, and the bone is consequently more spongy; in the loins they are still larger, the septa are still thinner, the vascular canals are much wider, and the bone is altogether very spongy.

their shape; Each vertebral body in the back and loins is constricted at the middle of the fore part and sides, and projected at the edges, as if the latter had been squeezed out above and below. This is most marked at the sides of the lumbar vertebræ (Pl. IX. fig. 9); and the outer wall is thickest and most dense at the narrowest part of each vertebra. The expansion of the upper and lower laminæ serves, as in the long bones, the purpose of affording a wider basis for the support of each bone and for the attachment of ligaments, so rendering the column practically as strong as if the diameter of the bodies were uniformly equal to the diameter of these their widest parts. The superficial transverse furrows thus formed on the surfaces of the several vertebræ are covered over by ligamentous tissue, extending between their projecting edges (Pl. XII. fig. 1), and transmit the intercostal arteries and branches from them to the vertebral bodies and to the spinal canal[1].

often not quite symmetrical; It may often be observed that the bodies of the vertebræ are not of equal depth on their two sides, not being quite symmetrical. This would lead to lateral curvature, were it not that the inequalities in one vertebra are compensated by inequalities of an opposite kind in the vertebræ above and below. Thus the body of the third lumbar vertebra may be thinner on the left side than on the right, but the deficiency is generally made up for, and the proper line of the column is preserved, by the body of the second, or the fourth, or both, being thinner on the right side than on the left.

their size. They decrease in size and weight as we trace them from below upwards, so that it is not correct to say that they are smallest at some part of the back, and that they collectively form two cones with their apices united in the back. This may be true if we regard their anterior aspect only, all the lum-

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[1] These furrows or wide channels on the fore part and sides of the bodies are much deeper in some of the whale's vertebræ. Indeed, in many of the caudal vertebræ of cetaceans they are covered over by bony plates, and are thus converted into complete canals, which nearly encircle the respective bones.

bar and a few of the cervical bodies having a greater transverse diameter than the fourth and fifth dorsal; but the difference is compensated to the latter by the extension of their antero-posterior diameters. A front view shows that the bodies diminish in width up to the fourth dorsal vertebra; that the third is rather wider than the fourth; and that there is often a sudden increase in the width of the upper two dorsal bodies, which is caused, in part, by a prominence of the bone in front of the articulating surface for the rib on either side. This prominence has relation to the fact, that the curved form of the two upper ribs and the manner in which they impinge upon the column renders such additional support or "stop" necessary in front. Moreover, at and above this point, increasing in distinctness up to the axis, are often found tuberculated projections from the fore part of the several vertebral bodies on either side of the middle line. These give attachment to the fibres of the longus colli; and they acquire an interest from their being probably rudimentary hæmal processes corresponding with much more marked prominences which exist in many animals, particularly in reptiles and birds, and which more or less completely enclose a canal transmitting the carotid arteries.

Neural pedicles.

The *neural pedicles*, by which are meant the parts of the neural arches that extend forwards from the articulating processes, are thickest at the lowest three dorsal vertebræ, and diminish in size above and below this. It has been mentioned (page 124) that the amount which they contribute to the formation of the respective bodies of the vertebræ is greater in the upper than in the lower part of the column. It may also be observed that their relations to the bodies of their respective vertebræ differ in different parts, they being on a relatively higher plane in the upper than in the lower regions. Thus the pedicle of the fifth lumbar vertebra is nearly on a level with the middle of the body of its vertebra; the several dorsal pedicles are on a level with the upper edges of the bodies of their vertebræ; the several cervical pedicles are above the level of the upper edges of their respective bodies; and, finally, the neural pedicles of the axis are on a level with and embrace the base of the odontoid process, which is the body of the atlas. In the back and in the upper part of the loins the neural pedicles run straight backwards from the bodies; whereas, in the neck, they are directed at first outwards, giving a greater apparent width to the bodies, and a greater width to the vertebral canal at this part. In the last lumbar vertebra their direction and the shape of the vertebral canal more resemble those in the neck. (Pl. IX. figs. 4, 5, 6, and Pl. X. figs. 4 to 8.)

Transverse processes.

The *transverse processes* are nearly in the same horizontal plane with the pedicles. Hence those of the upper dorsal vertebræ are on a level with the intervertebral spaces; and the ribs, passing from the intervertebral spaces directly outwards to them, are articulated with their *fore* parts (Pl. X. fig. 2). Lower down in the back the transverse processes are a little below the level of the intervertebral spaces; accordingly the ribs descend a little obliquely to them, and are articulated more with their *upper* surfaces. Hence the part of the back to which a given dorsal vertebra belongs may be pretty accurately known by the position of the articulating facet upon its transverse process.

In the upper three lumbar vertebræ these processes run straight outwards; in the lower two lumbar, and in most of the dorsal vertebræ, they slant a little upwards[1]; in the neck they are inclined rather downwards. As a general rule, in animals, the lumbar transverse processes, which in some, as the hare, are very long, slant forwards, that is, in a direction opposite to the slant of the ribs. In the dorsal region the transverse processes in man slant backwards as well as upwards. This is to permit that backward curve of the ribs which gives depth to the thorax. It is not so perceptible in the lower animals as in man, nor is it so marked in the little child, as it becomes after puberty.

Tubercles of the transverse processes;

The transverse processes are not quite such simple elements as they at first sight appear; and they afford a good illustration of the gradual mode in which changes in the shape and position of corresponding parts are brought about in different regions of the skeleton. If one be examined at the

[1] The transverse processes of the last lumbar vertebra sometimes extend to the hip-bones, and are jointed with them like those of the upper bones of the sacrum. (Otto's *Path. Anat.* by South, p. 199.)

in the back; middle of the back it will be seen to present, near its extremity, three projections or *tubercles* (Pl. X. fig. 2, *A*, *B*, *C*). Of these one (*B*) is in front, carries the articulating facet for the rib, and may be called the *costal tubercle*. The other two are behind; one (*A*), near the upper surface, may be called the *superior*, and the other (*C*), near the lower surface, may be called the *inferior tubercle*. They are very clearly seen in some human skeletons, and still more clearly in many animals (the beaver, Cape bear, &c.); and in the eagle the upper and lower tubercles are developed into long, broad processes which meet and overlap those of the vertebræ above and below, and contribute to give that solidity to the thorax which is required to furnish a firm basis of attachment to the wing-muscles. If we trace the transverse processes downwards, we shall find a gradual alteration or shifting of the positions of these tubercles. Take the last dorsal vertebra. The entire process has become very short in consequence of the shortening of its neck (that is, the stalk which carries the tubercles); but the tubercles have become more expressed and distinct from one another. in the loins; In the lumbar vertebræ the *costal tubercle* grows out into the long transverse process; the *superior tubercle* becomes connected with the upper articulating process, and gives great prominence to it; and the *inferior tubercle* forms a more or less marked projection from the under and back part of the base of the transverse process. In carnivorous and some other animals this inferior tubercle grows to much greater length in the loins; it projects downwards on the outside of the upper articulating process of the vertebra below, is articulated with it and hems it in so that the joint is very secure, and it is exceedingly difficult to separate the vertebræ in these animals[1].

The *superior tubercles* are all separate epiphyses in the skeleton of a rhinoceros in the Museum at Cambridge, which presents accordingly a good opportunity of tracing them through the changes in their position. We have observed (page 126) that in man they

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[1] An account of these tubercles, nearly corresponding with the above, is given by Retzius (*Ueber die richtige Deutung der Seitenforsätze an den Rücken- und Lendenvirbeln beim Menschen und beiden Säugethieren*) in Müller's *Archiv*, 1849, s. 593.

are in the loins sometimes developed from separate nuclei of ossification. The *costal tubercles* also are often developed from separate nuclei (page 125) in the back and in the loins. In the latter, where they form the chief part of the transverse processes, they are by some anatomists considered to be homologous with the ribs. I am not aware that the *inferior tubercles* are ever developed from separate nuclei. If we trace the transverse processes upwards from the middle of the back, we find that the tubercles nearly or quite disappear, and the articulating facets for the ribs, instead of being flat and seated on prominences, become concave and lodged in hollows. In the neck faint indications of the upper and lower tubercles may be detected in the form of slight projections at the extremities of the posterior transverse processes.

Cervical transverse processes.

In the neck the transverse processes are two, one in front of the other. They enclose between them the foramen for the vertebral artery, which is completed externally by a lamina of bone extending from one process to the other[1]. This lamina, with a part of the anterior process (probably the projecting tubercle of it), corresponds with the rib of the dorsal region. The relation between them is well shown in reptiles and birds. Though usually developed from a separate nucleus (page 126), the anterior transverse process of the seventh cervical vertebra is smaller than those immediately above it.

The *foramen* in the transverse process of the 7th cervical vertebra is generally smaller than in the others. It has occasionally been known to transmit the vertebral artery on the left side[2], more frequently it transmits the vein; but both artery and vein commonly pass altogether in front of this process to the foramen in the vertebra above. It is present in the giraffe, but absent in most other mammals, including monkeys. It is sometimes also absent in the human skeleton[3].

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[1] In the 4th, 5th, and 6th, there is occasionally a small hole behind that for the vertebral artery. It is said to transmit an artery, which is called "The accessory vertebral artery," though it appears to be only a muscular branch. Hildebrandt, *Anatomie*, II. 140.

[2] Struther's *Anatomical and Physiological Observations*, p. 127.

[3] Cuvier, *Leçons d'Anatomie Comparée*, remarks its absence in the skeleton of the Hottentot Venus at Paris.

Vertebral arches.

The width of the *vertebral arches* is greatest at the top of the column and diminishes as we trace them down to the middle of the back. Below this it again increases to the point of junction of the spine with the sacrum, corresponding with the increasing width of the vertebræ, which is for the purpose of giving the spine a larger basis of support upon the pelvis. (Pl. X. figs. 3 to 8.)

The arches are deepest (most flattened out from above downwards) in the back, where the antero-posterior movement of the bones is least free, and where the spine is bent backward; and by overlapping one another at this exposed part, they protect the vertebral canal. In the loins and neck, where there is more free movement and where the spine is less exposed, they are less deep; they are shallowest of all at the 5th lumbar vertebra[1] and at the atlas. The arch of the axis is very thick and strong.

Spinous processes in the neck;

The spinous processes are shaped with reference to the upright posture and the free movements of the head. That of the atlas is almost suppressed to prevent its interference with those movements. That of the axis is very large, and, like the four next to it, is bifid, to afford more room for the attachment of the muscles which cause the head to rotate upon the spine. The freedom and frequency of this movement is peculiar to man, and so is this bifurcation of the spinous processes. The 7th cervical and the upper three or four dorsal spines stand out boldly to give attachment to the muscles which fill up the interval between them and the occiput, and which assist to keep the head erect as well as to move it in various directions. Yet, forasmuch as in man the head is nearly balanced upon the spine, the office devolving upon these muscles demands far less force than it does in the lower animals, and the processes in question are

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[1] I found in the Museum at Bonn four specimens in which the arch of the fifth lumbar vertebra is separate from the articulating processes; and another in which it is separate on one side, the spinous process being also cleft, so that one half of the arch is loose. We may associate the fact of this separation with the greater width of the arch of this vertebra. It is also not unfrequently cleft in the median line by a more or less wide fissure extending through the spinous process. Such cleavage is more frequent in the sacrum; I have met with it occasionally in the atlas and dentata.

proportionately small. For the same reason the ligamentum nuchæ, which in graminivora is very thick and elastic and affords great assistance to the muscles in supporting the head, is in man reduced to a mere fibro-areolar band or intermuscular septum.

in the back; In the back the spinous processes are long, of triangular form, and sloped downwards, so as to overlap one another, and so as not to add unduly to the projection of this already prominent part of the column. Near their bases they are bound together by thick, strong, and elastic *ligamenta subflava*, which aid in restoring the column to its form when the dorsal curve has been at all increased; and near their extremities they are united by dense, fibrous tissue, which permits very little increase of the curve to be made. In the lower part of the back there is a tendency to bifurcation at their extremities, which, like the same conformation in the neck, has relation to the rotatory movement in the part above them, (page 166).

in the loins. In the loins the spinous processes are very large and square to give attachment to the erector muscles of the spine; and they are united by a large quantity of yellow elastic ligament[1]. In the lowermost two a smaller size is necessitated by the sharpness of the spinal curve and the freedom of movement about this part.

It is of some practical importance to be aware of the fact, that one or more of the spinous processes occasionally deviates a little from the perpendicular line; also that there may be, here and there, an interval between two spinous processes greater than between the adjacent ones. Irregularities of this sort are known also to be attendants on fractures of the spine and displacements from disease; so that we should sometimes be led into errors of diagnosis if we did not bear in mind that they may be the result of natural conformation.

The peculiarities in the shapes of the articulating processes will be described with the joints of the spine, (page 166).

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[1] They have occasionally been found touching one another with a joint formed between them. Mayer, in Tiedemann's *Zeitschrift für Physiologie*, II. 29.

See description on following page

Plate X.

Fig. 1.

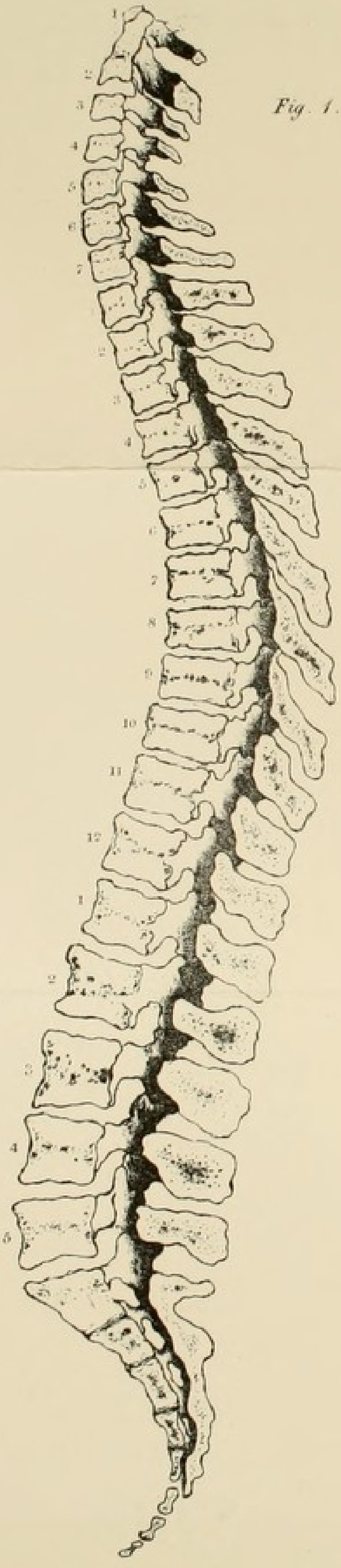
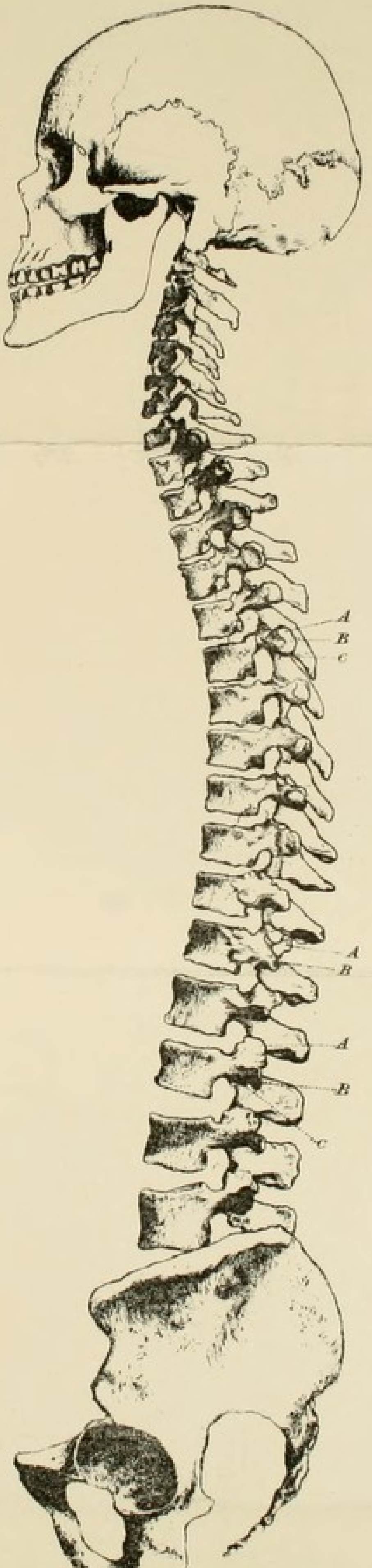


Fig 2.



3. 4. 5. 6. 7. 8.

THE SPINAL COLUMN CONSIDERED AS A WHOLE.

Advantage of a number of bones.

The construction of the spinal column of several pieces, superimposed upon one another, and jointed together so as to permit of slight motion between each of them, has the effect of allowing a considerable range of movement in the spine as a whole without much alteration in position between any two bones, or any great change in the shape of the column. This is very important, inasmuch as a free range of movement at any one point would necessarily have been attended with much diminution of strength, and would have exposed the cord to considerable risk of injury; whereas by the present arrangement great strength is combined with sufficient mobility. Moreover, by the interposition between the several bones of elastic fibro-cartilages, which act like buffers, the column is rendered highly elastic, and the communication of jars from one part to another is prevented.

DESCRIPTION OF PLATE X.

Fig. 1. Drawn from a section of the spine of a man æt. 60, which had been enclosed in plaster of Paris and cut with the ligaments, &c. entire, so as to preserve the shape of the curves and interspaces between the vertebræ. The length of the spine and the measurements of the curves differ somewhat from those given in the text, in consequence of the greater height and age of the patient (p. 155); but it exhibits most of the points there mentioned.

Fig. 2. Lateral view of skull spine and pelvis drawn from a specimen in which the bones are artificially joined together and in which the curves are not quite truthfully given. It shows the varying shapes and positions of the articulating surfaces on the transverse processes of the different dorsal vertebræ (p. 140), also the greater prominence of the inferior articular facets for the ribs on the dorsal bodies, as compared with the superior. *A* is the "superior tubercle" of the transverse process, *B* is the "middle," or "costal tubercle," and *C* is the "inferior tubercle." In the back they are close together at the extremity of the transverse process. In the loins they are separate, the "superior tubercle" being appended to the superior articulating process, and the "inferior tubercle" projecting downwards from the base of the "middle tubercle" which forms the chief part of the transverse process.

Figs. 3, 4, 5, 6, 7, 8, represent horizontal sections, of the atlas (3), of the axis (4), of one of the middle cervical vertebræ (5), of one of the middle dorsal vertebræ (6), of the upper lumbar vertebra (7), and of the fifth do. (8). They show the shape of the spinal canal, the direction of the neural processes, &c. in different parts of the column (p. 139).

The curves.

The elasticity of the column is still further provided for by the manner in which the component bones are arranged in a series of curves, instead of being placed perpendicularly one above the other. The column may, in this respect, be compared to a bent spring which yields easily, gradually and uniformly in all its parts when a weight is placed upon it, and which, in like manner, without any sudden jerk, resumes its former position when the weight has been removed. Thus, composed of many pieces arranged in curves and held together by powerful, and at the same time, elastic ligaments, the spine is able to meet these three requirements: 1st, of bearing great weight; 2dly, of undergoing great variety and considerable range of movements while it is the centre of the movements of the whole body; and, 3rdly, of transmitting the nervous cord safely, and of defending from undue vibrations the great nervous centre which it supports.

The number and direction of the antero-posterior curves.

The antero-posterior curves in the column (from the atlas to the coccyx) are four in number. They may be called, from their position, "cervical," "dorsal," "lumbar" and "pelvic." They alternate in the direction of their flexure and in the mobility of the several vertebræ which respectively compose them. Thus the dorsal and pelvic curves have their concavities in front, which lodge the thoracic and pelvic viscera, and the vertebral bodies composing them admit of comparatively little movement upon one another; those of the sacral portion of the pelvic curve are indeed quite fixed, and form a basis to which are appended the pelvis and lower extremities; whilst those of the dorsal curve are nearly fixed, and support the thorax and upper extremities. Whereas the cervical and lumbar curves, which present their convexities in front, are composed of vertebræ capable of much more free movement upon one another.

Measurements of the curves.

For the purpose of measuring these curves I made a vertical section in the median line of the spine of an adult female, which had been removed with the ligaments and pelvic bones and had been enveloped in plaster of Paris, after the manner adopted by Weber. By this means the curves are preserved nearly correct. Unless the spine be thus fixed in plaster of Paris, or in some other way, the middle of each intervertebral substance becomes squeezed out by the weight and elasticity of the adjacent parts, as soon as a section is made; and this has the effect of unduly approximating the apposed surfaces of the bodies, altering their relative positions and modifying the curves. (Of course the measurements would be found to vary a little in different persons.)

In this specimen the first, or *cervical* curve, commences at the top of the odontoid process and terminates at the middle of the second dorsal vertebra. It has its convexity in front, and forms 18^0 of a circle whose radius measures $6\frac{5}{8}$ inches; the most prominent point anteriorly is the fore part of the body of the fourth cervical vertebra. The second, or *thoracic* curve, commences at the middle of the 2nd and terminates at the middle of the last dorsal vertebra. It has its concavity forwards, and forms 42^0 of a circle whose radius measures $12\frac{2}{8}$ inches; the most prominent point posteriorly is at the hinder edge of the body of the 7th or 8th vertebra. The degree of curvature is nearly uniform, if not quite, in the several parts of each of these two curves. The third, or *lumbar* curve, commencing at the middle of the last dorsal, terminates at the lower and anterior edge of the last lumbar vertebra. It is convex anteriorly, and forms 80^0 of a circle whose radius is $5\frac{3}{8}$ inches. This is the mean measurement; the degree of curvature throughout this lumbar portion is not, however, by any means uniform, that is to say, it does not form a part of one circle, but is composed of parts of two or more; for the convexity of the lower three vertebræ is much greater than that of the upper two, which together with the last dorsal form nearly a straight line. The fourth, or *pelvic* curve, sharper than either of the others, commences at the upper edge of the sacrum and terminates at the tip of the coccyx. It forms 125^0 of a circle whose radius is $2\frac{5}{8}$ inches. In this, as in the lumbar region, the curve is not part of a true circle; the degree of curvature being not uniform but greatest a little below the middle, that is, at the lower part of the sacrum.

The sacro-vertebral angle.

The transition of the lumbar and sacral curves into one another is not, like that of the others, gradual, so as to render it rather difficult to tell where the convexity of the one merges into the concavity of the other, but it is sharp, forming a salient angle of 120°: this angle of union of the sacral with the lumbar portion of the column is called the *sacro-vertebral angle.*

The chords of the curves are in the line of gravity.

The upper three curves—the cervical, dorsal, and lumbar—are so arranged that their chords are in the same vertical line in the erect position of the body; and that vertical line coincides with the line of gravity of the head. This is easily ascertained in the following way. We know from experiment that the line of gravity of the head falls between the condyles of the occipital bone, and passes through the middle of the odontoid process. Now a plumb-line let drop from this point, in the specimen from which the above measurements were taken, passes directly through the middle of the body of the second dorsal vertebra, through the middle of the body of the last dorsal vertebra, and through the middle and antero-inferior edge of the last lumbar vertebra; it passes, therefore, through the points at which these three curves run into and support one another, i. e. it coincides with the chords of the curves. Prolonged further downwards the plumb-line falls just in front of the promontory of the sacrum, and bisects a line drawn transversely through the middle of the heads of the thigh-bones, or a very little behind the middle. The centre of gravity of the cranium with its contents is, therefore, placed immediately over the heads of the thigh-bones; and the points of confluence of three of the intermediate spinal curves are in the line of gravity.

The dorsal curve backwards equals the cervical and lumbar curves forwards.

The line of gravity thus drawn from the head through the spine to between the heads of the thigh-bones, coinciding with the chords and points of junction of the spinal curves, corresponds with the hinder edges of the bodies of those vertebræ which are situated at the foremost part of the cervical and lumbar curves, neither of these vertebral bodies being entirely in front of it; whereas it runs quite in front of the bodies of the fifth, sixth, seventh, eighth, and ninth dorsal vertebræ. Hence there is a larger portion of the dorsal curve behind the line of gravity than there is of either the cervical or dorsal curves in front of it; so that the one dorsal bend backwards is made about sufficient to compensate for the cervical and lumbar flexures in the opposite direction.

Cause of the curves.

The curves are due partly to the shape of the vertebral bodies, and partly to that of the intervertebral substances. The curvature in the neck is entirely to be attributed to the latter; for the upper and lower surfaces of the vertebral bodies in this region (as may be seen in the section, Pl. X.) are parallel, or even actually further apart behind than in front, the reverse being the case with regard to the intervertebral substances[1]. In the back the curvature is almost entirely due to the shape of the bodies, which are, especially at the middle of the curve, evidently deeper behind than in front. Each intervertebral substance here presents nearly a uniform thickness, the contiguous upper and lower surfaces of the vertebral bodies being almost parallel. In the lumbar region the shapes both of the vertebræ and of the intervertebral substances contribute to the curve. The body of the lowermost lumbar vertebra is nearly a third less deep behind than in front (Pl. IX. and X.). In the others the difference is less marked, the upper and lower surfaces being more nearly parallel. The depth of the lumbar intervertebral substances is also manifestly greater in front than behind. This account agrees, on the whole, with the measurements given at length by the brothers Weber[2].

Shape of vertebræ modified in reference to the curves,

A few other particulars in which the shapes of the vertebræ are modified in reference to the curves, deserve mention. *First*, the middle part of the body of each of the dorsal vertebræ, from the fourth to the eighth more especially, that is about the middle of the curve, is projected forward, so as to render its horizontal section somewhat heart-shaped;

in their bodies,

and when they are united together a sort of ridge is formed which projects into the interior of the curve, and affords additional support where it is most needed. Above and below this part, on the contrary, the vertebral bodies are expanded

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[1] It will be seen from the drawing that they are not truly parallel, both surfaces being rather concave, as in the loins, so as to give somewhat of a globular shape to the intervertebral substances lying between them, which facilitates the movement of the vertebræ upon one another. In the back, where the movements are very limited, not only are the intervertebral spaces shallower, but, as stated in the text, the upper and lower surfaces of the contiguous vertebræ are more truly parallel.

[2] *Mechanik der menschlichen Gehwerkzenge*, s. 92.

laterally; and in the lumbar region, in an especial manner, they are spread out at the postero-lateral parts where the weight chiefly falls. (Pl. IX.)

Secondly, the posterior aspect of the dorsal bodies is flat and even, presenting a plane uninterrupted surface to the vertebral canal, which is quite necessary, because the anterior wall of the canal which is formed by them, being convex, the cord is in close contact with it, and may be said to be stretched over it. The dura mater is also adherent to the ligament which covers the hinder surface of the bodies of these vertebræ. In the lumbar region, on the contrary, where the anterior side of the vertebral canal is concave and where the cord is consequently not in close contact with it, the dura mater is less adherent and the surface is much less even; the middle parts of the bodies of the several vertebræ are here hollowed out, and their upper and lower edges, with the intervertebral substances, are proportionately prominent. Thus there are interspaces left between the concave vertebral bodies and the spinal cord in this situation, which are occupied by fine soft fat. Fat, indeed, exists in considerable quantity about this part of the vertebral canal, furnishing protection to the nervous cords against the injuries which would be likely to result from the comparatively free movements of the bones.

in their spinous processes,

Thirdly, the spinous processes are slanted very obliquely so as to overlap one another and to project very little in the back, where the prominence of the column itself affords sufficient leverage to the muscles. In the neck and loins, where this advantage is wanting, owing to the concavity of the hinder aspect of the column, the deficiency is, in part, supplied by the greater prominence of these processes. So that we should make quite an erroneous estimate of the amount of flexure of the several parts of the column, if we were to form our judgment from the curves presented by the line of the spinous processes.

and arches.

Fourthly, the depth and overlapping of the vertebral arches in the convex dorsal portion of the column afford protection to the spinal cord: this has already been mentioned (page 143), and contrasted with the shape of the same parts in the concave cervical and lumbar regions.

Curves enable the spine to bear greater vertical weight.

The disposition of the vertebræ in three curves between the pelvis and the head enables the spinal column to bear a greater vertical weight than it could have done if the bones had been arranged in a straight line one above the other. This may seem paradoxical, and would be untrue if we could regard the part as inelastic, for any inelastic column must clearly be strongest when straight. Practically, however, all columns are more or less elastic, and if pressed by vertical weights first bend, and then break. It has been calculated that when a column is just going to bend, the weight sustained is inversely proportional to the square of the length; greater force is therefore required to produce bending in a short column than in a longer one which is equal in breadth and material. Now the spine, consisting of three curves, and being elastic, must *bend in three curves* (that is, must bend as though it were composed of three short columns); and a greater force—say, nine times as much—is required to bend it than if it had been straight, and, therefore, capable of bending in one curve.

Their advantages in the movements of the body.

And when we consider the spine, not merely as a stationary but as a moving column, carried to and fro and subjected to sudden changes of position and jerks in different directions, we perceive how greatly the arrangement of its bones in alternate curves must further contribute to its general resisting power and security. Suppose, for instance, the lumbar portion, instead of being bent, had been continued up in a straight line from the sacrum: in that case when the pelvis was carried forwards, in walking or running, the strain upon the ligaments that unite the fore parts of the bodies of the vertebræ together and to the sacrum, would have been so excessive that a far greater strength than now would have been necessary to attain the same security, and it would have been much more difficult to maintain the proper balance of the trunk. Owing, however, to the curve in which the bones are arranged, the onward impulse of the sacrum is shared between the bones and the ligaments, being communicated in an oblique line, partly to the body of the last vertebra, and partly to the tough inelastic fibrous bands that unite the fore parts of that vertebra with the sacrum. The broken force thus received by the last vertebra is, in like manner, transmitted obliquely onwards, and is shared between the body of the fourth vertebra and the ligaments which, forming the fore part of the intervertebral substance, connect it with the vertebra above; and so on. In this way, by virtue of the direction of the curve and the structure of the spine, the force is decomposed, and, being shared between several bones and their connecting ligaments, is borne without particular stress on any one part. The same applies to other regions of the column, though in a less striking manner than to this, which having to bear the greatest weight and to receive the first impulses from the pelvis is, as a compensation, provided with the sharpest curve[1].

It appears, indeed, that in the construction of the human spine every thing is disposed to such advantage, the bones are so shaped and sized, are so adjusted in curves and so arranged with intervening soft, semifluid intervertebral substances, that the required amount of elasticity, strength and capacity of movement are afforded by the smallest possible quantity and weight of materials. We find, accordingly, as we descend towards the lower parts, in proportion as the superincumbent weight increases so do the bones gradually become larger, and the intervertebral substances are likewise larger and thicker. We find also, that at the lowest part, where the weight is greatest and the movements are most free, the curve is the shortest as well as the sharpest; that in the neck, where the vertebræ are small and the movements are free, the curve is also short; and in the back, where the movements are very limited and the bones are of considerable size, the curve is the longest.

When the body is moved quickly, as in running, the whole column, with the pelvis, is inclined forwards, the degree of inclination increasing with the rate of progression; thus the bones and ligaments are placed in a more favourable position to receive the impulses from the lower extremities, in proportion as those impulses become more violent.

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[1] In the chimpanzee and other quadrumana, which are adapted for climbing rather than walking, the lumbar curve is less sharp and the bodies of the lumbar and sacral vertebræ are proportionately less large than in man.

Spine braced on either side by muscles.

The advantages afforded by the curves in the way just mentioned apply of course only to the backward and forward movements of the body; to the latter, which are the more forcible, in an especial manner. The movements from side to side are much less extensive and sudden; and, it must be remembered, that the column is strongly braced in a lateral direction by the muscles which pass between its transverse processes, and still more by those muscles which pass between the pelvis and thorax below, and between the thorax and cranium above.

Curves so disposed as to protect the cord in movements of the spine.

In addition to the resolution and distribution of forces which the curves effect during the movements of the body, it is to be remarked that they enable the movements of the several parts of the spine upon one another to take place without injury to the cord; and they are arranged with especial reference to this point. I find from observations, to be presently mentioned, that when the spine is bent forwards or backwards the movement takes place chiefly in its lumbar and cervical portions. Had, therefore, the bones in those regions been arranged in a straight line, or still more had they been curved backwards, it is evident that any bending of the spine forwards would have been attended with some projection into the vertebral canal, which would have been likely to cause injury to the nervous centre. But forasmuch as the curve is so disposed as to render the anterior surface of the canal concave, a considerable bend of the column can take place without any possibility of injury to the cord. In the back, on the contrary, where the posterior surfaces of the bodies and the intervertebral substances present an even convex surface to the canal, any considerable addition to the flexure of the column would be liable to stretch and damage the cord; we shall find, accordingly, in the disposition of the articulating processes and in other ways, that provision is made to prevent such movement.

The disposition of the organs and muscles with reference to the curves.

Not only do the curves contribute to the grace and elasticity of the movements of the spine, and prevent the communication of jars and injurious impulses of various kinds from one part to another; but they also afford additional surface for contact and additional means of support to the contiguous soft parts; and these are distributed, in some measure, with reference to them: thus the heavier viscera—the liver and spleen—are placed in the hollow at the lower region of the back so as to rest upon the lumbar prominence, and to be partly in and even a little behind the line of gravity. It is also worthy of remark that the anterior concavities of the curves occur in the thorax and pelvis where the rest of the wall enclosing the viscera is comparatively or absolutely unyielding. The inconvenience which would result from a convexity of the spine projecting into either of these regions is obvious.

Advantage is, in like manner, taken of the spaces which the curves afford in the back for the lodgement of muscles. Thus the fleshy bellies of the powerful muscles that maintain the trunk erect upon the pelvis, and of those that support and wield the head upon the spine, are placed in the concavities of the lumbar and cervical curves; while the convexity of the dorsal portion affords a favourable leverage for the attachment of the tendinous prolongations of both sets of muscles.

Not caused by muscular action.

It has been supposed by some anatomists that the curves are due to the contractions of these muscles predominating over their opponents and drawing together the arches and spines of the lumbar and cervical vertebræ; the dorsal bend in the opposite direction, being secondary to and consequent on these two primary curves in the neck and loins. There does not seem to be any good evidence in favour of such a view. It is more probable that the several flexures, that is to say, the shape of the spinal column, is a resultant of the same forces of development which evolve the forms of the several vertebræ and of the other parts of the body. It has been already said (page 134) that the curves scarcely exist at the time of birth although the preparation for them may be observed in the configuration of the vertebral bodies. For some time after birth the spine is so flexible that it is difficult to decide what is its true shape. The formation of all the curves, of the upper three at any rate, must commence and proceed almost cotemporaneously. If there be any difference in point of time it is that the dorsal curve has slightly the precedence, the lumbar curve following closely upon it. Up to adolescence all the curves become gradually more marked; and after maturity the dorsal curve often increases in length and depth at the expense of those above and below it (page 173).

Similar curves found in the spine of other mammals.

The respective parts of the column in other mammals present, generally speaking, similar curves to those in the human spine; though the degree of flexure varies a good deal in each part in different animals. The curve in the loins, which has especial relation to the upright posture, is in all much less marked than in man; in some animals the spine is here quite straight; in some, it is curved in a direction opposite to that in man: in the elephant, for instance, the spine from the pelvis to the neck forms a single arch. The dorsal curve is generally wider in animals than in man. In some it is sharper at the fore part than elsewhere; it is so in the horse, and in most animals whose weight is much thrown upon the fore legs in running and leaping.

Lateral curves.

A slight lateral curvature, with the convexity to the right, is commonly found in the middle and upper part of the back; and there are compensating curves above and below, so slight as scarcely to be perceptible. These lateral curves are not sufficiently pronounced to have any relation to the functions of the column as an organ of support or of motion. The chief, or primary one, to the right has been attributed to the presence of the aorta, which by pulsating along the left side of the column causes a slight flattening of the vertebral bodies in its track, and has been supposed to cause a slight deflexion of the spine to the opposite side. If the curve were really induced in this way we should expect to find it present at birth, which is not so; and the observation by Professor Otto[1] of a case in which the aorta arched to the right and descended on the right side of the spine, instead of the left, the curvature of the spine nevertheless taking its usual direction, quite proves that the curve and the vessel have no direct relation to one another in the way of cause and effect. It seems more probable that this bend of the spine to the right side in the back is

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[1] *Seltene Beobachtungen.* Zweite Sammlung, s. 61.

dependent upon the more frequent use and greater strength of the right hand and arm as compared with the left, and upon the consequent inclination of the upper part of the spine towards the left side for the purpose of maintaining the balance and giving a firm basis of action to the muscles moving the arm. This view derives confirmation from the fact that Beclard found the curve taking an opposite direction in the spine of a person who was known to have been left-handed.

Vertebral canal,—dimensions of at different parts.

The vertebral canal varies in its size at different parts of the column (Pl. IX. and Pl. X.). It is, on the whole, largest where the movements of the vertebræ are most free. At the second cervical vertebra its *antero-posterior diameter*, measuring $\frac{6}{8}$ of an inch, is greater than at any other part of the neck or at any part of the back. From this it gradually diminishes to the middle of the back, where it measures $\frac{5}{8}$ of an inch or less. As we trace it further downwards it gradually increases to the last lumbar vertebra, where it measures $\frac{7}{8}$ inch. Below this it diminishes quickly to its termination. The canal is, therefore, most roomy from before backwards in the neck and loins, where the antero-posterior movements of the spine are greatest, and where the cord is least closely attached to the vertebral bodies, which, in these regions, present an undulating surface to it.

The *lateral diameter* of the canal is greatest at the atlas, where it measures nearly an inch and a half. It must be remembered that the presence of the vertebral arteries, and the room required for the rotatory movements of the atlas upon the axis, curtail somewhat the space here allotted to the cord. Nevertheless, the great width of the canal at this part affords an explanation of the fact of the cord having escaped injurious pressure in some of those remarkable instances of displacement of the bones from disease, which are every now and then met with. At the axis the measurement of the canal from side to side is about an inch, and continues the same, or a little less, down the neck. At the second dorsal vertebra it is suddenly diminished, measuring only $\frac{6}{8}$ inch; so that the transverse section of the canal here is nearly circular; it is of the same shape through the greater part of the back. At the last dorsal vertebra the lateral diameter is $\frac{7}{8}$ inch. It increases to an inch in the loins and diminishes again in the sacrum[1].

Connection of cord with its anterior and posterior wall.

The cord is more closely connected with the bodies than with the arches of the vertebræ all the way down; and the dura mater is adherent to the posterior surface of the vertebral bodies, or, rather to the posterior vertebral ligaments, by fibrous tissue. It follows, as before said, the even convex surface of the dorsal bodies more closely than the undulating concavo-convex aspects of the cervical and lumbar vertebræ. The interval between the dura mater and the vertebral arches is occupied by fine adipose tissue, which quite separates the one from the other along the whole length of the canal.

It is remarkable how seldom the shape of the vertebral canal is altered, and the cord subjected to any injurious pressure, by outgrowths from the bodies of the vertebræ. These are very common at the fore part and sides of the vertebræ, particularly near the upper and lower edges of the bodies; but, fortunately, very seldom appear behind. I remember one instance, and only one, of this kind. A man had been paraplegic for many years; and we found, on post-mortem examination, that the loss of nervous power in the lower half of the body had been caused by a bony outgrowth from the hinder part of one of the dorsal vertebræ, which, projecting into the canal, had pressed upon the cord. It was of small size, and not rough; but, being situated in the part of the canal where the surface is convex it soon produced an effect upon the cord[2].

Position of the intervertebral foramina.

It will be observed from Pl. X. fig. 1, that the "intervertebral foramina" in the neck and loins are, with regard to their respective vertebræ, on a plane anterior to those in the back, that is, are closer to the bodies of the

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[1] Cruveilhier gives the following measurements of the vertebral canal:

	Transverse diameters.	Antero-posterior diameters.
In the neck	11 lines	6 lines.
In the back	7 lines	6 lines.
In the loins	10 lines	8 lines.

[2] Dr Reid has recorded a case in which a conical exostosis, growing from the posterior part of the odontoid process of the axis, caused fatal compression of the cord. *London and Edinburgh Journal of Medical Science*, 1843.

vertebræ. This has relation to the direction taken by the nerves emerging from them; the cervical and lumbar nerves passing forwards to their respective plexuses, whereas the dorsal nerves are at first directed backwards, along the lower edges of the ribs. In the neck the forward position of the foramina, which is more marked than in the loins, has relation also to the fact that the vertebral arches are at first directed outwards from the bodies instead of passing straight backwards as they do in the dorsal region.

Their shape and size vary in different parts.

Being included between the pedicles of the contiguous vertebræ the shape and position of the intervertebral foramina vary according to the relative size and position of the pedicles; though in all parts they are of ample dimensions to prevent injurious pressure upon the nerves during the movements of the vertebræ. In the neck, where the pedicles are relatively large, the intervertebral foramina are comparatively small and roundish. In the back where the pedicles are, for the most part, relatively small, the foramina are large and oval or ovoid, the larger end of the oval being directed upwards and backwards. The nerves here pass through the upper and larger parts of the foramina, under shelter of and close beneath the bridges formed by the junction of the pedicles with the inferior articulating processes; and this position of the nerves in their course upwards backwards and outwards to gain the lower edge of the ribs, accounts for their escaping so often in angular curvature of the back. In that disease the bodies of several dorsal vertebræ may be destroyed, the adjacent ones above and below the ulcerated chasm may fall together and become united, while the arches not being involved in the disease are thrown back, and the nerves escape. In the loins the bodies of the vertebræ are large, so that the pedicles stand well apart from one another, and the foramina are large and oval. The nerves in their passage obliquely through them from above downwards lie, not so much under shelter of the arch of the vertebra above, as upon the pedicle of the one below[1].

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[1] In certain fishes and in the buffalo, and perhaps in some other animals, the nerves pass through foramina in the pedicles of the respective vertebræ instead of between them; the foramina are in them accordingly *vertebral* not *intervertebral*.

CONNECTION OF THE VERTEBRÆ WITH ONE ANOTHER.

Intervertebral substances.

The great bond of union between the component parts of the spinal column is furnished by the *intervertebral substances*, which are inserted between the bodies of the several vertebræ. They are composed chiefly of fibrous and fibro-cartilaginous tissue, connected with the opposed surfaces of the vertebræ so that there is no periosteum in this situation. At the circumference of each intervertebral substance the fibrous tissue predominates, and is arranged in fibres or bands, which cross one another obliquely and are arranged in concentric layers (Pl. XI. fig. 4 and Pl. XII. fig. 1). Nearer to the middle part the layers become less distinct and are broken up into detached branching fibres: they here contain more fibro-cartilaginous and cartilaginous substance in their structure, with cartilage-cells irregularly dispersed in them; and there is a greater quantity of interstitial fluid. The latter increases towards the interior of the intervertebral substance, so much that in the middle it forms the chief constituent; and, being tightly embraced by the circumferential fibrous and fibro-cartilaginous layers, it constitutes a nucleus, or fluid cushion, or pivot, which supports the middle part of the body of each vertebra, prevents unequal pressure, and forms the centre of movement of one vertebra upon another. The tight manner in which this central and more fluid portion of the intervertebral substance is embraced by the circumferential ligamentous structure is shown by the manner in which it bulges out from its confinement when a longitudinal section of the spine is made[1]. This central compressed fluid ball is most marked in the neck and loins, where the movements of the bones are most free, and where the opposed surfaces of the bodies of the vertebræ are

[1] In the fœtal and young child the central cavity is still more distinct, being of greater proportionate size, and the contained fluid is more limpid (Pl. IV. fig. 1). This was observed by Ruysch, *Thesaurus Anat.* IV. No. LXIII. For an accurate chemical and microscopical account of this fluid see Luschka, in Virchow's *Archiv*, IX. 316. As a general rule, the cavity diminishes and the intervertebral substance becomes drier and more dense as age advances.

hollowed out to afford it greater space, presenting, in this respect, some similarity to the fish's vertebræ. When the fluid centre is cleared out a cavity is left, surrounded by the solid fibrous and fibro-cartilaginous portion of the intervertebral substance, and bounded above and below by the cartilaginous surfaces of the contiguous vertebral bodies. From these cartilaginous surfaces delicate fibres hang into the central cavity, containing at their free extremities cartilage-cells, and presenting some resemblance to the processes which hang into some parts of the synovial cavities.

Their structure displayed by vertical section.

Plate XI. fig. 1, gives a representation of a longitudinal section from before backwards of the lower three lumbar vertebræ and of the two intervertebral substances between them. Plates of steel were inserted between the vertebræ before the section was made to prevent their approximation and the consequent alteration of the direction of the intervertebral fibres. It will be seen, that immediately in front and

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DESCRIPTION OF PLATE XI.

Fig 1. Vertical section from before backwards of lower three lumbar vertebræ and their intervertebral substances, showing the structure of the latter. See description above.

Fig. 2. Horizontal section of vertebral column in the middle of the neck in recent subject. It has been made through the intervertebral substance and the articulating processes so as to show the shape and direction of their articulating surfaces. *A* the articulating processes of the vertebra above (all the rest of vertebra was above the section). *B* those of the vertebra below.

Fig. 3. Ditto in the back, through the lower part of the body and through (*A*, *C*, *D*) the articulating processes, arch and spine of the fourth dorsal vertebra. The articulating processes are disposed in a curved manner around the convex articulating surfaces (*B*) of the fifth dorsal vertebra. *E* the cut ends of the fibres of the ligamentum subflavum. *F* the transverse processes of the fifth vertebra. *G* sections of the ribs abutting upon the sides of the vertebral body.

Fig. 4. Ditto in the loins. *A* the articulating processes of the third lumbar vertebra, all the rest of the vertebra was above the section. Their cartilaginous surfaces, slightly convex, are directed outwards and embraced by (*B*) the slightly concave articulating processes of the fourth vertebra. *E* parts of ligamentum subflavum; other parts of this ligament connected with the spines and arch have been cleared away. The section passing through the intervertebral substance shows the concentrically laminated disposition of its fibres near the circumference, and the absence of distinct fibrous structure in the middle.

Fig. 1.

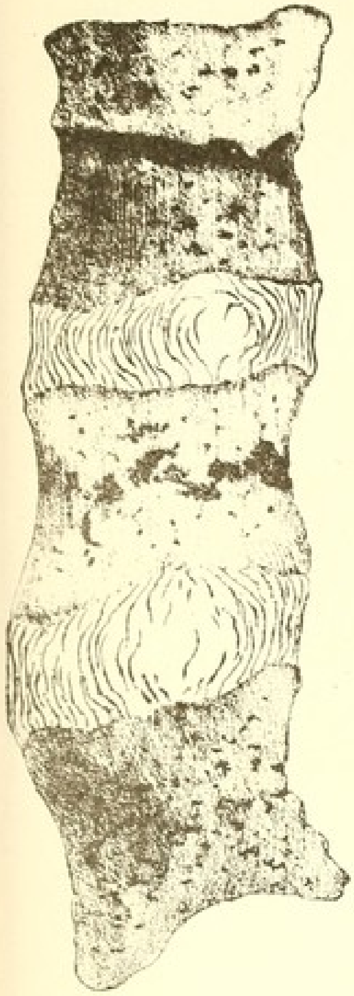


Fig. 2.

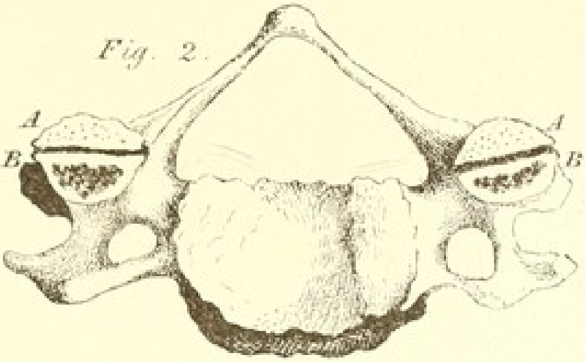


Fig. 3.

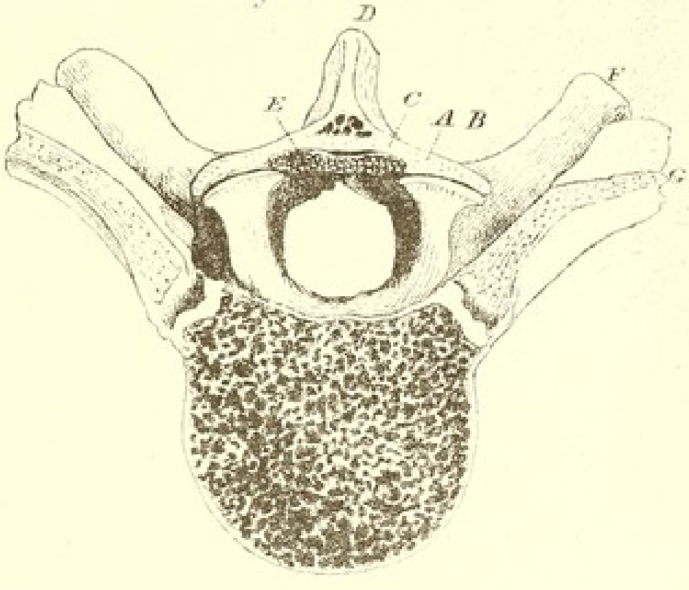
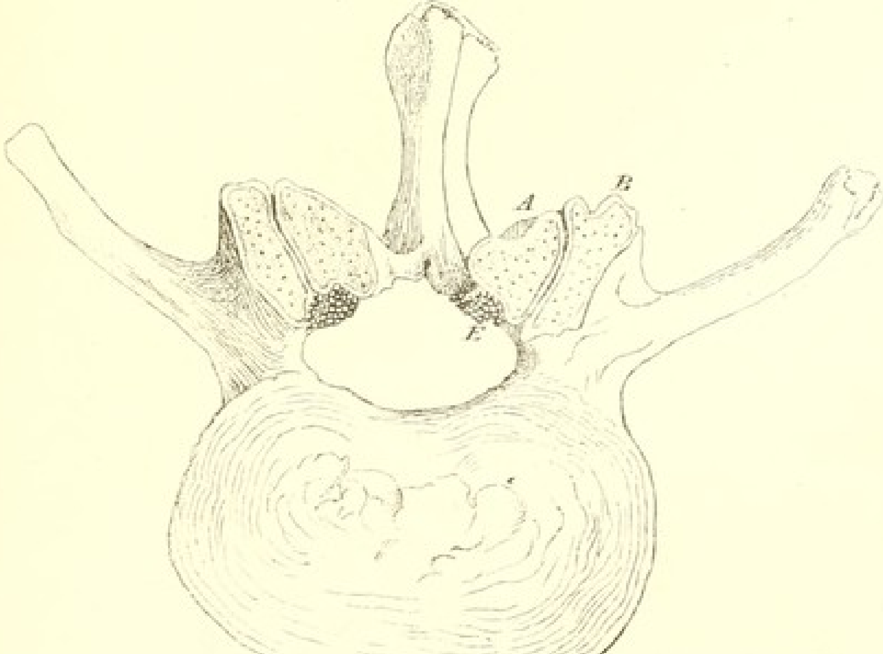


Fig. 4.



behind the central more fluid part the fibres connecting the opposed surfaces of the bodies are slightly bent, the curves which they form having their concavities towards the centre. As they lie nearer to the circumference the fibres are closer, more compact and straighter; the outermost are quite straight, so that the external surfaces of the intervertebral substances are flat. It may be observed, that the surfaces of the bodies of the vertebræ next the intervertebral substances present a waving line. They recede from each other at the middle, or a little behind it where the interspace is seen to be widest. They approach one another near the edge where the interspace is seen to be narrowest; and they again recede in the immediate neighbourhood of the edge. In the latter situation the intervertebral fibres pass quite straight from one vertebra to the other. If the bodies of the vertebræ be approximated to one another on one side these external fibres acquire a slight degree of the same curve as the more central ones at that part; and this is what takes place in the movements of the column, the surfaces of the intervertebral substances being bulged out a little in the direction to which the spine is inclined. I have made several sections to ascertain the correctness of this representation, and can discover no ground for the account given by Weber in Meckel's *Archiv* and also in the *Gehwerkzeuge*, which has been repeated by others, that the fibres, near the middle of the intervertebral substances are bent inwards, and that those near the circumference are bent outwards. The great thickness and strength of the ligamentous bands which form the fore part of the intervertebral substances in the lower region of the loins is a provision for resisting the strains to which this portion of the column is necessarily subjected when the lower limbs and pelvis are suddenly moved forwards.

The intervertebral substances are almost extravascular; vessels having been traced only a short distance into their outer sheets.

Their varying thickness.

They vary a good deal in thickness in different parts of the column. That between the second and third cervical vertebræ is thinner than any other. They are very thin in the middle of the back, or rather from the third vertebra to the seventh. They are rather thicker in the neck. Below the seventh dorsal vertebra they gradually increase as we trace them downwards to the lower part of the loins, where their great thickness not only tends to break the jars to which the lower part of the column is subjected, but also counterbalances the effect which the large area of the contiguous surfaces of the vertebral bodies would have in restricting the range of movement of the bones upon one another.

In the loins the central succulent or semifluid portions are especially well developed, and form a series of fluid balls round which the respective vertebræ revolve in their movements upon one another. They are placed nearer to the hinder than to the anterior surfaces of the bodies, so as to be almost in the line of gravity of the column. It would be difficult to conceive anything better adapted for transmitting weight from one bone to another, for preventing jars, and permitting some slight movement, than this ball of fluid tightly girt by circumferential bands of fibrous tissue.

Not often the seat of injury or disease.

The intervertebral substances give a little and become flattened out under the continued pressure of the superincumbent weight during the erect posture, so that a man loses one third or half an inch in height during the day. They are

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DESCRIPTION OF PLATE XII.

Fig. 1. Right side of two lumbar vertebræ and of part of a third, showing the anterior vertebral ligament (*A*), the ligamentous fibres (*B*) which run between the projecting upper and lower edges over the concave intermediate parts of each of the bodies of the vertebræ, and the oblique outer fibres (*C*) of the intervertebral substance crossing one another. The foramina (*D*) on the sides of the bodies transmit vessels into their interior.

Fig. 2. Hinder surface of the bodies of three lumbar vertebræ, exposed by cutting away the arches. *A A* the ligamentum posticum, which has been removed below to show the vascular foramen in the back part of the body of the vertebra. The ligament is thin; its edges are ill-defined and prolonged into the intervertebral foramina; it is in close contact with the intervertebral substances and the edges of the bodies of the vertebræ, but is separated from their middle parts by fat and blood-vessels.

Fig. 3. Vertical section from before backwards through the arches of three dorsal vertebræ, a little on one side of the spines. *A A A* ligamenta subflava. *B* the interspinous ligament between the extremities of the spines. *C* a fibrous web connecting the spinous processes between the ligamenta subflava and the interspinous ligaments.

Fig. 4. Arches of two dorsal vertebræ with ligamenta subflava, viewed from in front. *A A* cut edges of pedicles of arches. *B B B* ligamenta subflava.

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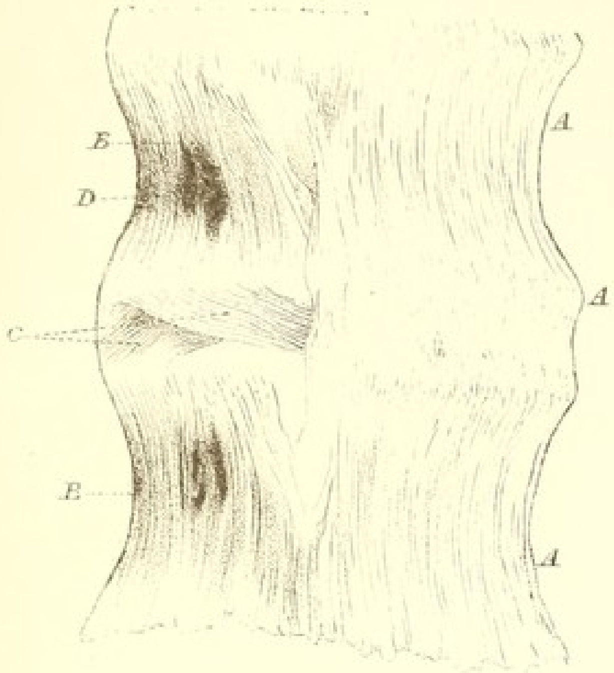

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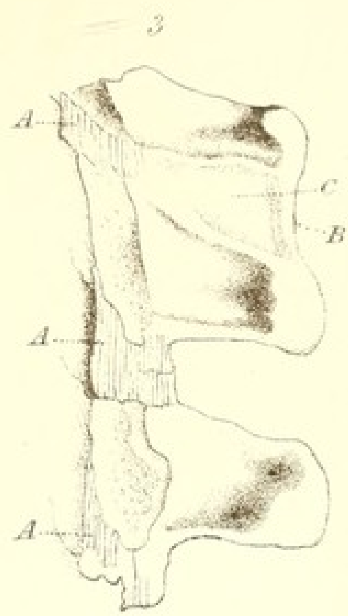

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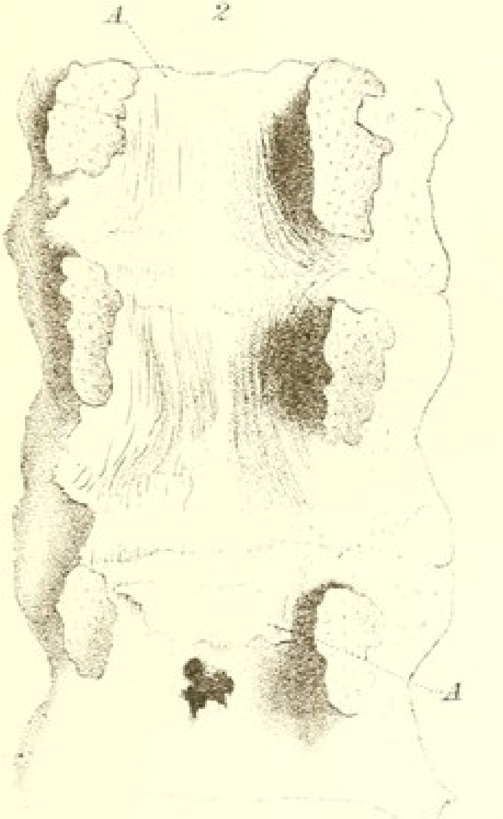

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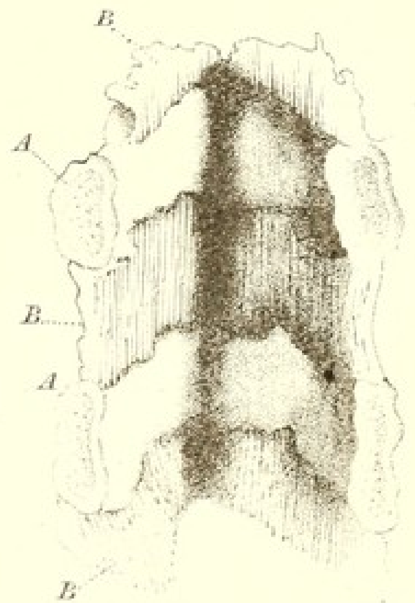

not very often the seat of disease, and their strength is such, that when the spine is subjected to a severe wrench, they are less likely to be injured than the bones which they unite. In advancing years, though they become drier, denser and of yellowish colour, they are rarely or never the seat of ossification. The anterior vertebral ligament, and, it may be the outermost fibres of the intervertebral substances, frequently undergo this change, which, however, does not penetrate much beyond the surface of the latter. This is the more remarkable because we know that in the sacrum, and in the space between the body and odontoid process of the axis, the intervertebral substances are, in great part or entirely, ossified in early life.

Ligamenta subflava.

The *ligamenta subflava*, which consist of the fibres recognised by microscopists as elastic tissue in a very pure form, are exceedingly strong; they extend between the arches of the vertebræ, and a short distance between the spines; and are particularly thick and strong in the latter situation in the lumbar portion of the column. They pass generally from the anterior and lower edge of one vertebral arch to the posterior and upper edge of that below. They are thickest in the loins, thinnest in the neck, and do not exist above the axis. Besides their use as bonds of union between the bones, they, in virtue of their high elasticity, permit that amount of separation between the arches which is necessary for the bending of the spine forwards, and also assist the muscles in restoring the spine to the upright position, as well as in maintaining it there. Their good influence in the latter respect will be more appreciated when we remember that the weight of the viscera and other soft parts, which are disposed in front of the column, exerts a continual pull tending to bend the body forward. The projecting spinous processes are for the purpose of giving the interposed yellow ligaments as well as the muscles inserted upon them a leverage to counteract this tendency; and great assistance is afforded, and considerable expenditure of muscular force is saved, by the presence of these elastic ligaments, which combine to support the trunk in the same manner that the *ligamentum nuchæ* of graminivorous animals assists the cervical muscles to support the heavy dependent head.

Interspinous ligaments.

In addition to the elastic yellow ligaments are strong inelastic ligaments passing between the extremities of the spinous processes, whose office it is to limit the bending forwards of the column. In this they assist the muscles and fasciæ which extend from the pelvis along the back to the head. They are thickest between the dorsal spines, where they greatly strengthen the column and prevent much increase of the dorsal curve when weight is placed upon the head or shoulders.

Spaces between several bodies and several arches of sacrum.

In the sacrum the intervertebral substances commonly exist more or less between the several component bodies, but they are encased in bone and encroached upon by ossification, so as to be seen only when a section is made; and the interspaces between the arches of this bone, which correspond to the parts occupied by the ligamenta subflava in other parts of the column, are also, in great part, occupied by bone.

The direction of the movements of the spine not regulated by the intervertebral substances,

We have found that the intervertebral substances are so constructed as to permit a slight rolling movement between the bodies of the several vertebræ; the fluid nucleus of each being the centre of that movement—the ball upon which the socket, formed by the contiguous surfaces of the vertebræ, revolves; but it is evident that they have little or nothing to do with the *direction* in which the movement takes place; and that so far as they alone are concerned that revolving motion may take place in any direction. The *amount* of it, it is true, is limited by the intervertebral substances, and by the contiguity and width of the vertebral bodies, that is, the movement is most free where the intervertebral substances are deepest, and where the area of the vertebral bodies is smallest; the former advantage being afforded in the loins, the latter in the neck. It is also most free in the direction in which the diameter of the vertebral bodies is least, viz. backwards and forwards in the neck and loins. But within the range thus assigned by their own shape and by their proximity to one another the vertebral bodies are free to revolve any way without hindrance from the intervertebral substances.

but by the articulating processes.

Yet we find upon examining a vertebral column, which has been recently removed from the body, that the directions in which the movements do actually take place are limited, and that they are not the same in different parts of the column. This limitation is effected by the shape and position of the *articulating processes*, whose office it is, in this manner, to give *steadiness* to the column and *direction* to the movements, at the same time that they do, to a certain extent, contribute to bear the weight of the superincumbent parts.

Extension most free in loins.

In order to ascertain, for certain, the direction of the movements of the different parts of the column I took out the entire spine with the heads of the ribs and the pelvis, the ligaments remaining entire, from the body of an adult, and, having fixed the pelvis, made the following observations. The forward and backward movement was decidedly most free between the third and fourth and the fourth and fifth lumbar vertebræ; that is, at the part where the lumbar curve is sharpest. At this region the nervous cords are less closely connected with the fore part of the vertebral canal than elsewhere; the spinous processes are large, and the interspaces between them are free and filled with stout elastic ligaments, which have a powerful effect in bringing the bones back with a spring when the column has been bent forcibly forwards. Moreover the projecting pubes and sternum in front, and the projecting sacrum and dorsal curve behind, enable both the flexor and extensor muscles to act with great power upon this part of the spine. The antero-posterior movement became suddenly much less above the third lumbar vertebra, and was further diminished towards the middle and upper part of the back, where it was very slight. It increased again in the neck; the capability of motion backwards from the upright posture being, in this region, greater than that of the motion forwards; whereas the reverse was the case in the loins. There was not much movement between the second and third cervical vertebræ, the intervertebral substance being there very shallow.

Lateral inclination most free in neck and loins.

Lateral inclination, or flexion to either side, was permitted at every part of the column, but was most free in the neck and between those lumbar vertebræ which possessed the greatest range of the antero-posterior flexion and extension.

Rotation most free in neck and back

Rotary motion was slight in the neck; more free in the upper part of the back. It decreased towards the lower part of the back, and quite ceased between the 10th and 11th dorsal vertebræ; no rotation at all being practicable in the loins.

Thus the neck enjoys each variety of movement; flexion, extension, lateral inclination and rotation, the two former freely, the two latter with moderate freedom. In the back there are also the four movements; but the three former are less free than in the neck, and the rotation ceases at the lower part. In the loins there is no rotation; but flexion, extension and lateral inclination are all very free.

Relation of the shape and position of the articulating processes to the movements in the loins;

Now if the shape and position of the articulating processes be examined in the several parts of the vertebral column, they will be found to accord with the direction in which these movements are permitted. The mere fact of there being an arthrodial joint on either side, with moderate-sized, closely pressed surfaces, is of itself sufficient to limit the movements of the bones upon one another in a great degree. In the loins (Pl. XI. fig. 4) the inferior articulating surfaces, which are turned outwards and embraced by the superior articulating surfaces on either side, entirely prevent any horizontal motion; and, forasmuch as a horizontal motion of the arches and articulating processes is essential to a rotation of the body of the vertebra upon its vertical axis, it is clear that the direction of the articulating processes in the lumbar, and one, two, or three lower dorsal vertebræ, is such as to render rotation of the column at this part impossible[1]; whereas there is nothing to prevent a sliding

[1] It is commonly stated that rotation is more free in the loins than in any other part of the spine. Hildebrandt, however, perceived that the manner in which the inferior articulating processes are here embraced by the superior processes of the vertebræ beneath must prevent rotation of the bones upon a vertical axis. *Handbuch der Anatomie*, II. 139. I think the mistake has arisen from anatomists observing that the inferior articulating surfaces of the lumbar vertebræ are ovoid, with their long diameter from above downwards, and convex, and that they seem, therefore, well adapted for rotation in the concave facets of the vertebræ below (Pl. XI. fig. 4). But it is obvious,

upwards and downwards of the articulating surfaces upon one another. This sliding permits the bodies of the vertebræ to roll forwards and backwards, or to either side, upon their intervertebral substances, and is the movement attendant upon the antero-posterior flexion and extension, or upon the lateral inclination, of this part of the spine.

in the back; In the back, where the column is already concave in front, any further flexion would necessitate, not merely a sliding of the inferior articulating surfaces of each vertebra upwards upon the superior ones of the vertebra beneath, but a curvilinear movement of them round the upper edges of the latter, which would require, at the least, some rounding of those edges. They are, however, particularly sharp; and the whole surface of each is quite flat from above downwards, and is closely applied against the corresponding flat surface of the vertebra below. It is clear, therefore, that such movement, being almost incompatible with the shape of the articulating surfaces, can take place only in a very limited manner in the dorsal part of the spine. The rotation, which occurs here, is provided for in the following way. If any of the upper dorsal vertebræ be carefully examined, it will be found that its articulating surfaces are not in the same plane. The two upper are slanted so as to look, not directly backwards and upwards, but backwards, upwards and outwards. They may be regarded as forming two portions of one circle, the centre of which is about the middle of the body of the vertebra, or an approximation to this (Pl. XI. fig. 3). The inferior articulating surfaces of the vertebra above are slanted in a corresponding manner—forwards, downwards and inwards—so as to be able to revolve a little upon the superior; and this revolving of the inferior articulating surfaces of the several vertebræ upon the superior articulating surfaces of those beneath, permits a rotation of the bodies of the vertebræ upon their vertical

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first, that the centre of any such rotary motion must be somewhere in the median line *behind* the vertebral canal, which would involve a shifting of the vertebral bodies upon one another in a horizontal plane quite incompatible with the structure of the intervertebral substances; *secondly*, that this disposition of the articulating facets will prevent horizontal rotation of one vertebra upon the other around any other axis than the one just indicated, and, therefore, that it is incompatible with the only horizontal rotation which the intervertebral substances permit, that, namely, upon an axis drawn through their own central fluid nuclei.

axes, and gives to the dorsal part of the column that rotary motion which I have described to belong to it.

In the neck. In the neck the greater obliquity of the articulating surfaces, together with a lateral slant which they exhibit, similar though in an opposite direction to that in the back, and the rounding off of the upper edges of the superior ones, permits the movements requisite for flexion and extension, as well as those for slight rotation of the bodies.

In the whole length of the vertebral column the articulating surfaces are so arranged as to permit slight lateral inclination; though the presence of the ribs renders it more limited in the back than in the neck and loins.

In addition to their synovial capsules, these joints are provided with strong fibrous ligaments binding the margins of the opposed articulating surfaces together. In the back the direction of these ligamentous fibres is, for the most part, vertical; in the loins it is transverse; in the neck it is oblique.

Fractures and Dislocations. So powerful are the ligamentous bands uniting the several parts of the vertebræ together, and such is the disposition of the articulating processes, that dislocation of the bones is a comparatively rare occurrence; surprisingly rare, when we consider the weights which the spine is made to carry, the blows, wrenches and shocks to which it is subjected, and, more particularly, when we remember the length of the column. It is, in great measure, indebted for this immunity, as already stated, to the number of pieces of which it is composed, to the powerful and yet elastic bands which unite those pieces together, as well as to the wavy line in which they are arranged upon one another.

When dislocation, or disjunction, of the vertebræ does take place, it is almost invariably attended with fracture, either of the bodies, the arches, or the articulating processes of the vertebræ, not unfrequently of all three. A few exceptional instances have been recorded in which dislocation of the bones of the neck was unattended with fracture[1]. But even in this region, where the direction

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[1] Mr Williams has collected some cases of dislocation of the cervical vertebræ without fracture: *Medical Times and Gazette*, August 15th, 1857. The most frequent seat of the accident is between the fifth and sixth vertebræ.

of the articulating processes is such as to permit dislocation more easily than in any other part of the column, the displacement is attended with fracture in by far the greater number of cases. Hence we are in the habit of using the terms "dislocation of the vertebræ" and "fracture of the spine" as almost synonymous.

Direction in which displacement occurs.

It is worthy of remark that the direction in which the spine gives way is almost invariably the same; the upper portion is driven forwards upon the lower, so that the cord is jammed between the upper edge of the body of the vertebra below and the lower edge of the arch of the vertebra next above the fracture[1]. It is possible that, where the displacement is slight, the cord may escape injury; but that must be a very rare occurrence[2].

Weakest part of the column.

A cursory glance at the skeleton is sufficient to reveal that the junction of the dorsal with the lumbar portion of the column, including the lower two dorsal and the upper one or two lumbar vertebræ, is the weakest part of the spine. It is so, *first*, because, although it has to bear nearly as great weight as the part of the column below it, its vertebræ are disproportionately small. *Secondly*, because the transverse processes are here very short, while the long transverse processes

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[1] The only exception to this that I have read of is "a case of perfect ankylosis of the five superior cervical vertebræ to each other, with dislocation backwards of the fifth from the sixth, without fracture," related by Mr Stephen S. Stanley, in the 56th volume of the *Edinburgh Medical and Surgical Journal*. In a case which occurred in my own practice, where three ankylosed cervical vertebræ were dislocated from the one beneath, the displacement took place in the usual direction. I find in the Museum at Bonn a preparation in which the fourth lumbar vertebra is driven *behind* the fifth. It is represented in Alber's *Atlas der Path. Anat.* Bonn, 1847.

[2] I am not aware that the spine has ever been broken by the direct contractile force of the muscles. The nearest approach to such an accident that I have seen recorded is a case related by M. Lasalle, quoted from the *Gazette Médicale* in the 13th volume of the *British and Foreign Medical Review*. A man, æt. 36, in a furious state of mania, was confined in a chair by means of straps. After making various efforts to break from his confinement, he threw his head forcibly backwards, and then flung it with great violence forwards. After this last movement the head remained bent on the neck, and his limbs were completely paralysed. On examination after death, which occurred thirty-six hours after these events, a solution of continuity was found between the fifth and sixth cervical vertebræ. The ligaments and intervertebral substance were torn, and the left transverse process of the sixth vertebra was broken.

in the lower part of the loins, added to the projecting crest of the ilium below, and the false and true ribs above, afford to the several muscles a powerful leverage, on either side and in front, against this region. *Thirdly*, the spinous processes are also short, though they have often a bifid tendency at their extremities; so that an examination of the line formed by the spinous processes shows this to be the most concave part of the dorso-lumbar curve. It is seen to be so in the living body, forming what is called the "hollow of the back;" and the circumference of the trunk at this part, "the waist," is less than elsewhere. *Fourthly*, it is near the middle of the column; so that a greater length of leverage can be brought to bear against it than against any other part. *Fifthly*, the component segments of the portion of the spine above it are, comparatively, fixtures. Every now and then we are awakened to a sense of the weakness of this portion of the column by the sudden jar which is felt here on making a false step, or slipping off the pavement. Here fatigue is felt, and aching in the preliminary stages of ague and fever. The labouring man still "girds up his loins" with a belt, and the nurse thinks to strengthen this part of the infant by enveloping it in a "swathe." She is conscious that it is a weak point with the child; and she knows that, if he be nursed improperly, the spine will be bowed backwards here. Fractures are of more common occurrence here, than at any part of the column, probably than at all others put together. A man was carrying a heavy sack of beans for a wager. His back broke under the weight, and he fell. I found the last dorsal vertebra driven forwards upon the first lumbar. It is the part most frequently strained, and is, consequently, often the seat of disease leading to caries, the formation of psoas and lumbar abscesses, &c.

Weak point in back.

Another weak point, though less so than the preceding, is to be found at the dorsal curve, where fracture is not a very uncommon occurrence, and where *angular curvature* is more frequent than at any other part. In a considerable majority of cases of humpback, the hump, formed by the projecting arches, is between the shoulders, and is caused by the bodies of the middle dorsal vertebræ, or those a little above or a little below the middle, having given way under the

Angular curvature.

superincumbent weight, and yielded to the processes of absorption or ulceration. I think, too, that in *lateral curvature*, except when it results from disease of the hip-joint, pelvis, or lower limbs, the first deviation from the proper line usually takes place here[1]. The principal deflection is at or near this part; and the curves above and below, which appear to be compensatory, or secondary to it, and which are, consequently, in an opposite direction, are much less sharp, the two being only sufficient to counterbalance the effect of that primary one, and to maintain the head erect.

Lateral curvature.

The spiral twist.

In this deformity, although it is called "lateral curvature," the deflection is not truly lateral. It is not, strictly, the sides of the bodies that yield and become compressed, but the hinder parts of the sides, or the points of confluence of the arches and bodies, where the vertebræ remain cartilaginous and soft after the rest of the bodies and arches have become ossified. In consequence of these parts yielding, the bodies become twisted or rotated a little to the opposite side. In this *twist* of the vertebræ, which is an almost constant accompaniment of lateral curvature, the bodies are turned away from the concavity of the curve, both in the primary and in the two secondary deflexions, so as to give an appearance of spiral twist to the whole[2].

Compression of vertebræ on one side.

On the concave side of the curve, the intervertebral spaces, as well as the bodies of the vertebræ, are rendered more or less shallow by compression, and the

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[1] I do not mean that there is actually much difference, in point of time, between the formation of the three curves which are commonly found in these cases. They must all begin at about the same time and proceed *pari passu*, otherwise an inclination of the head to one side would be an early symptom of the disease, which we know it is not. The elevation of one shoulder and the projection of the inferior angle of one scapula are the points which in most cases first attract attention. I mean that the yielding of the dorsal vertebræ is the cause of the yielding and accompanying curvature in the neck and loins; the fact of the primary dorsal curvature being so generally to the right side is owing to there being naturally a slight bend in this direction (page 155).

[2] See my Lectures on Surgery in *Prov. Med. and Surg. Journal*, 1850, p. 145. This twist in the column attendant on lateral curvature presents some similarity to the "revolving spine," *rotatio spinæ*, which occurs as a congenital disposition in some animals, more particularly in calves; such deformity is, however, very rarely congenital in man.

edges of the latter are protruded, squeezed out as it were, so as to project beyond the intervertebral substances. In some bad cases these protruded edges become united to one another by bridges of bone thrown over the intervertebral spaces, so as to cause complete ankylosis, and render ineffectual all attempts to restore the parts to a proper position. The compressed ribs may become united in a similar manner, forming one mass of bone perforated by the nerves in their passage from the intervertebral foramina. The deformity takes place usually about the time of puberty. Though often associated with rickets, after a certain period, I have not seen this "lateral curvature" of the spine in any of the rickety skeletons of fœtuses or very young children. The flexure which occasionally takes place in them is "antero-posterior," the spine being bowed backwards, but this generally diminishes, and the spine acquires its proper form as the child grows older and stronger.

Associated with rickets.

Senile curvature.

I have said that the line of gravity of the head, passing through the odontoid process and the points of confluence of the spinal curves, falls a little in front of the promontory of the sacrum. This applies, of course, only to the upright posture. In the stooping postures necessary for so many occupations the line of gravity falls in front, often considerably in front, of these points, and is maintained so during great part of the day. Hence the fore part of the bodies of the vertebræ have to bear a greater pressure, and the elastic ligaments and the muscles connected with the arches and spines are subjected to a greater amount of tension, than we should calculate if we considered the erect position as the common, or natural, position of the human spine. It is the usual position in walking or carrying weights; but is not ordinarily maintained in sitting and in following our various avocations. The muscular and ligamentous structures running from point to point between the pelvis and the occiput, being thus subject to frequent and long-continued tension, are, especially in persons with long backs, liable to become strained and weakened. They are also often the seat of lumbago and other rheumatic affections, by which they are still further weakened and rendered unable to contribute their proper share of help; and they consequently allow an undue amount of weight to fall upon the fore parts of the bodies of the vertebræ, which, in course of time, yield and undergo absorption, causing the spine to be bowed backwards. This change begins in the back; and, accordingly, the bent back is one of the well-known features of age[1]. It may extend beyond the back, affecting the neck and loins, reversing the natural curves in them, and causing them also to be bent backwards. A good illustration of this condition is furnished by a specimen of the spine of an old woman, preserved in the museum of the College of Surgeons. It presents an uninterrupted and nearly uniform curve from the sacrum to the atlas. Another senile change, shown by the same preparation, which may result from, or at any rate is often associated with, this alteration of the curves and undue pressure upon the fore parts of the vertebral bodies, is the presence of bony outgrowths springing from the edges of the bodies, bridging over the intervertebral substances, ankylosing the vertebræ to one another, and affording support along the arc of the curve. The arches of the vertebræ are occasionally united by bone in cases of angular and severe lateral curvature, and also after fracture; but not, that I am aware, as a result of age[2].

Peculiarities of the lumbar vertebræ;

It may be well, in conclusion, to enumerate briefly the peculiarities of the several vertebræ, though most of them have been already mentioned. The lumbar *bodies* are large and very cancellous, elongated transversely, particularly near their hinder parts, and deeper in front than behind. Their upper and lower surfaces are concave, the cups being deepest at a point nearer to the hinder than the anterior edge. Their hinder aspects are concave; and in their whole circumference, especially

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[1] It sometimes begins in the neck, the chin poking forward and approaching the sternum.

[2] An example of ankylosis of the arches, as well as of the bodies of all the cervical and the upper two dorsal vertebræ, is given by Sandifort, *Mus. Anat.* II. Tab. 15.

at the sides, they are more hollowed out than the other vertebræ. The *arches* stand directly backwards from the bodies midway between their upper and lower surfaces, and enclose a wide and deep *vertebral canal* and large oval *intervertebral foramina.* The *transverse processes* are long and stand out nearly horizontally, with a slight inclination forwards and upwards which increases in the lower ones; they are often developed from separate nuclei; their inferior tubercles are scarcely to be seen; their superior ones are appended to the upper articulating processes, and are developed there from separate nuclei. This gives great prominence to the superior *articulating processes*, which stand out boldly; their articulating facets, which are a little concave from before backwards, look almost directly inwards, and severally embrace the inferior articulating processes of the vertebræ above, which are adapted to them. The *spinous processes* are large and squared. There is much uniformity between the several lumbar vertebræ. The 5th is, however, characterized by the smallness of its spinous process, by the shortness and thickness of its transverse processes, by the want of depth of the hinder part of its body, and by the wide interval between its inferior articulating processes.

of the dorsal; The dorsal *bodies* are prolonged forwards so as to give their horizontal section a conical or cordate shape. Their upper and lower surfaces are nearly parallel; they are flat behind and not much hollowed out at any part of their circumference. The articulating facets for the heads of the ribs, which are situated upon the prolonged pedicles of the arches, acquire a relatively higher position as they are traced upwards; in the lower two they are large and placed upon the pedicles of their respective vertebræ; higher up they cover the intervertebral space and encroach upon the vertebra above, doing this more and more till we arrive at the first vertebra, to which the small head of the first rib is usually confined. The *arches*, thick and closely packed together, enclose a small and nearly circular vertebral canal, and ovoid intervertebral foramina. Their *pedicles*, very thick in the lower two, diminish and acquire a higher level in the upper ones, with an oblique slant forwards. The *transverse processes* are long, slanted backwards, and bulge at their extremities into the three *tubercles*—the *costal*, the *superior* and the *inferior*,—which three elements are very distinct in the 12th vertebra, where the neck of the transverse process is deficient. The articulating facet for the rib, wanting on the lowermost two, is flat, or a little concave transversely, and borne upon a prominence near the upper edge of each of the next succeeding transverse processes, and is concave from above downwards and situated near the lower edge in each of the upper dorsal vertebræ. The *articulating processes* are prolonged upwards and downwards from the arches in a nearly perpendicular direction. They present flat facets which look backwards and forwards, and at the same time a little outwards or inwards so as to permit a slight rotation. The lower articulating facets of the 12th (sometimes of the 11th also) are directed outwards and are slightly convex like those of the lumbar vertebræ. The *spinous processes* are sloped much downwards, especially from the 4th to the 8th, so as to overlap one another; they are of rather triangular shape, thick at their extremities, and, in the lowermost two are, more or less, bifid.

of the cervical; The cervical *bodies* are small, comparatively dense, elongated transversely, and flattened in front, with their lower and anterior edges prolonged downwards, so that each overlaps the fore part of the vertebra below. Their upper and lower surfaces (particularly the latter) are concave, from before backwards, or the lower one is concave and the upper one is flat. Transversely they are concave above and convex below. The lateral portions, which are not on the same plane as the other parts of the bodies, are contributed by the *pedicles* of the arches. The arches take a lateral direction on first leaving the bodies and then make a considerable sweep, so as to enclose a wide and deep *vertebral canal*. The *transverse processes* are double; those in front, which represent the ribs of the dorsal vertebræ, and are sometimes developed from separate nuclei, are ossified to the vertebræ and are joined to those behind by a lamina of bone so as to enclose the foramen for the vertebral artery. The *articulating surfaces* are disposed somewhat like those of the back, but are more oblique from above downwards, and the processes which bear them are less prolonged. The *spinous processes* are bifid, except that of the last, which is long and single.

of the atlas; In the atlas the body is detached to form the odontoid process of the axis; and the pedicles of the arches, or their epiphyses, running in front of it, unite to form the anterior part of the bone. The vertebral canal is wide. The hinder laminæ of the arches are narrow, nearly cylindrical and sloped a little upwards; and the spinous process is abortive. The upper articulating surfaces are adapted to the occipital condyles; the lower ones are plane or slightly convex to play upon the facets of the axis. Both are placed very forward, so that the nerves pass out behind instead of in front of them; the latter being the case in all the other vertebræ. The transverse process is not bifid at the extremity, though it is perforated by the vertebral artery.

The atlas varies a good deal in size and shape in different individuals, also in the size and shape of its upper articular facets; in some instances these are divided more or less completely by a groove extending across them; in some they are placed far back, while in some they extend so far forwards as nearly to touch the articular facet for the odontoid process. Sometimes a process arches backwards from them on either side over the vertebral artery, a peculiarity which derives interest from its being usually present in quadrumanous and carnivorous animals.

of the axis. The axis carries the odontoid process. The fore part of its body is much prolonged downwards, and presents a deep depression on either side of the middle line. The anterior extremities of its pedicles, which are advanced a good deal forwards and which embrace the root of the odontoid process as well as its own body, are sometimes developed from separate centres. Its upper articulating surfaces, large and slightly convex, are in a plane considerably anterior to its lower ones. Its arch and spinous process are thick and prominent, and the vertebral canal has a great antero-posterior diameter. The transverse processes are commonly double like the others, though the hinder parts are thin and sometimes deficient; they are not bifid at their extremities.

THE SKULL.

Formation of primordial cerebral capsule.

THE mode of development of the skull has been made the subject of accurate investigation by several observers, more particularly by Rathke[1] and Reichert[2]. It appears that the chorda dorsalis is continued forwards from the spine under the base, and terminates in a pointed manner near the fore part of the skull. The cerebrum is, at an early period, enclosed in a membranous capsule which is connected beneath with the termination of the chorda dorsalis. This membranous capsule is not the same as the dura mater, but a coating external to it and in close contact with it. It is moulded upon the brain, and presents eminences and intervening shallow transverse depressions, corresponding with the three chief primary vesicles of that organ. The cerebral portion of the skull is thus far formed before there is any appearance of the facial part. Soon, however, processes jut out from it on either side of the median line, which grow downwards, incline towards one another, and, uniting so as to form a series of inverted arches, constitute the primordial structure in which the face is developed.

Formation of the face. The frontal process.

These processes are four or five on either side. The first, or foremost, growing from the anterior part of the cerebral envelope—the forehead—is called the "frontal process." It is included between the eyes and consists of three plates. One plate, situated in the median line and named the "mid frontal" or "nasal" process, is continuous with the middle part of the base of the skull: it grows downwards and forwards, and

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[1] *Ueber die Entwickelung des Schädels*, Königsberg, 1839.

[2] *Ueber die Visceralbogen der Wirbelthiere*, Müller's *Archiv*, 1837; and *Vergleichende Entwickelungsgeschichte des Kopfes der nackten Amphibien*, Königsberg, 1848.

forms the septum of the nose; and in it are apparently developed the nasal bones, the median plate of the æthmoid, the septal cartilage, the vomer and the intermaxillary bones. The lateral plates, separated from the median plate on either side by a slight interval or furrow which forms the upper part of the nasal passage, also grow downwards and forwards in the same direction with the median plate and parallel with it, but do not proceed so far; they form the inner walls of the orbits, and in them are developed the lachrymal bones with the ossa plana and lateral masses of the æthmoid bone.

The superior maxillary processes.

The second pair of processes—called the "superior maxillary processes" because the upper jaw is formed in them with the palate and malar bones—spring from the base of the skull, a little further back, and grow forward beneath and on the outer side of the eyes, so as to include the orbits between themselves and the frontal process. Having descended a certain distance they incline inwards to meet, and unite with the lateral plates of the frontal process; they thus shut off the orbits from the nasal cavities, and, continuing their course forwards and inwards beneath the lateral plates of the frontal process, they form the lower part of the outer wall of the nasal cavities and reach the mid-frontal process. They soon become united with the fore part of the latter through the medium of the mass in which the intermaxillary bones are developed. The nasal cavity thus becomes closed below at its fore part, and the circle for the alveolar arch is completed. Subsequently the palatine laminæ, shooting from the inner sides of this arch, approach one another, and, uniting with the vomer, or with one another beneath it, form the roof of the mouth and the septum between the nasal and oral cavities.

The inferior maxillary processes.

The third or "inferior maxillary" processes are at their origin closely connected with the preceding, so closely that they are considered by Reichert to proceed from the same spot with them, and to form with them the *first visceral arch*. At their origin they are situated just beneath the Gasserian ganglion of the 5th pair of nerves, which is of large size at this early period. The inferior maxillary process of each side grows downwards, like the superior maxillary process, and inclines towards the median line, so as to meet its fellow of the opposite side and form the arch of the lower jaw.

The hyoidean processes. A fourth pair of processes—the "superior hyoidean"—growing from beneath the auditory vesicle, take a course parallel with that of the inferior maxillary processes. They constitute the *second visceral arch*, and form the basis of the styloid processes the stylo-hyoid ligaments and the lesser cornua of the hyoid bone. The first and second visceral arches—that is to say, the primordial elements of the lower jaw and of the stylo-hyoid apparatus—are separated from each other by the *first visceral cleft*, which is soon closed at the lower part by the union of the contiguous edges of the visceral arches. At its upper part the cleft remains open, forming a channel of communication between the pharynx and the exterior of the side of the neck. The part of this channel next to the pharynx is subsequently converted into the tympanic cavity and the eustachian tube; the middle part is surrounded by the tympanic portion of the temporal bone, and is interrupted by the tympanic membrane growing across it; and the outer part becomes the external auditory passage, and is expanded into the external ear.

Behind, and parallel with the superior hyoidean processes, near to them but separated from them at first, on either side, by the *second visceral cleft*, are the "inferior hyoidean processes," which make the *third visceral arch*. They are said to form the basis of the great cornua, and the body of the hyoid bone. They are closely connected with the second visceral arch; and the visceral cleft, between them and it, is obliterated in its whole length at a very early period. They are separated from the *thoracic visceral arch*, which is formed immediately behind them, by the *third visceral cleft;* and this also is soon filled up.

A quantity of formative material is laid down upon the concavities of these several processes, especially upon the part where they meet in the middle line to complete the visceral arches; and here are developed the tongue, the cartilages of the larynx, and the œsophagus. Extensions of these latter structures grow down in the long axis of the embryo and, reaching into the thorax and abdomen, constitute the rudimentary material for the lungs and stomach; at any rate they become continuous with them.

Cleft palate.

This account of the mode of development of the face derives particular interest and some confirmation from the malformations which we so often see in this part of the body. A great number of cases of malformation (as they are not quite properly called) are the result simply of imperfection in the progressive development of the structure concerned; the formative process, not having been sufficiently vigorous to carry on the work to completion, is arrested at some point, and leaves evidences of forms which the part naturally presents in its transition to the mature condition,—evidences from which we may derive much information as to the series of changes by which the perfect form is evolved. There may be superadded to the *imperfection* of development some *deviation* from the regular plan which would lead us into error were we blindly to take these varieties as our guides; but the effects of such deviations may generally be distinguished with a little care.

Now there is perhaps no region of the body in which developmental failures are of more common occurrence than the upper lip and jaw, where they give rise to "hare-lip" and the different varieties of "cleft-palate." In the latter, whatever the *extent* of the fissure, its *position* is invariably the same; not in the middle line, where it would traverse the intermaxillary bone and the middle frontal process, but on one side of the middle line, between the maxillary and the intermaxillary bones, that is to say, in the line of union of the median and lateral frontal processes. Accordingly we find, if the proper complement of teeth be present in such a case, that the canine tooth is always on the lateral or maxillary, and the outer incisor is on the median or intermaxillary side of the fissure. Generally some of the incisors are deficient; and there may be an attempt to fill up the gap by the formation of one or two supernumerary teeth in the maxillæ, reminding us of the development of wormian bones in hydrocephalic skulls for a similar purpose. If the fissure be on both sides the intermaxillary bones are quite isolated from the maxillaries, and hang down in the middle line dependent from the vomer alone. They commonly extend to about the same level as the maxillary alveoli and cause the cleft to be double in front; whereas the hinder part of the median process does not reach the level of the palatine processes behind, so that the cleft is there single. Both the frontal and the superior maxillary processes usually share in the imperfection, which is most marked in the latter at the hinder, that is, the palatine part of the cleft, and in the former at the alveolar part. Thus, though the vomer (or hinder part of the frontal process) does not quite reach its proper level, which may be owing to the pressure of the tongue, it has rather more than its usual thickness; whereas the palatine plates (which are derived from the hinder part of the maxillary processes) are scanty and thin: and the incisor teeth and their alveoli (which form the fore part of the frontal process) are commonly defective, the lateral ones in most instances and the middle ones in many; whereas the bicuspid and canine teeth and their alveoli (which form the fore part of the maxillary processes) are usually perfect. Indeed the frequent deficiency of the incisive sockets and teeth in hare-lip, and the frequent imperfections in the size and shape of the outer incisive teeth, where there is no hare-lip, seem to indicate the intermaxillary bone to be the part of the facial skeleton which is most difficult of formation. (See Pl. XIII. fig. 1.)

Instances sometimes occur in which the union of the frontal and maxillary processes having failed in their upper, or orbito-nasal, as well as in their lower or palatine parts, the cleft is continued from the palate through the nose, between the æthmoid and maxillary bones, into the orbit[1]. It may even happen that the frontal processes, which should descend between and separate the orbits, fail altogether; in which case the orbits form one cavity and the eyes are more or less blended in the middle line. Such a monstrosity is called "Cyclopian[2]." Or lastly, and this is remarkably frequent in the pig, the frontal processes may be misdirected and curl upwards when they should grow downwards. Their several elements and appendages are then developed into a trumpet-like proboscis on the forehead, instead of forming a nose between the eyes.

I have thought it worth while to direct attention to these instances of malformation, which are common and remarkably uniform in their

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[1] There is a description of such an example given by A. Meckel in Meckel's *Archiv*, IX. 156, in which the cleft ran on either side from the mouth quite into the orbit, separating the intermaxillary bones, vomer, nasal bones and nasal processes of the maxillary bones from the maxillary and palate-bones. It took, therefore, the direction of the infra-orbital canal.

[2] In cases of this kind the optic foramina are often blended into one, as they usually are in the hare and in birds.

characters, because they not only contribute to throw light on the manner of development of this region, but more particularly because they tend to confirm, what is often doubted and what it is difficult to prove in the embryo, that the intermaxillary bones are developed in connection with the vomer in the median frontal process, and that they are originally related to it rather than to the maxillary bones.

Formation of cartilage and bone.

To proceed with the development of the skull. When the brain is enclosed in its membranous capsule, and the processes above mentioned have been evolved so as to form a sort of ground-plan of the future fabric of the face, certain parts of the enveloping structure are soon converted into cartilage. This change takes place earliest where strength is most needed, viz. along the base of the skull.

The cartilage first appears on either side of the base, and extends to the middle line so as to enclose the chorda dorsalis. It also spreads laterally. But it does not spread over the whole of the brain or far into the face; indeed, with the exception of the median plate of the nose, it is almost confined to the base of the skull. The next thing is the formation of bone; and this takes place first at various detached points upon the exterior of the membranous capsule, where the cartilage does not exist. The bone is here immediately preceded by the production of an ossifying blastema upon the surface of the primitive capsule. This blastema is quickly converted into bone, in the manner described at a former page (34); and the outside of the newly-formed blastema and bone is furnished with periosteum. The primitive membranous capsule of the brain constitutes the internal periosteum of the bones, and is closely connected with the dura mater; so closely, that the two membranes are blended in an almost inseparable manner, and pass under the one name of dura mater.

Parts formed respectively from bone and cartilage.

The bones belonging to this class, i. e. formed from ossifying blastema without any preceding cartilage, are, according to Kölliker, "the upper half of the expanded portion of the occipital bone, the parietal and frontal bones, the squamous portion and tympanic ring of the temporal bone, the nasal, lachrymal, malar, and palate-bones, the upper and lower jaw, the vomer[1], and, apparently, the internal lamella of the pterygoid process of the sphenoid, and the cornua sphenoidalia. The blastema of these bones, which differs from that of the primary bones, in its being successively developed in a membranous matrix, simultaneously with the process of ossification, not existing previously in any considerable quantity, presents essentially, exactly the same conditions as that of the periosteal layers, and is also ossified in precisely the same way[2]." From the incomplete cartilaginous cranium are formed "the occipital bone (except the upper half of the expanded portion), the sphenoid (except the lamina externa (interna?) of the pterygoid process), the mastoid and petrous portions of the temporal bone, the æthmoid, the inferior turbinated bones, the ossicula auditus, and the hyoid bone[3]."

The ossifying process, as just stated, does not begin in the cartilaginous so soon as in the membranous parts of the skull. Thus in a fœtus of about three months I found that ossification had made considerable advances in the lower jaw, in the squamous and zygomatic portions of the temporal bone, in the frontal and the occipital bones. It had also begun in the great alæ of the sphenoid, in the lower or alveolar, and in the upper or facial, parts of the superior maxillary bones, and in the malar. There was a delicate flake in the parietal. Whereas the only osseous nucleus in the cartilage at the base was one for the basilar portion of the occipital bone. I should observe that there was also an osseous nucleus for each of the condyles, with one behind them forming the back part of the ring enclosing the foramen magnum, and one for each of the cerebellar as well as the one for the cerebral portion of the bone.

The sutures. "In the vault of the cranium, as the primary ossific points first appear in the situation of the tuberosities of the parietal and frontal bones, the bones are at first placed widely asunder, and are connected merely by a fibrous membrane, the continuation

[1] The vomer appears to be formed from the cartilage of the septum nasi, which is continued forwards from the base of the skull. Pl. IV. fig. 1, H.

[2] Kölliker's *Manual of Human Histology*, I. 369.

[3] Ibid. p. 339.

of the periosteal lamella of each, and which is united on the internal aspect with the remains of the membranous cranium of the embryo, and with the *dura mater*. The bones then continue to grow towards each other, and at last, constantly advancing in the above-described continuation of the *periosteum*, come very nearly into contact at the frontal and sagittal sutures; there remains, however, for a long time, one large vacuity, in particular, between them—the anterior fontanelle—but which closes in the second year after birth; whilst, at the same time, the bones, which up to this period adjoined each other with a straight line of juncture, send out interdigitating tooth-like processes, till ultimately, when their blastema is wholly consumed, they continue united only by the remains of the *periosteum* (the sutural cartilage, as it is termed, or better, the sutural ligament), but which also is capable of becoming ossified sooner or later, and, indeed, invariably first on the inner aspect of the suture, where the tooth-like processes are very little developed[1]." The indigitations of the bones at the sutures are less complicated in the lower animals than in man.

Succession of events.

The order of events is, therefore, as follows. The first rudiment of the skull is a mere membranous capsule thrown around the brain, adapted to it, and capable of enlarging quickly so as to keep pace with the rapidly increasing cerebral mass. Next, cartilage is formed at the base for the purpose of giving some strength and consistence to this part. Thirdly, an ossifying blastema is produced at several points upon the primordial membranous capsule, which soon becomes converted into detached flakes of bone. These, growing quickly, provide protection for the brain; while the intervening, still membranous, portions permit the expansion of the skull to take place in accommodation to its contents. Soon after the formation of the osseous flakes upon the vault of the cranium, bony nuclei appear in the cartilage at the base[2]. Fourthly, the various bones, some originating in

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[1] Kölliker's *Manual of Histology*, p. 373.

[2] These nuclei of the bodies of the occipital and the two sphenoid bones are represented in the cartilage of the base of the skull in Pl. IV. fig. 1 (p. 118), and the manner in which they form a continuation of the vertebral chain is there well shown.

blastema and some in cartilage, approach one another, and, becoming united at their edges in different ways, form a continuous unyielding bony case, which is admirably adapted for the defence of the brain, for the accommodation of the organs of special sense, and for the attachment of the ligaments and muscles by which the skull is supported and moved upon the spine.

At birth, and for some time before, the calvarial bones have acquired considerable breadth and hardness, as those well know who have been called upon to perform craniotomy. They lie imbedded between their periosteum and the external lamina of the dura mater, which constituted the primitive membranous capsule; and they may be separated without much difficulty from both. Their bevelled and serrated edges run into and are lost in the blastema which forms a continuation of them.

Congenital Fissures, The calvarial bones are often traversed, more or less extensively, by *fissures* extending from the margins towards the middle. These, which are the result of incomplete ossification, might be mistaken for fractures, and, therefore, possess interest in a medico-legal point of view. I have found them very marked in the parietal and frontal bones of young monkeys, and, less decided, in the human fœtus. They become filled up as ossification proceeds[1]. In consequence of a deficiency and inequality of the ossifying processes we sometimes find and Gaps. larger *gaps* or vacancies, not only at the edges but in the middle of the calvarial bones. These may be occupied only by membrane, or in course of time they may be closed by a thin lamina of bone. Such gaps most often occur when the ossification throughout the skull is rather imperfect, and are generally situated in or near the natural foramina for vessels. Thus in a thin calvarium in our Museum there is, on either side of the sagittal suture, in the place of the parietal foramen, a hole large enough to admit the end of one's finger, and in the Sicilian

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[1] Lobstein gives the representation of a congenital fissure extending nearly through the squamous part of the temporal bone, *Traité d'Anatomie path.* Pl. V. fig. 2.

Dr West, *Medico-Chirurgical Transactions*, XXVIII. states that fissures of the skull have been known to take place during labour, even in easy labours. He relates a case of fissure in the fore part of the parietal bone, which he supposes to have occurred in this way. It was attended with effusion of blood on both surfaces of the bone. He says, moreover, "the annals of legal medicine contain many instances of injury of the child before birth, and of fracture of its skull by a blow, or some other violence, inflicted on the mother," and gives references in proof of the statement.

dwarf, in the College of Surgeons, in which ossification is very backward, there is an irregularly shaped gap in the situation of the mastoid foramen of the temporal bone and another near the upper and hinder angle of the parietal bone. Some remarkable examples of extreme thinness of a considerable part of one or both parietal bones, which are probably of a similar nature, will be mentioned in the account of those bones. Deficiencies of this kind are not unfrequently met with in hydrocephalic skulls, in consequence of the stretching to which the ossifying membrane has been subject. The frontal bone from a hydrocephalic skull in Guy's Museum shews several such vacancies in its wall; and in Sandifort's *Museum Anatomicum* is the representation of a frontal bone, also from a hydrocephalic skull, in which there are two foramina in the cranial part, and the orbital portion is very deficient[1].

Bones at first thickest at the middle, subsequently at the edges.

Before the calvarial bones have united with one another, they are of nearly uniform thickness. There is, however, a slight preponderance in favour of the middle parts where ossification commenced; and the edges where the bones are still growing are rather thinner. Subsequently, after peripheral growth has been stopped by their confluence at the sutures, the bones become thickened at their edges. It is as though a reflux of the ossifying processes took place and spent itself in causing broad, ridge-like, more or less uneven prominences in the immediate neighbourhood of the sutures, both on the outside and on the interior of the cranium. Thus it often happens that the circumferential, most recently formed, parts of the calvarial bones—of the parietals more particularly—attain to greater thickness than the central parts where ossification began. While these changes are going on in the relative degree of thickness of the central and circumferential portions of the calvarial bones, the

[1] I have found similar holes in all parts of hydrocephalic calvaria. They are, however, most frequent in the frontal bones and in the parietals on either side of the sagittal suture.

It is no uncommon thing to find, when the normal growth of one of the calvarial bones has been arrested, in rickets, hydrocephalus, or other morbid condition, that the space which should have been occupied by the bone is covered by numerous separate nuclei. The irregular and incomplete coalescence of these independent ossicles with one another and with the central nucleus is probably one cause of the vacancies just mentioned.

former gradually become less prominent[1], and the various ridges and inequalities on the surface of the skull become more apparent.

The diplöe.

After the sutures have been formed and the skull has acquired a certain thickness, the process of resorption goes on in the interior of the several bones—that is, between their outer and inner surfaces, just as it does in the interior of the cylindrical bones, and reduces the structure to a more or less cancellated condition. The part so altered is called the *diplöe;* and the change serves the purpose of diminishing the weight of the skull without proportionately reducing its strength. The cancelli of the diplöe are occupied by a kind of marrow, which resembles that of the vertebræ in containing but little oil, and they are traversed by canals for vessels, which are elaborately represented in Breschet's work, *Sur le Système Veineux.* As a general rule, the diplöe begins to be evident about the tenth year, and becomes most developed in those skulls and in those parts of each skull which are the thickest; consequently it varies a good deal in different persons. In some cases of rickets it becomes enormously increased by deposit of bone upon the exterior of the skull which is attended with an imperfect ossification of the outer table, or which is soon followed by the reduction of that table to a cancellated state; and in some cases of wasting of the brain, from illness or old age, the diplöe is increased in thickness by deposit upon the interior of the skull and by corresponding changes in the inner table. I have often observed it to be thick in the skulls of idiots[2], and find that, as a general rule, the diplöe is thickest and the several bones of the head are also thickest where the skull is small; in other words, where the brain is small. Hence the propriety of the term "thick-headed," as a synonym for "stupid," derives some confirmation from anatomy.

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[1] In the rickety skull, and in some other instances where the brain is of disproportionately large size, the change of curvature which renders the central portions of the several calvarial bones less prominent does not take place as it ought to do; and this gives a peculiar square contour to the head. Dr Merei, in his work above quoted (p. 156) observes, (and the same thing has been remarked by others,) that in the great majority of rachitic children the brain is actually larger than in other children; its consistence and appearance being normal.

[2] In the skull of an idiot, represented by Lobstein, *Traité d'Anat. path.* Pl. III. fig. 3, the diplöe is very thick.

A further extension of the process which causes the diplöe gives rise to the formation of the frontal, sphenoid, and other sinuses.

The tables of the skull.

The formation of the diplöe divides the wall of the skull into three strata, viz. an outer and inner table with the intervening cancellous part. Of these tables the inner is rather more dense and brittle than the outer, which enables it to propagate in its own substance and carry off in a lateral direction some of the jarring vibrations that come from the exterior, instead of transmitting them onwards to the brain. This structure renders it rather more fragile than the outer layers of the skull; hence it is apt to be fissured to a greater extent than they in fracture of the skull: and it has occasionally been broken by a direct blow, although the outer table remained entire[1]. Nevertheless, it may escape splintering when a portion of the outer table is sliced off by a sabre or other sharp instrument.

The fontanelles.

The cranial bones grow into contact with one another and become united by sutures soon after birth; those of the face before those of the calvarium. They touch first, and the sutures are first formed at the parts nearest to their centres of ossification. Thus the four sides of each parietal bone, which are nearer to the middle part, become joined to the four surrounding bones at an earlier period than the four angles which are further removed from the centre. In the situation of the four angles there remain, accordingly, spaces in which the osseous envelope of the brain is defective after its other parts have been formed.

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[1] Guthrie, *On Injuries of the Head*, p. 73, *British and Foreign Medical Review*, XV. 401. "A well-marked instance of very extensive splintering and depression of the inner table, without any injury of a corresponding nature on the outer part," is mentioned by Hewett, *Medical Times and Gazette*, Jan. 9, 1858, as belonging to the Museum of St George's Hospital. Mr Hewett remarks that the greater splintering of the inner table, as compared with the outer, in so many cases, is partly due to the direction in which the force acts; "let the force act in the opposite direction, and then the common order of appearances becomes reversed." An instance is quoted of a pistol-ball passing through the skull so as to strike the inner plate of the opposite side and then the outer one; the latter was much more extensively splintered than the former. According to the same writer, comminuted and compound fractures generally spread to a less distance than simple fissures.

These spaces are called *fontanelles*[1]. The two at the inferior angles of the parietal bones are closed at birth or soon after. The two at the superior angles are larger and are closed later. The hinder of these two is the smaller, and is closed a few months after birth. The anterior, which is much the larger, is not closed till from one to two years after birth. It sometimes remains open much longer, and has even been found unclosed in old persons[2]. It is permanent in some fishes[3]. Its size and square shape are an assistance to the accoucheur in determining the position of the child.

Use of the fontanelles. This deficiency in the brain-case at the point of confluence of the angles of the frontal and parietal bones is to some extent a safety-valve during the first months of infantile life, at which time the brain bears a large proportion to the rest of the body, and is liable to sudden and considerable variations in size from temporary congestion, wasting of its substance, and other causes. The various bones of the skull are then becoming joined together, and the skull is becoming consolidated while the brain is increasing in density (p. 95); but the comparatively soft consistence of the brain renders it still liable to sudden variations in size, even after the greater number of the cranial bones have coalesced; and these variations are permitted by a portion of

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[1] So called from the pulsations of the brain, which may be seen resembling the rising of water at a fountain-head.

[2] Kerkringius and Otto, *Path. Anat.* by South, p. 164.

Dr Merei, *Disorders of Infantile Development*, has remarked a relation between the cutting of the teeth and the progress of ossification of the skull, as evidenced by the closure of the fontanelles. He finds the interval between the first-cut tooth and the closure of the fontanelles to vary from 4 to 7 months, and that both are retarded in sickly rachitic children. "The retarded ossification of the fontanelles, speaking in general terms, is pathologically more significative than retarded dentition; it acquires more importance when connected with an abnormally large size and angular shape of skull." "In the majority of cases, according to my experience, I may say, small skulls are sooner completely ossified than large ones; but there are numerous exceptions to this rule," p. 127.

Dr Elsaesser, *British and Foreign Med. Review*, XVII. p. 372, finds that the anterior fontanelle increases progressively in size during the first nine months of infantile life.

[3] "Each frontal sends up its own crest in the Tunny, the interspace leading to a foramen, penetrating the cranial cavity in front of the single occipital spine; a larger fontanelle exists in the Cobitis and some Siluroids between the frontal and parietal bones." Owen's *Lectures on Comparative Anatomy*, II. 97.

the skull remaining membranous for a time. Watch an infant suffering under diarrhœa or other malady which causes a sudden drain upon the system. In a very short time, cotemporaneously with the shrinking of the face, the fontanelle is observed to have fallen in; and in a short time again, during recovery, it is plumped up, perhaps beyond the surrounding level.

Sutures, why persistent; The sutures remain distinct for a long time after the closure of the fontanelles and the complete formation of the skull. They may, as suggested by Gibson[1], Sœmmerring, and others, serve some purpose in permitting an increase of the size of the cranium by the growth of the bones at their edges. It is evident, however, from the changes in shape which take place in the parietal and other bones during growth, that the enlargement of the cranial cavity does not entirely depend upon an extension of the bones at these sutural edges; but that it may also be caused by the removal of bone from the interior of the skull and the addition of bone on the exterior, after the plan that we have found to be followed in the shafts of the long bones. It by no means follows, therefore, that if the skull had originally consisted of one piece the cranial cavity could have undergone no increase of size; but that increase would have been slow, because so little assistance would have been supplied by interstitial growth in the bones. The cranium is formed in detached pieces, for the purpose of permitting that *rapid* growth which takes place in the brain during the earlier periods of life, as well as of providing for the quick variations in size which then occur, and of facilitating its passage through the mother's pelvis. After indigitation has taken place the interlocking of the bones is so intricate that I question whether growth can take place at their edges much more easily than in other parts of their extent.

when obliterated. The sutures serve also to break and disperse jarring vibrations, and in that manner minister to the security of the brain; but that they have not very great influence in any way is proved by the very variable periods at which they are obliterated. In some skulls, edentulous from age, I have found

[1] *Memoirs of Manchester Society*, 1813.

them still well marked; whereas in others, which bore evidence of having only just reached maturity, they could scarcely be traced. The fusion of the bones commonly takes place first at the fore part of the sagittal suture, next in the lambdoidal suture near the sagittal, then in the coronal suture near the inferior angles of the parietal bones. So that, as a general rule, the sutures are first obliterated at the parts in which the ossification of the skull was last completed, viz. in the neighbourhood of the fontanelles; and the cranial bones seem in this respect to observe a similar law to that which regulates the union of the epiphyses to the shafts of the long bones (page 41). The sutures are commonly obliterated earliest in those skulls in which a heavy hard condition of the bones evinces a preternatural activity of the ossifying processes.

Wormian bones: The number of centres of ossification in the skull is tolerably uniform. Additional ones are, however, sometimes supplied in the course of the sutures, giving rise to what are called *wormian bones*. They are most frequent in the lambdoidal suture, particularly when the occipital protuberance is very marked; but may be found in the sagittal suture and in other parts. One of considerable size sometimes replaces the superior angle of the occipital bone, covering in the posterior fontanelle; and there is not unfrequently one at the anterior inferior angle of the parietal bone, covering the fontanelle there situated. A wormian bone is also occasionally present in the anterior fontanelle[1]; and one has been found at the base of the skull in the lesser ala of the sphenoid bone and between the sphenoid and æthmoid bones[2]. Ossification does not commence in them so soon as in the other bones; not till six months or a year after birth. Beclard says that they are never found at birth. In accordance with the law just referred to, they are united to one another and to the rest of the skull at an earlier period than the other bones; so that in the fully formed skull it is

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[1] Bertin, Cruvelhier and Cuvier each describe this. Tiedemann, in *Zeitschrift für Physiologie*, III. gives plates of two in the same situation; also Sandifort, *Mus. Anat.* Tab. VIII. There are seven examples of it in the museum at Bonn. Blandin, *Anat.* I. 100, describes them in each of the fontanelles.

[2] Ward's *Human Osteology*, p. 47.

impossible to tell how many there may have been. With the exception of the one in the posterior fontanelle, which may be supposed to represent the "interparietal bone" of carnivora, they do not appear to be developed according to any particular law, and do not show any correspondence with the additional cranial bones of other animals. A comparison of the skulls of the latter, of the reptilian skulls particularly, with that of man, shows that the more numerous bones composing them have their representatives in the separate osseous centres from which the larger bones of the human cranium are regularly formed, and not in the occasional wormian bones[1].

under what circumstances oftenest found.

They are evidently stop-gaps developed in the membranous covering of the brain when the extension of the regular osseous nuclei is likely, for some reason, to be insufficient to cover in the cranial cavity. Thus I have seen several instances of rickety fœtuses in which the growth of the primary nuclei of the frontal and parietal bones has been arrested, and the circumferential parts, which they should have occupied were covered by detached ossicles, or wormian bones. The skull was not large in any of these cases. Such deficiency in the growing power of the regular centres is, however, comparatively rare. A far more frequent cause of the formation of wormian bones is the enlargement of the cranial cavity, and the consequent undue stretching of its membranous envelope, which takes place in hydrocephalus. In this disease the regular bones grow quickly, attain to great size, and may even suffice to complete the skull[2]. Commonly, however, assistance is supplied by wormian bones, which may be developed very numerously in the sagittal, lambdoidal, and squamous sutures, being sometimes two or three rows deep. It is curious that they are very rarely found either in the coronal or frontal sutures[3]. Often they differ

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[1] Wormian bones are found according to Dr Williamson (on the Human Crania in the Army Medical Museum, Fort Pitt, Chatham, *Dublin Quarterly Journal*, Aug. 1, 1857) as frequently in the occipital suture of the Negro as in the European; and they are said by him to be more frequently of large size in the former, often cutting off the superior angle of the occipital bone.

[2] In some hydrocephalic specimens in the Musée Dupuytren the crania are of enormous size, yet there are no wormian bones, or but few, the preternatural growth from the regular nuclei having sufficed to cover the expanded cerebrum, even closing the fontanelles, though the crania were evidently those of young subjects.

[3] In a hydrocephalic skull, No. 3487, in the College of Surgeons, a strong continuous plate of bone extends from the occipital to the æthmoid between the two

in size and number on the two sides, causing a want of symmetry in the shape of the head. It is interesting to observe how the forms of the wormian bones and the direction of the little osseous shoots from the margins of the cranial bones are affected by the tension of the membranous envelope upon which they are formed. In hydrocephalic skulls, where this tension is greatest, the osseous centres of the wormian bones often assume a linear form, so that they may be seen arranged in parallel lines, extending more or less across the interval between the contiguous bones, and looking like extensions of their radiating fibres, though really quite separate from them[1].

In hydrocephalus the fluid accumulates chiefly in the lateral ventricles; and it is accordingly the frontal and parietal bones that undergo the chief expansion. The fourth ventricle and the cerebellum are often not much altered; and the corresponding bone—the occipital—is not usually so much increased in size as the other two. The base of the skull is somewhat flattened, but does not undergo much change either in size or shape; it is consequently very small in proportion to the calvarial part[2].

Rate of growth of skull.

I have already (page 94) spoken of the proportion which the skull bears to the rest of the body, and of the differences in its rate of growth at different periods of life. Its most rapid increase is before the closure of the sutures. After that time its enlargement (as has been said, page 190) is effected partly by the growth of the bones at their edges, and partly by the removal of osseous laminæ from the interior and the addition of laminæ on the exterior of the skull; and the process goes on at a gradually diminishing rate till about the age of twenty. The assertion that the brain and skull do not enlarge at all after the seventh year[3] is

parietals and the lateral portions of the frontal. A median suture in some parts of its length indicates that it was originally formed of two halves which have coalesced.

[1] This is well shown in the Museum of the College of Surgeons, No. 3482, also in Sandifort's *Mus. Anat.* Tab. VII. fig. 2, and Tab. CXCII.

[2] This is because the base of the skull, as well as the cerebral ganglia in immediate relation with it, are less yielding than the calvarium and upper part of the cerebral hemispheres. In some instances the hinder parts of the temporal bones have been depressed below their proper level, so that their zygomatic processes have ascended obliquely to join the malar bones. Rathke, in Meckel's *Archiv*, VII. 486.

[3] This idea appears to have been taken from Sœmmerring and from Wenzel's book, *De penitiori cerebri structurâ;* though it is not quite in accordance with an extract from a table by the latter given in Dr Milligan's translation of Magendie's *Physiology*, p. 544.

disproved both by common experience and by careful observation (see Tables at pp. 106 and 110). Dr Sims[1] gives a table of the weight of the brain in 253 cases, from which it appears that the average weight goes on increasing to the age of twenty, that from that to fifty the increase is very slight, and that after fifty there is a gradual decrease in weight. Dr Reid[2] and Dr Milligan[3] obtained similar results.

Changes in age.

As years roll on, the skull, in some instances, becomes thinner, more compact, and lighter[4], its laminæ being finer and the cells of its diplöe enlarging. This is perhaps the regular and normal change, and it corresponds to a certain extent with what takes place in other bones. There is, however, this peculiarity in the skull; that, whereas during growth its size was increased, like that of the shaft of a long bone, by the removal of bone from the inside and the addition of bone on the exterior, the reverse now occurs. The removal of bone takes place from the exterior, and the addition is made on the interior; the latter giving rise to that close adhesion of the dura mater and those roughnesses and

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[1] *Medico-Chirurgical Transactions*, Vol. XIX.

[2] *Physiological, Pathological and Anatomical Researches*, p. 380. The *relative* weight of the encephalon to the rest of the body is shown by this physiologist to decrease rapidly during the period of growth, and to undergo comparatively little alteration after the age of twenty.

[3] Dr Milligan gives the following table of mean diameters of heads at different periods of life, obtained from a hatter:

For a child of	1 year	$5\frac{5}{8}$ inches.
,,	2 years	$5\frac{7}{8}$,,
,,	4 years	$6\frac{1}{8}$,,
,,	7 years	$6\frac{5}{8}$,,
,,	12 years	$6\frac{3}{4}$,,
,,	16 to 18 years	$6\frac{7}{8}$,,
Adults		$7\frac{1}{8}$ to $7\frac{3}{4}$ or 8 inches.

[4] The chief result of Tenon's comparisons of the measurements and weighings of the skull at different periods of life are, 1. The increase of size in intra-uterine life is very disproportionate to that at any other time; 2. It increases in weight most from the age of six to the adult period; 3. From the adult period to old age it decreases a little in size and loses as much as two-fifths of its weight. *Recherches sur la Crâne, Mém. de l'Institut*, Vol. I. Meckel found the skull of a woman, æt. 70, to weigh 14 oz.; while that of a woman æt. 20 weighed 24 oz. One edentulous skull, without the lower jaw (evidently from a very aged person), in the Cambridge Museum, weighs $11\frac{1}{2}$ oz.; another, with the lower jaw (from an aged female, whose whole skeleton is remarkably atrophied), weighs 14 oz.

projections which are commonly met with in the cranial cavities of old persons. When the former process exceeds the latter the skull becomes rather smaller and lighter. This, however, is by no means invariably the case. It not unfrequently happens that the process of internal addition, to fill up the space left by the shrinking of the brain, goes on at a greater rate than the external absorption, so that the skull is rendered actually thicker than it had before been. This thickening commences generally on the inside of the frontal and parietal bones, about the middle, partly filling up the concavities, and diminishing the inner curvatures of these bones. In some instances the diplöe is proportionately increased and its cells are widened, so that there may be little or no increase of weight; but in others this is not the case. It may remain unaltered, or it may actually undergo condensation, rendering the skull heavier. I have seen so many instances in which this tendency to an increase in the weight of the skull has been evinced in advancing years, that I conclude it to be a matter of no unfrequent occurrence[1].

Vascular supply. The arteries. The skull-bones are well supplied with blood through the medium of arteries which pass, from the dura mater on the one side and the pericranium on the other, through the numerous foramina observed upon both surfaces. There are not any which exactly correspond with the medullary arteries of the long and short bones—that is, any particular vessels, larger and

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[1] In the Cambridge Museum are two portions cut from the skulls of aged persons; both are thick, heavy and hard, with scarce a trace of diplöe. The skull of a man, æt. 104, from which the lower jaw and a large portion of the hinder part of the cranium (nearly a quarter of the whole) have been removed, weighs 17 oz. The lower part of an edentulous skull, with the lower jaw, evidently from a very aged person (from which the calvarium has been removed a quarter of an inch above the orbits), weighs 15 oz.; an entire edentulous skull, without the lower jaw, and from which the alveolary processes of the upper jaw have been quite absorbed, weighs 28½ oz.; and another, in a similar state, weighs 26 oz. All these are considerably above the average, and all are thick and dense. Weighing some other crania, for the sake of comparison, I found the large, well-proportioned skull of an Irish physician to weigh 26 oz.; that of an adult European female 21½ oz.; of an African, native of Guinea, probably a female, 26½ oz.; of a negro, from Congo, 32 oz. The lower jaw is present in all. The latter two are much less capacious than the former. In a short table given by Mr Ward, the African's skull weighed more than any other, although its capacity was less.

longer than the others, which enter at the points where ossification began. All are of nearly uniform size, and each is distributed to the part near which it enters. The supply from the meningeal vessels of the dura mater is considerably more free than that from the pericranium. Hence the orifices on the inside of the skull are larger and more numerous than those on the exterior; and hence the pericranium may be extensively detached from the bones without necrosis or other evil resulting. The meningeal vessels ramify in the exterior of the dura mater—in that which is the remnant of the primitive membranous cranium. They are derived from the middle, the anterior, and the posterior meningeal arteries, which are branches respectively of the external and internal carotid and of the vertebral arteries. Their offsets, passing from the dura mater to the skull, are not very strong, and are consequently torn through without much difficulty in taking off the calvarium after death: also during life they do not offer much resistance; the dura mater is consequently easily detached from the skull, by effusions of blood from the middle meningeal trunks or from the great venous sinuses, or by formations of pus or other causes. These offsets are however so small that their laceration, whatever be its cause, is rarely productive of any serious extravasation of blood. This is a point of some practical importance, inasmuch as we need not be apprehensive of any injurious result from effusion of blood between the dura mater and the skull, unless the injury be in the locality of the great trunk-vessels just mentioned, and unless the effusion be caused by their rupture.

The veins.

The blood is returned by veins which take different directions. Some of them pass at many points through the larger holes on the exterior and on the inside of the cranium, and communicate with the veins of the pericranium and of the dura mater. Some coalesce into larger branches which run for a considerable distance in canals hollowed out for the purpose in the diplöe. The vessels and the containing canals converge into four or five chief trunks on either side. Those of the fore and middle parts of the skull converge towards the supra-orbital notch of the frontal bone, in which may be usually seen a small foramen penetrating the outer table of the skull. This foramen

Venous canals in the diplöe.

transmits the vein of the diplöe, which here joins the supra-orbital vein; and its blood is conveyed, through the latter, under the roof of the orbit, to the ophthalmic vein, and so on to the cavernous sinus. A second set of veins, not always present as a distinct group, converges from the outer part of the frontal bone towards its external angular process, and, entering the orbit through a foramen there seen, also joins the ophthalmic vein. A third set converges from the side of the head to the anterior inferior angle of the parietal bone, where the common trunk joins the vein accompanying the middle meningeal artery. A fourth set converges to the postero-inferior angle of the parietal bone, and the resultant trunk, passing either through the mastoid foramen or a hole near it, finds its way into the lateral sinus. The fifth set, converging from the occipital bone, terminates in or near the posterior condyloid foramen, and unites with the posterior condyloid vein, or enters directly into the lateral sinus. The several canals which transmit these veins may be traced by filing away the outer table of the skull. Most of them are represented in Breschet's work, and have been copied from it into other books.

Calvarium more vascular and liable to disease than the base.

The calvarium is more richly supplied with blood than the base of the skull, and is more frequently the seat of disease. Thus, thickening of the bones, from whatever cause arising, is more common in the calvarium than in the base: and ulceration, which is not unfrequent in the former, is rare in the latter, and has its origin in the tympanum in most of the instances in which it does occur. Osseous tumours and malignant growths are also not unfrequent in the calvarium and about the orbits and nasal cavities; but are seldom met with at the base.

We may, in like manner, associate with the greater vascularity of the inner table of the calvarium, as contrasted with that of the outer, its comparatively greater liability to thickening, to puerperal[1] and other deposits, to small exostoses[2], &c. The deposits on the exterior are

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[1] The deposit in the skull which has been observed in pregnant women and has received the name of "puerperal orteophyte," is most frequent in the frontal and parietal bones, and is usually first formed in the grooves for the vessels.

[2] There are in Guy's Museum two specimens of exostosis on the exterior of the occipital bone; and the nodulated osseous growths, which occasionally affect the

almost confined to that which I have mentioned as an occasional attendant on rickets, unless they be the result of accident or of the peculiar chronic irritation of syphilis. We may associate also with the manner in which the calvarium derives its supply of blood from the dura mater on the interior, as well as from the periosteum on the exterior, the fact that inflammation and ulceration, more particularly when they are of a syphilitic nature, generally affect the whole thickness of the bone. They may begin on the outside, but they very soon make their way through to the interior, and spread in the latter direction quite as much as in the former.

Reproduction very slow.

It has been remarked (p. 61) that reproduction of bone takes place very slowly in the skull. The presence or absence of the dura mater seems to make no difference in this respect. I am not aware whether the pericranium has been known to be preserved in any cases; probably it would not much affect the result. Large portions of the calvarium, sometimes including its entire thickness, occasionally come away in a necrosed state after a severe burn, and the patient may survive. I have now and then seen detached osseous nuclei in the fibrous membrane which occupied the gap so caused in the skull[1].

Dura mater:

The *dura mater* which encloses the spinal cord has no immediate connection with the bones, being separated from the bodies of the vertebræ by the ligamentum posticum, and from the arches by a stratum of fat. As it passes into the skull it divides, at the back part and sides, into two layers, of which the outer runs to and is connected with the edge of the foramen magnum, while the inner is expanded upon the interior of the occipital bone. In front it becomes closely united with the ligamentum posticum, and is expanded with it upon the base of the skull. All over the lower part of the skull the dura mater is closely attached to the bones, adhering tightly to their surfaces, and is connected with them intimately through the medium of the many ridges, processes and foramina that exist here, as well as by the sheaths which it sends off to accompany the several nerves

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frontal bone, appear occasionally on the exterior, though less frequently and less early than on the inside.

[1] There is a specimen of the kind in the Musée Dupuytren; several bony nuclei are seen in the membrane that closes up a large gap, caused in the calvarium by necrosis.

and vessels. These sheaths line the foramina; and, like the process of dura mater which descends through the foramen magnum upon the cord, they are connected both with the nerves and vessels and with the margins of the foramina: at the edges of the latter they are continuous with the pericranium. Towards the sides and upper part of the skull the adhesion of the dura mater to the bones is less intimate than at the base; so that the calvarium may usually be separated without much difficulty. It follows from this difference between the degree of adhesion of the dura mater at the two parts, that in fracture at the base of the skull it is always torn through; whereas in fracture of the calvarium it often escapes; and this is one of the causes of the former accident being so generally fatal.

its adhesion to the skull increases with age.

The connection of the dura mater with the bones increases with age. In the fœtus and young child the several bones may be easily turned out from their bed between the dura mater and the pericranium. Nevertheless it is difficult to remove the calvarium entire, because of the close connection of the dura mater with the pericranium at the sutures and fontanelles. After the sutures and fontanelles are closed, the increasing size and strength of the vessels and fibrous processes which pass between the dura mater and the skull make the union between the two gradually more close. Finally, in old age, the ossification, slowly encroaching upon these processes, renders the union still closer, and makes it difficult to detach the calvarium without tearing the dura mater, or leaving flakes of the inner table of the skull sticking upon it. The connection between the dura mater and the skull is most intimate of all in those cases in which ossification has acquired an unnatural impetus, in consequence of chronic inflammation excited by syphilis or other cause, and has rendered the skull thick, hard, and heavy.

The Sinuses.

The dura mater serves other purposes besides that of forming an endosteum to the skull. Its processes—the *falx cerebri*, *falx cerebelli*, and the *tentorium*—projecting into the interior, give support to the brain, and by the mode of their formation give rise to the *sinuses*, or channels for the conveyance of the venous blood from the brain. These are formed in the following way. The dura mater, as we have already found (p. 182), consists of two layers; of which the outer appertains to the skull, and the inner, lined by the arachnoid epithelium, belongs to the brain. The two may be separated in infancy; but in the adult they are intimately blended in the greater part of their extent. In some places, however, as beneath the sagittal suture, they are separated on either side of the middle line; the outer layer is continued across beneath the bone, while the inner one, dipping inwards, meeting that of the opposite side, and descending with it, forms the falx. A triangular canal or sinus is thus made, which is strengthened at the sides and angles by interlacing bands of fibrous tissue.

Advantages resulting from the manner of their formation.

The other sinuses are formed in the same way. They are all lodged in the intervals between the great divisions of the brain; and the disposition and structure of their walls, added to the tension of the dura mater on the sides and of the falx and tentorium in the middle, are such that their shape cannot easily be altered by any external pressure; consequently the flow of the blood through them cannot be impeded by the pulsations or pressure of the brain in the varying positions of the body. The tense, unyielding character of their walls, moreover, does not admit of either collapse or distension; hence they must be equally full at all times, and must exert a uniform pressure upon the brain. So that, as on the one hand they cannot be compressed by the brain, neither can they be distended sufficiently to exert any injurious pressure upon it. This doubtless is the reason that the venous blood of the brain, instead of passing through large veins in its substance, as in other organs, is transmitted through the peculiarly constructed tubes called sinuses, on its exterior[1].

Skull adapted for protection of brain:

It is the office of the skull to protect the important nervous centres contained within it; and when we reflect how large a mass the brain is, and that its delicate vascular structure renders it peculiarly liable to suffer from contusion and jars, we perceive that it must be no easy matter to secure it from injury during the rapid movements of the body, and the collisions to which we are often exposed. Yet so admirably suited to this purpose are its coverings, and so nicely

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[1] For description and illustrations of the cerebral sinuses, &c. I must refer to Breschet's work, *Sur le Système Veineux*, or to woodcuts taken from it in the *Cyclopedia of Anatomy*, III. 630.

adapted to one another are the brain and the skull, that we very seldom find any serious mischief occurring to the brain, except it be from a fall upon the head, or a blow, sufficiently severe to fracture the skull. If therefore, in any case of injury to the head, we can assure ourselves that the skull remains entire, we may be pretty certain that the brain is not lacerated or shaken beyond recovery. The patient may be stunned; but he will probably recover his consciousness after a time, and eventually do well. A few instances are on record in which concussion has proved fatal without fracture; they are, however, very few, so few that they may be regarded as rare exceptions to the rule. On the other hand, if the symptoms of cerebral lesion be so severe as to preclude the hope of recovery, that alone is tolerably conclusive evidence of fracture of the skull. In short, the skull is constituted in such a manner that, so long as it retains its integrity, it is able to protect its contents from serious lesion; and nothing short of a blow, which breaks it, will succeed in contusing or tearing the brain.

strengthened by arches

Much is due to the rounded shape of the skull, whereby its strength is increased, and in consequence of which many blows glide off from it without doing harm. Then the arch of the calvarium is made up of five secondary arches, each of which is formed by one of the component bones. There is an occipital arch in the middle and a parietal and a frontal arch on either side. The centre and more prominent part of each is thicker than the rest in the little child, while the arch is still incomplete; and the early ossification and greater thickness of the more prominent parts of the skull, the edges of the bones being connected by membrane, defend the cranium and its contents from the many falls and blows to which little children are exposed, so completely, that we do not often see the skull fractured or the brain severely damaged in them. In the adult the arches, formed by the individual bones, are less marked, in consequence of the shape of the bones having been altered, so that their middle parts are less prominent. These middle parts, moreover, instead of being the thickest, have become rather the thinnest, parts of the skull; less substance is now required in them because, being the most curved portions, they receive more support from the contiguous wall, and because the fibres of the bone converging to them contribute to their strength[1].

and by ridges.

Further, the skull is strengthened by curved lines or ridges, which may be traced all round it. Thus, from each external angular process of the frontal bone a strong ridge passes over the orbit to the nose; another is directed backwards, bounding the temporal fossa, crossing the frontal the parietal and the temporal bones, and reaching the mastoid process of the latter. From that point a third ridge is continued across the back of the skull to the opposite mastoid process. In the interior of the skull also, from the *tuber occipitale*, where, being much exposed, the bone is very thick, strongly marked ribs diverge like the groining of a roof. One passes downwards, and spreads out into the thick edge of the foramen magnum; another passes upwards and forwards, along the median line, to the frontal bone, where it rises into a sharp crest and is prolonged over the æthmoid bone, forming its crista galli; a third and fourth ridge, on either side, bound the groove for the lateral sinus.

Part of the skull beneath the level of the ridges thin.

The part of the skull situated above the external circumferential ridges just described is covered only by the thin occipito-frontalis tendon and the skin, and is of considerable and nearly uniform thickness; both the tables and the diplöe are well formed in it, and present their respective characters in full. Beneath these ridges, on the contrary, the skull is, in each direction, protected by its situation and by a thicker covering of soft parts: it is accordingly thinner, the diplöe is less developed, the two tables are more closely united, and their respective characters are less obviously marked. Thus the same regard to economy of material and to the prevention of unnecessary weight is evinced in the construction of the skull as in other parts of the skeleton. The skull varies a good deal in thickness and strength: in some,

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[1] The occipital bone is, to some extent, an exception to this; inasmuch as the "tuber," which is the most prominent, is also, for peculiar reasons, the thickest part of the wall. If, however, we examine the four secondary arches of which the bone is composed, we shall perceive that the middle, most convex, portion of each is the thinnest.

it is able to withstand great violence; in others, it is so thin that a comparatively slight blow will break it.

Joining of the bones.

The several bones are so interlocked, tied together, and dovetailed at their edges, that they are more easily broken than forced asunder[1]; and their disposition with regard to one another is such as to offer the best resistance to external violence. Thus the parietal bones, united together, form a great arch across the upper part of the skull; the broad pillars of this arch are sloped inwards as they pass downwards, and are received between, and overlapped by, the squamous portions of the temporal bones, so that the tendency to an outward thrust which would be caused by any weight or force applied at the summit is well provided against. Again, for a similar purpose, the frontal bone overlaps the parietal at the middle of the coronal suture, and is overlapped by it on either side. So effectual are these and other provisions for the strengthening of the calvarium, that, as is well known, if a person falls on his head the base of the skull, which is furthest removed from injury and most under cover of the soft parts, is quite as likely to be broken as the crown, if not more so.

The weak part at the base.

Indeed, if we examine a skull, when all the soft parts have been removed, one of the weakest points we can find is in the middle of the base, at the sella turcica, just in front of the posterior clinoid processes. The sphenoid bone, which forms the chief strength of the part, is here constricted at the sides by the foramina lacera and the grooves for the carotid artery. It is hollowed out above for the lodgment of the pituitary gland; beneath, it is cut away behind the pterygoid processes; its middle is excavated for the sphenoidal sinus. It runs forward like a narrow stem; yet it has to bear the chief weight of the face and fore part of the skull. A vertical section shows, moreover, that there is a bend here; the fore part of the body of the sphenoid

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[1] In the Musée Dupuytren is a specimen of separation of the parietal bones at the sagittal suture; and another where from a fall upon the head the right parietal has been separated from the left and from the frontal bone along the line of the sagittal and frontal sutures. These are, however, exceptional instances; the fracture much more commonly traverses the bones than follows the lines of the sutures.

and the æthmoid forming an obtuse angle with the hinder part of the body of the sphenoid and the basilar process of the occipital bone (Pl. XV. fig. 1). Immediately in front of and behind this point the skull is strengthened by the descending pterygoid processes and the upper jaw in one direction, and by the thickening of the basilar process and the addition of the posterior clinoid plate in the other. Not only is the skull here weakened by the foramen lacerum medium[1] on either side, but external to that are the fissure between the spinous portion of the sphenoid and the petrous portion of the temporal, the fissura Glaseri, the tympanum, the external auditory canal, and the thin wall of the temporal fossa.

Frequency of fracture at the base.

The eye at once points to this part of the base as the most probable seat of fracture in any case in which the skull is subjected to a severe jar, such as that which would be caused by a fall from a height; and experience tells us that, in spite of its being so far removed from exposure to direct injury and so protected by soft structures, it is more often broken by force indirectly applied than any other part of the cranium. A man for instance falls upon the crown of his head; the part struck gives way, and the fracture, if it be severe, usually runs round to the base, traversing the sella turcica and the middle cerebral fossa, often in the exact line, from one temporal fossa to the other, which I have described. In some instances the fracture has taken place here, although the skull was not broken at the part struck. In such cases, and they are not uncommon, we must consider that the whole bone, regarding the skull as one bone, has been subjected to the disturbing influence of severe vibrations, and has given way at the weakest point: just as any other frangible body, of unequal strength at different parts, if allowed to fall, or if in any other way subjected to violent concussion, would break where it was weakest.

In order to prove that the direction of the line of fracture at the base is regulated rather by the construction of the skull than by any *contre-coup* from the vertebral column, I allowed a skull, with its cover-

[1] This exists only in man as a distinct foramen or fissure; it is obliterated in other animals by the bulging of the tympanum or by the contact of the sphenoid with the occipital bones.

ings and contents, recently removed from the spine, to fall several feet upon a brick pavement, taking care that the crown came first upon the floor. It descended with sufficient force to crack the bricks, but was not itself fractured till the third time, when the upper part of the frontal bone near the parietal was broken. A fissure, starting from this point, ran through the left temporal fossa, behind the zygoma, through the external auditory passage and the tympanic part of the temporal bone. Here the fracture was very severe, a portion of bone being quite loose and the cavity of the tympanum largely exposed. From this it reached the foramen lacerum, crossed the sella turcica to the opposite foramen lacerum, and terminated in the right temporal bone. A secondary fissure ran, nearly at right angles to the former, from the right foramen lacerum through the line of junction between the petrous and occipital bones to the jugular foramen, and terminated in the right side of the occipital bone. Thus the fracture took the ordinary course although the head was detached from the spine. The skull was broken at the point where the blow was received; but it may be remarked that the calvarium did not give way at all till it was struck at the junction of the frontal with the parietal bones, where the arch is a little flattened. The fracture traversed the narrowest and weakest part of the skull and was more severe in the base than elsewhere.

Sometimes, even when the blow is upon the occiput, the fracture travels round outside the petrous portions of the temporal bone to the sella turcica.

Fracture opposite to the part struck.

Besides the instances afforded by the base it is no uncommon thing for fracture to take place in the part of the skull opposite to that on which the blow was received, in consequence of the disturbance caused by the meeting of vibrations which have travelled round the skull. This may happen although the part which has been struck remains entire; thus I have known a blow on one side of the head, cause fracture of the opposite orbital plate of the frontal bone, without breaking any other part of the skull.

Vibrations dissipated by several layers of covering of different consistence,

In considering the mechanism by which the brain is protected from vibratory shocks, we must not forget the several strata of tissue, of different density, that intervene between it and the surface. These have the effect not only of preventing the spread of disease from the surface to the interior (page 17); but they also contribute to prevent the occurrence of jars and tend to dissipate vibrations in the circumference of the head, by giving them a lateral direction, instead of favouring their transmission straight onwards into the interior. The separation of the outer and inner tables of the skull by the intervening diplöe in this way renders the bony wall less permeable by vibrations than if it had been of uniform consistence. The inner, or "vitreous" table, which is the most dense, must exert an especial influence in lateralizing the vibrations and dispersing them on its own surface, instead of transmitting them onwards to the soft structures which lie next to it.

and by structure and disposition of the inner table of skull.

We cannot fail also to remark and admire the further provision for the exhaustion and safe conduct of those vibrations that have reached the inner table, which is afforded by the extension of its surface through the medium of eminences and depressions, and particularly by means of ridges jutting into the interior. These ridges, starting from some of the more exposed points, especially the tuber occipitale, not only strengthen the skull, but contribute greatly to carry off the jars from the various points at which they may be received and to distribute them in a harmless manner. They project into the intervals between the great divisions of the brain, where there is commonly more subarachnoid fluid than at other places; and they are intimately connected, at their edges and terminal points, with the strong expansions of the dura mater—the falx and the tentorium—which would still further distribute and exhaust the vibrations. Thus there is every facility for causing jarring impulses to deviate from the direct line and take a circumferential route, in which they are gradually weakened and rendered harmless.

So admirably adjusted are these provisions for the circumferential deflection of vibrations, that almost as much injury is to be apprehended from their disturbing influence upon the brain at the point where they meet, after travelling round the skull, as at the point where they were set going. Hence it is nearly as common to find ecchymosis and laceration of the cerebral substance at one of these points as at the other; and it has already been mentioned that fracture of the skull sometimes happens at the part opposite to that on which the blow was inflicted. In other words, the balance of adjustment has been attained with such nicety in the construction of the skull, that the property of transmitting vibrations could not have been increased or diminished without lessening the security of the brain.

Relation of the skull to the brain.

We have already found that, both in its primitive membranous and in its subsequent ossifying state, the skull is moulded upon the brain and grows in accordance with it. It is subservient to the brain, and there can be no question that the size and general shape of the brain may be estimated with tolerable accuracy by the size and general shape of the skull; and, further, that we may form a pretty correct notion of the relative proportions of the cerebral lobes by observing the proportions of the corresponding parts of the skull. The opponents of phrenology, by denying this, do not in the least advantage their cause in the estimation of thinking persons, because the statement is of a kind at once to commend itself to common sense as being highly probable. Neither do the objections to this mode of forming an estimate of the brain, which are often adduced from the varying size of the frontal sinuses and the projecting ridges, from the occasional presence of inequalities on the surface which have no correspondences in the interior, from the varying amount of fluid in the subarachnoid tissue and the ventricles, or from certain morbid conditions or congenital malformations[1], amount to much. These show that allowances must be made, and that we must not expect in this way to form an accurate estimate; but they do not affect the principle that the skull is moulded upon and fitted to the brain, and that its exterior does, as a general rule, convey pretty accurate information respecting the size and shape of that organ. The arguments against phrenology—if by phrenology be understood the assigning particular faculties of the mind to particular portions of the brain, and mapping out the skull accordingly—must be of a deeper kind than this to convince any one who has carefully considered the subject.

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[1] In a case, æt. 44, of congenital deficiency of the middle portions and left hemisphere of the cerebellum with hydrocephalus the bones of the skull were perfect and not thinner than usual, all the sutures were very distinct, and the shape of the head from before backwards was an almost perfect oval. *Trans. of Path. Society*, IV. 31.

They may, I think, be safely drawn from what we know of the physiology of the brain; but are rather weakened by these objections, which we often hear adduced in a hostile spirit, from the absence of an accurate correspondence between the skull and the brain. Such accurate correspondence may doubtless be proved to be wanting, and the confidence in the exact details of phrenology may be so shaken; but, forasmuch as the general correspondence between the two cannot be doubted, it might be thought that the principles of phrenology were thereby established, and that a little more caution and a little less attempt at exactness in working out its details would render it a branch of true science. Phrenology must be shown to be fallacious, not so much by a want of exact harmony between the skull and the brain, as by a want of harmony between its fundamental positions and the physiology of the brain. This, I think, might be done; but it is not within the scope of the present work to enter further into the subject.

The fossæ at base of skull.

Each of the fossæ observed in the interior of the floor of the skull is formed, in great part, by one of the cranial vertebræ—the occipital, the parietal, or the frontal—and each lodges one of the great divisions of the brain. The occipital fossa contains the cerebellum; the parietal, or sphenoidal fossa, lodges the middle; and the frontal fossa, the floor of which is raised by the orbits, lodges the anterior lobe of the brain. The so-called posterior lobe, which is distinguished only arbitrarily from the middle lobe, extends over the tentorium and cerebellum, and occupies the hinder part of the cranial cavity.

Olfactory fossa.

A fourth fossa, situated upon the cribriform plates of the æthmoid bone, bounded by the orbital plates of the frontal bone, and lodging the olfactory nerves or lobes of the brain, though small in the human skull, is of large size and forms a very distinct compartment in many of the lower animals.

The projecting processes at the base rendered harmless.

The lesser ala of the sphenoid bone and the anterior clinoid process which separate the anterior from the middle fossa, are received into the fissure of Silvius; and the posterior clinoid processes and the sella turcica correspond with the space under the third ventricle. These processes, which stand up in so bold and apparently hurtful a manner in the dry skull, are, in the recent state, covered in by the extensions of the tentorium so as scarcely to project at all above the surrounding level. There is also a good deal of subarachnoid fluid collected at this part, which protects the brain from their pressure, and from any vibrations which may result from the converging of numerous ridges at this particular spot.

Pituitary fossa.

The position of the pituitary gland in the sella turcica, shielded by the clinoid processes, and covered in by the dura mater, occupying the pituitary fossa, a recess which is so isolated and far removed from direct injury, yet which is a part of the skull more often traversed by fractures than any other, is worthy of remark.

Cerebral eminences and digital depressions.

Along the floor of the three great fossæ just mentioned are many blunt ridges separating shallow depressions. These *cerebral eminences* and *digital depressions* are of various sizes and shapes, and are irregularly disposed, seldom being symmetrical. In most skulls, they can be said to be symmetrical only in one part, and that is near the inner edges of the orbital plates of the frontal bone. The oblong depression running external to and nearly parallel with that edge on either side lodges the cerebral convolution which lies close by the olfactory nerve; and this, though not one of the so-called "primary convolutions" (the "olfactory convolution" lies on the inner side of the nerve), is nevertheless tolerably constant. All the other depressions, like the convolutions by which they are impressed, are very irregular and unsymmetrical. These ridges and depressions are to be found but sparingly on the calvarium, because the dura mater is there thicker, and because the brain is not always in close contact with this part of the skull. It is so only when it completely fills up the brain case. When it shrinks, as it often does from disease and other causes, it remains in close contact with the base of the skull, to which it is bound by the nerves and vessels, but retires from the calvarium; and the subarachnoid fluid accumulates at this part to fill up the interval between the upper convolutions and the bone.

Subarachnoid fluid.

This leads me to say a word or two respecting the office of the subarachnoid fluid as a means of permitting the variations in the size of the brain, which are necessary attendants upon variations in its function. This fluid, occupying the meshes of the pia mater and consisting of serum, appears to be chiefly the result of an exudation from the numerous small vessels ramifying in that membrane, and is capable of being quickly effused or quickly absorbed as occasion may require. Accordingly, when the intellectual functions are in high activity, and the brain is of sufficient size to fill up the cranial cavity, the subarachnoid fluid exists in small quantities. But when, on the other hand, owing to general wasting of the body, or to inactivity of the mental functions, the brain shrinks, then the fluid oozes forth, and, accumulating in the pia mater, fills up the interspace left between the brain and the skull. In persons who have died of phthisis or after protracted illness of any kind, especially illness dependent upon chronic cerebral disease, in old persons, and in those who have been long addicted to drink, the brain is often found to have shrunk a good deal, and the pia mater covering the convolutions and dipping between them is swollen and sodden with infiltrated subarachnoid fluid. This was formerly thought to be a morbid condition, was designated by the term "serous apoplexy," and was often thought to be a cause of death. It is now known to be only a natural and salutary phenomenon. A somewhat similar provision exists in the ventricles of the brain; and the same result appears in some instances to be attained by thickening of the dura mater and arachnoid, and by deposit of bone upon the inner tables of the skull, particularly on the frontal bone[1].

THE ORBITS.

The bones of the face are arranged to enclose the cavities for the eyes, the nose, and the mouth, and to give strength to the apparatus for masticating the food; and the two former organs are placed as guardians over the mouth.

Upper and lower margins in the same plane.

In man, as compared with other animals, the face is but a small appendage to the cranium, being much inferior in size, and compressed beneath its fore part; and the disposition of the facial bones in a nearly vertical manner beneath the

[1] Attention has been particularly directed to this subject by Dr Sims, in his paper on hypertrophy and atrophy of the brain, in the 19th Vol. of the *Medico-Chirurgical Transactions*.

cranium, instead of projecting obliquely in front of it, which is the case in all other animals, causes the lower or maxillary margins of the orbits, in the well-formed skull, to be in the same vertical plane with their upper or frontal margins, or nearly so. The eyes, consequently, look straight forward, in the erect posture, and occupy a commanding position in reference to the body, and to the lower as well as the upper extremities. Such an amount of ocular surveillance over the limbs is peculiar to man, and has relation to the more complete subjugation of his extremities to the dominion of the will (p. 88).

Their inner walls nearly parallel.

The great breadth of the fore part of the human cranium also allows the orbits to be placed in front, instead of on the sides of the head, and renders their inner walls parallel, or nearly so. In the lower animals, on the contrary, the latter are inclined inwards as they pass backwards, so that they nearly meet behind. This parallelism of the inner walls of the orbits in man is associated with the parallelism of the optic axes, and contributes, therefore, to that clear, accurate, and steady vision which results from the ready convergence of the eyes upon any object.

Provision to extend range of vision,

The near approach to parallelism in the orbits and optic axes in man is necessarily attended with a limitation of the range of his vision, although the outer margins of the orbits are in a measure suppressed to lessen this restriction. A great compensation is, however, afforded by the free and rapid rotatory movement of the head upon the neck, which is sufficient to enable us, by turning the head to either side, to see beyond the middle line behind; so that we possess the power of bringing the whole circle, in the centre of which we may be placed, into the range of vision without moving the shoulders. The backward or retiring slant of the outer margin of the orbit is greater at the lower, or malar part, thereby permitting a greater extension of the lateral range of vision upon the ground where it is most wanted; whereas above, the prominence of the external angular process of the frontal bone serves to protect the eye from injury in the direction in which blows are most likely to come. On the inner side protection is afforded by the prominence of

and protect the eye.

the nose and the overhanging of the brow, which is increased by the development of the frontal sinuses. It may be observed that, although the outer half of the margin of the orbit, which is formed by the malar bone and the external angular process of the frontal bone, is slanted backwards so as to increase the lateral range of vision, it is sharp and rather incurved, overhanging the orbital cavity. The inner margin of the orbit, on the contrary, though advanced further forwards, is sloped towards the nose, away from the cavity of the orbit, so that it is not well-defined, and scarcely interferes with the range of vision in that direction. This is most apparent at the inner and upper edge of the orbit; and the extension of the opening of the cavity in this manner, where it is bounded by the internal angular process of the frontal bone, in conjunction with the repression of its malar boundary at the diagonal point, gives to it an oval form; the long diameter of the oval being drawn from the middle of the malar bone to the internal angular process of the frontal bone. (Pl. XV. fig. 3).

Shape of the orbits.

Each orbital cavity is of conical form, its apex being at the confluence of the foramen lacerum with the sphenomaxillary fissure. It is not, however, by any means, a true cone, forasmuch as, from behind, its inner wall is directed nearly straight forwards, whereas the outer wall slants outwards and forwards.

Relation to the optic axes.

The optic axes, by which I mean lines passing through the antero-posterior diameters of the eyes from the middle of the corneæ to the "foramina of Sœmmerring," are parallel with the inner walls of the orbits, and with one another, in the state of rest. Under the muscular influence, which is called into play when the eyes are used, this parallelism is destroyed, and the optic axes are then made to converge upon the object we are examining.

Their inner surfaces.

The surfaces of the orbits are not marked by many foramina for blood-vessels; they are smooth, and the periosteum is loosely connected with them. In performing operations within the orbit it is well to bear this in mind, as also the position of the fissura lacera and its direct communication with the cerebral cavity, for fatal results would be likely to follow too free use of the knife in this direction.

The contribution by the palate-bone.

Of the seven bones—the frontal, æthmoid, lachrymal, sphenoid, superior maxillary, malar, and palate—which enter into the orbit, the last forms by far the smallest part. Indeed we are disposed to wonder at its appearance there at all, so constantly, and yet making so very small a contribution to the wall of the cavity. We find it forming a much more important constituent in the orbit of carnivorous and graminivorous animals. In them it projects in front of the sphenoid, between the frontal and maxillary bones, so as to occupy, more or less, the place of the os planum of the æthmoid, which disappears from the orbit in many quadrumana and in most of the carnivora[1].

Varieties in size and shape.

Although there is some difference in the shape, there is not much difference in the size of the orbits in the different races of mankind. It is, moreover, remarked by Mr Shaw[2], that "whether we take the rickety skull, that of the standard size, or that of the giant, the diameters of the orbits measure the same in all." This uniformity corresponds with that of the size of the eyes; and in fœtal and early life the orbits are large, which has relation to the early development and growth of the eyes. With regard to the differences of shape manifested at birth and in the adult, see Pl. XV. figs. 3 and 4, with the description.

THE NASAL CAVITIES

serve three chief purposes. *First*, they are the channels through which, under ordinary circumstances, air passes into the lungs. *Secondly*, they minister to the sense of smell. *Thirdly*, they give tone and fulness to the voice. A certain portion of them is, more particularly, devoted to each of these functions.

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1 In most carnivora the palate-bone extends as far forwards as the lachrymal bone. The latter is also much more largely developed in them and some other animals than in man. In many of the rodentia, however, the palate-bone does not enter into the formation of the orbit at all.

2 *Medico-Chirurgical Transactions*, XXVI. p. 353.

The respiratory tract.

The part beneath the middle spongy bone of each nostril, that is the two inferior meatus narium, lies in a direct line between the anterior and posterior openings of the nostril, and forms the channel for the passage of air to and from the lungs. It is open in its whole length; and, the floor of the nostril being smooth, there is nothing to obstruct the current of air here, except when the soft palate is placed in contact with the hinder surface of the pharynx during the act of swallowing. These two lower meatus are lined by a vascular, highly sensitive, mucous membrane, interwoven with the periosteal tissue; but it appears that the olfactory nerves reach them in very scanty numbers, if they do so at all. Accordingly, the sense of smell, though not entirely absent, is not present in this—the respiratory—tract of the

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DESCRIPTION OF PLATE XIII.

Fig. 1. Double cleft palate from a man. *A*, the vomer descending obliquely downwards and forwards from (*B*) the sphenoid bone. It does not reach the level of (*C* and *D*) the palatine processes of the palate and maxillary bones till near the alveoli; consequently the cleft, though double in front, is single behind. *E*, the intermaxillary bones, consisting of mere strips of bone united to one another in the median line and to the vomer behind by sutures. They project in front of the line of the alveoli and carried a piece of lip on their anterior extremity which was near the tip of the nose, but no teeth. The nasal bones (*FF*) are seen through the fissures on the sides of the intermaxillary bones. 1, place for the third molar tooth, which has not appeared; 2, second molar; 3, socket for first molar; 4 and 5, bicuspides; 6, canine; 7, a supernumerary canine tooth, of cylindrical shape, which stands at the fore part of the maxillary alveoli. On the opposite side there is a socket (8) which was occupied by a similar tooth; there is also (9) a milk-tooth remaining between the anterior bicuspid and the canine. The free margins of the palatine processes are thin, notched and curled a little downwards.

Fig. 2. Side view of nasal fossæ. *A*, cut surface of basilar process of occipital bone; *B*, posterior clinoid process; *C*, anterior do.; *D*, sphenoidal sinus of right side; *E*, do. of left side, with partition projecting into it—a bristle runs from this sinus through the opening into the upper meatus narium; *F*, ridge of æthmoid; *G*, cribriform plate of do. with grooves descending from it to *H*, the upper, and *I*, the middle spongy bone; *K*, the suture between the æthmoid and frontal; *L*, the suture between the nasal and the frontal—the bristle is passed through the passage from the frontal sinus into the middle meatus narium; *M*, lachrymal bone; *N*, unciform process of æthmoid; *O*, inferior spongy bone, with opening into antrum above it; *P*, intermaxillary bone; *Q*, sutural line between it and maxilla; *R*, suture between palatine processes of palate and maxillary bones; *S*, do. between palate and internal pterygoid portion of sphenoid; *T*, spheno-palatine hole.

Fig. 1.

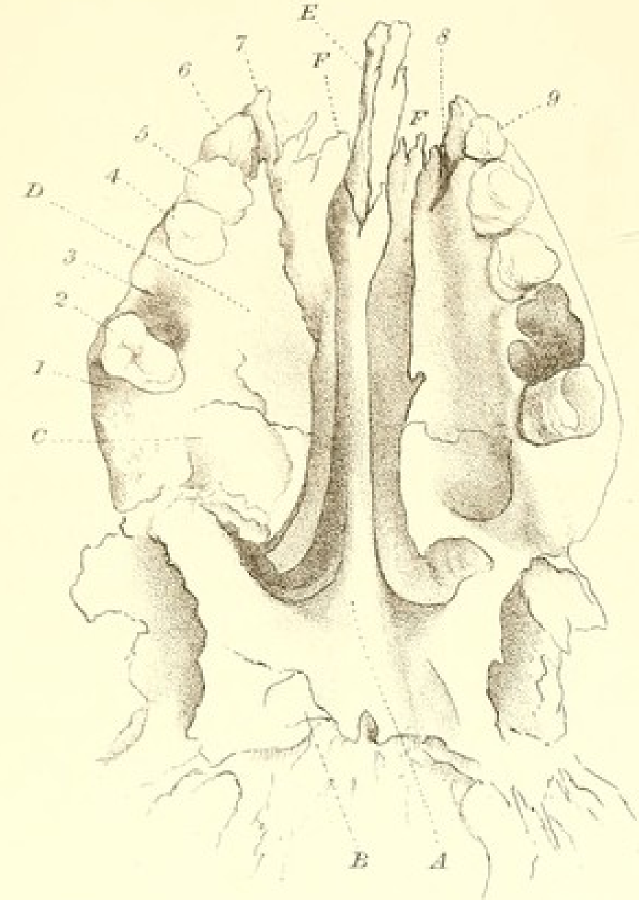
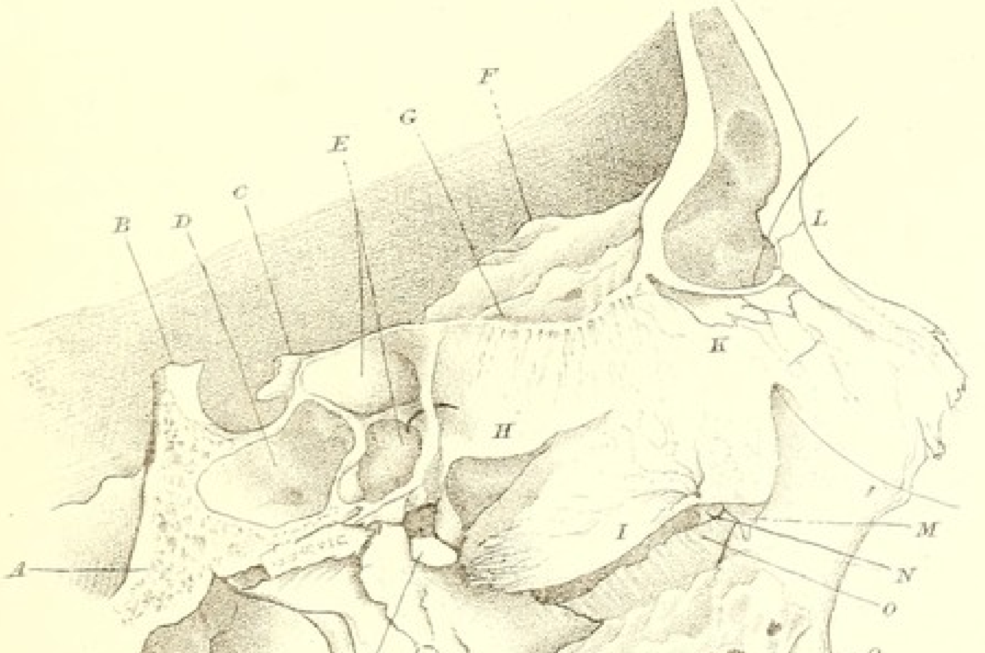


Fig. 2.



nostril, in any very acute degree. The inferior spongy bone hangs curling into it, so disposed that the current of air passes along both its inner and its outer surface.

How kept moist. The spongy bones present a remarkably uneven, channelled appearance; and the grooves upon their surfaces indicate the contact of the large vessels that ramify in their mucous covering. These vessels consist of dilated channels, intermediate between the arteries and the veins; they are circumstanced somewhat like the vessels of the malpighian corpuscles of the kidneys, and like those of the tufts of the choroid plexuses of the cerebral ventricles; and they appear to serve a similar purpose with them. They afford, namely, a facility for the more watery constituents of the blood to ooze through their walls upon the surface of the membrane in which they lie, which has the effect of keeping it moist. Were it not for some provision of this kind, the interior of the nostrils would be dried by the continual passage of air through them, and would be unfit to minister to the ordinary sensations of the part, as well as to that perfection of the sense of smell which is possessed by it. This arrangement, it should be said, is not confined to the lower regions of the nostrils, for the same exists higher up, where the olfactory properties are most developed. So effectual is this provision, that, in the healthy condition of the membrane, respiration through the nostrils may be continued for hours without any inconvenient dryness being perceived; which is not quite the case with regard to the mouth, as will be testified by persons who are in the habit of sleeping with the mouth open. When they awake the mucous membrane of the mouth is dry, causing discomfort and an inability to taste, or even to articulate properly, till the secretions are restored and the mouth is again moistened by a flow of saliva and mucus. Moreover, the air, becoming moistened in the nostrils and in the rest of the respiratory tract, is more fitted to perform its part in the work of respiration. The great importance of the secretion of these membranes in imparting moisture to the respired air is shown by certain diseases accompanied with fever, in which their secretion is more or less suspended; the quick breathing, the lividity of face notwithstanding the acceleration of the respiration, and the liability to inflammation of the lungs, which are attendants on such condition, being, in all probability, due, in part at least, to the dry state of the respiratory tracts. The drainage of the tears also, taking place through the lachrymal duct, which opens near the fore part of the inferior meatus, where the flow is directed by the shape of the bones backwards along the floor of the nostrils, contributes to keep this part moist.

The dilated vessels a safety-valve to cerebral circulation.

A further purpose served by the dilated, tortuous, delicate character of the vessels distributed in the loose and comparatively unsupported membrane which covers the overhanging spongy bones is, that they serve as a sort of safety-valve to the circulating system; they give way more readily than any other vessels when that system is surcharged with blood, and, allowing a certain quantity to escape, restore a proper balance, and so prevent an eruption in other parts where it might be more serious. In an especial manner do they minister in this way to the brain, placed, as they are, in close relation to it, and having a direct communication with its longitudinal sinus through the vein which traverses the foramen cœcum, besides their various indirect communications with vessels passing through the æthmoidal holes and the internal orbital foramina. Supposing the pressure of the blood to be increased in an equal degree in the vessels throughout the head, either by hanging the head down, by obstruction to the venous trunks, or, which amounts to the same thing, by the rarefaction and diminished pressure of the air, such as is experienced by travellers in ascending mountains, we should infer that the dilated, unsupported vessels of the schneiderian membrane, lying upon these projecting spongy bones, would give way in preference to the vessels of the brain, which derive a uniform support from the nature of the material by which they are surrounded and the closed cavities in which they are contained. And this is the case; blood being found to flow from the nose under these and other circumstances of the like kind. Many an attack of congestion of the brain and apoplexy has been warded off by a nose-bleeding. Indeed it is probably owing to this safety-valve afforded by the nose, and to the peculiar conditions in which the vessels of the brain are placed, that they rarely give way unless they have become diseased.

Foreign bodies arrested.

The spongy bones projecting into the nostrils assist, in some degree, to arrest the progress towards the larynx of foreign bodies that may be floating in the air; but in this office they are quite secondary to the hairs, which guard the external orifice so effectually that only very minute bodies find an entrance at all. Every now and then, as we walk along with the mouth open, a fly is carried into the larynx and excites a violent and irresistible fit of coughing; but this rarely happens if the mouth be closed. Of those bodies which do succeed in passing the capillary guardians of the nostrils, some, if in a very subdivided form, and inhaled incautiously, are carried into the larynx. Thus a pinch of fine snuff generally causes the uninitiated to cough. When the taker has learnt more caution, or has acquired by practice a better mode of inhaling, he contrives to direct the current towards the upper part of the nostril, where the fine particles are caught upon the moist membrane which is disposed over the irregularly-shaped walls of the passage, and where they excite the desired sensation by their contact with the schneiderian mucous tissue, instead of causing annoyance by being wafted into the larynx.

The blood circulating in the nostrils oxygenated.

In its passage through the nostrils, the air not only abstracts moisture from the blood, it has the effect of purifying and decarbonizing that fluid circulating in the vessels of the schneiderian membrane in some slight degree. So that the nostrils may be regarded as constituting an extension of the respiratory tract on this account, as well as from their affording channels for the passage of air to and from the lungs.

Floor of the nostrils sloped so as to direct secretions backwards.

A section of the skull shows that the bone forming the septum between the nose and the mouth is thick at the fore part, where it consists of the alveolar portions of the intermaxillary bones, and that it gradually decreases in thickness from this point to its hinder palatine margin. The slope thus given to the floor of the nostrils, considerably increased by the integumental and other structures which clothe the anterior openings, facilitates the passage of mucous and other secretions in a backward direction, so that they flow over the soft palate into the pharynx instead of streaming upon the face. Thus the shape of the bones at this part aids the ciliæ of the epithelial coat of the nostrils in directing the passage of the mucus in the most convenient and agreeable manner. These ciliæ, which are found upon the whole of the mucous membrane of the nose, including its supplemental cavities, with the exception of a small space near the external orifice, are probably the chief agents in conducting the secretions of the membrane in the requisite direction; and in some places, as the maxillary sinuses, they would seem to be the only powers concerned in the process.

The olfactory tract.

The superior and middle spongy bones and the contiguous laminæ of the æthmoid are the parts upon the mucous covering of which the olfactory nerves are chiefly distributed. The more delicate impressions of smell may be perceived to take place in this region of the nostril, which is so placed, above the line between the anterior and posterior openings of the nose, that in ordinary easy breathing not much air enters into it, and no acute sensations of smell are excited. The perception of odours aroused by the air in its passage through the lower meatus of the nose is sufficient to warn us against noxious effluvia, &c. but is not of that finer quality which results from the impressions made in the higher part of the nostrils. Accordingly, when we desire to bring the sense of smell more particularly into operation, we contrive to direct the current into the upper part of the nostrils by increasing the blast through them. This we do in two ways. First, by a succession of sharp, short inspirations. Secondly, by compressing and modifying the shape of the external orifices of the nose. A similar effect is produced by placing any foreign body in front of the nose, which partially obstructs the entrance of the air, and which, interfering with the slow regular current through the lower part of the nostrils, causes more blasts and more eddies and currents through the various upper chambers of those cavities. Thus we are often first conscious of an odour in the air when we place a handkerchief over the face for the purpose of blowing the nose. It has been found by experiment that the insertion of a tube into the nostril interferes very much with the sense of smell. Doubtless it does so, in great measure at least, because it destroys the power we possess, through the medium of a flexible and muscular external orifice, of regulating the blasts and directing the currents of air into the upper chambers of the nose. So that these nasal cartilages and the muscles connected with them perform for the organ of smell an office somewhat similar to that which the iris performs for the eye and the muscles of the membrana tympani for the ear.

Sense of smell not excited by expiratory current of air.

It is worthy of remark that the sense of smell is excited in a comparatively very slight degree during expiration, although the same air which had just entered by the nostrils, and had reached probably no further than the trachea, is immediately returned through them. This want of appreciation of returning odours may result, either from the shape of the nostrils and their respective orifices being so arranged as not to direct the expiratory current into the upper chambers of the nostril; or from an entire absence of any means of regulating the blast at the posterior openings; or from some particular mode of arrangement and disposition of the nerves; or from two, or more, of these causes combined.

Part in which smell is most acute.

Judging from my own sensations, I should say that the part of the nostril in which the sense of smell is most acute corresponds with the anterior portion of the middle spongy bone. This accords with the facts that the olfactory nerves have there broken up into their finest subdivisions, and that the membrane which covers that bone is very vascular. It will be seen also that the inferior surface of the middle spongy bone, the part of it, namely, which hangs lowest in the nostril, is, in front, flattened out so as to increase the surface exposed to the current of air, and is much marked by grooves and holes. This part is often greatly developed in monkeys. Its situation in man is better adapted to the purpose of ministering to the sense of smell than any other part of the nostril, being just above the direct line of the ordinary current of air to and from the lungs, yet so near to it that a very slight effort is required to direct the blast upon the bone. The disposition of this bone may also assist in further explaining the circumstance just now referred to that the sense of smell is excited very imperfectly or not at all by the expired air; for its lower edge is slanted from behind forwards and upwards; so that its hinder bulbous portion, hanging the lowest, must, to a very considerable extent, shelter the fore part, where the olfactory sense is most acute, from the expiratory current. The lower spongy bone presents the same shape and obliquity, though in a less marked manner. I need scarcely say that this provision for protecting the fore parts of the bones from the expiratory current will have a corresponding effect in exposing them to the air as it passes in the opposite direction.

The vocal tract.

The further office which the nose performs, namely, that of contributing to the proper modulation of the voice, depends in great measure upon the various cavities and *sinuses* contiguous to the nasal fossæ. It is of less importance than the other functions to which the organ is subservient: and it is not strictly correct to say that any part is especially assigned to this work; for though all the meatus and cavities of the nose combine to give the desired tone to the voice, none are constituted primarily for that purpose, there being an evidently more useful intention fulfilled by the formation of each. Thus the lower part of the nostrils—the region of the inferior spongy bone—ministers primarily to the function of respiration, as the higher part—the region of the middle spongy bone—does to the sense of smell; and the supplemental cavities—the maxillary, frontal, sphenoidal, and the æthmoidal sinuses—are manifestly excavated for the chief purpose of diminishing the weight of the fore part of the skull.

Use of the contiguous sinuses.

These *facial* or *nasal sinuses* are filled with air, because their situation, in close proximity to the nasal fossæ, affords a convenient means of supplying them with air, which is lighter than oil, and because the air contained in them contributes to the modulation of the voice. It is clear that they can have no particular influence upon either respiration or the sense of the smell, because they are removed from the respiratory current, and because the olfactory nerves do not reach them; neither are they supplied with very acute sensation of any kind. The orifices by which they communicate with the nasal fossæ, though of moderate size in the dry bones, are so much diminished by the mucous membrane they transmit, that they are only large enough to permit air to pass to and fro for the purposes of ventilation. These sinuses are not found, or are very diminutive, in the lower animals, many of which breathe entirely by the nostrils, and their sense of smell is generally more acute than in man. It has been supposed that the sinuses minister to the sense of smell, because they attain their maximum size after childhood, when the powers of distinguishing odours is also becoming more acute. It should rather be said, that their development is contemporaneous with the downward growth of the facial bones. In proportion as this goes on, and the vertical distance between the alveoli and the cranium is increased, so are the sinuses excavated to lessen the gradually preponderating weight in this part of the skull, and to maintain a near approach to equilibrium between the regions in front and those behind the occipital condyles. This vertical direction of the face, and the consequent formation of the sinuses, have, as we have already seen, relation to the erect posture of man; and they have relation also to the fact that the jaws are confined to the work of mastication, and are not employed as prehensile or defensive organs. For, when the jaws are thrown forwards to serve the latter purposes, the alveoli of the superior maxillary bones do not descend below the level of the base of the skull; and there is, accordingly, no space afforded for the formation of the sinuses. In those negroes, whose crania approach most nearly to the animal type, the sinuses are also comparatively small.

Direction of the opening of nostrils.

Another peculiarity of the human nose, which also has relation to the vertical direction of the face and the consequent vertical depth of the nasal cavities, is the position of the anterior opening of the nostrils. Instead of being carried forward with the mouth, and looking either upwards or straight forwards, or forwards and outwards, at the end of the snout, they are, directed downwards and overhang the mouth.

The bridge of the nose.

The elevation of the bridge of the nose, which forms so important a feature in the human face, results from the oblique direction of the nasal bones, and from their inner or apposed edges being elevated beyond the level of their outer or maxillary margins. The projection of the nose forwards is caused, in part, by the angle of junction of the nasal with the frontal bones, and in part by the antero-posterior curvature of the nasal bones in the course of their length. Both the prominence of the bridge and the forward direction of the extremity of the nasal bones, as well as the downward direction of the external orifices of the nostrils, are designed to increase the space in the upper chambers of the nose, and to assist in giving an upward direction to the current of air into those chambers. In the lower animals, where the antero-posterior diameter of the nose is increased at the expense of the vertical diameter, no such arrangement is required. The bridge is, in consequence, flattened, and the nostrils open forwards, or forwards and outwards.

Changes with growth.

At birth, when the face is very short, the nostrils are little more than mere tubes directed from before backwards; and the nose is flat and broad, approaching to the animal type. As the face grows downwards, the nose becomes elongated in the same direction, its bridge is thrown forwards, and it becomes relatively narrowed. The different degrees in which these changes occur give rise in part to the varieties of shape observed in different individuals. They take place in a less marked manner in the negro and Polynesian than in the European; and when carried to the greatest extent they give rise to what is called the Roman nose. The larger space provided to the nasal cavities by them permits the more perfect development of the organ of smell; and the supplemental nasal cavities are at the same time formed. The septum often does not preserve a true vertical direction, being inclined, in its middle, towards one of the maxillæ. This is usually associated with an inordinate growth of the middle spongy bone which lies on the concave side of the septum; and when mucous polypi are formed they commonly grow on this side.

DISTINCTIVE PECULIARITIES.

The great proportionate size of the cranial to the facial part is the grand characteristic of the human skull; and it corresponds with the superior power which man possesses of appreciating external impressions, of comparing them, and drawing inferences from them. In many of the lower animals the capability of receiving impressions is far greater than in man, but by none is the power of turning them to account, that is, of deriving information from them, possessed so fully as by him. This more than compensates for any inferiority in his receptive organs; and it is, as we might expect, associated with a greater nicety in the perception of impressions, though these perceptions may be less strong and vivid: just as his volitional control over the movements of his limbs is more direct and exact, though the movements themselves are less powerful than in many of the lower animals. Thus the superiority of the brain much more than makes amends for any inferiority of the sensational and muscular organs, and enables man to maintain the dominion over the brute creation. We must not, however, allow this train of thought to lead us to the idea that the well-developed *physique* is in man not compatible with a well-developed brain and with a powerful intelligence, or to the supposition that these do not naturally co-exist. Such would be an entire mistake. On the contrary, we have found from an examination of the several varieties of the human species (page 93), that a high order of intelligence and a well formed powerful frame usually go together; and, it may be added, that to the perfect man a full-sized face and well-developed limbs are almost as essential as an ample cranium. The important point is, not that the senses should be deficient in acuteness or the muscles in power, but that the brain should be vigorous to collate and reflect upon the impressions derived from the former, and to direct with precision the movements to be executed by the latter. The accurate observers and thoughtful delineators of the human frame in olden times were well aware of this, and represented their sages, as well as their heroes, with fine faces and well-formed limbs, no less scrupulously than with rising foreheads.

Distinctive peculiarities of human and chimpanzee skull.

I have several times had occasion to remark on certain approximations to the lower animals which are presented by the bones of some members of the human family. Some of these are striking and interesting, as softening down the line which separates man from other animals. Still they do so in a slight degree only; for it is certain that the differences between the skulls of the several races of men bear no comparison with those which exist between the skull of the lowest of the human species and that of the animal which approaches nearest to us. A mere glance at the two is enough to assure one of that. It is impossible for a moment to compare the skull of a negro, or even that of an idiot, which latter will be found to exhibit generally the peculiarities of the race to which it belongs, with the skull of the chimpanzee or orang, without feeling convinced that they must appertain to entirely different species; so marked in the monkey is the projection of the muzzle, the preponderance of the facial in comparison with the cranial part of the skull, and the position of the latter, not above, but behind the face. Professor Owen has pointed out several other distinctive peculiarities in the chimpanzee, such as 1. The "diastema" or interval between the cuspidate and incisor teeth in the upper jaw, and between the cuspidati and bicuspides in the lower jaw. 2. The greater size of the intermaxillary bones, indicated by the distance of the foramina incisiva from the incisive teeth, and their remaining distinct from the maxillary bones. 3. The more backward position and oblique plane of the occipital foramen. 4. The smaller proportionate size of the occipital condyles. 5. The larger proportionate size of the petrous bones. 6. The greater proportionate development of the jaws and teeth, particularly the cuspidati. 7. The flatness of the nasal bone, which is rarely divided in the mesial line. 8. The presence of the ant-auditory process of the temporal bone, and the absence of the mastoid and styloid processes. 9. The absence of the crista galli. In the orang utan, which is a grade lower than the chimpanzee, though the sphenoid joins the parietal, which it does not in the latter animal, there are two anterior condyloid, and three, or more, infra-orbital foramina; the cranial sutures become obliterated, but the maxillo-intermaxillary are more persistent; the jaws are proportionately larger; the sagittal crest is more, and the superciliary ridges are less, developed. Its facial angle[1] is 30°; that of the chimpanzee is 35°. It may be observed that the young of these animals approximate more nearly to the human type than do the adult specimens, which results, in part, from the fact that in them, as well as in the child, the brain, and consequently the brain-case, is of large proportionate size, and, doubtless, for the same reason (page 94).

Infantile cranium.

In some respects the skull of the human infant presents a nearer resemblance to the skull of the lower animals than does that of the more advanced child or the adult: such as the existence of the frontal suture; the large relative size of the petrous bone, and the small size of the occipital condyles; the absence of the mastoid and styloid processes; the small size or absence of the frontal, sphenoidal, maxillary, and mastoid cells; the shortness and obliquity of the pterygoid processes of the sphenoid, and the obtuseness of the angle of the lower jaw. These, however, are merely to be ranked among the many indications that a common

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[1] The *facial angle* is formed by a line—the *facial line*—drawn from the most prominent part of the frontal bone so as to intersect, at the fore part of the face, a horizontal line drawn through the lower part of the nose and the orifice of the ear. Having been first used by Camper in discriminating the difference of faces, it is called Camper's angle. (Camper's *Works*, by Cogan, 1794, pp. 33, 36.) Camper makes the facial angle in the Negro 70°, in the European 80°. He says the Grecian artists chose 100°, the best Roman artists limiting themselves to 95°. If it exceed 100° it assumes the appearance of hydrocephalus. The antique adult beauty thus represented with a facial angle of 100° seems an "ideal beauty" not existing among moderns, and probably not among the ancient Greeks themselves, for they have never given such a form when they simply aimed at delineating portraits. In a child of a year old Camper makes the facial angle 95° or 100°. Cuvier, *Leçons d'Anatomie Comparée*, gives the following measurements of the facial angle:

European, infant	90°
European, adult	80°
Negro, adult	70°
Bosjesman, female	71°
Orang-utan (young)	67°
Orang-utan (adult)	40°
Chimpanzee (young)	67°

plan has been adopted in the construction of the vertebrate classes, and that the different species are made to depart from it, by modification of its several features during development, so as to fit the various members for their respective positions and functions in the natural world.

Skulls of varieties of mankind.

On the peculiarities of the skull in the different varieties of mankind, I do not profess to have anything new, or any opinions of my own, to offer. The subject has received great attention at the hands of Blumenbach, Tiedemann, Retzius, Van der Hoeven, Owen, Pritchard, Carpenter, and others, so that I have not attempted to make many observations for myself in this well-worked field, and am content to draw the following information, often in the words of the author, from an excellent article by the last-named writer on the "Varieties of Mankind" in the *Cyclopedia of Anatomy*.

An examination of a large collection of skulls enables us to select three *typical* forms[1], which are—(1) that of a Negro of the Guinea Coast or a Negrito of Australia, the most marked feature of which is the projection of the jaws; hence this *type* is called by Dr Pritchard the *prognathous:* (2) that of a Mongolian or Tungusian of central Asia, or of an Esquimaux or Greenlander, which is marked by the breadth and flatness of the face; this, with the narrowness of the forehead, gives to the facial aspect somewhat of a *pyramidal* form, which is the designation applied to this type by Dr Pritchard: and (3) that of a native of Western or Southern Europe, which is not distinguished by any particular feature, so much as by the absence of the longitudinal

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DESCRIPTION OF PLATE XIV.

Copied from *Cyclopedia of Anatomy* (Art. "Varieties of Mankind").

Figs. 1, 2, 3. Prognathous cranium of a native Australian of the Western Port tribe.

Figs. 4, 5, 6. Pyramidal cranium of Mongolian race.

Figs. 7, 8, 9. Elliptical cranium of European.

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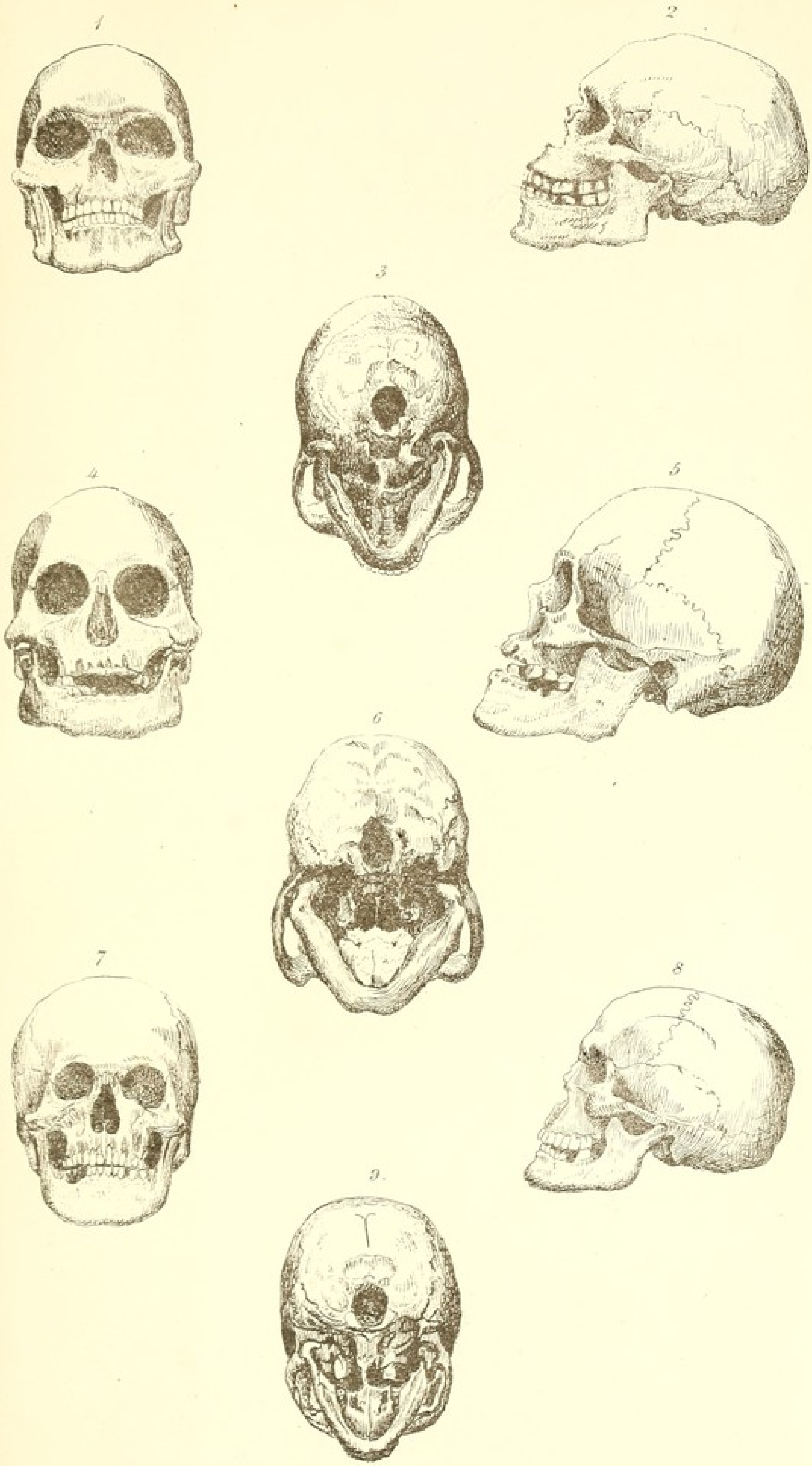
[1] Dr Monro remarks: "There is no part of the human skeleton which is more variable in its shape and the proportion of its several parts, than the skull, even amongst the inhabitants of the same nation." *Outlines of Anatomy*, I. 183.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projection of the first type or the lateral projection of the second, and by a general symmetry of the whole configuration, which has given to this type the name of *oval* or *elliptical*.

Prognathous type. It is the prominence of the jaws, as seen in profile, that gives the peculiar ugliness to the Negro and Australian. In both jaws the alveolar ridges project so that the front teeth meet at an angle. Moreover there is an appearance of general elongation of the cranium from back to front, so that the antero-posterior diameter is greater in proportion to the lateral than it is in the oval cranium; being, according to Van der Hoeven, 6.96 inches to 5.11 inches; or as 1.36 to 1.00: whereas the average length of the European skull is 7.04 inches and the breadth 5.47, or as 1.30 to 1.00. It will be observed that this depends rather upon the relative narrowness than the elongation of the Negro cranium; for its absolute length is less than that of the European. The temporal muscles cover a large surface, and rise high upon the parietal bones; and the zygomatic arch has a large opening, which is given by a forward rather than a lateral projection of the cheek-bones. The forehead is sometimes high; but seldom or never broad or full. When due allowance is made for the projection of the alveolar processes, the position of the foramen magnum has been shown by Dr Pritchard to be as central in the Negro as in the other races, its anterior border being immediately behind the transverse line bisecting the antero-posterior diameter of the base of the cranium. The average capacity of the Negro cranium is decidedly less than that of the European. On the other hand, the facial portion is not only relatively but actually larger. The nose is wider; the external auditory meatus is remarkably large; the orbits, though sometimes larger, are sometimes smaller than in the average of Europeans.

The prognathous type, although most remarkably developed among the negroes of the Delta of the Niger, is by no means confined to them nor to the African races in general. It is met with among the inhabitants of various quarters of the globe; but is nearly always associated with squalor and destitution, ignorance and brutality, the people among whom it prevails being, for the most part, inhabitants of low marshy tracts, with precarious means of subsistence.

Pyramidal type. The outward projection of the zygomatic arches forms the most striking feature in the *pyramidal type* of cranial conformation. It is due principally to the peculiar form of the malar bones, the facial surface of which is very broad and flat, but partly also to the large rounded sweep of the zygomatic process of the temporal bone. From this peculiarity, in conjunction with the narrowness of the forehead, it results that lines drawn from the zygomatic arches, touching the temples on either side, instead of being parallel, or nearly so, as in Europeans, meet at no great distance above the forehead, and form, with a line joining them below, a triangular figure. The upper part of the face being remarkably flat, the nose also being flat and the nasal bones, as well as the space between the eyebrows, being nearly in the same plane with the cheek-bones, the triangular space bounded by these lines may be compared to one of the faces of a pyramid. This, however, is by no means the most important feature of the type, for the antero-posterior diameter (according to the average of sixteen Laplanders' skulls measured by Retzius) is only 6.90, while the average breadth is 5.78 inches. The orbits are deep and large; and the conformation of the bones which surround them is such as to give the aperture of the lids an appearance of obliquity, the inner angle being directed downwards. The lower jaw is broad.

The greater part of the races representing the pyramidal type in a well-marked manner may be designated as pastoral nomades.

Oval or elliptical type.

The *oval* or *elliptical type* has the length of the Negro, or more, and the breadth of the Mongolian. It is particularly distinguished by the lateral fulness, as well as by the elevation, of the forehead; the breadth continues to increase above the orbits, and the cranial vault is rounded and capacious; whilst in the other two the breadth diminishes rapidly, especially in the frontal region, from the floor of the orbits upwards. The zygomatic arches do not project much laterally, nor the jaws in front. The front teeth are fixed nearly vertical. The cranial cavity is of large size[1].

Modifications of types.

Although certain specimens present the above characteristics in a well-marked manner, it must be added that these *typical forms* are softened down in intermediate gradations, so as to

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[1] The length of the skull and jaws is an indication of the degree of development of the posterior cerebral lobes and of the extent to which they overlap the cerebellum. This being a main distinction between man and the mammalia most nearly approaching him, must be a feature of great importance in the different varieties of the human species. Professor Retzius has accordingly made the length of the skull the basis of his ethnological classification, and arranges the different varieties of mankind in two great

present a continuous series from one type to another, in which no such hiatus is left as would justify the assumption of the specific distinctness of these types. Moreover it appears that very great modifications are capable of being produced in a few generations by external causes, such as geographical position, habits of life, &c.; thus it is found that when a Negro or Mongolian tribe becomes civilized, and inhabits a dry cultivated tract, the crania of its members begin before long to indicate symptoms of an approximation to the European type.

It is also highly probable that the distinctive features of the several types are less strongly marked in the fœtal than in adult crania of the several tribes. I do not know that this has been made a matter of observation; but it is a reasonable inference from what has been said respecting the approximative features of the young crania of man and of the lower animals, as well as from the general fact, that distinctive peculiarities are in great measure the result of growth.

Skull at birth. The peculiarities of the skull at birth may be briefly enumerated as follows. Its relative size is great. It is long from the forehead to the occiput in proportion to its breadth. Nevertheless, it is broad from one parietal protuberance to the other in proportion to its height, the measurement from the crown to the base being small. The facial and basilar portions are

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classes: the *long-heads*, or those whose cerebral lobes completely cover the cerebellum; thus giving an anatomical sanction to the meaning commonly implied in the term "long-headed;" and the *short-heads*, or those in whom the cerebral lobes do not extend so far. He subdivides the classes as follows:

CLASS I.—DOLICOCEPHALÆ.

Ord. 1. *Orthognathæ*. Gauls, Celts, Britons, Scots, Germans, Scandinavians.

Ord. 2. *Prognathæ*. Greenlanders, various North and South American Indian races, such as the Caribs, Botoculi, &c. Negroes, New Hollanders.

CLASS II.—BRACHYCEPHALÆ.

Ord. 1. *Orthognathæ*. Slavonians, Finns, and other Tschudisch races, Affghans, Persians, Turks, Lappes, &c.

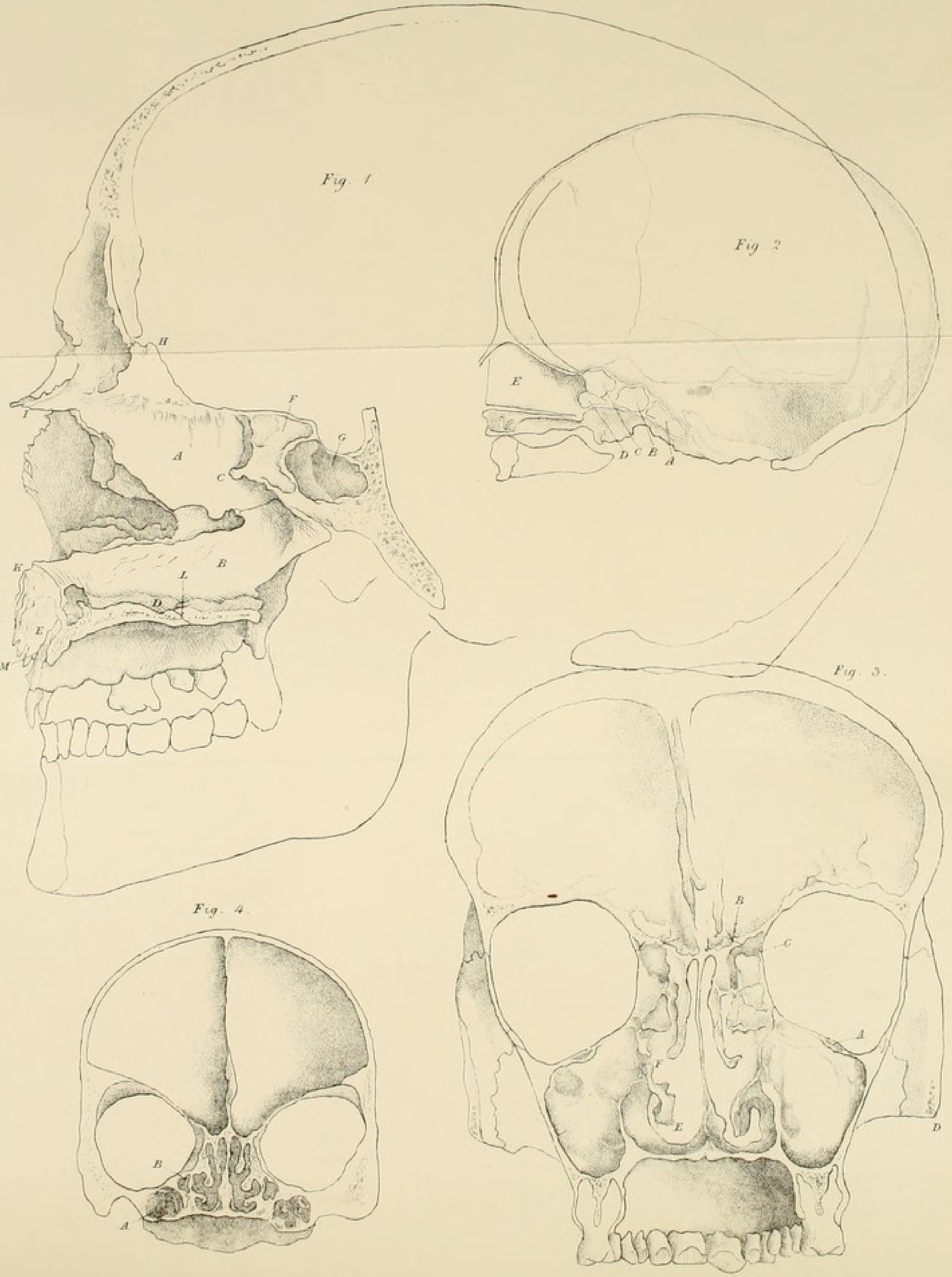
Ord. 2. *Prognathæ*. Tartars, Kalmucks, Mongols, various North and South American races, such as the Incas, Carruas, &c. Papoes.

British and Foreign Medical Review, XVIII.

Mr Ward has made experiments showing that in the Esquimaux, Chinese, African, and Flat-head Indian, the anterior segment of the cranium is less capacious than the posterior; while in the German, Hindoo, and Grecian, these proportions are reversed. *Human Osteology*, p. 154.

of small size in comparison with the remainder. The edges of the component bones are only just in contact, the sutures having scarcely begun to be formed. The only part in which any indigitation has commenced is between the two halves of the frontal bone. In the temporal fossa the overlapping of the parietal by the squamous bone has not commenced, the edges of the two being merely in apposition. The brain is covered in by bone, except at the fontanelles. It has thus acquired a case of bone; but that case is yielding in consequence of its segments not having grown together; and its interior is not impressed by the cerebral convolutions, the digital depressions not appearing till after the bones are united. The frontal and parietal protuberances are strongly marked. The under surface of the skull is almost flat; the several parts, including even the lower jaw, being nearly on a level with the base: it has, however, a slight convexity in a transverse direction, which gives a trifling elevation to the inner sides of the glenoid cavities. In the course of growth the direction of this transverse curve is reversed, the base becomes concave instead of convex; the jaws also gradually descend considerably in front, and the occiput descends a little behind the middle point. The membrana tympani is, at birth, attached to the ring-like tympanic bone, and is placed very obliquely, almost horizontally. This obliquity diminishes, but remains through life in some degree. The tympanic bone being very small, and the styloid and vaginal processes being not yet formed, there is not much protection against dislocation of the jaw backwards from the glenoid cavity. That cavity presents nearly a plane surface, being very little excavated, and the ridge which traverses its fore part not being yet developed; its long axis is nearly transverse. The pterygoid processes of the sphenoid bone are short and sloped obliquely outwards and forwards; hence the posterior openings of the nostrils are proportionately less deep and rather wider, especially at the lower part, than they subsequently are when these processes have grown longer, and have assumed a more vertical direction. The occipital condyles are scarcely perceptible; and their articular surfaces are nearly flat, on a level with the surrounding parts, and of small size. In consequence of the face and base of the skull being so

Plate XV.



small, the condyles are placed rather in front of the line of gravity. The child accordingly cannot easily maintain an equipoise; and the head is continually falling forwards or backwards, or to one side. Had the condyles been at all prominent, the difficulty of

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DESCRIPTION OF PLATE XV.

Sections of Crania from New-born Child and from Adult.

Fig. 1. Vertical section of adult cranium, a little to the left of the median line, showing the septum nasi, the linear junction of middle plate of the æthmoid (*A*) with the sphenoid (*F*) and with the vomer (*B*). The upper free edge of the latter is grooved for the reception of the cartilage of the septum nasi. *C* the projecting rostrum of sphenoid received into a retiring angle of the æthmoid. *D* is the ridge rising above line of union of palatine portions of palate and maxillary bones of either side. A wavy linear suture unites it with vomer. *E* the suture between palatine portion of maxillary bone and the intermaxillary bone (*K*). It is continued above into the suture between intermaxillary bone and vomer. There are two sphenoidal sinuses, of which the left (*F*) communicates with the left nasal fossa and extends across the middle line; the right (*G*) communicates with the right nasal fossa and also extends across the middle line behind the other. Consequently the section has passed through both sinuses. There is no communication between the two sinuses. *H* the crista galli; in front of it is the suture between the æthmoid and the frontal. The foramen cœcum is on the other side of this suture. *I* the suture between the middle plate of the æthmoid and the hinder surface of the nasal bones. *L* suture between palate and maxillary bones. *M* the anterior palatine foramen.

Fig. 2. Corresponding section at birth, showing the contrast of relative proportions between cranial and facial parts in it as compared with fig. 1. *A, B, C, D* are sections respectively of basilar portion of occipital bone, of the posterior and anterior parts of body of sphenoid, and of the vomer. The latter is situated at this time beneath the anterior portion of the sphenoid, whereas in the adult (fig. 1) it is beneath the hinder portion of that bone, and is directed more downward.

Fig. 3. Vertical section from side to side through fore part of skull, just behind margins of orbits and through the first molar tooth on either side. It is seen from behind; shows the shape of the orbits, the antra and the nasal fossæ. The section is just in front of the upper spongy bone, so that the two lower ones only are seen; above the point from which the inferior one (*E*) hangs is the opening of the antrum *F*. *A* is the slit-like infra-orbital canal. *B* the suture between the frontal and the cribriform plate of the æthmoid. *C* ditto between the frontal and os planum of the æthmoid; the cerebral and orbital laminæ of the frontal bone form respectively the upper part and side of the superior æthmoidal cell. The edge of the vomer rests upon the palatine process of one maxillary bone close by the palatine suture. *D* the cut surface of the malar bone.

Fig. 4. Corresponding section at birth, showing contrast in proportionate size of cranial cavity, orbits, sockets for molar teeth (*A*), and antra (*B*). The latter are quite diminutive cavities between the large molar sockets and the inner sides of the

maintaining a balance would have been still greater. The various processes and ridges are not developed. The orbits are comparatively large; their lower edges are more prominent, and their upper or superciliary edges less so than at a later period; their roofs are comparatively flat, and their floors concave. The sinuses of the frontal æthmoid, sphenoid, and superior maxillary bones are not yet developed. The facial angle is from 90° to 100°. The nasal bones are proportionately short. The alveolar processes constitute the chief part of both the upper and the lower jaws, the antral portion being imperfectly formed in the one and the inferior portion in the other; they appear as two ridges in each jaw, which form a groove; in this the teeth are laid, those of the lower jaw being placed almost directly beneath those of the upper. In the inferior maxilla the angle is very obtuse, the ramus and the condyloid portions being in nearly the same line; and the two halves of the bone are united by a suture at the chin. The zygomatic fossæ are very shallow, corresponding with the small size of the temporal muscle and the imperfect development of the jaws.

Female skull.

The skull of the female is rather smaller, thinner, and lighter than that of the male, though it is said to be rather larger in proportion to the rest of the skeleton (page 103); and the bones of the face are small in proportion to those of the cranium: the alveolar processes of the jaws are smaller and more elliptical; and the teeth are smaller and set more vertical: the frontal sinuses are less developed: the superciliary ridges are less prominent; and the facial angle is rather wider.

Skulls of idiots remarkably uniform.

The skulls of idiots contained in the various museums which I have had an opportunity of seeing, as well as those which are represented in books, present a remarkable uniformity in size and characters, so as to form a distinct class. This may

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orbits. The upper spongy bones, which are of large proportionate size, have been divided in the section and are seen.

The outline of the orbit differs in the two ages. In the adult the upper wall is convex towards the cranial cavity, and the lower wall next the antrum is flat. At birth, on the contrary, the upper wall is flat, and the lower wall is convex towards the face. That is to say, in the former case the orbits encroach on the cranial cavity, and in the latter on the face.

be partly owing to the fact, that the more marked specimens only have been preserved: and we may assume that a collection representing the various grades of idiotcy would include specimens approaching in different degrees to the ordinary human cranium. Such a collection however I have not seen.

Peculiarities of idiot's skull. The skull of the idiot presents in many respects an approximation to the skull of the lower animals, especially that of the ape, in the following particulars. The facial bones are proportionately large. The brain-case is contracted in every direction, more particularly in front and above, causing lowness and narrowness of the forehead, but also behind and below; the space behind the foramen magnum is small, and the bone slopes obliquely upwards from it to the occipital crest. The foramen itself partakes somewhat of this slant. The occipital condyles are small and preternaturally convex; and the basilar portion of the occipital bone ascends with unusual obliquity from them. The temporal fossæ are deep, and the cranial bones forming its inner wall are flattened. The temporal ridge is well marked and ascends to a comparatively high level; and this, together with the flattening of the parietal bones and the prominence of their sagittal portion, constitutes an approximation to a "sagittal crest." The line of union of the temporal with the parietal bones is straighter than usual, and the post-glenoid process is rather more marked. The frontal bone projects far backwards in the situation of the anterior fontanelle between the parietals. The posterior and middle cerebral fossæ are shallow. The orbital plates of the frontal bone are prominent in the interior of the skull, leaving a deep furrow between them for the cribriform plate of the æthmoid, which is an approximation to the anterior or nasal fossa of the lower animals. The foramen magnum and the other foramina for nerves at the base are comparatively large; the foramina for vessels, as well as the grooves for the sinuses, are, on the other hand, comparatively small. The cranial bones are generally rather thick and the sutures early obliterated; the bones in some instances, however, are thin.

The orbits are comparatively large; their anterior outlets are oblique, and the superciliary ridges are prominent, and project beyond the general width of the cranium. The bones of the face, though small in comparison with those of the well-formed skull, are large in comparison with those of the cranium, and are slanted forward, so as to reduce the facial angle as low as 50° or 55°. The nasal septum between the orbits is narrow, and the nasal bones are, consequently, much arched transversely.

The chin is retiring; and the angle of the lower jaw is rather wide. The skull being small the bones of the neck are also small.

Nevertheless, in spite of these peculiarities, no anatomist, as has been remarked by Professor Owen[1], would hesitate to refer the cranium of the idiot to the human species, retaining as it does the more important characteristic features of the latter in the descent of the cranial cavity below the level of the glenoid articulatory surfaces, in the number of the nasal bones, the construction of the jaws, the position and direction of the teeth, &c.

It is interesting to observe that the measurements of an idiot's skeleton, given in Tables I. and IV. pp. 106 and 108, shew the upper extremities to be rather long. In other respects the proportions coincide nearly with those of the average European standard.

THE OCCIPITAL BONE

The condyles constructed to bear and transmit weight of head to spine.

bears the whole weight of the skull, and transmits it through the condyles to the spine. The line of gravity in the erect position, with the eyes directed a little upwards, falls through the foramen magnum between the fore part of the condyles; and the skull, with its soft contents and coverings, when placed in the position just mentioned, balances upon the junction of the anterior with the middle third of the condyles[2].

This balancing point is a little the lowest part of each condyle, so that some advantage is given to the muscles that maintain the head erect. The articular surfaces of the two condyles are so shaped and disposed as to form parts of one globe or ball, which plays in the articular concavities of the atlas as in a socket; and the inner, or opposed, sides of the condyles afford broad rough surfaces for the attachment of the strong odontoid ligaments which bind the occiput to the axis. From either condyle pass three strong ridges

[1] *Zoological Transactions*, I. 372.

[2] See description of connection of head with spine at a future page.

or processes in a triradiate manner. One, directed forwards, is united with that of the opposite side to form the anterior margin of the foramen magnum, and is united also with the basilar process, which is continued forwards and upwards to the sphenoid. A second, passing backwards and inwards, meets the corresponding process of the opposite side in the thick strong ridge that ascends from the hinder part of the foramen magnum. A third, the *jugular* or *transverse process*, passes outwards to support the temporal bone. Each condyle may, therefore, be compared to a tripod resting upon these three processes, which converge to it so as to enclose three nearly equal angles where the bone is thin, and which transmit forces to and from the condyle in three different directions in a nearly equal manner; thus ensuring the combination of strength with lightness. The slight fossa in front of the condyle, and the deeper one behind, receive the projecting extremities of the articular surfaces of the atlas, and each contains a small cushion of fat to prevent injury to the bones from contact with one another[1].

Jugular and basilar processes.

The *jugular processes* are prolonged downwards in many animals, especially in graminivora and pigs, so as to form, on either side, a strong spike which might easily be mistaken for the styloid process. This seems in them rather to stand instead of the mastoid process, and has been called "paramastoid." In man it sometimes grows downwards so as to touch the upper surface of the transverse process of the atlas, and is articulated with it[2]. The *basilar portion* is very strong to carry the sphenoid and fore part of the skull, and is slanted a little upwards so as to transmit the weight in the most favourable manner towards the condyles. It is composed of a dense thick external layer enclosing a cancellated interior. The cells of the latter are sometimes very

[1] In a skull preserved in the Dupuytren Museum the right occipital condyle is, in consequence of congenital malformation, placed transversely, so as to project half-way across the foramen, yet without injuring the cord. It is concave in its long axis and slightly convex from behind forwards; the articular facet of the atlas was doubtless adapted to it. When the posterior condyloid foramen is absent, the vein that should be transmitted by it is said to pass through the foramen magnum.

[2] *Trans. of Pathological Society*, II. 93. There is a specimen of the kind in the Museum at Berlin.

large, and are occasionally continuous with and form an extension of the sphenoidal sinuses, in which case they are lined by a prolongation of the schneiderian membrane[1].

Foramen magnum.

The *foramen magnum* is an irregular oval. Its margins, of great strength, are formed by the condyles, by the processes diverging forwards and backwards from them, and by the basilar portion. Its anterior edge is bevelled and smooth where the medulla oblongata rests upon it. Its hinder edge is rough to give attachment to a thick strong process or band of fibrous tissue that descends as a sheath upon the dura mater of the cord and becomes blended with it. The fore part of the foramen is the narrowest; the odontoid process of the axis projects up towards this part, and being in the line joining the balancing points of the condyles, is situate in the line of gravity of the skull. The hinder part of the foramen is wide for the transmission of the cord and its membranes, and for the lodgment of the subarachnoid fluid which accumulates in the pia mater at this region and protects the cord from injury during the movements of the head. The foramen also receives a sudden increase of width about its middle, between the hinder parts of the occipital condyles, where the vertebral arteries enter the skull. The position of the foramen, so forward as to be near the middle of the base of the skull, and its being placed in a nearly horizontal plane, are characteristics of the human cranium.

It is occasionally of preternatural size, being occupied by a hernial protrusion of the brain. In a specimen of this kind, which I lately examined, it measured four inches by three; in another it was nearly as large. The importance of bearing in mind the liability to the occurrence of hernia cerebri in this situation is illustrated by a specimen in the Musée Dupuytren, in the account of which it is stated that an

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[1] Meckel, *Archiv*, I., once found a process projecting from the under part of the basilar portion, presenting some analogy to the single articulating facet for the atlas, which is situated here in most animals below mammals. The analogy was still closer in an instance described by Hyrtl (*Anatomie des Menschen*, s. 180), in which such a process was adapted to a concavity in the anterior ring of the atlas. Occasionally an exostosis-like growth into the skull takes place at the line of union of the occipital with the body of the sphenoid.

operation was commenced under the supposition that the tumour was of a different kind, and was attended with fatal results[1].

Expanded portion.

In the well-formed European skull the *expanded portion* of the occipital bone behind the foramen, that is to say, the part which supports the lobes of the cerebellum, is continued in a nearly horizontal plane as far as the inferior curved line. In some instances it bulges on either side below the level of the foramen magnum. In the inferior races, in the young child (Pl. XV. fig. 2), and in the idiot (page 233), it is more oblique, slanting upwards and backwards. In the Negro and Mongolian the external spines and curved lines are more strongly marked than in the European, in consequence of the greater preponderance of the facial part of the skull requiring increased strength in the muscles which are attached to these lines, and which keep the head in the erect posture. The great strength of the internal ridges and the purposes served by them have already been alluded to (page 202). These ridges of the occipital bone form the thickest portion of the whole calvarium, and the parts intervening between them are the thinnest[2].

Development.

At birth the occipital bone consists of four distinct portions; the *basilar*, which lies in front of the foramen magnum; the two *condyloid* parts, which form the sides and back of the foramen; and the *expanded* portion which lies behind the foramen. The three former are each developed from a single nucleus formed in cartilage; that for the basilar portion appears a little before those for the condyloid parts, soon after the third month. The expanded portion is formed from membrane; ossification

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[1] A remarkably small foramen magnum, with small flattened condyles, and one of large size, with large prominent condyles, are represented in Lobstein's *Anat. Path.* 2te Series, Pl. II. figs. 1, 2.

[2] In other mammals this portion of the bone is more flattened, and is directed more or less vertically upwards from the foramen magnum. In many it is quite flat, upright, and expanded at the upper part into a broad strong crest, which affords attachment to the muscles that raise the head. In the hog tribe this crest is of great size. In the elephant it is of vast thickness, and, like the other cranial bones, is hollowed out into cells which are filled with air and communicate with the frontal sinuses and the mastoid cells.

commencing about the eighth week. The number of nuclei in it vary. There may be only one near the middle[1]; or there may be four, two above and two below the curved line. When there are four they commence where the respective portions of the bone are thinnest, and become united at or before the fourth month; the upper two commonly coalesce first, and the spines and ridges are formed along the lines of union.

They do not, however, always unite. Sometimes the upper, or cerebral segments, remain separate from one another and from the cerebellar portions; or they may be united to one another and separated from the lower segment by a transverse suture[2]; and in a few instances the occipital bone has been found to terminate, not in a point but in a broad end, the lambdoidal suture being replaced by a wide transverse suture. In one skull I found the cerebral segments separated by a median plate running upwards to the parietals from the cerebellar portion. Some of these anomalies remind us of the "interparietal bone," which, in carnivorous and some other animals, occupies the angular interval between the occipital and the parietals. In them, however, the interparietal bone becomes united with the parietals sooner than with the occipital, and seems, therefore, rather to belong to the former. It is evident from these anomalies and from the conflicting observations of

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[1] Blandin, *Anatomie*, I., in all the instances that he examined, whatever the age of the fœtus, found the flat portion to consist of one piece, the ossification of which emanates, he believes, from a central nucleus in the situation of the occipital protuberance. Meckel, *Archiv*, I. 616, and *Handbuch der Anatomie*, II. 100, states that the bone is developed from eleven centres, of which four pairs form the expanded part. The first of these appears immediately behind the foramen magnum, on either side of the middle line, at about the 10th week. They soon unite together and are followed, after the middle of the third month, by a second pair situated further backwards and more laterally, which are joined to one another and to the first pair in the fourth month. A third and fourth pair appear in succession, after short intervals, one above another. In one fœtus I found a separate ossific centre for the thick triangular piece of bone that bounds the hinder part of the foramen magnum, and have noticed traces of the independent formation of the same in other instances. In some it is formed by a process from the expanded portion of the bone growing downwards between the extremities of the condyloid portions.

[2] Dr de Tschudi, *Edinburgh Philosophical Journal*, XXXVII. 252, found this conformation common in the skull of the ancient Peruvians, who were distinguished by a flattened occiput. It exists in a skull taken from a Romano-British burial-ground, which is preserved in the Cambridge Museum. Tiedemann, *Zeitschrift für Physiologie*, III. gives representations of these and other varieties in the occipital bone.

various anatomists, that the ossification of this part of the human skull is not conducted in a very uniform manner. Moreover, independent nuclei of "wormian bones" are often found in the lambdoidal suture after birth.

The condyloid and expanded portions unite together about the fourth year; and the former are joined to the basilar about the fifth year. The four pieces remain separate in reptiles.

Diseases.

This bone, so important from its connection with the parts of the nervous centres most essential to life, and from its bearing the whole weight of the head, is very rarely the seat of disease. There is an example of caries of the basilar portion in the College of Surgeons; with the exception of which, of an occasional exostosis on the basilar and expanded portions[1], and the changes in the condyles which are associated with ankylosis of the occipito-atlantal joint, I have not met with any instances of disease in the occipital bone. Dr Elsaesser, who has written a treatise on the "soft occiput," regards this bone as peculiarly liable to softening and other alterations in rickety children, in consequence of the head resting so much upon it in infancy[2].

THE PARIETAL BONE

is one of the simplest in the body. Developed from one centre which forms at the middle most convex part or a little below it, it spreads out to great size, contributing a larger share to the covering of the brain than any other bone: in some cases of hydrocephalus it attains to enormous dimensions. In the early periods of life it is sharply curved, and its protuberance stands out very boldly, giving a square shape to the head, which is retained through life in some of the inferior races of mankind, and in some Europeans, more particularly where there is a tendency to rickets.

Alternate levelling of its margin.

It is interlocked between the other bones in a remarkable manner: thus, it is overshot by the frontal above, and overlaps it below; it is covered by the squamous

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[1] There is a smooth oval exostosis on the external "spine," and another more nodulated on the "tuber" in Guy's Museum.

[2] *British and Foreign Medical Review*, XVII.

edge of the temporal, but overlaps its mastoid edge; it is overlapped by the occipital a little at the lower, and overlaps it a little at the upper, part of the lambdoidal suture; and a similar alternation is continued, in a slight degree, with the opposite bone in the sagittal suture. In this way it alternately overlaps and is overlapped by each of the four large bones with which it is connected; and a corresponding alternate bevelling of its edges at the expense of the outer and the inner tables may be traced all round. It is very thin where it forms part of the temporal fossa and lies under the shelter of the temporal muscle and fascia. The extent to which the muscle and fascia cover it varies in different races, being less in the European than in others. The bone is also less flattened in the European at this part, presenting a more generally full rounded contour, which has the effect of rendering the *protuberance* less prominent.

Connection with the sphenoid.

The parietal bone is regarded as the spine of the posterior sphenoidal vertebra which, in consequence, has received the name of "Parietal vertebra." Yet its connection with the great ala of the sphenoid is by no means constant. In the skull of a negro before me they are separated by the coalescence of the frontal with the temporal. They are separated in the same way in the chimpanzee, but are united in the orang-utan, the cat, and some other carnivora. The fact of its being supplied by the nutritious artery—the middle meningeal—which passes through the spine of the sphenoid, is a confirmation of the opinion that it is an appurtenance of that vertebra.

The meningeal groove.

The deep position of the artery in a groove or channel at the anterior inferior angle is a point of some practical importance, because it is liable to be wounded in fractures of this part of the bone; and the blood flowing from it may separate the dura mater from the skull and cause fatal compression. Hence, in cases where blows have been received on the side of the head, and symptoms of gradually increasing compression of the brain have supervened, the trephine has occasionally been applied and the blood removed; and in a few instances[1] the result has been good. In more the operation has

[1] Hennen's *Military Surgery*, 3rd edit. p. 327.

been unsuccessful; either the blood could not be removed, or the brain has not recovered itself, or hernia cerebri has ensued[1]. In some no blood was found; and in others, I believe, the wrong side has been opened. That the results of experience are not very encouraging to the performance of this operation need scarcely surprise us, when we remember that a fracture traversing this part of the skull will most likely be continued into the base and across the sella turcica (see page 204). I have already remarked (page 196) that this is the only part of the skull at which blood is thrown out between the dura mater and the bone in sufficient quantity to cause serious compression of the brain. The anterior inferior angle of the parietal bone is occasionally replaced by a wormian bone.

Size and forward position of parietals in man.

The size of the parietal bones, their elevation and comparatively vertical direction and the consequent forward position of their antero-superior angles, distinguish the human cranium from that of monkeys and other animals; and these characters are most marked in the higher races of mankind. Associated with these peculiarities is the concave outline of the lower edge of each bone, adapted to the convex rising margin of the squamous bone. The suture connecting the two is rather less curved in the Negro than in the European, and is nearly straight in the chimpanzee and inferior animals. The very obtuse retiring angle formed by the union of the two parietals in front is also a result of the forward position of their antero-superior parts. In monkeys the angle is much deeper and more acute to receive the frontal bone, which is prolonged backwards into a point in the middle line.

Sagittal crest.

The sagittal margins are often thick, and form by their union a strong broad ridge, which connects the projecting angles of the frontal and occipital bones and constitutes a strong arch at the upper part of the cranium. In the orang, the badger, and the dog more particularly, they are elevated into a lofty crest, which, at its back part, is overlaid by a separate osseous

[1] Abernethy's *Surgical Works*, II. 38; Bright's *Medical Reports*, II. 403; Guthrie, *On Injuries of the Head*, p. 60.

nucleus running forwards from the occipital bone. When the animals are young this nucleus may be seen extending through the whole thickness of the skull and forming a distinct triangular "interparietal bone" or "os triquetrum," occupying the posterior fontanelle and adapted to it. Its inner surface is connected with the tentorium, which is osseous in the cat (for the purpose of more effectually supporting the brain during the springs and powerful movements of the animal) and proceeds from the parietal rather than from the occipital bone. In rodents it is said to be developed from two osseous centres. The object of the elevated crest is to furnish an increased surface of attachment to the temporal muscles. In the young of some carnivora two inter-parietal bones are found in the *fore* part of the sagittal suture as well as two in the hinder part; all become united together with the two parietals into one bone during the growth of the animal. In the crocodile the two parietals are formed from one centre, and constitute a small irregularly shaped median bone.

Depressions near inner edge on inside,

In many animals where the sagittal ridge is strong the bone on either side is rather thin; and in the human skull we often find marked depressions of the *inner* table, at this part, adapted to the prominences of the upper margins of the cerebral hemispheres and to the "pacchionian glands." When these depressions are deep and sharply defined each one is usually connected with one of the large branches of the meningeal groove. I have seen also six instances (one in the Cambridge, four in the Dupuytren, and one in the Berlin Museum) of remarkable depressions on the *exterior* of the bone in this situation. The parietal bones, on the sides of the sagittal suture, between it and the parietal protuberances, were, in each, reduced to the thinness of paper, looking as if a portion of the outer table and diplöe had been sliced off so as to leave only the inner table, which preserved its proper line. The surface was smooth, and the edges sloped. The depression caused by this deficiency of part of the thickness of the skull was, in each instance, elliptical (about $2\frac{1}{2}$ inches by $1\frac{1}{2}$). The exact symmetry, the similarity of the deficiency in the several cases, and the absence of any trace of disease, render it most probable that the conformation was congenital; at any rate, they prove pretty clearly that it was not the result of accident. I have not

and on exterior.

seen a corresponding condition in any other part of the skull, and do not know how to account for its occurrence at this spot in preference to others. In all these instances the portions of the parietals intervening between the deficiencies were rather thicker than usual[1].

The aperture for the vein that runs through the upper and hinder part of the parietal bone into the longitudinal sinus is, in some skulls, of considerable size. In a specimen in the Cambridge Museum it is large enough to admit the end of the finger; it is situated further back and nearer to the sagittal suture than the thinning of the bone above mentioned, and has no relation to it.

Development and varieties. A single ossifying nucleus appears near the protuberance at about the third month. Ossification, radiating thence, reaches the angles last; and the distance of the two superior angles from the centre is one cause of the existence of the fontanelles at birth. It not uncommonly happens that an interspace or *third fontanelle* remains between the two bones, near the posterior angles, after they have coalesced in front and behind. It is usually

[1] There is a description of two similar specimens by Dr Maier (in Virchow's *Archiv*, VII. 336). He is disposed to attribute the thinning of the skull at the part to senile atrophy. But in the instances I have seen, and in one represented by Sandifort, *Exercitationes Anatomicæ*, 1753, p. 76, Tab. VII. the skulls did not appear to be those of old persons. I am the more disposed to regard it as a congenital conformation from the fact that I have, in several instances of hydrocephalus, observed a vacancy in the parietal bones at this part. It would seem, from a quotation made by Sandifort from Platuerus, that a patient narrowly escaped trephining after an accident by coming to himself and declaring that a depression in his head, which was exciting the apprehension of the surgeons, had existed from childhood.

There is a calvarium showing thinness of the right parietal bone in St Thomas's Museum. It is thus described in the catalogue: "The most prominent part of the right parietal bone sliced off by a sharp instrument, probably a sabre. The force was applied horizontally, so that, although a large portion of bone has been removed, the internal table has not been penetrated. The wound measures 2½ inches in diameter." It resembles the other specimens mentioned above, except that the deficiency is of more circular shape. Singularly enough the *exactly corresponding portion of the opposite side of the calvarium has been sawn out;* for what purpose it is impossible to say. The mutilation throws great doubt upon the correctness of the view taken in the catalogue; for, possibly, the presence of the part that has been cut out would show a similar deficiency on the other side, proving that neither was the result of injury.

Since writing the above I have seen an infant born with a depression in the right parietal bone, nearly as large as a half-crown piece. It is rather nearer to the temporal bone than in the instances mentioned in the text; but I believe it to be of the same nature with them.

of small size and oblong shape; but in an infant born with a prominent forehead and high vertex, in whom the fingers and also the toes were united together, I found this aperture, or fontanelle, of large size and square shape, so that it could not have been distinguished, by the touch, from the anterior fontanelle.

The two bones occasionally developed from one centre.

In some few instances the two parietal bones appear to be developed, as they are in the crocodile, from a single ossifying centre in the median line. At any rate, they sometimes are found united at a very early period, as early as the third year. When they are so the lateral expansion of the head is prevented, and there is, consequently, a preternatural increase in the height and in the antero-posterior diameter of the cranium[1]. Indeed, wherever the head is unusually long or deep we may be pretty sure that the sagittal suture was obliterated early, or did not exist. In some examples of remarkable elevation of the upper part of the cranium, I have found the frontal as well as the sagittal suture early obliterated.

Occasionally one or both parietal bones are divided, more or less completely, into an upper and lower half by a suture running from before backwards[2]. In one instance the dividing "suture ran partially vertical and diagonal[3]." The parietal bones are frequently deficient, wholly or partially, in anencephalous monsters. "Occasionally they are missed in natural fœtuses[4]."

THE FRONTAL BONE

not only covers the fore part of the cranial cavity and forms the upper walls of the orbits and the roof of the nasal fossæ; it, in addition, sends down three processes—the "nasal" in the middle,

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[1] See *Contributions to Craniology*, by Dr Minchin, *Dublin Quarterly Journal*, XXII. 350. An example is given by Sandifort, *Mus. Anat.* II. Tab. VIII. and IX. and *Exercitationes Anatomicæ*, 1785, Tab. I. of union of the parietals, the sagittal suture being undistinguishable, except a slight trace of it near the coronal. The cranium was in other respects remarkable chiefly for its length and for the thinness of its bones. The subject, a woman, is said to have had hydrocephalus, though the dimensions of the skull were not very great.

[2] Tiedemann, *Zeitschrift für Physiologie*, II. s. I. There are two examples in the Museum at Berlin.

[3] Otto's *Path. Anat.* by South, p. 169.

[4] Otto, p. 169.

and the "external angular" on either side[1]—which are the main stay of the face. Hence it is a bone of considerable strength, and it varies in its figure and growth according to the development both of the brain and the face. In proportion as that of the former takes place in the most perfect manner, that is, the manner which we find associated with the highest intellect, so does the cranial portion of the frontal bone become more upright and less encroaching upon the territory of the parietals, giving rise to that well-known indication of mental power, a high forehead.

Its upright position proportionate to development of cerebrum.

Accordingly an examination of the crania of the various races of mankind shows that the more debased is the mental condition so, on the whole, is the frontal bone more inclined backwards and more prolonged in the direction of the sagittal suture[2]. In the monkey these features are still more strongly marked; and in the lower races of animals the bone becomes quite horizontal, and is placed behind, instead of above, the eyes[3]. Similar remarks may be made with regard to the facial part of the bone; for, in proportion as the cranial portion slopes backwards, so do its facial buttresses—the nasal and angular processes—slant forwards; and in proportion as the brain is well developed and the cranial part of the bone is upright, so are the facial processes directed perpendicularly downwards. In the lower animals, for instance, they grow directly forwards; in the lower races of mankind they grow downwards and forwards; and in the best formed human skulls they grow almost vertically downwards. Hence, when the skull rests upon a horizontal plane, the angle formed by the anterior surface of the frontal bone with that plane, which may be called the "frontal angle," will afford at least as correct a means of estimating the degree of perfection of cranial development as what is commonly called the "facial angle." It will be found, as a general rule, that the prominence of the forehead is proportionate to that of the chin (see page

[1] In carnivora the external angular process does not reach the malar bone, so that the orbit and temporal fossa form one large cavity. The middle process of the frontal, which is the only support afforded by the bone to the face, is consequently very thick and strong in these animals.

[2] This conformation is well seen in the representation of a Peruvian skull given by Tiedemann in the *Zeitschrift für Physiologie*, V.

[3] In fishes it extends between the parietals as far as the occipital.

287), and to the bulging of the occipital bone below the level of the foramen magnum (p. 237).

The frontal sinuses: The downward growth of the middle or frontal process of the cranium (page 177), and its size, which is designed to give it strength as a main support of the face, would add considerably to the weight of the fore part of the skull, were it not hollowed out into cavities or cells. Of these, some formed in the æthmoid, or completed by it, are called "æthmoidal cells," others, included in the substance of the frontal bone itself and formed between its tables, are called "frontal sinuses." The latter are situated chiefly between the orbital and the superciliary plates of the bone. They are not developed till after puberty, and vary a good deal in size; not unfrequently they are of unequal size on the two sides. They are larger in men than in women and young persons, owing to the greater prominence of the superciliary ridges in the former. Where they are most developed they make the forehead seem to recede, which must be borne in mind in estimating the capacity of the cranium by either the frontal or the facial angle. The sinuses are on the whole larger in Europeans than in negroes. In some tribes—Australians for instance—it is said by Prof. Owen that they are very imperfectly developed, and that a peculiar want of resonance of the voice is a consequence of the deficiency. I have seen them extend over the whole surface of the orbit, reaching as far back as the junction of the frontal with the lesser ala of the sphenoid; the supra-orbital portions were partly shut off from the nasal portions, and the cavities further subdivided by incomplete partitions. Above they have been known to extend as far back as the parietal bones, and on either side as far as the external angular processes; in other cases they are almost absent[1].

variations in their size:

[1] "They extend backwards over the top of the skull in the ruminant and some other quadrupeds, and penetrate the cores of the horns in oxen, sheep, and a few antelopes. The most remarkable development of air-cells in the mammalian class is presented by the elephant; the intellectual physiognomy of this huge quadruped being caused, as in the owl, not by the actual capacity of the brain-case, but by the enormous extent of the pneumatic cellular structure between the outer and inner plates of the skull-walls." Owen, in Orr's *Circle of the Sciences*, p. 167.

It is necessary to be aware of these varieties in applying the trephine[1]. There is usually one on either side of the middle line: the left is said to be commonly rather the larger. They are separated by a thin septum, to the formation of which each half of the frontal bone contributes its share. Nevertheless, they communicate with one another by apertures in the septum; and each communicates with the superior meatus narium of its own side by a funnel-shaped opening, which transmits a prolongation of the schneiderian membrane to line the interior of the sinus, and which permits air to pass to and from the nasal fossæ.

are not often the seat of disease:

They are sometimes the seat of very acute pain in common catarrh, in consequence of the inflammation extending along the lining membrane from the nose; but the inflammation commonly subsides without much trouble, and it is remarkable how seldom they are the seat of chronic disease. It is related that insects have found their way into them; that fragments of brain have escaped from the nose in cases of fracture at the base of the skull involving the walls of these cells; and, that when an aperture has been formed in their outer wall, patients have been able to blow air through them[2]. The whole anterior wall has been carried away by fracture, leaving the hinder wall exposed, and the patient has done well.

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[1] A gentleman who measured several specimens found them ranging from two to four inches transversely, from one to two in height, and from half an inch to nearly two in depth. Mr Hilton, *On the Cranium*, p. 13, found them more extensively developed in the skull of a man belonging to one of the African tribes than in any other that he had seen.

[2] It is related by Dr Abercrombie (*Diseases of the Brain*, 3rd edit. p. 40) that an opening has been formed into the cranial cavity by ulceration consequent on disease of the lining membrane, and has been associated with abscess in the adjacent part of the brain. In the Musée Dupuytren is an enormous cavern, larger than the head, with bony walls occupying one side of the face. The case was published by M. Viallet in *Bull. de la Société de la fac. de Méd.* 1805, p. 72, and the commencement of the disease was ascribed by him to polypus of the frontal sinus. A careful examination of the specimen, and comparison of it with others, convinced me that it was more probable the disease began in the maxillary than in the frontal sinus. An account of this specimen is given in the *Muséum d'anatomie path. de la faculté de Médecine de Paris*, p. 437, and is represented in Pl. 10 of the Atlas accompanying that work.

their uses.

The frontal sinuses serve to lighten the fore part of the skull, to add to the resonance of the voice, and, by throwing forward the superciliary ridges, to protect the eyes. As before stated, p. 220, it is not probable that they have much, if any, connection with the sense of smell.

Orbital plates.

The *orbital plates* are arched transversely, as well as from before backwards (see Pl. XV. at page 231); they are deeply marked by the cerebral convolutions above, but present an even surface beneath so as not to interfere with the movements of the eyes, which lie close under them nearer to the roofs than to the floors of the orbits. Not being much exposed to injury this part of the bone is thin and easily perforated by any sharp instrument[1]; occasionally it is fractured by a blow upon the forehead, or more distant part of the head, the other regions of the skull remaining intact[2]. In the well-made European skull the orbital plates are nearly horizontal. In the Negro they are more oblique, slanting downwards and backwards. In hydrocephalus they are much flattened and depressed from their proper horizontal to a nearly vertical line, rendering the eyes prominent and giving a peculiar stare to the unfortunate sufferers. Their hinder and inner angles are sometimes replaced by wormian bones[3].

Superciliary ridge and notch.

The *superciliary ridges* are formed by the confluence of the anterior margins of the orbital plates with the frontal portion of the bone. They are strong and arched so as to be able to resist blows and to receive the malar and maxillary bones which are applied against the angular processes forming their outer extremities. The arching of the brows, added to the direction of the hairs placed upon the skin which covers them, diverts to the sides of the face the streams of sweat flowing from the forehead, and saves the annoyance they would otherwise occasion to the eyes.

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[1] *Trans. of Path. Soc.* I. 188. In a case quoted by Abercrombie, *Diseases of Brain*, p. 41, it would seem to have been perforated by matter forming in the orbit.

[2] Page 205, and Hewitt in *Med. Times and Gaz.*, March 27, 1858.

[3] See the contrast of their shape at the time of birth and in the adult, represented in Pl. XV. figs. 3 and 4. At the former period they are much less arched than in the latter, to afford more space for the large cerebrum.

The *outer* part of each superciliary or "supra-orbital" ridge is particularly prominent, defending the eye in this the most exposed direction, and giving shelter to the lachrymal gland. The *inner* part is less sharp. The ridge is interrupted near the inner part by the *supra-orbital notch*, which transmits the frontal nerve, and which is sometimes converted into a foramen. A small *hole* at the bottom of the notch transmits a vein from the diplöe to join the ophthalmic vein (page 196). Another vein from the same source often perforates the orbital plate near the external angular process; and a small hole in the latter situation sometimes transmits a branch of the anterior meningeal artery to the lachrymal gland[1].

The want of sharpness and projection of the inner part of the supra-orbital ridge is compensated for by the bulging of the anterior wall of the frontal sinuses; and the bone is here perforated by many holes for the transmission of vessels to and from the sinuses. In the middle line it often presents small closely-set transverse ridges and furrows, which are the remnants of the *frontal suture*.

Frontal eminences.

The *frontal eminences*, which are situated above the superciliary ridges, vary a good deal in different persons; often they are unsymmetrical in the same person. A want of uniformity in this respect led to the presumption of fracture in a case which occurred under Velpeau at the Hôpital de la Pitié.

Foramina cæca and orbitalia interna.

The *foramen cæcum*, when it is open, transmits into the nose a vein of communication between the vessels of the schneiderian membrane and the longitudinal sinus. It is sometimes impervious at the lower part, especially in old persons. The *internal orbital foramina*, transmitting branches from the ophthalmic veins to the nose, afford additional, though less direct, means by which vascular communications are established between the schneiderian membrane and the dura mater. If we add to these the cribriform holes themselves, we find here ample anastomosis between the nasal and the intra-cranial vessels.

Edges.

A slight elevation in the median line marks the position of the suture which united the lateral halves of the bone. In some of the lower animals this is elevated into a

[1] Jourdan, *Encycl. Anat.* II. 27.

ridge continuous with that of the parietal and occipital bones. The coronal edge of the frontal is bevelled so as to be adapted to the parietal, that is, at the expense of the inner table above, and of the outer one in its lateral parts. It will be observed that the serration is much less complicated near the middle line and at the sides of the suture, where the bones overlap one another in opposite directions, than at the intermediate parts where their edges are in the same plane. The same thing will be found in other regions of the skull: where there is much overlapping there is less serration than in parts where the edges of the bones are more directly opposed to one another.

Development. The ossification of the frontal bone begins very early, sooner than that of any of the other cranial bones; probably because it carries the face, through the medium of the three processes which run out from it for that purpose. Bone is first formed at the part subservient to this work—viz. along the superciliary portion, at or before the second month—and radiates from it backwards over the orbit and upwards upon the forehead[1]. We might expect separate nuclei for the external angular processes, forasmuch as they are separate bones in reptiles and fishes, called the "post-frontals;" but I have not succeeded in finding them[2]. At birth the bone is divided into halves by the frontal suture, which, at the upper part, expands into the anterior fontanelle. By the age of two years this suture is generally obliterated, and the fontanelle is closed.

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[1] Ossification is commonly said to commence in the situation of the frontal protuberances. I have, however, found it first just above the orbits; Kerkringius (*Osteogenia fœtuum*, cap. II.) describes it as beginning at this point, and says that it spreads upwards on either side towards the parietal bones so as to enclose a central portion which is subsequently covered in. Blandin (*Anatomie*, I. 78) gives the same account.

[2] In one hydrocephalic specimen the cranial was separate from the superciliary portion. This cannot, however, be relied on as a veritable exponent of the manner of development, because gaps of irregular shape and of considerable size, not always symmetrical on the two sides, are often met with in the frontal bones of children afflicted with this disease. They are probably the result of the stretching to which the primordial membrane and the growing bone have been subjected; and it is quite likely that the stretching may have caused the separation between the cranial and superciliary parts in the instance I have alluded to.

Frontal suture occasionally persistent.

The frontal suture remains as long as the other sutures in some quadrumana and other animals, and occasionally in man,—in about one skull in twenty[1]. When it is permanent, one of the frontal bones joins the opposite parietal diagonally, forming a union similar to that which usually occurs in the palate between the maxillary and palate-bones, and there is also a diagonal union of one of the frontal bones with one of the nasal at the other end of the suture. The side which is united diagonally with the opposite parietal may or may not be the one which is united diagonally with the opposite nasal.

Judging from what has been said at page 244 respecting the association of narrowness of the cranium with absence of the sagittal suture, I thought that there might be some relation between the width of the forehead and the persistence of the frontal suture; but have not found that it is so, the suture not being more frequently present in wide than in narrow foreheads. In hydrocephalus the two sides of the frontal bone are pressed apart, and an independent plate is occasionally developed in the interval between them[2]. In acephalous monsters the frontal portion is commonly deficient. Occasionally the frontal bone is entirely deficient, its place being supplied by the elongated parietal bones[3].

The varieties in this bone in width and height, in the angle of inclination, in the size of its sinuses, and in the prominence of its protuberances are perhaps of more importance in physiognomy than those of any other bone in the head.

Frontal bone often the seat of disease.

It is more frequently the seat of disease than the other cranial bones, being more subject to thickening, to syphilitic caries, and to malignant growths. There is one disease which hardly ever affects the other calvarial bones, except the frontal has been first attacked, I mean the formation of nodulated bony growths, or "osseous tumours," which may begin on either side, or in the middle line, of the frontal bone, and which spread along its surface, extending to the adjacent bones, attaining considerable size, and encroaching upon the cranial cavity as well as bulging outwards. They may also

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[1] Congenital consolidation has been observed, and the frontal suture has been found not running straight to the sagittal suture. Otto's *Path. Anat.* by South, p. 166.

[2] Foot-note 3 on page 192; and case by Dr Freckleton in *Ed. Med. and Surg. Journal*, XVII. 242.

[3] Otto's *Path. Anat.* by South, p. 106.

take their origin in the upper or lower jaw-bones, and spread thence to the frontal and the other bones; but this rarely happens.

Sebaceous cysts form upon it.

Lassus[1] quotes examples of osseous exostoses resembling horns springing from one or both sides of the frontal bone. Probably some of these were mere warty growths from the skin, with a thick corneous cuticular covering, or were consequent on the formation bursting and subsequent cuticular outgrowth of sebaceous cysts. This leads me to remark that such cysts are very frequently met with in close connection with the frontal bone, commonly just behind the external angular process, and often under cover of the temporal fascia; I have met with them occasionally upon other parts of the bone. They are, so far as I know, always congenital; though they often escape notice for some years, and I have been called upon to remove them in grown up and even elderly persons. If left alone they do not attain great size, and, after a time, for the most part, become stationary. They lie upon the bone itself, or in such close contact with it that it is usually necessary to expose it to effect their complete removal; I found one occupying a cup-like depression of considerable depth in its substance, which had probably been caused by the growing up of the bone around the cyst. They resemble the ordinary "wens" in structure and contents. I know no other part of the osseous system with which cysts of this kind grow in so frequent and intimate connection.

THE TEMPORAL BONES

Their varied offices and relations.

contain the organs of hearing, disposed on their exterior and in diversely shaped cavities and canals hollowed out in their interior. They contribute to the formation of the cranial cavity. They send buttresses—the zygomata—forward to support the upper jaw; and they form the sole resting-points of the lower jaw. They furnish the handles—the mastoid processes—for attachment of the muscles—the sterno-mastoid, splenii and trachelo-mastoid—which effect the more powerful rotatory movements

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[1] *Pathologie Chirurgicale*, I. cap. 80.

of the head; and they furnish the styloid processes, from which muscles pass to the pharynx the hyoid bone and the tongue. They are perforated by the arteries—the carotids—which transmit one half of the supply of blood to the brain; and they are grooved by the great veins—the lateral sinuses—which discharge all the blood from the brain. They are grooved also by two of the tributary sinuses—the superior and inferior petrosal—, besides being grooved by the main arteries of the dura mater—the middle meningeal—.They transmit the great motor nerves of the face—the portio dura of the seventh on either side—and the sympathetic. They lodge the Gasserian ganglia, from which pass the motor nerves of the lower jaw and the nerves of sensation to the entire fore part of the cranium and face. They form one side of the foramen which transmits the glosso-pharyngeal, the pneumogastric and the spinal accessory nerves. In addition to this there are foramina and channels in the bone for the passage of communicating filaments between all or most of these nerves. The bones, wedged in between the occipital and the sphenoid, appear to be compounded of derivatives from both, and of an osseous sense-capsule besides. I may observe, moreover, that, in the different classes of the animal kingdom, their several component parts undergo such great modifications and changes, (greater perhaps than those of any other bone of the skeleton,) that it is often very difficult to recognise them under their various metamorphoses. It is no wonder, then, that the sympathetic relations of this region with other parts of the body are so remarkable, that an ear-ache is the most intolerable of all aches, that in some persons the introduction of a speculum and the washing out the external auditory passage causes convulsive fits of coughing and choking, and that accumulations of wax and mucus in the cavities and passages are occasionally the source of so much annoyance: no wonder that the student finds it difficult to acquire a clear and accurate knowledge of the temporal bone: no wonder that anatomists are not agreed respecting the homological relations of its several parts.

The two temporal bones receive and support the parietals above, and are, in turn, received and supported by the sphenoid and occipital below. Their superior edges are, accordingly, bevelled at the expense of the inner, and their inferior edges at the expense of the outer laminæ. They consist of five portions which are commonly described separately, each being in some measure distinct, and each being developed from a separate osseous nucleus. These are the *squamous*, the *mastoid*, the *petrosal*, the *tympanic*, and the *styloid*[1].

Squamous portion.

The squamous portion is convex externally in the higher families of the human species, giving a rotundity to the exterior of the cranium at this part; and the great extent of its vertical depth, in comparison with its antero-posterior measurement, and the convexity of its upper border are peculiar to man. In quadrumana it is flatter and of more square shape, with a straight upper border. The *glenoid cavity*, lined with a thin layer of cartilage, is seen on its under surface. In front of the cavity is a *ridge* or eminence, also covered with cartilage, upon which the condyle of the jaw mounts when the mouth is widely opened, returning again into the glenoid fossa when the mouth is closed. This ridge, as well as the glenoid cavity, has its long axis directed inwards and backwards, in accordance with that of the condyle of the jaw, which facilitates the oblique or rotatory movements of the inferior maxilla in mastication. The glenoid cavity is separated from the petrous bone and the lower part of the tympanic bone by the *fissura Glaseri*, which is a remnant of the first visceral cleft of the early embryo (page 179), and which still communicates with the tympanum. Just in front of the outer part of this fissure may be noticed a small tubercle, the *post-glenoid process*, the representative of a much larger process which in other mammals descends behind the condyle of the jaw and prevents its being drawn backwards from the glenoid cavity in the efforts of mastication. Its large size in the skull of the chimpanzee constitutes one of the characteristic differences between that and the human skull. In the latter there is no necessity for so large a "stop," in consequence of the more vertical direction

Glenoid cavity.

Fissura Glaseri.

Post-glenoid process.

[1] I frequently call these "squamous bone," "mastoid bone," &c. to avoid the longer phrases, "squamous portion of the temporal bone," &c.

of the neck and ascending portion of the lower jaw, and in consequence of the downward growth of the tympanic and vaginal processes, which render dislocation of the jaw backwards almost impossible. Nevertheless, although the process is of smaller size in man than in the lower animals, it is still sufficient, under ordinary circumstances, to prevent the condyle of the jaw passing backwards, and is really the agent, at any rate is an important agent, by which such displacement is prevented. This is best perceived in a section of the joint in its recent state, such as is represented in Pl. XVIII. fig. 4 and 5 B. In some human skulls, particularly that of the Negro, which presents so many approximative tendencies to the skull of the quadrumanous animal, this process is strongly marked, growing downwards and pushing downwards the tympanic portion, which is situated below and behind it, and which is always quite distinct from it, being separated from it by the " fissura Glaseri."

Peculiarities of glenoid cavities in carnivora, graminivora, and rodentia.

In "carnivora" both the ridge bounding the fore part of the glenoid cavity, and the post-glenoid process stand out more sharply than in man, and curl, one backwards and the other forwards, so as to circumscribe the antero-posterior diameter of the cavity and reduce it to a mere furrow, in which the transversely elongated condyle of the jaw turns, like the pin in the angel of a hinge-joint. This arrangement permits only the movements requisite for opening and shutting the mouth, and prevents dislocation forwards during the wide separation of the jaws which these animals are able to effect, as well as backwards when the mouth is being closed. In "graminivora" the anterior ridge is almost absent, the articulating facet is nearly flat and extends forwards a considerable distance, so as to give greater range to the antero-posterior sliding of the condyles and the rotatory movements of the lower jaw. In the glenoid cavity of man the conditions are intermediate between these two; or rather the ridge is *much less* pronounced than in carnivora, and is *somewhat more* marked than in graminivora; so that this joint, like the teeth, approaches more nearly to the characters displayed in the latter class of animals, than in the former. The movements of the jaw, regulated by the shape of the articulating surfaces, resemble those which take place in both classes; but they are limited in their extent, the hinge-like action being less than in the carnivora and the lateral, or rotatory play, being less than in graminivora. In "rodents" the shape of the glenoid cavity is quite different. It is concave in a lateral direction, so as to form a deep groove in which the condyle of the jaw can play forwards and backwards with freedom; while the condyle itself is almost spherical, so as to permit the movement of opening and shutting the mouth to take place.

Depth of the cavity.

The wall of the skull forming the bottom of the glenoid cavity is slightly prominent in the interior of the cranium, as if it had been pushed up by the pressure of the condyle of the lower jaw. It is quite thin and translucent, and is surrounded and strengthened on all sides by thick ridges[1]. This deeper part of the glenoid cavity, where the partition wall between it and the cranial cavity is so thin, lodges the hinder thick edge of the interarticular cartilage, and is separated by it from the condyle of the jaw, being thus defended from any jars or injurious pressure which might otherwise have been caused during mastication. Its depth is, in the recent state, increased by the cartilage which surrounds its edge being thicker than that which covers its bottom. The cartilage is thickest upon the ridge, and this bears the chief pressure of the jaw during its movements, both in consequence of the forward curve in the neck of the jaw, and in consequence of the direction in which the greater part of the fibres of the pterygoid, masseter, and temporal muscles pull upon it (p. 288).

Zygoma.

The *zygomatic process* is an outgrowth from the squamous bone. At its root it is closely connected with the articular surface for the lower jaw, and greatly strengthens this part of the bone. Indeed, the glenoid cavity might almost be said to be formed by the bifurcation of its root; for the anterior division running inwards, constitutes the ridge upon which the condyle descends when the mouth opens; and the posterior division skirts the outer part of the glenoid cavity. The latter, passing beyond the glenoid cavity, forms the superior margin

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[1] In the *Journal Hebdomadaire des progrès des Sciences Médicales*, 1834, Tom. III. p. 335, a remarkable case is related in which the condyle of the lower jaw was driven through the glenoid cavity into the skull by a fall from a second story window. The patient, æt. 22, was drunk, and fell upon his chin; he lived more than five months after the accident, dying, at length, of an abscess at the base. It was supposed during life that the neck of the condyle was broken. The case is quoted at length by Mr Hewitt.—*Med. Times and Gaz.* March 6th, 1858.

of the external auditory meatus, and is prolonged backwards to join the temporal ridge and form a continuation of it. The upper edge of the zygoma to which the temporal fascia is connected is sharp; its lower edge is thicker and gives origin to the masseter muscle; and the upper surface of its root forms a smooth channel for the play of the hinder fibres of the temporal muscle. In the Negro the greater width of this channel throws out the zygoma into stronger relief, and, added to the flatness of the squamous portion, affords more space for the temporal muscle. On the smooth retiring part of its outer surface, just in front of the ear, lie the temporal artery and the branch of the fifth pair of nerves which supplies sensation to the adjacent skin. The zygomatic process overlaps the malar bone at the line of their union, so as to assist it and the superior maxilla to resist the upward pressure to which they are subjected in mastication. The extent of this overlapping, as well as the strength of the zygomatic arch and the size of the space enclosed by it, are greater in the Negro than in the European, and far greater in carnivora than in either.

Mastoid portion.

The hinder root of the zygoma, where it is continued into the temporal ridge, marks the boundary between the mastoid and squamous regions; and the upper edge of the mastoid portion differs from that of the squamous in being cut horizontally or sloped a little outwards, so that it bears, rather than encloses, the parietal bone. The mastoid is a thick, spongy portion of bone; and, where it is thickest, that is to say, where it forms the mastoid process, it is hollowed out into air-cells, which open into the tympanum and derive from that cavity a prolongation of its lining membrane through the foramen of communication. These mastoid cells, like the other sinuses of the skull, are not developed till after puberty. They serve to lighten the bone. Whether they, in addition, contribute to the sense of hearing is uncertain. It is probable that they serve some good purpose in extending the tympanic cavity and permitting it to contain a larger quantity of air, performing the same office as the hollow appendage to the tympanum, which is present in most carnivora, and which, in the cat particularly, constitutes a large globular process beneath the petrous portion of the temporal bone.

Emphysema is said to have been caused by the escape of air from the mastoid cells in fracture at this part; and abscesses sometimes form in them and burst externally. Occasionally the mastoid process on each side is double[1]; and I have seen the eminence on the inner side of the digastric groove bulged into a prominence as large as the mastoid, and containing an air-cavity which communicated with the mastoid cells. In the Elephant the enormously developed mastoid cells communicate, through the medium of the expanded pneumatic diplöe of the other cranial bones, with the frontal sinuses.

The mastoid processes afford a leverage to the muscles which rotate the head. Being placed behind the plane of the condyles they enable the muscles attached to them to assist in elevating the face and balancing the head in the erect posture. They do not exist in the infant; but grow out in childhood as the jaws and teeth are acquiring more weight. Like the other processes at the back of the head they attain to greater size in the Negro, for the purpose of aiding the muscles to balance the prolonged and more weighty maxillary apparatus. The mastoid bones are perforated near their hinder parts by one or two foramina, which transmit veins from the diplöe and from the exterior of the head to the lateral sinuses. Hence the selection of the back of the ear as the part for the application of leeches to relieve cerebral congestion[2]. Thus each of the cranial bones we have considered has a foramen for the purpose of permitting direct communication between the sinuses on its interior and the external veins. There is the *posterior condyloid* of the occipital bone, which, crossing over the hinder part of the condyle, and reaching the "anterior condyloid foramen," transmits a vein to join the lateral sinus immediately beneath the jugular hole. There

Foramina for veins.

[1] Hyrtl, *Anatomie*, s. 189.

[2] "In some subjects I have seen a branch of the occipital artery pass through this hole to serve the posterior part of the dura mater." Monro's *Anat. of the Bones*, 1736.

is the *parietal foramen* perforating the posterior superior angle of the parietal bone, and transmitting a vein to the longitudinal sinus: and there is the *foramen cæcum* of the frontal bone, through which the terminal portion of the longitudinal sinus finds its way into communication with the veins of the nose. As a general rule it is probable that the current of blood sets from without inwards through these foramina; but, by permitting it to flow in an opposite direction, they may serve to relieve or prevent over congestion of the cerebral veins. The same purpose may be intended by the large venous channels that ramify in the diplöe of the skull.

Petrous portion.

The petrous part of the temporal bone owes its chief interest and peculiarities to the fact of its containing the essential part of the organ of hearing spread out in a complicated system of cavities and canals, called the "labyrinth," which are hollowed out in its interior. It is especially devoted to this purpose and constructed for it. Its density, which increases towards the interior, is greatest in the immediate neighbourhood of the auditory cavities, so as to form what has been described as a "bony labyrinth" investing the "membranous labyrinth." This density of the bone serves to facilitate the vibrations of the fluid upon which the auditory nerves are expanded. It permits also the communication of sufficient vibrations through the walls of the skull to cause auditory impressions, independently of those which are transmitted through the external meatus. In case of a severe blow these vibrations may be so jarring as to discompose the delicate structures within and to induce concussion of them; and this is probably one cause of the deafness which sometimes follows a fall or sharp knock upon the head.

Parts observed on its exterior.

The exterior of the petrous bone presents indications of the parts contained within. The most marked of these is the prominence of the superior semicircular canal, seen near the middle of its anterior surface. This stands up in very strong relief in the young child (Pl. IV. fig. 1 M) and in many animals, in consequence of the space encircled by it being occupied only by cartilage or fibrous tissue. External to this prominence is a depression indicating the position of the tympanum. The bone is here very thin; and, in the dry state, the tympanic cavity is sometimes exposed[1]. Still more outwardly is a ridge, which is continuous behind with the prominent anterior margin of the canal for the lateral sinus, and which corresponds with the line of attachment of the membrana tympani. Near this ridge a fissure may be sometimes seen extending from before backwards between the petrous and squamous portions; it results from an incomplete union of the two parts. On the inner side of the prominent superior semicircular canal is a depression over the vestibule, followed by an elevation for the cochlea. Internal to the latter is another depression, near the extremity of the bone, in which is lodged the ganglion of the fifth pair of nerves. The convolutions of the brain are adapted to these eminences and depressions, with the exception of the one last mentioned, and are therefore pretty regular at this part. On the hinder surface, between the internal auditory foramen and the slit-like orifice for the aqueduct of the vestibule, is a transversely elongated eminence, which marks the position of the inferior semicircular canal.

The prominent angle formed by the union of the two cerebral surfaces of the petrous portion is truncated by the groove for the superior petrosal sinus. It is received into the interval between the cerebrum and cerebellum, and it gives attachment to the tentorium, which, in some carnivorous animals, is a bony lamina, extending from this edge to the occipital and parietal bones.

Carotid canal.

The *carotid canal* by its sharp bend gives a corresponding curve to the artery, which assists to break the

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[1] This is worthy of remark because, in chronic disease of the tympanum, ulceration sometimes extends through at this point, giving rise to fatal inflammation of the membranes of the brain. Abscesses of the brain, or between the membranes, are said occasionally to have found a vent in this direction, to the temporary or permanent relief of the patient. Abercrombie, *Diseases of the Brain*, p. 38. It is, however, most probable that in all such cases the bone was the primary seat of the disease. Moreover, this thin roof of the tympanum is often traversed by fractures at the base of the skull; and, the closely adhering dura mater, with its arachnoid epithelium, being torn, together with the membrana tympani, the fluid of the arachnoid cavity may escape through the ear.

jerk of the column of blood passing through it. Its proximity to the labyrinth may be, in part, a cause of that whizzing sound which is experienced, synchronously with the pulse, by some anæmic patients. The vessel lies at one part close to the eustachian tube, separated from it only by a thin layer of cartilage or fibrous tissue. A small process of bone projecting into the canal sometimes separates a lower narrow groove, which transmits branches of the sympathetic and other nerves and some absorbent trunks, from the upper larger part of the canal which is occupied by the artery. Mr Guthrie[1] has "seen fracture pass across the canal for the carotid artery and extravasation of blood caused by its rupture; a fact which has also been noticed by Bohn."

Tympanic portion.

The tympanic bone forms the lower four-fifths of the circle to which the membrana tympani is attached and part of the floor of the tympanic cavity. Its external edge is thick and rough for the connection of the cartilaginous prolongation of the external meatus. Behind, it is applied against the mastoid process (though often partially separated from it by a deep narrow channel), the stylo-mastoid hole, the styloid process, and the jugular fossa. In front it is separated from the glenoid cavity, the post-glenoid process, and the middle root of the zygoma, by the *fissura Glaseri*. Inferiorly it is prolonged into a sharp ridge, which extends as far as the carotid canal, and forms the boundary between the parotid and jugular fossæ. The part corresponding with this ridge is, in many animals, swelled out into a bulbous appendage to the tympanum.

Styloid portion.

The styloid bone varies much in size and shape; sometimes it is two inches long. It has been found composed of several pieces united by cartilage; and occasionally it is very thick, with a medullary cavity in its interior[2]. It commonly swells out a little near the extremity, where the *stylo-glossus* muscle is attached.

Connection of temporal with other bones.

Each temporal bone is wedged and dovetailed into the lower part of the skull, and enclosed between the sphenoid and occipital, in such a manner as to render

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[1] *Injuries of the Head*, p. 73.

[2] Hyrtl, *Anatomie*, s. 189.

it almost impossible that it should be displaced in any direction without fracture. It is worth while to examine its margin carefully all round, to observe the manner of its connection with the surrounding bones. Beginning at the hinder part of its mastoid portion, where it is joined with the occipital, we find the margin not deeply serrated, nor very obliquely cut; it is slanted, however, a little, at the expense of the inner table above and of the outer table below. Then we come to a remarkable flat triangular surface—the *jugular facet*—just behind the styloid process. This is united by a thin layer of cartilage to a corresponding facet at the extremity of the jugular process of the occipital bone, which runs out almost transversely to meet it, and which forms a very strong buttress to support the temporal bone and to prevent its being driven inwards and forwards. The jugular process we have already (p. 235) seen to be connected by a strong bony arch with the condyle of the occipital bone. The triangular facet of the temporal which it supports is surmounted by the strong ridge at the back part of the petrous bone, which forms the anterior margin of the groove for the lateral sinus, and which, curling backwards to the point of junction of the squamous with the mastoid bone—to the point, that is, where there is a sudden change in the direction of the suture with the parietal—, has to bear great part of the weight of the parietal bone. Thus the brunt of the weight of the parietal bone is transmitted along this curling ridge to the jugular process, and thence directly to the occipital condyles.

The mastoid edge.

The jugular facet and ridge ascending from it.

Immediately in front of this jugular facet is the deep *jugular fossa*, a part of the *foramen lacerum*, where is lodged the termination of the lateral sinus, which makes a sweep and bulges a little here previous to its becoming the jugular vein. The fossa is lined by fibrous tissue, between which and the bone, or in a groove in the latter, runs transversely the small filament from the vagus, which perforates the wall of the "aqueduct of Fallopius" to reach the facial nerve. It is surmounted by a sharp notched overhanging edge, from which strong bands of fibrous tissue pass over the lateral sinus to the adjacent prominent margin of the occipital bone. At one point the overhanging edge

The jugular fossa:

runs out into a distinct *process*, almost touching the occipital bone and connected with it by a strong fibrous band. This process separates the "jugular fossa" from the remaining narrow part of the "foramen lacerum" which transmits the eighth nerve; and this narrower part is again subdivided, by a delicate process of bone jutting out from the temporal to meet a corresponding process from the occipital, into a small anterior channel which transmits the glosso-pharyngeal nerve and a larger posterior channel which transmits the vagus and accessory nerves.

its separation from the rest of the wall of the foramen lacerum.

In front of the foramen lacerum the convex rough surface of the petrous bone is adapted to a concave surface on the side of the basilar part of the occipital. The upper edge of this convex surface overhangs the basilar process, is sharp and notched, and gives attachment to strong fibrous bands, which, passing over the inferior petrosal sinus, are connected with the rising margin of the occipital bounding the channel for that sinus. Beneath the notched edge just mentioned is a distinct groove which receives the sharp dentated edge of the basilar process. Beneath this again is a peculiar rough surface, which is united by means of strong, thick, ligamentous tissue with the corresponding rough lateral surface of the basilar process. One or more separate portions of bone are occasionally found here imbedded in the ligamentous tissue.

Union with basilar portion of occipital,

The tough ligamentous tissue, which unites the approximated under surfaces of the petrous and occipital bones, is continued round the anterior extremity of the former, along the lower edge of the carotid canal; and, passing from it to the adjacent surface of the sphenoid, connects these bones very firmly together, forms a continuation of the carotid canal, and closes the *foramen lacerum medium*. A portion of the petrous bone forming the lower boundary of the carotid canal is sometimes separate from the rest of the bone and lies imbedded in this tissue, like those just mentioned between the petrous and occipital[1].

and adjacent edge of sphenoid.

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[1] An independent osseous nucleus at the extremity of the petrous bone was remarked by Cortese in 1625, and was hence called *ossiculum sesamoideum Cortesii*. It

The retiring angle between the petrous and the squamous bones, which is continuous with the *fissura Glaseri* and so with the tympanum, receives the spine of the sphenoid, and the convex anterior edge of the squamous bone is received into the concavity of the great ala of the sphenoid. The interlocking of the two bones is further increased by the bevelling of the squamous edge at the expense of the outer table below and of the inner table above. The remainder of the convex squamous edge is very obliquely cut to permit of its overlapping and embracing the concave edge of the parietal. At the junction of the mastoid, however, a sudden change takes place. The bone is thicker, there is much less obliquity of its edge, so that it supports the parietal in a more firm, direct manner; and the outer table is, as before said, cut rather lower than the inner.

Development. Of the five centres of ossification from which the temporal bone is developed, two—the squamous and tympanic—are formed in membrane; the others—the mastoid, the petrous, and the styloid—are formed in cartilage. Ossification begins, about the middle of the third month, at the lower part of the squamous portion. It radiates thence to the temple, the zygoma[1] and the glenoid cavity. An osseous nucleus soon after appears at the lower part of the tympanic ring. In the fourth month osseous specks are seen in the cartilage of the petrous portion, in the situation of the labyrinth; these spread so as gradually to cover in the vestibule, the semicircular canals and the cochlea. Ossification begins in the cartilage of the mastoid portion at about the same time[2]. At birth the several pieces are united together; or they become so very soon after birth. Ossification is, by this time, completed in the squamous and zygomatic portions.

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has also been observed by Riolan (Monro's *Anatomy of the Human Bones*, Edinburgh, 1732), by Meckel, and Hyrtl.

[1] If the zygomatic process ever originates in a separate nucleus, which an observation of Beclard (Meckel's *Archiv*, VI. 427) renders probable, it becomes very quickly united to the squamous.

[2] Beclard says the mastoid is usually an outgrowth from the petrous, but that sometimes one or two separate nuclei appear in it and quickly unite with the petrous. Kerkringius, *de Osteogenia fœtuum*, cap. V. describes one or more separate nuclei in it.

The glenoid cavity is also formed and is covered by a very thin layer of cartilage. It is of comparatively small size, and the eminence in front of it is scarcely to be seen. The mastoid part is quite flat, there being no trace of mastoid process. The petrous bone is complete, except at its base or outer surface, where there is, in places, a thin layer of cartilage between it and the squamous portion: also between the superior semicircular canal and the internal auditory foramen (Pl. IV. fig. 1 L) there is a vacancy. The tympanic portion consists of a mere ring, or rather, a horse-shoe-like portion of bone, for it is deficient in about the upper eighth of its circumference. Its two extremities are united to the squamous bone—the hinder at about the seventh, the anterior at about the eighth month; the remainder of its circle is free for some time after birth. It slants very obliquely inwards towards the base of the skull; so that, although its upper and outer extremities are close beneath the zygoma, its convex lower and inner edge is near to the carotid foramen. Its concave border, to which the "membrana tympani" is attached, is finely serrated; its convex edge, applied against the petrous bone, is more smooth.

The external auditory passage, and membrana tympani at birth:

The cutaneous tube which forms the external meatus and the auditory passage, is, at birth, very narrow; its diameter, in the greater part of its length, being much less than that of the tympanic bone and the membrana tympani. At its inner part, near the tympanum, it is suddenly expanded, trumpet-like, to the same size as the drum, and its wall, which is tough, fibrous or fibro-cartilaginous, splits into two layers and embraces the tympanic bone between them. The innermost of these layers, reflected inwards over the concave margin of the bone and held to it by its dentated edge, forms the membrana tympani, which, like the "ossicula auditûs," is of nearly the same size as in the adult. The outer layer passes over the convex border of the bone to the adjacent edge of the petrous bone, against which it is applied, and to which it becomes attached as well as to the tympanic bone. It is thus the medium of union between the tympanic and petrous bones, holding the former in its place. If it be divided the tympanic bone is easily displaced from its position. At the upper part, where the tympanic bone is deficient, the membrane of the auditory passage is united to the squamous bone and is reflected from it upon the tympanum. The narrow auditory canal is directed towards this upper part, and consequently the sudden expansion near the drum affects chiefly its lower wall and sides.

Changes after birth.

After birth, the zygomatic and mastoid portions, arching over the external auditory meatus, prolong the upper wall of the auditory passage, while the gradually increasing depth of the tympanic bone prolongs its lower wall and sides. The latter bone becomes blended with the mastoid and petrous bones; but remains partially separated from the zygomatic and glenoid portions of the squamous by the fissura Glaseri. It grows by the increase of its inner, as well as by that of its outer border, so as to enlarge the cavity of the tympanum. By virtue of this growth the membrana tympani gradually acquires a more vertical position, and its lower border becomes distanced from the carotid foramen; at the same time the lower edge of the tympanic bone becomes prolonged into the sharp ridge which separates the parotidean from the jugular fossa.

Formation of the lower wall of the external auditory passage.

The mode in which the formation of the lower wall of the auditory passage takes place is as follows: at birth we may commonly discern small dentated processes (*C* and *D* in fig. 1, Pl. XVI.) jutting out from the concave edge of the tympanic bone at its fore and hinder part. These processes, growing beneath the membrana tympani, and approaching one another, shortly coalesce so as to form a more or less broad bar or plate, extending across the floor of the auditory passage. The outer jagged edge of this plate gives attachment to the fibrous cartilage of the tragus. Between its inner edge and the inner portion of the tympanic bone a hole is at first enclosed; and the floor of the passage is here, for some time, covered in only by membrane, which, however, gradually becomes ossified. The bone usually remains thin at this part, and, not unfrequently, a small aperture may be discovered in the adult bone, resulting from the imperfect closure of the hole just mentioned. The stages of this process will be better understood by reference to the accompanying plate.

The "fissura Glaseri" is the remains of the interval between the tympanic and squamous portions of the temporal bone. It is wider at and before birth than subsequently.

Although, in man, the tympanic bone becomes early united to the squamous, it remains separate from it in many of the lower animals; in some of these it is joined to the petrous and mastoid, and forms, with them and the styloid, a bone which continues distinct from the squamous. The mastoid portion remains quite separate in some animals, and occasionally, though very rarely, in the human skull.

Other changes in temporal bone after birth.

At birth (as stated page 230) the inferior surface of the base of the skull presents a slight convexity in a transverse direction, which causes the glenoid cavity, on either side, to have an inclination inwards and downwards. Subsequently the base becomes rather concave, and the glenoid cavity undergoes a corresponding change, and slopes a little upwards towards its inner part instead of downwards; the shape of the maxillary condyle is in like manner altered. The mastoid process becomes developed about the second year and hollowed into air-cells about puberty. The styloid process is not ossified till some years after birth, and is not united to the rest of the bone till a variable period after the adult age.

Varieties and diseases.

A congenital cleft, traversing the squamous portion, commencing near the petrous part and extending near to the most prominent part of the parietal bone, is represented by Lobstein[1]. Clefts are also described by Meckel[2]. The temporal bone does not, however, appear to be often the subject either of malformation or disease. The latter, when it occurs, generally originates in the mucous membrane lining the tympanic or mastoid cavities. The carotid canal has been found so small that it would hardly admit a pig's bristle, or quite closed, in consequence of thickening of the bone[3]. Exostoses now and then grow upon the zygomatic portion[4].

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[1] *Traité d'Anat. Path.* Pl. v. fig. 2.
[2] *Handbuch der Path. Anat.* I. 339.
[3] Otto's *Path. Anat.* by South, p. 172.
[4] *Trans. of Pathological Society*, VI. 279.

DESCRIPTION OF PLATE XVI.

Fig. 1. Temporal bone soon after birth, showing (*A*, *B*) the line of union of the convex margin of the tympanic bone with the petrous, and (*E*, *F*) the points of union of its extremities with the squamous. In the interval between *E* and *F*, it is wanting. Its crura have become elongated and rather less curved, so that it now encloses an oval space; and processes (*C*, *D*) are beginning to shoot from its inner margin before and behind. *G*, carotid hole. *H*, stylo-mastoid hole.

Fig. 2. Temporal bone of young child. *A*, tympanic bone. *B*, line of junction of tympanic and petrous; the dotted line passes over the process between carotid hole (*C*) and parotidean fossa (*D*). *E*, fissure, between tympanic and petrous bones, for the eustachian tube, tensor tympani, and corda tympani; they lie all three together at this time, and become subsequently separated by plates of bone growing between them. *F* and *G*, processes shooting from inner margin of tympanic bone, longer than the same processes (*C* and *D*) in fig. 1. *H*, stylo-mastoid hole. *I*, rudimentary mastoid bone, with merely a trace of mastoid process.

Fig. 3. Temporal bone a little more advanced. *A*, *C*, *D*, *E*, *F*, *G*, *H*, *I*, the same as in preceding figure. The processes (*F* and *G*) of the tympanic bone have approached near to one another.

Fig. 4. Under surface of temporal bone (still further advanced) with part of adjacent hinder edge of sphenoid. *A*, tympanic bone; its processes have coalesced, forming part of the floor of the external auditory passage, enclosing the hole *B*, and shutting it off from the external auditory foramen (*C*). The hole (*B*) is gradually obliterated by the growth of bone at its edges, and the osseous floor of the external auditory passage is thus completed. The jagged external border of the united processes is connected with the cartilaginous prolongation of the auditory passage. *D*, the mastoid process beginning to grow out. *E*, the foramen ovale of the sphenoid, open behind.

Fig. 5. Parts of sphenoid and occipital bones from fœtus at sixth month. *A*, triangular interval between bodies of sphenoid (p. 271, foot-note). *B*, lesser alæ, short and thick. *C*, process on side of hinder body of sphenoid, to which great ala is subsequently attached. The middle of the body is concave, and presents foramina for vessels. *D*, optic foramen. *E*, process on inner side of lesser ala, which, growing towards middle line forms the groove for olfactory nerve. *F*, body of occipital, concave on its upper surface, with foramina for vessels. *H*, neural process of occipital. *I*, anterior condyloid foramen (page 237).

Fig. 6. Vertical section from before backwards through body of sphenoid of a young child, showing the interval left in the middle between its two portions, like that between the component parts of the sacrum and of the axis. *A*, posterior clinoid process. *B*, olivary process. *C*, groove for optic commissure. *D*, fore part projected towards æthmoid. *E*, part from which azygos process grows. *F*, under surface. *G*, surface for union with occipital. (See page 272.)

Fig. 7. Inner side of superior maxilla at birth. *A*, nasal process. *B*, alveolus. *C*, orbital edge. *D*, palatine process. *E*, anterior palatine foramen, with fissure running up from it on inner side of nasal process, marking the division between maxillary and intermaxillary bones. *F*, lachrymal canal. *G*, depression on inner wall, indicating the commencement of antrum. (See page 285.)

Fig. 1.

Fig. 2.

Fig. 3.

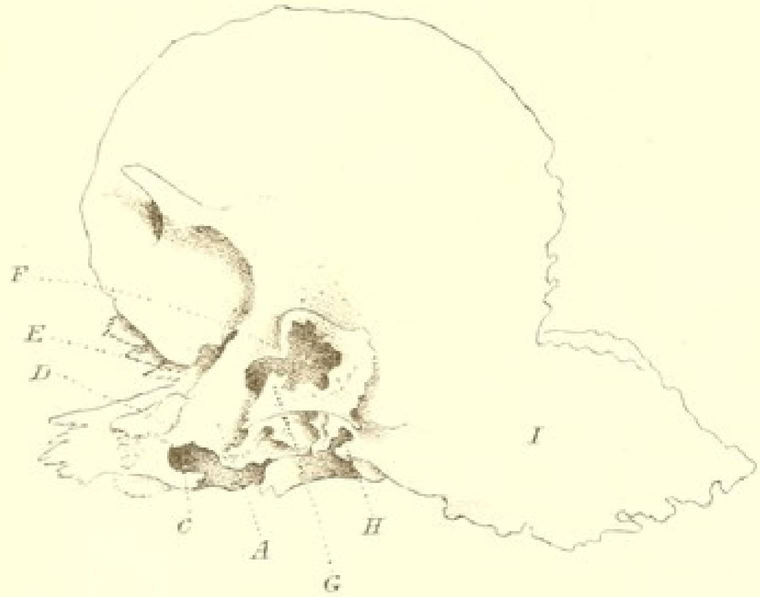


Fig. 4.

Fig. 5.

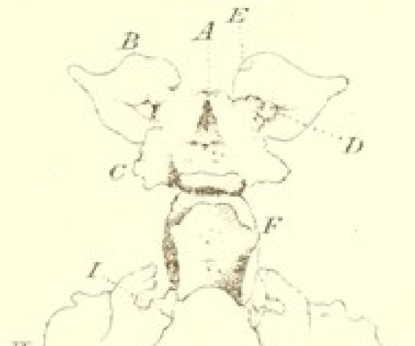


Fig. 6.

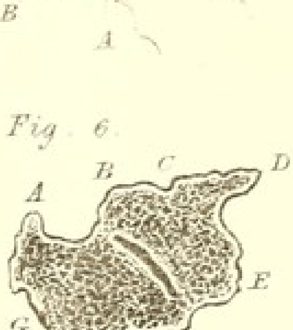
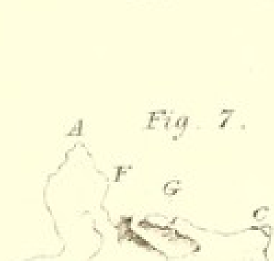


Fig. 7.



THE SPHENOID BONE

Its connections and offices.

has very extensive connections, inasmuch as it forms part of the cranial, the orbital, and the nasal cavities, as well as of the temporal, zygomatic, and spheno-maxillary fossæ; it is also united to all the bones of the cranium, and to five of those of the face, viz. the two palate, the two malar, and the vomer. It has to bear the weight of the anterior half of the head and face, which it does by means of processes radiating in various directions from its centre. Thus the frontal bone is supported upon its lesser and upon the fore part of its greater alæ; the summits of the latter serve as pillars to the anterior inferior angles of the parietal bones; and its hinder concave edges receive and carry the fore parts of the temporal bones, its spinous processes occupying the retiring angles between the squamous and petrous portions of those bones. To the face the sphenoid furnishes, in the middle, an attachment to the vomer, and through it to the septum nasi; its pterygoid processes descend to prop the palate and maxillary bones; and the anterior edges of its great alæ are united with the malar bones. The extension of the great alæ to the malar bones, shutting off the orbits from the temporal fossæ, and contributing so largely to the hinder and outer walls of the orbits, is peculiar to the human and quadrumanous skull, and has relation to the forward position of the eyes and the parallelism of the optic axes.

Its relation to nerves.

The sphenoid gives passage to the optic nerves and to the several motor nerves of the eyes, and is especially related to the fifth pair of nerves, for it transmits all the several branches of that great nerve through its *foramina lacera, rotunda,* and *ovalia*[1]. This relation derives interest from the fact that the

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[1] In many of the lower animals the foramen ovale is blended with the foramen lacerum medium; in some the foramen rotundum is blended with the foramen lacerum anticum; and in some the foramina ovalia and rotunda are so close together as to appear like one.

fifth pair of nerves supply sensation to the soft parts covering all the bones which are supported by the sphenoid: thus the fore part of the parietal and temporal, and the whole of the frontal, the malar, and the several facial bones are, directly or indirectly, borne upon the sphenoid; and they all derive their nervous supply from the branches of the fifth, transmitted through this bone.

Situate at the base, the sphenoid connects the foremost and the hindmost bones of the skull, transmitting the weight of the anterior half of the head to the basilar process of the occipital bone; and, stretched across the base, it unites the parietals of the two sides, serving as a clamp to prevent their separation. For this purpose the upper extremities of its great alæ are cut obliquely at the expense of the inner table, so that they may overlap and embrace the anterior inferior angles of the parietals. Their union with the temporals has already been described (page 263). The frontal bone is borne upon the broad truncated fore part of the upper extremities of the great alæ, while the orbital plates of the frontal bone are joined to the body and lesser alæ. The delicate extremities of the lesser alæ are, for about half an inch on either side, merely placed in apposition with orbital plates of the frontal, the suture being of the kind called "harmonia," without any serration. In the rest of their extent, where there is more thickness of bone, the serration is quite distinct, and the edges of the alæ generally overlap those of the orbital plates of the frontal. Near to the æthmoid, however, the projecting angles of the orbital plates slightly overlap the sphenoid; so that the principle of alternation in the direction of the overlapping at the sutures, which is so marked in other instances, is carried out even here.

The body.

The *body* of the bone is of large size, to afford sufficient space for the attachment of its various processes. At the same time, to lessen the weight of the skull, and to add to the resonance of the voice, it is hollowed out so as to form a mere shell. This does not take place till some time after birth, when the face is increased in size, and when the growth of the pterygoid processes and the vomer downwards and forwards is carried out.

Sphenoidal sinuses.

The *sphenoidal sinuses*, so formed in the middle of the bone, are of considerable size; but, like the other sinuses appended to the nose, they vary a good deal in this respect, and are commonly unsymmetrical. After the osseous union of the sphenoid with the occipital they are sometimes extended backwards into the basilar process of the latter, and may reach nearly to the foramen magnum. They are separated, often completely, by a bony plate, which commonly bends a little to one side of the median line, and which is prolonged forwards into the *azygos process*. They may be further more or less subdivided by imperfect partitions projecting into them. They are not unfrequently involved in fracture at the base of the skull; and are one source of the bleeding into the nose and pharynx, which is a common attendant on that accident (page 203).

The *clinoid processes* are outgrowths from the hinder surface of the sphenoid body; and serve partly for the purpose of deepening the "pituitary fossa[1]," and partly for the attachment of the prolongations of the tentorium. They correspond with certain other processes in the interior of the skull, which give attachment to the dura mater; such as the "crista galli" of the æthmoid, and the ridges on the interior of the frontal, parietal, and occipital bones. The extremities of the tentorium which run from the posterior to the anterior clinoid processes are sometimes replaced

[1] The "pituitary gland" is very constant in vertebrata; and in fishes it has a greater proportionate size than in others, though not provided with a special "sella." It is connected above with the infundibular process from the third ventricle, and may have some relation to the passage of the œsophagus through the corresponding part of the nervous centres in invertebrata. "Is this vertical slit," caused by "the vertical prolongation of the third ventricle through an interspace produced by the divarication of the main lateral columns of the encephalon," "homologous with the encephalic ring perforated by the œsophagus in invertebrata?" Owen's *Lectures on Comparative Anatomy*, II. 181. The "pineal gland" is a membrano-vascular growth from the upper part of the third ventricle, corresponding with the pituitary gland; and, like it, is a constant appendage to the brain of fishes, is of far greater proportionate size in them than in mammals, and may have some relation to the disposition of the œsophagus in invertebrata. It is interesting to observe, in connection with the comparison thus suggested between these parts and the anatomy of invertebrata, that the union between the two parts in which the body of the sphenoid is formed takes place last just beneath the infundibulum; and an interval, traversing the bone from above downwards, remains for some time between the two portions. Pl. XVI. fig. 5 A. page 268.

by bone; they contribute to the strength of the body of the sphenoid.

Width of the body of the sphenoid, and its connections with other bones.

The width of the body of the sphenoid is proportionate to the width of the æthmoid bone and to the interval between the orbits. It is greater, therefore, in man than in the lower animals. In many of the latter indeed—in rodents and others—the body is very narrow, and the optic foramina, which in man are separated by a long transverse groove whereon lies the optic commissure, are blended together[1]. It terminates posteriorly a little behind the level of the hinder edges of the great alæ and the pterygoid processes. The hinder surface is uneven, like that on the jugular process of the temporal, and, is till middle age, joined to the basilar portion of the occipital by cartilage. Ossification of the intervening cartilage begins at the upper part and travels downwards, cementing the two bones; so that, after a certain period, the line of their union can scarcely be distinguished, or is only indicated by a faintly nodulated ridge extending transversely across the cranial surface a little behind the posterior clinoid processes. The anterior and upper surface of the body of the sphenoid is prolonged forwards into a thin conical plate which reaches the hinder retiring edge of the cribriform plate of the æthmoid. It is overlapped a little by the angles of the orbital plates of the frontal bone. Sometimes there are one or more separate nuclei, or wormian bones developed here, which may appear to belong either to the sphenoid, the frontal, or the cribriform plate of the æthmoid bone.

Development.

The sphenoid, in reality, consists of two bones, an anterior and a posterior, which unite together about the situation of the olivary tubercle, near the time of birth[2]. Each of these is developed in three divisions from three or more nuclei.

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[1] In some monoptic human monsters there is only one optic hole which is in the median line.

[2] These remain separate in some quadrumana, and in many other animals; and in the human skull a more or less distinct fissure occasionally extends obliquely inwards and forwards from the root of the anterior clinoid process, on either side, indicating the line of union of the two bones.

One in the middle line for the body, which appears, shortly after that for the basilar process of the occipital bone, in the cartilage forming the base of the primitive cranium. Previously to the appearance of these, in the third month, ossification begins in the great alæ, and is soon followed by nuclei, on the outer side of the optic foramina, for the lesser alæ; and, near the same time, the internal pterygoid processes are developed from separate nuclei. There are thus ten centres for this bone, which all become united into one about the time of birth.

The following account of the development of the sphenoid is given by Meckel[1]:

Ossification takes place in it later than in any of the cranial bones, except the æthmoid. It is first observed, during the third month, in each great ala, near the foramen rotundum, and extends outwards into the ala and downwards into the external pterygoid process. Soon an independent point appears in the internal pterygoid process, and another in the lesser ala on the outer side of the optic foramen. So that at the end of the third month there are six centres of ossification. The external pterygoid process is an outgrowth from the great ala. In the fourth month a nucleus appears in the hinder part of the body, on either side of the middle line: these soon become united into one median nucleus; and, on each side another ossifying point is added, nearly over the internal pterygoid process. In the sixth month a separate nucleus forms in the lesser ala, on the inner side of the optic hole. In the seventh month two other ossifying points are added in the fore part of the body, between the central nucleus and the inner ends of the lesser alæ. The bone now presents a greater number of nuclei than at any other time; namely, five for the body, four for the great alæ and internal pterygoid processes, and four for the lesser alæ. From this time the number is diminished by their union with one another. During the seventh month the three hinder nuclei in the body unite into one; and the two anterior do so likewise. During the eighth month the two remaining nuclei of the body become united, the great alæ are joined to the pterygoid processes, and the two nuclei of each lesser ala also become united. So that the number of centres is now reduced to five. The lesser alæ next unite with the body. This is the stage at which it has commonly arrived at

[1] *Archiv.* I.

birth. The bone at that time, therefore, consists of three portions, viz. the body united with the lesser alæ forming one, and the great ala and pterygoid process forming another on either side. The union of these remaining parts is completed soon after birth. The *cornua* are developed subsequently. If we take them into account the bone is formed from fifteen separate centres of ossification[1].

Sphenoidal cornua.

The *Sphenoidal cornua* were first described by Bertin[2]. They appear in the third year as delicate osseous laminæ, which become curled as they grow, so as to present a concave surface towards the sphenoidal sinuses. Thus they increase the size of those cavities and form part of their anterior wall. At the same time the margins of the cornua become more closely applied to the circumference of the sinuses, and about the tenth or twelfth year are united with it. The line of their union may be distinguished long after. They sometimes become united with the æthmoid rather than with the sphenoid, and when the bones are separated remain attached to the former.

The sphenoid is not often the seat of disease. Portal[3] found it carious in some children who died of small-pox. It is often involved in fracture at the base (p. 204); and the sphenoidal sinus has been perforated by the end of a cane which passed through the nose into the skull, breaking off and carrying before it the posterior clinoid process[4].

THE ÆTHMOID BONE, (Pl. XIII. and XV.)

Contributes to the formation of each of the adjacent cavities.

like the frontal and the sphenoid, contributes to the formation of the cranial cavity, the orbits, and the nasal fossæ. It furnishes a good illustration of the manner in which the bones of the skull are made to combine together

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[1] Beclard assigns somewhat earlier periods for the appearance of the several nuclei; that for the great alæ from the 45th to the 50th day; for the hinder part of body from the 50th to the 60th day; for the fore part of the body from the 6th to the 7th month; the 7th month for the cornua. Blandin, *Anatomie*, I. 94, says the number of nuclei described by Meckel, as contributing to form the body are altogether exceptional; there being usually only one in the fore and one in the hinder part. Mr Ward, *Human Osteology*, p. 47, has seen a wormian bone in the lesser wing and four in the suture between the sphenoid and æthmoid bones.

[2] *Mémoires de l'Academie Royale des Sciences*, 1744.

[3] *Anat. Med.* Tom. I. p. 138.

[4] *Dublin Journal*, 1851, p. 347.

to cover in these cavities; so that each of the cavities is walled in by portions of several bones, instead of being formed by one or two. Thus the æthmoid forms a small part of the brain-case, a part of the orbit, and a part of the nose; it assists, moreover, to close each of the three facial or nasal sinuses (the frontal, sphenoidal, and maxillary). So, on the other hand, the æthmoidal cells are not, in any one direction, completely closed by the wall of the bone itself, but are indebted, for a part of their parietes, to contributions from all, or most of, the surrounding bones; they are closed above by the frontal, behind by the sphenoid the sphenoidal cornua, and the palate, on the sides by the ossa unguis, in front by the nasal, and below by the superior maxillary.

The *lateral masses*, which make up the chief parts of the æthmoid, are formed of two plates, an outer presenting in the orbit and called the *os planum*[1], and an inner descending from the cribriform plate, parallel with the septum, and terminating below in the superior turbinate bone. These two are connected by delicate, vertical, slightly curved plates, which pass across and divide the

Æthmoidal cells.

intermediate space into a series of cavities or *cells*, generally seven in number, placed in front of one another. These cells are of square or oblong shape, and vary in size and number, according to the more or less incomplete formation of the delicate plates which separate them. They are closed above by the frontal bone, and the foremost communicate with the frontal sinuses. They increase in size from before backwards, according to the increasing width of the æthmoid, are quite separate from one another in the perfect bone, and have, at the inner and lower part, separate openings into the nasal meatus. The three hinder and larger cells open into the superior meatus. The four anterior and smaller open into the middle meatus by a passage of considerable size, which is common to them with the frontal sinus. Currents of air must be continually passing to and fro between the cells and the nasal meatus; thus they may contribute, in some way, to promote the sense of smell.

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1 In some Quadrumana and in most Carnivora the æthmoid does not enter into the formation of the orbit at all, but is quite enclosed between the frontal and palate-bones which unite together, so that the os planum does not exist.

But the influence of the æthmoidal cells in aiding the olfactory organ cannot be very great, and must be quite secondary to their use in lessening the weight of the fore part of the skull[1]. The osseous plates bounding the cells are very thin, so thin that they derive their nutritious supply from the vessels ramifying on their exterior, and have no need of haversian canals in their substances.

Turbinate portions.

The *turbinate bones* which form the inner part of the lateral masses, and upon which the olfactory nerve is chiefly distributed, are very simple in comparison with their more complex, involuted, and plicated forms in many animals. In the Seal, for instance, they subdivide into a multitude of plates, like the leaves of a book, affording, it has been computed, a surface of 120 square inches in each nostril. In man they are merely curled plates, forming about a half or two-thirds of a circle, with slight transverse ridges and a few large channels in their concavities to strengthen them and carry blood-vessels. Their convex surfaces are more channelled and spongy for the distribution of vessels, particularly the inferior and anterior surfaces of the lower ones, which are flattened and slanted a little upwards to catch the inspired current of air. Here the finer branches of the olfactory nerves ramify in the schneiderian membrane, and here (as stated at p. 219) it seems that the sense of smell is most acute. A third æthmoidal turbinate bone, situated above the others, has been occasionally found on either side[2].

Perpendicular plate.

The *perpendicular plate* is thin in the middle, and is generally inclined a little to one side. It varies in size[3]. Above it is grooved on either side by channels for the descending olfactory nerves. Behind, its smooth edge is applied against the anterior median lamina of the sphenoid, and is united to it by "harmonia;" it presents below a notch for the reception of the

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[1] This is in accordance with the fact that their size in the various skulls of man and animals corresponds, not with the acuteness of the sense of smell, but, like the cavity in the body of the sphenoid, with the width of the septum between the orbits, and the more or less vertical direction of the face.

[2] Hildebrandt's *Anatomie*, II. 86.

[3] Mr Ward (*Osteology*, p. 132) has seen it extend a quarter of an inch beyond the nasal bones and articulated with the whole length of the vomer.

azygos process of that bone (Pl. XIII. fig. 1, *C*). Below, there is a rough edge or groove for union with the vomer. In front, its sloping edge is thick and rough for junction with the cartilage of the septum nasi. Its anterior extremity is prolonged forwards, beneath the frontal sinuses, to the suture of the nasal bones along which it is applied nearly to their lower edge (Pl. XIII. fig. 1, *I*).

Cribriform plate.

The foramina of the *cribriform plate*, about forty in all, are disposed in three rows on either side. The innermost and largest, though least numerous, are close to the *crista galli*. They transmit the olfactory nerves and vessels to the mucous membrane covering the perpendicular plate; and the foremost of them, which is slit-like and longer than the others, gives passage to the naso-lobular branch of the fifth pair of nerves. The foramina of the outer row transmit the olfactory nerves to the turbinate bones; and those of the middle row, which are the smallest, transmit fine nervous filaments and vessels to the under surface of the cribriform plate forming the roof of the nose. In some monsters (anencephalous and others) the cribriform plate is imperforate, or is perforated by only one or two large holes through which the water has been known to burst from the cranial cavity. It is occasionally the seat of caries, causing disease of the dura mater and brain[1], and it has become perforated by ulceration so as to allow pus and other fluids to percolate from the cavity of the skull[2].

Crista galli.

The *Crista Galli*, which rises along its middle, forming a continuation of the perpendicular plate, serves, like the clinoid processes of the sphenoid, for the attachment of the falx—one of the processes of the dura mater. It is commonly inclined a little to one side, usually the opposite to that towards which the lower part of the perpendicular plate is bent. It is let into the frontal bone, and forms a buttress supporting the hinder wall of the frontal sinuses. It contributes also to form part of the boundary of the sinuses; and, by the excavation on its fore part, adds a little to their size. It is said, in one case, to have been beaten upwards into the brain by a blow upon the nose, which

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[1] Abercrombie, *Diseases of the Brain*, p. 39.

[2] Otto's *Path. Anat.* by South, p. 176.

broke the nasal bones[1]. The orbital plates of the frontal bone overlap the sides of the æthmoid closing and extending the æthmoid cells; and, rising up on either side, they deepen the furrows upon the cribriform plate, which lodge the olfactory nerves. The corresponding part in the skull of some animals is, by the greater prominence of the frontal margins, converted into a separate anterior chamber of the skull.

Development. The æthmoid is later in its ossification than any other of the cranial bones, being cartilaginous till the middle of intra-uterine life. About that time an ossific nucleus appears in the upper part of each of the lateral masses, near the orbital plate. Just before birth a centre appears in each of the spongy bones; and soon after birth, from the sixth to the twelfth month, ossification takes place in the cribriform portion and the crista galli. The perpendicular plate next ossifies, and the several parts coalesce. But the cells are not formed till a subsequent period[2]. "During infancy the cribriform plate becomes narrowed, curved, and as it were compressed; the nasal lamella advances forwards; and the spaces between the septum and the outer walls are considerably increased[3]."

THE SUPERIOR MAXILLARY BONE, (Pl. XIII. and XV.)

on each side, forms part of the nasal fossæ, of the orbit and of the mouth, of the lachrymal, anterior and posterior palatine canals, and of the zygomatic, spheno- and pterygo-maxillary fossæ. It assists also to close the æthmoidal, and, in some instances, the frontal, sinuses. It is placed nearly in the same vertical plane with the forehead, instead of being protruded considerably in front of it, as it is in all the lower animals, where the jaws are required to serve as organs of prehension as well as of mastication. In order to give sufficient dimensions to the alveolar arch, and sufficient space to the several cavities which it contributes to form, the bone is of

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[1] Monro's *Elements of Anatomy*, I. 162.

[2] Beclard in Meckel's *Archiv*, VI. 426.

[3] *Cyclopedia of Anatomy*.

considerable size; and in order to reduce the weight its middle is hollowed out into a large cavity.

The antrum:

The *Antrum*—the name given to the cavity thus formed—is the largest of the facial sinuses, and, like the others, communicates with the nasal fossæ, and contributes to the modulation of the voice. Its shape is irregular, and its walls are, for the most part, thin. A transverse section shows it to be wider above than below, where its walls become thicker and converge to the alveolar processes (Pl. XV. fig. 3). Its interior is smooth, with the exception of a few ridges and channels which serve to strengthen its walls, while they transmit the branches of the infra-orbital nerve and artery to the teeth. The membrane which lines it, and which resembles that lining other parts of the nasal fossæ, consists of a fibrous periosteum and a mucous membrane united together by a fine layer of areolar tissue; it is easily detached. The great ragged hole in the flat inner wall is nearer to the roof than the floor of the cavity, and opens into the middle meatus narium on a level with the lower edge of the middle spongy bone. This hole is very much contracted by the encroachments of the æthmoid, palate, inferior spongy and lachrymal bones, so that fluids accumulated in the cavity do not easily escape, unless the head be placed quite on the side. It is, however, only in morbid states that such accumulations take place; for there are not many glands in the lining membrane of the antrum[1], and the slight simple secretion from its surface is either carried off by evaporation, or is wafted by its ciliated epithelium towards the orifice. In the recent state the schneiderian membrane still further diminishes the size of the opening, placing it quite under cover of the middle spongy bone, and is so disposed as to give it an oblique direction backwards from the antrum, whereby

shape and position of its foramen:

[1] The presence of glands in the interior of the antrum has commonly been denied. They are, however, described by Prof. Luschka (Virchow's *Archiv*, VIII. 422) to exist in the fibrous or periosteal sheet of the membrane, and to consist of branching tubes, which sometimes become dilated and give rise to the small cysts occasionally found projecting into the antrum; these are to be distinguished from the polypi that result from hypertrophy of the membrane itself.

the entrance of cold air and foreign bodies from the external meatus narium is prevented.

its wall: Being formed by the gradual extension outwards of a depression, which may be seen at birth in the situation of this opening (Pl. XVI. fig. 7, *G*), the antrum has a wall of its own, distinct from the exterior shell of the bone. The infra-orbital canal is situated between the two (Pl. XV. fig. 3, *A*); and so are the canals transmitting the several dental nerves from the slit-like openings on the hinder surface of the maxilla to the alveolar sockets. Some of these canals may be traced round the exterior of the antrum on their way to the bicuspid and canine teeth.

its liability to disease. Unlike the other nasal sinuses the antrum is frequently the seat of disease, depending partly upon its contiguity to the inferior spongy bone, the mucous membrane of which is often in a state of inflammation, and still more upon the proximity of the teeth. When it is distended by a collection of purulent or other fluid, the anterior wall generally yields first, just under the infra-orbital hole, between it and the bicuspid teeth. The bone is thin here, and becoming thinner in consequence of the pressure, an opening may be easily made through it to give vent to the accumulations. If the disease be long continued, and especially if solid growths occupy the antrum, the walls become stretched in every direction, encroaching upon the orbits the nose and the mouth, as well as protruding the cheek. The hinder wall, which is in contact with the palate-bone, is very thin, and is liable to give way and remain behind in the operation for the removal of the upper jaw, particularly when it is the seat of malignant disease.

Alveolar process. The *Alveolar processes*, continued round from one maxillary bone to the other, form a horse-shoe arch; the transverse diameter of which, being greater in proportion to its length from before backwards, causes a corresponding width of the palate, and is peculiar to the human skull. In the Negro this arch is more prolonged anteriorly and more compressed at the sides than in the European. Other differences may also be observed. Thus, in the European, the incisive alveolar processes and teeth are nearly vertical, with only a slight slant forwards; and the molar alveoli and teeth slant a little outwards. In the Negro the anterior teeth and their sockets are directed much more obliquely forwards; whereas the molar teeth are vertical or incline a little inwards. Again, if we take a profile view, we shall find that in the Negro, not only is the alveolar process prolonged further forwards than in the European, but its edge is more curved with the convexity downwards, the middle sockets on each side being in a lower plane than those in front and behind. This curve is more marked in the teeth than in the alveoli, and is sharpest in the situation of the bicuspid teeth.

The alveoli are of spongy structure to prevent their being chipped by the pressure of the teeth, and to permit a close and vascular connection with the gums. The quantity of fibrous and vascular tissue which is interwoven with the bone renders the latter liable to be involved in fibrous and fibro-vascular tumours called "epulis," and in ulceration arising from mercury and other causes. The hardest work in mastication is done by the second molars: these are accordingly the largest teeth and have the best developed fangs (two on the outer and one on the inner side); and the alveolus is thick here, and is strengthened by a ridge ascending from it to the malar process and the malar bone. The ends of the molar fangs lie close beneath the antrum and sometimes penetrate it in the dry bone; so that disease may readily be communicated from them to its lining membrane, and the cavity is easily opened from their sockets. The incisive and canine alveoli, which lie in front of the antrum, are placed beneath an expansion of the nasal process.

The maxillary bone is held in its place, behind, by the pterygoid processes of the sphenoid, through the medium of the palate-bone, which is adapted to its convex posterior edge; above, by the os planum of the æthmoid, and by the junction of the nasal process with the frontal, also by the frontal through the medium of the malar bone; and, internally, by the maxillary bone of the opposite side.

Nasal process.

The *Nasal process* presents a wavy outline from above downwards, and is projected forwards, at the middle and along the upper part, into a sharp edge which supports the nasal cartilages and bones and contributes to throw out the "bridge of the nose." Behind, it is channelled to assist in forming the lachrymal canal, which descends nearly vertically along it to the inferior meatus of the nose. When the nasal or lachrymal bones are small these processes are enlarged to supply the deficiency[1]. In most Graminivora, and in many other animals, the nasal processes are stunted to make room for the large lachrymal bones, and do not consequently reach the frontal bone.

Palatine process:

The *Palatine process* stretches transversely inwards to the median line, and is united with that of the opposite side by a suture, the teeth of which are linear. The united edges of the two bones are thrown upwards into a sharp crest (Pl. XV. fig. 1, *D*) with an undulating edge, upon which the vomer rests. The continuation of this crest in front, formed by the intermaxillary portions of the jaw-bones, is very prominent and stout (*E*, *K*). It receives the anterior extremity of the vomer, and contributes with the upper edge of that bone to the support of the septal cartilage of the nose[2]. On its upper surface the palatine process is concave, smooth, and covered by the even closely applied schneiderian membrane, so as to facilitate the passage of air to and fro. It is also higher in front than behind to direct the secretions of the nostrils and the tears back towards the pharynx. On its under surface it is rougher and more porous to give secure attachment to the thick fibrous and vascular soft palate. Abscesses are apt to form in this situation, and I have known alarming hæmorrhage follow incisions made to open them. The hinder edge is cut obliquely so that the anterior edge of the palate-bone, cut in a corresponding manner, may rest upon it. (Pl. XV. fig. 1, *L*, and Pl. XIII. fig. 2, *R*.)

Direction of its sutures.

The several surfaces for contact with other bones are cut so as to enable the maxilla to resist the pressure of the lower jaw; and the rough surface upon the malar process for union with the malar bone is no exception to this. The serræ upon it are directed upwards and backwards, and its anterior edge projects forwards and outwards, so as to rise up a little in front of the anterior edge of the malar bone.

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[1] The part of the nasal process which surrounds the lachrymal sac sometimes "forms a particular bone." Otto's *Path. Anat.* by South, p. 179.

[2] In some birds this process extends up as high as the nasal bones, and is received between them.

Orbital plate.

The *Orbital surface* is very smooth. It slants downwards and outwards towards the spheno-maxillary fissure and the malar bone, so that the lower and outer corner of the orbit is further removed from the eyeball than any other part; and the interspace between it and the eye is occupied by soft fat. The *infra-orbital groove* is, in the fore part of the orbit, converted into a *canal* by its outer edge growing over and uniting with the inner. The line of union of the two may often be seen in young skulls. Some anatomists suppose that this groove is the remains of a division which originally existed between the nasal process and the rest of the bone. I have not been able to find evidence of this by examination of fœtal bones. At the hinder part it is, in the recent state, completed by an extension of the periosteum over it. In a few instances it bifurcates, opening upon the cheek by two foramina instead of one; or it may be double in its whole length; peculiarities which derive interest from the analogy they present to the usual condition in apes and whales[1]. It is usually not a mere canal, but a slit extending some distance between the orbital plate and the wall of the antrum (Pl. XV. fig. 3, *A*).

Intermaxillary portion.

A delicate linear suture may commonly be seen on the palatine surface of the maxilla, crossing from near the anterior palatine foramen to the interval between the lateral incisor and the canine teeth. This marks out the *intermaxillary bone*, which contains the sockets of the incisor teeth, constitutes the whole thickness of the alveolus, including the floor of the nostril, the anterior nasal spine, and the front wall of the anterior palatine hole, and is connected above with the vomer and with the septal cartilage of the nose (Pl. XV. fig. 1, *EK*). The intermaxillary bones form a much more prominent feature in the lower animals. In them they are placed *in front* of the maxillæ and are, therefore, called "premaxillary bones," they also remain permanently separate from the maxillary bones, and send up a process to unite with the nasal bones on either side, so that, with the nasal bones, they complete the anterior opening of the nostrils.

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[1] Meckel's *Anatomie*, II. 127.

Opening of mouth.

The opening of the mouth extends, on either side, as far as the canine teeth, its corners about corresponding with the outer edges of these teeth; so that the size of the oral opening bears a relation to the size of the canine teeth, as well as to the size and direction of the incisors and of the intermaxillary portion of the jaw. When these are large and inclined forwards, the opening of the mouth is large; and this conformation, together with the thickness and eversion of the lips which are usually associated with large and protruding incisors, contributes to the ugliness of the Negro's mouth. The still greater protrusion of the fore part of the jaws, and the great size of the canine teeth, in the lower animals, causes the mouth to be extended to some distance on either side of the face, and renders it better adapted for its prehensile office. A comparatively small size of mouth, being thus associated with retiring alveoli, and being, therefore, an indication of departure from the brute type, comes to be looked upon as a beauty, and is, with some reason, regarded as an indication of intelligence.

Development.

The upper jaw is formed from membrane. Ossification begins so early, and the first nuclei, if there be more than one, coalesce so quickly, that it is difficult to ascertain their number with certainty. As a general rule there appears to be only one or two. There may, however, be more: thus one for the alveolar portion has been found by Beclard as early as the 30th day, quickly followed by three or four others, viz. one for the orbital plate and malar part, another for the malar process and facial part, a third for the intermaxillary portion, and a fourth for the palate; the latter is developed in connection with the internal lamina of the alveolar portion. By the end of the third month these three or four nuclei, supposing them originally distinct, have coalesced, so as to leave scarcely a trace of their separate existence[1]; about this time the alveolar ridges, shooting

[1] There are many fissures which extend to some depth in the fœtal and young bone; but we must not think that these are necessarily the indications of its having been developed from several centres. The most marked is that which gives the outline to the intermaxillary part; it extends from between the incisive and canine sockets through the palate to the anterior palatine hole, and may be traced on the floor of the nasal meatus, and up the inside of the nasal process, crossing the inferior turbinate bone and reaching as high as the top of the lachrymal duct. It would seem, therefore, from this, that the intermaxillary bones surround the chief part of the anterior meatus

down, enclose between them the groove in which the teeth are developed. The nasal process is now of considerable size. A wide channel between the latter and the orbital portion is the infra-orbital groove. This becomes covered over by a lamina of bone shooting from the sides, and arching over the nerve so as to form a canal. Occasionally this lamina is developed from a separate nucleus, and I have seen it ununited to the rest of the jaw in the adult. At birth the edges of the alveoli have inclined towards each other a little, overlapping the tooth-germs; and the dental groove is divided into sockets by partitions which have grown up from its bottom and sides. The whole maxilla is at this time very shallow: its orbital and alveolar portions are in close contact; the latter are in the same horizontal plane with the lower part of the occipital bone, and the wide dental groove occupies the body of the maxilla, and extends beneath the infra-orbital canal: as growth proceeds the bone acquires a greater depth, and the antrum is hollowed out in its interior. The latter, as before stated, may be traced at birth as a shallow depression of the inner wall of the maxilla. Gradually this depression is deepened, and extended outwards, so as to pass beneath the infra-orbital canal and occupy the situation before held by the dental groove. Compare figs. 3 and 4 of Pl. XIII.

Changes in age.

In old age the alveoli undergo absorption at their edges: this exposes the fangs of the teeth and causes them to become loose and fall out. The process of absorption continuing, the walls of the sockets become in time completely removed, so that the alveolar processes are on a level with the palate, leaving the nasal spine very prominent; and the whole bone is reduced to a

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narium, and reach nearly or quite to the nasal bones, as they do in the lower animals. Many doubt the development of the intermaxillary portion from a separate germ in the human fœtus. Even at the third month the suture or fissure just mentioned is the only evidence of its separate existence. M. J. Weber could find no trace of a distinct nucleus in any of the various fœtuses, of from two to four months, in the Museum at Prague. Nevertheless, he succeeded in detaching the intermaxillaries by immersing the maxillary bones in dilute nitric acid; this, together with their being so completely separate in many cases of cleft palate, he regards as conclusive evidence of their independent formation. He finds that the line of separation runs, not between the incisive and canine sockets, but through the inner part of the latter, which he connects with the absence of an interval between the canine and incisive teeth. Froriep's *Notizen*, Januar. 1828, s. 282.

light fragile fatty state. It thus returns nearly to its infantile shallow conformation. But there is this difference between the infantile and the senile maxilla, that, whereas in the former the want of depth results from the imperfect growth of the walls of the antrum, in the latter it results from the absorption of the alveolar portion[1].

Varieties. The frequency of some imperfection in the formation of the palatine and alveolar parts of the maxilla, causing the different degrees of cleft palate, has already been mentioned (page 180). An instance of congenital deficiency of the alveolar process of the upper jaw is given in the *Transactions of the Pathological Society*, Vol. I. 312. The plate of bone forming the roof of the antrum is sometimes in part deficient, so that this cavity may communicate with the orbit, or be separated from it only by fibrous tissue[2]. A process has been found extending from the orbital plate, behind the os planum to the frontal bone[3], and, in one instance, a "Zygomatic spine" was prolonged beneath the malar bone as far as the temporal bone[4].

Diseases. The presence of the teeth, and of the antrum with its vascular lining membrane, together with the lachrymal sac, the contiguity of the nose, mouth, and orbit, in each of which directions the bone is covered by a membrane differing from that in the other directions, renders the maxillary bone peculiarly liable to disease, more so than any other bone of the head. It is often the seat of cancer, of fibrous growths of various kinds, of exostosis, caries, and sometimes of necrosis.

THE INFERIOR MAXILLA

is the only bone of the skull capable of being moved upon the others. In the lower animals it is used as an organ of prehension, of attack and defence, as well as of mastication; and to fulfil these various functions it, together with the upper jaw, is prolonged for-

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1 There is this difference to be remarked, between the manner of the shedding of the first and second set of teeth; the former become loosened, and fall out in consequence of the absorption of their fangs, whereas the latter are lost in consequence of the removal of the walls of the sockets in which they were placed.

2 Lobstein, *Anat. Path.* Pl. V. fig. I.

3 Henle, *Handbuch der anatomie des menschen*, I. 159.

4 *Ibid.* I. 165.

wards, so as to be, in great part, clear of the rest of the skull; it is armed with powerful teeth, the muscles which move it are of great strength, and the bones which give attachment to these muscles are proportionately developed. In man, on the contrary, the jaw is restricted almost exclusively to the work of mastication; it is, accordingly, much shortened, its condyle and neck are directed vertically and placed nearly at right angles with the dental portion, so as to adapt the latter to the corresponding surface of the superior maxilla, which has, in its downward growth, descended considerably below the horizontal plane of the base of the skull. One result of this shortening of the jaw, and of the perpendicular position of the alveoli of the teeth, is to render the mental portion or chin broader and more prominent, so as to form a characteristic feature in the outline of the human face[1]. The inferior maxilla of the Negro exhibits some approximation to that of the lower animals in its greater massiveness, in the depth of its horizontal ramus, in the slant forwards of the alveoli and teeth, which causes the chin to be more retiring, in the greater obliquity of its neck, and in the more obtuse angle between its horizontal and ascending portions. It is also rather more curved along its alveolar edge, adapting it to the greater curvature of the alveolar portion of the upper jaw (p. 281). The inferior maxilla is a very hard bone, to enable it to resist the great force which its muscles are capable of exerting upon it, hence its section during operations is rather a tedious process.

The condyles.

The *Condyles* are set obliquely, so that lines drawn in the direction of their long axes meet in the fore part of the foramen magnum and form an angle of 150° or 160°; this arrangement facilitates the rotatory movements of the jaw. The slight elevation of their inner extremities, adapted to corresponding depressions in the glenoid cups, forms a sort of lock, and gives

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[1] The chin and the forehead (as mentioned at p. 245) bear a relation to one another in the degree of their prominence anteriorly, so as to maintain the balance of proportion between the upper and lower regions of the face. In the well-formed European both are prominent, contrasting with the idiot in whom both are retiring. The retiring of the forehead and chin, which gave unusual prominence to the teeth and openings of the nose, was very remarkable in the so-called "Aztecs," lately exhibited in this country.

steadiness and security to the joint; yet it is not sufficient to prevent some lateral movement. They are most thickly covered with cartilage at the fore parts where they are subjected to most pressure against the glenoid ridges.

The neck.

The *Neck*, on either side, though narrow in comparison with the condyle, is strengthened by ridges descending from the fore part and sides of the latter; it is, moreover, well protected, and is rarely broken[1]. It is curved (Pl. XVIII. figs. 4 and 5) so as to cause the head of the bone to present forwards, in a direction nearly corresponding with the line in which the chief bulk of the fibres of the masticatory muscles pull upon it in closing the jaw, and which throws the force of their action upon the strong ridge bounding the fore part of the glenoid cavity, (p. 256.)

The coronoid process.

The *Coronoid process* furnishes a good handle for the attachment of the temporal muscle, and gives greater force to the posterior fibres which draw the jaw backwards into the glenoid cavity, when the mouth is closed, and cause the lower incisors to be pulled up behind the upper ones like the blades in a pair of shears. It is inclined a little outwards to afford a more favourable insertion to the fibres of the muscle, which are chiefly implanted on its inner side and fore part. From its base a thick ridge passes down obliquely, on either side of the alveoli, to the base of the horizontal ramus, so as to strengthen this part of the jaw which has to bear the greatest stress in mastication. The *Angle* of the jaw is generally turned a little outwards. In some it is turned inwards. Whichever way it be the curve affords more space and a better purchase to the muscles—the mastoid and internal pterygoid—that are inserted on its sides, than a plane surface would have done. It is thin, hard, and marked by oblique ridges for the intermuscular tendinous fibres.

The alveoli.

The *Alveolar processes* form the sockets for the teeth: they are thicker, denser, and stronger than those of the upper jaw; hence the great force usually required to dislodge a

[1] There is in the Musée Dupuytren an example of united fracture of the neck of the lower jaw.

tooth from the lower jaw, and the mischief which has occasionally resulted from rough efforts to extract teeth. I know a patient, the whole of the horizontal portion of whose jaw was pulled away, when she was a child, in the rude attempts of a quack to draw a tooth. The foremost alveoli and incisor teeth are slanted a little forwards; the hindmost and the molar teeth are slanted a little inwards, that is, in an opposite direction to those of the upper jaw, which is favourable to the trituration of the food in the lateral and rotatory movements of mastication. The arch formed by the alveoli and teeth of the lower jaw is generally rather smaller than that of the upper jaw, so that the former is received within the latter when the mouth is closed. Hence the teeth are of somewhat less size, and their fangs are arranged, side by side in the alveolar sockets, in a rather more regular manner than in the upper jaw. Moreover, the molar teeth have only two fangs, one in front of the other. The hinder molar, or *wisdom tooth*, has often only one fang. It is situated close to the angle between the horizontal and the ascending ramus of the jaw, so that the space afforded to it is confined in proportion as that angle is small. This accounts for the trouble so often experienced by Europeans during the cutting of this molar; a portion of the gum which covers the fore part of the coronoid process being liable to be carried before the tooth, and to be subjected to inflammation and ulceration by its pressure. The limited space allotted to it may account also, in part, for the early decay of this tooth; and we may infer that these inconveniences are less frequently experienced in the Negro, in whom the angle is wider.

The dental canal.

The *Dental canal* corresponds in its office with the infra-orbital groove, transmitting branches of the fifth pair of nerves and blood-vessels to the bone, the teeth, and the contiguous soft parts. "The size and situation of the dental canal vary according to the age of the individual. At birth it runs near the lower border of the bone, and is of considerable magnitude; after the second dentition it becomes placed just above the level of the mylo-hyoid ridge; in the edentulous jaw of old age it runs along the alveolar border of the bone, its size is much diminished, and the mental foramen is found close upon the upper border of the bone[1]." (Pl. XVII.) The *Mental foramen* is generally placed beneath the interval between the two bicuspid teeth, in a vertical line with the supra- and infra-orbital foramina, or very nearly so. It is situated further back in the Negro, beneath the second bicuspid, or beneath the interval between it and the first molar.

Development. Ossification commences in the membrane from which the inferior maxilla is formed, at a very early period—from the thirtieth to the thirty-fifth day, according to Beclard. Soon after two months it is considerably advanced. The bone is then in halves, united in the median line by membrane. In each of these halves the condyle, coronoid portion, and angle are quite evident; the mental part is of considerable size; and there is a lamina, appended to the inner side of the ramus, which, shooting upwards, forms the inner wall of the dental groove and dental canal. The appearance of the several parts at this early stage certainly gives countenance to the supposition that each of them had a separate ossifying nucleus, corresponding, or nearly corresponding, with the five pieces into which the jaw of the crocodile is permanently divided; that is to say, one for the under and outer part of the ramus, another for the inner alveolar border, a third for the coronoid process, a fourth for the condyle, and a fifth for the angle. If it be so they become united together very quickly after their formation. The probability, however, is that in this bone, as in the upper jaw, there is usually only one nucleus on either side, and that the various processes are merely outgrowths; the instances in which the latter are developed from separate nuclei being exceptional[2]. As growth proceeds the inner

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[1] Partridge in *Cyclopedia of Anatomy*. Article *Face*.

[2] Kerkringius, *Osteogenia fœtuum*, cap. IX., describes the coronoid process as consisting, up to the third month, of an ossicle separated by a suture from the rest of the maxilla. Beclard mentions, in addition to the nucleus for the ramus which appears from the 30th to the 35th day, a nucleus for the coronoid process which appears about the 45th day. Autenrieth and Spix, Hildebrandt's *Anatomie*, II. 113, describe also a nucleus for the condyle and one for the angle, to the probability of which Beclard gives assent. According to Spix the inner wall of the jaw is derived from a separate nucleus. Blandin, *Anatomie*, I. 127, found the body, the coronoid process, and the hinder part of the bone, separate from one another, in a fœtus of three months.

lamina of the ramus rises nearly to the same level with the outer, and forms the inner alveolar border; the dental *groove* is deepened; and the anterior dental *sockets* become marked out and separated from one another by bony partitions, which grow from the sides and bottom of the groove. Near the coronoid process the inner lamina joins the outer, arching over and enclosing the dental *foramen* and the hinder part of the dental *canal*. The latter is, at this time, a mere channel, in which the nerves and vessels lie, at the bottom of the dental groove, in the greater part of its extent.

At birth.

At birth the two incisive, the canine, and the first molar sockets are partitioned from one another; the dental canal has become, in great measure, separated from the dental groove or sockets; and the dental foramen and the spine that projects upon its inner side are formed. There are always at this time, at least, two openings at the dental foramen. One, of larger size than the other, communicates with a *groove* which runs along the floor of the cavity for the hinder teeth. The other, smaller one, is the opening of a *canal* which runs beneath this groove to the milk-teeth. Both the groove and the canal carry vessels and nerves to the teeth, and communicate with the mental foramen, which is situated beneath the first molar socket, nearly in the same position as in the adult Negro[1]. When the milk-teeth fall out the canal which is devoted to them disappears, and the groove, becoming enlarged and covered over, is converted into the permanent dental canal. The bone is, at birth, still in halves, united by fibrous or fibro-cartilaginous tissue, in which one or two little bony germs are occasionally found[2]. The coronoid process is of large comparative size, and stands up boldly, at right angles from the rest of the bone. It is thrown into stronger relief from the fact that the condyloid part is nearly in the same horizontal line with

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[1] The above-mentioned dental groove and canal of the fœtus and young child do not always communicate with the same mental foramen; for there are sometimes, as represented in Plate XVII. fig. 1, two mental foramina, one in front of the other; the anterior of these, which opens into the canal, becomes obliterated with it during the second dentition.

[2] Otto, p. 182.

the ramus: at least it forms with it an angle of 160° or 170°; and this straight configuration of the lower jaw, together with the want of depth of the ramus, contributes to give the round shape to the face of the infant. The condyle is ossified up to its thin articular cartilage; this and the sternal end of the clavicle being the only bones in which that is the case[1]. The condyle itself is rounded on its fore part, and the movements of the jaw are nearly confined to opening and shutting the mouth; but little lateral or antero-posterior motion is possible in consequence of the small size of the glenoid cavity.

Changes after birth.

After birth the two segments become united at the symphysis. The union takes place from below upwards, and is complete at about a year. A small notch in the alveolar margin, which is a remnant of the former fissure, may sometimes be seen as late as the second year. In many of the lower animals the symphysial suture remains through life; but I do not know of any instance in which the halves have failed to coalesce in man, or in which an intermediate bone has been permanent in this situation[2]. The ramus becomes increased in thickness, partly by growth above the dental canal, to afford room for the fangs of the teeth, and, still more, by the thickening below, which takes place to enable the jaw to withstand the powerful contraction of the masticatory muscles. While these changes are going on, and the

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[1] Kolliker, adducing this as an instance in which part of one of the "secondary cranial bones," (that is, one of the cranial bones "ossifying from plasma secreted from the vessels of the periosteum,") is lengthened through the medium of cartilage, makes the following remarks: "The most striking example of this kind occurs in the condyle of the inferior maxilla, where, even during fœtal life, a thick cartilaginous layer is deposited, which, so long as the growth of the bone continues, precedes its longitudinal growth exactly like an epiphysial cartilage. I have noticed the same thing in the articular fossa of the temporal bone, where, however, the cartilage is less developed, at the angle of the inferior maxilla (in the calf) and at the anterior extremities of each half of the same bone, which are connected by a semi-fibrous, semi-cartilaginous substance." *Human Histology*, I. 373.

[2] The lower jaw is not unfrequently wanting altogether in the lower animals; in some instances the lateral portions remain separated by an interval, and there is a longitudinal cleft in the lower part of the mouth, Otto's *Catalog des Anatomischen Museums zu Breslau*, p. 37. A case of deficiency of the lower jaw in a human fœtus is related in his *Seltene Beobachtungen 2te Sammlung*, s. 168.

upper jaw is growing downwards, the condyloid part elongates, and the angle between the vertical and horizontal portions becomes less and less obtuse, till it is nearly a right angle[1]. The condyle becomes, at the same time, less rounded anteriorly, is hollowed a little immediately beneath its anterior articular edge, and is bent slightly forward where it is set upon the neck. The ramus elongates in its whole length, but more particularly behind the mental foramen; and the three additional double teeth of the second dentition are developed in this part. The time at which the several teeth appear is subject to considerable irregularity; and instances of elderly persons are every now and then met with, in whom the wisdom and some other teeth have not been cut[2].

Changes in age.

When, in advancing years, the alveoli are absorbed and the teeth drop out the bone again becomes shallow; particularly between the mental and condyloid portions, where it is often reduced to the size of the shaft of a metacarpal bone. At the chin it remains rather thicker, and its upper edge is slanted backwards, in consequence, probably, of the pressure of the lower lip upon it. But, whereas in infancy the alveolar processes constituted the chief element in the ramus, these have been removed in the aged person, and the lower, or "subdental," portion only remains; so that the mental foramen, which had been near the lower margin of the jaw, is now placed quite upon its upper edge. The bone is very hard in the edentulous state, and is not subject, so far as I know, to the interstitial absorption and fatty degeneration which are so frequently observed in other parts of the senile skeleton. In order to permit the jaws, deprived of teeth and alveoli, to be brought into something like proximity with one another, so that the food may be rubbed down between them and between them and the lips, the angle of the lower jaw again becomes widened to between 130° and 140°, and the neck of the bone is more or less bent backwards. These changes in the angle and

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[1] During the first dentition the angle varies from 150° to 130°. In the second dentition it is reduced to about 115°. In the Negro and Mongolian it is rather wider than in the European.

[2] Otto's *Catalog des Anatomischen Museums zu Breslau*, p. 53.

neck are, probably, in some measure, dependent upon the influence of the masseter internal pterygoid and temporal muscles, which tends to bring the condyle and the ramus into a straight line, after the resistance afforded by the contact of the teeth with those of the upper jaw has been withdrawn. As a consequence of these changes the jaw is elongated and the chin is thrown forwards, so that when the mouth is closed the latter is in a plane considerably in front of the corresponding part of the upper jaw, the nose and the chin come together, and the relation of the parts at preceding periods, when the upper jaw projected in front of the lower, is reversed. After all, therefore, there cannot be much contact between the upper and lower gums. The fact is, that mastication is performed very imperfectly, the food being merely softened by the saliva and rubbed down a little between the lips and the gums; and, as a compensation for the deficiency of trituration in the mouth, it would seem that the digestive powers of the stomach are increased. I have observed this to be the case in so many instances that I am inclined to regard it as a general rule, that the powers

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DESCRIPTION OF PLATE XVII.

Fig. 1. Side view of exterior of lower jaw at birth, showing the width of the "angle" and the prominence of the "coronoid process." *A* is the "anterior mental foramen," with a bristle (*B*) passed through it along the inferior dental canal. *C* is the "mental foramen," situated beneath (*D*) the first molar socket and communicating directly with it.

Fig. 2. Side view of jaw of child, in which first dentition is complete: the outer shell has been removed to expose the teeth. *A* and *B*, two molars, the latter a permanent tooth. *C* and *D*, second and third molars. *E, F*, the two bicuspids. *G, H*, the two permanent incisors. The six last mentioned lie quite concealed in the ramus of the jaw. The "angle" is nearly as wide as at birth.

Fig. 3. Similar view of adult jaw. The "angle" is nearly a right angle. *C*, the "mental foramen." There is no distinct trace of an anterior mental foramen.

Fig. 4. Similar view of jaw of an old person. The angle is obtuse; the coronoid process is sharp, the condyle flattened from before backwards. *C*, the "mental foramen," is large, and quite upon the upper edge of the ramus. *D*, the narrow part of the ramus. *E*, the upper edge of the mental portion sloped backwards. The alveoli are quite removed, and the upper edge of the jaw is smooth and hard like the rest of the bone.

Fig. 5. Side view of edentulous skull, showing the elongated condition of the lower jaw, and its relation to the upper jaw. *A*, the projecting nasal spine of the superior maxilla. The alveoli of both upper and lower jaws are gone. *C*, mental foramen.

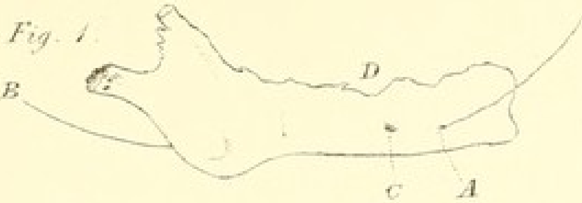

Fig. 1.

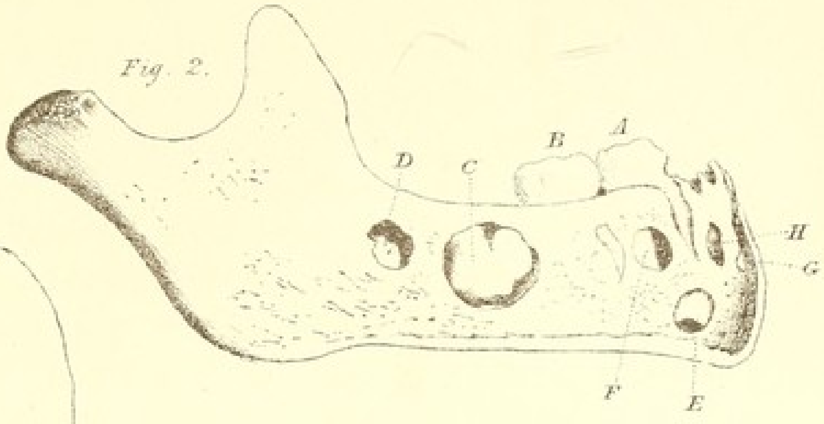

Fig. 2.

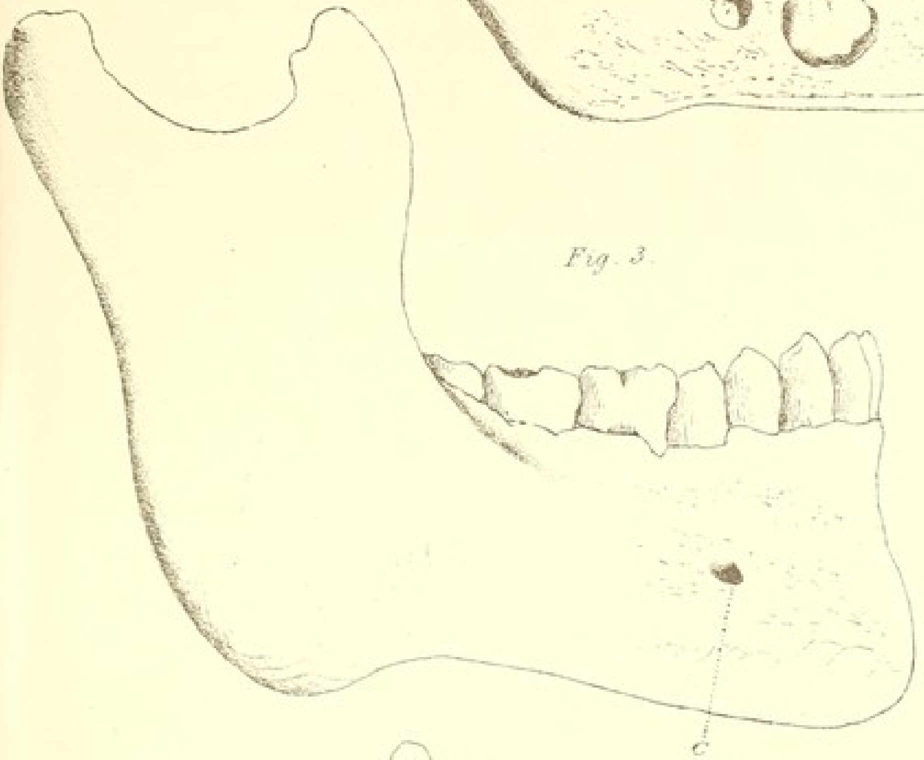

Fig. 3.

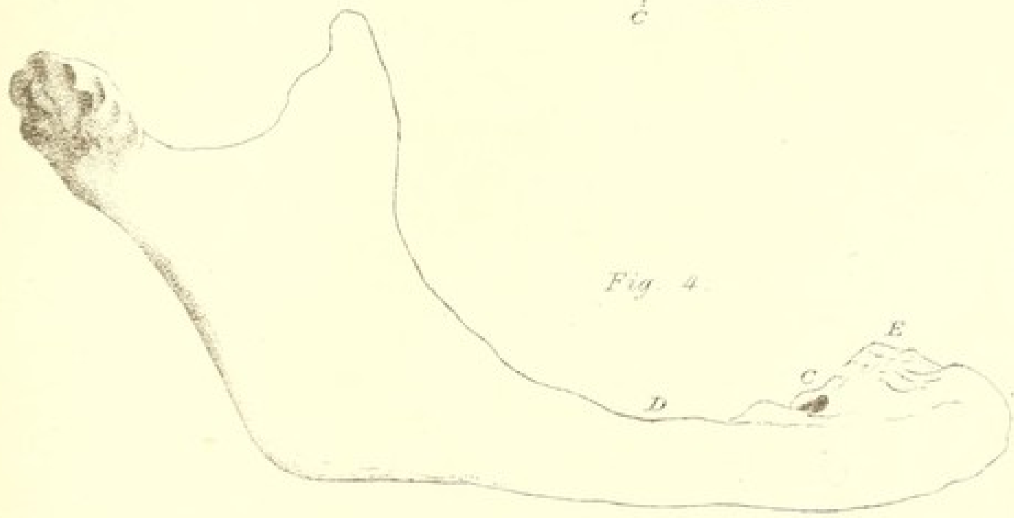

Fig. 4.

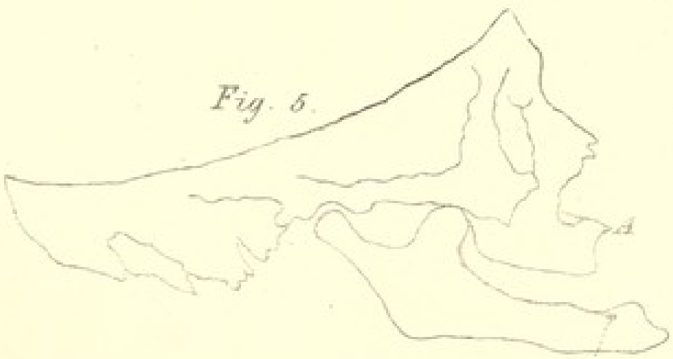

Fig. 5.

of the stomach increase about the same time that those of the jaws begin to fail. Among other changes incidental to age the coronoid process becomes thin and pointed, the condyles become narrow from before backwards, and more hollowed in front; they rest upon the glenoid cavity by a narrow portion of their anterior aspect, and the cartilage disappears from the remainder of their surface.

Diseases.

The lower jaw, like the upper, is subject to a variety of diseases, which are often excited by a morbid condition of the teeth, of the membrane which lines the alveolar sockets, or of the gums. Many tumours, of fibrous, osseous, cystic (simple and multilocular[1]), and cancerous nature, are developed in it. It is therefore often the subject of operation. Large portions may be removed without much difficulty or danger; but the effect of breaking in upon the alveolar arch is serious; inasmuch as the portion of the jaw which is left does not retain its proper position, and the teeth cannot usually be brought into contact with those of the upper jaw. The mental portion of the jaw is sometimes bent downwards, and the alveolar processes are directed forwards, so that the incisor teeth cannot be approximated to those of the upper jaw. This may result from the contraction of a cicatrix in front of the neck. I found the same change caused by the pressure of an enlarged tongue prolapsing through the mouth[2], and in another case by the long-continued pressure of an enormous ranula.

OTHER BONES OF FACE.

The palate-bones.

The *Palate-bones*, placed between the superior maxillary and sphenoid, are, as to their palatine and orbital portions (page 213), small in man in comparison with most of the lower animals. They embrace the posterior round ends of their respective maxillæ, overlap the palatine plates of those bones, and assist to cover the hinder part of the antral opening. At the point of union of the four corners of the maxillary and palate-bones two of the angles unite diagonally, separating the other two, just as we

[1] *Edinburgh Medical Journal*, Nov. 1857, p. 466.

[2] *Medico-Chirurgical Transactions*, XXXVI.

usually find to be the case with the angles of the frontal and parietal bones when the frontal suture is persistent. Each palate-bone is developed from one nucleus, which appears, between the fortieth day and the third month, at the angle of union of the horizontal with the vertical portion. The palatine process soon shoots inward to meet that of the opposite side. In the young child the bone has very little depth; the transverse measurement is greater than the vertical, and the orbital portion is not yet formed.

Vomer.

The thick furrowed upper extremity of the *Vomer* embraces the keel-shaped under-surface of the body of the sphenoid, so that the increase of the depth of the latter, and the formation of the sinus in its interior have direct relation to the downward growth of the jaws. The sharp median antero-inferior angle of the sphenoid is received between the plates of the vomer, which rise up on either side of it; and the bony laminæ which extend inwards from the bases of the pterygoid processes overlap the hinder forked extremity of the vomer. Thus the bone is held securely in its position, and displacement downwards and backwards, as well as upwards, is effectually prevented. It becomes thinner as it descends. Its hinder edge is free, forming the inner margin of each of the posterior openings of the nares. Its sharp lower edge is applied in a wavy line upon the projecting ridge formed by the union of the palate and maxillary bones of the two sides. Its anterior extremity, which is thicker, abuts against the nasal spine of the maxillæ. Its upper edge is thin and single, where it is in contact with the æthmoid; thicker, and in early life double, where it is connected with the septal cartilage. The vomer is marked on either side by a groove for the nerve descending, from the spheno-palatine, to the anterior palatine hole. (Plate XV. fig. 1.)

Ossification begins at the upper part at the fifty-fifth day (Beclard), or in the fourth month (Meckel). There is only one nucleus. From this two laminæ grow down, one on either side of the median line. They are, at first, separated by a considerable interval, and they enclose between them the unossified cartilage, which is prolonged forwards, and forms the remainder of the septum. The coalescence of the laminæ goes on from behind forwards, but is not complete till after puberty; even then there remains a groove for the reception of the septal cartilage. The laminæ remain separate to a greater extent in other mammals than in man.

Inferior Spongy bone.

Ossification begins in the *inferior Spongy bone* in the fifth month, and goes on quickly. The hook-like process which extends into the antrum is ossified after birth. It has its broad end directed forwards and applied against the nasal process of the maxillary bone. Its lower edge slants from behind, upwards and forwards in two-thirds of its length, so as to catch the inspired current. (See page 215.)

Lachrymal bones.

The *Lachrymal bones* form a small item in the human skull; and they vary in size and shape. In some cases the *crista lachrymalis* is wanting or very small; and there is, consequently, no line of division between the fore and hinder parts of the bone. Each lachrymal bone may be continuous with the lamina of the æthmoid, or be divided by a vertical suture[1], or be so small as not to assist in forming the lachrymal canal; or it may be absent altogether, its place being supplied by the nasal process of the maxillary bone[2], or by it conjoined with the æthmoid. These bones are much larger in other mammals; in Graminivora they occupy the place of the nasal processes of the maxillary bones, which are truncated and do not reach the frontal. Ossification begins in the lachrymal bones at about the 55th day (Beclard), or in the 5th or 6th month (Meckel). At birth their size, like that of the orbits, is large in proportion to that of the other facial bones.

Nasal bones.

The *Nasal bones* are applied against one another, and are joined together so as to form an arch, which rests upon the nasal processes of the maxillary bones. The line of union with the latter is serpentine; and there is an alternation in the overlapping of the respective edges, so that displacement is quite provided against. The thick, jagged, upper ends of the nasal bones are closely united with the deeply dentated nasal process of the frontal bone; and their thin, notched, lower edges are connected with the fibrous tissue and cartilages of the nose. The arch formed by their union, and the anterior curvature in their length, both contribute to throw out the bridge of the nose, the prominence of which

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[1] Hyrtl, *Anatomie*, s. 201. [2] Otto, p. 181.

is a characteristic feature of the human face, and is most marked in the higher races of mankind, and more marked in the adult than in the child. The groove on the hinder surface of each nasal bone, leading to the deep notch in its lower end, is for the naso-lobular branch of the fifth nerve. A separate branch of the nerve often passes through a small hole near the middle of the bone. The nasal bones begin to ossify as early as between the 2nd and 3rd month.

In a few instances but one nasal bone has been found, reminding us of the Monkey[1]: this is the case in the skull of a native of Congo, æt. 37, in the Cambridge museum. Or there may have been originally two bones which have become early united; and it may be observed that the suture between the nasal bones is obliterated earlier than any other in the face. Sometimes they are wanting, the deficiency being supplied by the enlarged nasal processes of the maxillary bones[2]. In the little child they are straighter and of more uniform width; as the face grows larger they become lengthened, more curved and arched, and wider at their lower ends.

Malar bones.

The *Malar bones* are yoke-bones between the jaws and the sides of the cranium, being connected above with the frontal and sphenoid, behind with the zygomatic processes of the temporal which overlap them, and in front with the sides of the upper jaw, in the manner mentioned at page 282. Like most of the other bones of the face each malar bone is perforated by a branch of the fifth nerve, which is distributed to the skin over it. It begins to ossify between the 50th day and the 3rd month. At birth it is fully formed.

In the Monkey the malar bone extends further into the orbit, and separates that cavity from the temporal fossa more completely even than it does in man; but in other animals it has little or no connection with the sphenoid; and in most Carnivora it does not even touch the frontal bone, but forms merely a band between the jaw and the temporal bone, so that the orbit and the temporal fossa are one cavity. In the Kangaroo it runs back beneath the zygoma as far as the glenoid cavity.

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[1] In the monkey the single nasal bone tapers towards its upper end, and barely reaches the frontal bone. In other animals there are two nasal bones.

[2] Otto, p. 181.

Breschet[1], having examined a vast number of skeletons, met with ten cases in which the malar bone was divided by a horizontal suture into two portions. In only one case did the division exist on both sides of the same skull. He found a similar condition in some of the Quadrumana; and, in a few instances, he met with two and even three nuclei in the human fœtus. In several young bones I have found a fissure extending horizontally through the orbital plate, so as to create a partial division of the bone into two pieces. Occasionally the bone is absent altogether[2].

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[1] *Annales des Sciences Naturelles*, 1844, Tom. I. A similar division of the malar bone into two or three pieces placed one above the other has been noticed by Sandifort, Sœmmerring, and Spix.

[2] Jourdain, *Encycl. Anat.* II. 61.

THE TEMPORO-MAXILLARY JOINT[1] (Pl. XVIII.)

is the only joint in the skull permitting one bone to move upon another. It is protected by ligaments which surround the joint, and which are almost continuous with one another, so that they might be described as forming one capsular membrane; but as they are thicker at some parts than at others, they will be better understood if they be treated of separately, as "external," "internal," "anterior," and "posterior" portions or ligaments.

External lateral ligament.

The *External lateral ligament* (fig. 1, *C*) is the strongest of all, and has the most extensive attachments. It arises from nearly the whole of the lower edge of the zygomatic process of the temporal bone. Its anterior fibres, which reach almost to the malar bone, and are of considerable strength, pass very obliquely backwards and downwards; the middle ones are less oblique, and the hinder ones are shorter and nearly straight: they are all inserted into the ridge descending from the outer extremity of the condyle. I do not find that any of them are attached to the condyle itself, so that this part of the bone is free to slide backwards and forwards under the ligament. The chief office of this ligament is to prevent the condyle being pressed backwards against the post-glenoid and vaginal processes of the temporal bone when the mouth is closed. Its hinder fibres prevent the condyle being thrust too far forwards when the mouth is open. It also limits the extent to which the jaws can be separated; and, when the mouth is being opened wide, it will, by fixing the neck of the jaw and making it the centre of motion, cause the condyle to advance forwards upon the glenoid ridge.

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[1] For shape of articular surfaces, see Temporal Bone (p. 254), and Lower Jaw (p. 287).

Long and short internal lateral ligaments.

The *Internal lateral ligaments* (figs. 2 and 3, *E* and *F*) are two; a *long* and a *short*. The former, usually described as "the internal lateral ligament," descends, from the outer part of the spine of the sphenoid bone and the contiguous edge of the glenoid cavity, downwards and outwards, to the lower jaw, beneath the dental foramen, where it is attached to the spine of the maxilla and covers over the groove for the mylo-hyoid nerve. The *Short internal ligament*, which seems to have escaped the observation of anatomists, though it is a well-defined structure, stronger and more worthy of attention than the preceding, arises by a broad base, a little external to and in front of it, from near the same point of the sphenoid spine, and is attached, by a narrower apex, to the sharp ridge descending from the inner extremity of the condyle, immediately behind the insertion of the external pterygoid muscle. It is separated from the long internal lateral ligament by fat and cellular tissue. Like the *external* lateral ligament it passes over the condyle, so as not to interfere with its backward and forward movement; and it combines with that ligament in limiting the advance of the condyle forwards when the mouth is open, and in preventing its too great retrocession when the mouth is closed. By fixing the neck of the bone, when the mouth is being opened, it also combines with the outer ligament in promoting the forward movement of the condyle. A line drawn through the neck of the jaw, between the points of insertion of these two ligaments (i. e. the short internal and the external lateral ligaments), represents the axis upon which the jaw revolves during the opening and shutting of the mouth; and the condyle plays forwards and backwards between the two ligaments, both of which tend to prevent its displacement in a lateral direction as well as backwards or forwards.

Posterior ligament.

The *Posterior ligament* (fig. 5, *L*) connects the external and the short internal ligaments together. It is attached between them to the hinder edge of the glenoid cavity, just in front of the *fissura Glaseri*, and is inserted between them into the hinder surface of the jaw, below the neck. It assists them in limiting the forward movement of the jaw. The long internal lateral ligament is also united to it by fibrous tissue, and, in some instances, Anterior ligament.

seems to be continuous with it. The *Anterior ligament* scarcely deserves a special name or description. It will be mentioned again presently.

Interarticular fibro-cartilage.

The *Interarticular fibro-cartilage* (fig. 3, *H*, figs. 4 and 5, *F*) forms an important element in this joint. It is shaped so as to fit upon the condyle, and is thinner at the middle than at the circumference. Now and then it is perforated in the middle. It divides the joint transversely into two distinct cavities, each having a separate synovial membrane; and these synovial membranes, strengthened by some fibrous tissue, which passes off from the circumference of the interarticular cartilage, above and below,

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DESCRIPTION OF PLATE XVIII.

Fig. 1. The right temporo-maxillary joint seen from the outer side. *A*, mastoid process. *B*, zygoma. *C*, external lateral ligament. *D*, the styloid process.

Fig. 2. The same joint seen from the inner side. *A*, cut edge of temporal bone. *B*, cut edge of sphenoid. *C*, spine of sphenoid. *D*, lower jaw, which has been drawn a little forwards. *E*, long internal lateral ligament, which has been partly removed. *F*, short internal ditto. *G*, external pterygoid muscle.

Fig. 3. Vertical section, from side to side, through the same joint, viewed from behind. *A*, cut edge of temporal bone at zygoma. *B*, cut edge of sphenoid. *C*, spine of sphenoid. *D*, lower jaw. *E* and *F*, long and short internal lateral ligaments. *G*, external lateral ligament. *H*, interarticular fibro-cartilage, with the fibro-synovial ligaments passing from its edge downwards to the neck of the jaw, whence the synovial membrane is reflected upon the lateral ligaments on either side and passes upwards to the glenoid cavity; so that the articular space above the fibro-cartilage is considerably larger than that below it.

Fig. 4. Vertical section from before backwards through the same joint, with the condyle resting in the glenoid cavity; the mouth being shut. *A*, cut edge of temporal bone. *B*, post-glenoid process. *C*, edge of tympanic bone, which separates parotidean fossa from external auditory canal. *D*, thin lamina of bone separating glenoid cavity from cranial cavity. *E*, ridge in front of glenoid cavity. The thick hinder edge of the interarticular cartilage (*F*) is in the deepest part of the glenoid cavity; its thinner middle part lies between the *fore* part of the condyle and the *hinder* part of the glenoid ridge; its antero-superior fibro-synovial ligament (*G*) is on the stretch. The external pterygoid muscle (*H*) is connected with the lower edge of the fibro-cartilage, with the infero-anterior fibro-synovial ligament and with the fore part of the condyle.

Fig. 5. Same preparation, with the condyle drawn forwards upon the glenoid ridge, the mouth being open. The fibro-cartilage has advanced with the condyle, which has revolved slightly beneath it; so that the thinnest part of the fibro-cartilage now intervenes between the *upper* surface of the condyle and the *middle* of the glenoid ridge. *A* to *H*, the same as in preceding specimen. *I* and *K*, supero- and infero-posterior fibro-synovial ligaments. *L*, posterior ligament of the joint.

Fig. 1.

Fig. 2.

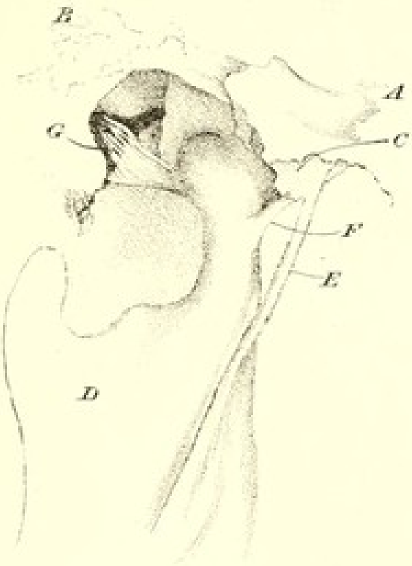


Fig. 3.

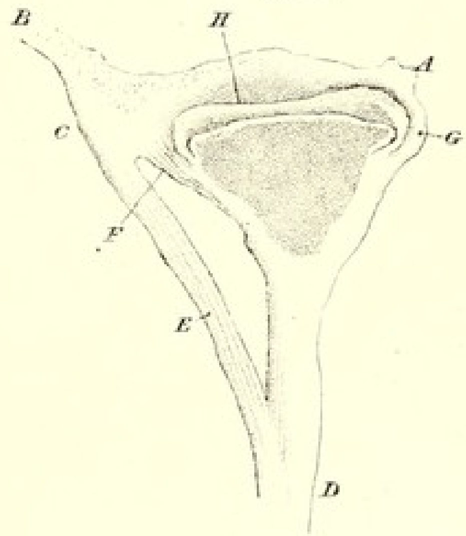


Fig. 4.

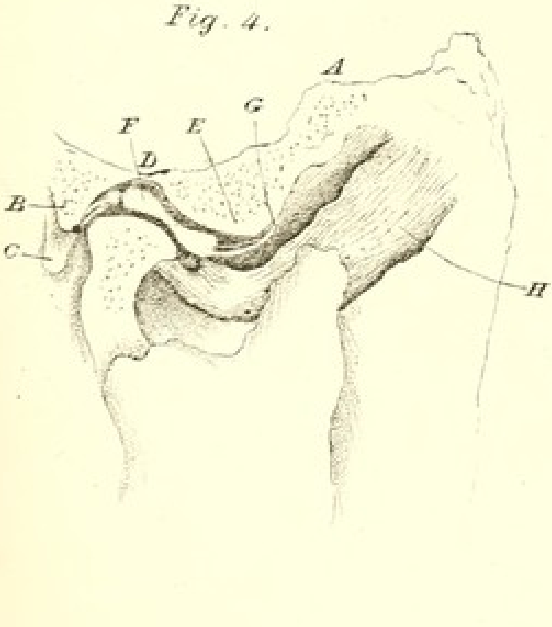
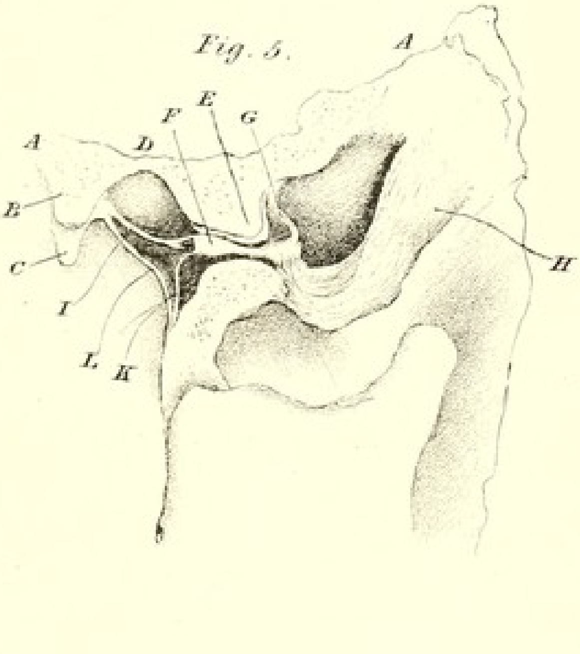


Fig. 5.



hold it in its place. On the sides the cartilage is connected with the lateral ligaments by loose cellular tissue, which permits it to pass freely between them in its attendance upon the movements of the condyle. The fibro-synovial membranes, or ligaments, leave the hinder edge of the cartilage and, diverging from one another, run some distance to reach the upper and lower attachment of the posterior ligament. The fibro-synovial membranes at the fore part of the interarticular cartilage are of less extent, and proceed upwards to the fore part of the glenoid ridge and downwards to the anterior edge of the condyle. They form the only *anterior ligament* of the joint; and some of the fibres of the external pterygoid are inserted into them and into the edge of the fibro-cartilage between them. The synovial sac above the fibro-cartilage is larger than that below it, in accordance with the larger size of the articular surface of the temporal bone in comparison with that of the lower jaw, and with the fact that the cartilage and the condyle slide backwards and forwards together upon the glenoid ridge. The anterior fibro-synovial ligaments are not of sufficient length to permit the fibro-cartilage to pass far back into the glenoid cavity; accordingly, when the mouth is shut, the hinder thick edge of that body occupies the bottom of the cavity and defends the comparatively delicate lamina of bone, which forms the septum between it and the dura mater, from the pressure of the jaw; and the thinner middle part intervenes between the glenoid ridge and the anterior surface of the condyle of the jaw. (Fig. 4, *F.*)

Movements of the joint.

The chief movement of this joint is the hinge-like one of opening and shutting the mouth, during which, in consequence of the action of the external pterygoid muscles, and of the disposition of the lateral ligaments just described, the condyle advances upon the glenoid ridge. It should not pass quite to the summit of the ridge, but should stop a little behind the summit, where it is so situated with regard to the temporal masseter and internal pterygoid muscles that when they contract, for the purpose of raising the ramus of the jaw and shutting the mouth, they, at the same time, press the condyle up the slope of the glenoid ridge back again into the glenoid fossa. By this oblique sliding of the condyle to and fro upon the slope of the glenoid ridge two points are attained. First, a greater range of movement is imparted to the alveolar portion of the jaw by a given amount of muscular contraction; and secondly, a cutting action is given to the incisor teeth, in consequence of the lower teeth being drawn up behind the upper, the anterior edges of the former being at the same time kept opposed to the hinder edges of the latter.

Dislocation.

Usually the advance of the condyle beyond the point indicated is restricted by the hinder fibres of the lateral ligaments, and by the posterior ligament; occasionally, however, when the mouth is opened very wide, as in gaping, the condyle overshoots its proper limits, passes over the summit of the ridge, and becomes lodged in front, constituting the common dislocation of the jaw. In that position the lateral ligaments, being tightened, prevent the return of the condyle over the ridge, and the contraction of the muscles tends rather to increase the displacement; so that artificial means are requisite to restore the bone to its proper position. This may usually be done, without much difficulty, by pressing down the molar and elevating the mental portion of the jaw. The dislocation is not commonly attended with any laceration of the synovial membrane or other soft parts; accordingly the patient feels no inconvenience directly after it has been reduced. It may be easily produced in the dead subject. It may be observed, that the anterior edge of the glenoid ridge is covered with cartilage, and we might, therefore, suppose that the condyle naturally plays upon this part; but it is not so. The cartilage here is for the contact of the interarticular cartilage and not of the condyle, which in the ordinary movements never reaches the front of the glenoid ridge.

Lateral movement and rotation.

Very little, if any, true lateral movement of the jaw is possible, in consequence of the oblique direction of the glenoid cavities and of the condyles which are slanted backwards and upwards as well as inwards. When the mental portion of the jaw is moved to one side the condyle of that side rotates slightly upon an axis drawn perpendicularly through its outer part, its inner edge mounting a little, and the opposite condyle still more, upon their respective glenoid ridges. Under ordinary circumstances however, in mastication, both condyles advance a little and perform a slight circular movement upon the glenoid ridges.

Hinge-like movements between condyle and fibro-cartilage; other movements are between fibro-cartilage and glenoid cavity.

The hinge-like movements of the jaw, in opening and shutting the mouth, are principally performed between the condyle and the fibro-cartilage, in the *lower* synovial cavity of the joint. In the movement of opening the mouth the condyle first advances a little beneath the fibro-cartilage, so as to be placed more under its middle; and then revolves beneath it upon a transverse axis. If the movement be carried beyond a certain point which is the usual limit, the condyle then again advances a little further forward under the cartilage. In the other movements—the sliding forwards and backwards and the rotatory movements—the cartilage, owing to its connection with the jaw and the external pterygoid muscle, accompanies the condyle and ever presents a concave surface to it. These movements, therefore, are chiefly performed between the cartilage and the glenoid ridge in the *upper* synovial cavity of the joint. Hence the interarticular cartilage performs a treble office; it presents a concave surface to the condyle when mounting upon the glenoid ridge; it presents one surface upon which the hinge-like, and another upon which the sliding, movement of the jaw may take place; and, forming a sort of elastic buffer between the two bones, it prevents and intercepts the many slight jars and shocks which necessarily occur during the process of mastication, and which would be very annoying in this situation.

I am not aware that any variety of dislocation has been described except the one just mentioned. Mr R. W. Smith[1] has given the account of a "congenital dislocation," which he had the opportunity of dissecting. The condyle of the jaw was scarcely developed at all; the transverse root of the zygoma was wanting, and there was consequently no glenoid cavity; indeed the whole zygomatic process of the temporal bone was very imperfect, and the malar bone was proportionately long,

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1 *Treatise on Fractures and certain forms of Accidental and Congenital Dislocations.* Dublin, 1847.

extending back to within half an inch of the external auditory canal. This joint is rarely the seat of any disease except "chronic Rheumatic arthritis," which gives rise to the same alterations here as in other parts, destroying the cartilages and the shape of the articular surfaces. In a young woman, in whose case the disease was the cause of great discomfort and distortion of the face, I excised the condyle of the affected joint with very good result[1].

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[1] *Association Medical Journal*, 1856, p. 61.

CONNECTION OF THE HEAD WITH THE SPINE.

OCCIPITO-ATLANTAL JOINT. (PLATE XIX.)

Movements. THE other moveable joint of which the cranium forms a part—that, namely, between the occipital bone and the spine—resembles the temporo-maxillary, in that it consists of two symmetrical joints placed one on either side of the middle line, whereby a greater width is given to the basis upon which the head rests. The resemblance is further carried out in the oblique direction of the articular surfaces of the joints with regard both to a vertical and a horizontal plane. Thus the condyles of the occipital bone are directed obliquely from within, outwards and backwards, along the antero-lateral edge of the foramen magnum; they are convex from before backwards and slightly so from side to side; and their surfaces are oblique, slanting upwards and outwards. The chief, if not the only, movement is of a hinge-like, to-and-fro, or nodding kind; it takes place on an axis drawn transversely through the condyles, or a little above them, about the centre of the circle of which they *both* form a segment. I have found, in addition, in some instances, a slight oblique rotatory movement in the direction of either condyle, upon an oblique axis drawn through the centre of the circle of which *each* condyle forms a segment. It was very slight in any, and in some it could not be produced at all without separating the articular surfaces; by this movement the face is turned upwards and to the left, or downwards and to the right, or in the diagonal directions, as may be required. No lateral movement is possible, and very little, if any, inclination to either side, or rotation upon a truly vertical axis.

Ligaments. The ligaments are disposed as follows: (1) The *Capsular ligament* passes between the corresponding articular edges, and covers in the cavity, on either side; it is not very strong. (2) The *Posterior ligament* (fig. 2, *I*) passes from the margin of the occipital hole, behind the condyles, to the upper edge of the posterior ring of the atlas. It is perforated by the vertebral artery and the suboccipital nerve on either side. It is not very strong, and has not much influence upon the movements of the joint, even upon the nodding forwards, for it can scarcely be rendered tense by forced flexion of the head upon the spine; that movement is brought to a stop chiefly by the ligaments passing over the odontoid process, before this "posterior ligament" is fully on the stretch. Though corresponding in situation with the *Ligamenta subflava* it has little or no elastic tissue in its composition. (3) The *Anterior ligament* (fig. 1, *G*) passes, from the anterior and upper margin of the atlas, to the under surface of the occipital bone, between and in front of the condyles. It is of considerable strength, especially in the middle, and limits the elevation of the face or throwing back of the head upon the spine. The lateral portions of it are disposed obliquely, running from the fore part of the condyles of the occipital bone, downwards and outwards, to the fore part of the articular processes of the atlas. A thick bundle of fibres, on either side, attached to the inner edge of the foramen lacerum, and passing downwards and outwards to the base of the transverse process of

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DESCRIPTION OF PLATE XIX.

Fig. 1. Anterior view of occipito-atlantal and atlanto-axoidal joints. *A*, the cut surface of basilar portion of occipital bone. *B, B*, ditto of jugular portions. *C, C*, transverse processes of atlas. *D*, ditto of axis. *E*, lower edge of body of axis. *F*, the tubercle on the fore part of the ring of the atlas, with the thick middle portion of the anterior occipito-atlantal ligament ascending from it to the occipital bone, and the middle portion of the anterior atlanto-axoidal ligament descending from it to the body of the axis. *G*, lateral portion of the anterior occipito-atlantal ligament. *H*, anterior oblique ligament. *I*, middle and lateral portions of anterior atlanto-axoidal ligament.

Fig. 2. Posterior view of the ligaments uniting the hinder parts of occipital bone, atlas, and axis. *A, A*, cut edge of occipital bone. *B, B*, mastoid processes. *C, C*, styloid ditto. *D*, body of axis. *E*, edge of foramen magnum. *F*, arch of atlas. *G, G*, transverse processes of atlas. *H*, arch of axis. *I*, posterior occipito-atlantal ligament. *K, K*, posterior oblique occipito-atlantal ligaments. *L*, the posterior atlanto-axoidal ligament. *M*, the lateral joints between atlas and axis exposed by the removal of the capsular ligaments; part of the latter is left at *N*.

Fig. 1.

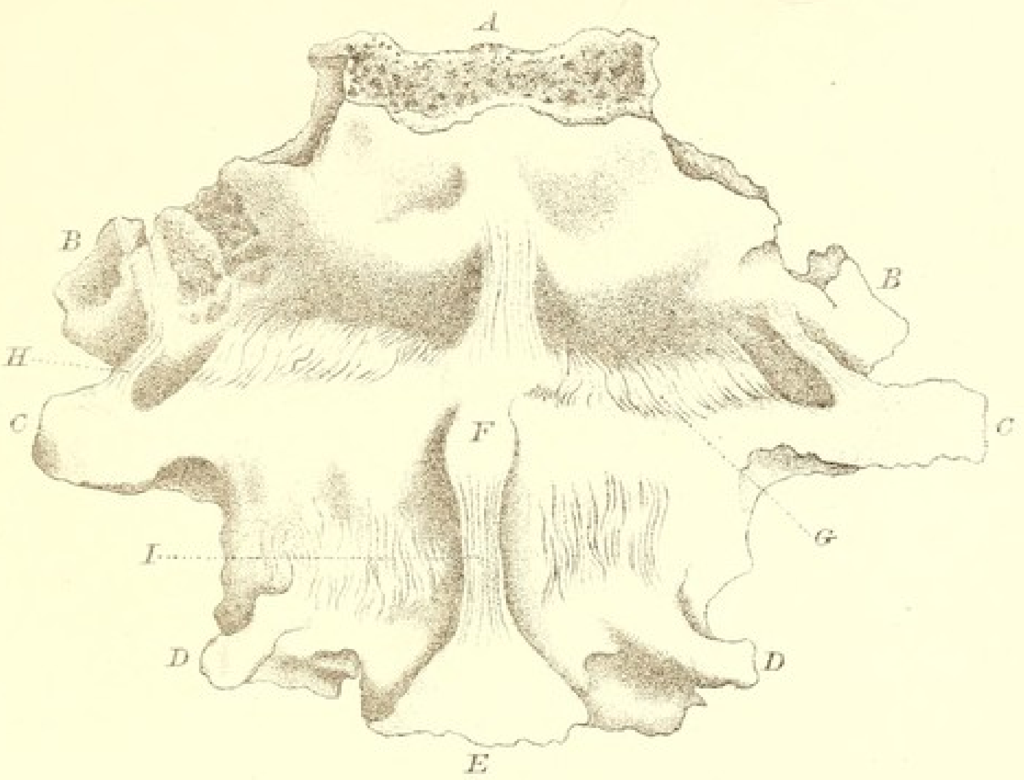
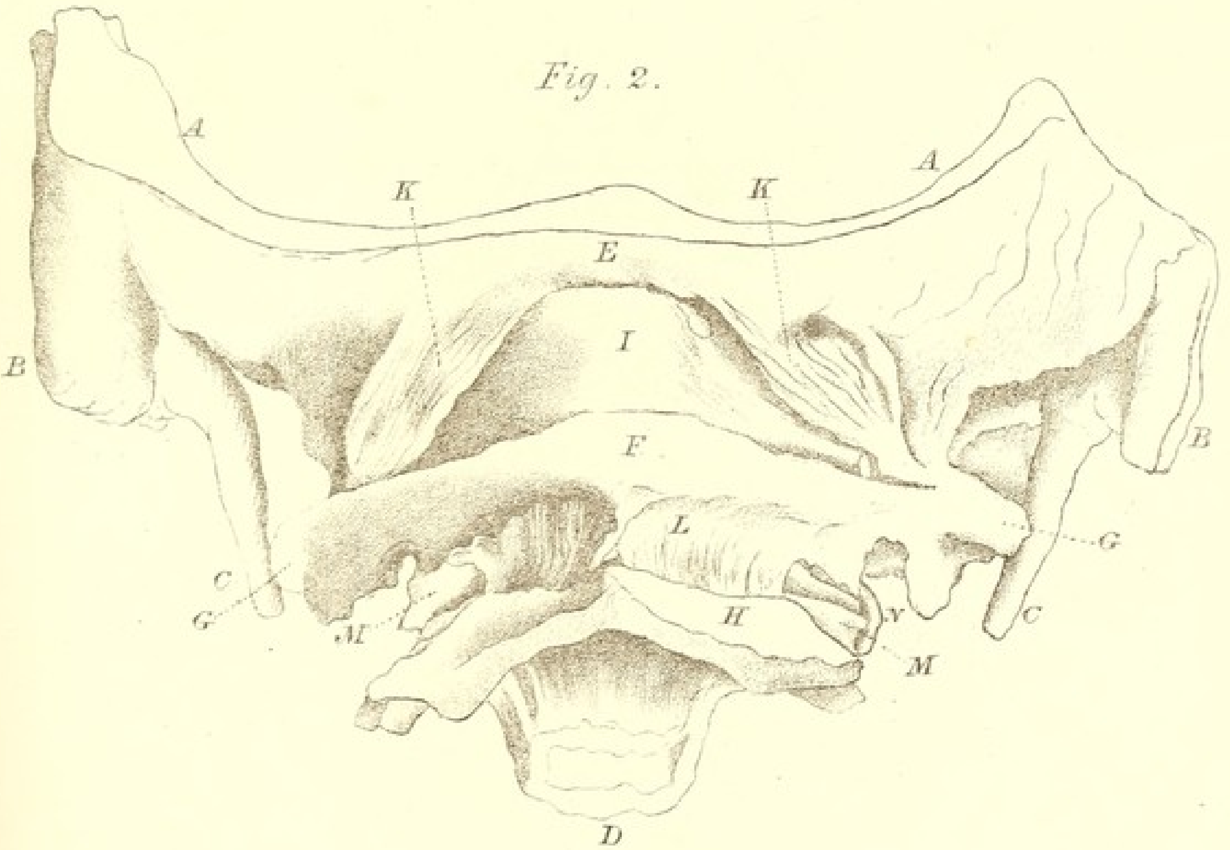


Fig. 2.



the atlas, is sufficiently marked to be called (4) the *Anterior oblique ligament* (fig. 1, *H*). Behind there is, on either side, a still stronger ligament, which may be called (5) the *Posterior oblique ligament* (fig. 2, *K*.), passing from the posterior edge of the articulating process of the atlas, where it overhangs the groove for the vertebral artery, upwards and backwards, along the margin of the foramen magnum, so as nearly to meet its fellow in the middle line. These "oblique ligaments," in addition to their influence in limiting or preventing rotation of the occiput upon the atlas, assist to hold the two bones together, and have some effect in limiting the nodding movements of the head upon the spine.

ATLANTO-AXOIDAL JOINTS. (Plates XIX. XX. XXI.)

The joints between the atlas and the axis correspond with those between the other vertebræ in consisting of a middle and two lateral parts distinct from each other. They differ from them, however, in that the middle joint is composed of a pin or pivot projected from one bone as the centre around which the other bone plays.

The lateral joints. The *Lateral joints* may be regarded as balancing props which maintain the level of the atlas. They also limit its movements to rotation in a horizontal plane, and support it in such a manner that the central pivot, formed by the odontoid process of the axis, is relieved from pressure and is free to play in its socket, or rather its socket is free to revolve upon it.

Shape of the articular facets. Like those of the joints of the lower jaw and of the occiput with the atlas, the articular facets of these lateral atlanto-axoidal joints are set obliquely in two directions, viz. they are sloped from above downwards and outwards, and from before backwards and downwards. Those of the atlas are of about the same size as those of the axis; but they are not, in shape, very well adapted to each other. The articular facets of the axis are decidedly convex in the antero-posterior direction, and slightly so from within outwards, the rise in the middle being increased by the cartilage, which is thicker at that part than at the sides. The corresponding articular facets of the atlas are also slightly convex. In the dry bones the latter are flat or even concave, but in the recent state the central depression is filled up by the cartilage, which, as in the corresponding position upon the facets of the axis, is thicker in the middle than at the sides. Thus there are two flat, or slightly convex, surfaces playing upon two facets which are distinctly convex. It is obvious that had the surfaces of the atlas been concave, so as to adapt them to those of the axis, the sliding movement, which is the essential one of this joint, would have been impeded or prevented.

So arranged as to preserve uniform tension of ligaments in different positions.

Why then do they not both present plane surfaces? The arrangement of the ligaments about the central joint will explain this. In the ordinary position, with the face directed forwards, the middle parts of the articular facets of the atlas rest upon the middle, most prominent, or highest parts of those of the axis, those portions of each which are covered with the thickest stratum of cartilage are in contact, and a considerable interspace exists between their marginal parts all around. This interspace is occupied by a fringe-like process of synovial membrane and fat, hanging from the capsule, (Pl. XXI. fig. 3, *G*). When the face is directed to one side, the articular facets of the atlas, sliding upon those of the axis, project (one forwards and the other backwards) beyond them, and the middle parts of the former, leaving the middle higher parts of the latter, descend gradually towards their respective anterior and posterior edges which are situated upon a lower plane. Hence, when the face is directed to one side, the atlas is placed at a somewhat lower level than when we look straight forward; the difference consisting in the difference of altitude of the middle of the articular facets of the axis above their anterior and posterior marginal portions. In accordance with this, if the anterior tubercle of the atlas be observed, when the rotatory movement of this bone upon the axis is made to take place, it will be seen to describe a curve in its passage from one side to the other, the highest point of the curve being attained when it is in the mid-position. The object of this arrangement is to maintain the ligaments that connect the axis with the occiput always in a state of tension, so as to ensure the security and steadiness of these parts, which is most important, under all circumstances, and in all positions of the head. For instance, when the face is directed forwards, the atlas resting upon the most prominent portions of the axis, and the occiput being thereby distanced from the axis, the ligaments connecting these two bones, and running straight from one to the other, are quite tense. During rotation to either side, the slight increase of distance between the points of attachments of the ligaments that would be effected by the shifting of the bones is just compensated for by the approximation of one bone to the other, in consequence of the atlas sliding on to the lower parts of the articular surfaces of the axis; so that no change of distance really takes place between the points of attachment of the ligaments, and the latter remain equally tight in every position. Were there not some provision of this kind, either the ligaments could not be always quite tight, or the rotatory movement could not take place. As it is, both ends are accomplished[1]. This point will be again alluded to presently, and will be understood more clearly when the anatomy of the ligaments of the central joint has been described.

Capsular ligament.

The *Capsular membranes* (Pl. XIX. fig. 2, *N*; XX. fig. 3, *M*) of these lateral joints are very loose, to permit the easy sliding of one surface upon the other. They are not strong, and have little to do in holding the bones together, though they may have some influence in limiting the extent of rotation of one upon the other.

Anterior atlanto-axoidal ligament.

The *Anterior atlanto-axoidal ligament* (Pl. XIX. fig. 1, *I*) covers the interval between the two bones in front, passing from the anterior surface of one bone to

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[1] We very often find in other joints that the obliquity of the movements and the oblique direction of the ligaments are so arranged with reference to one another that all, or nearly all, the fibres of the latter maintain their tension in every position; but in a joint where one bone rotates upon another in a truly horizontal plane this would be impossible. The fibres of such a joint, which are tense in one position, must be relaxed if any movement takes place; and it is to avoid the loss of strength consequent on such relaxation that the atlas describes the slight curve above mentioned in its rotation upon the axis.

the anterior surface of the other. In the middle it forms a thick, prominent, vertical band. On either side the fibres are more spread out and descend more obliquely from the atlas outwards to the axis. The middle portion is tense in every position of the bones. The lateral bands limit the rotation of the one bone upon the other, and are tense only when that movement is carried to its greatest extent.

The central joint.

The *Central portion* of the atlanto-axoidal articulation consists of the odontoid pivot, with the fore part of the atlas and the transverse ligament playing like a collar round it. The pivot is very strong; and its neck is strengthened by a ridge descending from its anterior articular facet upon the fore part of the body of the axis, and by another ridge descending, on either side, towards the anterior part of the transverse process. In front, it is in contact with the arch of the atlas, which forms the fore

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DESCRIPTION OF PLATE XX.

Fig. 1. Vertical section from before backwards, in middle line, through occiput and upper three cervical vertebræ. *A*, basilar portion of occipital bone. *B*, anterior arch of atlas lying upon the odontoid process of the axis. *C*, anterior occipito-atlantal ligament. *D*, anterior atlanto-axoidal ligament. *E*, posterior vertebral ligament. *F*, cervico-basilar; *G*, transverse, and *H*, *H*, vertical portions of crucial ligament. The fat which occupied the interval between the summit of the odontoid process and the occipital bone has been removed.

Fig. 2. Similar section through the basilar portion of occipital bone and the odontoid process, showing the same transverse and vertical parts of the crucial ligament more clearly, in consequence of the posterior vertebral and cervico-basilar ligaments having been removed. The transverse ligament is on a lower level than the arch of the atlas. The letters refer to the same parts as in preceding.

Fig. 3. Posterior view of joints between occiput and first two vertebræ. *A*, the cut edge of basilar portion of occipital bone. The hinder part of the occipital bone and the arches of the vertebræ have been removed by a vertical section made from side to side through the lateral joints, so as to show the shape of the articulating surfaces of (*B*) the occipital condyle, (*C*) the atlas, and (*D*) the dentata. *E*, the transverse process and arch of the third cervical vertebra. The section continued vertically downwards has passed in front of the articulating processes of the third vertebra. The posterior vertebral ligament has been removed, with the exception of the portion (*F*) which has been reflected; the cervico-basilar ligament (*G*) has also been divided and reflected from (*H*), its point of attachment to the second vertebra, for the purpose of displaying the crucial ligament (*I*) beneath it. *K*, the left odontoid ligament. *L*, capsular ligament of occipito-atlantal joint. *M*, ditto of atlanto-axoidal joint.

Fig. 1.

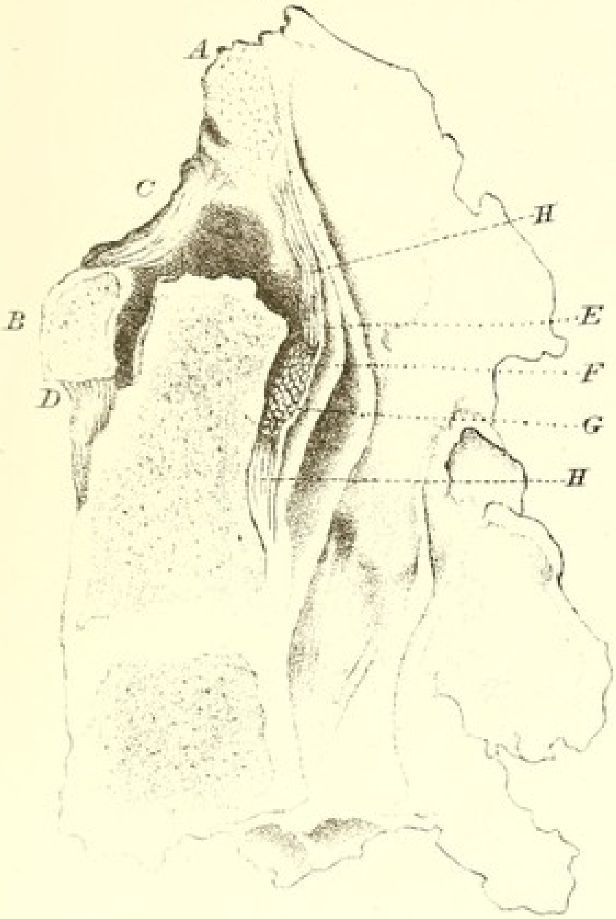


Fig. 2.

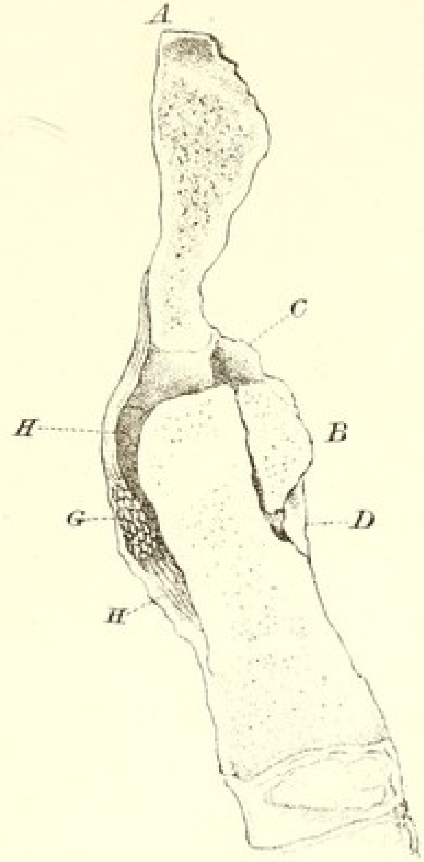
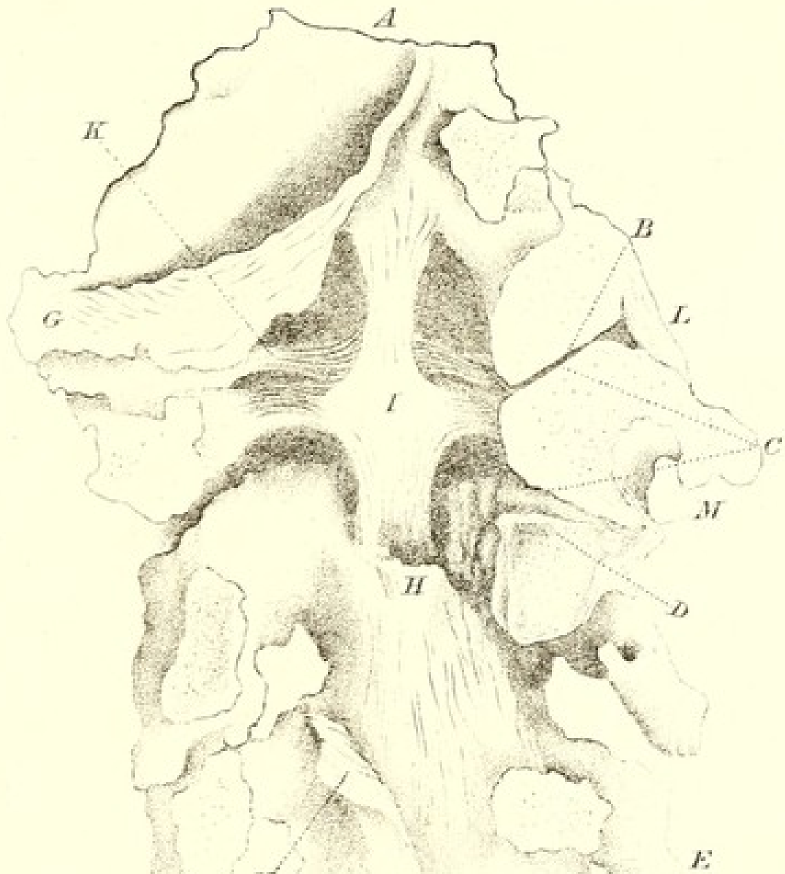


Fig. 3.



part of the encircling collar; and there are mutually adapted small articular facets on the opposed surfaces of the bones. Behind, it presents also an articular facet adapted to the hinder part of the collar, which is formed by the strong transverse ligament. The joint with the arch of the atlas is on a higher level than that with the transverse ligament (Pl. VII. fig. 6, page 129; and Pl. XX. figs. 1 and 2).

Posterior vertebral ligament.

The disposition of the *Transverse ligament* and of the other ligaments on the back of the odontoid process is as follows. If the vertebral canal and the cranium be laid open from behind, and the nervous centres be removed, the smooth shining surface of the dura mater passing from the spine to the skull is exposed. It is here not very thick; and, if it be dissected off, the *Posterior vertebral ligament* is seen ascending from the posterior surface of the bodies of the vertebræ, over the odontoid process, to the interior of the base of the skull, where it acquires attachment to the various projecting bony points that surround the bodies of the occipital and sphenoid bones. It reaches as far as the posterior clinoid processes and the hinder edges of the petrous portions of the temporal bones. It has also a connection with the bodies of the third and fourth vertebræ; but, between them and the points of bone just mentioned at the base of the skull, it lies upon another stratum of ligament resembling itself, yet distinct from it.

Cervico-basilar ligament.

This, which may be called the *Cervico-basilar ligament* (Pl. XX. fig. 3, *G* and *H*), is a very thick, strong structure, connected below with the lower edge of the body of the axis, and with the upper part of the body of the third cervical vertebra. It is narrow at first, gradually spreads out as it passes over the odontoid process, and is attached to the base of the skull beneath the posterior vertebral ligament and in a somewhat narrower circle. It must be reflected to expose the third and deepest layer of ligaments, which is also very strong and has been named *Ligamentum cruciatum.*

Ligamentum cruciatum.

It may very well be so designated, for it is of cruciform shape. Its stronger portion, which is transverse, and called the *Transverse ligament* (Pl. XXI. fig. 1, *D*), extends from one side of the anterior arch of the atlas, close to the inner edge of the articular surface for the occipital condyles, behind the odontoid process, to the corresponding point on the opposite side. It is a quarter of an inch in depth, is very thick and strong, and its anterior surface plays upon the smooth posterior surface of the odontoid process, from which it is separated by a synovial sac. From its office of holding the odontoid process in place and of protecting the medulla oblongata from the pressure of that process, it may be regarded as the most important ligament in the body[1]. The vertical

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[1] A ligament corresponding to this transverse ligament has been described by Professor Mayer, of Bonn, Müller's *Archiv*, 1834, to exist in the dorsal part of the column of cats and some other animals. It extends, between the ribs, transversely across, behind the intervertebral substance. He designates it *Ligamentum costarum conjugale*. In man it is reduced to fibres passing from the angle between the articular facets on the head of the rib to the intervertebral substance.

Gruber, Müller's *Archiv*, 1851, describes an "appendix" passing from the deepest stratum of the transverse ligament upwards and forwards to the summit of the odontoid process. He gives also an elaborate account of the synovial sacs and bursæ connected with the articulation of the atlas with the odontoid process.

DESCRIPTION OF PLATE XXI.

Fig. 1. Horizontal section through occipito-atlantal and atlanto-axoidal joints. *A, A, A*, cut surface of anterior tubercle and arch of atlas. *B, B*, transverse processes of ditto. *C*, cut surface of odontoid process, just below its summit. The saw has passed through the joint between the process and the fore part of the ring of the atlas, but above the joint between the process and the transverse ligament (*D*), which is on a lower level. *E*, cut edge of occipital bone. *F*, foramen magnum. *G*, cut surface of occipital condyles. *H*, odontoid ligament.

Fig. 2. Similar section at a lower level. The saw has passed just beneath the anterior part of the ring of the atlas and through the transverse ligament (*D*). The atlas (*A, A, B, B*) is pressed a little backwards, so as to expose the articulating surfaces of the axis (*I, I*) and show the synovial cavity between the transverse ligament and the odontoid process. The occiput has been quite removed. *K*, the divided middle portion of the anterior atlanto-axoidal ligament. *L*, spine of atlas.

Fig. 3. Vertical section, from before backwards through the occipito-atlantal and the atlanto-axoidal joints of right side, showing the shape of the articular surfaces. *A*, basilar, *B*, condyloid, and *C*, post-condyloid parts of occipital bone. *D*, atlas. *E*, axis. *F*, part of anterior occipito-atlantal ligament. *G*, anterior atlanto-axoidal ligament, with triangular fatty synovial appendage projecting into the interval between the articular surfaces. *H*, third vertebra. *I*, the arch formed by the lateral portion of the axis over the intervetebral foramen (p. 317). *K*, the body of axis. *L*, inferior articulating facet resting upon superior articulating facet of third vertebra.

Fig. 1.

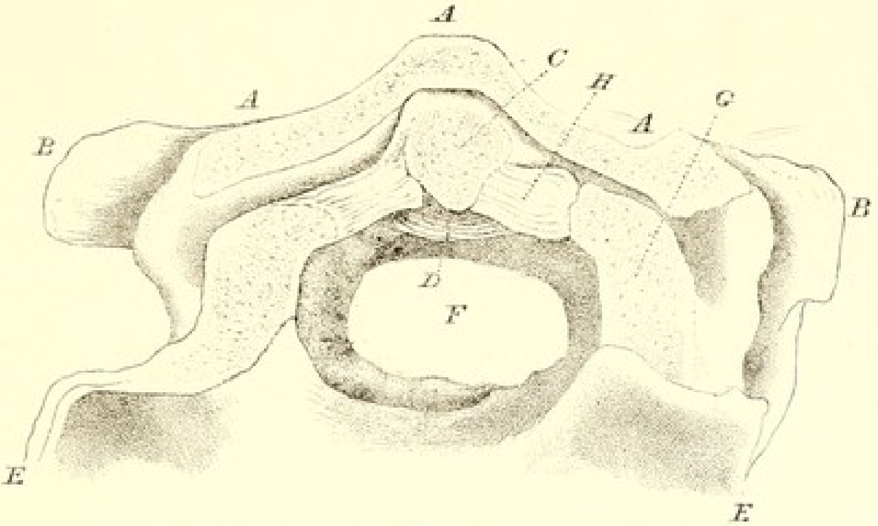


Fig. 2.

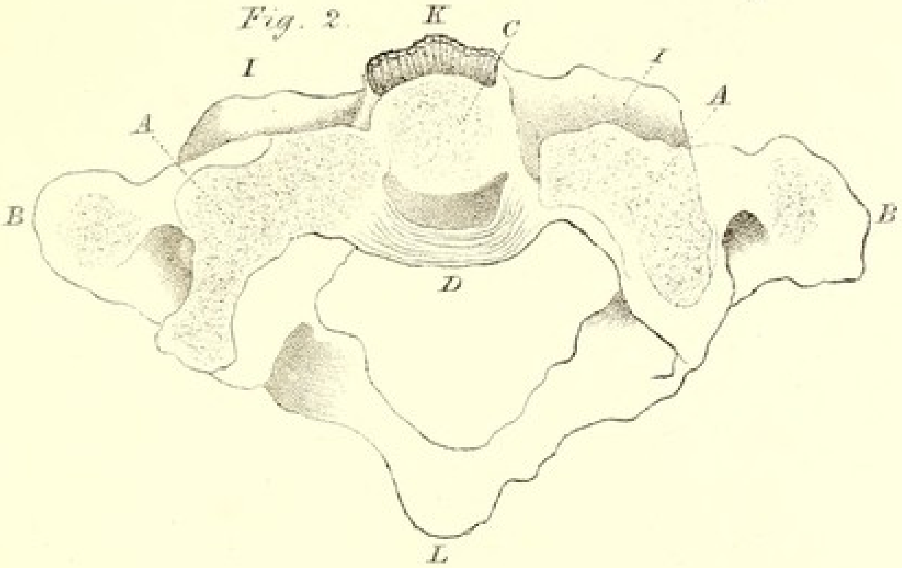
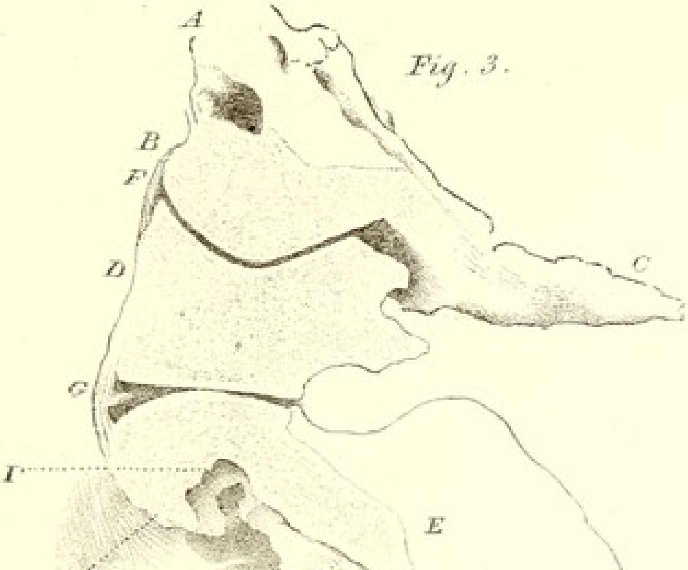


Fig. 3.



Odonto-basilar ligament.

part (Pl. XX. fig. 1, *H*) of the ligamentum cruciatum—the *Odonto-basilar ligament* as it may be called—is situated posterior to, though in close connection with, the transverse ligament, and derives some fibres from it. It consists chiefly of fibres running in parallel bundles from the hinder surface of the body of the axis, just below the root of the odontoid process, to the upper edge of the basilar process of the occipital bone, which forms the margin of the foramen magnum. It is the third and deepest of the three ligamentous strata which pass respectively from the 4th, the 3rd, and the 2nd cervical vertebra, over the odontoid process, to the base of the skull, and which assist to hold that process in its place, and to prevent the head from falling forwards upon the spine. These three ligaments check the nodding movement of the head forwards; forasmuch as they are rendered tense by that movement before the "posterior occipito-atlantal ligament" is put upon the stretch, and they are far stronger than it.

Now, forasmuch as all these ligaments, and particularly the odonto-basilar, run in nearly parallel lines from their respective cervical vertebræ to the occiput, it is clear that their complete tension in any one position of the joint would be incompatible with rotation of the atlas upon the axis into any other position, if that rotation took place in a truly *horizontal* plane. It is to meet this difficulty by giving a slightly curvilinear movement to the atlas upon the axis, that the peculiar construction of the facets of the "lateral occipito-atlantal joints" described in page 310 is provided.

Odontoid ligaments.

The *Odontoid ligaments* (Pl. XXI. fig. 1, *H*) are of great strength. They extend from the sides of the apex of the odontoid process, transversely outwards, to the rough inner edges of the anterior halves of the occipital condyles. They lie immediately above the sides of the "transverse ligament," crossing them obliquely, and coming into contact with the "odonto-basilar ligament." They limit the rotatory movements of the head and atlas upon the axis; and, binding the occiput firmly to the odontoid process, they contribute very much to steady the head and prevent its lateral inclination upon the spine. Such a check is required to be of considerable strength, in consequence of the great transverse diameter of the head; and there is no other ligament performing that office at all to be compared in efficiency with these odontoid ligaments. Some of the fibres of the odontoid ligaments, meeting together in the middle line, and passing from the summit of the odontoid process to the basilar part of the occiput, have been called the *Suspensory ligament*. They are few in number, and do not deserve a separate name.

Covered by what I have named the "cervico-basilar ligament" there are interspaces between the several structures—in front, and either side, of the "odonto-basilar" ligament, about the odontoid ligaments, and between the odontoid process and the occipital bone—; these are filled with fine soft fat, offering little or no impediment to the movement of the several parts on each other.

Balancing of head upon condyles.

It has been found by experiments made by Weber and others, and repeated by myself, that the head balances upon the occipital condyles a little in front of their middle, when placed in such a position that the eyes are directed slightly upwards. The exact amount of elevation required must differ in different cases. So near an approach to a balance upon the condyles in this position is quite peculiar to man, is associated with his erect form, and is a great relief to the muscles of the back of the neck, upon which the weight of the head is dependent in the lower animals. In them the weight is so adjusted as to render an elastic "ligamentum nuchæ" and great prominence of the dorsal spines necessary. In man, the latter are much suppressed, and the former structure is quite absent, being replaced by an intermuscular septum or fascia, which may contribute to prevent the head falling too far forwards upon the spine, but which can have little or no influence in maintaining it in its usual position. Under ordinary circumstances, when the eyes are directed straight forward, or, which is still more common, when they are inclined a little downwards, the head is indebted for the maintenance of its position to the muscles of the back of the neck. Hence, when those muscles cease to act as during sleep, or from other cause, the head falls forward upon the chest; unless, indeed, the face happen to have been so much raised that the line of gravity of the head is in a plane behind that of the condyles[1]. Again, when the muscles have become weakened by a blow, by rheumatism, or by age, so that they cease to give efficient support to the head, the chin gradually pokes downward and forward, the stretched muscles give less and less assistance, and a good deal of pain is caused by the weight of the head dragging upon the ligaments of the neck, unless mechanical assistance be given. I have found very great relief afforded in such cases by a light metal collar supporting the chin and resting upon the chest.

The weight of the head, transmitted through the condyles and the articular parts of the atlas, falls upon the axis on either side of the odontoid process, so that the line of gravity may be said to run through that process. The *superior* articular facet of the axis, on either side, forms a bridge over the second intervertebral foramen, resting with one, the larger, pillar, upon the body of the axis, and with the other, the smaller, pillar, upon the *inferior* articular facet of the same, which is in a plane behind the upper one (Pl. XXI. fig. 3, *I*, *K*, *L*). The weight is, therefore, transmitted, through the superior articular facet of the axis, in great measure, to the bodies, and, in a lesser degree, to the articular portions of the subjacent vertebræ; and it is borne chiefly by the bodies and partly by the articular processes all down the spine.

Combination of strength with freedom of movement.

When we consider the great weight and size of the head, the weight being in greater proportion to the size than that of any other part of the body at all approaching it in magnitude, we cannot fail to be struck with the admirable manner in which it is borne upon its narrow cervical stem: so continuously—commonly all the day long—yet without fatigue: so steadily and securely, that it is a favourite part upon which to carry burdens, yet capable of such varied and rapidly executed movements. This is attained, in great measure, by its being placed

[1] It may be observed, accordingly, that when a person nods in sleep, into which he has fallen in the sitting posture, the movement takes place forwards or backwards according to the degree of inclination of the head. If the eyes be directed straight forwards, or a little downwards, the nodding is forwards; if they be directed more upwards, the nodding is backwards.

immediately over the spine and the lower extremities; and, in part also by the manner in which it is connected with the spine by two pairs of joints, disposed symmetrically on either side of the middle line, with a pivot-joint between them. Had all the movements between the head and the spine taken place at one joint, there must have been great loss of strength; for none other than a ball-and-socket joint would have sufficed to permit the to-and-fro, and the rotatory movements upon vertical and oblique axes, and the lateral inclination; and a ball-and-socket joint would scarcely have been compatible with steadiness and strength. It is by the combination of several joints that freedom of movement is attained without sacrifice of strength; while a sufficiently wide basis of support is afforded by their being arranged in pairs, at a little distance from each other, on either side of the middle line. It must be further borne in mind that each of the several movements of the head acquires a greater range from the mobility of the cervical portion of the spinal column. The *lateral inclination* of the head towards either shoulder takes place chiefly in the neck; and the *to-and-fro movement* is at least doubled by the bending forwards and backwards permitted in the same part. The additional *rotation* that is derived from the neck is not so great in proportion.

These joints rarely dislocated.

The strength of the joints between the axis and atlas, and between the latter and the occiput, is further evidenced by the displacement of the bones being so rare an event. I am not aware that there is any case on record of the dislocation of the occiput from the atlas; and the only way in which the atlas has been dislocated from the axis has been by a sudden jerk of the head, such as is given in hanging by the executioner seizing the legs of the culprit, or in snatching up a child by the head[1]. More commonly the odontoid process gives

[1] The displacements which take place slowly as the result of disease in these joints are liable to be mistaken for dislocations from accident. Thus there is preserved in the museum at Bonn a specimen of supposed dislocation of the atlas. The bone is projected forwards both from the occiput and the axis, and is quite ankylosed to the former. The processus dentatus projects into the foramen magnum. It is from a woman who fell upon her head three years before. A careful examination of the specimen convinced me that the displacement and surrounding bony deposit are the result, not of sudden dislocation, but of disease excited by the accident and continued subsequent to it.

way. Even then (so firmly are the bones held together by the ligaments) the displacement may not be sufficient to produce immediately fatal compression of the cord; and the patient often lives several days. In one case of fracture of the atlas that occurred in the practice of Mr Clive, the boy, æt. 3, lived a twelvemonth after the injury, being obliged to walk carefully, and often to support his head with his hands[1]. In a case of transverse fracture of the atlas with fracture of the odontoid process related by Mr B. Phillips[2], the man was able to walk about and complained only of *stiff neck*. Moreover nearly the whole fore part of the ring of the atlas, including the entire facet for the articulation of the odontoid process, has been known to exfoliate and pass through an ulcer of the pharynx without bad result[3].

Displacements from disease in early life.

It is no uncommon thing to meet with specimens of ankylosis of these joints; and some of them are attended with such great displacement of the bones that it is wonderful the cord should have escaped pressure[4]. In all that I have seen it has been probable that the change was the result of disease taking place in early life; and I have met with several instances in children in which there was clear evidence of the progress of destructive disease here, though I have not known it to occur in grown-up persons. A peculiar and most annoying snapping is occasionally experienced in these joints; it is sometimes loud enough to be heard at considerable distance, and, being the result of involuntary movements, it may be the source of great discomfort and loss of rest. It is probably of a rheumatic or gouty nature.

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[1] Cooper's *Dislocations and Fractures*, 8vo, 1842.

[2] *Medico-Chirurgical Transactions*, Vol. XX.

[3] Case by Mr Wade in *Medico-Chirurgical Transactions*, Vol. XXXII.

[4] Sandifort, *Exercitationes Academicæ*, 1783, Tables I. II. III., and 1785, Tables IV. and V.

THE THORAX.

General construction and peculiarities in different animals.

The thorax, or middle part of the skeleton, is a bony case affording support and protection to the great organs of nutrition; that is to say, to the organs of digestion, of respiration, and of circulation. It is constructed on a uniform plan throughout the vertebrate kingdom, being formed by the spinal column behind, by the ribs on either side, and by the sternum in front. All these parts, however, are not invariably present; thus in the Frog there is a sternum which serves to carry the upper extremities, but there are no ribs, or only rudimentary ones; in Snakes there is no sternum, but numerous ribs, which supply in part the place of limbs, inasmuch as they assist in progression. The length of the thorax and the number of pieces of which it is composed vary very greatly in different animals. In Mammals the cavity is divided into two parts by the diaphragm stretching across; of these the upper, or thorax proper, contains the heart and lungs; and the lower, or abdomen, covers, more or less completely, the stomach, liver, spleen, kidneys, and alimentary canal. In all the lower orders of mammals the antero-posterior diameter of the upper division of the thorax exceeds the transverse. In Quadrumana the transverse diameter equals or exceeds the antero-posterior; but not to so great a degree as in Man. In him the thorax is, in an especial manner, spread out laterally; and it is also pressed backwards for the purpose of assisting to balance the body in the erect posture. In many animals the bony part of the thorax reaches almost to the pelvis; but in man it is shortened, for the purpose of permitting a free range to the flexion and extension of the trunk; and, for the same purpose, the lowermost ribs are of small size, are very moveable, and are fixed only by one end; and the ribs immediately above these are slanted upwards towards the median line, and are attached to the sternum by long flexible cartilages.

THE STERNUM. (Plates XXII. and XXIII.)

Sternum is broad in man.

The human sternum, in conformity with the shape of the chest, is broad in proportion to its length as compared with the sternum of most of the lower animals. It is not projected forwards into a keel-shaped ridge, as in birds and some mammals; neither does it run far upwards above the level of the ribs for the purpose of supporting the clavicles. On the contrary, it is spread out laterally, and is flat on its anterior and posterior aspects. This is particularly marked in the *Manubrium*, which is very broad and strong, with small superficial facets, not on its side but on its upper edge, for the clavicles; and its upper margin, which is directed a little backwards, towards the spine, is scooped out, or notched, in the middle, for the purpose of giving a slight increase to the antero-posterior diameter of the upper opening of the thorax, and of preventing pressure upon the trachea. This notch is scarcely perceptible at birth. The average length of the sternum, in the adult, is six inches; the longest of several that I measured was seven inches, the shortest was five inches. It is rather longer in the male than in the female. Its width varies in different parts; it is greatest between the cartilages of the 1st ribs, and least between those of the 2nd ribs, or in the interval between the cartilages of the 2nd and 3rd ribs. In the latter situation it is accordingly most liable to be broken, either by a blow or by heavy pressure, or, which now and then happens, by the sudden violent contraction of the recti and other muscles attached to its lower end. Thus a woman who fell on her back on the pavement was found to have broken her sternum, and a man raising himself suddenly in bed in a fright met with the same accident[1]. When it is broken, the inferior portion may be driven either in front or behind the superior.

[1] Two cases of fracture of the sternum, occurring during the expulsive efforts in labour, are quoted from the *Bulletino delle Scienze Mediche di Bologna* in the Dublin *Quarterly Journal of Medical Science*, XXIV. 477.

Junction of manubrium with body.

The liability to fracture is much lessened during the early periods of life by the sternum being composed of two portions, the point of junction of which is at the narrowest part of the bone. The mode of union of the manubrium and body of the sternum are shewn in Pl. XXII. fig. 2, drawn from the longitudinal section of a recent specimen. The interval between the two is there seen to be wider at the hinder part, where the bones are joined by short strong bundles of fibrous tissue, passing direct from one to the other, than in front, where the uniting medium is cartilage or fibro-cartilage. The fibrous element at the hinder part of the *Symphysis* is so tight and strong that it causes the two bones to form a slight angle or arch in front. If firm pressure be made on the anterior surface the arch is lowered a little by the compression of the anterior cartilaginous element of the symphysis, which immediately recoils and restores the bones to their natural position when the pressure is withdrawn. This arch of the sternum, which is increased by the slightly curved shape of each of its two segments, and which contributes materially to the elasticity of the bone and to its power of resisting external pressure, is strengthened by longitudinal bands of fibrous tissue placed upon its hinder surface; these form a thick sheet of membrane underlying and supporting the periosteum[1].

Structure, &c. of the bone.

The sternum is a light bone, composed of fine cancellated texture covered by a thin layer of compact structure; the latter is thickest and strongest in the manubrium, at the part lying between the clavicles. The posterior concave surface is smooth; and the bony fibres have there rather a longitudinal direction, converging towards the symphysis, so as to constitute a faint groining underneath the arch.

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[1] We occasionally find the arch of the sternum increased in a very marked manner, so as to form quite a hump, the prominent point of which is usually, below the symphysis, between the third costal cartilages. Probably this preternatural curvature has been caused, in some of these instances, by pressure upon the lower part of the bone in certain avocations; though such explanation cannot always be found. In twenty-two instances of the deformity examined by M. Woillez, three occurred in shoemakers, and in only two of the remaining nineteen was the bone subjected to any particular pressure.

Facets for the ribs.

The bone presents, on each side, seven depressions for the articulation of the cartilages of the seven true ribs[1]. The upper of these depressions is larger and longer than the others, is narrow at its lower part, broader above, with a wide overhanging upper edge, which is more marked in front than behind. This serves to prevent the displacement of the cartilage of the first rib when it is drawn upwards and forwards by the action of the scaleni muscles in inspiration, and enables it more readily to carry the sternum with it in that movement. It also supports the sternum against pressure or blows on its front. The next three depressions for the costal cartilages are situate at a considerable distance from the first and from one another. They are angular notches in the edge of the sternum; and it may often be seen that the sides of each are covered with cartilage, while the angle at the deepest part of the notch is rough for the attachment of the "middle sterno-costal ligament." The angle at the bottom of the notch for the second cartilage is formed by the symphysis between the manubrium and the body of the sternum; the superior side of the notch being formed by the manubrium, and the inferior by the body. In like manner, in the regularly formed bone, each costal cartilage impinges upon the sternum, on the line of junction of two of its primitive component portions. This is well seen in most of the lower animals, where the several portions of the bone remain separate much longer than in man. In each instance the upper side of the notch is larger and more overhanging than the lower, and the anterior edge is more prominent than the posterior, for the purpose of resisting the pressure of the cartilage, which is made in an upward and forward direction when the rib is raised in inspiration. These two particulars, viz. the union of each costal cartilage, except the first, with two sternal bones, and the greater prominence of the articular facet upon the upper of each of these two bones, constitute striking points of similarity between the mode of connection of the ribs with the sternum, and their mode of connection with the several bodies of the dorsal vertebræ. The lower

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[1] In a specimen in the Cambridge Museum which measures seven inches, there are eight cartilages of ribs separately united to the sternum.

three depressions for the costal cartilages are placed close together, and surround the inferior end of the sternum, which is widened for the purpose of affording greater space to them. They are shallower than the upper three; and their upper and anterior edges are less prominent, because the line of pressure of these cartilages during inspiration more nearly corresponds with that of the plane of the bone. They do not, moreover, show any appearance of division into two parts. The one or two lowermost are situated in front of the attachment of the ensiform cartilage.

Often perforated at lower part. The broad lower part of the sternum is often perforated by a round hole, large enough to admit a goose-quill. It is a variety resulting from the mode of development of the bone, but does not serve any particular purpose beyond that of lightening it a little.

Ensiform cartilage. The *Ensiform* or *Zyphoid cartilage* is rather more than an inch long, with its point downwards. It is curved a little, so that the point is directed forwards as well as downwards. Its shape varies; though, in most instances, it terminates in a point, it has, in some, a broad square extremity; in some it is bifid; and, occasionally, like the sternum, it is perforated by a hole (Pl. XXIII. fig. 1, *F*) which may transmit communicating branches between the internal mammary and the epigastric arteries.

It is joined to the lower extremity of the sternum, behind the 7th costal cartilages, and is united by fibrous tissue to the hinder surface of the latter. The fibres of the recti muscles, arising from its fore part, in the interval between the converging costal cartilages, fill up that interval and conceal the ensiform cartilage, so that it is not easily felt during life. The ensiform cartilage contributes to the covering and protection of the abdominal organs at a very tender part, and affords an increased surface for the attachment of muscles, particularly of the *triangularis sterni*. A broad thick fasciculus of this muscle, arising from the hinder surface of the ensiform cartilage, on either side, proceeds directly outwards to the cartilages of the 5th, 6th, and 7th ribs, and, by its contraction, draws them towards the middle line; by this means it serves to diminish the capacity of the chest, and ministers to expiration. The position of the ensiform cartilage, which is behind the level of the other cartilages, and which is thrown still further back by the contraction of the recti muscles during expiration, favours this influence of the triangularis sterni.

The ensiform cartilage in some instances becomes ossified and united by bone to the sternum. In others it remains cartilaginous to the last.

Development. The primordial cartilage of the sternum is formed at a comparatively early period of fœtal life. Ossification, however, takes place comparatively late, not commencing, even in the manubrium, till half the intra-uterine period is passed.

Varieties in development. The number of nuclei varies in different instances. There is commonly one of large size in the manubrium; though not unfrequently there are two, which is probably the more complete condition. When two nuclei are present they are usually placed one above the other, and the upper one is the larger. When, which is rarely the case, the two nuclei are placed side by side, they are commonly unsymmetrical, though one of the clavicles may rest upon each. In Plate XXII. fig. 1, a small second nucleus is seen, on one side, near the symphysis. This is very common. In the body of the bone there is usually one oval centre, or two oblong centres, placed side by side in each interval between two pairs of ribs; these begin to appear about the 7th month. The upper ones appear first, and are, therefore, for a time, the largest; though subsequently the lower ones become the widest, and give the greater breadth to this part of the sternum. At birth there are, according to Meckel, usually four pairs of osseous nuclei present; viz. those between the 2nd and 3rd, the 3rd and 4th, the 4th and 5th, and between the 5th and 6th costal cartilages. In some instances there are only three or two pairs. The nucleus for the 5th bone of the sternum, when it is formed separately, may appear at any time between 6 months after birth and the 7th or 8th year. The nuclei between the 3rd and 4th and between the 4th and 5th ribs are more often double than the others. The lower portion of the sternum, which is common to the 5th, 6th, and 7th ribs, is not unfrequently developed from a single centre. When it is developed from lateral portions, and the ossification fails to reach the middle of the bone, the aperture which has been mentioned above, remains. About the 12th year the various lateral nuclei, which are frequently unsymmetrical both in size and position, unite in the middle line. The resultant segments subsequently coalesce with one another; the lower ones uniting first; the body does not become ossified to the manubrium till late in life. Often these two are found separate in old persons; the ensiform cartilage is, according to Meckel, more often ossified to the body than the latter is to the manubrium[1].

Varieties in animals.

In the lower animals, although complete ossification of the several centres, which are developed, not in pairs, but from single nuclei in the median line, takes place earlier,

[1] According to Beclard, the 5th (that is, the segment in the space between the 5th and 6th costal cartilages) unites with the 4th from the 15th to the 20th year, the union taking place sometimes before its lateral portions have joined together; the 4th and 3rd unite between the 20th and 25th year; subsequently the 3rd unites with the 2nd; the union between the 2nd and the manubrium does not take place till 60, or even later; whereas the ensiform cartilage is often found ossified to the sternum at 45 or 50, its extremity remaining cartilaginous for 10 or more years after; the ossification of the ensiform cartilage takes place from one nucleus, rarely from more; the period at which this appears is very variable, from the 2nd to the 25th year, or even later.

DESCRIPTION OF PLATE XXII.

Fig. 1. Front view of sternum and costal cartilages from a child, æt. 5. *A*, large osseous nucleus in manubrium. *B*, small ditto, near lower angle of manubrium, on right side. *C*, large single nucleus in 2nd bone of sternum. *D*, two oblong nuclei, placed side by side, in 3rd bone with (*E*) a small separate nucleus in the interval between their upper ends. *F*, two similar nuclei in 4th bone. No other nucleus appears below these. A transverse fibrous division is seen between the cartilage of the manubrium and that of the 2nd bone; but the cartilage of the rest of the sternum forms one piece. The upper costal cartilage (*G*) is continuous with that of the manubrium. The 2nd (*H*) is separated from the symphysis and the cartilage above and below it by a line of areolar tissue, which permits slight movement upon an antero-posterior axis. The other costal cartilages are united to the cartilage of the sternum in a similar manner, no distinct synovial cavity being yet formed between them. There is, however, a small synovial cavity at *I* between the opposed surfaces of the 7th costal cartilages, where they meet in front of the ensiform cartilage. *K*, broad thick process descending from the 5th costal cartilage to upper edge of the 6th; the line of union covered by the anterior ligament. *L* and *M*, 7th and 8th costal cartilages united by continuity of tissue.

Fig. 2. A vertical section, from before backwards, through the lower part of (*A*) the manubrium, (*B*) the upper part of the body of the sternum, and the symphysis between them. It shows the shape of the latter, the fibrous structure (*C*) occupying its wider posterior part, and the cartilage, or fibro-cartilage, with some delicate areolar tissue in its narrower fore part.

Fig. 3. Sternum of an eighth month fœtus. There is one osseous nucleus in the manubrium, one in the upper segment of the body, and two in each of the 2nd, 3rd, and 4th segments.

Fig. 1.

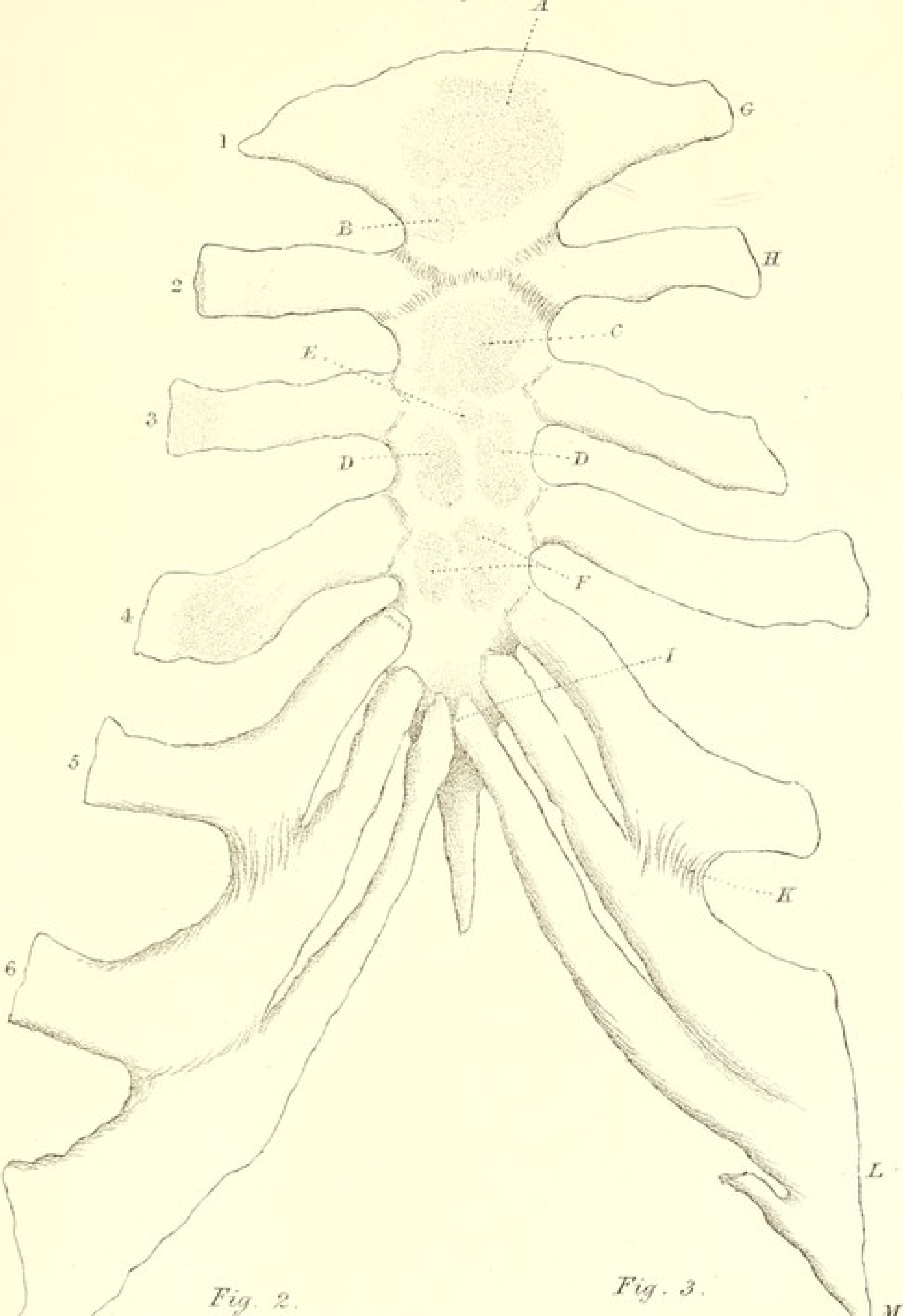


Fig. 2.

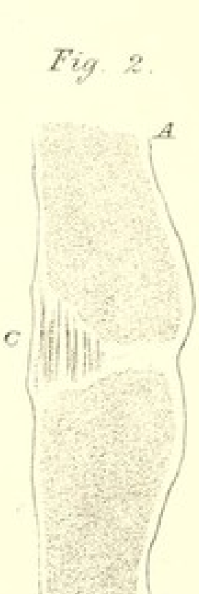
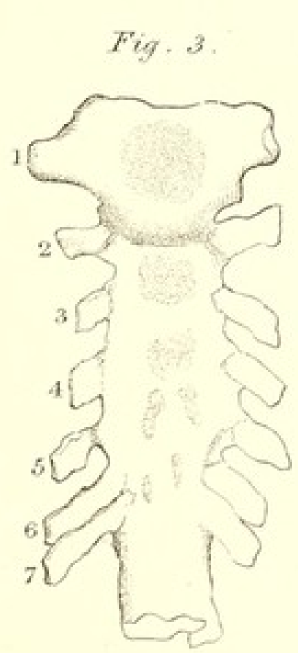


Fig. 3.



they remain separate to a much later period, commonly throughout life. The Orang is an exception to part of the above statement, inasmuch as the pieces of the sternum of that animal are developed in pairs and the lateral portions of each centre remain separate; so that the bone consists permanently of as many portions as there were primary osseous nuclei. In Birds one large broad bone is formed at an early period, and a keel-like process is developed along its fore part. In the Ostrich the latter is wanting.

Episternal bones.

Breschet[1] describes two additional osseous centres—*Os sus-sternaux*—forming small pisiform bones on either side of the notch. They are connected with one another by a transverse ligament, and are jointed with the sternum by a synovial capsule. He regards each of them as the anterior rudiments of a rib, of which the posterior rudiment is presented by the separate nucleus for the anterior lamina of the transverse process of the 7th cervical vertebra. These *Episternal* bones are rarely met with. Cruvelhier saw them in only one instance. They have their analogue in the episternal bone of monotrematous animals.

Imperfections in development.

The sternum is in some instances entirely wanting[2], or more or less divided into two parts by a fissure down the middle[3]. These imperfections are more frequent at the lower part than at the upper; which accords with the facts that the closure of the thoracic cavity of the fœtus commences at the upper part, and that the manubrium is formed in cartilage before the other parts of the sternum. When the bone is thus imperfect, it, now and then, though rarely, happens that the skin and other tissues are present, and cover in the cavity of the thorax, the sternum alone being deficient or fissured[4]. More commonly the failure of development is manifested

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[1] *Annales des Sciences Naturelles, Zoologie*, X. 1838.

[2] Weidemann, *Programma ueber des fehlende Brustbein*.

[3] *Transactions of the Path. Society*, II. 281. *Medical Times and Gazette*, 1837.

[4] This is the case in M. Groux, who lately exhibited himself in Cambridge and many other places; the sternum is divided in two lateral parts by a median fissure, extending through the manubrium and body of the bone, and he possesses the power of widening the fissure to nearly three inches, by pressing the hands together, or of narrowing it, by bringing the deltoid muscles into action. The defect does not interfere much with respiration nor with the movements of the arms. The skin covering the fissure is quite natural; and it would seem that each half of the bone is well formed, or nearly so, but that the halves are separated by an interval, which may be

in the soft structures as well as in the bone, so that the thorax is open, and perhaps the heart is uncovered, constituting what is called *ectopia cordis*. It has already been noticed that the bone is shorter in women than in men, and that it varies a good deal in length in different persons; it does so also in width and shape, being broad or narrow, straight or much curved, with a well-marked waving or nearly straight margin. Now and then it is bifid, and it is said to be occasionally keel-shaped, resembling somewhat the sternum of a bird[1]. The manubrium has been known to extend as low as the third rib[2], and Desault saw the zyphoid cartilage descend as far as the umbilicus.

Varieties of shape.

Diseases.

Though subject to the same diseases as the rest of the skeleton, it is not so frequently the seat of them as many other bones. Rokitansky observes that the inflammation and induration which occur in syphilitic disease are rarely met with in the

regarded as of similar kind to the hole often found in the lower part of the sternum; the only difference being that, in this instance, the division exists in the whole length of the bone, instead of being, as usual, confined to one spot.

[1] Blandin, *Nouveaux Élémens d'Anatomie*, I. 50.

[2] Meckel's *Archiv*, IV. 480.

DESCRIPTION OF PLATE XXIII.

Fig. 1. Sternum from a lad æt. 10, viewed from behind. There is one nucleus (*A*) in the manubrium, and one (*B*) in the first segment of the body. The two nuclei (*C*) in the 2nd segment have coalesced, and those (*D*) in the 3rd have begun to do so. There is one nucleus (*E*) in the ensiform cartilage which is, in this instance, continuous with the cartilage of the sternum. The ensiform cartilage is bifid and there is a small hole (*F*) through its middle.

Fig. 2. A vertical section from side to side through one half of the sternum, the sterno-clavicular articulation and the costo-sternal joints. *A*, the manubrium. *B*, the body of the sternum. *C*, the symphysis. *D*, the clavicle. *E*, the interarticular ligament of the sterno-clavicular joint. *F*, the 1st costal cartilage united to the sternum in its upper half by dense fibrous tissue, and in the lower half separated from it by a narrow synovial cavity. *G*, the interarticular ligament connecting the 2nd costal cartilage with the symphysis. *H*, *H*, upper and lower edges of capsule of 3rd costo-sternal joint. *I*, fibrous ligament uniting lower part of head of 4th costal cartilage to the sternum. *L*, synovial cavity between upper part of the same and the sternum. *M*, 5th costal cartilage united to sternum by areolar tissue. *N*, 6th costal cartilage with distinct synovial cavity between it and sternum.

Fig. 3. Front view of a costo-sternal joint showing the anterior ligament.

Fig. 2.

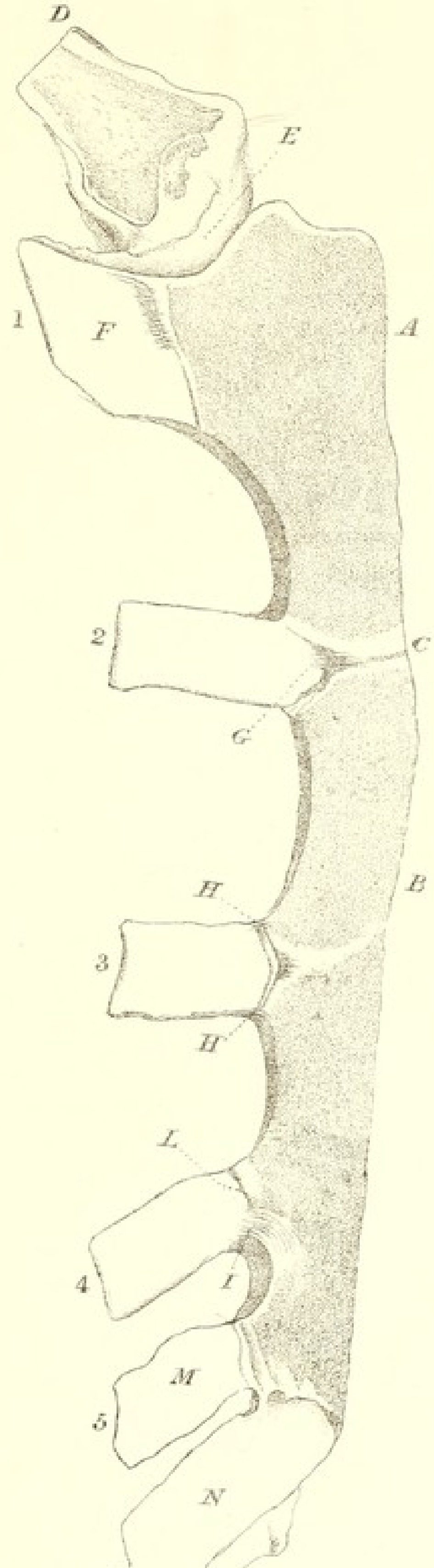

Fig. 1.

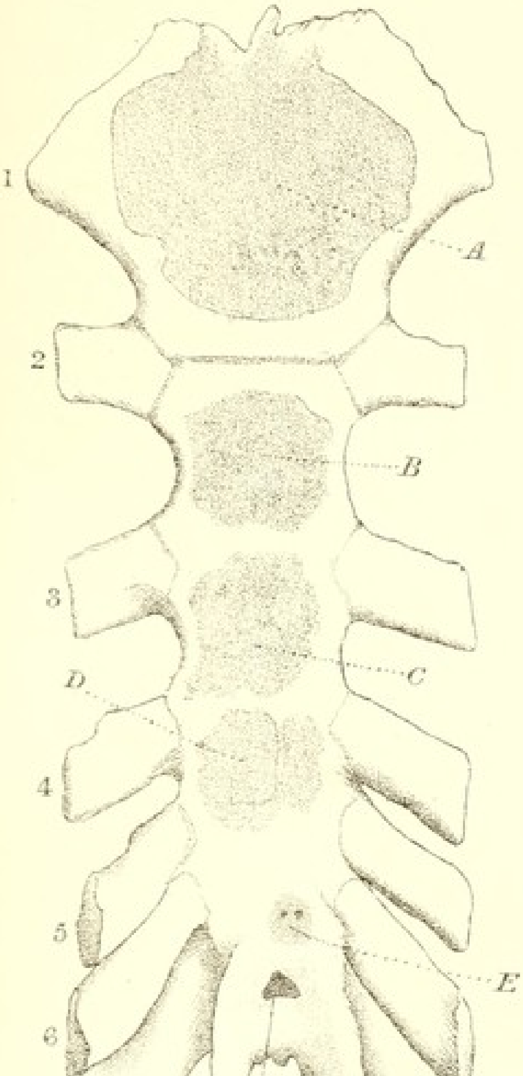

Fig. 3.

sternum. Frequent exercise of the right arm in lifting weights has been thought, in some instances, to have been the cause of slight deviation of the bone to the right side by means of the increased action of the pectoralis major. In curvature of the spine it often inclines to one side or other of the middle line.

THE RIBS.

General resemblance and particular differences.

The twelve ribs present a good illustration of that resemblance in general features and dissimilarity in details which pervade, more or less, the various parts of the skeleton, and which may indeed be observed throughout the whole of the physical world to constitute a general law in creation. They are all alike in the plan of their construction, yet each one differs from the others in certain particulars. Thus each has an articulating head, a neck, angle, body, and certain curves and twists; but all, or nearly all of these, present varieties in the different ribs, so that each particular rib, just as we found to be the case with each particular vertebra, has peculiarities sufficient to characterise it to the scrutinising observer. Many points of interest may be observed in these apparently simple and unattractive bones; for the purpose of examining them, it is a good plan to arrange the several ribs upon a table in the order in which they are placed in the body.

Length.

The ribs increase in length from the 1st to the 7th; then decrease again to the 12th. The latter is of about the same length as the 1st, though it varies a good deal in different persons.

Curves in horizontal plane.

Each of the ribs is curved, and curved in unequal degrees in different parts of its length; so that a rib cannot be said to form a segment of one circle, but may rather be described, in a general manner, to form segments of two circles of unequal radius. The sharper of these two curves is situate near the hinder part, and gives rise to the marked prominence behind, which is called the *Angle* of the rib. This posterior projection brings the ribs nearly to a level with the spinous processes, and causes that flatness of the back and that ability to lie at ease upon the back which is peculiar to man. It also increases the capacity of the chest, and makes some amends for the comparatively small antero-posterior diameter of the human thorax. The degree of curvature of the ribs, and particularly of that sharper curvature which forms the angle, varies a good deal in the different ribs; it is most marked in the first, and undergoes a progressive and almost regular diminution to the last, in which there is little or no difference in the degree of the curvature of the different parts. So that in the last rib the angle can scarcely be said to exist; and the whole of this bone may be considered to form a segment of one large circle. On the concave side of the curve each rib is strengthened by a *Ridge* proceeding from the head, generally from the lower part of the head, and projecting into the arc of the curve. The ridge is strongly marked at its commencement, where it occupies the inside of the angle, and is gradually lost about the middle, or towards the anterior extremity, of the rib. It forms the upper edge of the so-called *Groove for the intercostal artery*, and gives attachment to the fibres of the internal intercostal muscle. It is very strongly marked in the 1st rib, giving that breadth to the bone which is one of its characteristics, and is scarcely perceptible in the 12th. At the part where it is most marked, that is to say, at the neck and angle, each rib is of nearly cylindrical shape; where it begins to fail the rib becomes extended from above downwards or flattened out. Near to their anterior extremities the vertical diameter of the lower five or six ribs is again somewhat curtailed; and the end of each is thickened and cup-shaped for the reception of the costal cartilage.

The ridge on internal surface.

Nutritious foramina.

Beneath the ridge just mentioned, and upon it, may be seen numerous small *Foramina* traversing the wall of the shaft obliquely from before backwards. These transmit small vessels to the interior; they take an opposite direction to that of the intercostal artery, and correspond with the nutritious foramina of other long bones in being slanted away from the epiphysis which is last united to the shaft. In the interval between the tubercle and the head of the rib the direction of these foramina is less constant;

some of them pierce the bone perpendicularly, some are slanted forwards, some backwards.

Curves in vertical plane. In addition to the above-described curves in a horizontal plane, which are so disposed with their concavities towards the median line as to give capacity to the thorax, there are other curves in the ribs, by means of which their fore and hinder extremities acquire an inclination upwards or downwards. The effect of these curves ("twists" or "torsions" they are often improperly called) in the vertical plane is well seen when the ribs are arranged in order upon a table, lying on their lower edges. The 1st rib is found to be nearly flat; its head, however, is directed a little downwards, owing to a bend, with the convexity upwards, at the angle. In the 2nd and 3rd ribs there is a similar, but slighter, inclination of the heads downwards. In the 4th rib the head is curled a little upwards, so as not to touch the table when the bone is placed upon its lower edge. This inclination upwards increases to the 7th rib; and then it diminishes again to the 12th, the head of which, like that of the upper three ribs, has a slight inclination downwards. Thus, when the several ribs rest upon their lower edges, their heads present a waving line, and the summit of the wave is formed by that of the 7th rib. Their anterior extremities, on the other hand, are all curled a little downwards; those of the 1st and 12th in the least, and those of the 7th, 8th, 9th, and 10th, in the greatest degree.

Articular facets on head of rib. The heads of the greater number of the ribs present each a double *Articulating Facet*, or two facets separated by a projecting ridge running from before backwards, which is slightly roughened at the summit. This is in accordance with the fact that each of these ribs is connected with two contiguous vertebræ. The first and the lower two or three ribs are each connected with only one vertebra, and have each but a single facet. The two facets are most distinct from the 4th or 5th to the 8th or 9th ribs. The superior facet is, in each of these, directed somewhat more obliquely from the intervening ridge than is the inferior facet; and this has relation to the greater prominence of the corresponding articulating facets of the vertebræ. In the 1st rib the articulating surface is situated on the inner and *posterior* surface of the head. This is less the case as we travel downwards through the series of ribs; and in the 12th it is placed on the inner and *anterior* surface, quite at the extremity of the rib.

The tubercles.

The *Tubercle* is much more prominent in the upper two or three ribs than in those lower down; in the lower two or three it does not exist at all. The *Articular Facets* on the tubercles of the upper two or three ribs are elongated from within outwards and slightly convex from above downwards, being thus adapted to the concave and similarly elongated facets on the corresponding transverse processes of the vertebræ (page 175); whereas those lower down are, for a like reason, round or oval, with the greatest diameter from above downwards. In all the ribs, in those below the first more particularly, the articulating facets are nearer the lower than the upper edges of the tubercles (see p. 140), and are surmounted by rough projections which serve for the attachment of the posterior costo-transverse ligaments.

The neck.

The *Neck*, or portion intervening between the head and the tubercle, is long and thin in the case of the upper ribs; below the 4th it is thicker and shorter. In the case of the lower two ribs there is no tubercle, and the neck, therefore, cannot be said to exist. The necks of the ribs are separated from the transverse processes of the vertebræ by intervals which correspond to the foramina in the transverse processes of the cervical vertebræ[1].

Surfaces.

The flat *Surfaces* of the 1st rib look almost directly upwards and downwards. Those of the 2nd rib are inclined a little outwards and inwards; those of the 3rd and 4th are still more so. In the 5th and succeeding ribs the flat surfaces look directly inwards and outwards; the upper edge is rounded,

[1] An interesting confirmation of this relation is furnished in the *Lithographic Drawings of the Arteries*, by Quain and Maclise, Plate XXII. fig. 5. It is an instance in which the superior intercostal artery on the right side is derived from the vertebral, and passes downwards into the thorax through the foramen in the transverse process of the 7th cervical vertebra, and afterwards between the necks of the upper three ribs, and the corresponding transverse processes of the dorsal vertebræ, sending branches to the upper three intercostal spaces. The first aortic intercostal branch also occupies a similar position in reference to the bones.

and the lower edge is sharp. In the 12th rib the upper edge has a slight inclination outwards, and, accordingly, the sides have again a disposition to look upwards and downwards; but, whereas in the 1st rib the external surface looks upwards and the internal or pleural surface looks downwards, in the 12th rib it is the reverse, for the internal surface looks upwards, and the external surface looks downwards.

Relation of these individual peculiarities to the movements of the ribs.

Most of the above-mentioned peculiarities in the shape of the individual ribs have relation, not only to the general shape of the chest, which is obvious enough, but also to the particular movements which the respective ribs undergo in respiration. The 1st rib, placed at the upper and more contracted region of the thorax, and overlying part of the apex of the lung, is flat on its upper and under surfaces; it is connected by a broad thick cartilage with the manubrium of the sternum, and, during inspiration and expiration, its anterior extremity is simply raised and depressed; and in this movement the whole bone, with the sternum, revolves on a transverse axis which passes through the tubercle and head of the rib, running parallel with the articulating surface of the former, and traversing the articulating surface of the latter, or nearly so. Accordingly, a sort of hinge-like motion takes place in the joint between the tubercle of the rib and the transverse process of the vertebra, and a rotatory motion occurs in the joint between the head of the rib and the body of the vertebra. And it is to permit these movements in the respective joints that the articulating facet of the tubercle is elongated transversely, and is received into the hollowed socket of the vertebral process; and that the articulating surface on the head of the rib is rounded or ball-like, and is lodged in a corresponding concave round socket on the side of the vertebral body (Pl. XXV. figs. 1 and 3). Hence the axis of motion of the first rib, on the one side, about coincides with that of the first rib on the other side. In other words, the two, with the sternum between them, may be described as playing up and down, in a hinge-like manner, upon an *axis* drawn through the tubercles, necks, and heads of both ribs, and traversing the body of the first dorsal vertebra upon which they are placed. The same remarks apply generally to the

2nd rib, the shape and movements of which correspond very closely with those of the first.

In the case of the ribs situated lower down, more particularly of those occupying the intermediate position between the highest and the lowest, the movement is not quite so simple. There is, as in the case of the first rib, an elevation of the anterior extremity and body of each bone; but this is not effected by a mere hinge-like movement of the rib upon the vertebra. Such a movement, seeing that the rib lies upon the side, instead of upon the upper surface, of the thorax, would not have caused much variation in the size of that cavity, and, consequently, would not have contributed much assistance to the respiratory process. Accordingly a different movement and a different shape of the articulating surfaces are provided. In inspiration the bodies and angles of these ribs are raised as much, or nearly as much, as their anterior extremities, so as to increase the transverse diameter of the chest; and the whole of each rib revolves upon an axis drawn, not transversely, but from before backwards through the costo-vertebral joint, and nearly corresponding with the prominent ridge which separates the two articular facets upon the head of the rib. The shape of the latter is modified accordingly (Pl. XXV. figs. 2 and 4); and as it is a necessary attendant on such movement of the middle parts of the ribs that the tubercles should slide a little up and down upon the transverse processes of the vertebræ, we find that the opposed articulating surfaces are nearly flat, and that they are round, or a little elongated in a vertical direction. (See p. 175.)

Development of the ribs. The ossification of the ribs takes place very early; it commences, at the middle of each rib, from the 45th day of fœtal life to the end of the 2nd month. By the end of the 3rd month, the bony part bears as large a proportion to the costal cartilage as at the full-grown period. Between the 16th and 20th years a nucleus appears in the epiphysis which forms the articular surface of the head of each rib, and another in that of the tubercle. These become united to the shaft soon after 20. There is no separate centre for the tubercle in the 11th and 12th ribs.

In women the ribs are rather smaller than in men, with the exception of the first two, which Meckel finds to be absolutely a little larger;

they are also rather more sharply curved at the hinder part, and are flatter or straighter at the sides, so as to render the transverse diameter of the chest less in proportion to the antero-posterior (page 350.)

Fractures occur with about equal frequency in the various parts of their shafts. They commonly result from the direct application of force, such as a blow or a wheel passing over the chest. In one case, that of a man who fell from a height upon one side of his chest, the 4th, 5th, and 6th ribs are said to have been found broken on the opposite side near their cartilages by the *contre-coup*[1].

Costal cartilages: their connection with the ribs.

The *Costal cartilages*, which may be regarded as the anterior epiphyses of the ribs, and which in birds are regularly ossified, forming what are called the "sternal ribs," connected with the sternum by regular synovial joints, are united to their respective ribs in a very firm manner. The rounded end of each cartilage is received into the concavity at the extremity of its rib, and is joined to it just in the same way that the cartilaginous epiphyses in other parts of the skeleton are connected with their respective bones. Hence, in breathing, the ribs and their cartilages move together upon the sternum, and separation of one from the other is very rarely caused by external force. I have known it take place in the course of ulcerative and suppurative disease, as sometimes happens in the case of other epiphyses[2].

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[1] *Archives Gen. de Méd.* 1837, Tom. II.

[2] Prof. H. Luschka, *Müller's Archiv*, 1857, s. 327, found a linear cavity at the junction of the first rib with its cartilage, on either side, in the body of a man, æt. 55. It was surrounded by the cartilage, and did not interfere with the firm union of the rib with the cartilage. He connects this anomaly with the observation of Bruch, *Beitrage zur Entwickelungsgeschichte des Knochensystems*, s. 15, that the costal cartilages are not mere portions of ribs to which ossification has not extended, but that they are distinct portions of the skeleton, separated by formative tissue, in the early fœtal state, from the sternum on the one side and the ribs on the other, just as the latter are separated from the vertebræ. This formative tissue commonly becomes converted into a synovial cavity between the lower cartilages and the sternum; whereas between the first cartilage and the manubrium, and between all the cartilages and the ribs, it usually disappears. Luschka's case affords the rare example of its undergoing, in the latter situation, a change similar to that which takes place at the juncture of the lower cartilages with the sternum. In the same instance, also, the union between the first cartilage and the sternum was not direct, but by means of a line of fibro-cartilage. See a small synovial cavity in this situation, Pl. XXIII. fig. 1.

They differ from one another.

The several cartilages, like the ribs, differ from one another in many respects. Thus the cartilage of the 1st rib is shorter, thicker, and stronger than the others. It is so because it forms the chief support of the manubrium which has to bear the clavicles. So that the 1st rib and its intercostal cartilage constitute the medium of connection between the upper extremity and the vertebral column; and for this purpose they are suited by their comparative immobility, as well as by their greater strength. Moreover the shortness and flattened shape of the 1st rib and of its cartilage, and the extent to which the concavity of the curve of the rib is filled up by the growth of the inner margin, are additional provisions for affording an efficient support to the manubrium. The other costal cartilages decrease in thickness from the 1st to the 12th, which is the thinnest of all. Like the ribs they gradually increase in length to the 7th, and below this they again decrease to the 12th. The 1st cartilage, descending with slight obliquity to the sternum, is continued in the same direction as the rib; and the intention of affording an efficient support to the manubrium is, in this manner, still further carried out. The 2nd cartilage joins the sternum at a right angle, forms a wide angle with its own rib, and is of nearly equal width in its whole length. The difference of direction between the cartilages and their ribs becomes more and more marked as we trace them downwards. The ribs being slanted with increasing obliquity from the vertebral column *downwards* and forwards, the cartilages must *ascend* with a proportionate increase of obliquity to reach the sternum; or, failing this, to reach the cartilages of the ribs above them. They also become narrower as they approach the sternum. The lowermost two, called the "floating cartilages," are short and pointed, and follow more the direction of their ribs. They are not connected with the other cartilages or with one another.

Their ossification.

The so-called *Ossification* of the costal cartilages takes place in a very irregular manner and at very uncertain periods. It consists rather in an amorphous clustering of earthy granules, which form nodulated masses scattered irregularly through the cartilage, than in a regular process of ossification. The matrix of the cartilage first undergoes fibrillation; and this may often be seen to have occurred to a considerable extent when no earthy matter has been deposited. The "ossification" takes places in the first cartilage sooner than in the others, and in men more frequently and at an earlier period of life than in women. The remarks at p. 58 indicate that it is a morbid change rather than an attendant upon old age.

COSTO-STERNAL JOINTS. (Plate XXIII. Fig. 2.)

The mode of connection of the several cartilages with the sternum varies somewhat in different individuals, as well as in the several costo-sternal joints of the same person; and it is not always symmetrical on the two sides. In the uppermost joint, where much strength and little movement is required, the cartilage may be united directly to the bone; or, as in the Example represented in Pl. XXIII. fig. 2, it may be fastened to the sternum by strong fibrous tissue at one part, and be separated from it by a small synovial cavity at another. The 2nd cartilage is more regular in its mode of union with the sternum than any of the others. It is received into the interval between the manubrium and the body of the sternum. A strong fibrous interarticular ligament (*G*) runs from a ridge-like projection at its extremity to the symphysial structure between the two bones; and the upper and lower surfaces of the head of the cartilage are applied, the one against the edge of the manubrium, the other against the contiguous edge of the body of the sternum; a synovial cavity or some fine areolar tissue intervening in each instance. The 3rd cartilage frequently, as shown in the drawing, terminates in a rounded end, or rather in an end compressed a little above and below, so as to present a slight ridge upon its summit. This cartilage is received into a socket in the edge of the sternum; and the joint is provided with a regular synovial capsule (*H*). The 4th cartilage ascends obliquely to join the sternum; it is united to its socket in that bone, at the lower part of its head, by strong ligamentous fibres

(*I*), which run upwards and inwards from the bone to the cartilage; and at the upper part by a synovial capsule (*L*). Hence when the cartilage is raised with the rib in inspiration, its pressure against the upper part of the socket, and its traction by means of the ligamentous fibres, upon the lower part of the same, combine to carry the sternum with it. The 5th cartilage joins the sternum at a still more acute angle than the 4th, and, in the instance represented, was united to it by fibrous tissue without any synovial cavity at all. The 6th runs to the lower end of the bone, and has a synovial cavity as extensive as that of the 3rd. The 7th also has often a synovial cavity. In some instances, however, especially in young subjects, there are no synovial cavities at all discernible, and the several cartilages are joined to the sternum by variable proportions of tough ligamentous and delicate areolar tissue (Pl. XXII. fig. 1, and XXIII. fig. 1). There are, in connection with each costo-sternal joint, except the first, two ligaments consisting of radiating fibres, which pass from the cartilage to the sternum, one in front, and the other behind the joint (Pl. XXIII. fig. 3).

Movements. The movement permitted by these joints is slight, and in one direction only, viz. a hinge-like movement of each cartilage, upwards and downwards, upon an axis drawn, from before backwards, through the most projecting part of its extremity. There is scarcely any antero-posterior movement, that is, movement upon a vertical axis, possible. In their antero-posterior movements the cartilages do not revolve upon the sternum, but carry that bone with them; whereas, in the elevation and depression to which they are subjected with the ribs during respiration, they revolve a little upon the sternum as well as carry it with them. So that although the sternum advances and retires with the cartilages, and to as great an extent as they, it does not ascend and fall in nearly the same degree that they do. This difference in the share taken by the cartilages of the ribs and the sternum in the respiratory movements may be distinguished by any one who places his fingers upon his own sternum and upon his costal cartilages near the junction with the ribs, and examines the changes of position which they respectively undergo in respiration.

Union of the cartilages with each other.

The 5th and 6th, and the 6th and 7th cartilages are united to one another at, or just in front of, the point at which they make their bend and turn up to reach the sternum. (Pl. XXII. fig. 1, *K.*) The cartilages about this spot are thickened; and a broad blunt process extends from the lower edge of each to the upper edge of the one below, and comes into contact with it, and the opposed surfaces are flattened and separated by a synovial cavity. A series of regular joints is thus provided, which permit slight lateral movement of the cartilages upon one another; and the several cartilages are securely bound together by ligamentous fibres passing, from one to the other, across the respective joints. By the connection of these long cartilages with one another in so firm a manner, the framework of the chest is much strengthened, just at this part where it is entirely dependent upon the costal cartilages for its firmness. The other cartilages, as low as the 10th, are united together, either in a similar manner, or by fibrous tissue only, or by continuity of structure; the perichondrium of the one is, in the latter case, continuous with that of the other. The 11th and 12th cartilages are connected with each other only by the intercostal and abdominal muscles.

COSTO-VERTEBRAL JOINTS. (PLATES XXIV & XXV.)

The joints between the heads of the ribs and the bodies of the vertebræ (of those at least from the 1st to the 10th) resemble that of the 2nd costal-cartilage with the sternum, inasmuch as each rib is fitted into a depression between two vertebræ, and each presents a ridge upon its summit from which an *Interarticular ligament* runs to the symphysial or intervertebral substance. This interarticular ligament (Pl. XXIV. fig. 2, *C*) is not very thick. It is connected rather with the lower than with the upper part of the intervertebral substance, in consequence of its fibres having a slight inclination downwards from the rib for the purpose of preventing the ascent of the head of the rib, which the contraction of the inspiratory muscles tends to induce. There are

Interarticular ligament.

various other provisions which combine to counteract this tendency, and to keep the head of the rib steady in its place, and which make it the centre of motion in the ascent and descent of the shaft during respiration. Thus the articulating surface of the vertebra above stands out boldly, more boldly than that of the vertebra below, so as to afford the head of the rib an efficient *point d'appui*, and most of the costo-vertebral ligaments are so disposed as to contribute to the same object. The interarticular ligament divides the joint into two synovial cavities; one above, between the upper facet of the head of the rib and the vertebra above; and one beneath, between the lower facet of the head of the rib and the vertebra below.

Anterior costo-vertebral ligaments.

The upper, fore, and under, parts of the articulation are covered and protected by the fibres of the *Anterior costo-vertebral ligament* (fig. 1, *A*), which radiate from the margin of the head of the rib to the adjacent parts of the bodies of the vertebræ and the intervertebral substance. The lower portion of the ligament—that which covers the inferior of the two joints, and which is attached to the inferior of the two vertebræ—is the strongest. It is rendered tense when an attempt is made to raise the body of the rib, and it limits, or rather prevents, that movement: it also limits the rotation of the head of the rib which occurs during the elevation of the shaft in inspiration.

DESCRIPTION OF PLATE XXIV.

Fig. 1. Front view of articulations of three middle ribs with their vertebræ. *A, A, A,* anterior costo-vertebral ligaments. *B, B,* anterior fibres of superior costo-transverse ligaments passing from each rib upwards and *outwards* to the transverse process above it. *C, C,* posterior fibres of the same passing from each rib upwards and *inwards* to the transverse process above. *D, D,* fibres of anterior vertebral ligament.

Fig. 2. Vertical section from side to side through the joints of two ribs with the vertebral bodies, showing the shape of the articular surfaces. *A, A,* cut edges of upper and lower parts of anterior costo-vertebral ligaments. *B,* anterior fibres of superior costo-transverse ligaments. *C, C,* interarticular ligaments.

Fig. 3. Hind view of three ribs and the corresponding transverse processes of vertebræ. *A, A,* cut surfaces of bodies of vertebræ seen obliquely. *B, B,* spinous processes. *C, C, C,* transverse processes. *D, D,* posterior fibres of superior costo-transverse ligaments. *E, E,* posterior costo-transverse ligaments.

Plate XXIV.

Fig. 1.

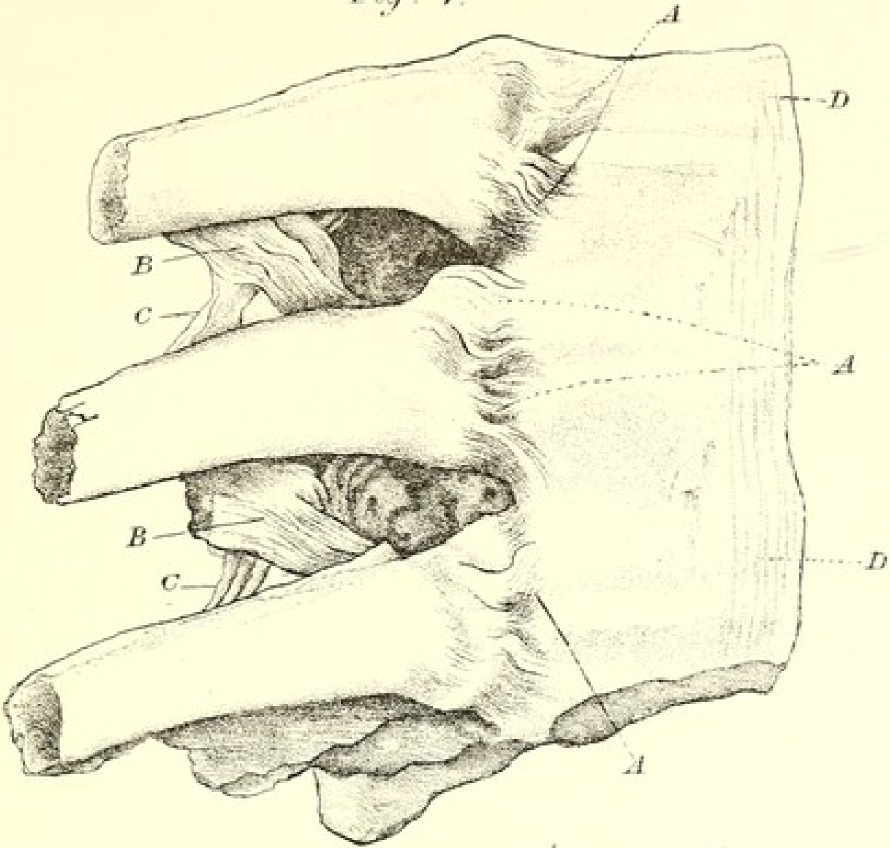


Fig. 2.

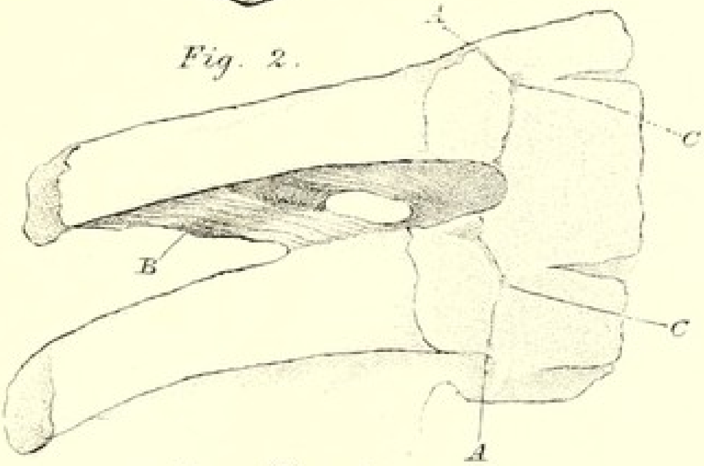
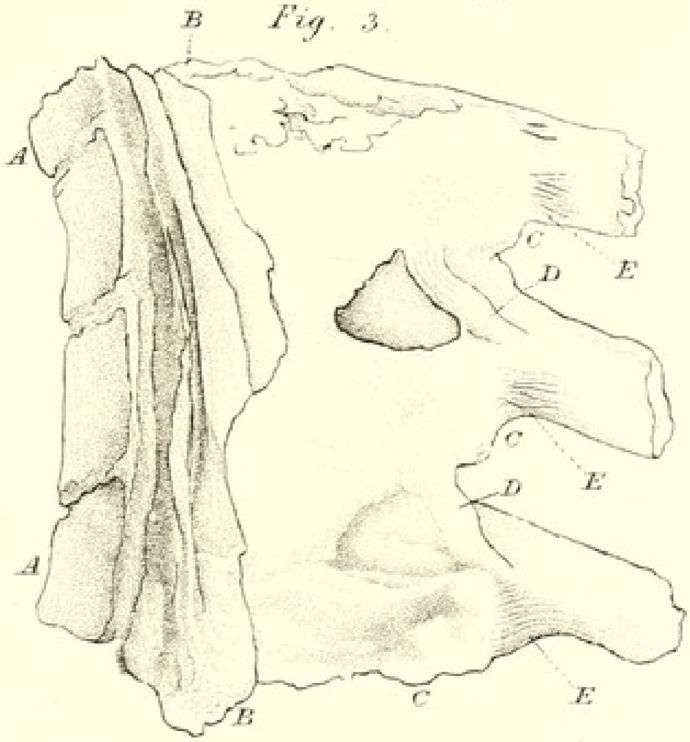


Fig. 3.



Costo-transverse ligaments.

A synovial cavity, with a loose capsule, intervenes between each rib and the transverse process upon which it rests; and three *Costo-transverse ligaments* (Pl. XXIV. *B, C, E*) connect each rib with its transverse process. Of these the *Superior* passes to the transverse process above; it consists of an anterior and a posterior portion, the fibres of which take different directions, crossing one another. The fibres of the anterior portion (*B*) pass from the prominent ridge on the upper edge of the neck of the rib, upwards and outwards, to the under edge of the transverse process. They prevent the head of the rib from being driven inwards and forwards; and, being rendered tight when the shaft of the rib is much depressed, they have some influence in checking that movement. Moreover, from the obliquity of their direction, they limit the rotation of the head and neck of the rib upon the vertebræ, and so set bounds to the elevation of the shaft of the rib. They, therefore, serve the double purpose of restraining both the rising and falling of the ribs in inspiration. The fibres of the hinder portion (*C*) are fewer and thinner. They pass from the hinder part of the upper edge of the rib upwards and inwards to the hinder and lower edge of the transverse process. They limit the descent of the rib in expiration. The *Posterior costo-transverse ligament* (fig. 3, *E*), strong and broad, passes from the extremity of the transverse process, outwards, with a slight inclination upwards, to the roughness on the exterior of the articulating facet of the rib. It limits both the ascent and the descent of the rib; but the direction of its fibres is such as to render it a more effectual check upon the former movement. The *Middle costo-transverse ligament* (Pl. XXV. fig. 2, *B*) consists of fibres passing directly between the transverse process and the neck of the rib; it is not seen unless the bones be separated from one another, or unless a section be made through them. It limits all the movements, and prevents the ribs being driven forwards. In the case of the lower ribs, where the tubercles are deficient and the vertebral transverse processes are much shorter, these costo-transverse ligaments are longer and weaker, and have less restricting influence upon the movements of the ribs.

These joints rarely dislocated or diseased.

The joints between the ribs and the spine and between the cartilages and the sternum are very seldom the seat either of dislocation or disease. Their remarkable immunity from disease may possibly have some relation to the incessant recurrence of their movements, which is maintained throughout life in the work of respiration; probably it has still more relation to the limited range and the great regularity of these movements, and to its being scarcely possible that they should be overstrained by any voluntary or involuntary exertion.

Intercostal spaces.

None of the ribs lie in a truly horizontal plane. They are all directed, more or less obliquely, downwards from the vertebral column, so that the anterior extremities are at a lower level than the posterior. This is so even in the case of the

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DESCRIPTION OF PLATE XXV.

Sections of first and seventh costo-vertebral joints contrasted.

Fig. 1. Horizontal section through the body of the first dorsal vertebra and the joint with the first rib on either side, showing the transverse direction of the neck of the rib, the shape of the head of the rib, and its position on the *side* of the body of the vertebra. *A*, anterior costo-vertebral ligament. *B*, middle costo-transverse ligament.

Fig. 2. Horizontal section through the joints of the 7th ribs and the intervertebral substance between the 6th and 7th dorsal vertebræ, showing the oblique direction of the neck of rib on either side, the comparatively small antero-posterior depth of the head of the rib, and the position of the articular facet for it upon the *back* part of the body of the vertebra. *A* and *B*, as in preceding figure. *C*, the spine and arch of the 6th vertebra. *D*, the ligamentum sub-flavum. *E*, the interarticular ligament.

Fig. 3. Vertical section from side to side through the bodies of the last cervical (*A*) and the upper two dorsal vertebræ (*B* and *C*), and through the upper two costo-vertebral joints, showing the slight depth, from above downwards, and the rounded form of the articular ends of the ribs (*D* and *E*), particularly of the first rib. *F*, *F*, *F*, *F*, edges of costo-vertebral ligaments.

Fig. 4. Corresponding section through the 7th costo-vertebral joint. The middle of this joint, being on a plane behind the bodies of the vertebræ, the saw has passed through the vertebral arches, and exposed the vertebral canal. The two facets of the rib on either side are seen placed almost at right angles with regard to one another, and are adapted to the facets on the bodies of the contiguous vertebræ. *A*, *A*, cut edges of upper and lower parts of anterior costo-vertebral ligament. *B*, interarticular ligament. *C*, the lower part of 6th rib, its upper edge and upper articular facet have been removed with the body of the vertebra above.

Fig. 1.

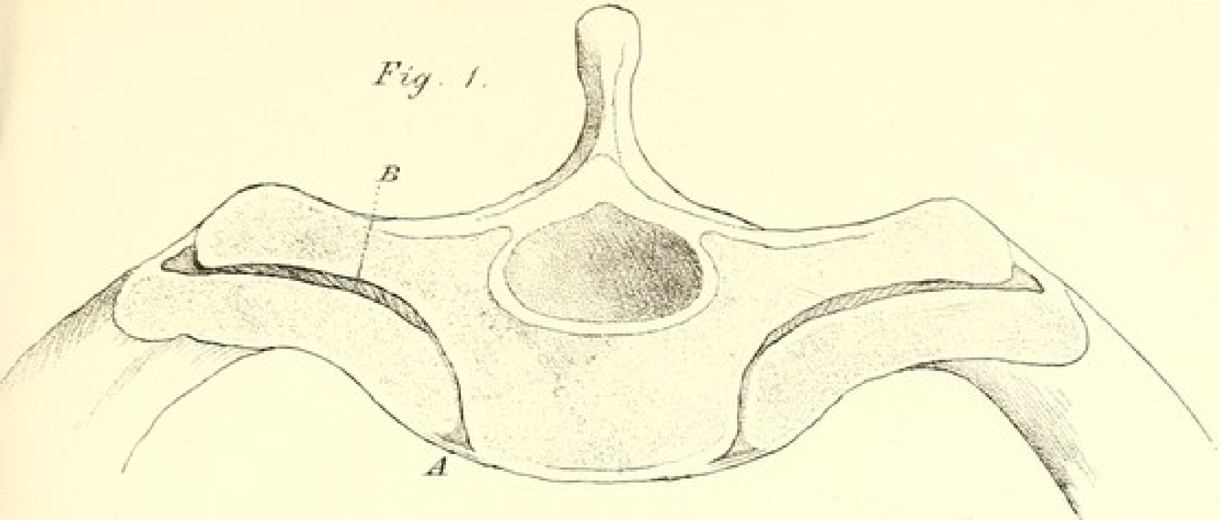


Fig. 2.

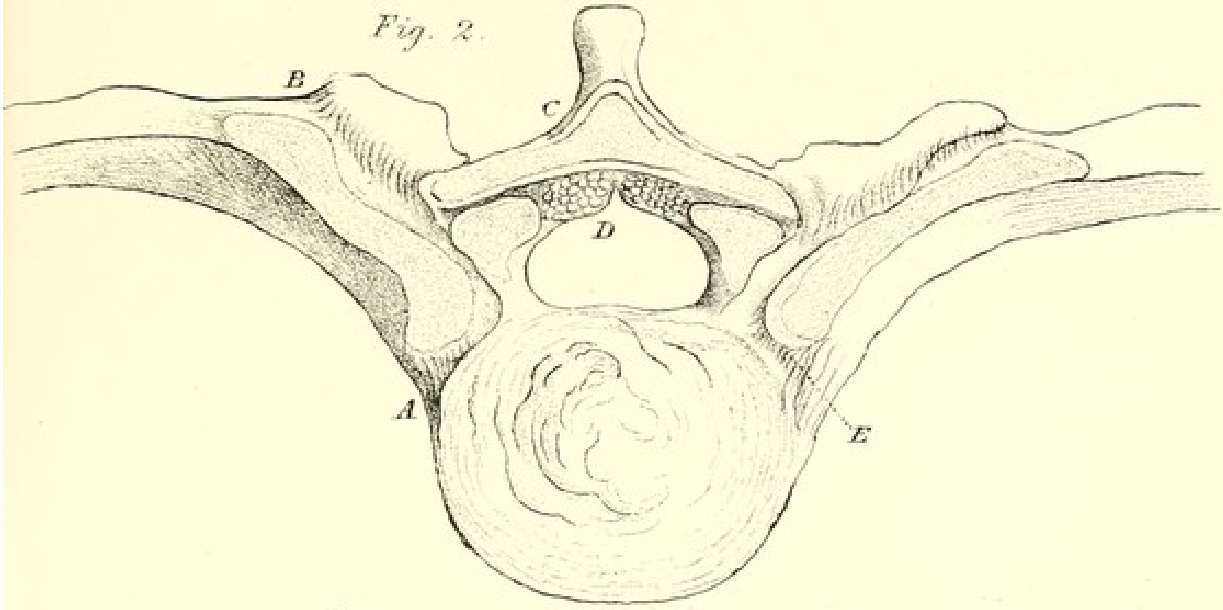


Fig. 3.

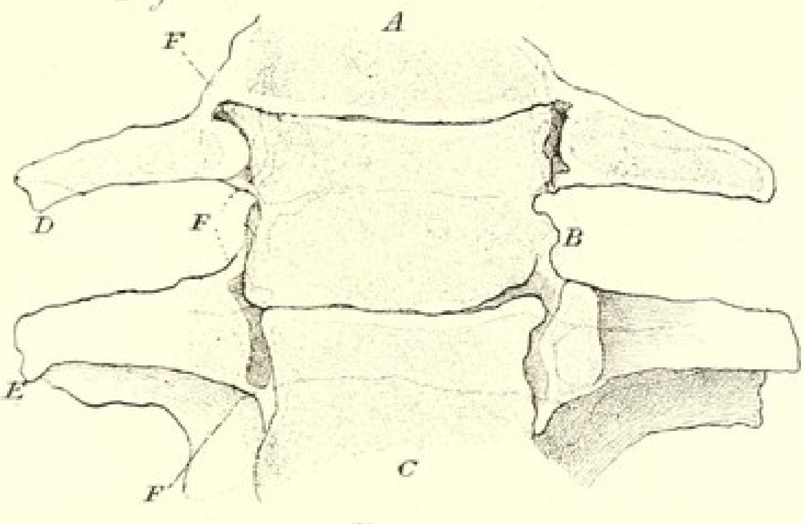
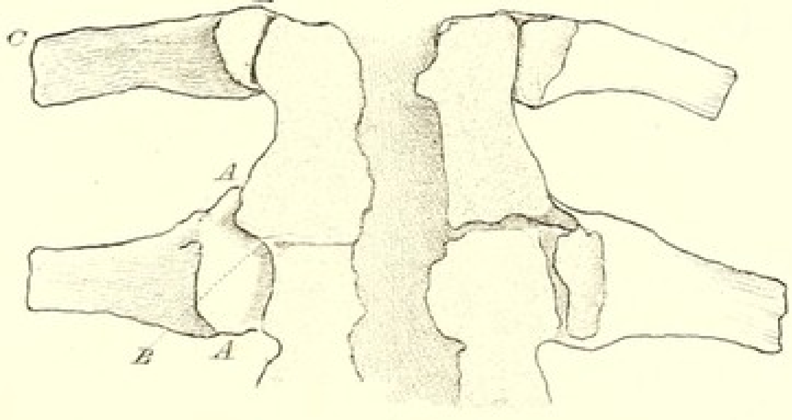


Fig. 4.



first rib; and the upper edge of the sternum is accordingly below the level of the first dorsal vertebra. The degree of obliquity with which the ribs descend from the spine increases from the 1st to the 7th. Hence the intercostal spaces are wider at the antero-lateral parts of the chest than behind; and this is more especially the case in the neighbourhood of the 7th rib. Owing to the manner in which the costal cartilages converge to the sternum (Pl. XXII. fig. 1), the intercostal spaces, from the 3rd to the 8th particularly, become quickly narrower as they approach the middle line in front. These spaces are accordingly narrowest near the sternum; some of them are quite pointed there; they gradually widen as they approach the ribs, are widest between the fore parts of the ribs, and again become a little contracted as we trace them nearer to the spine.

Effect of oblique position of ribs in inspiration.

It follows also from the oblique direction of the ribs and the construction of the costo-vertebral joints, that when the shafts of the ribs are raised in inspiration, the anterior extremities are brought more nearly to a level with the posterior, and the *antero-posterior* diameter of the chest is thereby increased. This end is still further attained by the sternum being so connected with the cartilages of the ribs that it is raised with them, and is carried forward at the same time.

But the ribs are not only slanted in the direction just indicated, viz. downwards and forwards from the vertebral column; they are *oblique* also in their relation to a *transverse* plane; that is to say, their middle parts are, on either side, placed at a considerably lower level than their points of connection with the vertebral column and the sternum. This, which results from the curvature of the ribs in a horizontal plane referred to at page 329, and from the oblique descent of the costal cartilages from the sternum, is most marked in the middle of the chest, and is scarcely observable in the upper and lower ribs. It results from the obliquity in this direction, that when the ribs are raised the *lateral* diameter of the chest is increased as well as the antero-posterior diameter; and the increase which takes place in both diameters is proportionate to the degree of the obliquity in the two directions indicated, and to the amount of downward bend in the ribs near their angles. It is therefore but slight in the highest and lowest parts of the thorax; and is greatest at the middle, or about the 7th rib. This accords with the statement made page 333, that the upper ribs, in their ascent and descent during respiration, revolve upon *transverse* axes, drawn through their heads, necks, and the intervening vertebræ; but that the centres of motion of the ribs nearer the *middle* of the chest are *antero-posterior* axes, drawn from before backwards through the joints with the sternum and through those with the spine. It accords also with what has been said of the differences of shape of the articulating surfaces of both the costo-vertebral and of the costo-transverse joints in these two parts of the chest.

Movement outward of fore part of ribs.

The provision thus afforded for increasing the transverse diameter of the middle part of the thorax, by means of the downward bend of the ribs at their angles, affects chiefly the *posterior* half of the chest. An additional provision for increasing the transverse diameter of the *anterior* half of the chest, is afforded by the movement of the anterior extremity of the ribs *outwards* when they are raised in inspiration. These are not only elevated and carried *for*ward, they are also carried a little *out*wards or abducted, and are again drawn *in*wards or adducted in expiration. So that it is not correct to say that a rib rotates upon the chord or line drawn through its two extremities, unless the cartilage be included with the rib, and the chord be drawn through the projecting line dividing the articulating surface on the head of the rib and through the terminal point of the costal cartilage.

Thus, in inspiration, the *antero-posterior diameter* of the chest is increased by the elevation of the fore parts of the ribs, so as to bring them more nearly to a level with their hinder extremities, and by the consequent projection of the sternum and costal cartilages forwards; and the *transverse diameter* is, at the same time, increased, *in front*, by the outward movement of the anterior extremities of the ribs, and, *behind*, by the elevation of the sides of the ribs. These changes in the diameters of the chest are effected, easily and quietly, by very slight movements of the individual ribs, owing to the skilful construction and admirable jointing of those bones with the spine, and of their cartilages with the sternum.

Part where most increase of capacity of chest is gained.

The variation in the size of the chest, by the alteration of the length both of its antero-posterior and transverse diameters in the manner just mentioned, takes place to the greatest extent where its capacity is already greatest, where, accordingly, the largest amount of lung is contained; that is, about the situation of the 7th rib. This rib is the longest, the most obliquely placed, and the most bent downwards at its angle; it possesses, therefore, in the greatest degree, the qualities for increasing the diameters of the chest when it is raised in inspiration, and it encircles the most voluminous part of the lung. The first rib, which possesses these qualities in the least degree and is least moveable, encircles the lung near its apex; and the ribs below the 7th have less and less relation with the lungs in proportion as they are lower and shorter, and, therefore, less adapted to affect the capacity of the thorax by their movements. The part of each rib moreover—of the ribs at least between the 3rd and the 8th—which is most oblique, and which, by a given amount of movement, causes the greatest alteration in the size of the chest, is the hinder portion of the shaft—the part at and near the angle—; and this part is in contact with the thick hinder region of the lung, where a greater number of air-cells and blood-vessels are crowded together than in any other area of equal size, and where, accordingly, a larger proportion of the work of respiration is carried on.

Increase of capacity in a vertical direction.

The increase in the capacity of the chest in a *vertical* direction is effected above, where the lung is small, by the elevation of the upper ribs, the flat surfaces of which look upwards and downwards. Below, where the lung is large, it is effected by the descent of the diaphragm; the convex upper surface of which ascends to a considerable height into the lower broad part of the thorax, and acts in an especial manner upon the inner concave parts of the lungs, while the ribs affect chiefly their exterior convex surfaces.

It may be observed that the acute diseases of the lung are most frequent at the parts where the changes in the capacity of the thorax are greatest, viz. at the lower and hinder parts; and that the chronic diseases are more common in the upper regions, where the movements of the thoracic parietes are least free.

Effect of intercostal muscles upon the movements of the ribs.

The disposition of the ribs, with reference to the action of the intercostal muscles, is well explained by Dr Hutchinson in the *Cyclopedia of Anatomy*, Art. *Thorax.* He finds by experiment "that, although the chest is conical, the ribs segments of circles, and the spine mobile, yet that treating them as planes and lines will not lead to error." For instance, if the rotation of parallel straight bars on a rigid perpendicular body (as in Pl. XXVI. fig. 1) increases and decreases the distance between them, it will do so when they are curved like the ribs; and the intercostal muscles, acting as forces between bars or ribs which rotate upon the spine, have the effect of inducing this rotation, of causing the anterior extremities of the ribs to rise or fall, and so of increasing or decreasing the intercostal spaces accordingly.

The mode in which this takes place, and the share which the external and internal intercostal muscles have, in different parts of their length, in producing these movements, are illustrated in the article just mentioned by a series of diagrams, from which those in Plate XXVI. are taken, with some slight modifications. In fig. 2, the bars (or ribs) *AB*, *CD* rotate upon the perpendicular rod (or spine) *EE*. They are connected by oblique tensions (or intercostal fibres), x and y, representing respectively the external and internal intercostals. It is found that the action of each such tension *tends to move both bars or ribs towards that fulcrum which is nearest to one of its attachments.* The effect, therefore, of the action of x (the external intercostal fibres) will be to elevate the bars towards A, whereas that of the other tension y (the internal intercostal fibres) will be to depress them towards C. The position of the bars at m is an exaggerated representation of that of the ribs in the human thorax slanting obliquely from the spine downwards and forwards. It is evident that the effect of the contraction of the fibres x will tend to shorten them, and, in so doing, will raise the anterior extremities of the bars, and will increase the distance between them. Thus the parts are so arranged that the external intercostal fibres, passing obliquely between the several ribs, have the effect of

Fig. 1.

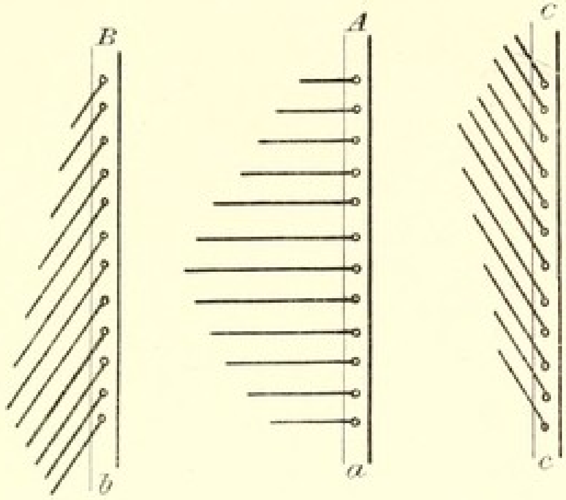


Fig. 2.

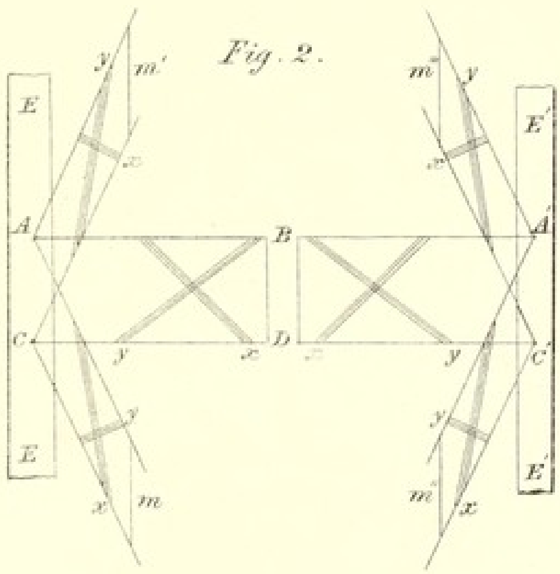
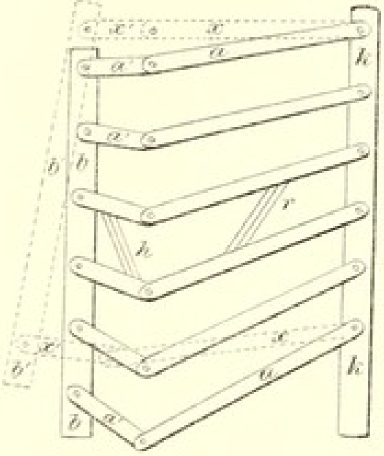


Fig. 3.



elevating them all, and, by so doing, increase the intervals between them. The maximum distance between the ribs is attained when they reach the horizontal position; and this is the limit beyond which they cannot be raised. It may seem strange that a series of muscular fibres passing from one bone to another can, by their contraction, increase the distance between the two bones. Nevertheless, such is evidently the effect of the action of the greater number of external intercostal fibres upon the several ribs to which they are attached. The action of the internal intercostals, which take a different direction from the fibres of the external intercostals, is just the reverse of the latter. By their contraction they tend to depress the anterior extremities of the ribs, and to diminish the intervals between them; but, forasmuch as they do not extend along the whole length of the intercostal spaces, being deficient between the angles and heads of the ribs, their influence is not so great as that of the external layers.

The reason that the external intercostals do not extend between the costal cartilages.

It is to be remembered that the direction of the costal cartilages is different from that of the ribs; they slant *back*wards and downwards from their fulcrum at the sternum instead of downwards and *for*wards; and the effect of the action of the intercostals between them must also be different. According to the rules just given, it is evident that the external intercostals, if continued into the spaces between these cartilages, would tend to depress the anterior extremities of the ribs, and to decrease the distance between them; in short, would just tend to antagonize the influence of the fibres of the same muscles which are placed upon the ribs. To prevent the loss of power which would be thereby entailed, these muscles stop short at the extremities of the ribs, and do not extend into the intervals between the cartilages. Their office in this situation is supplied by the internal intercostals which here act the part of elevators of the ribs. It results, therefore, from the direction of the ribs and their cartilages, that the intercostal fibres are all elevators of the ribs and agents in inspiration, with the exception of that portion of the internal layer which is situated between the costal cartilages and the angles of the ribs.

This is further illustrated in fig. 3. "*kk* represents the spine, *bb* the sternum, the bars *aa* the ribs, and the bars *a′a′* the costal cartilages united to the bars representing ribs by moveable joints; *r* represents the external intercostals. These we know act as elevators; while those at *h*, representing the internal intercostals, are associated with them in action, although they observe a contrary direction, because they act upon the fulcrum *bb*. In fact they are elevators of the levers representing the cartilages." "What now is the combined action of a series of two such tensions? The whole body of levers will be raised, and the part *bb* representing the sternum will have two motions. It will be raised and moved forwards into the position of *b′b′*. This is precisely the motion of the sternum in deep inspiration." "It will also be seen that these six bars, though moving equally," inasmuch as they differ in length and degree of obliquity, "will produce an unequal effect upon the body *bb*, forcing out the lower end more than the upper end. The ribs of man, in the same manner, increase in their length from the 1st to the 8th, and, therefore, by an equal mobility, an unequal protrusion of the sternum is produced, advancing the lower end more than the upper end. We have reason to believe that the mobility of all the ribs is the *same*, and that it is by their different lengths that the different degrees of the protrusion of the anterior part of the thorax may be accounted for[1]."

Parts of chest most enlarged in inspiration.

Thus, during inspiration, the cavity of the chest is enlarged in every direction, except that of the spine, which forms the fixed point or fulcrum upon which the movements of the other parts takes place. It is true that a slight change—a slight straightening—occurs even in the spine during deep inspiration; but this has relation, rather to the placing the ribs in a more favourable position for the expansion of the thorax, by increasing their obliquity with regard to the spine, than to any actual increase of the cavity of the chest as a direct effect of the movement itself. The wall of the chest immediately opposite to the spine—the sternum—is that which, next to the spine, is least effected by the movement of inspiration; and the part of the thoracic cavity intervening between these two, which is, by far, the

[1] *Cyclopedia of Anatomy*, "Thorax," p. 1054.

shallowest part, measuring only about four inches from before backwards, undergoes less change of size than any other in respiration. The comparative uniformity of this median portion of the thorax accords well with the nature of its contents, which are the heart and great vessels, the absorbent glands, the œsophagus and the bronchi. All the other regions of the thorax above the diaphragm are occupied by lung, and into the spongy tissue of the various parts of this organ the air is sucked by the expansion of the thoracic cavity in every direction.

Order of expansion of several parts.

In the normal expansion of the thorax the upper ribs are raised first, the others following in quick succession. In the female the commencement of this movement precedes that of the diaphragm by a very slight interval; whereas, in the ordinary inspiration of the male, the latter has a little the precedence. On this account the former has been called "costal," the latter "abdominal" respiration. In both male and female the abdominal type prevails in early life. It gradually changes towards puberty, when it becomes costal in the female. It again partakes more of the abdominal character in old age in both sexes.

Expiration, how effected.

The expansion of the chest, which is the result of a muscular effort, is a forced condition; forasmuch as the walls of the thoracic cavity and of the abdomen, and other parts are, during inspiration, forced from that which may be called their condition of rest, and are put upon the stretch. When the active effort of inspiration ceases, they gradually return to their more natural state; and in so doing they compress and partially empty the lungs, in which they are assisted by the elastic quality of the pulmonary tissue. There is no doubt, however, that the ordinary movement of expiration is effected more by the resiliency of the thoracic parietes than by the contraction of the lung itself, and that the air is driven out of the lung, in great measure, by the external pressure gradually exerted upon the surface of the organ. It is by regarding this external pressure as the great agent in expiration that we can alone explain the protrusion of the lung which we sometimes see taking place through a wound in the thoracic parietes, or the occurrence of emphysema of the subcutaneous cellular tissue consequent on a wound of the lung from fracture of a rib, while the ordinary respiratory sounds may be heard throughout the affected lung. The latter I have repeatedly observed; and in one case of extensive wound, through an intercostal space where the lung was uninjured, I was much struck with the manner in which the lung protruded, and continued to do so after I had returned it, even after I had stitched up the wound[1].

Mode of effecting artificial respiration.

Not only does the resiliency of the thoracic parietes restore them to the ordinary condition of expiration when they have ceased to be influenced by the contraction of the inspiratory muscles. It will do the same if by any means, such as the pressure of the hands upon the chest, a preternaturally *forced state of expiration* be induced. In this way artificial respiration may readily be maintained, without any apparatus or difficulty, by simply squeezing the fore and lower part of the chest between the hands, so as to drive out the air and effect a forced state of expiration; and then removing the hands, when the chest will expand and air will re-enter. The proceeding may be repeated as long as necessary. In children, especially, where the walls of the chest are flexible and elastic, this plan will often answer well: I am sure that I have more than once saved life by resorting to it[2].

Size and vital capacity of thorax.

The following are the more important mean measurements of the thorax taken from fourteen males and six females by Dr Hutchinson:

	Males.	Females.
Maximum internal circumference	32 inches	24 inches
Internal circumference of right half	15	13
Do. left half	15	13
Greatest depth from before, backwards	6.5	6
Distance between sternum and bodies of dorsal vertebræ	4	4
Greatest breadth of cavity	9	8
Internal superficies of costal walls of thorax	258 sq. in.	212 sq. in.
Depth from apex to arch of diaphragm, right side	7 in.	7 in.
Do. left side	9	8
Vital capacity	205 cub. in.	187 cub. in.

[1] The force required to overcome this costal elasticity for the insufflation of 200 cubic inches of air is estimated by Dr Hutchinson as equal to 450 lbs.

[2] Dr Marshall Hall's method of imitating respiration in cases of asphyxia, consists in repeatedly "turning the body gently but completely *on the side and a little*

He observes that "a certain rule of relation must necessarily exist between the size of a man and the dimensions of his thoracic cavity. A man seven feet high will have a larger chest than one five or six feet high. But there is no *constant* and uniform relation of the *size* of the chest, either to the height or weight of the body. The *function* of the chest, however, as indicated by the quantity of air which we can expel, is in strict relation to the minute difference of a single inch of stature, or to 10lbs. of weight." "A man 5 feet 4 inches high measured from the apex of the chest to the base 10½ inches, whilst a man of 5 feet 10 inches only measured 7½ inches in the same direction, or the shorter man exceeded the taller by 3 inches in the perpendicular depth of his thoracic cavity" (the transverse measurement is not given); "but the taller man could exceed the shorter by a volume of 77 cubic inches of air at one deep expiration. In fact the whole of the internal measurements (cubic or diametric) clearly bear no relation to the height or weight of the man, whilst *vital capacity* does so in an exact ratio."

Development. The walls of the thorax are developed in the visceral plates of the embryo, which, passing over the sides, unite in the median line in front. The union takes place first at the upper part where the manubrium sterni is formed, and progresses downwards towards the abdomen. Throughout fœtal life the thorax is of small size in comparison with the rest of the fœtus, and particularly in comparison with that of the abdomen, which accords with the relation in size between the lungs and the liver at this time. Its antero-posterior measurement also exceeds the transverse; the ribs are but little bent at their angles, and proceed almost directly forwards and downwards from the spine.

Changes after birth. Immediately after birth the chest undergoes considerable lateral expansion; it, as well as the other organs concerned in respiration, having been already fitted for the entirely novel conditions in which they are now suddenly placed, by the marvellous preparatory workings of the developmental

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beyond (when *in*spiration will occur) and then on the face, making gentle pressure along the back (when *ex*piration will take place) alternately," *Lancet*, August 2, 1856.

processes. Subsequently a progressive increase in the size of the thorax goes on through the whole period of life; which is attended with some alteration in shape. The transverse diameter gradually gains more and more upon the antero-posterior; the difference between the two being greatest in the old man. These changes are effected, till, and for some time after, adolescence, by the growth of the several components of the walls of the thorax, and by the bolder sweep which the ribs take at their angles, as well as by the diminished obliquity with which they pass from the spine.

In the chest of the child the hollow formed by the curve of the ribs on either side of the spine is comparatively shallow, and the dorsal spinous processes project on the posterior aspect beyond the level of the ribs. In the adult this hollow beside the spine is much deepened, the ribs and the transverse processes being inclined backwards from the bodies of the vertebræ in a more marked manner; so that the convex posterior surface of the ribs is on a level with, or even projects beyond, the spinous processes. Moreover the bend in the ribs downwards from their heads is more decided in the adult than in the child.

Enlargement of chest: change of shape attended with lessening of vital capacity.

The chest not only *grows larger* and undergoes the changes of shape just mentioned, during the approach to adolescence; it also acquires more the shape and conditions which it has during inspiration. After the adult period the walls of the thorax cease to grow. Nevertheless, the chest commonly gets larger, broader and rounder. This is effected by a diminution of the obliquity of the ribs, by a nearer approach, that is, to the condition of inspiration in the position of the ribs and the sternum; there is also a greater depth of the vertebral curve in the back. So that although the *actual* capacity of the chest thus becomes greater, yet the mobility of its parietes and its *vital* capacity, as measured by the amount of air it is able to admit and expel, are diminished[1]. Indeed it may be stated as

[1] This accords with the result of observations made by Dr Hutchinson in a great number of cases; viz. that the vital capacity of the chest increases a little from 15 to 30 years of age, after which it undergoes a gradually progressive diminution; and this inverse sort of relationship between the actual and the vital capacity of the thorax may

a general rule that the respiratory capacities of the chest decrease in proportion as its cavity is enlarged, when that increase of size results from other causes than growth. During all this time the size of the lungs is increasing *pari passu* with that of the thorax; and the change after adolescence is attended with, perhaps is a consequence of, a loss of elasticity and strength in the pulmonary tissue, which leads to a dilatation of the air-cells, and to a still further diminution of the vital capacity of the thorax. A more or less marked condition of the same change in the structure of the lungs occurs sometimes in the earlier periods of life, and is attended, in some instances, with a fatty degeneration and a giving way of the walls of the air-cells, constituting what is called emphysema. In this disease the lungs acquire a preternatural size; and, to accommodate them, the thoracic walls are maintained in a permanent state of inspiration, leading to that round, " barrel-shaped" configuration of the chest which is a well-known feature of the malady. The respiratory powers are proportionately diminished; and the patient is short-breathed and has difficulty in expelling the mucus that collects in his air-tubes.

Relation between elasticity of lungs and size of chest.

Thus, at the different periods of life and in the various conditions of health and disease, a pretty exact relation is maintained between the elasticity of the lungs and the mobility or vital capacity of the thorax. Where the chest is preternaturally round we know that the obliquity of the ribs and, consequently, their mobility is diminished; and we may infer, with tolerable certainty, that the elastic or contractile power of the lungs is impaired, that the air-tubes and air-cells are more or less dilated, and that the patient is short-breathed and liable to bronchitis and accumulation of mucus in the bronchial passages.

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explain the results obtained by M. Woillez, which seem at first so improbable, viz. that trades requiring but little muscular exertion of any kind are more favourable to the development of the chest than those which bring the upper extremities into constant and severe action. It may be, that under the former circumstances that *conformation* of the chest is retained which is adapted to carry on the respiratory processes with the greatest efficiency, though the *size* of the chest is not so much increased.

Influence of movement of lower margin of thorax upon diaphragm.

The lower margin of the thorax forms the circumferential line of attachment of the diaphragm. It is very important that it should be well thrown out to permit the perfect action of that muscle, as well as to afford space for the lungs. The manner in which it is widened during inspiration tends in some measure to distance the points of attachment of the muscular fibres of the diaphragm, and so to promote their efficiency. At any rate, this makes amends for any loss of power which may be sustained by that muscle owing to the elevation of the lower edge of the thorax in inspiration. Probably the gain to the muscle by the expansion of this part of the chest is about equal to the loss sustained by its elevation.

Lateral depression of thorax;

It must be remarked, however, that a great effort is required on the part of the forces of development and of the inspiratory muscles to establish and maintain the natural prominence of the lower edge of the chest; more especially of that part of the lower edge which is formed by the sixth costal cartilage and the four next below it. Upon this part, which is most distant from the fulcrum, or spine, the expanding forces act with the greatest disadvantage of leverage; and they are not always able to resist the suction influence of the inspiratory muscles acting upon other parts of the thorax, as well as the direct tendency of the diaphragm to draw these cartilages inwards. Hence we so often find in feeble and rickety children, more particularly when there is any obstruction to the entrance of the air into the lungs[1], that this region of the chest, and the extremities of the ribs on either side, are drawn inwards, or depressed, while the sternum projects forwards, and the costal cartilages are more or less incurved, constituting the malformation called "pigeon-breast;" and in the worst cases of the kind, where the lateral diameter of the thorax is considerably diminished, and the antero-posterior diameter is augmented, the movements of this part of the chest in respiration are just the reverse of what is natural: it is drawn in during inspiration, and expands in expiration. The whole force of the inspiratory

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[1] Dupuytren found the "lateral depression of the walls of the thorax" sometimes associated with enlargement of the tonsils, which caused difficulty of breathing, and relief was afforded by their excision.

muscles seems to be expended in dilating the upper and posterior regions of the thorax, and exerts little or no expansive influence upon this lower and anterior wall, which, instead of affording a proper *point d'appui* to the diaphragm, is pulled inwards by each contraction of that muscle, and by the suction caused by the efforts at inspiration. The energies of the diaphragm are thus injuriously diverted to the effect of narrowing the chest and diminishing the capacity of the thoracic cavity, instead of enlarging it in a vertical direction; the abdominal organs are scarcely at all depressed by its contraction; and the breathing is seriously, it may be fatally, embarrassed[1]. In one feeble child, where the malformation proved fatal at the age of 14 months, I found the ribs much bent inwards at their junction with the cartilages, and thickened so as to form considerable projections into the cavity of the thorax. Other children of the same parents were affected in a similar manner. In each the deformity was first observed about the 6th month after birth, and was thought to have been caused by an attack of bronchitis, with difficult breathing.

occasionally takes place in old age.

In old age, more particularly where the bones are the subject of mollities, the chest sometimes collapses into the condition of "lateral depression," forming a marked contrast with the rotundity of the thorax, which I have stated (p. 352) to be the more common configuration at that period of life.

An elongation and narrowing of the chest from paralysis of the intercostal muscles has been described by Engel, and named by him the paralytic thorax[2].

Depression of sternum.

I have sometimes seen the sternum, more especially its upper part, preternaturally depressed, instead of being thrown forward as in the "pigeon-breast," causing shallowness of the chest, or diminution of the antero-posterior diameter, and

[1] This lateral depression of the thoracic walls may be partly owing to a want of power in the pectorales and serrati magni muscles, which assist in raising the fore parts of the ribs and in increasing the transverse diameter of the thorax. But that it is not a necessary consequence of such imperfection in those muscles is proved by the shape of the chest having been natural in certain cases in which they were congenitally deficient or imperfect. Two instances of the kind were related by Dr Paget at the Cambridge Philosophical Society, March 8, 1858. In the frequent persistence of this conformation we recognize another instance of the difficulty which is experienced in shaking off the fœtal and animal type when the developmental forces are weak.

[2] Oesterr. *Jahrb.* April, 1841.

increase of the lateral diameter. Under these circumstances the manubrium does not afford a proper support to the clavicles; the shoulders hang forwards, and the upper extremities are deficient in strength, partly by reason of the deformity of the chest, and partly by reason of a weakness of the muscles with which that deformity is always associated. There has been no evidence of unusual predisposition to phthisis in those instances that I have seen.

Changes attendant on lateral curvature of spine;

It is interesting also to observe the changes in the shape of the thorax which are attendant on lateral and angular curvature of the spine.

In the *former* of these affections it has been remarked (p. 171) that, in addition to other changes, the vertebræ are rotated upon their vertical axes, so that their bodies are turned towards the convexity of the curve. This gives a twist to the whole thorax; for the transverse processes on the concave side of the curve being turned forwards, the ribs of that side are advanced with them, and run nearly straight forwards, projecting their costal cartilages and the corresponding side of the sternum on the anterior aspect of the chest. Whereas, on the other or convex side of the spinal curve, the transverse processes and the ribs are at first directed more backwards than natural; then the ribs make a sudden very sharp bend at, or near, their angles, by which they are enabled to advance forwards and to run parallel, or nearly so, with those of the opposite side. But they cannot of course reach so far. Accordingly the fore part of the chest is oblique; and the side of the sternum and the costal cartilages on the concave side of the dorsal curve are in advance of the corresponding parts of the other side. I have seen the flexure of the ribs on the convex side of the curve so sharp as to bring their shafts into contact with the twisted bodies of the vertebræ. Other results of this disposition of the ribs are a diminution of the transverse, an increase of the antero-posterior diameter of the thorax, and more or less inequality of size in the two sides of the thoracic cavity; some impairment of the respiratory functions is a necessary consequence of these changes.

the anterior surface of chest oblique, and the transverse diameter lessened;

or the anterior surface flat, and the transverse diameter increased.

Such obliquity in the fore part of the thorax, and alteration in the diameters of the cavity, are not, however, uniform attendants on the changes in the spine that take place in lateral curvature. There are some instances in which the anterior surface of the sternum and costal cartilages remains flat, and in which the fore part of the chest is approximated to the spine, instead of being distanced from it, and the transverse diameter is increased, instead of the antero-posterior. This peculiarity of shape is caused by the ribs on the concave side of the spinal curve being bent a little backwards after they are clear of the transverse processes, or by the latter being bent backwards together with the ribs; so that the ribs on this side are, in their whole course, brought more into correspondence with their fellows on the convex side, and, like them, fail to reach the natural distance in front of the spine. I cannot tell why the twisted and transversely narrowed thorax, in some cases, and the flat widened thorax, in others, should be the concomitant of lateral curvature of the spine. Some cases that I have examined rather favour the supposition, that the latter conformation is present in those cases where the spinal deformity took place in childhood, while the formative and adaptive powers of the skeleton were in full vigour; and that the former is the attendant upon the curvatures which take place at a later period. I am not, however, sure that this rule holds good uniformly, or even usually.

Fusion of the ribs.

In severe and long-standing cases the ribs on the concave side, as well as the transverse processes and the arches of the vertebræ, become fused together, forming a broad osseous plate, which is perforated by holes for the transmission of the nerves. Such a condition would, I need scarcely say, entirely preclude the possibility of success attending upon any curative treatment.

Changes attendant on angular curvature.

In *angular* curvature the upper part of the spine is brought more nearly to a right angle with the ribs; and the obliquity with which these descend from their respective vertebræ is diminished, and their range of movement is proportionately lessened. They do not take so wide a sweep outwards as usual, but run more straight forwards; hence the lateral diameter of the thorax is diminished, and the antero-posterior diameter is increased.

Varieties.

The number of the ribs is subject to some variety. Now and then the 12th rib is absent, or is very small[1]; and occasionally there is a 13th rib on one or both sides, more frequently on both. There is, for the most part, in company with those peculiarities, a deficient or excessive number of dorsal vertebræ. Not unfre-

[1] In examples of acephalous monstrosity and in spina bifida, a greater number are often wanting. In one of the former Meckel, *Handbuch der Path. Anat.* I. 201, found only eight dorsal vertebræ and as many ribs.

quently, as has been already mentioned (p. 127), a rib is developed upon the 7th cervical vertebra. The extremity of this supernumerary rib is either free or connected with a process growing from the upper surface of the 1st true rib. I have not seen an instance in which it reached the sternum, though this is stated occasionally to be the case[1]. The process just mentioned may exist, although the supernumerary rib be not present, and may form a sort of exostosis, and this, by throwing the subclavian artery upward, has been known to give rise to a suspicion of aneurism. Exostoses may also grow from other parts of the ribs. Sometimes they present the form of slender processes jutting downwards and backwards, and resembling the appendages to the ribs in birds. One process growing downwards from a rib may unite with another growing upwards from the rib below, so joining the two ribs together in a more or less complete manner; and it is no uncommon thing to find two ribs thus united together by a more or less broad plate of bone extending between them through the intercostal space[2]. This is usually near their junction with the spine. The extension of the thorax downwards by means of additional ribs reminds us of the manner in which the thorax is prolonged towards the pelvis in most mammals; and the occasional presence of cervical ribs reminds us of those parts in birds. Now and then a rib is too short, and, failing to reach the sternum, terminates in a pointed cartilage, like a floating rib. This is said sometimes to be the case with the 1st rib, as well as with those lower down. Two ribs may unite to one cartilage; or, on the other hand, a rib may bifurcate towards its anterior extremity and be joined to the sternum by means of two separate cartilages. Now and then a supernumerary cartilage projects from some part of the side of the sternum, usually between the 3rd and 4th costal cartilages, and is lost among the muscles, not being connected with any rib[3].

In a specimen of rickety fœtus in the Dupuytren Museum, the ribs are short and thick, and the cartilages are long; the same condition was found in the deformed skeleton of a child described by Rathke[4].

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[1] When a cervical rib is present the head of the first true rib is often articulated with the body of the seventh cervical vertebra, as well as with that of the first dorsal and with the intervertebral substance.

[2] Sandifort, *Museum Anat.* Tab. XLVIII. and XLIX.

[3] Blandin, *Anatomie*, I. 55.

[4] Müller's *Archiv*, VII. 486.

THE BONES OF THE UPPER EXTREMITY.

THE CLAVICLE

In what animals present.

stretching transversely outwards from the sternum to the acromion process of the scapula forms a support to the shoulder; its chief office is to keep the shoulder steady and to afford a fulcrum by which the muscles are enabled to give lateral movement to the arm. Accordingly it is absent in those animals in which the movement of the fore limbs is only of the to-and-fro kind, and in which the limbs are hoofed and used only in progression, as in Pachydermata, Ruminantia, Solidungula, and some Carnivora. It is present in all Quadrumana and in most of the Rodentia in which the anterior extremities are unguiculated and used in prehension, as the rat, squirrel, beaver, and rabbit; also in Cheiropterous and Insectivorous animals, as the bat, mole, and hedgehog. It is present in many of the Edentata, as the ant-eater, the armadillo, and the megatherium. In the latter animal, however, it is united to the first rib instead of to the sternum. In Marsupials the clavicles are present, with few exceptions, and are of considerable strength. In Monotremes they are connected with a separate bone at the upper end of the sternum called the "episternal bone." In a large section of Carnivora, including the bear, dog, and cat, the clavicle is either absent, or present only in the rudimentary form of a small bone suspended among the muscles, and not connected either with the sternum or with the scapula. In Birds, where great resistance is required to counteract the tendency of the powerful pectoral muscles to approximate the shoulders, the clavicles are of large size, and, in most instances, are united together at an angle in the median line, above the sternum, forming what is called the "furculum;" and a still more efficient support to the extremity is afforded by an extension of the coracoid process of the scapula into a broad thick bone, called the "coracoid bone," which reaches as far as the sternum. In Reptiles the broad "coracoid bone" constitutes the main, or the sole, support of the scapula; for in some only is the clavicle present.

Its curved form.

The clavicle presents in its *Sigmoid shape* a good illustration of the tendency to a curved form in the long bones. By this form a more extensive surface is afforded for the attachment of muscles; and they are by it enabled to act upon the bone with somewhat greater advantage of leverage. The bone is less liable to be fractured, because the forces which impinge upon it are diffused from point to point over a greater space, and are rendered less injurious at the place of contact; and the jar resulting from blows received at the extremities is also somewhat broken by the additional elasticity which the curved shape imparts. The curve at the sternal end, which has its convexity in front, occupies two-thirds of the length of the bone, and is a segment of a considerably larger circle than the sharper shorter curve at the scapular end. To obviate the inequality of strength in the two parts of the clavicle that would be entailed by this difference in the degree of their curvature, the outer third is widened in the direction of the curve by being flattened from above downwards, whereas in the inner two-thirds the bone is nearly cylindrical. The result is that the portions forming the outer and inner curvatures are nearly of equal strength. The point at which it most frequently gives way, in consequence of falls upon the shoulder, is a little external to the middle, where the inner curve is beginning to pass into the outer; and where, as is usually the case at the points of confluence of the curvatures in the shafts of bones, the clavicle is smaller than in other parts. The curves are, as a general rule, most marked in the strongest persons, and more marked in men than in women; this is observable in both the curves, though more particularly in the outer one. In women the clavicle lies nearly horizontally. In men it is inclined downwards to the sternum, which makes the latter somewhat high-shouldered. Notwithstanding its sharper curvatures in men, it is a little longer in them than in women.

Nutritious hole. On the under side of the bone, where it is most compact, *i.e.* a little external to the middle, is the *Hole for the nutritious artery*. It slants away from the sternal end, so conforming to the general rule (p. 24), inasmuch as there is no epiphysis developed at the acromial extremity. It is often very small. In the examination of numerous specimens Cruveilhier could discover no trace of it.

Relation of subclavian vessels. The clavicle covers and protects the subclavian vessels and nerves, and is our guide to them when we wish to compress or tie the artery. The latter will be found crossing over the first rib, just behind the narrow smooth part of the clavicle, where the inner curve is beginning to pass into the outer. The clavicle cannot be dragged down so as to compress the vessels and nerves against the rib; and I have not met with any recorded instance in which either of them were penetrated or seriously injured by the projection of the broken fragments in fracture of the bone.

Development. Ossification of the clavicle takes place very early, commencing at the middle, or near the situation of the nutritious artery, as early as the 30th day, according to Beclard. Meckel says that, at the 6th week the osseous portion is three lines long, being longer than that of either the humerus or femur. Not till the 4th month does the humerus exceed the clavicle in length; at birth it is one quarter longer, and in the adult twice as long. At birth the clavicle is ossified in nearly the whole of its extent, there being only a thin layer of cartilage at either end (Pl. I. fig. 1, p. 39). A thin epiphysial nucleus appears at its sternal end about 20, and becomes united to the shaft about 25 (Pl. XXVII. fig. 1). It is difficult to conceive what purpose it can serve, being of small size, developed so late, and remaining separate from the shaft for so short a period. There is no epiphysis at the scapular end, ossification taking place to the very extremity of the bone, as in the case of the condyle of the lower jaw, at an early period of fœtal life.

Varieties and diseases.

The clavicle and scapula are very rarely absent in man, even though all the rest of the extremity may be wanting, which is remarkable considering the inconstancy of this bone in the animal scale. Meckel quotes from Roux's *Journal* an instance in which the acromial end was deficient. The sternal end has also been undeveloped[1]. It is not very liable to rickets, struma, or other disease. It has been removed entire when it had become the seat of morbid growths. It is occasionally the seat of syphilitic node, which, as in the case of the tibia and the skull, may be partly owing to its subcutaneous position. It is more subject to ulceration than to necrosis[2].

Liability to fracture.

The clavicle, being exposed to the full force of blows upon the shoulder, and being well secured at either end so as to prevent dislocation, is very often broken; and the fracture is commonly at the part just mentioned, viz. a little external to the middle. The outer third, which more immediately receives the force, is broken more often than the inner third. It is remarkable how seldom the fracture is compound, although the bone lies in its whole length almost immediately under the skin. The skin escapes because it moves so freely upon the clavicle, and because the outer end of the fracture, which receives the impulse, is almost always driven behind the inner one into the loose cellular tissue of the neck[3]. In a patient lately in Addenbrooke's hospital, whose clavicle was broken by earth falling upon him, the inner fractured end penetrated the skin. When the clavicle is broken, the shoulder falls, and the patient is commonly unable to raise the hand to the head, or to oppose it to the other hand; though instances have occurred in which he could do the former. The difficulty experienced by the surgeon in maintaining a correct apposition of the broken ends during their reunion is well known, and a variety of appliances have been devised to assist in overcoming it. It depends very much upon the small diameter of the shaft

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[1] Otto, p. 217.

[2] A case of necrosis of the clavicle is recorded in the *Répertoire Général d'Anatomie et de Physiologie Pathologiques*, II. 224.

[3] A rare exception to this rule is given by Professor Syme, *Edinburgh Journal*, July, 1835. Occasionally in adults, and frequently in children, there is no displacement. M. Blandin, *Journal de Méd. et de Chirurg. Prat.* July, 1842. Professor Hamilton, *New York Journal*, Vol. III. found *partial* fractures more frequent in the clavicle than in any other bone.

and the weight of the upper extremity hanging upon it. There is no lack of reparative activity, and there is, therefore, in most instances, abundance of callus thrown out; nevertheless union may fail in consequence of the outer fragment of the bone being involved in the movements of the extremity, unless care be taken to prevent those movements. This is proved by two specimens of false joint in the clavicle, preserved in the Cambridge Museum. In the last fortnight I have seen two cases of infants, in whom a lump, evidently resulting from fracture, or partial fracture, had been observed in the clavicle within a week after birth. In one the labour had been difficult, and the fracture was at the junction of the outer and middle thirds. In the other it was near the middle. I could not learn how the accident had been caused. We may associate the fact of the early ossification of the clavicle with the liability to such accidents in early life, and may regard it as being, perhaps, in some measure intended as a provision against them.

THE SCAPULA

Position in relation to the thorax.

is concave on its inner surface so as to be adapted to the convex exterior of the thorax, which it assists to protect in a comparatively undefended part. In its movements forwards and backwards it describes a segment of a circle upon the thorax; whereas its upward and downward movements are nearly in a vertical plane. In the state of rest its base is almost perpendicular, about an inch from, and nearly parallel with, the vertebral spines. The upper angle corresponds with the interval between the 1st and 2nd ribs. The lower angle is on a level with the 8th rib, or with the space between the 8th and 9th ribs. The lower part of the bone is applied close against the ribs, and is supported by them. The upper part, owing to the contraction of the thorax above, is more distant from the ribs, and is held out in its position by the clavicle. The distance becomes remarkable, giving an overhanging wing-like appearance to the shoulders, when, from phthisis, or other disease or malformation, the upper part of the thorax fails to acquire or maintain its proper dimensions.

General construction. The scapula consists of two chief parts; of which the one, composed of the *acromion*, *spine*, and *base*, is united to the sternum through the intervention of the clavicle. The other, consisting of the strong *inferior costa*, carries the *glenoid cavity* upon the fore part, and sends off the *coracoid process*. These two parts constitute the framework of the scapula. In the interval between them is a thin plate of bone forming the floor of the *infra-spinal fossa;* and a continuation of this plate, growing above the level of the spine, forms the *superior angle* of the scapula and the floor of the *supra-spinal fossa*. This thin intermediate plate of bone is strengthened on its under side by *ridges* passing obliquely upwards and forwards from the base which give attachment to the tendinous bands intersecting the bundles of the subscapularis muscle. Between them the surface of the bone is very smooth, and the periosteum is loosely attached; so that matter forming here upon the bone, and unable to escape, may spread and detach the periosteum from the bone. In one such case I found it necessary to trephine the floor of the infraspinal fossa to give vent to the pus collected beneath it.

Convex shape. The *Body* of the scapula derives strength in consequence of its being arched, both from above downwards and from before backwards. The summit of the vertical arch is situate just beneath the spine so as to support that process, and is most prominent close behind the glenoid cavity, where springs the thick stem of the acromion. From the under side of the deepest part of the arch arises the thickest portion of the subscapular muscle. This part is nearly on a level with the lesser tubercle of the humerus; and the direction of the fibres of the muscle is, therefore, most favourable for their action upon the humerus.

Spine and acromion. The *Spine* is a remarkable feature in the scapula, standing upwards and outwards and surmounted by a very strong thick flattened ridge, which has a serpentine form and spreads out into a broad triangular termination behind, where it is connected with the base. Towards its fore part the spine increases in thickness and strength as well as in depth, and its anterior edge, which carries the acromion, is particularly strong. Both the spine of the scapula and the *Acromion process*, are very strong and prominent, having to transmit forces from the upper limb to the clavicle, and giving an ample surface for attachment and some advantage in leverage to the powerful deltoid muscle. For the more effectual attainment of these objects, the spine of the scapula is slanted obliquely upwards, and terminates, in front, in a strong round stem, from which the acromion is thrown forward over the joint. The acromion also, at its most prominent part, is truncated, and presents a broad thick edge capable of giving attachment to a large number of the deltoid fibres at a point most favourable to their action.

Prolongation of inferior angle

The tendency of the deltoid is to draw together the acromion and the middle of the shaft of the humerus; and in order to render the former the fixed point and to enable this muscle, as well as the other muscles which pass from the scapula over the shoulder-joint, to produce their required effect upon the humerus, the scapula is prolonged downwards at its *Inferior Angle*. By the extension of the bone in this direction, regarding the glenoid cavity as the centre of motion, a leverage is afforded to the muscles whose office it is to maintain the position of the blade of the scapula, which leverage more than counterbalances that afforded by the acromion to the deltoid.

a compensation for projection of acromion.

Evil resulting from imperfection of muscles which fix lower angle of scapula.

The importance to the movements of the arm of such provision for the efficient action of these muscles is well illustrated by cases in which the latter are weak or paralysed or inactive from some cause, or in which the angle of the scapula has slipped from beneath the edge of the latissimus dorsi. In such cases the contraction of the deltoid, instead of causing the head of the humerus to rotate in the glenoid cavity, causes the glenoid cavity to roll upon the humerus, and pulls the lower angle of the scapula backwards and upwards, so that it projects beside the spine. The patient may be thus rendered quite unable to raise the arm, each attempt to do so being followed by the revolution of the scapula, instead of by the elevation of the elbow. Thus the vertical elongation of the scapula in man, in comparison with its depth from before backwards, has relation, not only to the small antero-posterior diameter of his thorax and the sharp curvature of his ribs, but also, and more particularly, to the freedom and power of the movements of his arm. It may be remarked that the angle at which the humerus is set upon the shoulder-blade, though favourable to the general range of movement at the shoulder, is particularly unfavourable to the muscles which have to raise the arm. The acromion is therefore thrown out to afford some compensation in the way of leverage to the great muscle which has the principal part of that difficult duty to perform; this necessitates more secure provision for fixing the scapula so as to render it a firm *point d'appui;* accordingly, the growth of the inferior angle in one direction has relation, and is in general proportionate, to the growth of the superior angle, the spine, and the acromion in the opposite direction.

Coracoid.

The *Coracoid process* corresponds with the acromion, arching, like a half-bent finger, over the inner, as the acromion does over the outer, side of the shoulder-joint; and, in proportion to its prominence, it affords a leverage to the *coraco-brachialis* and the short head of the *biceps*, as the acromion does to the deltoid. Its relations, therefore, to the inferior angle of the scapula, and the antagonistic relation of its muscles to those which fix the angle of the scapula, are the same as in the case of the acromion. The coracoid process is manifestly an appendage to the glenoid cavity, being borne together with it in front of the neck of the scapula; so that in any case in which a fracture has passed through the neck, the coracoid process would be detached with the glenoid cavity from the rest of the bone; and the finger pressed down upon the coracoid, in the interval between the edges of the deltoid and pectoral muscles, would probably detect some evidence of the separation. Indeed it may be properly said to contribute to the glenoid cavity; for the prolonged upper and inner portion of the articular surface of the latter, lying at the base of the coracoid process, is often marked off from the rest by a *notch* on the inner side, which has its analogue in a more complete fissure in Birds and Reptiles, where the coracoid bone is separate, and enters into the construction of the shoulder-joint. At its base the coracoid is very thick; and it is flattened on its inner side (Pl. XXIX. figs. 1, 2,) where the conoid ligament plays upon it. That ligament arises from the under and hinder edge of the flat surface. The process presents a rough ridge above for the attachment of the trapezoid ligament, and is hollowed underneath to permit the play of the subscapular muscle which is separated from it by a bursa. At its middle it is contracted into a sort of neck; and it again swells out at its extremity, where it presents three facets for the attachment respectively of the *pectoralis minor*, the short tendon of the *biceps*, and the *coraco-brachialis* muscle.

The coracoid process in man, and in nearly all other viviparous animals, is of small size, as compared with its dimensions in Monotremes, and in oviparous animals. In the latter it extends as far as the sternum, is a broad, strong, and for the most part, separate, bone, which connects the scapula with the sternum and constitutes its chief support. In some Reptiles it is the only osseous connection of the upper extremity with the sternum, the clavicle being wanting, and the spine and acromial part of the scapula being also deficient.

Supra-scapular notch.

The *Notch* in the superior costa, just behind the coracoid, which transmits the supra-scapular nerve, and which is closed by a ligament separating the nerve from the supra-scapular artery, is a true foramen in some Sloths; and in them the supra-spinal fossa receives considerable extension from a plate of bone which connects the coracoid process with the superior angle, and forms the upper boundary of this foramen. Occasionally in the human scapula also the *notch* is converted into a *foramen* by the ossification of the ligament; and sometimes there is a distinct hole *beneath* the notch.

Ossification.

The ossification of the scapula commences, in the 2nd month of fœtal life, by the formation of a bony plate, a little behind the glenoid cavity, about the point where, on the inner side, may be subsequently seen the foramen for the chief nutritious artery. This plate soon becomes triangular; and, in the 3rd month, the spine grows up from it. The spine is at this period situated near the upper edge of the scapula, and occupies the position which is permanent in some of the lower animals[1]. Subsequently the growth of the scapula above the spine

[1] In Monotremes the spine is so near the superior costa that it was confounded with it by both Cuvier and Meckel.

places the latter at about a quarter of the length of the bone from the upper edge.

At birth.

At birth, the chief part of the scapula is osseous (Pl. XXVII. figs. 2 and 3); but the coracoid, the acromion, the edge of the spine, the inferior angle and the base, still remain cartilaginous. (See Pl. I. fig. 5, at page 39.) The cartilage is deeper at the inferior angle than elsewhere, the bone being yet deficient in that vertical length which is the characteristic feature of the adult human scapula. The rounded shape of the inferior extremity of the macerated bone causes it to resemble the ilium at the same period; and the resemblance is increased by the imperfect condition of the part from which the glenoid cavity is to be produced. The floor of the supra-spinal fossa extends but a short distance above the spine, the superior costa is very curved, and the superior angle is turned inwards. The spine is imperfectly developed in its hinder third; and runs out from the fore part of the blade, suddenly and boldly, into the straight blunt acromion. The blade of the bone is nearly flat, and is of nearly equal thickness in its whole extent; perhaps the middle part is rather the thickest. In the subsequent process of development (as in the case of the flat cranial bones, page 186) the edges become thicker, and the lamina between them becomes comparatively, if not actually, thinner.

After birth.

In the 1st year after birth a nucleus appears in the middle of the coracoid process[1]. This becomes united to the rest of the bone about the 15th year (Pl. XXVII. figs. 4 and 5)[2]. About this time a nucleus appears in the cartilage at the extremity of the acromion (fig. 5), and another in the cartilage which extends along the base and inferior angle of the scapula. The nucleus for the acromion varies in the size to which it attains; in some

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[1] The coracoid is ossified from a separate centre in Mammals, and it is subsequently united by bone to the scapula. In Birds, and Reptiles, it remains distinct throughout life.

[2] In some instances, according to Beclard, an additional nucleus is formed both at the apex and at the base of the coracoid. I have found the same in specimens in the Museum at Prague (Pl. XXVII. fig. 5). In Quain's *Anatomy*, 1856, Vol. I. p. 113, a thin scale (an epiphysis) is described as forming on the convex part of the coracoid, after the process has been joined on to the general mass of the scapula.

it forms only the tip, in others it constitutes the chief part of the process. Now and then it remains permanently separate, or is united with the spine only by fibrous tissue; and, under these circumstances, the mistake may arise of supposing that it has been broken off, and has not been reunited[1]. As a general rule, this and the other nuclei, which are developed about the same time, coalesce with the scapula from the 22nd to the 25th year. The long marginal epiphysis of the base, which resembles that of the ilium, is the last to unite with the rest of the bone. I have found separate nuclei for the edge of the glenoid cavity in other instances besides the one represented in fig. 5.

Abnormal conditions. Even if the whole of the remainder of the upper extremity fail to be developed, the scapula, with its fulcrum the clavicle, is very rarely absent or malformed, though it is sometimes remarkably thin and slight. It has been found cleft[2]; and occasionally the plates of the supra- and infra-spinal fossæ are incomplete, presenting irregularly shaped apertures occupied by fibrous tissue. These are probably caused, like similar deficiencies in the parietal bones (p. 242), not by a primary imperfection in the ossifying processes, but by an excess of that modelling absorption by which the blade of the bone is thinned as its edges become thickened.

Fractures. Its mobility, the support it receives from the thorax, its covering of muscles, the fragility of the clavicle, and the weakness of the shoulder-joint, combine to render the scapula less liable to fractures than any of the large bones of the upper extremity. Fractures are most frequent in the acromion[3]; in the blade below the spine they generally take a transverse direction, or are oblique, running from the base upwards and forwards towards the glenoid cavity; sometimes they involve the glenoid cavity[4]; sometimes they extend only part of the way across the bone[5]. The coracoid process is occasionally broken

[1] Cruveilhier speaks of two osseous centres for the acromion, in which he is followed by Quain and other anatomists. They unite together before joining the spine.

[2] Otto's *Path. Anat.* p. 217.

[3] I am not aware of any instance of bony union of a fracture of the acromion.

[4] Specimens in Musée Dupuytren.

[5] Museum of College of Surgeons, 2918.

off[1], and the neck of the scapula[2] may be fractured; but these are rare accidents.

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[1] Cases by Mr South and Mr Arnott, *Medico-Chirurgical Trans.* XXII. p. 100. There is a specimen of the kind in the Dupuytren Museum. I do not know that this fracture has ever been united by bone.

[2] A specimen of fracture of the neck of the scapula in Guy's Museum, accompanied by transverse fracture of the blade below the spine, is represented by Mr Callaway, in his *Essay on the Clavicle and Shoulder-joint*, and is described at p. 93 of that work. "A case of fracture of the neck of the scapula and of the coracoid process" is given by Mr Brodhurst in *Medical Times and Gazette* for March 7th, 1857. An instance of fracture of the body of the bone by muscular action is quoted in Ranking's *Abstract*, II. 105.

DESCRIPTION OF PLATE XXVII.

Fig. 1. Section of sternal end of clavicle, from a female æt. 25, shewing the epiphysis.

Figs. 2 and 3. Scapula, at birth, after maceration. Fig. 2, external surface. Fig. 3, internal surface. They shew the shape of the bone, the convex border of its base, the deeply concave upper margin, the shallowness of the supra-spinous portion, the abrupt projection of the spine, the convex shape of the glenoid portion. *A*, the part of the glenoid portion to which the coracoid process is subsequently attached. *B*, the foramen for the nutritious artery.

Fig. 4. Section of glenoid part of scapula at æt. 10 (reduced). *A*, the ossified portion of coracoid process tipped with cartilage, and united by cartilage to the rest of the bone. *B*, the cartilaginous surface of the glenoid cavity.

Fig. 5. Scapula from young subject (much reduced), showing a fissure still remaining between fore part of coracoid and the rest of the bone; it extends to the glenoid cavity. There is a separate nucleus at the extremity of the coracoid, also at the extremity of the acromion; and the osseous rim of the glenoid cavity is likewise separate.

Fig. 6. Transverse section of left humerus, an inch from the lower extremity. *A*, the external ridge; *B*, the internal ditto; *C*, the anterior ditto.

Fig. 7. Transverse section of left humerus, just below point of attachment of deltoid. *A*, *B*, *C*, as in preceding.

Fig. 8. Longitudinal section of humerus, from before backwards, shewing the shape of the medullary cavity, the thickness of the outer wall in different parts, and the disposition of the cancelli. *A*, the greater tubercle. *B*, the trochlea. *C*, thin part above the trochlea.

Fig. 9. Longitudinal section of humerus, from side to side. *A* and *B* as in preceding. *C*, outer condyle; *D*, inner ditto. The upper epiphysial line is still distinct between the head and the shaft; its continuation between the tubercle and the shaft (towards *A*) is nearly obliterated.

Plate XXVII

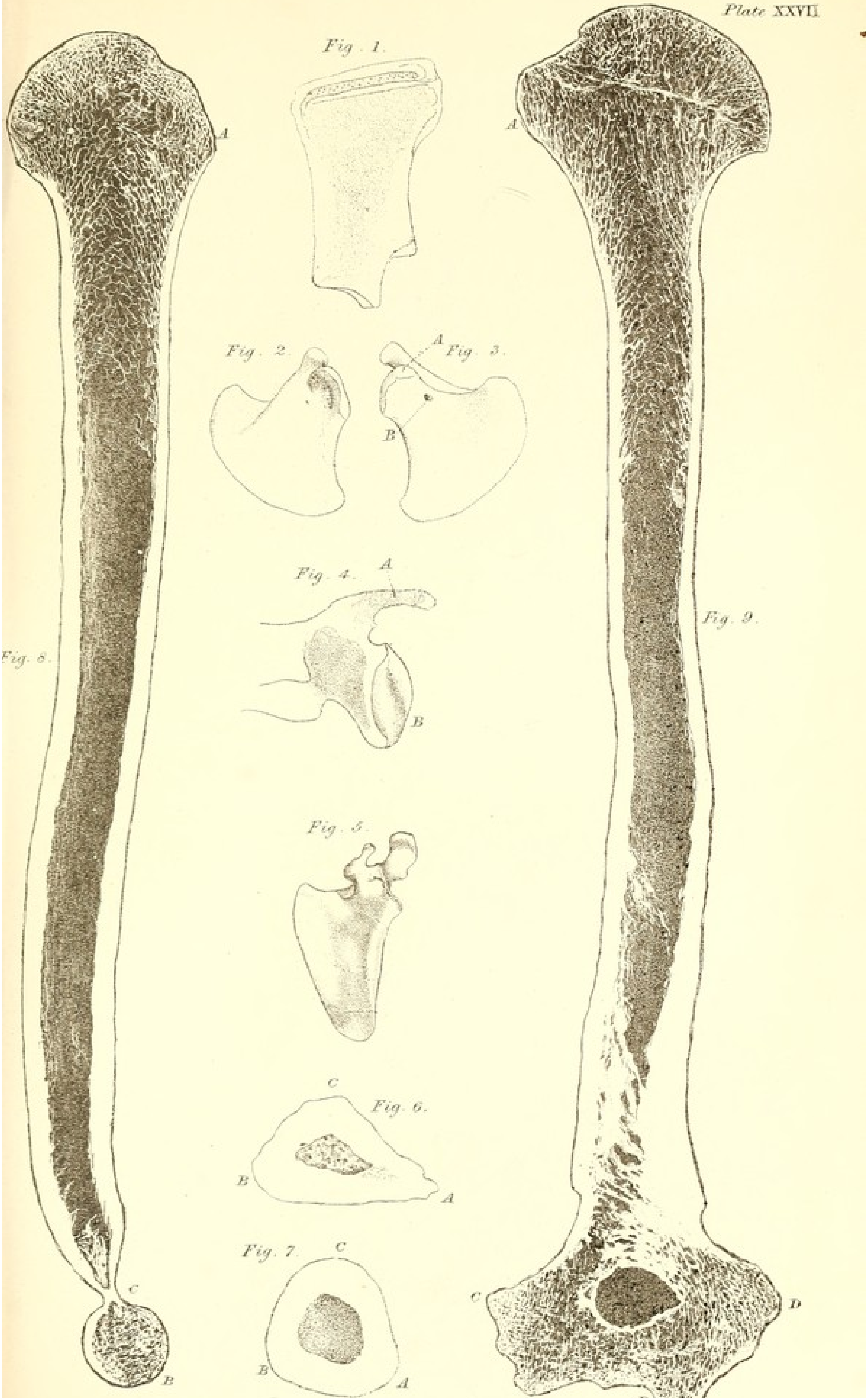
Fig. 1.
Fig. 2.
Fig. 3.
A
B
Fig. 4.
A
B
Fig. 5.
Fig. 6.
C
B
A
Fig. 7.
C
B
A
Fig. 8.
A
C
B
Fig. 9.
A
C
D
E

THE HUMERUS. (PLATE XXVII.)

averages from 12 to 13 inches in length. It is a good illustration of the general features of construction which have been described (p. 10) as prevailing in the long bones. Thus its extremities are expanded for the purpose of giving security to the joints and of affording attachment and increased leverage to the muscles; its articular surfaces look in different directions, the upper one upwards, inwards, and a little backwards, the lower one forwards and downwards; its shaft is contracted for the purpose of affording greater space for the bellies of the muscles; its interior is hollowed so as to present a well-marked medullary canal; its exterior is strengthened by projecting ridges; and it is curved in two directions, so as to have somewhat of an S shape.

The shaft: its curves;

Of the *Curves* in the shaft, that in the upper half has its convexity forwards and a little outwards. It is rendered more prominent externally, at the lower part, by the rough projection for the attachment for the deltoid muscle, which is implanted into the bone at the part most favourable to its action. The shaft of the humerus looks as if it had been pulled out of the straight line by the action of the deltoid; and that appearance is more striking in cases of rickets in which the curve is morbidly increased. This projection is very strongly marked in Solipeds and some other animals; and in the Mole it is thrown out into a long spike, so as almost to meet a similar process which springs from the outer condyle. The inferior curve has its concavity in front, and is so disposed as to make the lower articular end of the bone present forwards as well as downwards, thus bringing it more nearly into the direction in which the fore-arm is generally placed when we fall upon the hand or when we use the limb in any strong exertion, and placing it, therefore, in the position which is most favourable for the reception of forces transmitted from the fore-arm.

Both these curves are occasionally increased, but more particularly the upper one, in those cases of fœtal or infantile rickets in which the arms are affected.

Part most liable to fracture.

The shaft, as in the case of the clavicle and most of the long bones, is smallest and hardest at the point of confluence of the curves, and is here most frequently broken. Occasionally it is broken by the contraction of the muscles. I have already (page 8) mentioned an instance in which this occurred when a man was helping himself upstairs by the hand-rail; and many others of a similar kind have been recorded[1]. In consequence of the attachment of the tendinous fibres of the deltoid of the coraco-brachialis and of the brachialis anticus in this neighbourhood, the periosteum is closely connected with the bone, and does not, therefore, become separated in case of fracture so much as in other places. This, together with the movements to which the broken ends are subjected, unless the hand be well secured, is probably the reason that union is more liable to fail here than in all the other parts of the shafts of long bones put together. From this point the shaft gradually increases in size and becomes less compact as we trace it upwards.

Surgical neck.

Just below the head of the bone there is an apparent, rather than a real, constriction; it is caused by the projecting rough spaces for the insertion of the axillary muscles below, and the bulging of the tubercles and articular surface above. This, which is called the *Surgical Neck*, is often the seat of fracture; it is particularly liable to be broken in old persons, in whom the cancellous texture of the interior is becoming absorbed and replaced by fat.

The three ridges.

Traced downward from its narrowest point the shaft is seen to become flattened from before backwards (fig. 6), so as to carry the transversely elongated articular surface for the radius and ulna. A ridge is thus formed on either side; these with a third, rather less prominent, ridge on the fore part give

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[1] Mr. Turle, *Med. Times and Gazette,* Aug. 15, 1857, has collected fifty instances of spontaneous fracture of this bone, and has not been able to meet with a single recorded example of any healthy long bone (except the humerus) being broken by the force of its attached muscles. I have (p. 8) mentioned one in which the femur was so broken; and the gentleman who witnessed that case heard of another precisely similar.

to the section of the bone a somewhat triangular figure. Of these angles or ridges the outer (A), called the *external supra-condyloid ridge*, is by far the most prominent and strong; it is also more in a line with the shaft than the inner one. It descends to the outer condyle and bears, therefore, the chief pressure of that bone of the fore-arm which carries the hand. The inner (B)—or *internal supra-condyloid ridge*—descends to the inner condyle. The anterior (C)—or *supra-trochlear ridge*—is broad and thick, though less prominent than the others; it bifurcates at its lower part to enclose the coronoid fossa, and forms the support of the lateral elevations of the trochlea. Posteriorly, the surface of the humerus, formed between the external and internal ridges, is broad and flat; and the ridges, separating below, enclose the "olecranon fossa," and descend to their respective condyles. Traced upwards the external supra-condyloid ridge expands into the back of the shaft, and ascends to the head of the humerus, forming a tolerably direct line, from the condyle which carries the radius, to the superior articular surface of the bone. The supra-trochlear ridge, which is next in strength, forms the fore part of the shaft, and ascends to the great tubercle. The internal supra-condyloid ridge continues its course, along the inner side of the bone, to the lesser tubercle.

Supra-condyloid process.

A hook-like process of bone is occasionally found projecting from the inner side of the shaft, about two inches above the inner condyle. It is directed downwards; and its extremity is usually connected with the inner condyle by a ligament or band of fibrous tissue, enclosing a hole which corresponds with the "supra-condyloid foramen" in the feline tribe of animals. In them it transmits the brachial artery or one of its primary branches and, commonly, the median nerve, and is supposed to be a provision for preventing the compression of the artery by the contraction of the muscles when the creature is seizing and holding its prey. Tiedemann[2] found the supra-condyloid foramen, in certain apes, associated with a high division of the brachial artery; the ulnar-branch and the median nerve passing through the foramen. We might expect the same disposition would

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[1] Home's *Lectures on Comparative Anatomy*, I. 76.

[2] Meckel's *Archiv*, IV. 544.

occur in the human subject, knowing how often the high division of the artery is an attendant on anomalies in the anatomy of the arm. The point, however, is not mentioned in the accounts of cases which I have read; except in one related by Wilbrand[1], where the brachial artery and the median nerve are described as passing through the foramen.

Lower end.

The depth of the olecranon and coronoid fossæ, which is so great as to leave only a transparent lamina between them, and their size, together with the superficial fossa for the radius above the outer condyle, weaken the humerus just above its articular end, so much that, in spite of the additional strength imparted by the ridges above mentioned, fracture not unfrequently occurs at this part, and is apt to be confounded with dislocation at the elbow[2]. The *internal condyle* being very prominent is liable to be broken off. It shelters the ulnar nerve, and affords a surface of attachment and a leverage to the flexor and pronator muscles of the fore-arm. It is in a plane behind that of the *outer condyle;* and its greater length, compared with that of the outer condyle, corresponds with the power of the muscles connected with it, as contrasted with the power of the extensors and supinators which arise from the outer condyle. The latter is so short that it is little exposed to injury, and is very rarely broken off. Specimens in the Musée Dupuytren prove, however, that this accident does, now and then, occur.

Upper end: the tubercles.

The *Tubercles* at the upper end of the humerus are much compressed in comparison with their size and prominence in some of the lower animals; this is for the purpose of permitting a free range of movement in the shoulder-joint[3].

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[1] *British and Foreign Medical Review*, XIX. 571.

[2] In quadrumana, carnivora, and some other animals, the thin plate of bone between the coronoid and olecranon fossæ does not exist, so that there is communication between the two. This is occasionally found also in man, and, it is said, more frequently in the Negro than in the European.

[3] In man the processes of the scapula—the acromion and coracoid—are large, but stand wide of the joint and do not interfere with its movements. In the lower animals, particularly in Solipeds, they are small; whereas the tubercles of the humerus are of great size, and encroach upon the joint. In these animals also the articular surface of the humerus is nearly in the same line as the shaft, and not set off from it at an angle by means of a neck as it is in man.

The smaller tubercle, and the outer part of the larger one, give attachment respectively to the *subscapularis* and the *teres minor* muscles, which rotate the arm inwards and outwards. The middle part of the great tubercle gives attachment to the *supra-* and *infra-spinatus* muscles, which assist in the elevation of the arm by causing the head of the humerus to revolve in the glenoid cavity, so enabling the *deltoid* to perform its intended function of raising the arm. Were it not for the assistance thus afforded by these two muscles, a considerable part, at least, of the force of the deltoid would be lost, in consequence of the direction of its fibres being such as to draw the head of the humerus straight upwards against the acromion.

Anatomical neck. The shallow constriction which is situated between the tubercles and the articular surface, and is continued beneath the inferior edge of the latter, is called the *Anatomical Neck*. It corresponds, in many respects, with the neck of the femur, and, like it, carries the head at an angle of about 120° with the shaft. It is invested with fibrous tissue, which is formed, in part at least, by fibres reflected from the insertion of the capsular ligament, backwards, to the margin of the head, and which is overlaid by synovial membrane. It serves the purpose of giving power to the rotators of the limb, and of increasing the range of movement of the joint; but in consequence of the shallowness of the glenoid cavity, it needs not to be of so great length as the neck of the femur, and it is proportionately less liable to fracture. Nevertheless, fracture does sometimes occur[1] in old age, when the cancellous structure in its interior, like that in the neck of the femur, often undergoes absorption and fatty degeneration.

Medullary cavity, and wall of shaft. A longitudinal section of the bone (figs. 8 and 9) shews the *Medullary Cavity* to be of large size, and to extend along the whole length of the shaft. The *Nutritious Artery*

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[1] In the Dupuytren Museum I found three specimens of fracture through this part. Dr Knox, *Medical Gazette*, XXXI., found fracture of the anatomical neck of the humerus, within the capsular ligament, in dissecting the shoulder of an aged female. There are two specimens in the Museum of the College of Surgeons of fracture close to the anatomical neck. The bones are remarkably light from atrophy: in one instance the patient was seventy-seven, and in the other seventy-nine.

enters, a little below the insertion of the coraco-brachialis, through a channel directed obliquely downwards. Sometimes there is a second nutritious artery, higher up, which takes the same direction. The wall of the bone is very thick and dense a little below the middle, where the diameter of the shaft is smallest, and where the medullary canal is wide. Towards the upper end the size of the shaft gradually increases; and the wall becomes thinner, in consequence of laminæ passing off from it into the interior. Near the head of the bone, where the circumference suddenly enlarges, these laminæ separate in greater numbers from the expanding wall and ascend vertically to the epiphysis. The latter is generally composed of rather compact cancellated structure. At the lower end, where a sudden widening of the bone takes place, the separation of the components of the wall into vertical or radiating laminæ is also very marked; and the laminæ which pass from the outer side to support the capitulum for the radius are particularly strong.

Development. About the middle of the 2nd month a nucleus appears near the middle of the shaft; or there may be two nuclei, corresponding with the two nutritious arteries which are occasionally found; when this is the case the two quickly coalesce into one, which soon extends to the extremities of the shaft. The ends of the bone remain cartilaginous till after birth. Some time during the 1st year ossification begins in the upper one; and, a few months later, a nucleus appears in the outer part of the lower extremity. This grows into the tubercle for the radius and the outer edge of the trochlea; or there may be a separate nucleus for the former. The concave portion and inner edge of the trochlea are either developed from a separate nucleus, which appears about 12, according to Beclard, or are formed by an extension of the shaft in that direction (Pl. II. fig. 6, page 40). At about 8 the nucleus for the inner condyle appears; I have found it very distinct at 10. In some instances a small nucleus is formed on the outer condyle at about 15. These all are united together at about 17, and to the shaft before 20. At the beginning of the 3rd year the nucleus for the great tubercle is seen, and at the end of the 5th year that for the lesser tubercle. These soon unite together;

and, about a year after their union, they coalesce with the head, forming the upper epiphysis, which is not united to the shaft till 21. This epiphysis is not very deep; and the neck of the humerus is chiefly formed by the shaft, which is prolonged inwards and upwards for that purpose, just as the shaft of the femur is prolonged to form the neck of that bone.

The length of the humerus is great in proportion to that of the other bones of the limb, goes on increasing during development and growth (p. 98), and is one of the characteristics of the human frame (p. 89). In the orang and some other monkeys the radius and ulna are as long as, or longer than, the humerus (p. 106). Its growth is liable to be arrested in rickets; and in some of the examples of this disease it is remarkably short, as well as abnormally curved and thick. Its development occasionally fails altogether, or in part, with or without failure of the other segments of the extremity. In the case of a lady, mentioned by Velpeau, the total and congenital absence of the humerus interfered but little with the movements of the fore-arm[1]. Its shaft is not unfrequently the subject of sclerosis and growths of various kinds.

THE BONES OF THE FORE-ARM

present rather more interest than attaches to the other long bones, because, in addition to their movement together upon the humerus, the radius undergoes a partial revolution upon the ulna for the purpose of permitting the pronation and supination of the hand. In this movement the radius rotates upon an axis drawn straight downwards, as a plumb-line would fall, through the most prominent part of the articular surface of the outer condyle of the humerus. The upper portion of this axis passes directly through the centre of the button-like head of the radius, which rests upon the condyle. But as we trace it lower down, in consequence of the inclination of the bones of the fore-arm outwards from the humerus at the elbow, it soon ceases to traverse

Axis of rotation of the radius in pronation and supination

[1] The humerus, "as a rule, appears to be wanting in fishes." Van der Hoeven's *Handbook of Zoology*, by Dr Clark, II. 17.

the radius, and takes its course, along the interosseous space, to the lower end of the ulna, through the middle of which it runs, just as above it had run through the middle of the end of the radius. Accordingly, in pronation and supination, the *upper* articular surface of the radius rotates upon its own axis, on the tubercle of the humerus, and in the lesser sigmoid cavity of the ulna: whereas the *lower* end of the radius plays around the lower extremity of the *ulna*, and describes a segment of a circle upon it, revolving upon an axis which passes through the centre of the extremity of that bone. Thus, although the axes of movement of the two extremities of the radius in pronation and supination coincide in the same perpendicular line, that of the one passes through the end of the radius, and that of the other through the end of the ulna[1]. If now this perpendicular line be prolonged downwards through the hand it passes through the ring finger; so that, in the movement referred to, the hand, with the radius, rotates upon an axis drawn from the middle of the outer tubercle of the humerus to the extremity of the ring finger; and the axis traverses the lower end of the ulna, which forms a *point d' appui* for the member to revolve upon. The lower end of the ulna is a fixed point, or nearly so. Perhaps, during rapid and forced movements, it may be subjected to a slight inclination in the opposite direction to that of the radius, that is to say, inwards during supination, and outwards during pronation; but this is very slight, and, under ordinary circumstances, does not appear to take place at all.

is perpendicular from outer condyle of humerus to end of ring finger.

Lower end of ulna a fixed point.

Mid-position that of greatest ease and strength.

The state of complete supination is a forced and rather uncomfortable position; and the same may be said of complete pronation. When at ease the hand and forearm fall into a mid-position between supination and pronation; and the deepest parts of the opposed articular surfaces of the radius and ulna are then in contact. This, accordingly, is the position which we select when we wish to confine the limb in cases of fracture of the fore-arm; and it is the one in which we can

[1] I find that Mr Ward (in his *Human Osteology*, p. 312) describes correctly this axis of rotation of the radius, and illustrates it by a diagram.

exert the greatest power with the hand and in pressing with the palm. The condition of complete pronation is more agreeable, both to the feeling and the eye, than that of complete supination. This accords with the shape of the articular surfaces; and it accords also with the position which is permanent in most of the lower animals.

Free supination peculiar to man.

For, it may be remarked, the power of supination is peculiar, or almost peculiar, to man and quadrumana among mammals. In the greater number of mammals the hand and arm are used for support as well as for prehension; and in proportion as the former purpose is the more important, so is the configuration of the radius more adapted for strength, and less for rotatory motion. Even in carnivorous animals a great difference from the condition of the human fore-arm is observable. The head of the radius, instead of presenting a circular facet to the humerus, is in them transversely elongated, its fore part projects, beyond the level of the capitulum, half-way across the articular surface of the humerus, and the bone can scarcely be moved from the state of pronation. This is still more the case in Rodentia, Pachydermata, Ruminantia and Solidungula; in these, with the exception of the elephant, the transversely elongated head of the radius occupies the whole of the fore part of the elbow-joint, to the entire exclusion of the ulna, the fore-arm is quite prone, and no supination is possible. In the sloth, seal, kangaroo and ant-eater, where the anterior extremity is used less for support and more for prehension, &c. there is a nearer approach to the quadrumanous condition, the head of the radius is more restricted to the outer condyle of the humerus, and the faculty of supination is possessed by them in a more or less considerable degree.

Relation of the size of the ulna to the number of the digits.

Of the two bones of the fore-arm the radius is by far the most constant and the most important in the animal series. The size and length of the ulna vary very greatly in the different classes; its lower part especially is often absent or very imperfectly developed, and the varieties of this bone bear a marked relation to the development of the digits. Thus in Man and Quadrumana, where the proper complement of the latter is *five*, the ulna is of full size, and extends from the elbow to the wrist. In Carnivora, where one, or more, of the digits is imperfect, the relative size of the ulna is less, though the olecranon is larger. In Rodents also, where the thumb is short, or consists of two segments, or is represented by only a single ossicle, the ulna is comparatively small; in some it forms only a thin slip at the back of the radius, and the olecranon is large. In the elephant, which rests upon the extremities of *five* digits, the ulna is of great size and strength, entering largely into the formation both of the elbow and wrist-joint; and the radius is proportionately small and is confined to the outer tubercle of the humerus. In the rhinoceros, which has *four* digits, the ulna is smaller and not seen in the front of the joint. The hippopotamus bears upon only *three* toes, and has a proportionately small ulna, which is in great part blended with the radius. In Ruminants, where there are *two* toes, the olecranon is large, and the shaft of the ulna is reduced to a mere delicate splint or slip running down the back of the radius to near the carpus. In Solidungula, which rest upon *one* toe, the ulna is reduced almost to its olecranon portion, and the shaft is represented by a thin splint which reaches only a little below the elbow. In the sloth, seal, kangaroo and ant-eater, the number of toes is greater, and the ulna is proportionately larger. In most Reptiles there is the full complement of toes, and the ulna often exceeds the radius in size and is joined with the carpal bones.

This diminution of the size of the ulna, in accordance with the lessening of the number of the digits in the animal series as we travel downwards from man, is the more peculiar, because we do not find the subtraction of the digits to take place *first* on the *ulnar*, but rather on the *radial*, side of the hand; for instance, the thumb is imperfect or altogether suppressed in some animals (the rhinoceros for instance) which retain all the fingers.

Ulna not more often undeveloped than the radius in man.

Notwithstanding these variations in the size of the ulna in different animals, it does not appear that in the human subject its development is more liable to fail than that of the radius. One or both of these bones may be absent or more or less defective; and this condition is usually associated with an absence or deficiency of a corresponding part of the hand.

THE ULNA

diminishes in size from above downwards. It is of considerable dimensions at the upper part, where it enters largely into the formation of the elbow-joint and gives attachment to the great extensor, as well as to one of the flexors of the fore-arm, and to some of the flexors and pronators of the hand. At the middle it is also very strong, and is furnished with projecting ridges which give its section a triangular form. Just above its lower articular surface it is smaller than elsewhere, and the ridges have disappeared, so that it is reduced to a mere neck carrying the lower articular end. It presents two *Curves* in its shaft; one of which is wide, involving the upper two-thirds of its length, and is directed backwards and inwards; the other is rather sharper, involves only the lower third of the bone, and has its convexity forwards and outwards. The most bent portion of the ulna is that which is also the smallest, namely, the part just above the lower end. The *Medullary Canal* is large in proportion to the size of the bone, and runs the whole length of the shaft. The *Nutritious Artery* enters the fore part, at a third from the upper end, and runs obliquely upwards.

Coronoid process.

The *Coronoid process* has to bear the chief force of the trochlea in pressing forwards with the hand; it is strengthened by ridges, which descend from its outer and inner edges and converge upon the fore part of the shaft. These ridges give attachment to muscles and ligaments; and the *brachialis anticus* is implanted into the rough surface between them. So strong is the root of this process that it is very seldom broken off, though a few instances of the accident have occurred.

Olecranon.

On the middle of the broad upper surface of the *Olecranon* there is a slight prominence which has the effect of distancing the triceps tendon a little from the centre of motion of the elbow. It is smooth, and a bursa intervenes between it and the tendon which passes on to the roughness beyond it. The hinder aspect of the olecranon presents a triangular surface, which is covered by dense closely adhering longitudinal stripes of fibrous tissue connected with the triceps tendon (Pl. XXXII. fig. 2, *G*). More distinct processes of the tendon pass along the ridges that form the lateral margins of this triangular surface. Near its juncture with the ulna the olecranon is rather narrower than elsewhere. It is here liable to be broken by falls upon the elbow or by spasmodic action of the triceps. The fragment so detached is commonly, more or less, drawn up by the muscle; and, for that and other reasons, bony reunion is not to be expected.

Development. Ossification commences, in the 2nd month, near the middle of the shaft. The upper extremity of the bone is formed chiefly by the prolongation of the shaft. Separate nuclei are, however, superadded from the 6th to the 10th year; one, pretty constant, for the olecranon, which, in its first appearance, is compared by Meckel to the kneepan[1]; one, sometimes, for the coronoid process, of small size; and another, rather larger, for the lesser sigmoid cavity. That for the olecranon and the other two unite to the shaft soon after puberty. In the lower end there are, according to Beclard, two nuclei, which appear soon after birth, one for the articular extremity, and one for the styloid process; they soon unite together, but are not joined to the shaft till near 22. According to Meckel there is, in the lower end, only one nucleus, which does not appear till the 5th or 6th year.

The posterior edge of the ulna is, in a considerable part of its extent, subcutaneous; and it participates with the inner surface of the tibia, which is similarly circumstanced, in a liability to be the subject of nodes.

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[1] Professor Owen, in opposition to Vicq-d'Azyr and others, regards the olecranon to be homologous, not with the patella, but with an extension of the upper end of the fibula above the knee-joint, which is met with in the Ornithorhynchus and some other animals. He finds in the Bat a sesamoid bone superadded to the olecranon "which corresponds with a detached ossicle situated over the highly projecting upper end of the fibula in the Wombat." "In certain bats there is a development of a sesamoid bone in the tendon of the biceps brachii, in front of the elbow-joint, which is the true homotype of the patella in the leg." *On the nature of Limbs*, pp. 24 and 19. I cannot but feel, however, that there are some strong grounds for adhering to the old view of the olecranon being truly the homotype of the patella. Of this, however, more will be said hereafter. The occurrence of a sesamoid bone above the olecranon, and united to it by ligament, has been occasionally observed in the human subject; also on the summit of the coronoid process. Jourdan, *Encycl. Anatomique*, II. 137; Blandin. *Anat.* I. 161. In the frog the olecranon process is wanting, and a substitute for it is provided by a thickening of the tendon of the *extensor cubiti*, where it passes over the joint, aided by the lower end of the humerus, which is thrown out into a prominence at this part. In the Surinam toad there is a sesamoid bone interposed, like a patella, between the tendon of the extensor cubiti and the elbow-joint. *Catalogue of Museum of College of Surgeons.*

THE RADIUS

averages rather more than nine inches in length. Its shape is, in many respects, the reverse of that of the ulna. It is constricted above, instead of below, and it increases in size from the upper towards the lower end. It forms but a comparatively small part of the elbow-joint, whereas it is the chief bone of the wrist. Its upper articular surface for connection with the ulna is convex; the lower is concave. Its shaft presents, like that of the ulna, two *Curves;* but they are in opposite direction to the curves in the latter bone; the upper is the sharper, occupies the superior third of the bone, and has its convexity inwards and forwards; the lower is wider, occupies the lower two-thirds, and has its convexity outwards and backwards. Hence the two bones are bent towards one another in the upper part of the fore-arm, which renders the interosseous space there narrow; whereas, lower down, they are bent away from one another, and the interosseous space is wider[1]. Besides the secondary curves in their shafts both the radius and ulna present a primary curve, with the concavity in front, involving their whole length, which is for the purpose of affording more space and better leverage to the flexor muscles of the hand and fingers.

Attachment of biceps tendon at the prominent part of the upper curve.

The most prominent part of the superior curve of the radius gives attachment to the great supinator of the fore-arm—the *biceps* muscle; and the bone is here thrown out into still greater prominence, by the formation of the *Tubercle*, for the purpose of increasing the leverage of that muscle. The tendon of the biceps is implanted into the projecting posterior edge of the tubercle and into the rough space just behind it, being separated from the smooth fore part of the tubercle by a bursa, thus obtaining, in every position of the bone, all the advantages which the tubercle affords.

The tubercle.

[1] In the monkey the radius describes a considerably bolder, as well as longer, curve in its lower part than it does in man; and the interosseous space is proportionately wider.

The action of this strong muscle upon the tubercle of the radius renders the power of supination greater than that of pronation; and the tools of workmen are, for this reason, so made, that screw-driving, gimlet-turning, and mechanical work of the like kind, is done by supination of the right hand. From the tubercle a strong ridge runs upwards and outwards, in front of the neck, towards the head of the bone; and another ridge runs downwards and outwards to the exterior of the fore part of the shaft, near its middle. These ridges strengthen the radius in the two directions into which the force of the biceps muscle is resolved in its efforts to supinate the radius.

Ridges ascending and descending from the tubercle.

Attachment of pronator teres at the prominent part of the lower curve.

Just as the great *supinator* is attached to the most prominent part of the convexity of the *upper* curve of the radius, which is on the *inner* side, so is the great *pronator*—the *pronator teres*—attached to the most prominent part of the convexity of the *lower* curve, which is on the *outer* side. A rough space, a little above the middle, on the exterior of the shaft, indicates the point of insertion of the tendon of this muscle, which, like that of the biceps, takes all possible advantage of the leverage afforded by the shape of the radius, inasmuch as it runs nearly to the lower edge of the rounded outer margin of the bone.

Ridge on ulnar side.

A very prominent and sharp ridge runs along the inner edge of the radius, in the arc of its lower curve. It gives attachment to the interosseous ligament, and contributes greatly to the strength of the bone at a part where such assistance is much needed. Above, it is smoothed down before it reaches the tubercle, because the presence of so sharp a ridge there would have been a hindrance to the free movement of the radius in pronation and supination. Below, the inner edge is flattened so as to form a broad surface which presents a concave facet for articulation with the ulna.

Medullary foramen.

The *foramen for the medullary artery* is situated a little lower down than that of the ulna.

Bend at lower part.

A slight bend, with the convexity backwards, at the inner part of the shaft, has the effect of slanting the lower end of the bone forwards, so as to give it the best direction for receiving the forces that are transmitted to it from the palm when pressure is made with the hand, or when we fall upon the hand.

This part of the radius, however, being so much exposed to violence, is frequently broken. The upper fractured end is, in most instances, driven in front of the other, the line between them being more or less oblique[1]. Fractures may also occur at any other part of the bone; indeed they are frequent at every part.

Development. Ossification commences in the shaft at the same time as, or a little earlier than, in the ulna. It begins, in the 2nd year, in the lower epiphysis, which is united to the shaft at about 20; and in the 8th or 9th year, in the upper epiphysis[2], which is joined to the shaft in the 13th year.

A peculiar feature in the pathology of the radius is the liability of its lower end to become enlarged in children of strumous habit. The ulna sometimes undergoes the same change; this takes place in no other bones with anything like the same frequency or to the same extent. The lower end of the radius is sometimes the seat of acute inflammation, causing ulceration at the epiphysis[3].

THE HAND

is the most important part of the whole limb, inasmuch as it is the part to which all the rest is subservient. The office of the shoulder, arm and fore-arm, is to bear the hand, and to carry it at a convenient distance from the trunk so that it may enjoy a sufficient range of movement,

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[1] In consequence of its proximity to the wrist-joint, fractures of this part of the radius are rather difficult to discover, and they are very often overlooked. Frequently they are mistaken for dislocation of the wrist, which is strange, since it is, or ought to be, a well-known fact that dislocation of that joint is of very rare occurrence.

[2] It is stated in Quain's *Anatomy* that ossification begins in the upper epiphysis before the fifth year.

[3] In Sandifort's *Museum Anatomicum*, II. Tab. V. is the representation of the bones of the extremities of a rickety subject, in which both radius and ulna are greatly curved inwards at the junction of the middle and upper thirds, the ulna forming the concavity and the radius the convexity of the curve; the leg is also curved, the fibula being on the concave, the tibia on the convex side.

and be able (in man) to be applied to every part of the body. In some animals (Cetaceans) the hand is fully developed, although the rest of the limb is only rudimentary; and in some examples of monstrosity in the human subject it is present and appended to the trunk, although the other segments of the extremity are wanting. The human hand is not to be distinguished by its size, being exceeded in this particular by that of the monkey and of some other animals; nor by the number of its bones; but by the relative proportions of its several components, and by the variety and nicety of movement which they enjoy. In Quadrumana, for instance, the metacarpal bones and phalanges are much larger and longer in proportion to the carpus than in man, which gives a great extent and strength of grasp to those animals; but the movements of the fingers are less delicate and exact, and the hand is, therefore, less adapted to fulfil the office of ministering to an intelligent will than it is in man.

The thumb.

The chief distinguishing features of the human hand are, however, to be found in the *thumb*. It, at once powerful and capable of great variety of movement, stands out from the palm so as to increase greatly the width of the hand; and it is so constructed that it can be brought in opposition to each of the fingers with the greatest facility. When the hand is opened the fingers and thumb all diverge from one another, and cover a large area. When the hand is being shut they all converge together; the fingers are first bent a little, and their tips are brought to a level with that of the thumb, so as to enclose a cup-shaped cavity, in which objects may be safely held; and then, by a slight effort, the pulps of the four fingers may be made to converge upon the thumb, or the latter may be opposed to each separately. As the fingers are further bent they are folded down nearly in the planes of their respective metacarpal bones, and the thumb is folded beneath them, or is laid upon them so as to strengthen their grasp. Thus the thumb, by its relation to the palmar surfaces of the fingers, acts as an antagonist when we grasp a body with the whole hand; and, by its relation to their dorsal aspects, it assists them, and gives increased security to the clenched fist.

THE CARPUS

forms a centre, from which all the other bones of the hand radiate, and upon which they all, directly or indirectly, rest, so that they are carried together with it in the pronation and supination of the fore-arm, and in the movements of the hand upon the fore-arm. The eight bones which compose the carpus are formed of close cancellous tissue surrounded by a layer of compact bone, are jointed to one another by a considerable extent of surface, and are united by very stout ligaments; hence the wrist is as strong as if it had been constructed of one solid piece of bone; while the slight gliding movements which take place between the several bones give to it an elasticity which serves to break the jars that result from falls and blows upon the hand. Moreover, the several bones are joined to one another by a large extent of surface; but each one is united to three or more others; and their surfaces are so variously moulded, and obliquely arranged with regard to each other, that forces received by one are broken and dispersed among the others, and are so resolved that, unless they be of a very severe crushing nature, they fail to produce any injury at the wrist. Were it not for these provisions fractures of the radius would be far more common than they now are. Indeed it would have been necessary that the whole extremity should have been more stoutly and heavily constructed to possess its present amount of strength.

Great strength of the wrist.

Convex dorsal and concave palmar aspects of carpus.

The bones are so arranged that the carpus presents a dorsal, comparatively even, convex surface upon which the extensor tendons play, and a palmar concave surface on which the flexor tendons lie. The latter surface is surmounted on either side by two marked projections—the process of the unciform bone and the pisiform bone on the ulnar side, and the edges of the trapezium and trapezoides on the radial side. The projections are bound together, and are connected with those of the opposite side by strong ligamentous bands, which pass across the wrist and form the anterior palmar arch. These ligaments gird the bones in a powerful manner, protect the subjacent parts, and constitute a pulley on which the flexor tendons play. In the centre of the concavity of the carpus is a slight prominence, formed by the os magnum; ligaments converge to this from the various surrounding bones, strengthening still further the palmar arch, and giving an evenness to that surface which, in the dried state, seems very unfavourable to the play of tendons.

Hand and carpus divided into a middle and two lateral parts.

The *Pisiform bone* scarcely enters into the composition of the carpus. It is rather to be regarded as a sesamoid bone, or as a process for the attachment of tendons and ligaments[1]. The other three bones of the upper row—the *Scaphoid*, *Semilunar* and *Cuneiform*—present together a convex surface which is received into the concavity formed by the radius and the triangular ligament. The *Semilunar*, or middle bone of the three, bears the *Os magnum*, which, in turn, carries the metacarpal bone of the middle or longest and largest finger. In consequence of this finger projecting beyond the others, and of its knuckle being also more prominent than any of the other knuckles, its metacarpal bone has to bear the severest blows and pressure. It is accordingly thicker than the other metacarpals; and forces are transmitted from it to the os magnum, which is the largest and most central bone of the wrist, and which terminates in a ball fitted into the concavity of the semilunar and scaphoid bones (Pl. XXXIII. fig. 1). The forces transmitted through the os magnum are chiefly received by the semilunar bone, and by it again are transmitted to the inner, or most strongly supported, division of the articular surface of the radius.

The *Scaphoid* carries two bones of the second row, viz. the *Trapezium* and *Trapezoides*, and, with them, the thumb and forefinger. The *Cuneiform* bone, in like manner, carries the *Unciform*, which is equivalent to two bones, being sometimes developed from two nuclei in man, and consisting permanently of two bones in

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[1] "Ad carpum revera non pertinet."—*Albinus.*

turtles and some other reptiles; and the unciform carries the two smaller fingers.

Hand and carpus in three divisions.

Thus the hand and carpus may be described to consist of *three divisions;* a middle and two lateral. The *middle division*, which is the most essential element, is composed of the middle, or large, finger, with the os magnum and semilunar bones, which are carried upon the ulnar side of the radius. The *outer division* consists of the thumb and index fingers, with the trapezium and trapezoides, all carried upon the scaphoid bone, which rests upon the styloid portion of the articular surface of the radius. The *inner division*, consisting of the two lesser fingers, is carried, by the unciform and cuneiform bones, upon the articular facet of the ulna, through the intervention of the triangular fibro-cartilaginous ligament. The distribution of the *nerves* into median, radial, and ulnar branches, corresponds generally, though not by any means exactly, with this tripartite division of the hand. The arrangement of the *interosseous* muscles also accords with it; those on the palmar aspect being adductors to, and those on the dorsal aspect being all abductors from, a line drawn through the middle finger; and, associated with the arrangement of these muscles, is the manner in which, during flexion, all the other fingers and the thumb are approximated towards the line of the middle finger, and in which, during extension, they all diverge from it.

The radius, as just said, carries the two outer divisions of the hand, through the medium of the scaphoid and semilunar bones; and the ulna carries the inner division through the medium of the cuneiform bone. This disposition prevails generally throughout the animal kingdom; and some curious modifications in the arrangement of the bones are instituted, here and there, as it were, for the purpose of maintaining it.

The middle division most constant in animals;

I speak of the middle division of the hand as the most essential of the three, not only because it has the largest finger, and because each of its carpal and metacarpal portions is the key-stone of the transverse arch of which it forms a part—thus, the semilunar bone may be called the key-stone of the first row or arch, the magnum of the second, and the head of the metacarpal bone of the third—but also because it is the most constant in the animal series. Gradually, in the various mammalian classes, we find the other digits disappear, first the thumb, then the others, leaving this one alone. In Quadrumana and in the elephant, as in man, they are all five present; though, in the elephant, the thumb has lost a bone and consists of two phalanges instead of three. In the hippopotamus the thumb is wanting. In the rhinoceros the little finger has likewise disappeared, leaving only three digits. In Ruminants the index and the middle digit remain; and in Solipeds the middle finger is left alone, or with only rudimentary traces of the others, which do not reach the ground.

so is also the radius upon which it rests.

It has been remarked before (p. 380) that the size of the ulna is very variable in the animal series, being influenced by the number of the digits; that in the elephant it is large, larger even than the radius; that in the rhinoceros it is smaller; and that in Ruminants and Solipeds it is reduced almost to the olecranon portion. The radius, on the other hand, which is the supporter of the middle more constant division of the hand, is always large, and increases in size as that division acquires a greater prominence over the others.

Adaptation of two carpal rows to one another.

The first row of carpal bones presents a wavy, alternately convex and concave, surface, for the reception of the second row (Pl. XXXIII. fig. 1). Thus the outer or radial part, formed by the outer half of the scaphoid bone, is convex, and carries the trapezium and trapezoides. Then comes a large concavity or socket, formed by the inner half of the scaphoid with the semilunar and the outer part of the cuneiform, in which are received the head of the os magnum and part of the unciform. Lastly, the innermost part of the cuneiform is slightly convex, and is fitted into a corresponding shallow cavity in the unciform. By this means the security of the joint between the two rows is provided for, and rendered compatible with a certain amount of movement.

THE METACARPUS.

Metacarpal bones of fingers.

The *Metacarpal bones* resemble other long bones, except that, like the clavicle, each has only one epiphysis, which is situated at its distal end. The nutritious artery is directed towards the other or carpal end; it may commonly be found near the middle of the shaft, a little on one side of the palmar edge. The upper extremities of the metacarpal bones are large and set closely together. In the case of the index and middle fingers they are *square*, and are fixed so firmly to the carpus as to permit scarcely any movement. In the case of the ring and little fingers they are *convex* from before backwards, and are so adapted to the corresponding concave facets of the unciform bone that a slight hinge-like movement, upon a transverse or oblique axis, is permitted; this shape is most marked in the case of the little finger. It enables the distal extremities of the metacarpal bones of these two fingers to be moved a little forwards, and towards the thumb, or in an opposite direction; thus increasing or diminishing the depth of the cup of the hand, as occasion may require, and permitting a movement like that which takes place between the thumb and the trapezium.

Movement of the two smaller upon the carpus.

They form a continuation of the carpal arch.

The metacarpal bones are so placed upon the wrist as to form a transverse arch, which is continuous with that of the carpus, and which, as just stated, can be increased or diminished by the movement of the two smaller metacarpal bones upon the unciform, and still more by the movement of the thumb upon the trapezium[1]. Each bone is concave upon the palmar and convex upon the dorsal aspect; and each is strengthened by ridges, of which one, on the palmar surface,

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[1] It results partly from this disposition of the metacarpal bones in a curve, that when the fingers are bent they converge together, and that they diverge during extension. The divergence in extension takes place, although the extensor tendons, which effect the movement, radiate, like the flexor tendons, from one central point beneath the annular ligament at the wrist, and have, therefore, a tendency to draw the fingers together.

passes between the two extremities, in the arc of the curve; and two, on the dorsum, converge from the tubercle, on either side of the distal end, towards the middle of the shaft. The interosseous muscles are attached to the lateral surfaces which are bounded by these ridges.

They slant away from the thumb and diverge from one another.

The metacarpal bones of the fingers diverge from one another and slant a little away from the thumb, as they descend from the carpus; this increases the width of the hand and the extent of grasp between the fingers and the thumb, and directs towards the radius forces which may be received at any part of the hand.

Their large heads afford mutual support.

The distal extremities of the metacarpal bones are of large size to give strength and freedom of play to the joints with the fingers. The articular surfaces upon them are convex and prolonged forwards into knob-like prominences on either side (Pl. XXXIV. *X*, *X*), to which are attached strong ligaments binding the metacarpal bones together and holding down the sesamoideal fibro-cartilages. These prominences are most marked on the radial side of the index and on the ulnar side of the 5th metacarpal; between them, in each bone, is a small depression (*Y*) occupied by fat; and at the bottom of the depression are foramina for the passage of vessels into the head of the bone. The heads of the metacarpal bones are sufficiently near together to afford support to each other, and to resist the tendency of the flexor and extensor muscles to draw them together. They are also united together by transverse ligaments which prevent undue separation of the fingers. Hence the whole hand is weakened and the power of flexing and extending the fingers is considerably diminished, if one of them be removed.

Point of selection in amputation.

This is a matter of practical importance, inasmuch as it bears upon the point to be selected when amputation of a finger is required. The operation is most frequently needed for the middle finger; and if any portion of the finger be left, as a stump, it is commonly found to be in the way. It is, therefore, the best practice to take away the whole finger, when it is necessary to remove a part. But it is a question whether the head of the metacarpal bone also should be taken, or whether it should be left. If it be left it forms a projection which is rather unsightly, throwing the cicatrix into prominence, perhaps retarding the sound healing of the wound, or rendering it liable to be reopened by injury. If it be removed, a certain amount of support to the other fingers is sacrificed, in consequence of which they incline too much towards one another and lose strength. Both these evils are avoided by an intermediate procedure, that is, by removing the distal half of the head of the bone, which would cause the cicatrix to project, and leaving the proximal half by which the neighbouring bones are supported. For some years I have adopted this plan, and find it to answer exceedingly well.

Shape of the bones, and differences between them.

The metacarpal bones are thinnest and most liable to be broken just above the middle, the interspaces between them are widest at that part, and the bellies of the interosseous muscles are placed there. The several bones are easily distinguished from one another by differences in their size, and by the shape of their proximal extremities. That of the index finger presents a concave, or broadly notched, surface to receive the convex trapezoides. That of the 2nd finger is flat where it rests upon the os magnum; and it has a marked tooth-like process which is received into a depression between the magnum and the trapezoides. The tendon of the extensor carpi radialis longior (Pl. XXXIII. fig. 2, *P*) runs over this process to be inserted into a depression just below it, and is thrown up by it so as to be thereby distanced a little from the centre of motion. The surfaces of the 4th and 5th metacarpal bones, which rest upon the unciform, are, as before said, convex; and that of the 4th presents facets for articulation with its neighbours.

THE PHALANGES

form continuations of the lines of the metacarpal bones; but they are jointed with the latter in such a manner that they may be moved more readily and to a greater extent towards the ulnar side, than towards the radial side. This, like the slanting of the metacarpal bones in the same direction (p. 392), is for the purpose of increasing the width of grasp between the fingers and the thumb.

The phalanges differ from the metacarpal bones in their form, in having the epiphyses at their proximal ends, and in having the chief nutritious arteries, which are found a little below the middle of the palmar surface, directed towards their distal ends. The narrowest part of each, where ossification commenced, is at or near the entrance of the nutritious artery. They are convex posteriorly, where they are covered by the flat extensor tendons, and concave on the palmar surface, where they lodge the thick rope-like flexor tendons. The latter surface is bounded, on either side, by a rough ridge for the attachment of the strong sheaths of the flexor tendons; and the two extremities of each phalanx are rendered prominent on the same surface, for the purpose of throwing forward and giving some leverage to the flexor tendons.

Peculiarities of terminal phalanges.

Each terminal phalanx presents an uneven eminence, near the proximal end of its palmar surface, for the attachment of the tendon of the *flexor profundus*, and another more marked uneven eminence near its terminal extremity. From the latter radiate *bundles of fibrous tissue*, which traverse the fat and fibro-cellular tissue composing the pulp of the finger, and being implanted into the tough deeper layers of the cutis, serve to maintain the connection between the skin and the bone. From the hinder surface of the phalanx fibres pass backwards and upwards towards the matrix of the nail[1].

Liability to necrosis.

The close connection of the phalanges, particularly of the terminal phalanges, with the fibro-cellular tissue and with the skin of the fingers, is the reason that inflammation spreads to them so easily when the superficial structures are affected, and that they are liable to necrosis. Hence whitlow is often attended with the loss of one or more of the phalanges. It should be borne in mind that the destruction is sometimes confined to the thick extremity of the terminal phalanx; and that sufficient of the bone may remain, after the removal of this decayed piece, to support the nail and to preserve a useful joint to the finger.

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[1] See representation of similar disposition of structures in section of terminal halanx of great toe. (Pl. LVIII.)

Expansion of their extremities peculiar to man.

The expansion of the ends of the terminal phalanges serves the purpose of supporting the pulp of the fingers, as well as the nail, and so ministers to the sense of touch; it is almost peculiar to man. A similar conformation is observable in the corresponding bone—the coffin-bone—of the horse's foot, which is expanded to give a wider base of support, and to carry the sensitive frog. In some animals, as the turtle, the ungual phalanges are of great size and length in proportion to the other bones. In the feline tribe they are retracted upon the sides or back of the 2nd phalanges, and are held in this position by elastic ligaments, except when they are thrown forward by the flexor muscles for the purpose of seizing some object.

Bones of the thumb consist of a metacarpal bone and two phalanges.

The thumb consists of three bones, instead of four like the other fingers; and it has always been a question whether all three are to be regarded as phalanges, or whether that forming the proximal segment is a metacarpal bone. In favour of the former view it may be urged that the proximal bone, in its development and general shape, and in the direction of its nutritious artery, corresponds with the phalanges[1]. In favour of the latter view several reasons may be given. *First*, the proximal bone rests upon the carpus; being set upon the trapezium and forming with it a joint, not unlike that of the smallest metacarpal bone with the unciform, though admitting of greater variety and freedom of movement. *Secondly*, the lower end of the proximal bone is convex like those of the other metacarpal bones, instead of being concavo-convex, or trochleariform, like those of the phalanges; and its articular surface is prolonged upon the palmar aspect by means of tubercular processes, with a depression between them occupied by fat, and by vessels passing into the head of the bone, just as in the case of the other metacarpals. *Thirdly*, the second bone is, at its base, shaped more like a first phalanx than a second phalanx; it has *two* sesamoid *bones* appended to it, instead of *one* sesamoid *body;* it receives the tendons of the short flexor, the abductor and the adductor muscles, not the tendon of a long flexor. It is evident, in short, that the first bone is neither truly a metacarpal bone nor a phalanx, but is intermediate between the two. Taking all things into consideration,

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[1] In the fins of Fishes (with the exception of the polypterus) the metacarpals are considered to be wanting; the rays, which are supposed to correspond with the fingers, though they far exceed them in number, being sustained immediately by the carpal bones. Van der Hoeven's *Handbook*, II. 17.

it is perhaps most correct, as it is certainly most convenient for description, to continue to call it a metacarpal bone, and to consider that the second phalanx, with its flexor perforatus tendon, is the digital segment which is missing in the thumb[1].

Development of carpal bones, The carpal bones are modelled in cartilage by the 3rd month, so that their shape can be distinguished. Ossification is late, not beginning in the *Magnum* till near the end of the 1st year. It soon follows in the *Unciform*, which is said, by Cloquet and some other anatomists, to have two centres corresponding with the two separate bones in reptiles, of which it is the representative. It begins in the cuneiform[2] at about the 3rd year; in the trapezium and semilunar at about the 5th; in the scaphoid, near its inner part, where it does not rest upon the radius, at about the 6th; in the trapezoid at about the 8th; and in the pisiform, which is the latest in the body, at about the 12th or 14th year.

of metacarpal bones, In the metacarpal bones the ossification of the shafts commences soon after that in the bones of the fore-arm, that is, at the end of the 2nd, or in the early part of the 3rd, month. Each upper end is developed from the same nucleus as the shaft; the epiphysis at the lower end begins to ossify in the 3rd year, and is united with the shaft at about the 20th year.

of phalanges. The ossification of the phalanges takes place from nuclei, for the shafts and lower ends, which appear in the first row soon after the corresponding nuclei in the metacarpal

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[1] This view derives confirmation from comparative anatomy, inasmuch as the number of phalanges is subject to some variety in the lower animals; thus the third and fourth fingers of some saurian reptiles have four or five phalanges each, whereas the fingers and toes of the land tortoises have only two each, the two distal bones being apparently fused into the one large hooked ungual phalanx. Moreover, we occasionally find children born with two phalanges in each of the fingers and toes, instead of three. I have just dissected an instance, in which only the proximal and ungual phalanges of each of the four outer toes were present; and in the pollex there was only the ungual phalanx, which rested upon the metatarsal bone. In the hand there was a similar deficiency in the fingers; and the ungual phalanges were all fused together into one bone, which was covered by a broad plate of nail. In the thumb a diminutive first phalanx was placed at the side of the joint of the ungual phalanx with the metacarpal bone.

[2] The magnum and cuneiform are the only carpal bones in which ossification has taken place in the Sicilian dwarf, æt. 10 years, in the College of Surgeons.

bones. The epiphyses for the upper ends begin to ossify in the end of the 3rd year, and are united to the shafts about the 20th year. The ossification of the 2nd and 3rd rows is somewhat later.

Hand of the Quadrumanous animal.

The hand of the Quadrumanous animal differs from that of man, first, and especially, in the shortness and weakness of the thumb, which barely reaches to the level of the head of the metacarpal bone of the forefinger; the little finger is also comparatively small; the wrist-bones, though more numerous, owing to the presence of an additional bone between the scaphoid and trapezoid, as well as of two sesamoid bones in front of the scaphoid, are smaller, particularly the trapezium and trapezoides; the metacarpal bones and phalanges, with the exception of those of the thumb, are longer; and the 1st phalanges are as long as the 2nd and 3rd put together[1]: hence the hand is longer and straighter in proportion to its breadth, and is more adapted for clinging and climbing than for the variety of accurate movements and numerous purposes to which the human hand is fitted by the nice adaptation of its several parts to one another. The components of the ape's hand are constructed with reference to external objects; those of the human hand with more reference to one another, as is exemplified by the manner in which the fingers and the thumb can be brought together[2].

Liability to cartilage tumours and rheumatism.

A remarkable feature in the pathology of the hand is the liability of the phalanges and metacarpal bones to the formation of *cartilage tumours*, which pervade their interior

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[1] Ilg, *Monographie der Sehnenrollen, Zweite Abschnitt*, Prag. 1824, s. 6.

[2] Meckel, *Handbuch der Anatomie*, I. 220, says that a 9th bone is sometimes found in man, between the trapezoid and magnum, corresponding to one in the ape. The 9th bone in that animal is, however, usually between the scaphoid and trapezoid. Ilg describes two *sesamoid* bones, in addition, in the ape's wrist; one on the radial side, between the scaphoid and trapezium, connected with the lateral ligament and the abductor pollicis; and the other in the anterior ligament of the wrist in front of the upper part of the scaphoid bone. In a case of congenital dislocation of the wrist described by Mr R. W. Smith, *Treatise on Fractures and Dislocations*, Dublin, 1847, p. 252, the semilunar bone consisted of two perfectly distinct portions, an anterior and a posterior. This author relates three other cases of congenital dislocation of the wrist, in which the bones of the fore-arm were short and defective at the lower end, and presented an articulating facet for the carpus upon the anterior or posterior surface; the carpal bones of the front row were either defective or small and misshapen in each. In the skeleton of a negro in the Jardin des Plantes, there are only three bones in the first row of the carpus, the semilunar and cuneiform being united on both sides. Jourdan, *Encycl. Anat.* II. 139.

as well as grow upon their outsides. These affect the metacarpal bones and all the phalanges; the terminal phalanges and those of the thumb less often than the others. Their frequent occurrence in this part of the skeleton must be the result of some peculiarity in it, though it is not clear wherein that peculiarity consists. The several joints of the hand and wrist are often the seat of *chronic rheumatism*, and become in various ways nodulated, distorted and fixed, or ankylosed thereby. The predisposition to this malady is probably induced in them partly by the exposure of the hand to cold; but must be partly also owing to some peculiarity in the construction of the joints. In the distortion which often follows, the fingers are generally bent upon the metacarpus, and slanted away from the thumb; the first phalangeal joint is commonly kept extended, sometimes preternaturally so, and the second joint is flexed; the terminal phalanx is, in addition to being flexed, often inclined to one side.

THE JOINTS OF THE UPPER EXTREMITY.

STERNO-CLAVICULAR JOINT. (PLATES XXIII., XXVIII.)

Articular surfaces not adapted to each other.

IF we compare the corresponding articular surfaces of the sternum and of the clavicle, we find that they present no appearance of adaptation to one another; and we should never imagine that they were intended to be jointed together and to play the one upon the other. Nor, indeed, strictly speaking, are they directly united; for they do not at any part touch one another, but are entirely separated by the interarticular ligament. The facet upon the upper edge of the manubrium, on either side, is saddle-shaped, convex from before backwards, and a little concave from within outwards; its longest diameter is in the latter direction. The corresponding extremity of the clavicle is of considerable thickness, by far the thickest part of the bone. It is truncated obliquely from behind, forwards and outwards; so that its posterior edge is the most prominent, and its lower part is rather more so than the upper. The inner or articular surface is excavated in the middle, and this gives a still greater prominence to the hinder edge; it is uneven in its whole extent, except in a small area at the lower part, where is a smooth facet covered with cartilage. This facet is slightly concave from before backwards, in which direction is its greatest diameter; it is convex from above downwards. It is therefore, in shape, just the reverse of the articular facet of the sternum.

Interarticular ligament.

The great bond of union between the two bones, which also forms a cushion between them, adapting itself to both, holding them together and presenting an articular surface for each to play upon, is the *Interarticular ligament* or *Fibro-cartilage* (Pl. XXVIII. figs. 1 and 2, *E*). It is broad, thick, and very strong, is sometimes a little thicker at the middle than at the circumference, but this varies. Connected below with the outer edge of the sternal facet and with the adjacent surface of the cartilage of the first rib, it passes obliquely upwards and inwards to the fossa on the middle of the inner articular end of the clavicle, and is inserted into it. Its attachment is broad and surrounds the small articular facet which exists here, except at its lower part. It is united to both the bones by means of short thick tendinous fibres. It thus bisects the joint; and has a separate synovial cavity upon either surface, one above, between it and the facet on the clavicle, and one beneath, between it and the facet on the sternum. At the same time that it prevents the clavicle from being driven inwards and upwards from the sternum, it forms an elastic cushion between the bones, which contributes to break the jarring effects of blows.

Other ligaments. The clavicle is further bound to the sternum by other strong ligaments. First, the *Posterior sterno-clavicular ligament* (fig. 2, *K*) passes from an uneven space behind and beneath the sternal facet, upwards to the projecting posterior edge of the inner extremity of the clavicle; it limits the rolling of the clavicle forwards upon the sternum. Secondly, the *Anterior sterno-clavicular ligament* (fig. 1, *D*) passes, from the prominent anterior margin of the sternal facet, upwards and forwards, to the

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DESCRIPTION OF PLATE XXVIII.

Fig. 1. Front view of sterno-clavicular joints. *A*, *A*, cut edge of manubrium. *B*, first costal cartilage. *C*, clavicle. *D*, anterior sterno-clavicular ligament. *E*, inter-articular ligament, separating the articular facet on the sternum (*F*) from that on the clavicle (*G*). *H*, the inter-clavicular ligament. *I*, costo-clavicular ligament.

Fig. 2. Sterno-clavicular joints viewed from behind. *A*, *A*, *B*, *C*, *E*, *F*, *G*, *H*, *I*, the same as in preceding. *K*, posterior sterno-clavicular ligament. A vertical section, from side to side, has been made through the right joint to show the inter-articular ligament (*E*) and its relation to the articular surface of the sternum (*F*) and of the clavicle (*G*).

Fig. 3. Horizontal section of acromio-clavicular joint. *A*, the clavicle. *B*, the acromion. *C*, the ligament in front is thicker than *D*, the ligament behind.

Fig. 4. Vertical section from side to side through the acromio-clavicular joint. *A*, the clavicle, overlaps *B*, the acromion. *E*, the ligament above, is thicker than *F*, the ligament beneath. The cartilage on the extremity of the clavicle, in this instance, is very thick, and resembles fibro-cartilage.

Fig. 1.

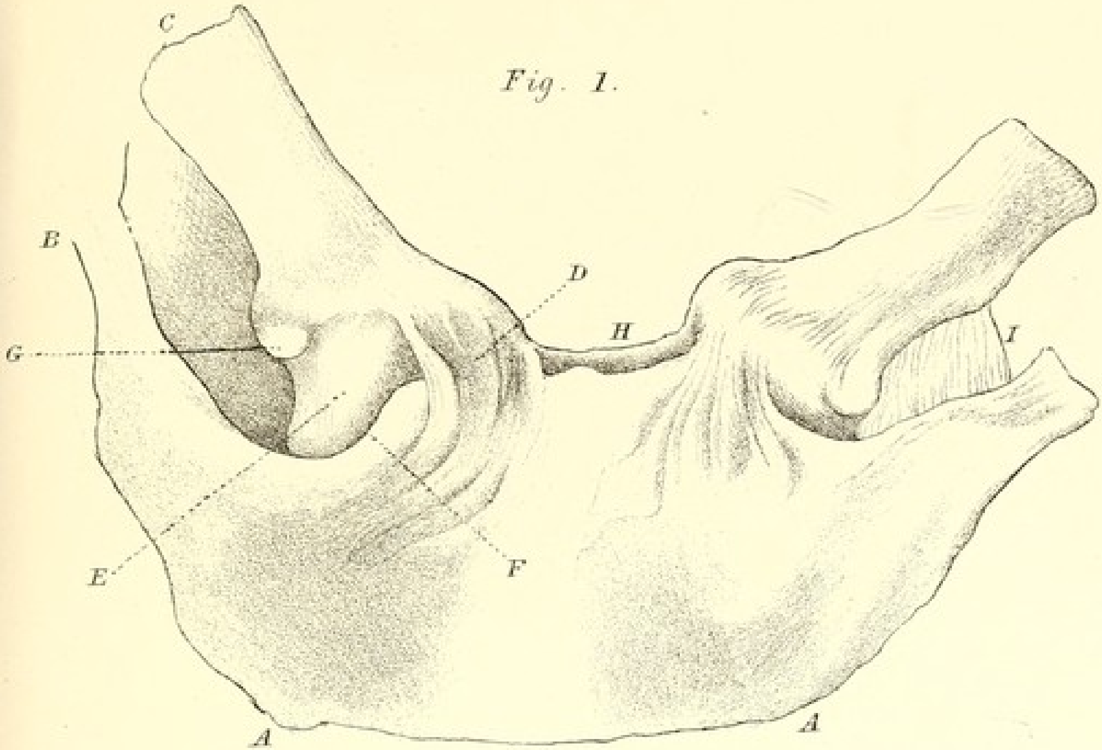


Fig. 2.

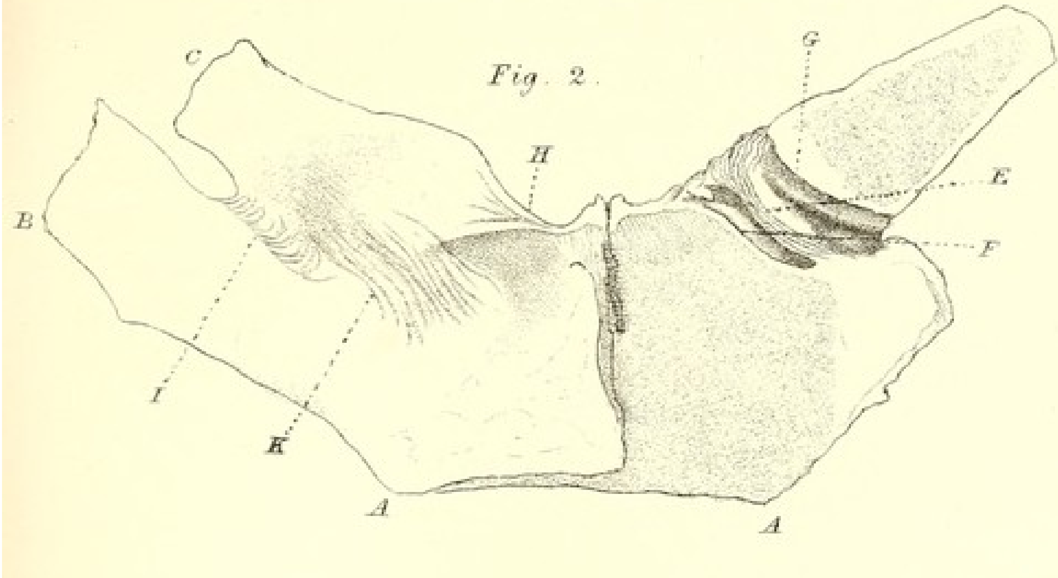


Fig. 3.

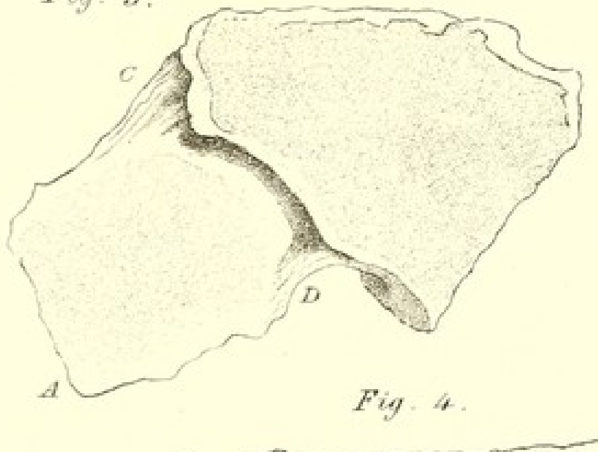
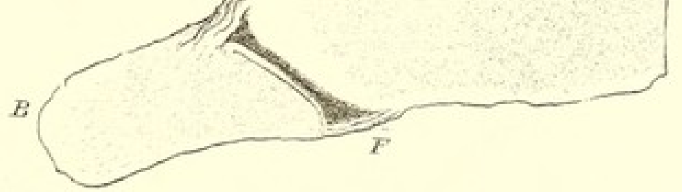


Fig. 4.



anterior edge of the clavicle, and to a slight notch which is often found in that edge. It limits the rolling of the clavicle backwards upon the sternum. Thirdly, the *Costo-clavicular* or *Rhomboid ligament* (fig. 2, *I*) passes, from the upper and fore edge of the costal cartilage, obliquely inwards, forwards, and upwards, to the rough space on the under and hinder surface of the clavicle, near its head. It limits the elevation of the shoulder. It also limits the movement of the clavicle forwards and backwards, as well as upwards, that is to say, it limits the movements in nearly every direction; and it resists the tendency of the pectoral and other muscles to draw the clavicle inwards, and assists the interarticular ligament to prevent the bone being driven inwards over the top of the sternum by falls and blows upon the shoulder. It is a strong ligament; and its distance from the joint increases its efficiency. There is also the *Interclavicular ligament* (fig. 1, *H*) passing between the upper edges of the clavicles, and forming an inverted arch over the upper edge of the sternum, with which it has some connection.

Dislocation rare.

All these ligaments are very strong; and they form so effectual a bond of union between the sternum and the clavicle that, notwithstanding the want of adaptation of the two bones and notwithstanding the severe forces and strains to which the joint is subjected by the action of surrounding muscles and by falls upon the shoulder, dislocation or severe injury of any kind is of comparatively rare occurrence. In fact, the joint is stronger than the collar-bone; and the latter, accordingly, gives way far more frequently than the former. Dislocation does, however, occasionally take place. The head of the clavicle may be driven above the sternum, a little behind it or a little in front; the latter is the more frequent. To permit either of these displacements, all the ligaments, with the exception of the interclavicular, must be torn through. They were so in a case of dislocation forwards which I had the opportunity of dissecting; the interarticular ligament was rent from its attachment to the clavicle. All the bonds of connection being thus destroyed, and the shape of the bony surfaces rendering the surgeon no assistance, it is very difficult to maintain the displaced clavicle in correct position; and various devices have been resorted to for the purpose of supporting the shoulder and holding down the end of the bone, but none have been found very efficient.

Movements.

The movements, though varied, are of limited range; for the ligaments are all tight, or nearly so, in every position of the clavicle; this adds to the security of the joint, and renders it less liable to suffer from sprains. The movements attendant on elevation and depression of the shoulder take place between the clavicle and the interarticular ligament, the bone rotating upon the ligament on an axis drawn from before backwards through its own articular facet. When the shoulder is moved forwards and backwards, the clavicle, with the interarticular ligament, rolls to and fro upon the articular surface of the sternum, revolving, with a slightly sliding movement, round an axis drawn nearly vertically through the sternum. In the circumduction of the shoulder, which is compounded of these two movements, the clavicle revolves upon the interarticular cartilage, and the latter, with the clavicle, rolls upon the sternum.

Disease rare.

The joint is occasionally the seat of chronic rheumatic arthritis, rarely of any other disease.

THE ACROMIO-CLAVICULAR JOINT (PLATES XXVIII. XXIX.)

Strength derived from ligaments.

resembles the sterno-clavicular in the slight security afforded by the shape of its articular surfaces, in the limited range of its movements, and in its strength, which, though derived almost entirely from ligaments, is sufficient to resist most of the shocks to which it is exposed.

Dislocation rare.

Dislocation is, accordingly, very rare; when it has taken place there is, for the same reason as in the case of the sterno-clavicular joint, great difficulty in maintaining the bones in proper position. The tendency of blows upon the shoulder, combined with the shape and disposition of the articular surfaces (Pl. XXVIII. fig. 4), is to drive the acromion (B) under the end of the clavicle (C); and the ligaments, some of them at least, are disposed so as to prevent this accident. Instances are, however, recorded in which the displacement took place in the opposite direction, the extremity of the clavicle having been driven beneath the acromion[1].

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[1] *Archives Gén. de Médecine*, 1837, III. 463.

It maintains the *straightforward* direction of shoulder in movements of scapula on chest.

To understand thoroughly the offices of this joint, it is necessary to consider the manner in which the scapula moves upon the trunk. It is capable of being thrown forwards and backwards, of being raised and depressed, and of being moved in a circle, or "circumducted," as it is called; and throughout these movements the chief part of the base, and the lower angle, are maintained in contact with the ribs. Forasmuch as the exterior of the ribs presents a curved line from before backwards, it follows that whenever the scapula is advanced or drawn back, it must describe part of a circle upon the chest; and the centre or axis of that rotatory movement is represented by a vertical line drawn through the sterno-clavicular joint, or nearly so. Had there been no joint between the clavicle and the scapula, the circular movement of the scapula would have been attended with a greater alteration in the direction of the shoulder than is desirable: for instance, when the scapula was thrown forward, the glenoid cavity would have been directed inwards; and when the reverse movement took place the glenoid cavity would have been directed outwards; and it would have been impossible to give a blow straight forward with the full force of the arm, that is to say, with the combined force of the muscles of the scapula arm and forearm. In order to maintain a uniformity in the direction of the shoulder during the movements of the base of the scapula, and to permit the former to be carried directly forwards and backwards while the latter is kept in contact with the convex wall of the chest, the acromio-clavicular joint is interposed between the clavicle and the scapula. It is so adjusted as to enable either bone to turn in a hinge-like manner upon a vertical axis drawn through the other, and it permits the surfaces of the scapula, like the baskets in a roundabout swing, to look the same way in every position, or nearly so[1]. When the shoulder

[1] It will be observed by those who adopt the ordinary views and expressions respecting the rotation of the moon in its movement round the earth, that the object of this joint is to prevent a similar rotation of the scapula in its movement round the chest, and to enable it to present its glenoid face always in one straightforward direction.

is advanced the acromial end of the clavicle is drawn forwards with the scapula, a hinge-like movement between the two takes place, and the retiring angle between the hinder edge of the clavicle and the spine of the scapula is rendered more acute. When the shoulder is carried backward, the acromial end of the clavicle goes with it, and the angle just mentioned is widened. To permit the requisite movement the articular surface of the clavicle is slightly convex from before backwards, and that of the acromion is slightly concave in the same direction (Pl. XXVIII. fig. 3).

Provision to permit the rising and falling of the shoulder.

Again, in the rising and falling of the shoulder the centre of motion is at the sterno-clavicular joint; and this movement would evidently be incompatible with the juxtaposition of the inferior angle of the scapula to the ribs, if there were no joint between the clavicle and the acromion. The acromial facet is slightly convex from above downwards, and the clavicular facet is slightly concave, so as to permit the requisite hinge-like movement upon an antero-posterior axis when the shoulder rises and falls.

Shape of articular surfaces.

The *Articular surfaces* of this joint are, moreover, cut obliquely from above, downwards and inwards, so that the facet of the clavicle overlaps that of the acromion. When this disposition prevails in a marked degree, as represented in Pl. XXVIII. fig. 4, taken from a recent specimen, the convexity of the acromial and the concavity of the clavicular surface are scarcely perceptible; and it is probable that, in such case, the one slides a little upon the other when the shoulder rises and falls. The overlapping of the clavicle serves to prevent displacement of the acromion when we use the hands and arms for the purpose of pressing against any foreign body, or when we allow the weight of the trunk to rest upon them. In some instances the extremity of the clavicle is so much elevated as to simulate exostosis or dislocation.

Capsular ligament.

The articular surfaces are held together by a *Capsular ligament* (figs. 3 and 4, *C, D, E, F*) composed of strong fibrous bundles, which are not sufficiently tight to interfere with movement, and which are, for the most part, directed, from the acromial edge, obliquely backwards and outwards, to the margin of the clavicular facet. This direction of the ligamentous fibres indicates their office to be, not merely to hold the articular surfaces in apposition, but to cause the clavicle to be carried forward with the acromion, when the latter is advanced by the muscles of the scapula. The movement in the opposite direction is sufficiently provided for by the disposition of the articular surfaces, that of the acromion (fig. 3, *B*) being situated a little in front of that of the clavicle (*A*).

Conoid Ligament.

The *Conoid ligament* (Pl. XXIX. fig. 1, *C*) is connected with the root of the coracoid process, just in front of the supra-scapular notch, and just beneath the flat smooth surface on the inner side of the base of the process (*Q*). It spreads out as it ascends to the clavicle, and has a broad attachment to the rough surface on the posterior and hinder edge of the most prominent part of the external curve of that bone. It obviously acts as a check upon the to-and-fro movements of the acromio-clavicular joint, and, therefore, upon the advance and retrocession of the shoulder. Moreover, by binding the hinder edge of the coracoid to the clavicle, it prevents the scapula from being moved or driven too far backwards by the strong action of the muscles or by blows upon the front of the shoulder. During the movement of the scapula forwards and backwards, within the range permitted by it, this ligament plays to and fro upon the flat smooth surface on the inner side of the coracoid process. The ligament may also, in addition to its influence upon the to-and-fro movements of the scapula, set a limit to the descent of the bone upon the side of the chest. It is of considerable strength; and its distance from the acromio-clavicular joint gives it great power to set bounds to the movements of that joint. In this and some other respects it reminds us of the costo-clavicular ligament which is attached near the other end of the clavicle.

Trapezoid ligament.

The *Trapezoid ligament* (*D*) arises from the hinder part of the inner edge of the coracoid process, and from the fore part of the flat smooth surface at the root of the conoid ligament. It passes outwards, narrowing a little as it goes, to the rough space on the under surface of the expanded end of the clavicle, half or three-quarters of an inch internal to the articular extremity. It is a great stay to the shoulder; it supports the scapula in its place, and combines with the conoid ligament to prevent the coracoid, and therefore the acromion, from being carried inwards beneath the clavicle by the contraction of the powerful muscles that pass to the scapula from the trunk or by blows upon the shoulder. The oblique disposition of the articular surfaces of the acromio-clavicular joint renders such a provision for preventing displacement very necessary. The ligament is tense in every position of the shoulder; and its fibres, to a certain extent crossing one another, have some influence in limiting both the forward and the backward movement of the scapula.

Coraco-acromial ligament. The *Coraco-acromial ligament* (*E*) may be mentioned in connection with this joint. It is spread out, fan-like, between the coracoid and the acromion; has a broad attachment along the outer edge of the former, and a narrow insertion into the tip of the latter, just in front of and beneath its articular facet. It binds the two processes together, and renders them a support to one another, preventing the acromion from being

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DESCRIPTION OF PLATE XXIX.

Fig. 1. Front view of acromio-clavicular and shoulder-joints. *A*, the acromion. *B*, the extremity of the clavicle. The fibres of the capsule are seen passing between the two. *C*, the conoid ligament; *D*, the trapezoid; *E*, the coraco-acromial; *F*, the suprascapular. *G*, *G*, the cut edge of scapula. *H*, the triceps. *I*, the sub-scapularis muscle detached from the scapula and thrown back so as to show the wide opening in the capsule which it covers. *K*, thin edge of the capsule raised with the sub-scapularis, which makes the opening rather larger and discloses beneath it (*L*) the gleno-humeral ligament and (*M*) the biceps tendon. *N*, the cut end of the biceps lying in the bicipital groove and covered by the ligamentous tissue that binds it there. *O*, the inner, and *P*, the inferior ligament. The head of the humerus is drawn a little away from the glenoid cavity, so as to render the capsule tense. *Q*, is the smooth surface upon the coracoid process, on which the conoid ligament plays.

Fig. 2. External view of the glenoid portion of a scapula from which the acromion has been sawn away at *A*. *B*, *B*, cut edge of scapula. *C*, root of coracoid process. *D*, the glenoid ligament attached along the outer border of the glenoid cavity. *E*, the biceps tendon; some of its fibres are continued into the glenoid ligament, and others into (*F*), a prominence of the scapula at the upper and hinder border of the glenoid cavity. *G*, the triceps tendon; some of its fibres are continued into the glenoid ligament and the capsule, which are here blended, and others are attached to the lower border of scapula.

Fig. 1.

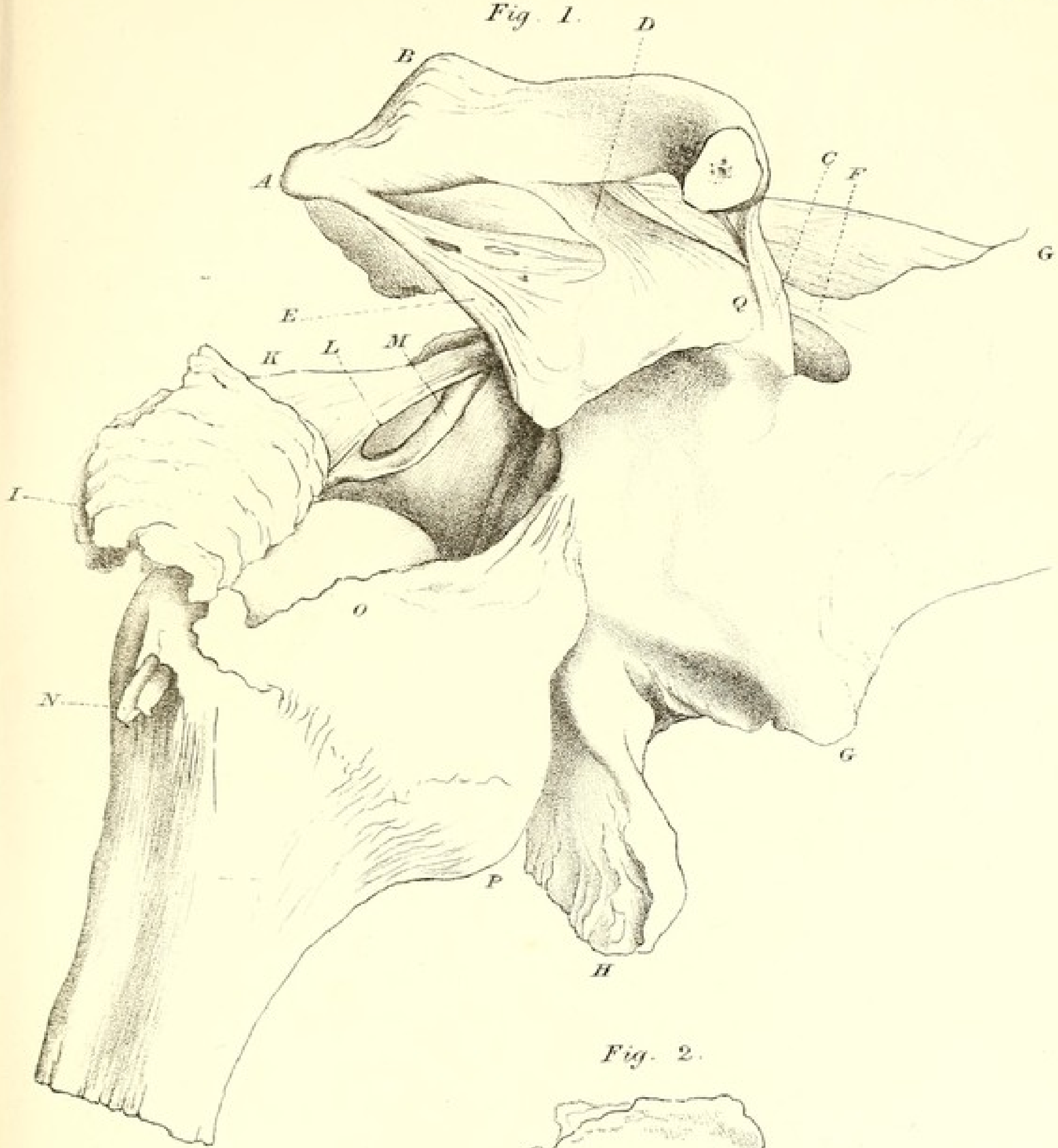
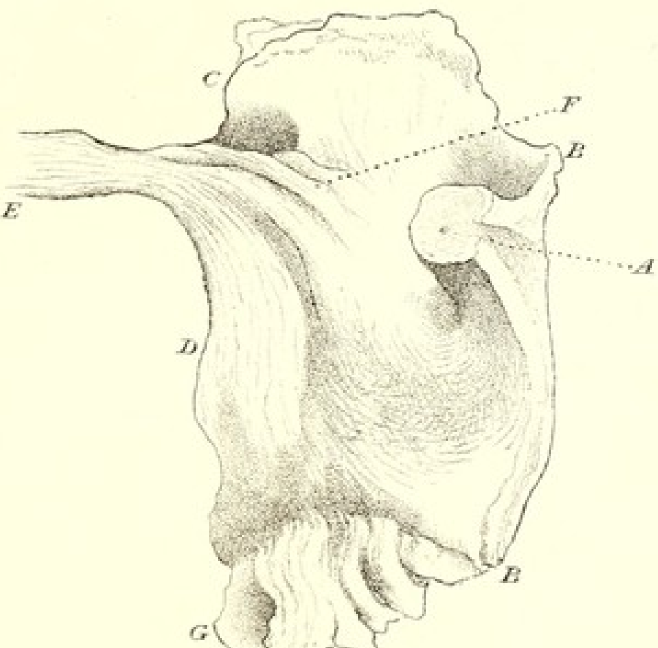


Fig. 2.



driven outwards by the pressure of the clavicle, and preventing the coracoid and adjacent edge of the glenoid cavity from being driven inwards by the pressure of the humerus. It is the representative of a bony arch which in Sloths connects the two processes.

Inter-articular cartilage.

A more or less complete *Inter-articular fibro-cartilage* is sometimes found in this joint. It is usually thickest at the circumference, where it is connected with the capsule. It may be present in the upper part of the joint, and deficient below.

THE SHOULDER-JOINT. (PLATES XXIX. XXX.)

Shape of the articular surface of the humerus.

The articular surfaces of the humerus and scapula —a large ball playing in a shallow cup—are peculiarly adapted for free and varied movements. That of the head of the humerus forms part of a true sphere; but its margin is by no means a true circle, inasmuch as it is extended in some directions much more than in others. Its greatest measurement is from the proximity of the bicipital groove, with which it is nearly continuous, downwards, inwards, and backwards. A vertical section in this direction shows the cartilaginous margin of the cut surface (Pl. XXX. fig. 1) to form a segment (140°) of a circle, so that it approaches to a semi-circle, the radius of which is about an inch and a line. The measurements across, and in other directions, are less. If the vertical section just mentioned be continued downwards, it cuts the lower articular surface very obliquely; it takes off a small piece of the fore part of the tubercle for the radius, and falls considerably behind the inner condyle, so that the two surfaces are oblique with regard to one another. The lower portion of the articular surface on the head of the humerus is of considerable width, and, in the position of rest, with the arm near the side, occupies the lower wide part of the glenoid cavity. In this position rotation is most free, and the muscles of rotation—the *sub-scapularis* and the *teres minor*—act with greatest advantage on the tubercles of the humerus. The middle of the articular surface is still wider than the lower part; and this permits a free range of lateral movement of the arm when the extremity is raised to a right angle with the side. The greatest elevation of the arm can be obtained by rolling the articular surface of the humerus in the direction of its greatest measurement, which is done by carrying the arm obliquely upwards, forwards, and outwards. If we raise the arm straight forwards we cannot lift it quite so high; still less if we endeavour to raise it behind.

Shape of the glenoid cavity. The *Glenoid cavity*, surrounded by its marginal ligament, presents a shallow cup of oval shape, adapted to the ball of the humerus, and with its longest diameter in a corresponding direction. Its cartilage is thinnest at the deepest part of the cavity, whereas that of the humerus is thickest at the centre of the head. The lower broader part of the cup sustains the chief pressure of the head of the humerus, not only when we carry weights and when blows are received upon the shoulder, but also when the deltoid is employed in raising the arm, because the *supra-spinatus*, *infra-spinatus*, and *biceps* tendon so act upon the upper end of the humerus as to press it against, and cause it to revolve upon, this lower part of the glenoid cup. To enable the latter to bear this

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DESCRIPTION OF PLATE XXX.

Fig. 1. Section through shoulder-joint, with the arm at right angles to the body. It shews how the biceps tendon, pressing the humerus close against the glenoid cavity, prevents its being dragged over the edge of the cup by the action of the pectoralis major and latissimus dorsi. *A*, insertion of biceps tendon into upper edge of glenoid cavity. *B*, the lower part of capsule, which is loose even in this position, and does not, therefore, assist to prevent dislocation till the arm is more raised.

Fig. 2. View of parts attached around glenoid cavity; a section has been made through the shoulder-joint, detaching the humerus from the scapula. *A*, the overhanging edge of acromion. *B, C, D, E*, the cut edges of sub-scapularis, supra-spinatus, infra-spinatus and teres minor muscles. *F, F, F*, the cut edge of the capsule, distinct from the muscles, at its lower part continuous with the edge of the glenoid ligament, but above separate from it, and passing behind it and the biceps tendon. F^1 and F^2, the parts where the capsule is strengthened by the inferior and by the coraco-brachial ligaments. *G*, the glenoid ligament overhanging the upper part of the glenoid cavity. *H*, the division of the glenoid ligament which is lost upon the edge of the glenoid notch. *I*, the division which passes over the notch. *K*, the biceps tendon. *L*, the gleno-humeral ligament. *M*, the internal ligament. *N*, the orifice of communication between the synovial cavity and the bursa under the sub-scapularis.

Fig. 1.

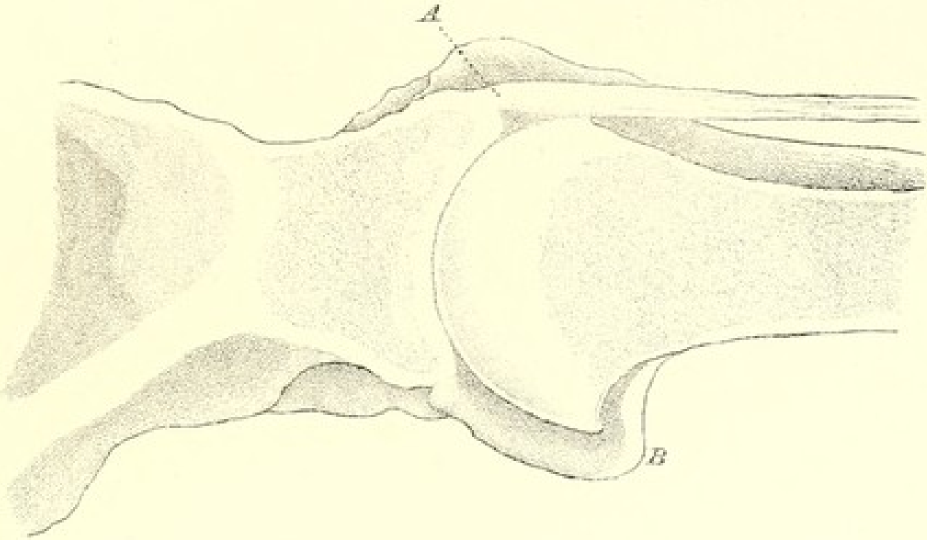
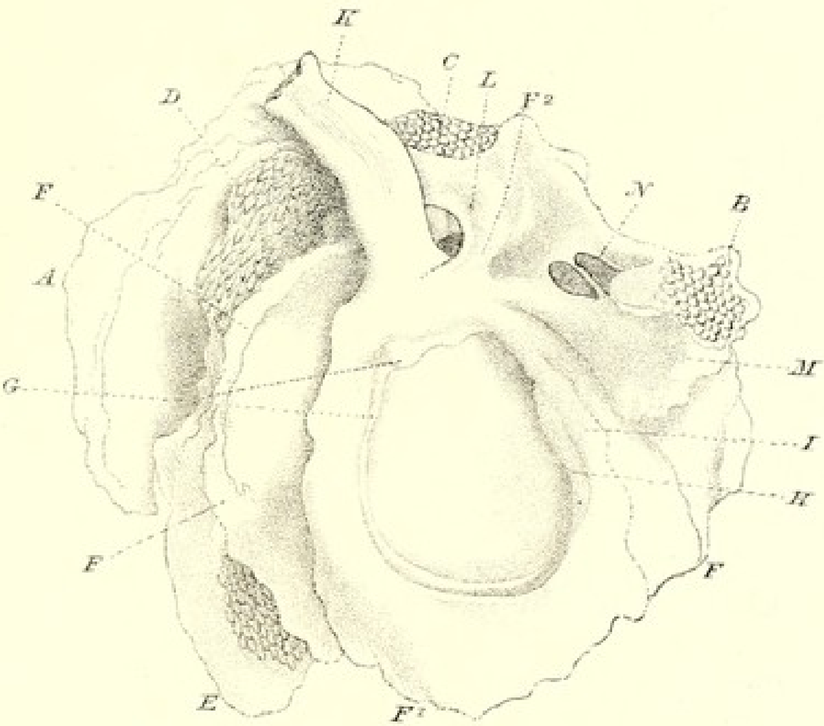


Fig. 2.



pressure it is placed upon the thick strong inferior costa of the scapula. The base of the spine contributes to the support of the middle of the glenoid cavity; and the base of the coracoid process forms its upper edge. The section represented in Pl. XXX. fig. 1, shows the firm bony arch upon which the glenoid cavity is carried. The edge of the glenoid cavity is rather more prominent on the inner side, in which direction the humerus is more liable to be displaced by the action of the muscles and by blows on the shoulder, than it is on the outer side.

Glenoid ligament. The *Glenoid ligament* (fig. 2, *G*, *H*, *I*) is composed of circularly disposed, more or less interlacing fibres, which lie upon and deepen the edge of the cup, and which are attached to the latter in its whole circumference. At the upper part it is of considerable thickness; it here (*G*) overhangs the cartilage of the glenoid cavity, is separated by an interval from the capsule (*F*) which passes clean over it to the upper surface of the scapula; and its fibres are continuous with some of the fibres of the "biceps tendon" and of the "coraco-brachial" and "internal ligaments," and derives a considerable accession from them. Traced round the outer and lower parts of the glenoid cavity it gradually becomes shallower, ceases to overhang the glenoid cavity, and its surface is continuous with the articular cartilage above, and with the fibres of the capsule below. As it ascends along the inner edge of the glenoid cavity it splits into two portions; of which the one (*H*), keeping close along the margin of the cup, is lost upon it about the bottom of the notch, and the other (*I*) passing over the notch, (like the cotyloid and transverse ligaments of the hip), completes the circle of the ligament and deepens the cup at this its shallowest part.

The glenoid ligament not only serves to deepen and extend the articular surface of the glenoid cavity; it also prevents its being chipped and broken; and it forms a tough, soft, circular cushion for the reception of the head of the humerus, defending the opposed cartilaginous surfaces from the many jars to which they are liable on account of the exposed position of the shoulder. It supports the circumference of the head of the humerus, and, being held in close contact with it by the capsule, by the surrounding muscles, and by the tension of the biceps tendon, it lessens the amount of pressure which is sustained by the bottom of the glenoid cavity.

Apposition of the bones not dependent upon the ligaments.

It is essential to the free movement of the shoulder that, when the joint is at ease in a mid position, the ligaments connecting the humerus with the scapula should not be tight at any one part. If they were so, it is evident that movement in one direction would be prevented. In most positions of the joint, therefore, the apposition of the two bones is not, in a direct manner, dependent upon the ligaments. If they alone remained the humerus would fall an inch from its proper position, or nearly so; and the contact of the articular surfaces is due to the pressure of the atmosphere, aided by the contraction of the muscles and the elasticity of the various surrounding tissues[1].

Capsular ligament.

The *Capsular ligament*, accordingly, is, in all ordinary positions of the joint, loose at every part; and it only becomes tight when the movements of the humerus in any direction have attained to their full extent. The office of this ligament is not so much to *maintain the apposition* of the surfaces as to *limit the movements* of the joint; though it is true that, by performing the latter office, it does contribute to effect the former. It is connected with the margin of the glenoid cavity and with the outer part of the anatomical neck of the humerus; and some of its innermost fibres are reflected from the line of attachment to the humerus back upon the neck of the bone, and run to the projecting margin of the head. These are covered by the synovial membrane, and they correspond with the fibrous investment of the neck of the femur.

The aperture on its inner side;

At the inner side of the joint there is a round or quadrilateral aperture (fig. 2, *N*), under cover of the subscapularis muscle; and, at this point, the tendon of that muscle, like the tendon of the iliacus at the hip, is in contact with the synovial membrane. The synovial membrane

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[1] This maintenance of contact between the articular surfaces by means of the pressure of the atmospheric air, without the intervention of connecting ligaments, renders the movements of the joint much more easy than they would otherwise have been, and permits a swinging pendulum-like vibration of the limb when the muscles are at rest.

bulges through this opening, forming a sort of bursa for the tendon. The opening is of considerable size; and the head of the humerus is sometimes driven through it in dislocation, without there being necessarily any laceration of the capsule[1].

its connection with surrounding muscles.

The short muscles that pass over the joint are closely connected with the capsule; but they are not blended with it, and may, therefore, be dissected off from it. Some of the fibres (Pl. XXIX. fig. 2, *G*) of the tendon of the long head of the *triceps* muscle, which is attached to the rough space just below the glenoid cup and to the outer margin of the cavity, become blended with the capsule in the same way that the fibres of the tendon of the rectus femoris, with which this portion of the triceps corresponds, become blended with the capsule of the hip.

Accessory ligaments.

The capsule is strengthened at three parts by supplemental fibres, or bands, passing from the scapula to the humerus, which have been rather unnecessarily dignified by names. Of these one, called the *Coraco-brachial ligament* (Pl. XXX. fig. 2, F^2), springs from the upper edge of the glenoid cavity, between the root of the coracoid process and the point of attachment of the biceps tendon, and is attached to the lesser tubercle of the humerus and to the adjacent edge of the great tubercle. It is spread over the bicipital groove; and its diverging fibres are connected at this part by transverse bands, which, passing from one tubercle to the other and arching over the groove, serve to hold the biceps tendon in its place.

Gleno-humeral ligament.

Some of the fibres of this coraco-brachial ligament project into the interior of the joint, along the inner edge of the biceps tendon, and are inserted into the inner and upper part of the bicipital groove, at a point nearer the margin of the head than the line of attachment of the rest of the capsular ligament. This bundle of fibres (Pl. XXIX. fig. *I*, *L*), which has been described by Dr Flood, under the name of the *Gleno-humeral*

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[1] In addition to the process of synovial membrane above mentioned, there is sometimes a separate *bursa* between the sub-scapularis tendon and the root of the coracoid process.

ligament, corresponds probably with the *ligamentum teres* of the hip-joint, and with that structure in the frog which has been called the *ligamentum teres* of the shoulder-joint. The similarity is increased by the fact that the whole circumference of the gleno-humeral ligament is sometimes covered by synovial membrane.

Inner ligament.

A third accessory to the capsule is the *Inner ligament* (*O*) which runs from the inner edge of the glenoid cavity, along the lower margin of the subscapularis tendon, to the lower part of the lesser tubercle of the humerus. It is between this and the coraco-brachial ligament that the aperture in the capsule permits the subscapularis tendon to lie in contact with the synovial membrane of the head of the humerus; and it is the inner ligament which is commonly stretched or torn in dislocations beneath the pectoral muscle.

Inferior ligament.

The fourth accessory, called the *Inferior ligament* (*P*), passes, from the under edge of the glenoid cavity, to the under part of the neck of the humerus; it is of considerable strength, and renders this the thickest part of the capsule. It is put on the stretch when the arm is raised to its fullest height; and, in falling upon the arm in this position, it is liable to be torn, and the head of the bone to be driven, through the rent, into the axilla. It is always torn in dislocation of the humerus beneath the glenoid cavity, and usually about the middle.

Fatty processes.

A few fatty folds and delicate processes are often found hanging from the synovial membrane, about the lines of its reflection from the capsule to the humerus and to the glenoid cavity. In some states of the disease, particularly in the course of chronic rheumatic arthritis, they become hypertrophied and increased in number, and may form polypose excrescences of considerable size, which hang by pedicles into the cavity of the joint.

Lower part of capsule liable to become contracted.

The part of the capsule which, in the ordinary position of the joint with the arm against the side, is the most loose is the inferior portion (Pl. XXX. fig. 1, *B*), where it is strengthened by the "inferior ligament;" and the looseness of the capsule in this situation is necessary to permit the free elevation of the arm. Unfortunately it is the part which is most liable to become thickened, stiffened, or contracted in the various inflammatory affections of the joint; and this is especially likely to happen when, after injuries, or during inflammation of the joint, the arm is kept close to the side for the sake of rest, being perhaps bandaged there. Hence impaired movement, particularly an inability to raise the elbow to a right angle with the body, is a very common and very troublesome sequence of injuries or diseases of the shoulder. Even in cases of fracture of the clavicle or humerus, this defect, which may be, partly or entirely, the result of the necessary treatment, often constitutes the most enduring memento of the accident. It may, sometimes, be overcome by perseverance in moving the arm; or by suddenly and forcibly pulling up the elbow, thereby stretching the capsule, and tearing through any adhesions that may have been formed; an expedient not unfrequently, and not always unsuccessfully, resorted to by empirics, under the pretence of reducing a dislocation, which they affirm to have been overlooked. The liability to this occurrence is a warning to the surgeon to keep the shoulder-joint fixed and inactive no longer than is absolutely necessary.

Biceps tendon.

A peculiar feature in the shoulder-joint is the *Biceps tendon*, which, lying in its groove in the humerus, perforates the capsule, and becoming ensheathed in synovial membrane or covered by epithelium, traverses the joint to reach the upper edge of the glenoid cavity; the greater part of it passes over the glenoid ligament and is attached to the bone (Pl. XXIX. fig. 2, *F*). Some of its outer fibres, and a few of the inner, diverge to join the glenoid ligament on either side (Pl. XXX. fig. 2, *K*).

Purposes served by its prolongation into the shoulder-joint.

Several purposes are served by the peculiar course and disposition of this tendon. 1. It strengthens the capsule at the upper part, and assists to prevent the head of the humerus being pressed against the acromion by the contraction of the deltoid and other muscles. 2. It assists the supra- and infra-spinatus muscles to cause the head of the humerus to revolve in the glenoid cavity when the arm is raised from the side; thus it is, indirectly, as well as directly from the line of its action, an elevator of the arm. 3. By its passage along the bicipital groove it assists to render the head of the humerus steady in the various movements of the arm and forearm; in this way it serves the purpose of a ligament, with the advantage of being available in all positions of the joint, and without restricting the range of movement in any direction. In its course between the tubercles it plays upon the inner, rather than upon the outer, one, as may be inferred from the depth of the groove it makes in it by working round it as upon a pulley. By its pressure upon this inner tubercle, the tendon prevents undue rotation of the head of the humerus outwards; and, in this way, the biceps muscle is enabled to counteract the influence which its own pull upon the tubercle of the radius tends to exert. For, during the action of the biceps in flexion, and more particularly in supination of the forearm, the force exerted by it upon the tubercle of the radius is transmitted, through the neck of that bone, obliquely outwards to the outer condyle of the humerus, and gives to the humerus a tendency to rotate outwards, which is resisted by the pressure of the long tendon of the biceps, exerted at the same time upon the outer side of the lesser tubercle. Thus the same power, which by its pull upon the tubercle of the radius, would cause the humerus to rotate outwards, by its pressure upon the tubercle of the humerus, prevents that movement, and renders the outer condyle a firm resisting point upon which the supination of the radius may be effected. The advantage of such a provision is more particularly experienced when the hand is pressed against any body during supination, as in driving a gimlet; for the onward force exerted upon the gimlet by the extension of the forearm, as well as the twisting force resulting from the action of the biceps and of the other supinators, is, in great part, transmitted to the outer condyle of the humerus. 4. The tendon of the biceps serves to hold the humerus firmly in contact with the glenoid cavity, and to prevent its slipping over the lower edge of the cavity or being displaced by the contraction of the latissimus dorsi and pectoralis major, when the arm is raised from the side, as in climbing and many other movements (Pl. XXX. fig. 1). That such provision to resist the pull of these muscles is not superfluous is proved by the fact that the displacement sometimes takes place in spite of it. I was, not long since, called to a gentleman who had dislocated his shoulder, for the first time, in swimming; and Monro mentions an actress who often dislocated her arm in the exercise of her profession. Let a person support himself, on his elbows, upon a bar on either side, with the arms horizontal and the forearms perpendicular; he will find that he can do so more easily if he holds a stick between his hands, because the stick, supporting the radius, affords a point of resistance to the contraction of the biceps, and enables it, by giving tension to its long head, to keep the humerus firmly in the glenoid cavity.

Injuries to tendon.

No wonder that this long tendon, in its course round the head of the humerus and through the shoulder-joint, should occasionally be *snapped* by the sudden contraction of the powerful biceps muscle. I have known the accident happen in two instances. It was, in each case, attended with a swelling in front of the forearm, caused by the unresisted tonic contraction of the belly of the muscle[1]. It was not, however, attended with any displacement of the head of the humerus, which has been mentioned by some writers to be a symptom of the rupture of this tendon. The rent most often happens about half an inch from its glenoid attachment; and is most frequent in elderly persons, in whom the tendon becomes thin, in whom the synovial fluid is rather scanty, and in whom other changes, attendants on chronic rheumatism, are likely to be in progress. Under these circumstances there can be no doubt that the tendon sometimes becomes *worn through* by the friction of the head of the humerus upon it; and I quite agree with the writer in the *Cyclopedia of Anatomy*, that many of the specimens, in which the biceps tendon stops short in the bicipital groove, or becomes lost in the capsule of the joint, are to be attributed, not to rupture of the tendon, but to the continued effects of chronic rheumatism, originating in an accident, or commencing spontaneously[2]. Possibly the defect may, in some instances, have been the result of original conformation. In the greater number of cases of dislocation of the joint the tendon of the biceps is uninjured; in some it is torn through; and in others it is displaced from its groove, and thrown upon the outer side of the great tubercle, the transverse ligamentous fibres, which hold it in its place, being rent across.

Dislocations.

The shallowness of the glenoid cavity, the free range of movement of the joint, the looseness and thinness of the

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[1] A similar case is related and represented by Mr Calloway, *Injuries of the Shoulder-joint*, p. 148.

[2] It would appear, from some dissections of the shoulder-joint described by Mr J. G. Smith, *Medical Gazette*, XIV. p. 280, that, not only may the tendon of the biceps be worn through, but that the capsular ligament and the tendons of the supra- and infra-spinatus muscles may undergo the same change, and the sub-deltoid bursa thus become opened into the cavity of the joint. In several of the cases mentioned the sub-scapularis tendon was more or less detached from the lesser tubercle. Mr Smith regards these changes as the result of accident; but several other points in the state of the joints, and the existence of similar conditions in both shoulders of the same person, render it more probable that they were the gradual result of friction and chronic rheumatism.

capsule, the exposed position of the shoulder, and the length of the arm, combine to render this joint very liable to dislocation. The accident, however, seldom occurs before puberty. The head of the bone most frequently passes downwards into the axilla; in which case the lower part of the capsule is rent, and the upper part of the capsule, with the contiguous small muscles, may be torn from the humerus. The dislocation inwards is next in frequency; and in it the head of the humerus may be driven through the hole near the subscapularis, without any, or with but little, laceration of the capsule. The dislocation backwards is a rare event, in consequence of blows not being often received in such a manner as to produce it. Partial dislocation, that is, when the head of the humerus rests upon the edge of the glenoid cavity, is not very likely to occur. The condition of the joint in one instance that I have examined, and in others of which I have read the account, renders it most probable that the unnatural position was not the direct result of accident, but of slow changes in the joint occasioned by chronic rheumatic arthritis[1].

THE ELBOW (Plates XXXI. XXXII.)

is a true hinge-joint. The radius and ulna, in flexion and extension of the forearm, revolve upon a transverse axis, drawn through the lower extremity of the humerus[2], and traversing the centres of the circles, of which the trochlea and the articular surface of the outer condyle of the humerus respectively form segments. The plane in which the movement takes place corresponds nearly with the line of the humerus; any obliquity in the direction in which the hand is carried upwards or downwards being imparted by the rotation of the humerus at the shoulder. Thus, in bringing the hand to the mouth, the inclination of the hand towards the middle line of the body is caused, not by anything in the construction of the elbow-joint, but by a movement at the shoulder.

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[1] Two specimens are mentioned by Sandifort, *Museum Anatomicum*, III. p. 239, Nos. DCLXI. and D.

[2] This axial line passes through the lower and fore part of the outer condyle and through the fore part of a ridge that runs forwards from the inner condyle to the side of the trochlea; the inner condyle itself is behind the axis of motion of the joint.

Configuration of articular surfaces.

The joint depends for its strength, rather on the configuration of the bones, than on the strength of the ligaments. The *Olecranon*, hooking round the trochlea, effectually prevents any displacement occurring from traction upon the forearm or hand; and the *Coronoid* process, jutting up in front of the humerus, tends to prevent the forearm being driven backwards by force applied in an opposite direction, and gives power in pressing or pushing with the hand. It is, however, a less efficient stop than the olecranon; for, though it suffices to resist all forces resulting from the contraction of the muscles of the arm, it often fails to protect the elbow against the sudden and violent impulses that are caused by falls upon the hand. Hence dislocation of the forearm backwards at the elbow is a common occurrence. Some additional security is afforded by the transversely waving character of the articular ends, which renders the surfaces of contact more extensive, and assists in preventing displacement, especially displacement in a lateral direction.

Lower end of humerus oblique.

The lower end of the humerus is cut a little obliquely; so that when the bone rests upon it on a table the shaft slants obliquely outwards, in the same manner, and at about the same angle, as does the femur when similarly placed; and the *inner* side of the trochlea (Pl. XXXI. fig. 1, *I*) is the most prominent part of the articular surface. This gives to the ulna and radius a slight inclination *outwards* from the humerus in every position of the elbow, and resists the tendency of the strong pronator and flexor muscles of the hand to drag these bones towards the condyle or to give them an inclination inwards[1].

Adaptation of surfaces.

The groove (*K*) of the trochlea is occupied by the ridge which traverses the sigmoid cavity of the ulna from before backwards. The ridge (*L*) which forms the outer margin of the trochlea occupies the furrow in the interval between

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[1] The prominence of the inner side of the trochlea is most marked at the inferior part; and the outward inclination of the forearm is, accordingly, most observable in the extended position of the elbow. In *rickety* subjects the degree of this inclination is sometimes exaggerated. More commonly, however, the inclination of the forearm takes an opposite direction in rickets, in consequence of the shaft of the humerus being bent with the convexity outwards.

the edges of the radius and ulna. The groove (*M*) on the outer side of that ridge receives the margin of the head of the radius; and the outer tubercle, or capitulum (*N*) of the humerus occupies the hollow upper extremity of the radius.

The capitulum.

The cartilaginous surface of the *Capitulum* of the humerus does not extend very far backwards; and, in the completely extended position of the elbow, the articular edge of the radius projects beyond the capitulum, and may be distinctly felt to form a prominence at the hinder part of the joint. It is well to remember this when examining the elbow for the purpose of discovering the nature of an injury. There is, indeed, only one part of the capitulum which is wide enough to give support to the entire cup of the radius, namely, its anterior and lower part. The radius rests upon that part when the elbow is bent to an angle of 120° or 130°; and this is the position in which we possess the greatest power of supinating the forearm.

Articular surface of ulna.

The articular surface which the ulna presents to the humerus—the *greater Sigmoid cavity*—is formed partly by the upper surface of the coronoid process, and partly by the

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DESCRIPTION OF PLATE XXXI.

Fig. 1. Vertical section, from side to side, through the right elbow-joint in the extended position. *A*, humerus. *B*, ulna. *C*, radius. *D*, internal lateral ligament. *E*, external lateral ligament. *F*, cut edge of coronary ligament. *G*, loose fibrous and synovial membrane descending from lower edge of coronary ligament and reflected upon neck of radius. *H*, lesser sigmoid cavity sloped so as to underhang head of radius. *I*, *K*, *L*, *M*, *N*, parts of articular surface of humerus.

Fig. 2. Vertical section, from before backwards, through the right radio-humeral joint, slightly bent. *A*, the humerus. *B*, the radius. *C*, posterior ligament, with a triangular synovial fatty process (*D*) projecting from it into the interval between the radius and the capitulum of the humerus. *E*, *E*, cut edges of coronary ligament. *F*, *F*, fibrous and synovial membrane descending from lower edge of coronary ligament, in front and behind, and reflected upon neck of radius. *G*, anterior ligament. *H*, fossa in front of humerus, above capitulum.

Fig. 3. Similar section through right humero-ulnar joint. *A*, humerus. *B*, ulna. *C*, part at bottom of greater sigmoid cavity, where fat exists instead of cartilage. *D*, posterior ligament and synovial membrane. *E*, fat which occupies upper part of olecranon fossa. *F*, situation of bursa upon olecranon. *G*, point of attachment of triceps tendon. *H*, anterior ligament. *I*, fat occupying coronoid fossa in humerus.

Fig. 1.

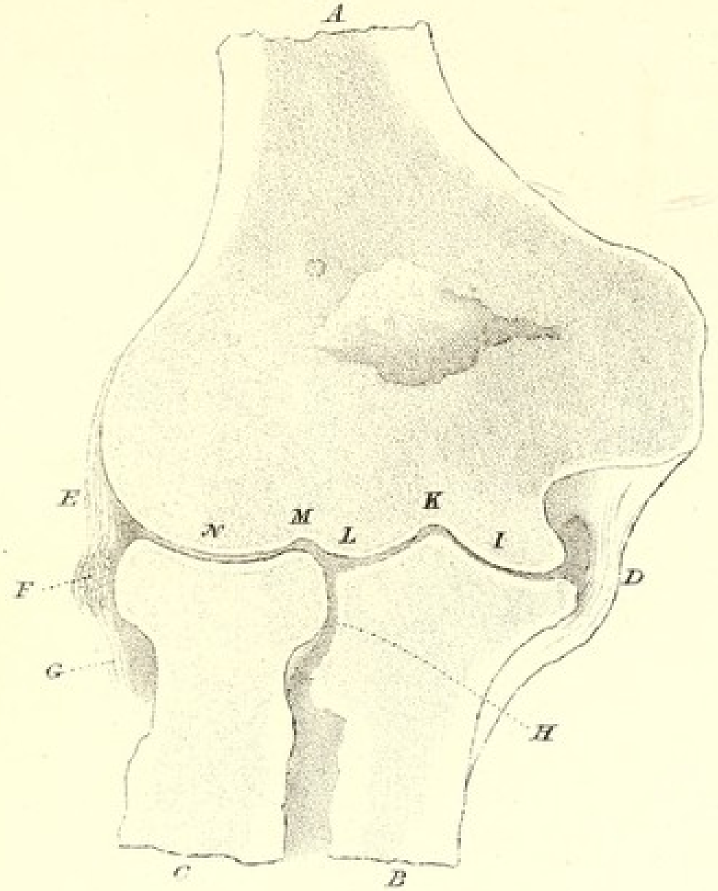


Fig. 2.

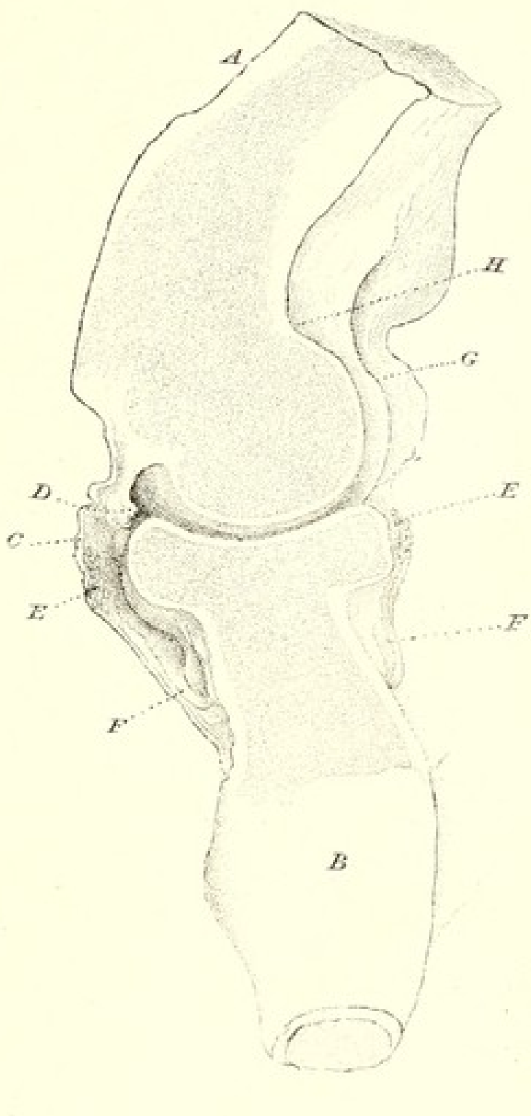
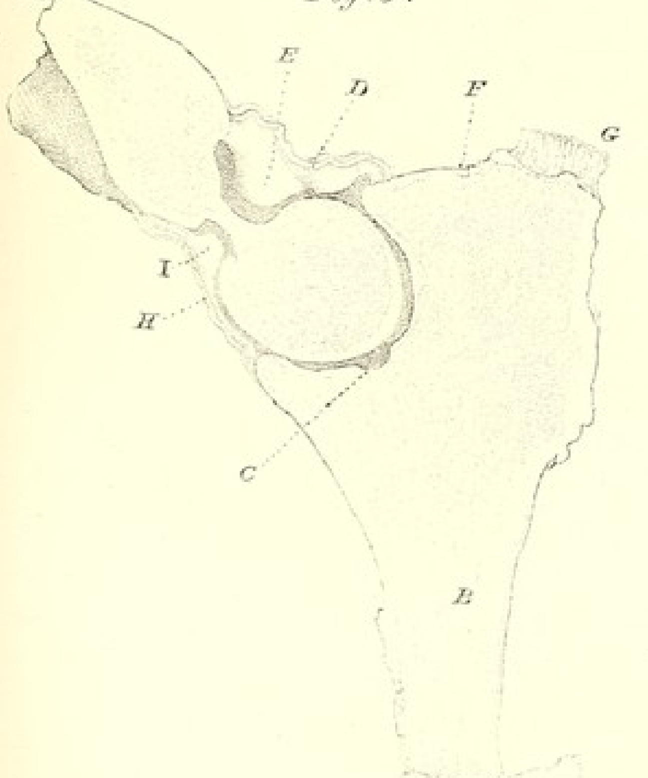


Fig. 3.



anterior surface of the olecranon. Between these two is an intermediate transverse depression (fig. 3, *C*) which is not subject to much of the pressure of the humerus, and which is often found to be devoid of cartilage; a band of synovial membrane, with fat, sometimes extends across it. The sharp projecting edges of the olecranon and coronoid process, do not, in the most extreme flexion and extension, come quite into contact with the floors of their respective fossæ. Such contact would be liable to cause chipping or some injury of the bone; accordingly a stop is put to the movements of the joint, and any mischievous collision of the articular edges is prevented by the shape of the articular surfaces, and by the disposition of the ligaments. The *lesser Sigmoid cavity*, which is continuous with the greater, is concave, and it is narrower at the fore and hinder parts, than in the middle. The opposed margin of the head of the radius is shaped in a corresponding manner; and the two surfaces have their broadest parts in contact, and are exactly adapted to one another in the posture of semipronation, which is the posture of most ease, and of greatest strength (page 378).

Articular surface of radius. One is surprised that so shallow a cup upon the extremity of the radius should suffice to withstand the tendency of the biceps muscle to pull it forwards from the condyle. It could not do so if the radius were not tightly bound to its place in the sigmoid cavity of the ulna by the coronary and other ligaments, which are nevertheless so arranged as to leave the bone free to rotate upon the condyle. The inner and hinder margin of the cup, which has, in a more particular manner, to resist the pull of the biceps, is rather deeper than the rest of its circumference[1]. The circumferential margin is flattened and covered with cartilage all round, so as to lessen the friction upon the lesser sigmoid cavity of the ulna and the coronary ligament, in the rotatory movements of the bone. The inner part, which plays in the lesser sigmoid cavity, is much deeper than the remainder

[1] A case is related by Mr Adams, *Cycl. Anat.* II. 73, in which, after the elbow had been weakened by an injury, the ligaments gave way and the head of the radius was gradually drawn forwards by the contractions of the biceps, so as to rest upon the fore part of the condyle of the humerus.

of the edge. Both it and the corresponding surface of the ulna (*H*) are sloped a little outwards from above, so that the edge of the ulna underhangs the surface of the radius; this prevents the latter from being drawn away from the ulna by a pull upon the hand. The disposition of the articular surfaces in the lower joint between the radius and the ulna is just the reverse (Pl. XXXIII. fig. 1).

Anterior ligament.

The *anterior ligament* of the elbow (Pl. XXXII. fig. 1, *D*) is composed of crossing and interlacing fibres, which pass from the front of the humerus above its articular surface, enclosing the coronoid fossa, to the edge of the coronary ligament in front of the head of the radius, and to the margin of the coronoid process of the ulna. It is of considerable strength; and it sets bounds to the extension of the joint, before the tip of the olecranon comes into contact with the bottom of its fossa in the humerus. The prominence of the trochlea and of the fore part of the outer condyle of the humerus, over which the ligament becomes stretched as the extension of the joint proceeds, increases its power of limiting that movement. In flexion of the joint the ligament

DESCRIPTION OF PLATE XXXII.

Fig. 1. Front view of ligaments of left elbow-joint. *A*, *B*, *C*, cut ends of humerus, radius, and ulna. *D*, anterior ligament. *E*, internal lateral ligament. *F*, external ditto. *G*, smooth external surface of coronary ligament. *H*, fibres passing from coronoid process to join coronary ligament. *I*, loose fibro-synovial membrane beneath coronary ligaments.

Fig. 2. Hind view of ligaments of left elbow-joint. *A*, *B*, *C*, cut ends of humerus, radius, and ulna. *D*, *D*, thin portion of posterior ligament, passing from edge of olecranon to olecranon fossa. *E*, thicker portion of posterior ligament, passing from edge of lesser sigmoid cavity to hinder surface of external condyle. *F*, fibres passing from lower edge of lesser sigmoid cavity to coronary ligament. *G*, tendinous fibres running from olecranon along back of ulna.

Fig. 3. View of inner side of left elbow-joint. *A*, internal condyle of humerus. *B*, ulna. *C*, anterior fibres of internal lateral ligament. *D*, the same continued down inner side of coronoid process. *E*, middle, and *F*, posterior fibres of internal lateral ligament. *G*, fibres passing across between olecranon and coronoid process.

Fig. 4. View of outer side of left elbow-joint. *A*, *B*, *C*, cut ends of humerus, radius, and ulna. *D*, outer condyle. *E*, external lateral ligament. *F*, coronary ligament tightly stretched over head of radius. A needle has been thrust beneath the loose fibro-synovial membrane below the coronary ligament.

Fig. 1.

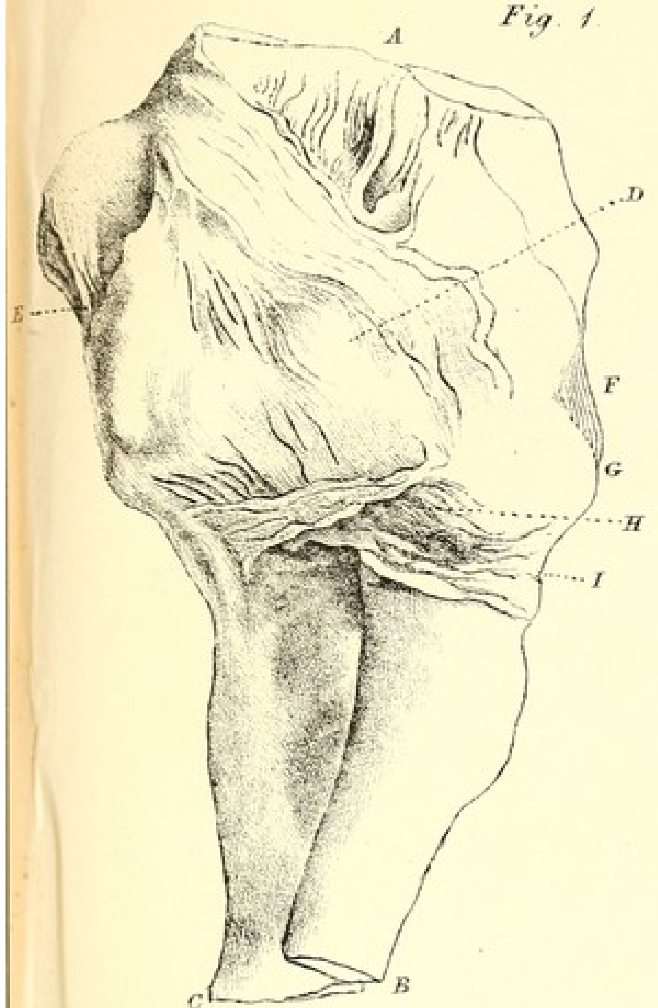


Fig. 2.

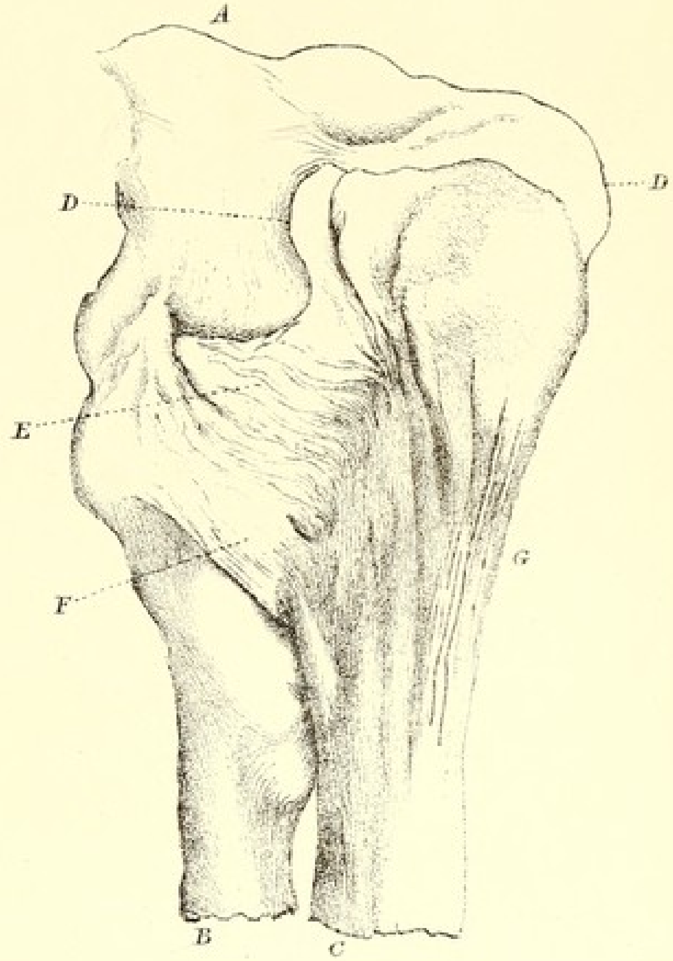


Fig. 3.

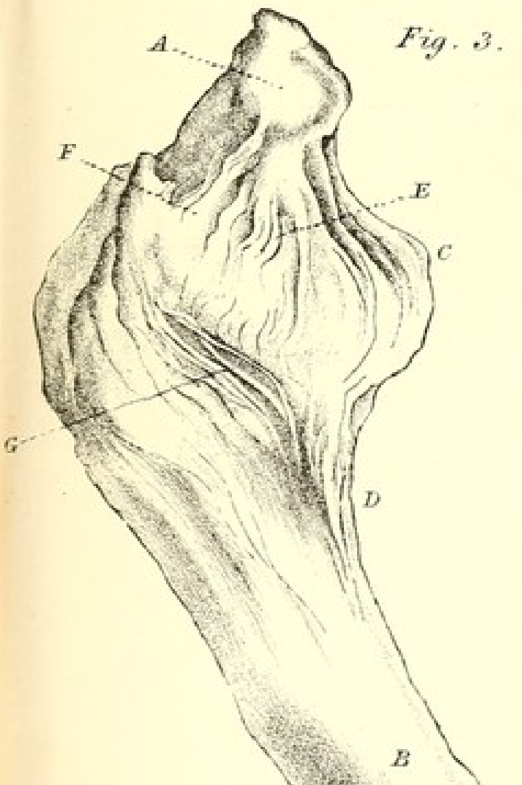
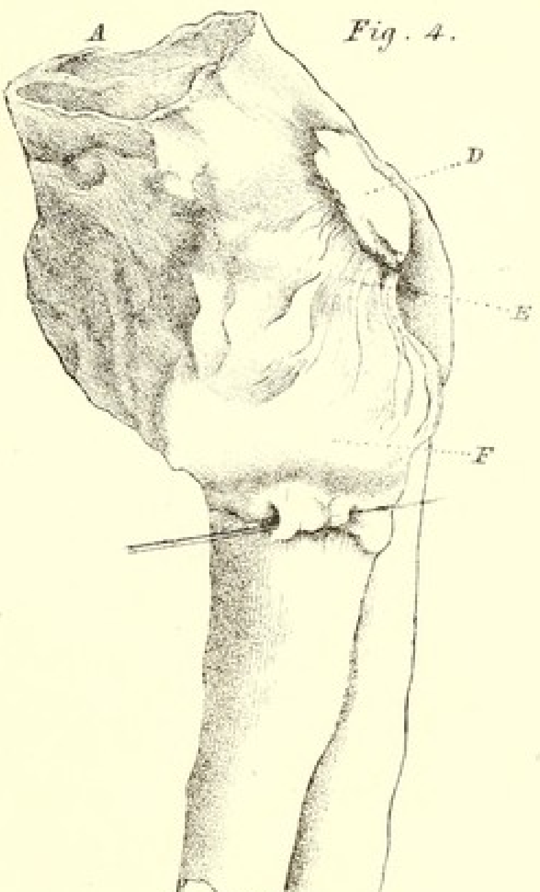


Fig. 4.



becomes transversely wrinkled; and its folds are carried before the ulna and radius, and are received into the upper part of the coronoid fossa and into the depression in front of the outer condyle, where there is sufficient space to prevent its being squeezed between the approximated surfaces of the bones. The preponderating direction of the chief bundles of the fibres of this ligament is from above downwards and *outwards*, though some of them pass downwards and inwards.

Posterior ligament. The *Posterior ligament* is thinner than the anterior. Its fibres are disposed in two divisions, of which one (fig. 2, *D* and Pl. XXXI. fig. 3, *D*) passes, from the upper surface of the olecranon, between its margin and the smooth eminence (*F*) for the bursa under the triceps, to the outer and inner sides of the trochlea, and to a line extending transversely across the olecranon fossa. This line divides the fossa into two nearly equal parts; of which the lower is included in the joint, while the upper is occupied by an elastic cushion of fat and soft cellular tissue, which adapts itself to the varying space in the fossa caused by the movement of the olecranon to and fro.

The synovial membrane is looser and less closely invested by surrounding tissues in the neighbourhood of the olecranon than at any other part; and the ligaments are here weaker. Hence in case of effusion into the joint the swelling may be first perceived in this situation, and there is a bulging on either side of the olecranon and of the tendon of the triceps.

The other division of the posterior ligament is situated nearer to the exterior of the joint (Pl. XXXII. fig. 2, *E*). It passes from the hinder margin of the lesser sigmoid cavity of the ulna, and from the adjacent part of the coronoid ligament, upwards and outwards, to the hinder edge of the articular surface of the outer condyle. It is thicker than the inner division which is connected with the olecranon. It is rendered tight by flexion of the joint; and limits that movement. The preponderating direction of its fibres is downwards and *inwards* from the condyle of the humerus, which is the reverse of that of the fibres of the anterior ligament. The one (the posterior ligament) has, consequently, a tendency to prevent displacement of the radius and ulna *in*wards, while the other has a like influence in preventing dislocation *out*wards.

Internal lateral ligament. The *Internal lateral ligament* (fig. 3) is of triangular shape; it radiates from the under edge of the internal condyle (*A*) of the humerus to the thick projecting inner edge of the coronoid process, to the rough inner and upper portion of the olecranon, and to the interval between the two processes. It is of considerable strength, and may be described as consisting of three distinct portions. 1. The middle and largest portion (*E*) rises from the short thick ridge that descends from the internal condyle, just below the smooth depression for the attachment of the tendon of the flexors of the forearm, forwards and downwards, towards the side of the trochlea; from this point the fibres radiate out, and are connected with the inner margin of the sigmoid cavity, between the coronoid process and the olecranon. Near their insertion they are covered by, or are more or less blended with, a bundle of tendinous fibres (*G*) passing from the olecranon to the coronoid process. The point of attachment of this middle portion of the ligament is in, or near, the axis of motion of the joint, and its component fibres are, therefore, tight in every position of the forearm. 2. An anterior division (*C*) of the ligament runs from the fore part of the condyle to the side of the coronoid process, and is tense during the state of extension only. Some of its fibres (*D*) descend upon the side of the coronoid process to the shaft of the ulna. 3. A posterior portion (*F*) passes from the lower and hinder edge of the condyle to the margin of the olecranon, and is tight only when the joint is flexed.

External lateral ligament. The *External lateral ligament* (fig. 4, *E*) is also a radiating ligament. Its upper narrower end is attached to the lower and anterior edge of the rough projecting ridge on the exterior of the outer condyle (*D*), and to a small pit between the extremity of that ridge and the middle of the articular surface of the capitulum. Its fibres pass downwards, are spread out fan-like, and are connected with the outer part of the coronary ligament (*F*); the foremost fibres, which are the longest, advance upon the front of the joint to a greater extent than do the hinder ones upon the back of the joint. The latter are blended with the fibres of the posterior ligament (fig. 2, *E*), and the former with those of the anterior ligament. Some of the fibres are tense in every position of the joint; many of them, however, being connected with the condyle of the humerus a little in front of the axis of motion, are tightened only when the joint is extended.

Coronary ligament.

The *Coronary ligament* (Pl. XXXI. fig. 1, *F*, fig. 2, *E*, and XXXII. fig. 4, *F*) is a broad strong structure applied like a collar round the flat edge of the head of the radius, and encircling its whole circumference, except that part of it which occupies the lesser sigmoid cavity of the ulna. It is attached to the anterior and posterior margins of the lesser sigmoid cavity of the ulna, and, by long stout bundles of fibres (fig. 2, *F*), to the rough ridge that descends from the hinder edge of that cavity, as well as to the ridge that descends from the inner side of the coronoid process near the anterior edge of the cavity (fig. 1, *H*). The fibres from these two ridges, passing outwards, in front and behind the joint, meet on the exterior and form an inverted arch, which is tightened and strengthened by the blending of the fibres of the external lateral ligament (Pl. XXXI. fig. 1, *E*) with its highest point, as well as by the union of the fibres of the anterior and posterior ligaments, in front and behind (Pl. XXXII. fig. 1, *D*, and fig. 2, *E*). While the upper edge of the coronary ligament is thus tightly fixed by its connection with these three ligaments the lower concave edge is quite free, from one extremity to the other, having no connection with the radius, except through the medium of the synovial membrane. The latter lines the inner surface of the coronary ligament, passes beneath its lower edge for some distance, and is thence reflected with a few bundles of fibrous tissue upon the neck of the radius (Pl. XXXI. fig. 1, *G*, and fig. 2, *F*). The upper part of the neck of the radius, like those of the humerus and femur, is surrounded by synovial membrane with a thin layer of fibrous tissue; and it, together with the head of the bone, is quite free to rotate upon the outer condyle of the humerus, in the circle prescribed by the coronary ligament.

Neck of radius circumstanced like necks of humerus and femur.

Dislocations.

The elbow-joint is very liable to dislocation, especially in children. The accident is commonly caused by a fall upon the hand; and displacement of both the bones backwards is the most common form of dislocation. When the displacement is so great that the coronoid process of the ulna is driven back into the olecranon fossa of the humerus, there must be extensive laceration of the anterior and lateral ligaments. I have found, however, that the displacement is not generally so complete, but that, more commonly, the *coronoid process rests upon the hinder part of the trochlea*, its passage into the olecranon fossa being resisted by the ligaments and muscles which are less torn than in the complete dislocation. The signs of the displacement under these circumstances are not very distinct, so that it may be overlooked, without care; or the case may be mistaken for one of fracture of the lower end of the humerus. The dislocation, whether complete or incomplete, may generally be reduced without difficulty; indeed it is often reduced by the patient or by a friend, before it is seen by the medical man. Nevertheless, I have now and then found it necessary to use considerable force in reducing it. It is probable that, in such cases, the resistance to the replacement of the bones was owing to the lateral ligaments remaining more or less uninjured. The coronary ligament is torn only when one of the bones is dislocated without the other; for instance, when the ulna is thrown backwards, or when the radius is thrown forwards or backwards upon the outer condyle. The displacement of the radius in the latter direction, according to the experience of Sir A. Cooper, is a less frequent occurrence than forwards, which we should have been scarcely led to expect from a consideration of the anatomy of the parts and of the direction in which the disturbing forces are usually received.

Several examples of congenital dislocation have been described[1]. The peculiar features of this deformity are deficiency of the capitulum of the humerus, and elongation of the neck of the radius; so that the head of the latter bone is on a level with the extremity of the olecranon, affording an interesting illustration of the tendency to the overgrowth of the extremity of a bone when it is not checked by the pressure of the bone against which it should have been applied (see p. 49).

Loose cartilages.

Loose cartilages are occasionally met with in the elbow-joints; also ossicles, smooth or nodulated, are, now and then, found hanging into the coronoid and olecranon fossæ[1]. These

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[1] *Cycl. Anatomy*, article "Elbow."

ossicles are the result of disease, and must not be mistaken for sesamoid bones.

THE INFERIOR RADIO-ULNAR JOINT (Plates XXXIII. and XXXIV.)

corresponds in many respects with the superior radio-ulnar joint. In the latter, however, the round head of the radius rotates, upon its own axis, in the circle formed by the orbicular ligament and the lesser sigmoid facet of the ulna; whereas, in the present instance, the end of the radius revolves round the lower end of the ulna, and the concave surface on the side of the former bone is adapted to the convex facet on the side of the latter. The direction of the articular surfaces is very oblique from below upwards and outwards, (Plate XXXIII. fig. 1); so that the ulna *over*hangs the radius, and receives part of the forces transmitted from the wrist[2]. The great bond

Triangular ligament.

of union between the two bones is the strong *triangular ligament* (*C*), which is connected, by its base, with the projecting ridges that bound the concave facet of the radius in front and behind, and with the angular line that intervenes between those ridges and separates the facet for the ulna from that for the semilunar bone. The apex of the ligament is attached to a rough space on the ulna, in the retiring angle, just above the styloid process, and is the centre around which the base of the ligament, with the radius, revolves in pronation and supination. The synovial cavity extends a short distance between the base of the ligament and the lower part of the convex surface of the ulna, and is quite shut off from the wrist-joint by the ligament; it extends up some little distance between the radius and ulna, and is enclosed merely by the synovial membrane, which is attached to the opposed margins of the articular surfaces of the two bones, and which forms a loose bag between them permitting free movement, called the *Membrana sacciformis* (fig. 2, *S*).

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[1] Guy's Museum; Otto, *Seltene Beobach.* II. 37; and *Transactions of Path. Soc.* II. 109 and 248.

[2] In the superior radio-ulnar joint the direction of the shape of the articular surfaces is just the reverse, that of the ulna *under*hanging that of the radius. (Pl. XXXI. fig. 1, *H*.)

JOINTS OF THE WRIST AND HAND.

Of the three rows of joints between the forearm and the metacarpus, the upper—or *Radio-carpal*—admits of the most, and the lower—or *Carpo-metacarpal*—of the least motion. In neither of the joints is much security afforded by the shape of the articular surfaces, nor, indeed, by the ligaments, the especial office of which is to bind the bones together. Nevertheless dislocations at this part are very rare, scarcely ever occurring except as the result of some violent contusion, which is attended with extensive laceration of the soft parts and with fracture of the bones. The strength of these joints is in great measure due to the number of tendons which pass over them, and to the quantity of tough fibrous tissue which forms the sheaths of the tendons. So firmly are the several bones bound together by these means, that the carpal and metacarpal joints are capable of withstanding a far greater force than the radius and ulna. Their strength is also partly due to the fact that the movements are shared by several joints, and are, therefore, not very free in any one.

DESCRIPTION OF PLATE XXXIII.

Fig. 1. Vertical section, from side to side, through the right wrist. *A* the radius. *B*, the ulna. *C*, triangular ligament. *D*, internal lateral ligament. *E*, external lateral ligament. *F*, scaphoid bone; *G*, semilunar; *H*, cuneiform; with ligaments uniting their upper edges. *I*, trapezium. *K*, trapezoid. *L*, magnum. *M*, unciform. Transverse ligamentous fibres unite the two latter. *N*, *N*, transverse ligaments between heads of middle metacarpal bones. These, in consequence of the arched form of the part, laid behind the section which passed through the heads of the metacarpal bone of the thumb (*O*) and the little finger (*P*).

Fig. 2. Hind view of left wrist-joint. *A*, radius. *B*, ulna. *C*, triangular ligament. *D*, internal lateral ligament, passing to cuneiform bone, and on, from it, to lesser metacarpal bone. *E*, external lateral ligament. *F*, *G*, *H*, portions of posterior ligament passing respectively to cuneiform, semilunar and scaphoid. *I*, transverse ligament extending from (*K*) the scaphoid to (*L*) the cuneiform bone. *M*, head of os magnum. *N*, unciform bone. *O*, Tendon of extensor carpi radialis longior. *P*, tendon of extensor carpi radialis brevior, raised to shew the process of third metacarpal bone upon which it lies. *Q*, Transverse ligament between metacarpal bones of thumb and forefinger. *R*, carpo-metacarpal and transverse metacarpal ligaments. *S*, membrana sacciformis.

Fig. 1.

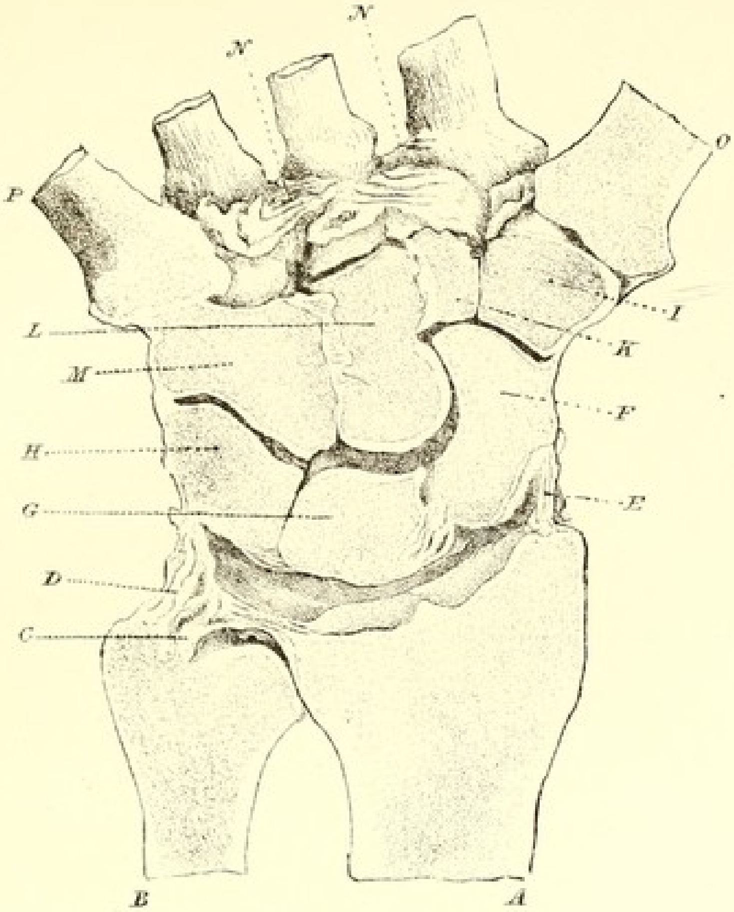
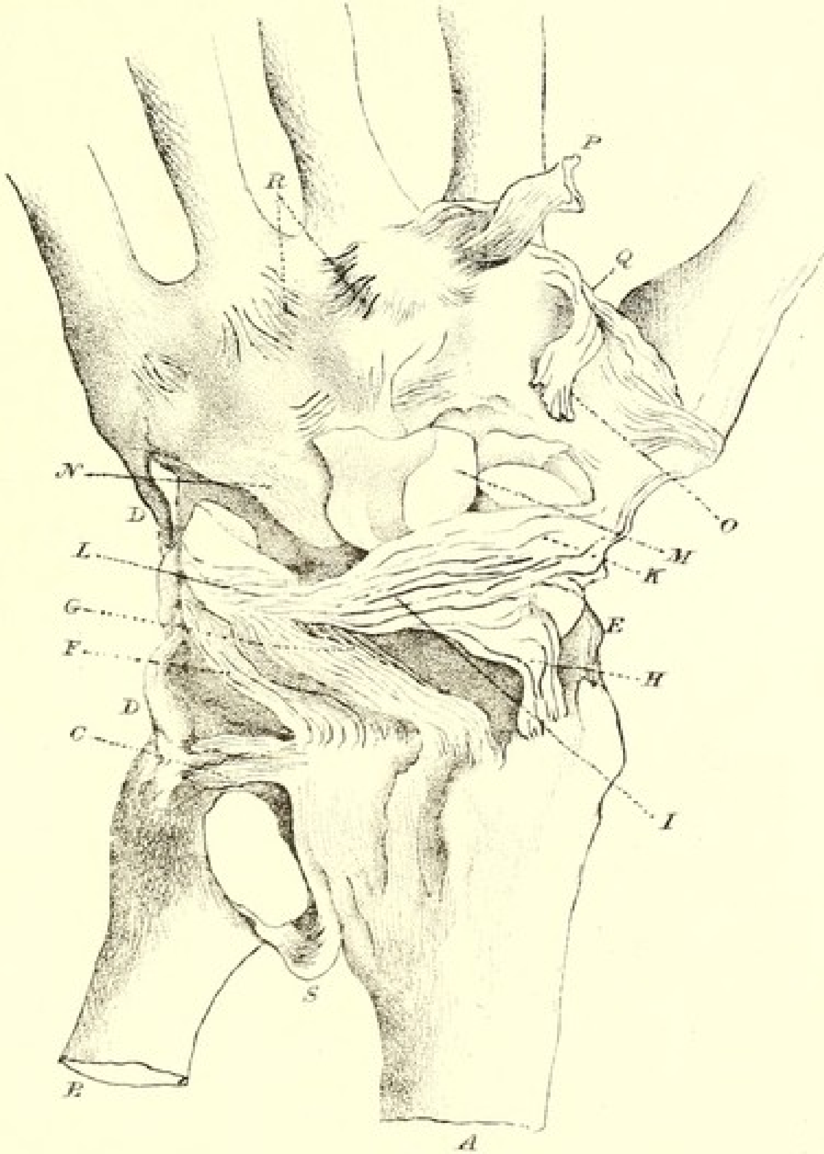


Fig. 2.



THE RADIO-CARPAL JOINT. (Plates XXXIII. and XXXIV.)

Disposition of articular surfaces.

In the *Radio-carpal* joint the lower end of the radius, and the triangular ligament supported upon the ulna, present a superficial concave surface which receives the convexity formed by the Scaphoid, Semilunar, and Cuneiform bones. The middle and larger portion of this surface is oval, with the greatest diameter from before backwards, and is devoted to the Semilunar bone. The outer, more cone-shaped, division receives the Scaphoid; and the inner or smallest segment, which is formed by the triangular ligament, bears the Cuneiform bone. The two latter bones rest upon their respective surfaces in a partial and slanting manner only, their position being such that a considerable part of the weight received by them is transmitted to the semilunar bone which rests more perpendicularly, and by a larger area, upon the radius.

Movements.

The movements of this joint are not very free in any direction. They are *flexion* and *extension*, in which the carpus revolves upon a transverse axis drawn between the extremities of the styloid processes of the radius and ulna; and *abduction* and *adduction*, in which the carpus revolves upon an antero-posterior axis drawn through the head of the os magnum. Adduction may be effected to a greater extent than abduction, in consequence of the mode of disposition of the lateral ligaments; and with greater power, in consequence of the leverage afforded by the projection of the cuneiform and pisiform bones on the inner side of the wrist. This is the reason that the hand commonly assumes the position of adduction, and the little finger becomes inclined towards the ulna, when, from disease or other cause, the muscles lose the influence of volition and exercise an uncontrolled sway over the part.

Rotation does not take place in the wrist, being prevented by the transversely elongated shape of the articulation. It is, however, provided to the hand by the pronation and supination of the radius upon the ulna. There are movements intermediate between those above mentioned (that is, between flexion and extension, on the one hand, and abduction and adduction on the other); these constitute a sort of *circumduction.*

Posterior ligament.

On the back of the joint the ligaments are weak. One band (Pl. XXXIII. fig. 2, *F*) passes from the edge of the groove upon the radius, which is occupied by the extensors of the fingers, to the back of the cuneiform bone; another (*G*) runs from the ridge and groove for the extensor tertii internodii pollicis to the back of the semilunar bone; and a third (*H*) from the groove for the radial extensors to the back of the scaphoid bone. These three, more or less closely united by intervening fibres, make up the *Posterior ligament.* The direction of their fibres is chiefly *outwards* as well as downwards, so that they assist in carrying the hand with the radius in pronation.

Anterior ligament.

The *Anterior ligament* (Pl. XXXIV.) is much stronger; and the fibres, passing obliquely *inwards* as well as downwards, assist in carrying the hand with the radius in the powerful movement of supination. It consists of two chief bands; an outer one (*F*), arising from the stout ridge just above the styloid process of the radius, or rather from an uneven depression between that ridge and the margin of the articular surface for the scaphoid bone, runs over the scaphoid bone, having very little connection with it, and is attached chiefly to the semilunar bone; some

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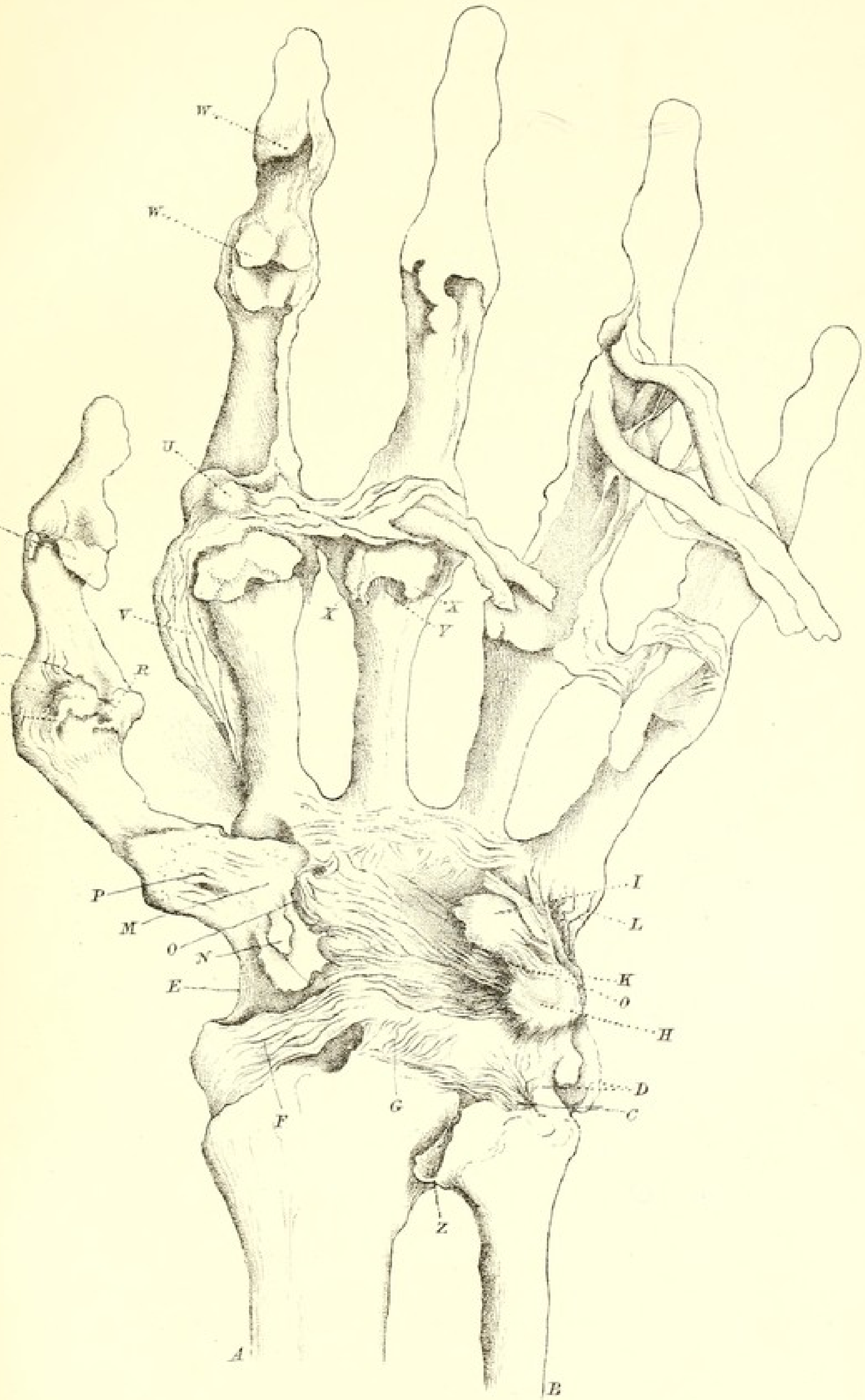
DESCRIPTION OF PLATE XXXIV.

Front view of joints of wrist and fingers. *A*, radius. *B*, ulna. *C*, triangular ligament. *D*, internal lateral ligament. *E*, external lateral ligament. *F* and *G*, outer and inner portions of anterior ligament, with the interval between them. *H*, pisiform bone; *I*, unciform process, and *K*, strong interosseous ligament between the two. *L*, ligament from pisiform to 5th metacarpal bone. *M*, trapezium. *N*, tendon of flexor carpi radialis entering groove in trapezium. *O*, *O*, cut edges of anterior annular ligament. *P*, capsule of carpo-metacarpal joint of thumb. *Q*, sesamoid bone connected with the other sesamoid by transverse ligament (*R*), with the metacarpal bone by anterior fibres of lateral ligament (*S*), and with phalanx by short stout fibres (*T*). *U*, sesamoid body of forefinger connected with interosseous muscle (*V*), with the phalanx, and with the transverse ligament. *W*, *W*, sesamoid bodies in front of phalangeal joints. *X*, *X*, prominences on fore part of head of metacarpal bone. *Y*, depression between the prominences. *Z*, membrana sacciformis.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of its fibres run on to the magnum and unciform bones. The inner band (*G*), arising from the eminence that surmounts the articular surface for the semilunar bone, runs over the semilunar bone, and is attached to the adjacent parts of the magnum unciform and cuneiform bones. The fibres of this band are less oblique than those of the outer portion. Between these two bands is an interval corresponding with a slight depression in the radius. Vessels pass into the joint here.

External lateral ligament.

The *External lateral ligament* (*E*) passes, from the extremity and fore part of the styloid process of the radius, to the inner and fore part of the scaphoid and the adjacent edge of the os magnum. The fibres of this ligament, being directed inwards, to the fore part rather than the side of the joint, so as to be blended or nearly blended with those of the anterior ligament, combine with the latter in limiting the extension of the wrist, as well as in assisting to carry the hand with the radius in supination. They also serve to limit adduction of the hand.

Internal lateral ligament.

The *Internal lateral ligament* (*D*) passes, from the extremity and outer side of the styloid process of the ulna, to the side of the cuneiform and the pisiform bones. Some of its fibres, arising in close connection with those of the triangular ligament, pass outwards, nearly parallel with them, and are attached to the fore part of the cuneiform and to the adjacent edges of the unciform and semilunar bones. It limits abduction of the wrist, and also contributes, with the anterior and external lateral ligaments, to limit extension.

THE CARPAL JOINTS. (Plate XXXIII.)

The surfaces of the carpal bones present great variety of form, and are well adapted to each other. The several bones are bound together by short ligaments passing, from one to the other, in front and behind, as well as by an extension upon them of the fibres of the ligaments of the wrist-joint just described, by the sheaths of the tendons, and by the annular ligaments. The bones of each row are also united together by secondary ligamentous bundles extending between them in a transverse direction. In (fig. 1) these

Intermediate ligaments. *Intermediate ligaments* are seen passing from the scaphoid to the semi-lunar and from the semi-lunar to the cuneiform; also from the unciform to the magnum, whereas between the trapezoid and the trapezium the continuity of the carpal with the carpo-metacarpal joints is shown. In the first row they are situated close to the *upper* edges of the bones, so as to fill up the intervals between them, to prevent their separation by the pressure of the os magnum, and to present an even convex surface to the radius and the triangular ligament. The intermediate ligaments are all *transverse*, uniting the bones of the respective carpal rows, and not passing between the two rows, so that the latter are left free to play upon one another.

Joint between first and second row of carpal bones. Thus a second hinge-joint is formed, which resembles the wrist-joint, and increases the range of flexion and extension of the hand upon the forearm. In the wrist-joint extension is more free than flexion, owing to the articulating surfaces being continued further upon the dorsal than upon the palmar aspect of the carpal bones. This, however, is more than counterbalanced by the amount of flexion which is permitted in the joint between the two rows of carpal bones. So that, on the whole, the range of flexion of the hand upon the forearm is greater than that of extension. The alternating concavo-convex facets of the two rows are so adapted to one another as to prevent all movements besides flexion and extension; and the joint is rendered very secure by the extent and variety of shape of the opposed surfaces.

Dislocation rare. Dislocation of the second row *forwards* is prevented by the manner in which the concave surfaces of the trapezium and trapezoid rest upon the posterior convex facet of the scaphoid, as well as by the undulating manner in which the side of the unciform is disposed with regard to the side of the cuneiform. Displacement *backwards* is prevented by the manner in which the round head of the os magnum (fig. 2, *M*), and the convex posterior and upper surface of the unciform (*N*) are let into the hollow formed in the anterior and inferior surfaces of the scaphoid semilunar and cuneiform.

Transverse ligament.

The cup for the head of the os magnum is further deepened by a strong *Transverse ligament* (*I*) extending, across the head of the os magnum, from the back of the scaphoid (*K*) to the back of the cuneiform (*L*).

Other ligaments.

The joint between the two rows has, in addition, special ligaments, resembling those of an ordinary hinge-joint. The *Posterior ligament* consists of a few delicate bundles, which pass between the adjacent edges of the contiguous bones. It is weak, much strength being rendered unnecessary by the quantity of fibrous tissue which is derived from the sheaths of the tendons at the back of the wrist. The *Anterior ligament* consists of bundles similarly disposed, and is stronger than the posterior, though, for a similar reason, it is not very strong. The *External ligament* is broad and strong, and composed of bundles of fibres passing from the outer edge of the scaphoid to the outer edge of the trapezium. Its anterior fibres limit extension, and its posterior fibres limit flexion. The *Internal ligament* passes from the edge of the pisiform to the adjacent edge and hamular process of the unciform. It is situated nearer the front than the back of the joint, and serves to limit extension.

Annular ligaments.

The several carpal bones are held together by other short ligaments which need no especial description. Besides these, there are the *Anterior* and *Posterior annular ligaments*, both of which are of considerable strength. The *Anterior*, passing from projecting bony points—the pisiform and the hamular process of the unciform—on the one side, to the scaphoid and trapezium on the other, strengthens the carpal arch and binds down the flexor tendons. Its deeper fibres are reflected inwards upon the anterior surface of the carpal bones, are continuous with the interosseous ligaments, and converge towards the head of the os magnum. The *Posterior annular ligament*, arising from the ridges on the hinder surface of the radius, passes inwards and downwards to the cuneiform, pisiform and little metacarpal bones; it binds down the extensor tendons, and assists to carry the hand with the radius in pronation. Its uppermost fibres, which curl beneath the lower extremity of the ulna, in their way to the pisiform bone, and which bind down the extensor carpi ulnaris, are particularly strong.

The various carpal joints are continuous with one another, with the radio-carpal joint above and with the carpo-metacarpal joints below.

CARPO-METACARPAL JOINTS.

The distal edge of the carpus presents a remarkably wavy line, to which the metacarpus is adapted; each bone is convex at one part and concave at another (Pl. XXXIII. fig. 1); and the several convexities and concavities are arranged alternately, which affords so great security that dislocation scarcely ever takes place. The metacarpal bones are united to the carpal by short ligaments passing from one to the other on the dorsal (fig. 2, *R*) and palmar surfaces; and the proximal extremities of the former are bound together by transverse ligaments (fig. 1, *N*). The metacarpal bones of the index and middle fingers are almost immoveable; and the ligaments uniting them with the carpus are consequently short. The metacarpal bones of the ring and little fingers are, to a certain extent, moveable (p. 391), and are less tightly bound to the carpus; and, in the case of the little finger, there is a regular capsule of considerable strength, resembling very much that which binds the thumb to the trapezium[1].

JOINTS OF THE THUMB. (Plate XXXIV.)

Carpo-metacarpal joint. The carpo-metacarpal joint of the thumb is protected by a *capsular ligament* (*P*), which is composed of bands passing from the trapezium to the metacarpal bone. These are stronger at some points than at others, have been described as separate ligaments, and have been named, according to their position, *dorsal*, *palmar*, *internal*, and *external*. They are stronger upon the hinder part, where the joint is least covered by muscles, than elsewhere. These bands are not tight, do not hold the bones closely together, and do not, therefore, prevent move-

[1] See similar disposition described in the account of the tarso-metatarsal joints.

ment in any direction; they merely set bounds to it. The movements are regulated by the shape of the articular surfaces. In flexion and extension the thumb slides to and fro upon the trapezium, and revolves in a circle, the centre of which is at some distance above the trapezium; whereas in abduction and adduction the thumb revolves, in the socket of the trapezium, upon an axis drawn through its own head. Circumduction may take place freely; but there is no rotation.

A ligament (Pl. XXXIII. fig. 2, *Q*), corresponding with the transverse metacarpal ligaments just mentioned, runs from the upper end of the metacarpal bone of the thumb to the adjacent extremity of the metacarpal bone of the index finger, and serves to prevent undue separation of the thumb from the fingers.

The thumb is much exposed to injury, the range of its movement upon the carpus being free. But the ligaments binding it to the trapezium are very strong; and this joint receives so much support from adjacent muscles and tendons that it is rarely dislocated. Sir A. Cooper and Boyer each met with but one instance of the accident.

THE METACARPO-PHALANGEAL JOINT

of the thumb is practically a hinge-joint, the ordinary movements being those of *flexion* and *extension*. Slight *lateral motion* may be effected when the joint is a little bent; but much lateral motion is not here required in consequence of the free play of the metacarpal bone upon the carpus. The articular surfaces present a similarity to those both of the metacarpo-phalangeal and of the phalangeal joints of the fingers. Thus the head of the metacarpal bone resembles the heads of the other metacarpal bones in its rounded form, and in the prolongation of its articular surface upon the palmar aspect by means of two stout lateral tubercles with a marked depression between them. These tubercles, upon which the sesamoid bones rest, and the intervening fossa, are even more marked in this than are the corresponding features in the other metacarpal bones. The first phalanx of the thumb, on the other hand, resembles the second phalanges of the fingers in presenting a slight projection forwards of its articular surface in the middle, so as to form a blunt tooth-like process, which, jutting between the sesamoid bones, and falling, when the thumb is bent, between the lateral prolongations of the metacarpal bone, on which the sesamoids rest, serves to steady the joint and to prevent lateral motion in the flexed position.

Lateral ligaments.

The *Lateral ligaments* (Pl. XXXIV. *S*) are short and very strong. They radiate from the depressions on the sides of the head of the metacarpal bone to the sides of the base of the second phalanx, and to the sides of the sesamoid bones. They are so arranged, with the greater number of their fibres attached a little in front of the centre of motion, that they are most tight when the joint is extended; and they serve, therefore, to limit extension, as well as to prevent lateral motion when the joint is extended. When the joint is a little bent they are relaxed, and permit some lateral motion to take place. If the joint is more bent the hinder fibres become tightened; and, pressing the bones closely together, they serve to limit flexion, and again prevent lateral motion. They are connected behind by ligamentous fibres passing from one to the other, across the joint, and forming a loose capsule, which contributes to limit flexion.

Sesamoid bones.

The two *Sesamoid bones* (*Q*) receive the tendons of the short flexor muscle, and fulfil the several purposes which are served by similar bones in other parts. They are connected with one another by a transverse ligament (*R*), upon which the long flexor tendon plays, and with the fore part of the base of the phalanx by very strong short ligamentous fibres (*T*). With the metacarpal bone they are united only by means of the short flexor muscle and a few fibres of the lateral ligaments (*S*).

Cause of difficulty in reducing dislocations of this joint.

When the joint is dislocated, which almost always takes place from the phalanx being bent forcibly backwards, the sesamoid bones are carried back with the phalanx and become placed behind the head of the metacarpal bone, which is pressed forwards between the bellies of the short flexor muscle. This is the cause of the dislocation being often so difficult to reduce; for the displaced sesamoid bones intervene between the hinder surface of the metacarpal bone and the anterior surface of the phalanx, and, being drawn upwards in this position by the contraction of the short flexor muscle, prevent the articular surfaces from coming into contact, and offer an obstacle to their replacement, which has often been found insurmountable. That this position of the sesamoid bones and of the short flexor muscle is really the cause of the difficulty may easily be proved by dislocating the bones in the dead subject. It will be found that one or both the lateral ligaments are torn, and that the sesamoid bones retain their connection with the phalanx, and with the short flexor muscle in the manner I have described[1]. If now the short flexor be seized with the forceps and kept on the stretch so as to act only slightly upon one sesamoid bone, very powerful traction may be used without replacing the phalanx. Whereas if the lower end of the sesamoid bone be hitched a little forward upon the head of the first phalanx, or even if the influence of the short flexor be relaxed, the dislocation is, at once, easily reduced. In the living subject the difficulty may sometimes be overcome by bending back the phalanx, and so tilting the lower edges of the sesamoid bones downwards and forwards upon the head of the metacarpal bone. If a case resisted traction, tried to a fair extent, I should be disposed to make an incision, at a convenient place, sufficiently large to admit a small blunt hook with which I would endeavour to pull forwards the sesamoid bones. It should not be forgotten that, though the sesamoid bones create so much difficulty in reducing the dislocation, they afford very great protection to the joint against such displacement, extending, as they do, the area of the osseous surface articulated with the metacarpal bone, and converting it, from an almost flat, to a deeply concave shape, in short, constituting a quasi olecranon to the base of the phalanx[2].

Phalangeal joint.

The terminal joint of the thumb is a simple hinge-joint provided with *Lateral ligaments*, which are strong, and which arise from depressions on the sides of the first phalanx, at points about corresponding with the axial line of motion of the joint. They are implanted into the projecting lateral margins of the second phalanx near its base, and into the edges of the

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[1] In a dissected specimen in the Berlin museum the same thing is seen. The sesamoid bones are thrown back with the phalanx, and the head of the metacarpal bone presents between the bellies of the short flexor muscle.

[2] Velpeau has twice seen the first phalanx of the thumb pass in front of the metacarpal bone; and in the first example, which had occurred three days previously, he, as well as MM. Bougon and Roux, failed in their endeavours to reduce it.

sesamoideal body. They are in a state of nearly equal tension in every position of the joint. Perhaps they are somewhat more tight when forced extension is attempted than at other times; but the difference is not great.

Sesamoid body

On the palmar surface of the joint is a *Sesamoid body* (*W*) composed of a flattened lump of fibro-cartilage with, in some instances, a bony nucleus or sesamoid bone in its interior. This body lies beneath the flexor tendon and serves to increase its power by throwing it out from the joint, and distancing it from the centre of motion. Like the sesamoid bones of the metacarpo-phalangeal joint it is only slightly connected with the bone on the proximal side of the joint, and that chiefly through the medium of the lateral ligaments which run into its edge. It is united by tough ligamentous fibres to the base of the distal phalanx, and follows it in its movements.

creates difficulty in reducing dislocations.

Accordingly, as in the case of the preceding joint, it serves to prevent dislocation of the last phalanx backwards; and when that accident does take place it is carried with the displaced bone behind the head of the 1st phalanx. Being here placed between the two articular surfaces it prevents their coming into contact when attempts at reduction are made; and the greater the force which is exerted the more tightly is it wedged between the two bones. I have proved this to be so by experiments on the dead body. In one case of compound dislocation in which powerful extension and divers expedients to reduce the bones had been made for more than an hour by myself and others without success, I contrived to carry a probe to the back of the joint beneath the sesamoid body and tilted up its lower edge; the dislocation was immediately reduced and without any further difficulty.

JOINTS OF THE FINGERS.

The metacarpo-phalangeal and the phalangeal joints of the fingers resemble those of the thumb very closely. On the palmar surface of the metacarpo-phalangeal joints are thick plates of fibro-cartilage, which are joined together by strong transverse ligaments binding the metacarpal bones together. They are grooved by the flexor tendons; and tendinous expansions pass from their edges over the tendons. These *Sesamoid bodies*, like the sesamoid bones of the thumb, are connected, at their sides, with the lateral ligaments. Their upper edges are slightly united with the metacarpal bones, and their lower edges are more closely bound to the phalanges. They serve the purpose of preventing dislocation backwards, and of distancing the tendons from the centres of motion. They follow the phalanges in the movements of the joints and in dislocations, but do not offer so formidable an obstacle to the reduction of the bones as in the case of the thumb. Sesamoid bones are occasionally, though rarely, developed in them[1]; they are most frequently found on the radial side of the index, and on the ulnar side of the little, finger. Sesamoideal fibro-cartilages, similar in shape, connections, and use, to that in the second joint of the thumb, are found on the palmar surfaces of each of the phalangeal joints of the fingers. They are much smaller than that in the thumb; and I am not aware that bone is ever developed in them[2]. They are all more intimately connected with the distal than with the proximal bones of the several joints, and are to be regarded as appendages to the former rather than to the latter; in the same manner as the olecranon is an appendage to the ulna rather than to the humerus, and the patella to the tibia rather than to the femur.

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[1] Morgagni, *adv. anat.* 2; *animadv.* 30, p. 64.

[2] Ilg, *Monographie der Sehnenrollen*, Prag. 1823, Erste Abschnitt, s. 3, describes these bodies under the name of *Sehnenrollen*, and says that they are present, throughout the mammalian class, on the flexor side of the fingers and toes, wherever the movements are free, and that whenever sesamoid *bones* are developed in those of the proximate joints they are generally in pairs, whilst in those of the distal joints they are single. In the Ape, he says, there are two sesamoid bones in the *Sehnenrollen* of each of the metacarpo-phalangeal joints of the four fingers and of the thumb—one on the radial, the other on the ulnar side—; whereas in the ungual joints there are neither sesamoid bones nor *Sehnenrollen*, which is an exception to the general rule in mammals.

THE PELVIS

The ring the essential part: is a bony ring interposed between the spine and the lower extremities, so as to transmit the weight of the head and trunk from the former to the latter. The essential part of the pelvis is the circle which separates the true from the false pelvis, and which is formed, above and behind, by the upper portion of the sacrum; below and in front, by the upper part of the pubic bones together with the symphysis; and, on the sides, by the lineæ ilio-pectineæ, and the adjacent thick middle portion of the iliac bones. This circle is connected with the spine, above, in the middle line, and with the thigh-bones on the sides; and it is the direct means by which the weight is conveyed from the spine to the extremities. It is placed very obliquely, forming an angle of from 60° to 65° with the ground on which we stand[1]. When the pelvis is in this position, that is, when a man stands erect, the transverse plane of gravity of the head and trunk, descending vertically through the chords of the curves of the vertebral column (p. 148), and through the promontory of the sacrum, traverses the heads of the thigh-bones, and passes through the lower extremities to the ankles.

its angle of inclination:

its shape: The ring of the pelvis is by no means a true circle. It is rather heart-shaped. Its transverse diameter exceeds the antero-posterior in the proportion of 5 to 4; and the widest part is a little above the acetabula. If an imaginary transverse division of the pelvic ring be made here, the upper half is a wide arch with a flattened or slightly depressed centre at the pro-

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[1] Naegele, *Ueber das weibliche Becken,* and Weber, *Gehwerkzeuge.* According to the former, the extremity of the coccyx is, in the female, in the erect posture, situate in a horizontal plane seven lines above the lower edge of the symphysis pubis; the upper edge of the symphysis being in the same plane with the lower edge of the second bone of the coccyx.

montory of the sacrum, and with its crura resting upon the thigh-bones. The shape of the curve of the lower division of the ring is different from that of the upper one, being most arched in the middle, i.e. at the symphysis pubis, and most flattened at the sides in the situation of the lineæ ilio-pectineæ.

Its weak points. It results from this configuration of the pelvic ring that it is weakest at five points; viz. at, or a little external to, both sacro-iliac synchrondroses, at the symphysis pubis, and midway between the latter and the acetabula. Hence fractures, whether from falls, blows, or foreign bodies passing over the pelvis, are most frequent at these points, and the bones most commonly yield in them in cases of rickets and mollities.

Pelvis, how balanced upon thighs. The pelvis can be moved in any direction upon the head of either thigh-bone, in consequence of the hip being a perfect ball-and-socket joint. When, however, both lower extremities are placed firmly upon the ground, the pelvis can be moved in one direction only, which is that of rotation upon a transverse axis drawn through the heads of both thigh-bones. By this movement, its angle of inclination is altered with regard to the ground, but not much with regard to the spinal column, which is carried with the pelvis, and which communicates to the trunk an inclination, forwards or backwards, proportionate to the movement of the pelvis. The trunk is thus, in some measure, firmly placed upon the extremities; and, while the latter are steady, can be moved only in one vertical plane. Still, as it is balanced in this plane, in an unstable equilibrium, upon the smooth slippery surfaces of the heads of the thigh-bones, there would necessarily have been great insecurity, if the pelvis had depended for its further fixity entirely upon muscular tension. Moreover, in the propulsion of the pelvis and trunk forwards by the lower extremities, much power would have been lost had it been necessary to prevent the backward inclination of the trunk solely by muscular force. Accordingly an additional provision is furnished in the ligaments of the hip-joint, which are so disposed that, when the body is upright, they are quite tight and prevent any further rolling of the pelvis and trunk backwards upon the thighs. Hence the only direction in which the pelvis and trunk can be moved, from the erect posture, upon the extremities, when the latter are kept fixed, is that of rotation *forwards*, which is one reason that the trunk commonly falls forward when volition is suddenly withdrawn, as in fainting, epilepsy, &c.

Processes projecting upwards and downwards from the pelvic ring

From the ring of the pelvis, which is thus the essential or basement portion of the structure, *Processes* project upwards and downwards, for the purpose of affording leverage to the muscles which roll the trunk upon the thighs, and of protecting the internal organs. The largest of these processes are the *alæ* of the iliac bones, which rise upwards and outwards, forming what is called the "false pelvis," supporting the abdominal viscera, and giving attachment to the abdominal, glutæal, and other muscles. Five processes run downwards and form the "true pelvis;" viz. the *Sacrum* in the middle, and the *Pubic* and *Ischiatic bones* on either side. These five are united together below, the two latter by bone, and the ischia and the sacrum by the strong sacro-sciatic ligaments. By this means the lower part of the pelvis is strengthened, and an inferior circle is formed, which is called the *Inferior strait*, and which is widest beneath the pubic arch. The *Sacro-sciatic* and *Obturator foramina* are openings left between these processes, for the sake of lightening the pelvis, and of affording space for the transmission of vessels and nerves to the lower limbs.

afford leverage to extensor muscles.

The leverage which these processes afford is advantageous in proportion to the distance at which they are placed from the plane of the axis of motion, that is, from an imaginary plane carried upwards and downwards through the heads of the thigh-bones. When the pelvis is in the erect posture, and when the trunk is, consequently, nearly balanced upon the lower extremities, the several processes are all comparatively near to this imaginary plane, and the leverage afforded to the muscles is slight. When, on the other hand, the pelvis is inclined forwards, and, the balance of the trunk being lost, the difficulty of maintaining the position is increased, then the several processes—the sacrum, ischiatic tubera, and anterior spines of the ilia at least—become gradually more distanced from the axial plane, and the leverage presented by them is proportionately increased. By virtue of the additional power which is thus given to the muscles, we are enabled to maintain a stooping posture for some time and with much steadiness, as well as to exert great force in extending the trunk upon the thighs.

Less amount of leverage required by flexors.

It has been already stated that the construction of the ligaments of the hip is such as to prevent the inclination of the pelvis backwards beyond the erect posture. The flexor muscles have, therefore, light work to perform in comparison with their opponents; for when the body is erect, the extensors, combined with the ligaments of the hip, are sufficient to keep it so without any assistance from the flexors. Moreover, the work of bending the body downwards and forwards, which devolves upon the flexors, is not nearly so arduous as that of raising it upwards and backwards, which devolves upon the extensors. The former set of muscles are attached to the processes in front of the axial plane; and it will be observed, that these project very little, and afford, consequently, but slight leverage; and the most prominent of them—the os pubis—projects less and less in proportion as the body is more and more bent. The processes, on the other hand, which are situated behind the axial plane, and give attachment to the extensor muscles, stand out more strongly so as to afford a better leverage to those muscles; and they, the ischiatic tubera more particularly, project further backwards in proportion as the trunk is bent forwards, so as to afford to the muscles an increasing leverage as the office they have to perform becomes more difficult.

Difficulty of raising trunk from stooping to erect posture.

This work of causing the pelvis to revolve upon its axis, so as to bring the trunk from a stooping to an erect posture, is one of the severest efforts which our muscles are called upon to make, both in consequence of the great weight to be raised, and in consequence of the length of leverage, measured by the distance of the head in front of the hips, in which that weight is disposed when the body is much bent. The largest, strongest, and coarsest muscles in the body—the glutæi—are assigned to the task, and they are attached to the back of the sacrum and the hinder parts of the ilia; that is, to the parts of the pelvis most favourable to their action.

Width of ilia and ischia assists muscles to fix pelvis.

The great width of the iliac bones, and the outward slant of their alæ, as well as the width and strength of the ischiatic bones, is also for the purpose of affording attachment to muscles and of enabling them to fix the pelvis upon the thighs, and of preventing too great inclination to either side when the weight is supported upon one limb, as in walking.

Lower processes adapted for sitting.

The prominent, thick, blunt tuberosities of the ischia are placed immediately under the acetabula, in such position that when the trunk is erect the transverse plane of gravity falls through their fore part. We are thus balanced upon them when sitting upright, or when inclined a little backwards. If we lean further back the weight falls partly upon the sacrum; and we then rest upon the tripod formed by the ischiatic tubera and the sacrum. The latter bone is curved forward at its lower part to afford a greater basis of support, and to permit of our sitting with comfort, or of our rolling to and fro upon our seat. Had it descended straight, as it does in most of the lower animals, it would have projected to, or beyond, the level of the ischia, and, by its pointed shape, would have interfered greatly with our comfort. The bend of the sacrum forwards, moreover, serves, in the erect posture, to support the viscera.

Curve of pelvis.

This bend of the sacrum gives to the interior of the cavity of the true pelvis a *curve*, which is peculiar to the human subject, and which constitutes one of the difficulties in parturition; for the head of the child has to follow this curve, and has, consequently, a less easy passage than if the pelvis had been straight. An imaginary line following the curve, and drawn through the centre of the pelvis, so as to fall at right angles upon the upper, lower, and various intermediate, antero-posterior diameters, is called the *axis of the pelvis*.

Size and shape of cavity.

To meet the difficulty resulting from the curved form of the pelvis and from the large size of the fœtal head, the depth of the cavity is reduced, and the transverse diameter of the pelvis is increased, in comparison with that of the lower animals, so that the apertures have a more circular shape than in the latter. These peculiarities are most marked in the pelvis of the female. Moreover, the shape of the cavity varies in different parts of its depth.

Thus, at the upper aperture, or *brim*, the transverse diameter, measuring about 5.4 inches in the well-formed female pelvis, is greater than the antero-posterior diameter, which measures 4.4 inches, or than the oblique diameter, which is 4.8 inches. In the middle of the cavity the presence of the obturator or sciatic holes renders the oblique diameter, which is here 5.2 inches, greater than any other: the antero-posterior diameter is here 4.8, and the transverse 4.3 inches. At the lower part, or inferior outlet, the pubic arch, together with the mobility of the coccyx, causes the antero-posterior diameter, drawn from the extremity of the coccyx to the lower edge of the symphysis pubis, to be the greatest; it measures about 5 inches, the transverse being 4.3, and the oblique, from the middle of the sacro-sciatic ligament to the ramus of the ischium and pubes, 4.8.

Passage of fœtal head. The fœtal head is of oval shape, with the greatest diameter from before backwards; and, in its passage through the pelvis, it is, as a general rule, so placed, by the mere pressure of the surrounding parts, that its longest diameter is, at each stage, accommodated to the greatest diameter of the pelvis. Accordingly in the first stage of parturition, the head[1], as it enters the pelvis, is placed transversely, the occiput being directed towards one ilium, and the face towards the other; the narrowest end of the oval which the head presents, namely that formed by the occiput, takes the precedence. During the second stage, as the head descends through the pelvis, it undergoes a half-quarter turn, so that in the middle of the cavity the occiput is turned towards one obturator hole, and the face towards the opposite sciatic hole. The rotation continuing with the progress of labour, the head undergoes a further half-quarter turn; so that in the last stage, during the transit through the inferior outlet of the pelvis and along the vagina, the occiput is directed forwards under the pubic arch, and the face is turned towards the sacrum and coccyx. The twist or screw-like movement, which is thus given to the fœtal head in its progress through the pelvis, has the further advantage of rendering its passage more easy than it would have been if the same direction had been preserved during the whole process.

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[1] For cause of frequency of head-presentations, see p. 95.

The accoucheur will fall into mistakes who is not aware of this peculiarity in the shape of the pelvis, and of the rotation which the head, in consequence, undergoes. Thus, in protracted cases of labour, where the head rests at the upper aperture of the pelvis, it is often erroneously supposed that the transverse position of the cranium is the *cause* of the difficulty. Moreover when forceps are necessary, the direction in which they are passed should be varied according to the part of the pelvis in which the head may be placed.

Lower outlet the narrowest part of pelvis.

It may have been observed from the measurements given above that the upper aperture of the pelvis is somewhat the largest, and the lower the smallest part of the cavity; hence difficulty in labour is most frequent in the latter situation, especially as years advance, when the size of this aperture becomes further diminished by the stiffness of the sacro-coccygeal and coccygeal joints, and by the general want of suppleness of the adjacent tissues. The surgeon also should be mindful of the general shape and of the curve of the pelvis in his operations upon the viscera contained in it. More particularly in passing instruments into the rectum he should remember that the bowel follows the curve of the sacrum, and that a straight instrument is likely to meet with obstruction when it comes into contiguity with the promontory of that bone. The difficulty thus created has, in many instances, caused a false suspicion of the existence of stricture in this part of the bowel.

Difference between male and female pelvis.

The pelvis of the *Female* is altogether a lighter, more expanded, and less compact structure than that of the male. Its processes are shorter and further apart, its cavity shallower and wider, and the several diameters are somewhat greater, particularly the transverse diameter of the brim, which measures 5.4 inches, that of the male being only 5.1. The antero-posterior diameter, measuring 4.4 inches, does not, to so great a degree, exceed that of the male, which measures 4.3 inches. The obturator and sacro-sciatic foramina, as well as the apertures, are larger. The symphysis pubis is less deep, and the pubic arch is considerably wider; the junction of the rami of the pubes at the symphysis has been estimated to form an angle of 90° or 100°, whereas in the male it does not exceed 80° or 90°. The sacrum is less curved, is wider, and is directed more backwards from the promontory. The width of the forepart of the pelvic outlet is increased; and the escape of the fœtus is further facilitated, by the slope from within outwards, which is given to the rami of the ischium and pubes near their junction.

All the ligaments uniting the several bones are said to be rather softer and more yielding. It is scarcely necessary to add that these peculiarities of the female pelvis have reference chiefly to the work of parturition.

Pelvis before puberty.

At birth the pelvis is proportionately of small size; and its shape differs from that of the adult both male and female, but chiefly from that of the latter, and approximates somewhat to the pelvis of the lower animals. Thus the antero-posterior diameter equals or exceeds the transverse (p. 110); the cavity is deeper, the sacrum is less curved, and the projection of its promontory forwards is less marked. This latter peculiarity is associated with a straighter spine, and with a greater amount of inclination of the pelvis. The pubes is rather lower, and the hinder part of the alæ of the ilium is proportionately higher than in the adult. Hence the bladder is situated at a somewhat higher point in relation to the pubes in the little child, which should be borne in mind in performing the operation of lithotomy. As growth proceeds, and as the spine becomes more curved, the pelvis gradually acquires more of the adult shape; the promontory of the sacrum becomes more pronounced; the alæ of the ilium become slanted more outwards; and the rami of the pubic and ischiatic bones become more separate, diminishing the relative depth of the symphysis pubis. But it is not till after puberty that the distinctive peculiarities of the male and female pelvis, particularly the preponderance of the transverse diameter, are observed[1]. Hence, at first, the pelvis bears a similarity to that of the lower animals; about puberty it accords in both sexes, nearly, with the type of the adult male pelvis; and after puberty the female pelvis acquires its characteristic shape[2]. In old age the pubes becomes lower again in consequence of the inclination of the trunk forwards; and the enlargement of the prostate often causes the bladder to ascend higher above the symphysis.

Monkey's pelvis.

In Quadrumana the pelvis is longer, and is placed more in a line with the spine. The upper aperture is narrow,

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[1] Indeed it would seem that sometimes the antero-posterior diameter increases in a greater ratio than the transverse, up to puberty. The measurements given at p. 110 do not, however, prove this to be the rule.

[2] It appears that, occasionally, in consequence of arrest of development, the pelvis retains the triangular infantile shape, with prolonged antero-posterior diameter. Specimens to illustrate this fact are preserved in the Musée Dupuytren.

and elongated from behind forwards, so that the antero-posterior diameter measures more than the transverse (p. 106); and the upper edge of the pubes is on a line with, or is lower than, the bottom of the coccyx. The sacrum is nearly straight; and its promontory is less marked, in accordance with the straighter shape of the spine and the smaller size of the lumbar vertebræ. The pubic bones are broad and deep. The iliac bones are long and straight, but narrow in proportion to their length; they are directed transversely outward from the sacro-iliac symphysis, so as to be almost in the same plane with the sacrum; their inner and anterior surfaces are nearly flat, and their posterior surfaces are concave for the attachment of the glutæal muscles. The ischiatic tubera are slanted from before backwards and outwards, in a more marked manner than in the human pelvis.

Negro's pelvis.

The pelvis of the Negro is smaller in all its dimensions than that of the European, and presents a slight general approximation to that of the monkey; more particularly in the deficiency of its width (p. 106). There is a greater difference in this respect between the male and female in the Negro than in the European sexes, so much so that, as remarked by Hildebrandt, it is often difficult to believe that the specimens belong to members of the same race. In some of the male Negroes the small size of the pelvis, and particularly the shortness of the transverse diameter, is very remarkable. In many of the females it is as large as in the European female; the average size, however, is

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DESCRIPTION OF PLATE XXXV.

(Measurements in inches.)

Fig. 1. Pelvis at birth (European). Trans. diam. 1.3; ant. post. diam. 1.3.

Fig. 2. Pelvis (with 5th lumbar vertebra) of European female, æt. 11. Trans. diam. 2.8; ant. post. diam. 3.

Fig. 3. Pelvis of European male adult. Trans. diam. 5.1; ant. post. diam. 4.4.

Fig. 4. Pelvis (with 5th lumbar vert.) of Negro female adult. Trans. diam. 5.4; ant. post. diam. 4.3.

Fig. 5. Pelvis (with 5th lumbar vert.) of Negro male adult. Trans. diam. 4; ant. post. diam. 3.8.

Fig. 6. Pelvis (with 5th lumbar vert.) of European female adult. Trans. diam. 5.7; ant. post. diam. 4.5.

Fig. 7. Pelvis (with two lumbar vert.) of large monkey. Trans. diam. 2.7; ant. post. diam. 3.

Fig. 1.

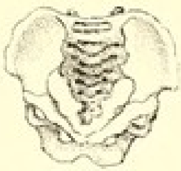


Fig. 2.

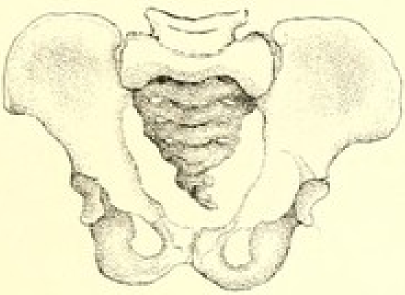


Fig. 3.

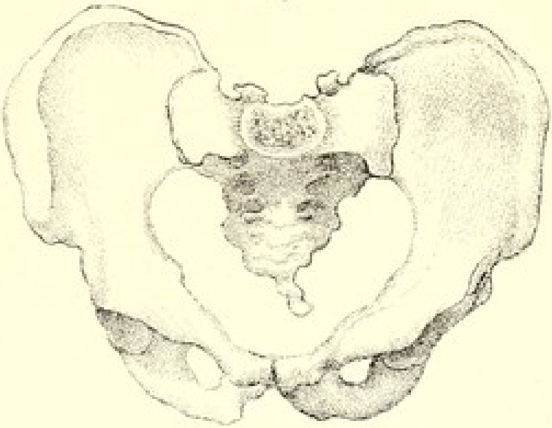


Fig. 4.

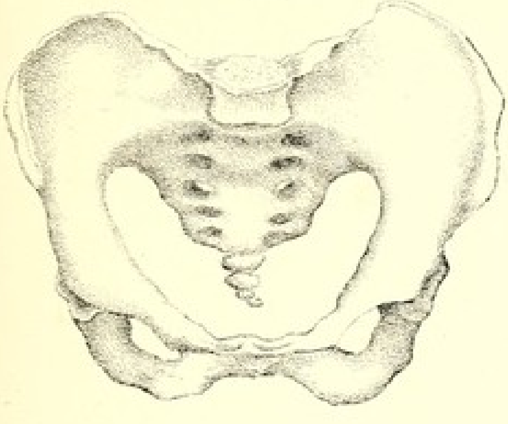


Fig. 5.

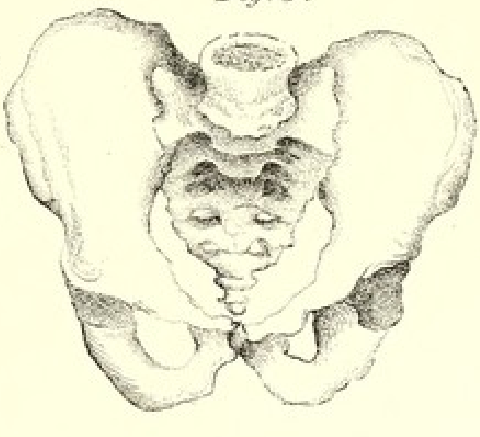


Fig. 6.

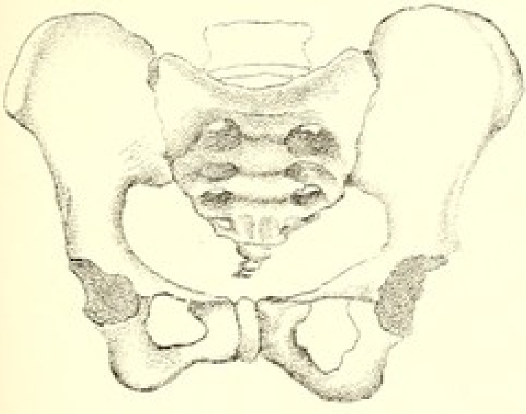
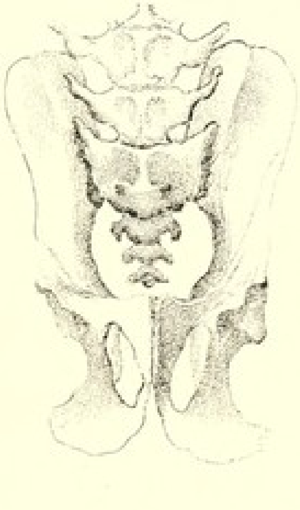


Fig. 7.



somewhat less, in accordance with the slight inferiority of the dimensions of the fœtal head in the Negro. Parturition is also facilitated by the sacrum being somewhat less curved in the Negro than in the European.

Varieties in size.

In the European the differences in size between different members of the same sex, as well as between the two sexes, seem to be less than in the Negro. The size is not much influenced by stature. Short persons are comparatively broad across the pelvis, and short women bear children as well as, if not better than, tall ones. Examples occasionally occur in which all the diameters of the pelvis are small, constituting what is called *the equally contracted pelvis.* The deficiency "may not be more than a quarter of an inch in every direction, or it may be as much as a whole inch. We do not know of any case where it has exceeded this last degree." The "equally contracted pelvis has been said to resemble the pelvis of a girl in its general appearance; but this only holds good in point of size; for in the relative proportions of its diameters, it presents all the characters of a well formed pelvis. It is not accompanied with a corresponding diminutiveness of the rest of the skeleton, most of the patients in whom it has been observed being well formed and of the usual stature. Fortunately it is of rare occurrence, for even a very small diminution in the size of the bony passages, which is uniform in *every direction*, presents a most serious obstacle to the passage of the child[1]."

Deformity from rickets.

In some cases of *Rickets*, where the lower extremities are affected, I have observed the pelvis to be small, and to have retained the infantile type, more or less, both in the proportion of its antero-posterior diameter and in its general shape, affording another example of the defective development and growth which is often associated with the disease. Far more commonly, however, the pelvis is modified, not so much in size as in shape, in consequence of the bones bending under the superincumbent weight. The change of shape usually takes place in one of two ways. Either the antero-posterior diameter is reduced, and the whole front of the pelvis is flattened, the symphysis pubis, as well as the acetabula, being pressed backwards towards the sacrum; and in these cases the sacrum is straighter than usual, being flattened out in both the transverse and longitudinal directions, the ischiatic tubera diverge from one another, being slanted outwards and backwards

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[1] Rigby's *System of Midwifery*, in the *Library of Medicine*, p. 184.

in a preternatural degree, like a monkey's, and the pubic arch is widened; or, instead of the whole front of the pelvis being approximated to the sacrum, the acetabula only are pressed inwards and backwards towards the promontory of the sacrum, which also advances to meet them, so that the upper strait of the pelvis is reduced to a triradiate form. In the latter case the sacrum is preternaturally curved, both transversely and longitudinally, and the ischiatic tubera, though in the earlier stages they may be rather *écarté*, become subsequently pressed towards one another, and the pubic arch is widened. I do not know to what especial causes the occurrence of one of these shapes, in preference to the other, in particular cases of rickets is to be assigned; both varieties take place in that disease, and with nearly equal frequency; perhaps the former rather more often than the latter. In *Mollities ossium* the abnormal shape is induced after the time when the pelvis has attained its full growth, and the triradiate form is the more usual; indeed I have not met with a well-marked instance in which the front of the pelvis was flattened in consequence of mollities; and most of the *severe* examples of the triradiate pelvis are due to that disease[1].

Deformity from curvature of spine.

Other deformities occasionally take place in the pelvis. Thus lateral curvature of the spine, when it affects the lumbar portion of the column, may be continued into the sacrum, which becomes curved, and its component vertebræ become rotated in an opposite direction to the lumbar vertebræ. Thus if the lumbar curve be, as it often is, to the left, the sacrum will be curved to the right, its upper margin will be higher on the right side than on the left, and the rotation of its component bones will be from left to right, corresponding, like its curve, with that which takes place in the back. Under such circumstances it is not uncommon to find the alæ of one side of the sacrum, the concave side, or the one which is rotated forwards, narrowed as much as a third or a half of its width; and this causes a proportionate diminution of the circle of the pelvis on that side, and gives it a peculiar oblique appearance as if it were awry. The change is accompanied by a tilting of the pelvis from its proper level, the iliac crest being highest on the side opposite to that on which the shortening

[1] I think the term *triradiate* better than *triangular* for this deformity, inasmuch as it more correctly indicates the shape assumed, and because the latter term may be used to designate the pelvis with preternatural elongation of the antero-posterior diameter, in which the shape of the brim is more or less triangular.

takes place; and there is commonly ankylosis of the joint between the narrowed ala of the sacrum and the adjacent iliac bone. It seems not improbable that this continuation of a spinal curvature into the sacrum, and the changes resulting from it, are, in some instances at least, the cause of that deformity of the pelvis which has been described by Naegele, as a special malformation, under the name of *pelvis obliqué ovata*[1], and which is regarded by him as a congenital defect. In all the examples represented in his treatise, as well as in those described by Rokitansky, and in others which I have seen, the sacrum and lumbar portion of the spine are curved in a manner corresponding with what takes place in lateral curvature of the spine. Still it may sometimes be difficult to decide whether the curvature in the spine, or the defect in the pelvis, was the starting-point of the deformity.

The observations of all subsequent pathologists confirm the remark made by Meckel and others, that, in cases of curvature of the spine, the pelvis does not generally suffer, either in size or shape, unless there is some morbid condition of the rest of the skeleton. Whatever, therefore, may be the amount of deformity of the spine, we have little to fear respecting the condition of the pelvis, provided the lower extremities are straight.

Now and then, when a patient has long been confined in one position, the sacrum becomes twisted on its vertical axis. One of its sides is advanced forwards, carrying with it the corresponding os innominatum, and causing it to project at the symphysis pubis. A specimen of this kind, in which a *horizontal obliquity* of the whole pelvis has been induced, is in the Museum of the College of Surgeons[2].

THE SEPARATE BONES OF THE PELVIS.

Sacrum and coccyx.

The Sacrum and Coccyx are composed of ten vertebræ, which decrease in size, and in the number and distinctness of their processes, from above downwards. The vertebra which forms the upper bone of the sacrum is as large as a lumbar vertebra, and has a well-shaped vertebral canal enclosed by

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[1] *Das schräg verengte Becken.*

[2] For further information on deformities of the pelvis, see Rokitansky's *Pathological Anatomy.*

an arch, with distinct spinous, transverse, and articulating processes. From this bone there is a gradual transition to the lowermost bone of the coccyx, which is commonly a mere sphere no larger than a pea.

The upper five of the ten vertebræ are joined together so as to form one solid bone, the sacrum. By this means additional strength is given to the pelvic arch, into which the upper *three* bones of the sacrum enter; and the consolidation of the *two lower* bones of the sacrum serves to support the pelvic viscera, assists in bearing the

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DESCRIPTION OF PLATE XXXVI.

Fig. 1. Sacrum at birth (back view). *A, A*, cartilaginous tips of neural laminæ of 1st sacral vertebra, united to one another by a fibrous band (*B*), which occupies the place of the future spinous process. The laminæ of the 2nd vertebra have grown nearer to one another and are separated only by a piece of cartilage (*C*). *D*, piece of cartilage uniting laminæ of 3rd vertebra. *E*, fibrous band uniting those of 4th. *F*, lamina of 5th vertebra. *G*, ditto of 1st bone of coccyx. *H*, osseous nucleus of body of 1st bone of coccyx. *I, I*, nuclei of lateral portions of 2nd bone of coccyx; nucleus in the body of that bone not yet appeared. *K*, cartilaginous ala of sacrum.

Fig. 2. Back view of sacrum and last lumbar vertebra from a young subject. *A*, piece of cartilage in the situation of the spine of the last lumbar vertebra. *B, B*, neural laminæ of 1st sacral vertebra separated by a considerable interval. *D, D*, ditto of 2nd sacral vertebra, deeper than those of the 1st, approximated nearer to one another and united by a piece of cartilage. *E, E*, ditto of 3rd vertebra, almost as close as those of 2nd. *F, F*, ditto of 4th vertebra, far apart. *G, G*, ditto of 5th vertebra. *H*, ditto of 1st bone of coccyx. *I*, osseous nucleus in 1st bone of coccyx. *K, K, K, K*, cartilaginous central pieces of 4 lower bones of coccyx; osseous nucleus not developed in any of them.

Fig. 3. Front view of sacrum from young subject, æt. about 15. The bodies of the component vertebræ are separate. The sides are united in an irregular manner; the upper three only slightly; the 3rd and 4th are quite united on the left side, but separate on the right side; the 4th and 5th are quite united on the right side, but separate on the left.

Fig. 4. Back view of the same. The arches of the upper 4 are united; those of the 4th and 5th are separate. The lateral portions of the 4th and 5th are united; but those of the upper 4 are separate.

Fig. 5. Os innominatum, æt. about 10 (much reduced). The rami of the pubes (*A*) and ischium (*B*) are united; but the pubes, ischium, and ilium are all separate at the acetabulum, and there is a separate piece of bone (*C*) between them.

Fig. 6. Os innominatum at birth, viewed from inner side. *A*, the ossified portion of pubis. *B*, ditto of ischium. *C*, cartilage forming the acetabulum. *D*, the cartilage forming the rami and fore part of the pubes and ischium. *E*, ossified portion of ilium. *F*, foramina for vessels. *G*, cartilage forming margin of ala of ilium.

Fig. 1.

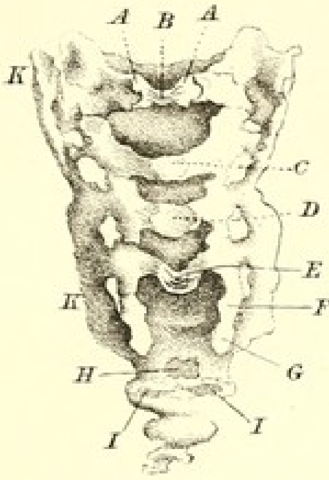


Fig. 2.

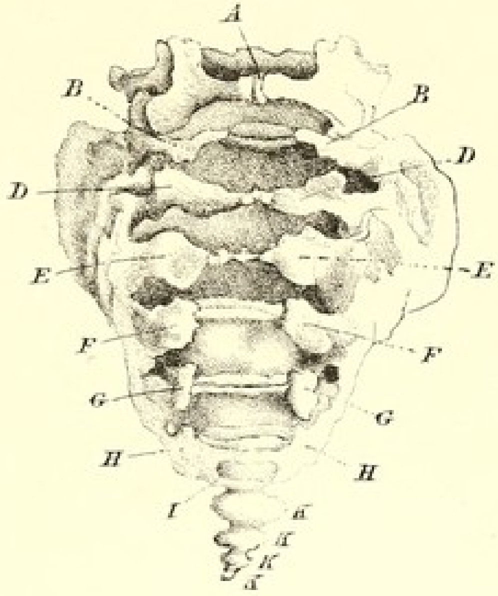


Fig. 3.

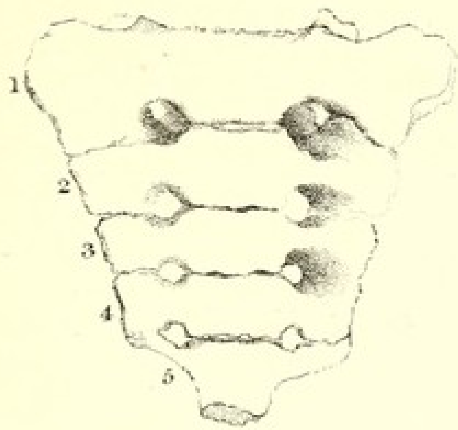


Fig. 4.

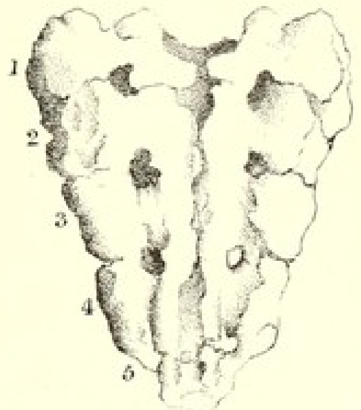


Fig. 5.

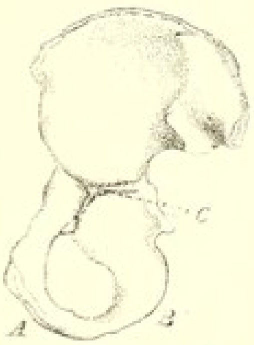
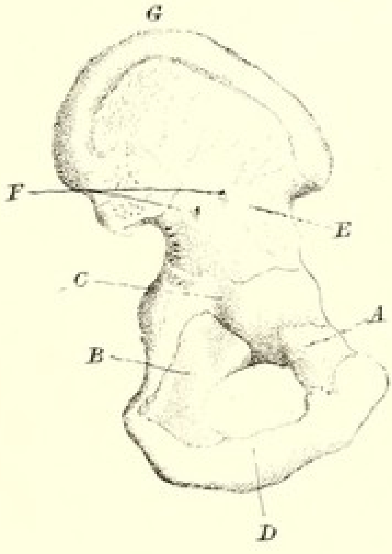


Fig. 6.



body in the sitting posture, and increases the firm basis of attachment for the muscles which move the trunk upon the thighs and which hold the trunk steady in the erect posture.

In most other Mammals, and in Reptiles, only two vertebræ are united with the ossa innominata to complete the pelvic arch. The number, besides these two, which are joined together to form the sacrum varies a good deal. In the Crocodile the sacrum is very short, being composed solely of the two vertebræ which are articulated with the iliac bones; and these two are only partially united together. Mr Carlile[1] observes that the "os ilium, in the fœtal state, and for some years after birth, in the human subject, is connected to only *two* of the sacral ribs; at a more advanced period of life it is connected by a cartilaginous intermedium to the extremities of three sacral ribs." In the skeleton of a Negro he observed it conjoined to four[2].

The components of the sacrum: the bodies.

The *Bodies* of the several sacral vertebræ remain, to a considerable extent, distinct from one another, being united by bone only at their edges; and the greater part of the interval between them is filled by soft inter-vertebral substance. The union takes place earlier, and to a greater extent, between the lower bones than between the upper. The body of the first bone presents very much the shape and characters of those of the lumbar vertebræ; like that of the fifth lumbar vertebra, it is wide, and deeper in front than behind. Lower down the several bodies become more and more elongated from above downwards, and flattened from before backwards; they are deeper behind than in front, in accommodation to the curve of the sacrum; and each one is a little concave upon its anterior and convex upon its posterior aspect.

The arches and spines.

The sacral *Arches* are rather thin and spread out, so that the edges of each, with the exception of the first,

[1] *Report of British Association* for 1837.

[2] "In the adult chimpanzee the two superior sacral vertebræ only are united to the iliac bones, and, hence, the trunk is less firmly connected with the pelvic arch, and is more in need of additional support from the anterior extremities than in man." Owen, *Zoological Trans.* I. 357.

are in contact with those above and below, and become united with them at an early period, forming a continuous plate of bone, which covers the vertebral canal, and contributes much to the strength of the sacrum. The arch of the upper sacral vertebra slopes obliquely downwards from its body, so as to leave an interval between it and the arch of the last lumbar vertebra. This interval, which is sometimes of considerable size, is required for the purpose of permitting the movement of the last lumbar vertebra upon the sacrum, in consequence of the space being limited by the retiring angle which is formed at this part of the spine.

Varieties in the arches and spines.

The upper sacral arch is formed later than the others, and varies a good deal in thickness. Frequently it is more or less imperfectly formed; and this part of the vertebral canal is consequently, more often than any other, the seat of spina bifida. In one sacrum now lying before me, the arch of this vertebra is incomplete, the laminæ not having extended above half way, from either side, towards the middle line; so that there is no spinous process, and the vertebral canal is wide open from the last lumbar to the 2nd sacral arch. In others, the laminæ have met, and each one is prolonged into a spinous process curling downwards; but, though the two spinous processes, thus formed, run side by side and are in close contact, they are not united, a fissure remaining between them. In others, the laminæ have grown together, and a single spinous process has been formed, which varies much in size, being thin and stumpy, or thick and standing out free like one of the lumbar spines. In some, the 1st spinous process and arch are united with those of the 2nd; in others, they are free, a more or less considerable interval existing between them. The laminæ of the four lower sacral vertebræ are more or less united together in all specimens that I have seen; and those of the 2nd and 3rd, in every instance, and those of the 3rd and 4th, in most instances, are joined in the middle line, so as to complete the osseous covering of the vertebral canal. It appears, however, from the observations of others, that the canal is sometimes open to a greater extent than this, in consequence of the vertebral arches not having grown together. The spinous process of the 2nd bone is short, and shoots upwards so as nearly to meet that of the 1st vertebra. This direction of this process, and its shortness, prevent its being in the way when we sit down or lie on the back. The spine of the 3rd vertebra is shorter still; often it does not stand out as a process at all. That of the 4th is commonly absent; and the centre part of the arch of this vertebra forms a depression, rather than a prominence, between the representatives of the articulating processes which stand out as tubercles on either side. In some instances the spinous process is present, being single or bifid; and in some it is blended with that of the 3rd vertebra. Occasionally all the spinous processes are wanting, and the united laminæ form an even plate of bone extending over the whole of the sacral part of the vertebral canal. The arch of the 5th vertebra has been incomplete in all the instances that I have seen, leaving the terminal portion of the vertebral canal quite open; indeed the lamina that should form the arch can scarcely be said to exist.

Articulating processes.

The upper *Articulating processes* of the first bone are large, and shaped like those of the lumbar portion of the spine. They are separated by a considerable interval to receive the lower articulating processes of the last lumbar vertebra, which are further apart than those of the other vertebræ (p. 174). All the other articulating processes of the sacrum are usually blended together, and are merely recognisable as a row of tubercles situated on the inner side of the posterior intervertebral foramina. The lowermost project downwards to meet the corresponding processes of the coccyx, and often become united with them.

Transverse processes.

The representatives of the *hinder*[1] *transverse processes* form a series of well-marked tubercles, situated on the outer side of the posterior vertebral foramina. That of the first bone is large, and resembles, in direction and shape, the corresponding process of the last lumbar vertebra.

The alæ.

The *Alæ*, or lateral parts of the sacrum, seem to be formed by a re-appearance of the anterior transverse and pleural processes (Pl. IV. fig. 5, *H*), which are spread out and united together and with the hinder transverse processes, so as to form a broad, firm mass, strengthening the sacrum and supporting the iliac bones[2].

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[1] See *Appendix on the Morphology of the Skeleton.*

[2] Mr Carlile, loc. cit. shows that some of the Saurian reptiles afford good examples of distinct and well-developed sacral ribs, two in number on each side; the anterior are

Intervertebral foramina.

The *Intervertebral foramina*, being arched over by the union of these anterior and posterior transverse and pleural processes of the several vertebræ, are divided into an anterior and posterior set, which transmit the nerves in the corresponding directions. They are all very large, especially the anterior and upper ones. Each is enclosed, in two-thirds of its circumference, by the body and processes of the vertebra above, and, in one-third, by those of the vertebra below. (See Pl. XXXVI. fig. 3.)

The curvature.

The *Curve* of the sacrum, which determines the curve of the pelvis, varies very much in different persons. As a general rule it is sharper in men than in women, though there are many exceptions to this; it being not unfrequently as straight, or straighter, in men than in women. It is not uniform, being generally sharpest at the middle of the bone, that is, at the third vertebra (Pl. X. fig. 1), where, in some instances, it almost forms an angle[1].

The upper bone of sacrum sometimes forms part of lumbar curve.

As a rule the upper edge of the 1st sacral vertebra forms the "promontory." In a few instances, however, the promontory is formed by the upper edge of the 2nd vertebra; and the 1st vertebra is sloped backwards, so as to be the commencement of the lumbar curve. Where this peculiarity exists, the 1st sacral vertebra resembles those of the loins in several particulars. For instance, the spinous process and arch are more free and separate from those of the 2nd vertebra than usual; the inferior articulating processes, as well as the superior, are free; the anterior surface of the body is rounded off at the sides, instead of being squared; the posterior

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articulated to the bodies of the last lumbar and the first sacral vertebræ and to their intervertebral substance; the posterior to the last sacral and the first caudal vertebræ. In the human subject he finds 4 sacral ribs on each side; they remain in a separate and distinguishable state until the age of from 3 to 7 years.

[1] Mr Quain found that in one series of skeletons the anterior surface was comparatively straight, and the slight bend which existed was near the upper end; in another the bone was much curved in its whole length, but especially about the middle; a third set were intermediate, the degree of curve being moderate and affecting chiefly the lower end. The measurement of a considerable number of these bones, taken from both sexes, has shown him that the curvature cannot be relied on as a distinctive character. Some of the variations of the curve, in company with distortion of the pelvis in rickets and mollities, have already been mentioned (p. 447).

transverse process is more distinct; its contribution to the ala is small, and it, as well as the body, are united late to the rest of the bone. So that, unless the regular number of the components of the rest of the column be present, it may be difficult to decide, in such an instance, whether the vertebra in question really belongs to the loins or to the sacrum.

Sacrum in the female.

In the female the sacrum is broader in proportion to the rest of the pelvis than in the male, and its curve, as just stated, is less sharp. It is also said to incline more backwards from the direction of the lumbar vertebræ, thus forming a more prominent "sacro-vertebral angle."

Development.

Each bone of the sacrum is, as in the case of the other vertebræ, developed from three chief centres; but the nuclei for the bodies appear before those for the arches. Thus the nuclei for the upper four bodies appear, according to Beclard and others, in the first four months of fœtal life, and the nucleus for the body of the 5th vertebra appears at about five months and a half; the nuclei for the several arches appear from two to three months later than those for their respective bodies. Besides these three primary centres, others are formed at later periods, respecting which there is some uncertainty. One is admitted to appear, on either side of each of the upper three vertebræ, in the part which is articulated with the ilium; and it is probable that similar nuclei may be superadded to the two lower bones. In a specimen before me there is clearly a separate centre in the laminæ forming the upper and lower edges of each of the several bodies. Thus there are three nuclei in each of the component bodies of the sacrum, and one or two in each side of the several arches, making in all from thirty-one to thirty-five centres. Besides these, independent nuclei may, in some instances, be developed in the spinous processes; and thin separate osseous laminæ are sometimes seen on the articular facets for the ilium. The lateral portions become united with the bodies at an early period (about 2½ years according to Beclard) in the lower vertebræ, and at about the 5th year in the upper ones. After the respective segments of the several vertebræ have united, so as to form five bones, these five become joined by the fusion of their articulating processes and arches, which begins usually at the lower part of the sacrum and travels upwards. The bodies long remain separated by fibro-cartilages resembling the intervertebral substances in other parts of the spinal column. These, at some time after puberty, become surrounded and bridged over by bone which grows from the contiguous edges of the bodies. Not till 25 or 30 are the bodies of the 1st and 2nd vertebræ thus joined; and, in some instances, they remain separate for life. In the lower parts of the sacrum only is the intervertebral space entirely ossified; some of the fibro-cartilage remains permanent between the upper three or four bones, leaving interspaces in the section of the macerated and dried bone.

Varieties and diseases.

The sacrum has been found occasionally to consist of 6, or of only 4 bones. It is subject also, as we have seen, to many varieties in its shape and in the degree of development of its component parts, and is often the seat of spina bifida. It is not, however, so liable to disease as might have been anticipated from the complexity of its structure, and from the number of its points of development.

THE COCCYX

consists normally of five bones, of which the upper is often ankylosed to the sacrum, making it appear as if that bone were composed of six vertebræ instead of five. The uppermost of the coccygeal segments resembles the lowermost of those of the sacrum, except that it is smaller, that its lateral portions are less developed, and that the rudiments of its arches are mere cylindrical processes, or *Cornua*, which are slightly tuberculated at their extremities and are directed, upwards, from the upper and posterior part of the bone, to meet the corresponding processes of the sacrum, which are directed downwards. This difference in the direction of its cornua affords a ready means of distinguishing the first bone of the coccyx from the last of the sacrum. The cornua of the sacrum and coccyx, approaching near to one another, are united by fibrous tissue, so as to complete the arch over the intervertebral foramen, which transmits the last sacral nerve.

The 2nd bone of the coccyx has short wing-like projections, the representatives of the alæ of the sacral bones, and tubercles on its posterior aspect, the representatives of the arches. Of the lower three bones the uppermost has a somewhat triangular shape, and the other two are simply pisiform.

The bones of the coccyx, especially the lower three, are composed of very spongy structure.

The ossification of the 1st bone commences in the 1st year after birth; that of the 2nd in the 2nd year; and that of the 3rd in the 3rd or 4th year. That of the others is later. The lower three are often ankylosed together soon after puberty; and, as the 1st is also frequently united to the sacrum in a similar manner, the 2nd bone is the one which remains longest distinct.

THE OS INNOMINATUM.

The acetabulum is the centre of the os innominatum, with the broad ala of the ilium springing from it above, the pubes connected with its fore part, and the ischium descending from it beneath.

Ilium.

The *Ilium* is very thick and strong over the sciatic notch, in the interval between the articular surface for the sacrum and the cotyloid cavity, where it bears the weight of the trunk, and transmits it from the sacrum to the femur. This part is first ossified, is very hard, and the chief nutritious artery of the bone enters on its inner side. It is very strong also near its edge, or *Crest*, where it gives attachment to powerful muscles and to fasciæ; it is almost transparent in the middle, to lessen its weight. The whole ala is broad and slanted, from below, outwards and upwards to afford space for the abdominal viscera, and to sustain them when the trunk is erect; and its two surfaces, as well as its crest, are disposed in a wavy manner. It is prolonged backwards inwards and downwards behind the sciatic notch, so as to cause the sacrum to occupy a comparatively low position with regard to the pubes. This prolongation of the ala backwards and downwards assists in maintaining the balance of the trunk upon the thigh-bones, and in preventing its falling forwards; and the part behind the sciatic notch is inclined inwards and downwards to afford a better support to the sacrum. The *Anterior inferior spine* is peculiar to the human pelvis. It serves to give a slight leverage to the *rectus femoris*, making some amends to that muscle for the unfavourable position in which it is placed by the erect posture.

Pubes. The *Os pubis* runs forwards and inwards from the acetabulum, so as to complete the pelvic arch and afford a projecting point of attachment for the muscles of the thigh and trunk. Just in front of the acetabulum it is narrow and triangular, and is liable to be bent inwards under the pressure of the thigh-bone in rickets and mollities. It rises into an eminence near the line of junction with the ilium; and the femoral artery crosses over it just on the inner side of this eminence.

Ischium. The *Ischium* presents a broad thick surface for the body to rest upon in the sitting posture, gives attachment to the sacro-sciatic ligaments which contribute to close in the lower part of the pelvis, and affords a projecting point for the attachment of the extensor and adductor muscles of the lower extremity. These muscles, the hamstring muscles more especially, are very powerful; and the *Tuber ischii* is enabled to bear their pull, partly by reason of the great thickness of the neck which connects it with the acetabulum, and partly from the support afforded by the rami of the ischium and pubes in front, and by the sacro-sciatic ligaments behind.

Development. Ossification begins in the fœtal cartilage of the ilium, just above the sciatic notch, during the 2nd month, and quickly radiates through the ala, which is, at first, of nearly uniform thickness; it commences, during the 3rd month, in the thick part of the ischium, just below the acetabulum; and, during the 4th or 5th month, in the horizontal portion of the pubes, near the acetabulum, just over the obturator hole. The acetabular cavity is, therefore, soon surrounded by the three ossifying centres, which all appear in its immediate neighbourhood. They approach one another, forming the circumference of the acetabulum; and a Y-shaped piece of bone (Pl. XXXVI. fig. 5 *C*) is often formed in the cartilage that unites them at the bottom of the cup. They become united to this, or to one another, soon after puberty.

The union between the rami of the ischium and pubes takes place at about the 7th year; next the ischium is united to the ilium; and, lastly, the pubes is joined to the other two in the acetabulum. About puberty four *epiphyses* appear; one on the crest of the ilium, extending along its whole length; one on the anterior inferior spine of the ilium; a 3rd, a broad plate, is formed on the tuber ischii, and extends some distance along the ascending ramus of the ischium; a 4th, a thin plate, appears on the inner margin of the pubes, and the symphysial fibro-cartilage is attached to it. All these epiphyses become united to the os innominatum at about 25; and their union with it is so close that it is not easy to recognise any line of demarcation.

Changes in obturator hole. In early life the obturator hole is nearly oval; subsequently it is extended forwards and inwards by the growth of the pubes in this direction, so that it assumes somewhat of a triangular form. This change is most marked in the female pelvis.

Varieties. Occasionally the rami of the ischium and pubes fail to meet and to complete the circle of the obturator hole[1]. Occasionally also the bottom of the acetabulum is incomplete or is very thin. In a few instances the bony margin of the acetabulum has been carried round its whole circumference, so as to leave no notch, only a foramen, at the lower part[2]. In a specimen of the malformation called "extroversion of the bladder," contained in the Musée Dupuytren, the pubic bones are well formed, though rather short; and they are directed forwards, instead of forwards and inwards, so that they are three inches apart in the middle line. Sometimes the spine of the pubes is developed as an epiphysis, which has been compared to the marsupial bones of the non-placentalia; Lassus[3] saw in the male subject an apophysis, from two to three inches long, growing, from the inner surface of the pubes, on either side of the symphysis.

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[1] This is the permanent condition in Chelonian reptiles. In most reptiles the rami of the ischium and pubes do not approach one another below; but the ischium, like the pubes, is continued across to meet its fellow of the opposite side, so that the two foramina ovalia are united together in the middle line and form one great transverse gap between the pubic and ischiatic bones.

[2] Hyrtl, *Anat.* s. 251.

[3] *Pathologie Chirurgicale*, I. cap. 80.

SACRO-ILIAC JOINT. (Plate XXXVII.)

Dislocation rare.

The sacrum, or key-stone of the pelvic arch, is so firmly wedged in between the alæ of the ilium that displacement can scarcely take place, unless some other part of the circle of the pelvis is broken either by fracture of the bones or by rupture of the symphysis pubis. Further, the ligaments that bind the sacrum and ilium together are so strong that when the part is subjected to great force it is no uncommon thing for one of the bones to give way, while the joint remains entire. Thus, in the case of a man who fell from a height upon his left leg, a longitudinal fracture was found through the left side of the sacrum, and there was fracture through the horizontal and descending rami of the pubes; but the ligaments, both of the sacro-iliac and of the pubic joints, were uninjured[1]. Nevertheless the disjunction of the bones is sometimes caused by heavy weights passing over the pelvis.

[1] The specimen is in the Musée Dupuytren, and the case is related by Richerand, *Nosographie et Thérapeutique Chirurgicales*, II. 44.

DESCRIPTION OF PLATE XXXVII.

Fig. 1. Vertical section from side to side through the sacro-iliac joint of a male adult, showing the wavy line of union between the cartilaginous surfaces of the sacrum and of the ossa ilii. It is seen to be not perfectly symmetrical. *A*, the sacrum. *B*, *B*, iliac bones. *C*, *D*, *E*, upper middle and lower parts of articular margin of sacrum. *F*, superior sacro-iliac ligaments. *G*, *G*, inferior ditto.

Fig. 2. Horizontal section of sacro-iliac joint from young male. *A*, the sacrum, the lateral portions of which (*I*, *I*) are still united by cartilage to the central part. *B*, *B*, the iliac bones. *K*, concave margin of articular surface of sacrum. *L*, stop formed by edge of ilium projecting in front of sacrum. *M*, posterior, and *N*, anterior sacro-iliac ligaments. *H*, epiphysis of ilium.

Fig. 3. Vertical section, from side to side, through the symphysis pubis of a young man. The cartilaginous edges of the bones are united in their whole length by tough tissue, in which transverse fibres are manifest. *A* and *B*, supra and infra-pubic ligaments.

Fig. 4. Similar section, through the same part, from a woman æt. 21, who died in the 7th month of pregnancy. There is a vertical line in the middle of the symphysis which indicates the position of a fissure or linear cavity. I found a precisely similar fissure in a female, æt. 25, who had never been pregnant.

Fig. 1.

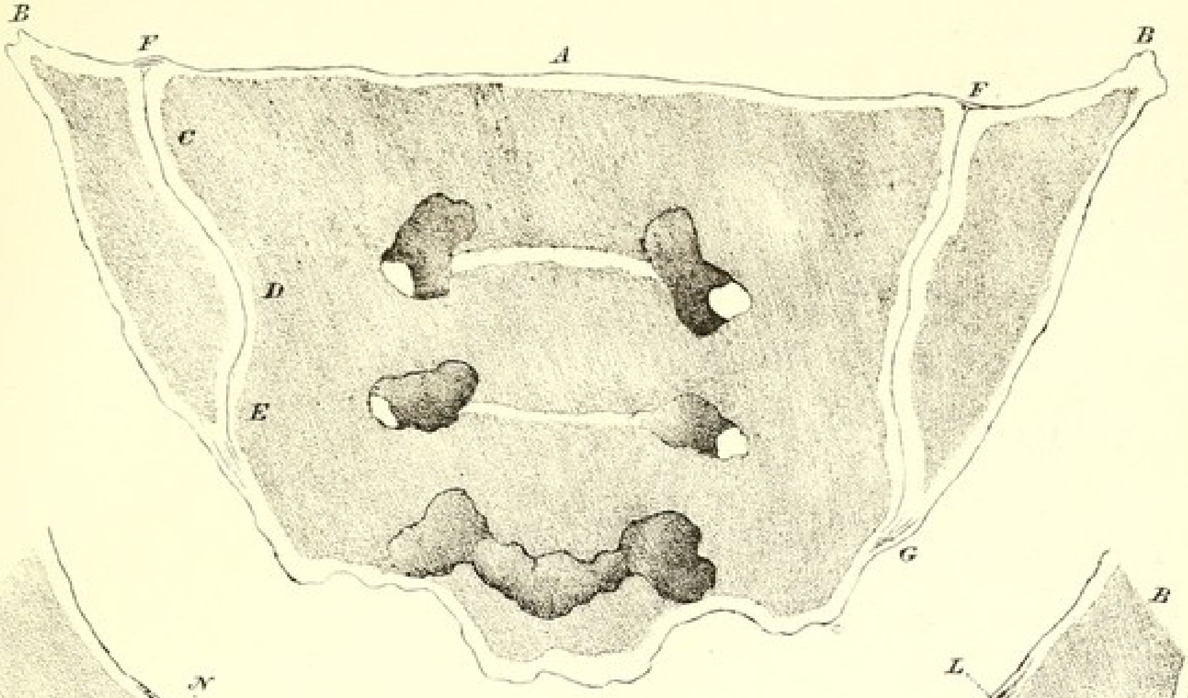


Fig. 2.

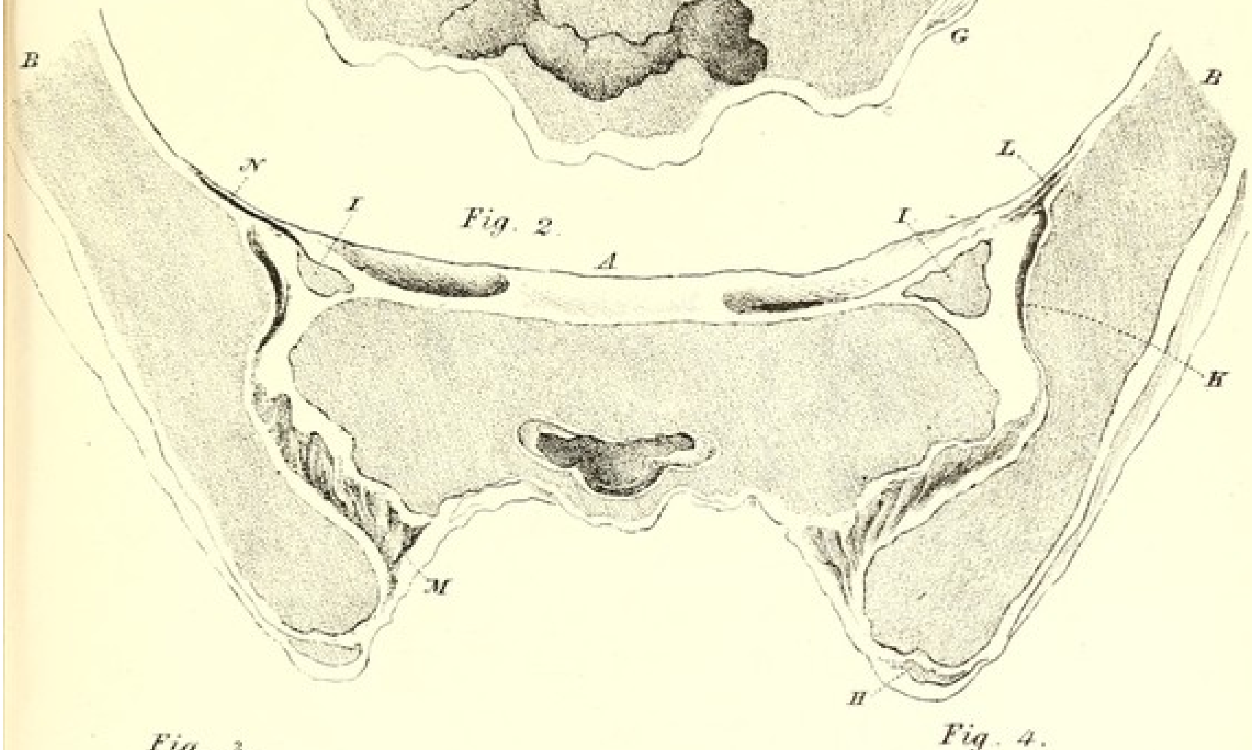


Fig. 3.

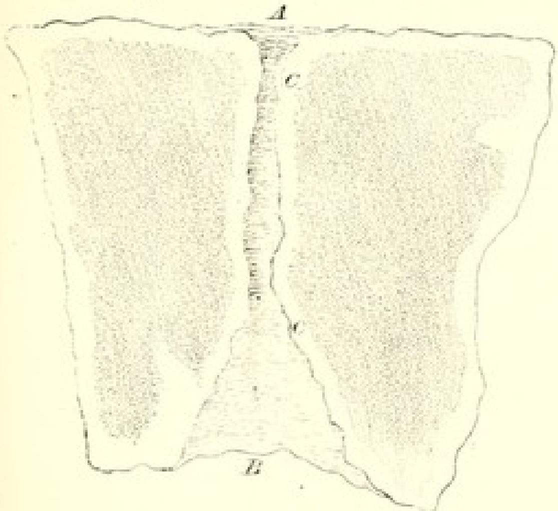
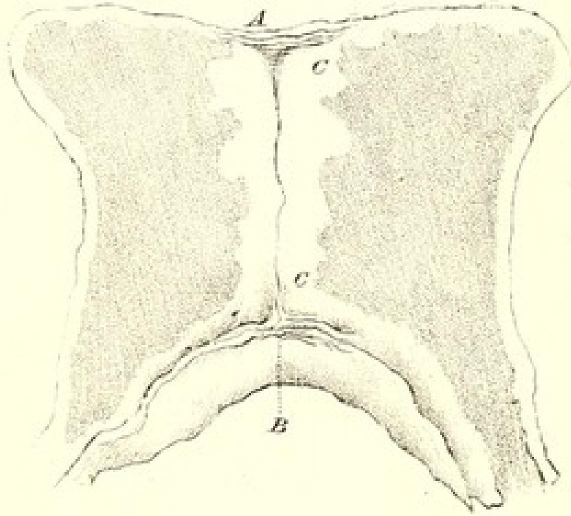


Fig. 4.



Shape of the articular surfaces prevents displacement downwards and upwards,

The displacement of the sacrum *downwards* is prevented by the wedge-like shape of the bone, and by the undulating disposition of the surface by which it is jointed with the ilium. The articular surface of the sacrum, situated on either side of the ala, extends over three of the component bones (see fig. 1). It is, accordingly, of considerable length; and it is curved with its convexity forwards, that is, in a direction opposite to that of the curvature of the sacrum. From some resemblance to the human ear it has been called the "auricular facet." The upper part (*C*), which is wide and bears the chief weight of the trunk, is inclined so as to overlap the corresponding surface of the ilium. The middle part (*D*) is concave from above downwards; and the lower part (*E*) is projected outwards beneath the edge of the ilium, so as to prevent displacement of the sacrum *upwards*.

backwards,

Displacement *backwards* is prevented by the obliquity of the articular surfaces, which are sloped, from before, inwards and backwards (fig. 2), in such a manner as to permit the iliac bones to enclose the hinder part of the sacrum to a considerable extent. So complete is this provision, that the sacrum is scarcely ever forced backwards from its position.

forwards.

The tendency to pass *forwards* is obviated, partly by the disposition of the ligaments presently to be mentioned, partly by the articular surface of the sacrum (fig. 2, *K*) being concave from before backwards to receive the convex iliac facet, and partly by a ridge (*L*), which forms the anterior margin of the iliac facet, being thrown out in front of the edge of the sacrum, so as to constitute an effectual stop to any advance of the bone in that direction. The security thus afforded by the shape of the articular surfaces is increased by the mutually adapted inequalities which they present and by the thin layer of cartilage which cements them firmly together.

Sacro-iliac ligaments.

The joint is further strengthened in its whole circumference by ligaments passing from one bone to the other. Of these the *Posterior sacro-iliac ligaments* are the strongest; they fill up much of the interval between the uneven hinder surfaces of the sacrum and the iliac bones, and are composed of short thick bundles disposed in different directions, with more or less obliquity, so as to prevent displacement either way: the greater number of them pass obliquely, forwards and inwards, from the ilium to the sacrum, so as to prevent the advance of the sacrum forwards. In case of a tendency to such advance they are tightened in consequence of the direction of their fibres; and, drawing the two iliac bones more firmly to the sacrum, they contribute still further to the security of the joint.

Ilio-lumbar and sacro-sciatic ligaments.

The *Anterior*, *Superior*, and *Inferior sacro-iliac ligaments* (*N*, *F*, *G*) pass over the edges of the bones as represented in the figures. The tendency to *rotation forwards upon a transverse axis*, resulting from the oblique manner in which the sacrum is placed in the pelvis, is prevented by the disposition of the *Ilio-lumbar ligaments* above and the *Sacro-sciatic ligaments* below; for both of these act as stays, the former upon the upper, the latter, upon the lower end of the sacrum. The ilio-lumbar ligaments, passing, backwards and outwards, from the transverse processes of the last lumbar vertebra to the crest of the ilium, on either side, resist pressure of the vertebra and of the upper part of the sacrum forwards and downwards; and the sacro-sciatic ligaments, passing from the tuber and spine of the ischium, upwards and backwards, to the edge of the sacrum, beneath the joint with the ilium, prevent the tilting upwards and backwards of the lower part of the sacrum. In Birds, and in the three-toed Sloth, the place of the sacro-sciatic ligaments is occupied by a bony plate, which connects the ischium with the sacrum, so converting the sacro-sciatic *notch* into a true *foramen*.

Symphysis pubis:

The union of the pubic bones at the *Symphysis* (figs. 3 and 4) is, like that of the sacrum and the ilium, very strong, but is effected in a somewhat different manner. The opposed surfaces of the pubic bones are broad and flat; and each presents a dentated edge, which bears a more or less thick pad of cartilage. The cartilages of the two sides are united by tough tissue (fig. 3), which is fine towards the middle part of the symphysis, or which may be altogether absent there, leaving the cartilages in juxtaposition, and separated only by a narrow fissure (fig. 4); towards the circumference the connecting tissue is coarser and more distinctly fibrous. The symphysis is flat in front, and convex, from above downwards, behind. It is deeper and narrower in men than in women; the greater width in the latter is chiefly owing to the thickness of the cartilaginous pads on either side. It is covered by ligamentous fibres passing between the adjacent edges of the bones, and named, according to their position, *Supra-*, *Infra-*, *Anterior*, and *Posterior pubic ligaments.*

The mode in which the pelvic bones are united by the interposition of cartilaginous and fibrous pads contributes greatly to prevent the transmission of jars from the lower extremities to the spine.

Seldom the seat of disease.

Ulceration has been known to commence in the symphysis[1]; but it is rarely the seat either of ankylosis or other disease. A case is related by Otto[2], where it, as well as the right sacro-iliac joint, was completely ossified in a woman æt. 32; this was supposed to be due to a diastasis, or to fracture of the parts caused by the violent use of the forceps in a former labour. He quotes two other cases of ossification of the symphysis pubis, and remarks that it not uncommonly becomes ossified in apes and other animals in which the cartilage is less thick than in man. In the sacro-iliac joint, on the contrary, where the apposition of the bones is closer in man than in the other animals, ankylosis is of more common occurrence. In many of the lower animals the symphysis is much deeper, uniting the rami of the pubes, in their whole extent, as well as part of the ischium, so affording more support to the viscera beneath which it is placed in those animals, instead of being in front as in man.

Softening of ligaments in pregnancy.

It has long been a question whether the pelvic joints become more lax in pregnancy. Rokitansky observes that, in pregnancy, the firmness with which the bones are connected is slightly diminished, the fibro-cartilages becoming succulent, soft (and vascular?). Otto quotes from Frank the case of a woman whose pelvis was so move-

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[1] *Trans. of Path. Soc.* V. 246.

[2] De rariori quodam plenariæ ossium pubis ankylosis exemplo.

able, every time she became pregnant, that she was unable to stand. In a woman who died in the 7th month I found the pelvic joints permitted rather more movement than usual; and in a woman on whom I performed the cæsarian operation, in consequence of deformity of the pelvis from mollities, this was very marked. In two others, who died at the full term undelivered, I could not be certain that any change had taken place.

THE LOWER EXTREMITY.

THE FEMUR (Plate XXXVIII.)

Comparison with humerus. presents many points of similarity to its correspondent bone (the humerus) in the upper extremity. Its hemispherical head is set off at an angle from the inner side of the shaft; and its transversely widened lower end is so shaped that the movements at the knee are, like those at the elbow, of the hinge-kind. The weight of the body is received on the inner side at the upper end, and is transmitted chiefly through the outer part of the lower end, that is to say, through the outer condyle. There is a great and a lesser "tubercle" or "trochanter" near the upper end, to give attachment to the muscles which rotate the bone on its axis as well as move it in other directions; there is a rough projection on the outer side of the shaft for the great abductor muscle; and there are other obvious features of resemblance between the two bones. The femur, however, forms part of a larger extremity, and has to bear great weight; it is, therefore, a larger and a stronger bone than the humerus; it measures 18 inches in length, and is united more securely to the pelvis than the humerus is to the scapula. The range of its movements is consequently more limited, and its trochanters stand out more boldly. Its head is carried upon a longer neck, to give a wider basis of support to the trunk and for other purposes presently to be mentioned. Its curves and twists are somewhat different. Thus its shaft is bowed forward below and backward above; and its head and neck are directed obliquely forwards and inwards from the shaft, instead of backwards and inwards as in the humerus; hence the lesser trochanter is in a plane behind the head, instead of lying in front of it as it does in the latter bone. Moreover the articular surface is prolonged upon the posterior surface of its lower end, instead of upon the anterior surface, which permits the flexion of the knee to take place backwards instead of forwards.

Relative size great.

It has already been remarked (p. 89) that the great *proportionate* size of the femur is one of the peculiarities of the human skeleton; and that it is, on the whole, most marked in those races of mankind whose bodily framework and whose intellectual powers are best developed. In addition to its size as a whole, in proportion to the rest of the skeleton, the human thigh-bone is marked by the length and size of its neck and head in proportion to the rest of the bone, by the extent to which the head is covered by cartilage, and by the secure manner in which it is held in the acetabulum, while the range of its movement is greater than in most of the lower animals. It may be stated as a general rule that the bone is straight in proportion as it is long; that is to

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DESCRIPTION OF PLATE XXXVIII.

Sections of Thigh-bone.

Fig. 1. Longitudinal section, from side to side. *A*, part of inner condyle, near which the cancelli are far apart. *B*, do. of outer condyle. Between *A′* and *B′* a dense network of cancelli indicates the line of union of the epiphysis with the shaft. No trace of such union of the epiphysis of the head is visible. *C*, part of outer condyle, from which cancelli ascend vertically to outer wall of shaft. *D*, hinder part of trochlea, above which the cancelli are fine. *G*, Upper wall of neck, towards which cancelli converge from outer and inner wall of shaft. *H*, upper surface of head, from which cancelli descend vertically to inner wall of shaft. *I*, great trochanter filled with delicate cancelli.

Fig. 2. Horizontal section through head, neck, and great trochanter. It shews the concave outline of the posterior surface of the neck, the dense cancelli in the head, the light cancelli in the fore part of the neck and the trochanter (*I*), and the cancelli radiating from the hinder wall of the neck (*K*).

Fig. 3. Horizontal section through middle of shaft. *L*, Linea aspera.

Fig. 4. Horizontal section above condyles. *A*, projection of inner wall of shaft. *B*, projection of outer wall. *C*, projection of anterior wall.

Figs. 5 and 6. Horizontal sections through upper and through lower parts of condyles. *A*, inner condyle. *B*, outer condyle. *C*, projecting anterior edge of outer condyle. *D*, trochlea for patella. *E*, intercondyloid fossa; the cancelli radiate from the wall of the bone, which bounds the fore part of this fossa. *F*, groove for tendon of poplitæus.

Fig. 1.

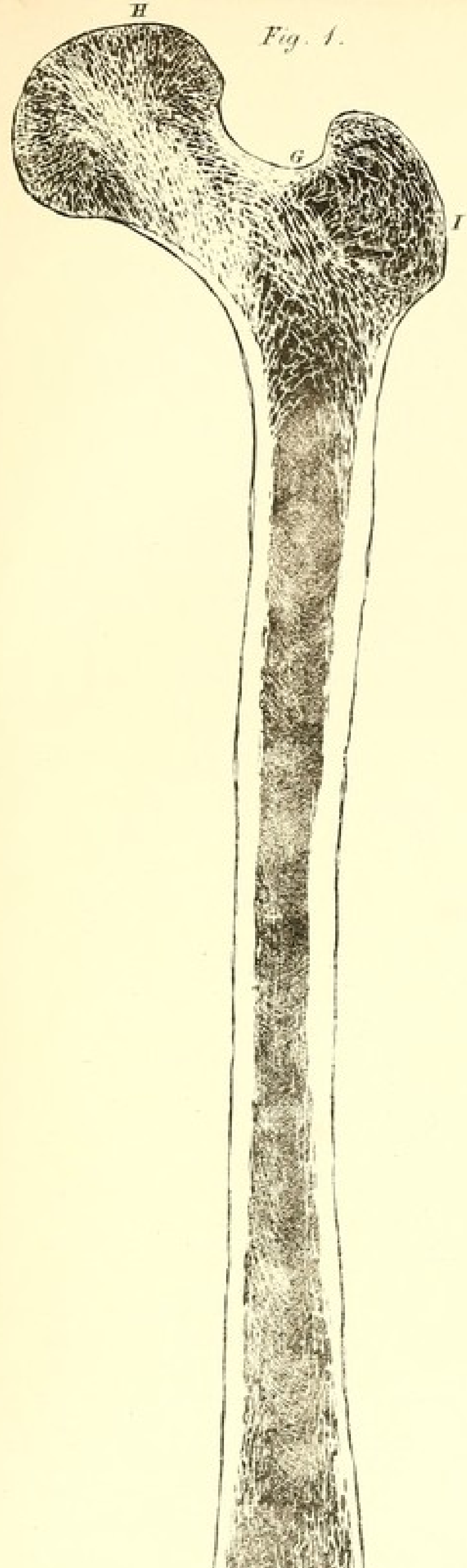

Fig. 2.

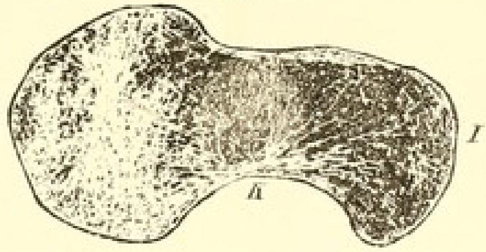

Fig. 3.

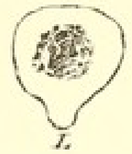

Fig. 4.

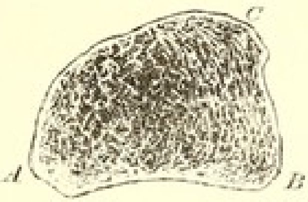

Fig. 5.

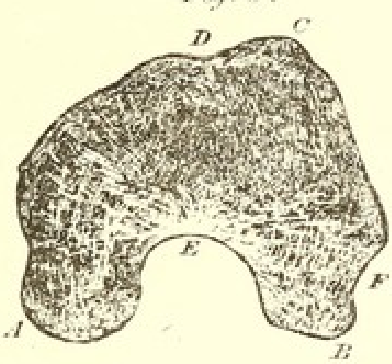

Fig. 6.

say, the curves in the shaft are slighter, and the angle formed by the neck with the shaft is wider, in a long thigh-bone than in a short one.

The shaft: its curves,

The most distinct *Curve* in the shaft is the one forwards, which involves its whole length, and which is most marked in the middle. Near the upper end of the bone the direction of the curve is reversed, in consequence of the head and neck being slanted forwards; and the lesser trochanter forms the most prominent point of this backward curve. Slight secondary curves may be observed in the shafts of some thigh-bones; the direction of these is inwards at the lower part, and outwards in the upper third.

its thinnest part.

The *narrowest part* of the shaft is at and near the middle, about the situation of the greatest convexity of the forward curve, and about the situation of the confluence of the two lateral curves. The bone is here denser, and its outer wall is thicker than elsewhere (fig. 1); and it is here further strengthened by the marked projection of the *linea aspera* in the arc of the curve. In spite of these compensatory aids, however, it remains rather a weak point, and the femur is more often broken here than elsewhere. The lines which are combined in the *linea aspera* diverge, above and below the middle third, ascending to the trochanters, and descending to the tubercles of the condyles. The line that passes to the inner condyle is less strongly marked than that to the outer condyle, and is interrupted soon after it leaves the *linea aspera*, for about two-thirds of an inch, by a smooth space, upon which the femoral artery lies in its passage, from the front of the thigh, into the ham.

Femoral artery exposed to injury in fracture at lower third.

The artery here lies so close to the femur that it may be injured in cases of fracture. I remember one case in which it, as well as the vein, was divided in a case of simple fracture by a sharp fragment of bone driven backwards against them; and in another case the artery was obliterated by the pressure of one of the displaced broken extremities of the bone. That it so often escapes injury when the bone is broken is due, partly to its own strong elastic structure, and partly to the fibrous sheath of the triceps adductor muscle in which it is contained at the part where it lies nearest to the femur.

Canal for medullary artery.

Just above this smooth point is the orifice of the canal for the medullary artery, which is directed upwards. The orifice of another canal for the same purpose, and taking the same direction, is sometimes found higher up, at about the junction of the middle with the upper third of the shaft.

Lower part of shaft.

The lower part of the shaft becomes large and broad as it approaches the condyles, especially in the direction of the inner condyle, which stands off from the axial line of the bone in a more marked manner than does the outer condyle. The latter, which bears the greater weight, is placed more directly beneath the shaft; and the lower part of the shaft is, accordingly, very thick (from before backwards) on the outer side, and is strengthened by ridges descending along its anterior and posterior surfaces. Hence a transverse section of this part of the shaft presents a somewhat triangular outline (fig. 4).

Upper part.

The upper third of the shaft is not so large as the lower. It is spread out a little near the trochanters; and its wall is thickened on the outer side, at, and near, the insertion of the glutæus maximus.

When fracture of any part of the shaft takes place, the lower portion is almost always driven up behind the upper. The exceptions to this are very rare.

Neck of thigh-bone:

The neck of the thigh-bone is long and strong, for the purposes of widening the basis of support of the trunk, of extending the range of movement at the hip, and of increasing the leverage of the muscles which are attached to the upper end of the thigh-bone[1]. It, moreover, contributes somewhat

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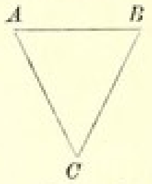
[1] Bell, *Principles of Surgery*, I. 76, illustrates the advantages derived from the obliquity of the neck of the thigh-bone by the dishing of a wheel. He remarks that when the body is equally supported on both thigh-bones, the weight is transmitted to them in an unfavourable direction, but then each bears its own share, and the centre of gravitation falls in the middle between them; and when the body is inclined to one side, the whole weight falls upon the neck of one thigh-bone, but it falls upon it in a new and more favourable direction, bearing upon it almost perpendicularly. The comparison fails, however, in the important particular that the inclination of the body to one side is not attended with a corresponding inclination of the thigh. On the contrary, the thigh upon which the body rests is inclined in an opposite direction, so as to be brought more perpendicularly under the centre of gravity, and the neck of the femur, being thus placed more nearly at right angles with the horizon, is actually in a

its angle with the shaft proportionate to length of thigh and narrowness of pelvis.

to the elasticity of the skeleton, by transmitting the weight in a curve instead of in a straight line. It forms an angle of about 125° to 130° with the shaft. This, however, varies a little. As a general rule the width of the angle bears a proportion to the length of the thigh-bone and the narrowness of the pelvis. This may be illustrated by the accompanying diagram in which *A* and *B* represent the angles of junction of the necks of the thigh-bones with the shafts. *AC* and *BC* are the two thigh-bones approximated to one another at the knees *C*. The line *AB* represents the transverse diameter of the pelvis with the heads and necks of the thigh-bones; and is accordingly the transverse measurement between the upper ends of the thigh-bones, the length of which is regulated chiefly by the width of the pelvis. It is evident that the angles at *A* and *B* will be reduced in proportion as the distance from *A* to *B* (in other words as the width of the pelvis) is increased. Again it is evident that they will be reduced in proportion as the length of the lines *AC* and *BC* (which represent the thigh-bones) are shortened. In women, accordingly, the pelvis being wide and the thighs short, we find that the neck of the thigh-bone forms more nearly a right angle with the shaft than it does in men[1]. In short men, also, the angle is smaller than in tall men.



Varies at different periods of life,

The angle varies somewhat at different periods of life. It is wide in the cartilaginous condition of the fœtus and in the child; and this, together with the deficiency of width of the pelvis in early life (p. 445), causes the hips to be narrow and the trochanters to project but little. Hence it is comparatively difficult to distinguish the nature of injuries about the hip-joint in

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rather *less* favourable position than it was before. Compensation is however afforded in this way. When the body rests upon both lower limbs, the weight is borne upon the *extremities* of the heads of the thigh-bones, at the points most distant from the shafts. When the body is inclined to one side so as to rest upon one limb, the tilting of the pelvis throws the weight more directly upon the *upper* part of the head of the femur, nearer to the line of the shaft, and almost perpendicularly over the dense stratum of cancelli that descends, from this part of the head, to the inner wall of the shaft (Fig. 1, *H*).

[1] It is said by Sue that the neck of the thigh-bone is a few lines longer in women than in men.

children. As growth proceeds the hips become widened, the trochanters are rendered more prominent, and the angle of the neck with the shaft is reduced; these changes are most marked after puberty, and in women. In old age the angle becomes further reduced; whereby the hips are thrown into still greater prominence, and this part of the thigh-bone is more exposed to injury[1].

and in rickets and other states.

In rickety subjects, as we might have anticipated, the angle becomes reduced, often to a right angle, and sometimes even below this. It may undergo an alteration also under some other circumstances, as when a fracture of the shaft has united in a bad position. Such alterations, whether from rickets or other causes, are usually attended with an extension of the articular surface upon the upper, and its diminution upon the under, side of the head of the bone.

Its shape:

The neck of the thigh-bone is enlarged at its base, and its vertical diameter is increased, by the extension and thickening of the lower edge which slopes down to join the lower trochanter and the shaft. The strength thus imparted is required here in consequence of the angle at which the neck is set upon the shaft. Another strong projecting ridge runs along the upper and anterior part of the neck to the great trochanter. Hence the neck is, in its outer, or trochantral half, flattened from before backwards, so that its antero-posterior diameter measures a third less than the vertical diameter. Near to the head it is smaller and of more circular shape; this is accordingly the weakest part, and the most frequent seat of fracture.

its curve forwards.

The horizontal section (fig. 2) shews that the neck describes a slight curve, with the convexity forwards, that is, opposite to the direction of the curve, which is formed at the junction of the base of the neck with the upper part of the shaft. The curvature is greater on the hinder, than on the anterior, surface of the neck.

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[1] This alteration does not invariably take place. Thus I have found the angle to measure 125° in some edentulous skeletons; but in the greater number that I have had an opportunity of examining, it was much below this, being generally about 110° after the age of 70. The change in the degree of inclination of the neck of the thigh-bone is one of the causes of the decreasing of the height of the figure in advancing years.

Periosteum on fore part of neck usually torn through in fracture.

It results from this curve, that when fracture is caused by a blow or fall upon the trochanter, the bone yields in the direction of its convexity, that is in front, and the periosteum and synovial membrane are apt to be lacerated in that situation by the sharp projecting edges of the fracture. Moreover, the anterior convex surface of the neck is rough, perforated by many holes for vessels, and is therefore closely connected with its periosteum, in comparison with the posterior concave surface, which is very dense, smooth, and loosely connected with its periosteum. For these two reasons we find that in by far the greater number of cases of fracture of the neck of the thigh-bone the periosteal and synovial investments of the bone are torn through in front, but retain their continuity behind.

Close to the overhanging cartilaginous edge of the head of the femur the neck is suddenly enlarged a little, and is perforated all round by holes for vessels. Besides the vessels derived from these sources and from the cancellous texture in the interior of the neck, others are transmitted to the head of the bone by means of the round ligament. It is evident, therefore, that the head and neck of the femur are as well furnished with blood as other parts of the osseous system, and that the failure of reunion after fracture, which is so commonly observed in this portion of the skeleton, cannot be attributed to a deficient supply of nutritive material.

Causes of liabilities to fracture,

The liability to fracture of the neck of the femur in elderly persons, and especially in elderly females, is dependent on the following causes. *First*, this part of the skeleton has to bear a considerable weight, which falls upon it in a very unfavourable direction; and the direction becomes increasingly unfavourable with advancing years, owing to the gradual decrease of the angle between the neck and the shaft. *Secondly*, during the early and the adult periods of life, the neck of the femur is enabled to meet this difficulty by the large amount of cancellated texture which fills up its interior, and by the cancelli being disposed in such a manner (fig. 1, *H*) as to afford support in the direction in which it is most needed; so that the neck of the femur is very much dependent for its strength upon the arrangement and perfection of its cancelli. In old age, however, at the same time that the difficulty is being increased by the alteration of the angle, the compensatory aid is being withdrawn by that absorption of the cancellated tissue, which takes place, more or less, in all parts of the skeleton at this time of life (p. 56), and which seems to begin, and to proceed, most quickly in the upper end of the thigh-bone. *Thirdly*, the lessening of the angle formed by the neck of the femur with the shaft, in elderly persons, throws the hips more out, and renders them more exposed to injury.

and failure of union.

These are, probably, the chief causes of the frequency with which fracture occurs through the neck of the thigh-bone in old age, and of the comparative exemption of young persons from the accident. The breakage, as I have already said, takes place most frequently near the head of the bone; it is also not uncommon in the opposite or trochantral part of the neck. In the latter situation reparation will, under favourable circumstances, commonly take place, and bony reunion will be effected. In the former situation such a result is not to be expected; because the bone is here surrounded by only a thin sheet of fibrous and synovial tissue, which affords no opportunity for the formation and lodgement of the materials from which any *external callus* might be formed; because the bony surfaces themselves are not retained in sufficiently close and steady apposition to permit of the slow process of *direct* osseous union between them; and because that process is still further disturbed by the admission of synovial fluid into the fracture. It has now and then happened that the two fractured surfaces have been held closely together, probably because a portion of one was driven tightly into the other; and, under such circumstances, bony union has been established; but it is a rare event. Sometimes the parts are joined by fibrous tissue; often, however, they remain nearly or quite unconnected; indeed the portion of the neck that intervenes between the fracture and the trochanters usually undergoes absorption, in consequence (probably) of the pressure and friction to which it is subjected, against the acetabulum and surrounding parts, by the weight and movements of the limb, and by the contraction of the muscles.

Trochanters.

The *Trochanters* (τρέχω or τροχάω, to run) are situated at the junction of the neck with the shaft; and they serve to strengthen that part, and to give attachment and leverage to the muscles. The great trochanter ministers in this way to the muscles which abduct and rotate the thigh outwards; and the lesser trochanter, in like manner, to the *psoas* and *iliacus*, which bend the thigh upon the trunk. The latter process, which is directed inwards as well as backwards, serves also to keep the tendon of the *psoas* and *iliacus* clear of the neck of the femur. These two muscles are very powerful; they are the great agents in advancing the lower extremity in walking or running, and they have the leverage afforded by the whole length of the limb against them; and the ridge which runs from the fore part of the head of the femur, along the upper and anterior surface of the neck, to the great trochanter, is mainly for the purpose of enabling the neck to bear the forcible tug of these powerful and frequently acting muscles. The top of the great trochanter is about ¾ of an inch lower than that of the head of the femur. The difference of elevation between the two varies, however, with the degree of inclination of the neck.

A rough prominent surface for the attachment of the tendon of the *glutæus maximus*—the great opponent of the *psoas* and *iliacus*—is situated a little external to the trochanter minor, and runs for some distance down the hinder and outer part of the shaft[1]. Thus the powerful muscles which are the great agents in moving the lower extremity backwards and forwards upon the trunk—or in rolling the trunk backwards and forwards upon the extremity—are attached to the femur, in close proximity to one another.

Intertrochanteric ridges.

Of the *Intertrochanteric ridges* the *posterior* and thicker, running directly between the trochanters, serves to support them both and to strengthen the bone at this part where the weight is received from the dense concave posterior side of the neck. The *anterior* gives attachment to the strong anterior ligament of the hip. It descends from the fore part of the great trochanter, along the base of the neck, to the level of the lesser trochanter; and then makes a sudden bend, or rather an acute angle, and runs upwards, upon the lower part of the neck, without touching the trochanter.

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[1] The space for the attachment of the *glutæus maximus* runs out into a broad bold process in the hare and some other animals, resembling the prominent ridge in the humerus of the mole, to which the *deltoid*—the corresponding muscle of the upper extremity—is attached.

Interior of the bone.

A longitudinal section of the thigh-bone (fig. 1) shews the external wall to be peculiarly thick and dense in the middle third of the shaft, or rather in the upper part of the middle third, where the bone is narrowest, and where the medullary canal is most completely formed. Traced above and below this, as the bone becomes expanded, the outer wall becomes thinner, in consequence of its inner surface being more and more resolved into cancellated texture, which extends further and further into the medullary canal, narrowing and finally obliterating it. So that, in the upper and lower thirds, and in the articular extremities particularly, the outer wall is reduced to extreme tenuity, the medullary canal is quite lost, and the bone is almost entirely made up of cancelli. This is the case, to a greater extent, in the lower third of the shaft than in the upper third; and the medullary canal is continued further, and terminates more abruptly, in the latter direction than in the former.

Arrangement of the cancelli in the neck,

The disposition of the bony plates forming the cancelli is worthy of remark. In the upper end of the bone they run, in great strength and in parallel lines, from the summit of the head (*H*), where the greatest weight is borne, downwards to the expanding inner wall of the shaft, which is there very thick and is strengthened by the proximity of the lesser trochanter. Other plates, passing off from all round the interior of the wall in its whole circumference, where it expands, above the level of the lesser trochanter, run upwards and converge, near the junction of the neck with the great trochanter (*G*), so as to form a series of arches which support the upper wall of the neck. The great trochanter itself, which lies external to the line in which weight is transmitted, is composed of very light structure, i. e. of delicate cancelli enclosing large cells.

Now in old age the more delicate parts of the cancellated structure of the bone are first removed, that is to say, the cancelli in the great trochanter, and in the neighbouring part of the base of the neck. Hence a blow often breaks in the great trochanter, or causes the base of the neck of the femur to be broken and driven into the interior of the great trochanter, which, being reduced to an almost adipose state, offers little resistance. The same change, occurring at the other end of the neck, clears away the delicate cancelli on either side of the strong parallel vertical plates above mentioned, so as to leave the latter almost alone. These, too, become weakened by the same process; and the bone which is, at this part, chiefly dependent for strength upon the perfection of its cancelli, is easily broken when subjected to any sudden jar or blow.

in the lower end.

At the lower part of the femur the cancelli, gradually separating from the inner surface of the wall, as the latter becomes more and more expanded, descend chiefly in perpendicular plates to the articular surface. They are interrupted an inch above it by a wavy transverse line, which marks the junction of the epiphysis with the shaft, and which is more apparent than the corresponding line between the head and the neck, in accordance with the later union of the lower epiphysis. This line is first obliterated in the middle, above the part where the nucleus of the epiphysis was first formed, which seems to indicate that the union of the latter with the shaft is first effected here. The cancelli are strongest, and most decidedly perpendicular, above the middle of the outer condyle (*C*), where the greatest weight is borne. Above the space between the condyles (*D*) the direction of the cancelli is more confused. Above the outer part of the inner condyle they are again more perpendicular. A small space on the outer part of the outer condyle (*B*), and a larger space on the inner part of the internal condyle (*A*),—both being out of the line in which the chief weight is borne—are composed of light cancelli with large interspaces. Near the articular surface the cancelli become much closer, and their arrangement is less clear, though their chief direction is still perpendicular to the surface.

Length of the condyles.

When the lower ends of the two thigh-bones are placed near together upon a level surface, as when they rest upon the upper surfaces of the tibiæ in the erect position, their shafts slant away from one another, so that each forms an angle of about 15° with a perpendicular line falling between them. The degree of obliquity varies a little; it is, as a general rule, greatest in women and in short persons, i. e. in those persons in whom the angle of the neck with the shaft is smallest. The inner condyle of the femur is longer than the outer, in order to render the articular surface at the knee level. Its length, therefore, bears a relation to the obliquity of the femur, and also to the angle formed by the neck with the shaft. This obliquity of the thigh-bones, and the prolongation of the inner condyles, permit the tibiæ to be brought close together under the line of gravity, whereby oscillation of the trunk from side to side in walking is diminished or prevented.

Bandy-leg and knock-knee.

In some instances the object is not completely attained, the inner condyle not having quite its proper length. The knees then are wide apart, and the individual is said to be "bandy-legged," and has rather a waddling gait. On the other hand, the inner condyle may exceed its proper length[1]; the knees are then too close together; and the tibiæ, instead of descending vertically, acquire a slant outwards, so that the ankles are separated from one another. This constitutes "knock knee;" it is always attended with weakness of the limbs and an imperfect gait.

Holes for vessels.

At the bottom of the deep hollow between the hinder part of the condyles are two, three, or more foramina for vessels. They correspond with the medullary foramina in the shafts of long bones, and with certain large foramina in the vertebræ and other short bones; and they indicate the point at which ossification began. Between the 7th and 8th month of fœtal life, vessels are seen to enter the epiphysial cartilage at this spot, and to be distributed in the contiguous substance of the cartilage.

Development.

Ossification of the femur begins, near the middle of the shaft, at about the 40th day of fœtal life, which is a little earlier than in the shaft of the humerus. A nucleus appears in the lower epiphysis, just above the interval between the condyles, about a fortnight before birth. This and the adjacent

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[1] It would be more proper to say that the *outer* condyle *does not attain* its proper length. I made out this deficiency of length of the outer condyle to be the cause of "knock-knee" by careful examinations of patients who were the subjects of the deformity (Lectures on Surgery in *Provincial Med. and Surg. Journal*, 1850, p. 91); and I lately found, in the Musée Dupuytren, a specimen in which the shortness of the condyle is very apparent; still more recently I had an opportunity of verifying the same by dissection.

epiphysis of the tibia are the only ones in the body in which an osseous nucleus exists at birth. The presence of this nucleus is sometimes of importance in a medico-legal point of view, as affording a means of assisting us to determine the age of a fœtus. In accordance with the law that epiphyses, which are first ossified, are last united to their shafts, the lower epiphysis of the thigh-bone remains separate longer than any other in the body. Ossification extends from the shaft into the neck. A nucleus appears for the epiphysis of the head at the end of the 1st year; in that for the great trochanter about the 4th year; and in that for the lesser trochanter about the 13th year. The several epiphyses are united to the shaft in the inverse order to that of their appearance; the lesser trochanter soon after puberty; the great trochanter at about 17; the head at 18[1]; and the lower extremity from 20 to 25.

Proportion to rest of skeleton at birth, &c.

At birth the femur presents, in a more or less marked manner, the same curves and prominences as in the adult[2]. The neck is short and more nearly in the same line with the shaft (Pl. I. p. 35); the two thigh-bones are more nearly parallel; and there is less difference in length between the outer and the inner condyle. The bone is comparatively short at birth, and does not attain its proper relative length till after puberty (Table at p. 110). It is, relatively to the rest of the skeleton, longer in man than in most animals, and in the European than in the Negro (pp. 106 and 108). In cases of rickets it not unfrequently fails to attain its proper length on one or both sides (pp. 53, 63, 100).

Diseases.

The connecting medium between the lower epiphysis and the shaft is, not unfrequently, the seat of acute ulcerative inflammation in young persons. Exostoses may grow from various parts of the thigh-bone; the most frequent situation is the front of the shaft, where they are commonly broad and flat, and the neighbourhood of the attachment of the adductor longus to the inner condyle, where they

[1] Meckel says the union of the head takes place before that of the great trochanter.

[2] The curve backwards in the upper part is commonly rather more, and the curve forwards in the middle and lower part of the shaft is rather less decided than they subsequently become.

are generally more elongated[1]. It is frequently, perhaps more frequently than any other of the long bones, the seat of encephaloma, which may spring from its shaft, from the spongy texture of its internal condyle, or from any other part.

THE PATELLA (Plates XXXIX. and XL.)

Protects knee and affords leverage to quadriceps.

serves to protect the front of the knee-joint; and it affords some leverage to the *quadriceps extensor* muscle, by distancing its tendon from the centre of motion in the knee. For the former purpose it is spread out so as to cover a large space; and it is flattened upon the anterior surface to permit of kneeling upon it without discomfort. For the sake of leverage it is thick, so as to present a prominent anterior edge, which is removed to some little distance from the articular surface. To this prominent edge the tendon of the *quadriceps* is connected above, and its continuation, the *tendo-patellæ*, below; and some fibres of communication between the two occupy the longitudinal furrows on the anterior surface of the bone. The interval between the insertion of the tendons and the margin of the cartilage of the patella is, in each instance, occupied by a roll of fat (Pl. XXXIX. *F* and *I*). The upper edge of the patella is broad, to receive the broad tendon of the quadriceps, and is sloped a little, from above, downwards and forwards. The lower edge is more pointed, the tendo-patellæ being less wide than that of the quadriceps; it is prolonged to a considerable distance below the level of the articular surface; and it overhangs the mass of fat (*I*) which lies on the front of the joint.

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[1] Barkow, *Anatomische Abhandlungen*, Breslaw, 1851, describes a process, occasionally met with, projecting from the outer side of the shaft of the femur, at a variable distance above the condyle. He calls it "external supra-condyloid," and regards it as analogous to the process found in the horse, beaver, armadillo, &c. Dr Wilbrand, *Brit. and For. Med. Rev.* XIX. 571, describes such a process, in a strong man, situated at the attachment of the short portion of the biceps femoris; it was one inch and a half long, four lines thick, and projected outwards nearly three-fourths of an inch, and had not at all the appearance of a morbid exostosis.

Relation to condyles in different positions of the joint; In the bent position of the knee the prominent anterior surface of the femoral condyles affords a leverage to the quadriceps; and the patella, occupying the interval between the tibia and femur, projects very little. During extension of the joint, as the tibia comes more into a level with the fore part of the femur, and as the leverage afforded by the latter, accordingly, diminishes, the patella mounts upon the prominent surface of the condyles, stands out more strongly in relief in its whole length, and keeps the quadriceps at a distance from the centre of motion. In the last stage of extension, when the flat under surface of the femur slides, without much resistance, into its position upon the surface of the tibia, and when, therefore, much muscular power is not required to complete the movement, the patella again occupies a less prominent position, for it lies upon the uppermost, slightly retiring, part of the condyles, and upon the still more retiring anterior surface of the femur, just above the condyles.

in the flexed state; The patella must, therefore, be considered with reference to each of these three positions of the joint. In the most flexed position (fig. 3), only the upper third, or fourth, of its cartilaginous surface lies upon the condyles of the femur; and the lower two-thirds, or three-fourths, rest upon the large mass of fat (*I*) which occupies the triangular interval between the patella, the femur, and the tibia. Accordingly, when the knee is bent, the lower part of the patella can be made to recede upon pressure; and it resumes its position, when the pressure is removed, proving that it is supported, not by bone, but by the elastic pad of fat just mentioned.

during extension; As extension takes place, more of the patella is gradually drawn upon the front of the condyles; and, before the limb is quite straight, the whole surface of the patella passes over this part. At the intermediate point between the straight and the most bent positions (fig. 2), the greater part of its surface is in contact with the condyles. The whole of its middle third, at any rate, has become so. The patella rests now upon the most prominent portion of the condyles, affords a greater advantage of leverage to the quadriceps than in any other position of the knee, and is subjected to a severe strain from the pull of this powerful muscle. It is, accordingly, when in or near this position that it is most frequently snapped by the sudden forcible contraction of the muscle; and in that accident the lower portion of the bone is usually broken off from the rest—or, to speak more strictly, the part above this is broken off from it. Hence the line of fracture of the patella is commonly transverse, and is situated at about the junction of the lower with the upper two-thirds of the bone, or a little below the middle. The articular surface of the dried patella is often concave at this part; but, in the recent state, the concavity is, in great measure, filled up by the cartilage, which is thicker here than elsewhere.

in the extended state.

In the third position—that of the fully extended knee (fig. 1)—the patella is drawn up, so that only the lower third or fourth, or even less, of its articular surface rests upon the articular surface of the condyles; and the upper two-thirds, or three-fourths, lie upon the bed of fat which covers the lower and fore part of the shaft of the femur.

Three facets on articular surface of patella.

In some patellæ (Pl. XL. fig. 1) three facets may be observed upon the articular surface, denoting the parts which are respectively in contact with the condyles in these three positions. There is the concave middle facet (*D*) which occupies two-thirds of the surface, and which lies upon the prominent convex portion of the condyles in the mid-position of the joint. This is separated by slight transverse ridges, above and below, from the narrow flat facets (*E* and *F*) which respectively lie upon the condyles in the extended and flexed positions.

DESCRIPTION OF PLATE XXXIX.

Patella in three positions of Knee.

Fig. 1. Right-knee joint viewed from outer side in the extended position. *A*, femur. *B*, tibia. *C*, fibula. *D*, section of patella. *E*, Rectus tendon. *F*, fat behind rectus tendon. *G*, layer of fat upon front of femur. *H*, tendo patellæ. *I*, mass of fat behind tendo patellæ. *K*, external lateral ligament. *L*, external semilunar cartilage. *M*, tendon of poplitæus.

Fig. 2. The same partially bent. The letters as in Fig. 1.

Fig. 3. The same fully bent. The letters as in Fig. 1.

Fig. 1.

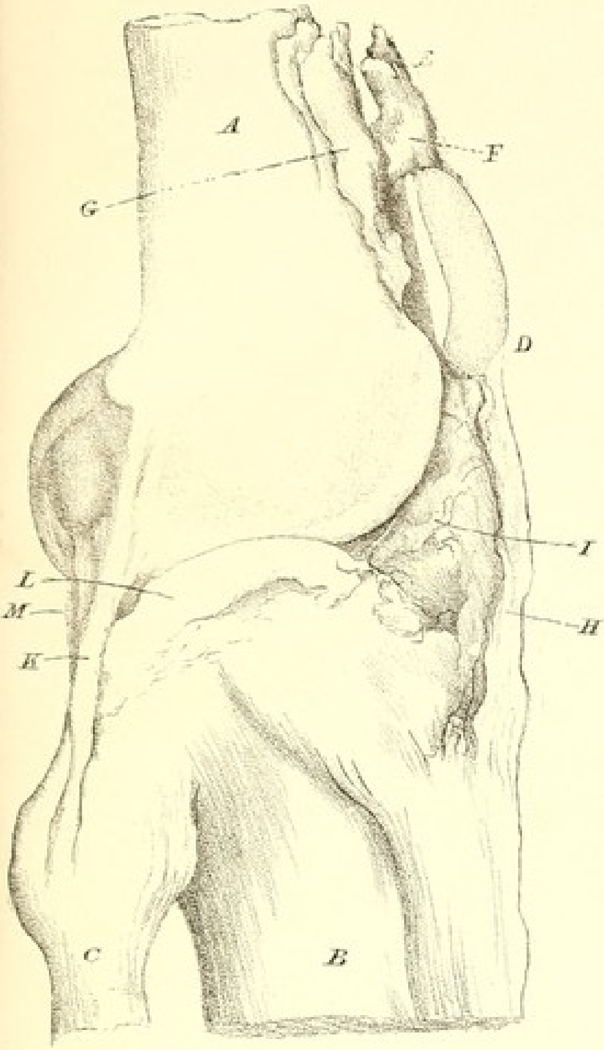


Fig. 2.

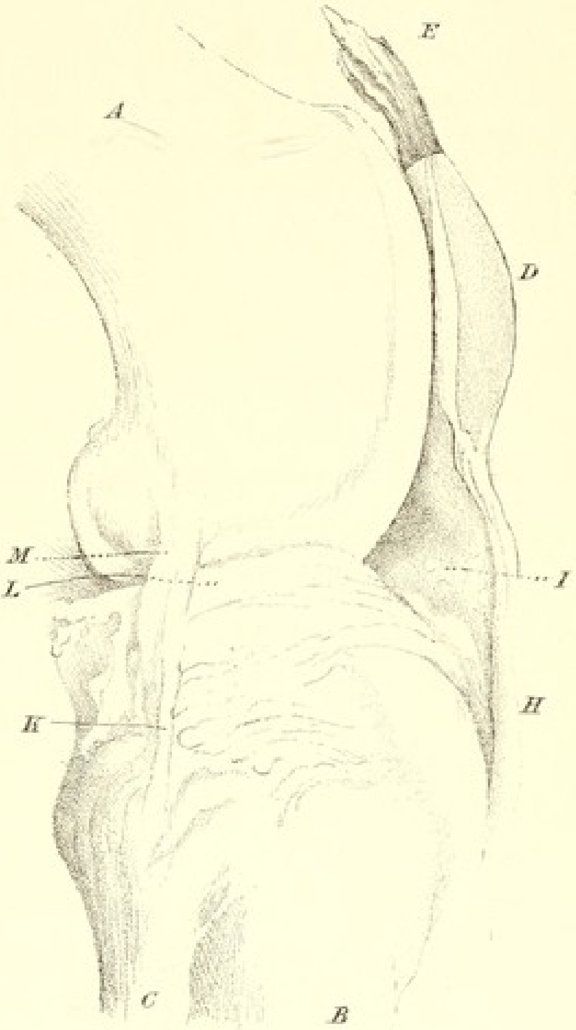
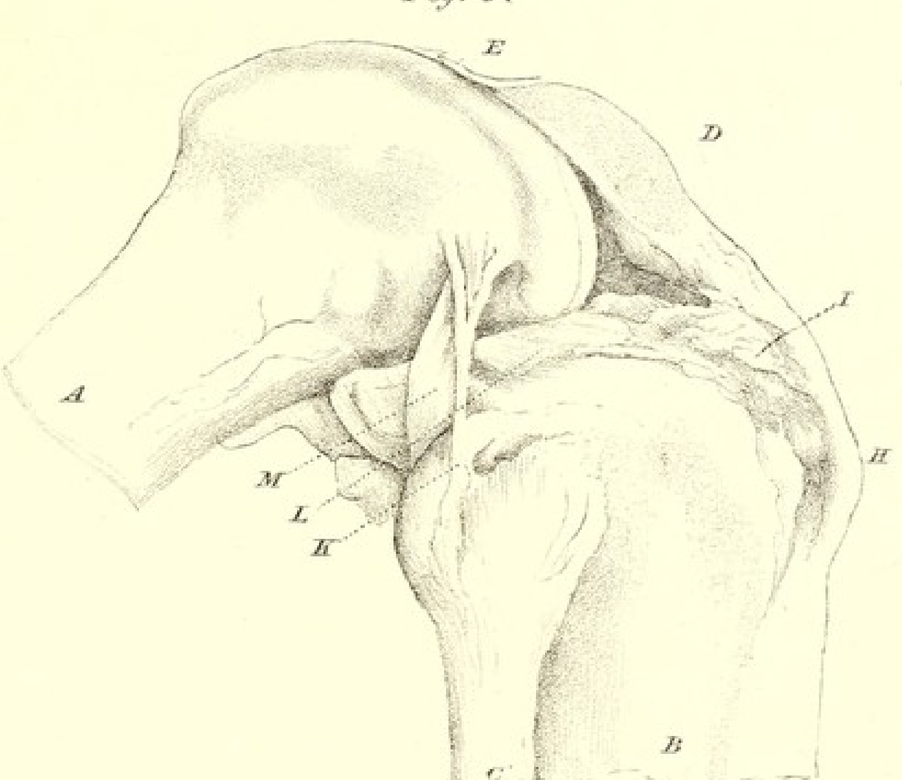


Fig. 3.



Substitute in frog and other animals.

In the frog there is no patella; but its place, as an assistant to the quadriceps muscle, is, in some measure, supplied by the tendon of the *tibialis anticus*, which, arising from the forepart of the condyle of the femur, and lying beneath the tendon of the quadriceps, serves to distance the latter from the centre of motion. In some other animals, as the kangaroo and ostrich, where the patella is absent, the loss is compensated for by the greater prominence of the tubercle of the tibia.

Patella borne chiefly upon outer condyle of femur.

Owing to the inclination inwards of the shaft of the femur, and the great strength of the vastus externus, the contractile power of the muscular fibres which pass, from without inwards, to the patella exceeds the force of those which are directed upon it from the inner side. There is, consequently, a more forcible traction exerted upon it in an outward, than in an inward, direction; and, to resist the tendency of the bone to pass outwards by reason of this superior force, and to afford a better fulcrum for the action of the extensor muscles, the outer condyle of the femur presents a larger articular surface for the patella than does the inner condyle, and the outer edge of the former (Pl. XXXVIII. fig. 6, *C*) is advanced further forward, than is the inner edge of the latter[1].

Dislocation; from disease;

In spite of this provision, however, when dislocation takes place in consequence of muscular contraction, which it does in some diseased conditions, the bone is invariably drawn on to the *outer* side of the joint. It has been known to be drawn so far *backwards* in this direction that, passing behind the centre of motion of the knee, when the joint was bent, it has caused the quadriceps to act as a *flexor* of the leg upon the thigh[2].

from accident.

Also when dislocation takes place from an accident, which is usually a blow, the patella is commonly driven on to the outer side of the joint, because, lying principally upon the outer

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[1] The prominence of the outer condyle in front, and of the inner condyle behind, have reference, not only to the inclination of the thigh inwards, but also to the slightly oblique plane, in which the leg is moved, in flexion and extension, upon the thigh. (See description of the knee-joint.)

[2] Robert, *Vices de Conformation*. *Brit. and For. Med. Rev.* July, 1852.

condyle, it is more easily forced in this direction. Moreover, when it has once passed over the edge of the outer condyle it is less likely to be replaced, than if it had gone in the opposite direction, both in consequence of the greater prominence of this condyle, and of the preponderating force of the vastus externus as compared with that of the vastus internus.

Size of outer articular facet peculiar to man.

The articular surface of the patella is divided by a longitudinal ridge into two unequal facets, of which the outer and larger is adapted to the outer condyle of the femur; the inner and smaller rests upon the inner condyle; and the ridge between them is fitted to the furrow between the condyles. This preponderance in size of the outer articular facet is peculiar to man. It is associated with the prominence of the fore part of the external condyle, which has relation, as just said, to the inclination inwards of the human thigh-bone as it descends, and also to a slight twist in the shaft of the femur, which throws the outer condyle a little forwards.

In Quadrumana the thigh is nearly vertical, the trochlea is in the middle, between the two condyles, and the articular surface of the patella is divided into two equal portions by the ridge which occupies the trochlea.

In most animals, below quadrumana, the thigh-bone is inclined outwards, away from the trunk, and the twist in the shaft is in a direction opposite to that in the human femur; the inner condyle is, consequently, thrown more forward, is more prominent than the outer, and has to bear the chief stress of the pull of the extensor muscle. The patella is shaped in a corresponding manner in these animals, its inner articular facet being larger than the outer. By the mere observation, therefore, of the relative size of its articular facets, the human patella may be distinguished from that of any other animal.

Patella resembles sesamoid bones in structure.

The patella corresponds with the other sesamoid bones in being composed throughout of nearly uniform, dense, cancellated structure. Hence it is of great strength, which is necessary to withstand the powerful contraction of the quadriceps. That it has no greater strength than is needed, is proved by the fact that it is not unfrequently snapped by the sudden pull of the muscle; it more frequently gives way than either of the tendons by which it is connected with the muscle and with the tibia.

Development.

It is formed of cartilage in the third month of fœtal life; and it remains cartilaginous till the second or third year after birth, when an osseous nucleus appears near the middle, beneath the spot, on its anterior surface, where several foramina for vessels may be usually seen. The nucleus soon acquires a knotty or tuberculated outline, which is quite different from that of ordinary bones, being a peculiarity of the sesamoid bones. Ossification is complete about the time of puberty. The patella attains to greater proportionate size in man than in the ape, and in the European than in the Negro. It is usually small in rickety persons.

Its homologue.

Its relation is evidently rather with the quadriceps extensor muscle than with any particular bone; and, in deciding its correspondence with any bone, or bony process, in the upper extremity, we must be guided chiefly by the connection of such bone or process with the muscle in the arm which corresponds most nearly with the quadriceps. The triceps extensor of the forearm, in function and attachments, answers in many respects, in more respects than any other muscle, to the quadriceps extensor of the leg, and may, I think, fairly be regarded as its correspondent. As this muscle has no sesamoid, there is no distinct homologue of the patella in the upper limb, and the only part which, it seems to me, can fairly be considered as presenting a claim to be compared with it is the olecranon process of the ulna, into which the triceps tendon is implanted.

THE TIBIA (Plate XL.)

The narrow and weak point.

is about $14\frac{1}{2}$ inches in length. The shaft gradually decreases in size from the upper end to about 4 inches above the ankle, and then expands again a little; and a cursory glance at the skeleton indicates that this narrowest part of the tibia has to bear a greater weight upon a smaller area than any other bone. The section shews the wall of the shaft to be rather thick here; but experience tells us that this does not quite make amends for the smallness of the calibre of the bone, and that the tibia constitutes no exception to the rule that the several bones are, in the adult at any rate, weakest where they are smallest.

Liable to fracture and disease.

The lower third of the leg, indeed, is more often broken than any other part of the inferior extremity. When a man falls from a height on one or both feet, fracture, if it occur, takes place most frequently in this situation. The first evidence of rickets is generally afforded by an increase of the bend in the lower part of the tibia; and that the bone is here vitally, as well as physically, weak is proved by its being more often the seat of inflammation, with the various sequences—sclerosis, node, ulceration and necrosis—than

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DESCRIPTION OF PLATE XL.

Fig. 1. Vertical section, from before backwards, through patella. *A*, upper edge where rectus tendon is attached. *B*, lower edge where tendo patellæ is attached. *C*, anterior surface; the cancelli immediately beneath it lie parallel with it. *D*, *E*, *F*, middle, upper and lower portions of articular surface. The cancelli radiate from this surface towards the other parts of the bone.

Fig. 2. Vertical section from before backwards through tibia. *A*, crest. *B*, posterior wall. *C*, spine. *D*, space in front of spine; *E*, ditto behind spine. *F*, *F*, line of union of upper epiphysis. *G*, *G*, ditto of lower epiphysis. *H*, tubercle. *I*, point of insertion of tendo patellæ.

Fig. 3. Vertical section through fibula. *A*, upper articular surface. *B*, lower ditto, with cancelli radiating from it. *C*, projecting upper extremity to which external lateral ligament is attached. *D*, outer malleolus; the cancelli are here parallel with surface.

Fig. 4. Tibia and fibula at birth, viewed from inner side, shewing the curve of tibia near upper end.

Fig. 5. Horizontal section through tibia and fibula near the middle of leg, shewing the relative position of the two bones, &c. *A*, crest of tibia. *B*, posterior wall. *C*, ridge for interosseous membrane. *D*, edge on fibula for attachment of extensor longus digitorum. *E*, hollow on outer side of fibula for peronei. *F*, ridge for interosseous membrane.

Fig. 6. Horizontal section through tibia and fibula at narrowest part. *A*, *B*, *C*, *D*, *E*, the same as in preceding.

Fig. 7. Horizontal section through tibia and fibula a little above lower articular surface of tibia. *A*, anterior surface. *B*, posterior surface.

Fig. 8. Vertical section, from side to side, through upper end of tibia. *C*, inner tubercle of spine. *C′*, outer ditto. *F*, *F*, line of union of epiphysis. *K* and *L*, inner and outer articular surfaces, with dense bone beneath them and bony plates descending vertically to the inner and outer walls of shaft; whereas beneath the spine, where no weight is borne, the cancelli are fine and irregularly disposed.

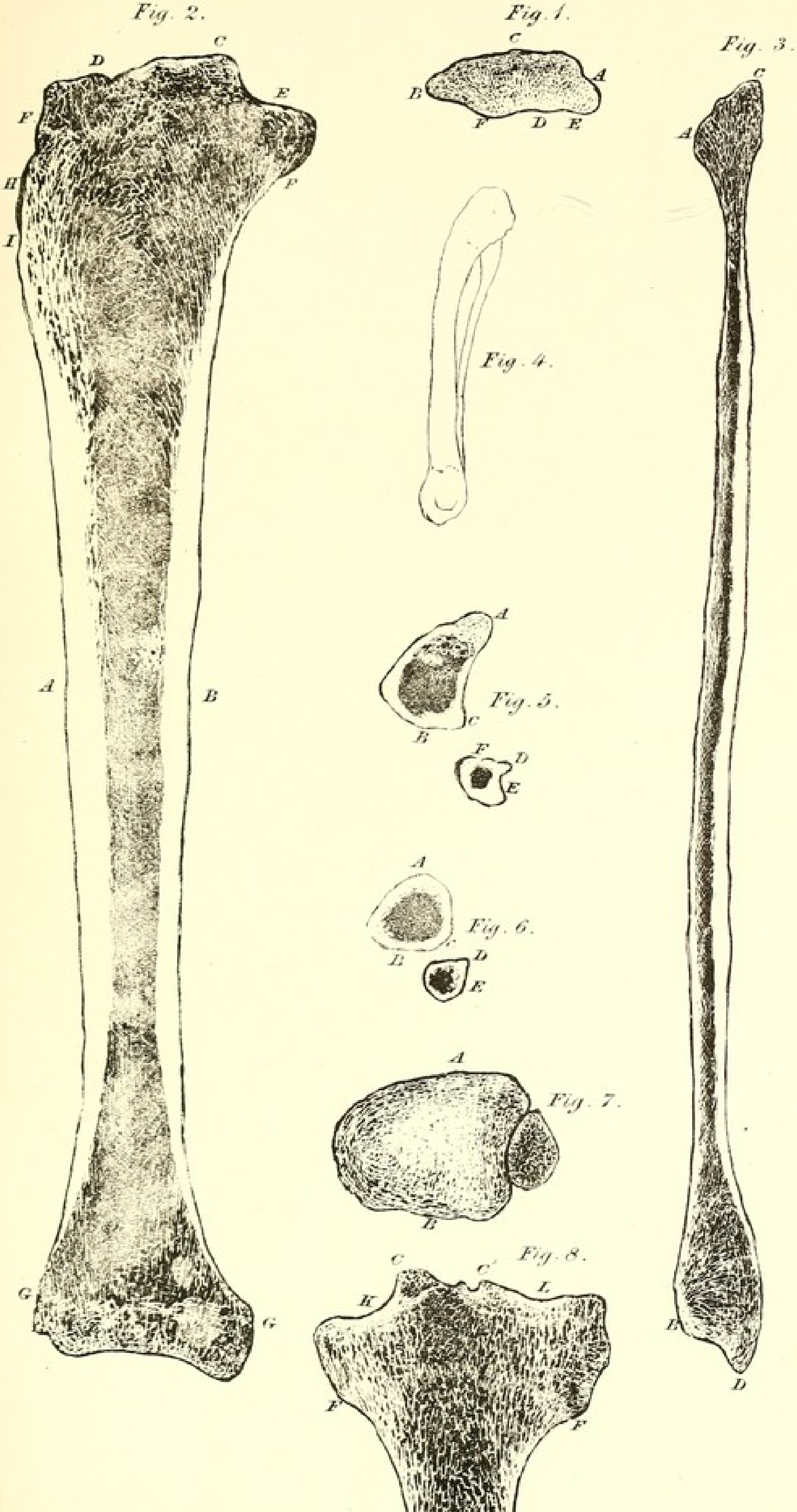
Fig. 2.
Fig. 1.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.

any other part of the skeleton. It would seem, too, as if the adjacent soft parts partook of this infirmity; for varix of the subcutaneous veins, and of the small cutaneous vessels, purpurous spots, erythema, and ulcers are far more common in this region than elsewhere.

Advantages of small size of leg at this part.

We naturally enquire what are the advantages gained by this economy of size, to compensate for the disadvantages which it entails. In the first place, it is essential to activity that the components of the extremities should, as much as possible, decrease in size as they become more distant from the centre, inasmuch as the area through which they must be moved increases in like proportion with the distance from the centre of motion, and much bulk and weight would be an impediment to quickness of movement. Accordingly, although the foot is spread out to afford a basis of support upon the ground, the bones of the lower limb diminish in size as they approach the ankle; the slight exception afforded by the enlargement of the lower ends of the tibia and fibula being requisite to give greater security to the ankle-joint. In like manner, the bones of the forearm decrease in size as they descend, till near the wrist-joint, when they again expand a little. Secondly, the contraction of the leg above the ankle gives greater space for the play of the opposite foot, when it is carried forward in walking and running, and prevents the one limb being caught and injured by the other.

No muscles attached here.

To admit of the small size of the bones at this part few or no muscular fibres take their origin, and no tendons are implanted, here. The various tendons, to which the muscular fibres have converged, are reduced to the smallest dimensions compatible with the required strength; they lie close to the bones, being connected with them by loose areolar tissue or synovial sheaths, and are bound in their places by strong bands of fasciæ.

Sides of the shaft.

At the point to which I have been referring, the tibia is nearly cylindrical. Above this the shaft is distinctly three-sided. Of these sides the inner, or broadest, forms the shin, and is covered only by skin and subcutaneous tissue. The fascial investment of the rest of the limb is connected with the anterior and posterior edges of the tibia, and does not extend upon this inner side, which is, accordingly, a good deal exposed to injury, and occasionally suffers from the extension of inflammation from the skin. I have called it the inner side;

but it is really inclined so as to look forwards and inwards, and, meeting at an angle the strong fascia which extends to its anterior margin from the fibula, it gives to the fore part of the leg a shape favourable for making its way through the air and water, or through long grass, underwood, heath, &c. The hinder and the outer sides of the tibia present nothing remarkable. They are smooth, giving origin only to muscular fibres, except in the *popliteal line*, where the bone is rough for the attachment of the tendinous fibres of the popliteal muscle and fascia.

Canal for medullary artery; why so large.

A little below the popliteal line, in the posterior aspect of the shaft, is the large opening of the *canal for the medullary artery*, slanted downwards, and directed, as usual, towards the epiphysis first united, and towards that part of the shaft which is smallest and hardest, and which contains the medullary canal in its most developed state. The reason that this orifice and the vessel it transmits are so large, in comparison with those of other bones, is, not that the medullary canal is larger than in other bones, for that of the femur is both wider and longer, but because the contents of the medullary canal, and of the cancellated tissue for some distance below, are almost entirely dependent upon this artery for their supply of blood. They are so, to a greater degree than corresponding parts in other bones, forasmuch as the wall of the shaft of the tibia, being here very dense to enable it to bear so great weight upon so small an area, can transmit very few vessels to the interior.

The ridges;

Of the three *ridges* that separate the three sides of the shaft, the anterior, called the *Crest*, is the most conspicuous. It contributes greatly to the strength of the bone. It is serpentine, being curved outwards in its lower, and inwards in its upper, part; and the flexures in the slighter cases of rickets are usually exaggerations of these curves in the crest. In the more severe cases of rickets, where the effects of the malady are evinced at an earlier period, there is often only one flexure; and this is an exaggeration of the forward curve which is presented by the bone between its two extremities, and which is most marked near the upper end. In the lower third of the shaft the anterior surface of the bone is flattened, and the crest disappears. At the upper part the crest is connected chiefly with the outer condyle of the head of the tibia. It is partly interrupted by the tuber tibiæ; the arrangement is such that the pull of the great extensor muscle is made directly upon this strong anterior part of the tibia.

The *inner ridge* may be traced, below, to the hinder part of the malleolus; above, it is lost in the inner side of the head of the tibia. The *outer ridge* is most distinct in the middle part of the shaft, and gives attachment to the fibres of the interosseous membrane. It is continued, above, into the outer part of the head of the tibia; and, below, it is directed towards the concavity for the lodgement of the fibula.

their disposition with reference to the transmission of weight from the femur.

It would seem, therefore, from the disposition of these ridges, that the weight, received from the outer condyle of the femur, is chiefly transmitted along the outer and anterior part of the tibia, while that from the inner condyle is chiefly transmitted along the inner and posterior part of the bone. This construction of the tibia, and this disposition of the weight received from the respective condyles, accord with the fact that a slight rotation of the tibia outwards at the knee accompanies the extension of the leg upon the thigh[1]; it being evident that such rotation will bring the outer condyle of the femur into more close relation with the anterior surface of the tibia, and the inner condyle into more close relation with the posterior surface.

The tuber.

The slight obliquity, from above, downwards and outwards, which may be observed in the direction of the rough ridge on the lower part of the tuber, for the insertion of the tendo patellæ, and the direction of the little processes which create the roughness, have relation also to this rotation which accompanies extension of the knee. For they indicate that the fibres of the tendon descend with slight obliquity inwards to the tuber; and, consequently, that the traction, made upon the tuber by the quadriceps, will exert some influence in rotating the tibia outwards, in addition to the greater result of extending it upon the femur.

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[1] See description of knee-joint, p. 526.

Line of union of epiphysis.

It is well to remark how near to the articular surface (about half an inch only from it) is the faint ridge encircling the upper end of the bone, which indicates the line of union of the epiphysis with the shaft. Because if, in a young person, the section be made below this line in the operation of excision of the knee, and the whole of the epiphysis with a portion of the shaft be removed, the stratum of cartilage, by means of which the shaft is increased in length, will be taken away; and it is probable that the subsequent growth of the limb will be impaired (p. 44).

Upper end.

The upper end of the tibia is wider behind than in front, corresponding with the shape of the under surface of the femur. It overhangs the shaft, behind, whereas, in front, it is rather retiring; thus creating a curve at the junction of the shaft with the head, which is more marked in the fœtal (Pl. XL. fig. 4) and young bone than in the adult (fig. 2). The outer condyle projects in an especial manner over the fibula, so as to transmit some weight to it; and, for the same purpose, the articular facet for union with the fibula is almost horizontal. A curved line runs forwards from this facet, and, descending on the outer side of the tuber, joins the crest; it gives attachment, below, to the *fascia* of the leg and to the uppermost fibres of the tibialis anticus and the extensor longus digitorum; above, it gives attachment to some fibres of the biceps tendon near the fibula, to a strong process of the fascia lata which descends upon the outer side of the knee from the tensor vaginæ femoris, to the fibres of the vastus externus, and to the fascial investment of the knee. A corresponding curved line, ascending from the inner side of the tuber, beneath the inner articular end, terminates in the rough ridge for the insertion of part of the semi-membranosus tendon; it gives attachment to the vastus internus, and to the fascial covering of the inner side of the knee. It is less marked than the outer line. Beneath the ridge for the semi-membranosus is a rough space for the attachment of the internal lateral ligament, and above it is a groove, lined with cartilage, but not communicating with the joint. This groove is occupied by a part of the semi-membranosus in the flexed position of the joint; and the portion of the tendon which is so placed runs on to be inserted into the bone just in front of the groove.

Interior of the bone.

A section of the tibia (fig. 2) shews the *medullary cavity* to be well formed where the bone is smallest, and where the wall of the shaft is thickest; that is, rather below the middle. It shews also the plates of the cancelli diverging from the inside of the wall, as it expands and becomes thinner, above and below. At the lower part they run perpendicularly to the articular surface; above, they do the same, but are directed in greatest numbers towards the *middle* of each articular facet, where there is a thickish stratum of dense bone intervening between them and the *cartilage*.

Development.

Ossification begins in the middle of the shaft of the tibia at about the 50th day of fœtal life, and quickly extends upwards and downwards. A nucleus for the upper epiphysis (Pl. I. p. 35) appears before birth; the tubercle is usually formed by a prolongation of this, but now and then has a separate centre. The nucleus for the lower epiphysis appears at about a year after birth; an extension of it forms the internal malleolus (Pl. II. p. 40); it is united with the shaft about the 18th year. The union of the upper epiphysis with the shaft does not take place till between the 20th and 24th years. The curves at birth are commonly as marked as at subsequent periods; the anterior one near the upper end is more so.

THE FIBULA. (Plate XL.)

Increased surface for attachment of muscles.

The hinder part of the outer tuberosity of the tibia projects a good deal, so as to overhang the shaft; and the fibula, which is articulated with this part, serves, in some measure, as a prop to it; but the office of the fibula is less to carry weight than to widen the space for the attachment of muscles and to give security to the ankle-joint. Accordingly, it is covered by muscles, except at the lower part, which is left exposed in consequence of the muscles and tendons separating to pass, some in front of, and others behind, the ankle. Its value as a means of increasing the basis for attachment of muscles must not be estimated simply by the external area of the bone itself, which is small; but it must be remembered that the whole space between it and the tibia is, through its means, rendered available for the same purpose by the aid of the interosseous membrane. The fibula is firmly bound to the tibia above and below; so that both bones are often broken together. When they are so, the fracture in the fibula is commonly at a higher point than that in the tibia.

The shaft.

It has one chief *Curvature*, which is backwards; in an opposite direction, therefore, to the chief curve in the tibia. This causes it to be, in a considerable part of its extent, behind the level of the tibia, so much so that, in the middle of the leg, its anterior edge lies in a plane *behind* the posterior edge of the tibia (figs. 5 and 6). Hence, unless care be taken in the flap amputation, the point of the knife is very likely to be passed between the two bones, which causes some embarrassment in the operation. The lateral curves are slight; the chief is one, in the middle, towards the tibia. The narrowest part of the bone is nearly on a level with that of the tibia; it is the part which is usually broken when the ankle is dislocated. The shaft is thicker at the middle than at either end, and presents projecting ridges which increase the surface for attachment of muscles. The medullary artery pierces the hinder surface of the shaft a little above the middle, and slants downwards towards the narrowest part.

Inconstancy of the fibula in the animal series.

The fibula is a very inconstant bone in the animal series. Some relation may be observed between the extent of its development and that of the ulna; but this is not uniform. In Carnivorous and Pachydermatous animals it extends from the end of the tibia to the ankle, as in man. In most Rodents it is united with the tibia at the lower part. In Ruminants it altogether disappears. In Birds it is present, its upper extremity entering into the knee-joint, and being articulated with the outer condyle of the femur. In this class of animals it is applied close against the tibia, like the ulna in Ruminants, and dwindles and disappears about the middle of the leg. In Reptiles it is of large size; in many extending to the knee-joint above and to the tarsus below. In the Bat the lower half of the fibula and the upper half of the ulna are retained. In some of the Monotremes it extends up in front of, or beside, the knee-joint, and is expanded, like the olecranon in these animals and in the Bat. There is a relation between its presence and absence, and the presence and absence of the outer toes, as we found to be the case between the ulna and the outer fingers (p. 379); but it is not so close as in the latter instance. For example, in the rhinoceros, which has only 3 toes (the outer and inner being wanting), it is as well developed as in the elephant (which has 5), or as in man; and in Ruminants (which have 2 toes) it is wanting altogether.

Development. The ossification of the shaft begins rather later than in the tibia. Both the epiphyses are cartilaginous at birth. The lower one is longer and larger than the upper, and is said by Beclard to be ossified before it; the nucleus appearing, according to him, in the 2nd year, whereas it is not seen in the upper epiphysis till æt. 4½ years. Nevertheless, contrary to the general rule, the lower epiphysis is joined to the shaft before the upper; the former union taking place in the 18th, the latter in the 20th year.

Varieties and diseases. Although so inconstant in the various classes of animals, the fibula, like the ulna, is rarely absent in man[1]. It is not very frequently the seat of disease. The circumstance of its being covered by muscles in great part of its extent, and its having no movements independently of the tibia, cause a difficulty in detecting fractures of this bone. Often we cannot discover any crepitus, and are obliged to form our opinion from the amount of resistance which it offers to lateral pressure, and from the presence or absence of its natural elasticity.

It is sometimes united to the tibia by a broad plate of bone, which may be congenital, or may result from processes shooting from both bones and coalescing in the interosseous space. This union may take place at any part, but is most frequent near the lower ends of the bones, and acquires some interest from the fact that in Rodentia and Insectivora the tibia and fibula are joined in their lower parts. In rickets the fibula is, not unfrequently, widened, and bent so as to reach the tibia and become united with it.

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[1] I found a specimen in the Musée Dupuytren in which the fibula and the cuboid bone, on either side, were absent. There were only four toes; and the outer one of these (the representative of the ring and the little toes) rested upon the os calcis, which projected forward into the place of the cuboid.

THE FOOT.

The plantar arch.

The foot is placed at right angles with the leg; and this disposition, like the similar relation of the head with the spine, occurs in scarcely any animal besides man, and has relation to his erect attitude. It is constructed to bear and to propel the body; and both purposes are served by its being made in the shape of an arch. The summit of the arch is at the top of the astragalus. The hinder limb of the arch is formed by the hinder part of the astragalus and by the os calcis; and the anterior limb is formed by the other tarsal and the metatarsal bones. It is sometimes said that the foot is a tripod in consequence of there being a transverse arch in the metatarsus; and that two of the limbs of the tripod are in front, and are formed by the ends of the metatarsal bones of the great toe and of the little toe. This, however, is not quite correct; for when the foot is planted upon the ground it rests, in front, not upon the balls of the great toe and of the little toe alone, but upon the balls of all the toes, upon those of the middle toes as much, in proportion to their size, as upon the others. Indeed, when the bearing of the foot is correct, the sole of the shoe becomes worn out first beneath the balls of the middle toes, shewing that the weight falls here rather more than at the sides.

Foot not a tripod.

Advantages derived from the shortness and solidity of the hinder pillar of the arch,

The two pillars of the arch differ from one another in many respects. In the first place, the hinder one is shorter than the anterior, in the proportion, roughly speaking, of about three inches to six, that is to say, it is not above half as long. Its descent from the summit of the arch to the ground is, consequently, more sudden, and the leverage afforded by it is thereby reduced to a still lower proportion, in comparison with that which is afforded by the anterior pillar, viz. to about the proportion of 1·5 to 4·2. This adjustment of the relation of parts in front of and behind the astragalus has reference to the fact that, in walking, the hinder, or heel part, of the arch is raised by the muscles attached to it through the medium of the tendo achillis, and the centre of gravity of the body is, partly by this means, thrown forwards over the balls of the toes. Now the power required to effect this movement is directly, and the celerity with which it can be done is inversely, proportionate to the length of leverage which the hinder part of the foot affords in comparison with the fore part; and, in accordance with the principle usually observed in the construction of the skeleton, power is sacrificed to celerity by the shortening of the heel. This is particularly the case in the well-formed foot of the European.

Not only is the hinder pillar of the arch shorter than the anterior, and its inclination more sudden: but it is composed of only one bone—the os calcis—in addition to the hinder part of the astragalus; whereas the anterior part of the arch is composed of several bones carefully jointed together. The object of this construction is to give solidity to the hinder portion upon which the elevator muscles act, and to prevent the power of these muscles being unnecessarily expended by any movements between the point of their attachment and the ankle-joint. Whereas by the numerous joints and ligaments in the fore part of the arch elasticity is given to the foot, and jars are prevented both in the foot itself, and in the rest of the body. In conformity with this disposition of parts we usually, in running and jumping from a height, alight on the ground upon the balls of the toes, and the weight of the body is directed forwards, from the leg, towards the tarsus and the toes. Moreover, when, as in walking or in jumping a distance along the ground, the heel first comes in contact with the ground, the weight is directed forwards towards the balls of the toes, so that they quickly reach the ground, and bear the greater part of the stress. If, on the contrary, it happens that, in descending from a height, we alight upon the heels, so that the weight comes vertically upon them, an uncomfortable jarring sensation is apt to be experienced throughout the frame, of a kind which rarely occurs when the weight is received in the ordinary way upon the balls of the toes.

and from the elasticity and width of the anterior pillar.

The width of the anterior pillar contributes to this same result, permitting the distribution of forces over a wide space, and so preventing their operating with great severity upon any one part. It increases along the metatarsus and attains its maximum at the balls of the toes. The line formed by these—that is, by the distal ends of the metatarsal bones—is not straight, but curved, in consequence of the end of the second metatarsal bone projecting a little beyond the level of the others. Nevertheless in walking they all touch the ground nearly, or quite, at the same time. A broad basis of support is provided by this expansion of the fore part of the foot, and firmness is given to the step.

Construction of the anterior pillar in two divisions.

The foot in front of the ankle—that is to say, the anterior pillar of the arch—consists of two divisions; an inner, or larger, composed of the neck and head of the astragalus, the scaphoid, and the three cuneiform bones, with the three inner metatarsals; and an outer, or smaller division, composed of the cuboid with the outer two metatarsals. It may be observed that the broadest part of the upper articular surface of the astragalus is in front of the summit of the plantar arch, so that, when the foot rests flat upon the ground, the chief part of the weight is transmitted from the tibia forwards, through the astragalus, to the scaphoid and the inner three metatarsal bones. It will also be seen that the anterior part of the articular surface of the astragalus is prolonged further on its inner than on its outer side, to be adapted to the prolonged fore part of the articular facet on the inner side of the internal malleolus. This has the effect of directing a considerable portion of the weight along the inner edge of the foot upon the great toe, which is far stronger and better able to bear it than any of the others. The outer division of the foot bears less weight, and acts as a lateral stay to the inner. The cuboid, especially, supports the side of the outer cuneiform bone, just where it has a tendency to bulge. In addition to this the cuboid receives some weight from the os calcis, or hinder pillar of the arch, and transmits it forwards through the outer two metatarsal bones.

Flat-foot.

The perfect formation of the inner part of this anterior arch, with such a combination of length with elasticity and strength as to permit the weight of the body to be borne, for some time, upon it in standing, and to be carried fully and steadily over it in walking, would seem to us to constitute one of the greatest difficulties in the construction of the human skeleton; the perfect form is realized only in the highest branches of the human family. Even in them, particularly in those members of them who are ill-fed or over weighted, or whose feet have been strained or cramped during growth by thick heavy shoes, the form is often defective; the arch yields at that, which, for various reasons, is its weakest point, viz. at the joint between the astragalus and the navicular bone, the person becomes "flat-footed;" and the effects of the imperfection are evinced in the diminished firmness of the tread, and in the consequent ungainly movements of the whole body.

Foot in Negro

In the Negro the heel, or hinder limb of the arch, is longer than in the European, the fore part of the foot is flatter and more sprawling, and the outer edge of the foot is, to a greater extent, in contact with the ground.

and monkey.

In the monkey the arch is still more defective, and the foot is more sprawling; it rests more upon its outer side, and requires more aid from the upper extremities in the support and movement of the body.

Secondary arches in the foot, outwards,

The well-formed foot presents other arches besides the one chief plantar arch which we have been considering. It is, in its whole length, from the point of the heel to the balls of the toes, curved a little outwards; the inner edge being concave, and the outer convex. This presents the best shape for receiving the weight of the body, which, owing to the inclination inwards of the thigh and of the whole extremity, and to the inward bend of the lower end of the tibia, is directed upon the foot obliquely downwards and *inwards*. It is, in like manner, in accordance with the oblique direction in which the weight is received, that the inner side of the foot is stronger than the outer, that the metatarsal bone of the pollex is twice as strong as any of the others, and that the arch of the instep is higher on the inner side than on the outer.

transverse.

The foot is also arched transversely. This is most marked about the middle, between the junction of the internal cuneiform with the great metatarsal bone, on the inner side, and the junction of the cuboid with the small metatarsal bone, on the outer side.

The arches, besides giving strength to the foot, provide a hollow in the sole for the lodgement of the muscles, vessels, and nerves. They owe their existence to the shape of the bones, and particularly to the configuration of the articular surfaces of the bones; and they are maintained by the powerful ligaments[1] and fasciæ, which, passing between the several bones, bind them firmly together.

The uses of the toes.

The toes, which are so much smaller and weaker than the fingers, do not add much to the strength or elasticity of the foot. Their office is to enlarge the area of the foot, and to adapt it to inequalities of surface, enabling it to cling to the ground, to prevent slipping, and to assist in climbing. They also afford to the flexor muscles an opportunity to give a last impulse to the step, before the foot is withdrawn from the ground. They are, accordingly, of most service to man when he is in his primitive state, living in woods and on unreclaimed ground, and engaged in contest with other animals for subsistence. The small size of the phalanges of the toes forms a characteristic feature of the human skeleton as compared with that of monkeys and most of the lower animals. They are smallest in the higher branches of the human family. They are the only parts of the skeleton which can be said to be thrown nearly into disuse by civilization; and their services can be spared without detriment to the rest of the frame. Also, provided they are not galled or distorted by undue or unequal pressure, they bear their confinement well and are seldom the seat of disease.

Peculiarities of human foot as distinguished from that of quadrumana.

The human foot is distinguished from that of other animals, not merely by the relatively small size of its phalanges; but also by the relatively large size and strength of the other components, and by the firm compact manner in which they are bound together so as to form a large and strong basis whereupon the body may stand securely. The importance of this provision can scarcely be over-estimated, enabling man as it does to maintain the

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[1] For a description of these ligaments, of the shapes of the articular surfaces, and the movements which take place between the component parts of the foot, see description of the joints of the foot.

erect posture, and leaving the upper extremities entirely free to act as agents of the will. In the animals which approach nearest to man the foot differs in many respects from the human foot, and, as the name (quadrumana) given to these animals implies, resembles the hand. It is suited more for prehension and less for support; and, therefore, it is unable to carry the body steadily without the help of the hand. The phalanges and metatarsal bones are much longer; the heel and the other components of the foot are smaller, less closely adapted to one another, and less firmly bound together; and the arches of the foot are consequently not so well formed as in man. There is, moreover, the further striking peculiarity in the quadrumanous foot, that the pollex, instead of being very strong, and placed, in a line with the other toes, directly in front of the tarsus, so as to bear great part of the weight of the body, is puny and weak, and is directed away from the other toes, after the manner of the thumb. In consequence of this, and of the flatness of the sole, the animal bears chiefly on the outer edge of the foot, and is obviously not fitted for the erect posture.

The foot in other animals.

In animals below Quadrumana the number of digits in the hinder limbs diminishes, as a general rule, *pari passu*, with those in the anterior extremities. In Carnivora the pollex is dwindled or gone. In the elephant the five digits exist, behind, as in front, the pollex being small. In the hippopotamus the latter has disappeared, although the internal cuneiform bone remains, and is elongated so as to extend down, for some little distance, along the inner side of the adjacent metacarpal bone. In the rhinoceros the little toe has disappeared, as well as the pollex, leaving the middle three toes. In ruminants the number of digits is reduced to two, viz. the two next to the great toe; and these are borne upon one metatarsal bone. It may be observed as a fact of some interest, in connection with this construction of the ruminant's foot, that the corresponding digits in man are more closely united than the others, the skin extending up rather further in the interval between them than it does between the others; these two are also more often found congenitally united together than any of the others. In Solipeds there remains only the middle digit, which is developed to great size. In many reptiles there is the full complement of digits in the posterior, as well as in the anterior, extremity.

The tarsus is divided transversely into two rows of bones. The hinder row consists of the astragalus, os calcis, and the scaphoid or navicular bone; the anterior row consists of the three cuneiform bones and the cuboid.

THE ASTRAGALUS

The astragalus. forms the summit and key-bone of the plantar arch, and is itself in the form of an arch. The uppermost convex part presents a broad articular surface for the tibia; and the under part is hollowed out into a deep groove (Pl. XLI. *B*), directed, from within, outwards and forwards, for the interosseous ligament which binds the astragalus to the heel-bone. Behind this groove is the large articular facet for the os calcis; in front of it is the smaller facet for the same bone, continuous with that for the scaphoid. The upper wall of the groove is the most compact part of the astragalus; it is perforated by several large holes for vessels which correspond with the medullary arteries of the long bones, and it is immediately surmounted by the most cancellous part of the astragalus, which corresponds with the medullary canals of the long bones. The line of greatest width of the articular surface for the tibia, where the greatest weight is received, is situated nearly over this groove, or, rather, crosses it diagonally. Immediately beneath that line is a dense mass of cancelli; and from these a number of strong laminæ radiate into the interior of the bone, and are directed forwards, towards the upper part of the articular surface for the scaphoid bone, and, backwards and downwards, towards the hinder articular surface for the os calcis. It is evident, therefore, from the

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DESCRIPTION OF PLATE XLI.

Vertical section, from before backwards, through bones of inner side of foot and great toe, shewing their shape and the direction of their cancelli. *A*, neck of astragalus. *B*, groove for interosseous ligament. *C*, corresponding groove on os calcis. *D*, point of attachment of plantar fascia. *E*, ditto of tendo achillis. *F*, projection of bone above attachment of tendo achillis. *G*, scaphoid bone. *H*, internal cuneiform bone. *H'*, metatarsal bone of great toe. *I*, first phalanx of great toe. *K*, second phalanx of great toe. *L*, projection for insertion of flexor longus pollicis. *M*, rough projection for attachment of fibrous tissue which runs to skin (Pl. LVII. fig. 1, *B*).

structure displayed by a section of the astragalus, that the weight of the leg is distributed, chiefly, in these two directions, viz. forwards, to the scaphoid, and backwards, to the hinder part of the os calcis, and that but little weight is transmitted towards that under and fore part of the astragalus, which, resting upon the anterior facet of the os calcis, upon the calcaneo-scaphoid ligament, and upon the tendon of the tibialis anticus, is comparatively devoid of firm support.

Its neck.

In front of the articular surface for the tibia is the *neck* of the astragalus, which has occasionally been broken[1], though that is a very rare event. The concavity on the upper surface of the neck lodges a little cushion of fat, which receives the anterior edge of the tibia in the flexed position of the joint, and which prevents the direct pressure of the two bones upon one another. The neck is inclined a little inwards from the middle of the astragalus, so as to render the bone somewhat concave on the inner side. This inclination is more marked, and the neck is longer, in the fœtus and in the monkey than in the adult man.

Occasionally dislocated.

Though the astragalus is almost buried among the surrounding bones, and is forcibly bound to them by ligaments, nevertheless, the great weight and the severe strains to which it is subject are sufficient, now and then, to produce more or less complete dislocation[2].

THE OS CALCIS

Oblique position.

is the largest bone in the tarsus; but it is not nearly so dense in structure as the astragalus. It is of large size in man in comparison with the nearly allied quadrumana. It is

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[1] *Transactions of Pathological Society*, I. 327.

[2] It may be turned with its under surface beneath the outer malleolus, and may be confined there by the peronei tendons, *Trans. of Path. Soc.* I. 145; or its anterior surface may be driven upon the scaphoid, *Ib.* I. 318, or upon the cuboid, I. 109. Owing to the difficulty or impossibility of reducing the dislocation, amputation of the limb has been resorted to in some instances, and excision of the displaced bone in others. In one case of dislocation forwards and outwards, within my knowledge, reduction was easily effected after division of the tendo achillis.

placed obliquely, slanting from the ground, upwards and forwards, so as to receive its share of the weight from the astragalus, by means of the articular facets upon the anterior part of its upper surface, and to transmit it to the ground, through the hinder extremity of its lower surface, which is the only part that rests upon the ground. It is also placed obliquely in another direction, inasmuch as it slants, from the ground, *outwards*, as well as upwards and forwards. Moreover, the surface by which it is applied to the ground is cut rather obliquely, so that the bone rests a little upon its *outer* edge. The oblique position of the os calcis, and of the basis upon which it rests, would cause the bone to be overbalanced outwardly, if the weight were transmitted from the tibia in a vertical line; but this very obliquity makes the bone better able to receive the weight which comes upon it in an oblique line from without inwards.

Articular facets.

The hinder articular facet is adjusted to support the hinder part of the astragalus, and to receive a weight coming in the line I have mentioned; and the inner articular facet is so placed as to prevent any tilting of the bone outwardly, and to support the head of the astragalus.

Gives leverage to muscles of calf.

The anterior extremity of the os calcis runs forwards on the outer side of the foot, supports the cuboid, and forms a sort of pivot on which that bone revolves in the movement between the first and second rows of tarsal bones. The hinder part of the os calcis affords attachment and leverage to the muscles of the calf, and has to bear their pull nearly at a right angle; this is, perhaps, a greater strain than is imposed upon any other bone in the body, but no more than it is well able to withstand, for it very rarely gives way. The *tendo achillis* is inserted into the lower part of its posterior surface. The bone runs up vertically, or with a slight inclination backwards, above the line of insertion of the tendon, for the purpose of giving more leverage to the muscle; and for some distance it is separated from the tendon by a bursa. The part to which the tendon is attached is on a line with the ankle-joint and with the middle of the balls of the toes; and the effect of the muscle is simply to raise the heel vertically.

Point of attachment of tendo achillis.

If, however, the point of the heel be inclined a little to either side by twisting of the foot, the muscle will increase the amount of the deviation, at the same time that it raises the heel. Hence the influence of the calf-muscle in increasing the deformity in talipes varus and talipes valgus, as well as in talipes equinus; and hence the necessity of dividing the tendo achillis in treating the worst cases of either of these varieties of club-foot.

Connection with skin.

Beneath the line of attachment of the tendo achillis is the part of the os calcis that rests upon the ground. This is widened transversely by two *tubercles;* of which the inner, and larger, gives attachment to the middle division of the plantar fascia, and the outer, or smaller, gives attachment to the outer division of the same. From the under part of this portion of the bone, between the attachment of the plantar fascia (Pl. LVI. fig. 3, *D*) in front, and the tendo achillis behind, several *bundles of fibrous tissue* (*B*) pass off, which traverse and interlace with the fibres of the thick tough cushion of adipose tissue, that intervenes between the heel-bone and the skin, and are lost in the fibrous tissue of the cutis. The chief direction of these fibrous bundles is, from the bone, downwards and backwards, to the skin, so as to resist the tendency of the former to ride forwards upon the latter when the foot is planted on the ground.

The os calcis is compressed at the sides, more particularly on the inner side; this gives space for the safe conduct of the vessels and nerves to the sole. A sesamoid bone is sometimes found in the tendon of the *peroneus longus* muscle, where it runs upon and braces the outer side of the os calcis.

Structure.

A section shews that the hardest part of the os calcis, corresponding with the hardest part of the astragalus, is that which lies beneath the groove (Pl. XLI. *C*) between its articular surfaces. Under this hardest part the structure is more cancellous than elsewhere; indeed there is often quite a cavity there, and the medulla is supplied by nutritious arteries passing through the adjacent wall of the bone. The hinder articular facet for the astralagus is underlaid by dense tissue, from which lines of cancelli radiate backwards and downwards. Near the hinder and under surface they are crossed by cancelli, which are disposed according to the outline of the bone.

THE SCAPHOID BONE

does not correspond in position with the bone of the same name in the wrist, inasmuch as it is not articulated with the tibia; it is reduced to the subordinate office of connecting the inner division of the foot with the astragalus, and of facilitating the movements of the former upon the latter; and it is the only intermediate bone between the two rows of the tarsus. In the monkey it is more spread out and extended inwards so as to support the diverging pollex. A vertical section made from before backwards (Pl. XLI. *G*) shews the cancelli in its upper part to be strong, and well-marked, and directed straight forwards between the two articular surfaces. The inner projecting portion, to which the tibialis posticus and the calcaneo-scaphoid ligament are attached, and the lower part, which extends below the level of the cuneiform bones, bear but little weight; and the texture of these parts is very spongy.

THE CUNEIFORM AND CUBOID BONES.

The bones forming the anterior row of the tarsus, though only four in number, are equivalent to five, because the cuboid is the representative of two bones, which are distinct in some reptiles. They are of simple shape; all of them are more or less wedge-like; and they form a transverse arch. The internal cuneiform and the cuboid have their bases turned downwards and inclined a little towards each other, while the other two cuneiform bones, which are placed between them, have their bases in the opposite direction, namely, on the dorsum of the foot. The weight of the body is transmitted, from the scaphoid and the os calcis to the metatarsals, chiefly, through the upper or dorsal parts of these several bones. Hence their upper surfaces are on the same level with the other bones, which gives an evenness to the dorsum of the foot; whereas their plantar surfaces present many inequalities, which serve for the attachment of strong ligaments, tendons, &c. For the same reason the upper parts of these bones are comparatively dense, and are composed of stout cancelli, which are directed from behind forwards, whereas the lower parts are composed of light spongy tissue.

Their proximal ends present a crooked line for articulation with the metatarsal bones, in consequence of the internal and external cuneiform advancing further than the other two; this serves to prevent lateral displacement of the metatarsus. The internal cuneiform projects further than any other of the row, as if to make amends for the deficiency in number and length of the other components of the pollex. It is interesting, in connection with this point, to observe that in some animals, where the great toe is, in a still greater measure, suppressed, as in the elephant, the hippopotamus, and the Cape ant-eater, the internal cuneiform extends forwards, for a considerable distance, alongside the adjacent metatarsal bone.

THE METATARSAL BONES

all slant a little inwards, as well as downwards, from the tarsus; this disposition places them in the direction most favourable to receive the weight of the body, which descends upon them with slight obliquity inwards, downwards, and forwards; and it contributes to the lateral curve of the foot. To prevent an undue amount of this inclination the metatarsal bone of the little toe is applied obliquely against the outer surface of the cuboid; and its proximal extremity is prolonged for some distance behind the articulation with that bone, so as to give greater leverage to the tendons of the peronei and to the ligaments which serve to maintain it, and with it the other metatarsals, in their proper position.

The shafts are convex on the dorsal surface; and each is pierced by a hole for the medullary artery, near the middle, on the outer side, with the exception of that of the little toe, in which the hole is on the inner side. The hole slants, in accordance with the rule

(p. 24), towards the distal end of the metatarsal bone in the pollex and towards the proximal end in the others. In the former the part of the shaft towards which it is directed is, as usual, the smallest and hardest part, and the medullary canal is here most developed; but in the other metatarsal bones the narrowest and hardest parts of the shafts are in the opposite direction to that of the foramina, and the medullary canals are as much developed towards their distal as towards their proximal ends. Their proximal ends are wedge-like, particularly those of the 2nd and 3rd toes, corresponding with the bones upon which they rest. The distal ends resemble those of the metacarpal bones; but are rather more flattened at the sides, because the width of the foot, at this part, is less than that of the corresponding part of the hand.

The great size of the metatarsal bone of the pollex is peculiar to the human foot, distinguishing it from that of quadrumana, and still more from that of other mammals; for in the descending series it, with its phalanges, soon diminishes and disappears. Its proximal extremity is prolonged towards the sole, and is inclined a little outwards, to give attachment to the tendon of the peroneus longus; this tendon is a powerful brace to the sole of the foot, and combines with the tibialis posticus, which is attached near the same point, to raise the ankle in walking.

THE PHALANGES,

with the exception of those of the pollex, are smaller than the phalanges in the hand, but resemble them in most other particulars. The middle phalanges of the outer three toes are especially diminutive; sometimes they are reduced to the size and shape of a pea, and occasionally they are united with the terminal phalanges, so as to form one bone, resembling the ordinary condition of the Chelonian Reptiles.

Ridges for flexor and extensor tendons.

Each of the terminal phalanges presents on its dorsal aspect a prominent transverse ridge surmounting the articular facet. This ridge gives attachment to the extensor tendon, and serves to support the hinder edge of the nail; it is prolonged, on either side, into a tubercle, which gives attachment to the lateral ligament. On the under surface of each terminal phalanx is a rough ridge, with which the flexor tendon is connected; and the distal extremity of each is swollen, and nodulated, for the purpose of giving attachment to a number of fibrous bands which pass, from the end of the bone, through the adipose pulp of the toes, towards the skin, with the deeper layers of which they are interwoven, so as to bind the skin to the phalanx. They may be well seen in the great toe (Pl. LVII. fig. 1, *B*); the principal bundles run from the phalanx forwards to the cutis, and serve to hold the skin and the bone together when the phalanx is pressed upon the ground in giving the last impulse to the step.

Nodulated extremity.

Exostosis.

The nodulated extremity of the terminal phalanx of the great toe is liable to grow out, on either side, into a spongy exostosis, which, pressing up the nail, causes great annoyance. The exostosis may be easily cut away without much detriment to the phalanx.

Development of the tarsal bones.

The tarsal bones are formed in cartilage by the 3rd month of fœtal life. About the 6th month an osseous nucleus appears in the os calcis, beneath the groove for the interosseous ligament, at the part where the bone is subsequently most cancellous. A month later ossification begins in the corresponding part of the astragalus, that is, just above the interosseous groove. At birth these nuclei have attained considerable size (Pl. I. fig. 4); but, at this time, there may be no other point of ossification in the tarsus. Sometimes there is a nucleus in the cuboid[1] at birth; or it appears soon after birth, and is followed, in about a year, by a nucleus in the scaphoid. The internal cuneiform begins to ossify in the 1st year; and the other two cuneiform bones begin between the 2nd and 4th years. At about the 10th year a flat epiphysial nucleus is formed in the hinder part of the os calcis, and becomes united to it in the 20th year. The os calcis is

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[1] Meckel (in opposition to Albinus and other anatomists) says a nucleus is always present in the cuboid at birth. It has not been so in the instances that I have examined.

the only one of the short bones, except the bodies of the vertebræ, which has a separate epiphysis. The ossification of the shafts of the metatarsal bones begins as soon as the 3rd month; it begins in their epiphyses (at the proximal end in the great toe and at the distal ends in the others) during the 2nd year. The epiphyses unite with the shafts some time after puberty.

Of metatarsals.

Of phalanges.

Ossification begins in the phalanges in the 3rd and 4th months; is first seen in the proximal row, then in the third row, and in the second row latest. It is said to take place in the second phalanx of the great toe sooner than in the first. The epiphyses are at the proximal ends, and begin to ossify (according to Beclard) in the 4th or 5th year; they are united to the shafts at about the 16th or 18th year[1].

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[1] The periods of the commencement of ossification are stated by Beclard as follows: in the os calcis at $4\frac{1}{2}$ months; astragalus at $5\frac{1}{2}$ months; cuboid a month after birth; internal cuneiform 1 year; other cuneiforms in the 4th year; scaphoid in the 5th year; epiphysis of os calcis in the 10th year, united to the rest of the bone in the 16th year; metatarsal bones a few days later than the metacarpals; their epiphyses are united somewhat earlier; first row of phalanges after the 50th day of fœtal life; their epiphyses about the 4th year, united about the 18th; second row of phalanges in the middle of fœtal life; their epiphyses about the 6th year, united about the 17th; third row of phalanges about the 45th day; their epiphyses about the 5th year, united about the 17th.

THE JOINTS OF THE LOWER EXTREMITY.

THE HIP-JOINT (Pl. XLII. to XLVI.)

is the most complete ball-and-socket joint in the body, that is to say, the socket encloses the ball to a greater extent than it does in any other joint. It admits of great variety of movement; the articular surfaces revolving upon one another in every direction. We speak of flexion, extension, abduction, adduction, rotation inwards and outwards, and circumduction. It is to be remembered, however, that the movements are not confined to these, but take place in every intervening direction. Nevertheless the joint is so invested by ligaments as to be very strong and capable of resisting great force; and the ligaments are so disposed, in antagonism to the several muscles, as to oppose the contraction of each set after a certain point, and to render this ball-and-socket joint one of the most steady, as well as one of the most secure, in the body.

Movements.

It is well to be clear respecting the corresponding movements of the thigh upon the pelvis, and of the pelvis upon the thigh. Flexion and extension of the thigh correspond with inclination of the pelvis forwards and backwards. Abduction and adduction of the thigh, with the joint extended, correspond with inclination of the opposite side of the pelvis upwards and downwards; in the flexed position of the hip, with the trunk erect, they correspond with inclination of the opposite side of the pelvis backwards and forwards. Rotation of the thigh outwards and inwards, in the extended position, corresponds with the rolling of the opposite side of the pelvis backwards and forwards; in the bent position, they correspond with the inclination of the opposite side of the pelvis downwards and upwards. These differences, resulting from the fact that the trunk is usually maintained erect, though the thigh be bent, or that, in our descriptions, we usually consider it to be so, are apt to render an account of the uses of the several ligaments perplexing, unless attention has been previously drawn to the subject.

Head of the thigh-bone,

The head of the thigh-bone is three-fourths of a sphere, with a diameter measuring about an inch and a half. It is a segment of a true sphere; except that just around the dimple for the *ligamentum teres* its surface bulges a little more than at any other part of the circumference, as represented in Pl. XLIII. fig. 1. This prominence corresponds with the bottom of the cotyloid cavity, where the cartilage is deficient. The edge of the cartilaginous surface of the head of the femur does not present an even line all round, but is prolonged upon the neck, at the fore part, beneath the psoas tendon, and behind, beneath the short rotators of the hip, more than it is above or below.

is rarely injured.

Being included within the acetabulum, and well fitted to it, the head of the thigh-bone is very little exposed to injury; so that, although the neck and other parts of the femur are often broken, I have never seen an instance in which the head had suffered from contusion[1]; neither is its shape altered in rickets, although the lower end of the bone is often very much deformed in that disease.

The Dimple for round ligament.

The *Dimple* for the *ligamentum teres* is situated, not in the line of the axis of the head and neck of the thigh-bone, but below it, in the line of the axis upon which the head rotates during flexion and extension. So that a line drawn transversely through the pelvis, and prolonged through the "dimple," on either side, represents the axis upon which flexion and extension of the thighs take place, and, consequently, the axis upon which the trunk is inclined forwards and backwards upon the thighs. There are two or three foramina for vessels at the bottom of the dimple; the fibres of the round ligament are inserted above these; and the part of the dimple just beneath its upper

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[1] In the Musée Dupuytren is a specimen where both acetabula have been broken in by the wheel of a heavily laden cart passing over the side of the pelvis; but the heads of the thigh-bones have escaped injury.

edge, which is not filled up by the ligament, is occupied by fat (Pl. XLVI. *I*).

The acetabulum. The *cartilaginous surface* of the *acetabulum* is, at every point, exactly applied to that of the head of the femur, so that there is no interval between them in any position of the joint; this may be proved by sections made through the joint in the recent state. It is a broad band disposed in the form of a horse-shoe. Its width is greatest, and its cartilage is thickest, beneath the part contributed by the ilium, where the greatest amount of the weight of the body is borne, and where the pull of the great flexor and extensor muscles of the hip is chiefly felt; towards this part also the lines of the cancelli in the neck and head of the thigh-bone (Pl. XXVIII. fig. 1, *H*) are principally directed. It is narrowest at the part contributed by the pubes, and is absent, together with the wall of the acetabulum itself, at the anterior and lower part, where there is, commonly, no weight sustained and little force applied. It is deficient also in a circular space, as large as a half-crown-piece, at the bottom of the acetabulum. This space, which is filled up to the level of the cartilaginous surface of the cavity by soft fat and synovial membrane, corresponds with the round ligament, with the dimple in the head of the femur where the ligament is attached, and with the slight prominence of the cartilaginous surface surrounding the dimple; and it represents the area traversed by them in the various movements of the hip. The fat readily yields before the ligament, and, rising on either side of it, prevents any void space being created when the latter is shifted from place to place.

The wall of the acetabulum, at this part, is not usually subjected to much force, and is thin and spongy. It is sometimes perforated by ulceration in disease of the joint, and is occasionally broken by a severe blow upon the trochanter; the head of the thigh-bone may even be forced through it into the cavity of the pelvis. The cushion of fat is connected with it only by a layer of loose areolar tissue, and may, accordingly, be easily detached by the handle of a scalpel, or be separated by maceration.

The margin of the acetabulum is abrupt on its inner or articular surface, and is more gradually sloped on its outer surface. It is also uneven; it presents a marked notch at the fore part, beneath the groove for the psoas tendon; this notch indicates the point of union between the pubes and the ilium. There is another less marked notch at back part; this indicates the point of union between the ilium and the ischium.

The cotyloid ligament.

The acetabulum does not form more than 170° or 175°, that is, not so much as a half circle in any direction; it does not, therefore, embrace the greatest circumference of the head of the femur, and has no power to hold it in its cavity. It is, however, deepened by the *cotyloid ligament*, which is attached to its margin, and which embraces the head of the femur at, and a little beyond, its greatest circumference, so contributing very much to the security of the joint. This structure (Pl. XLII. fig. 1, *F* and XLIII. fig. 1, *E*) is composed of firm yellowish-white fibrous rings, and is attached by a wide basis to the border of the acetabulum, to the edge of the cartilage that lines the acetabulum, and to the fibrous capsule that springs from its outer edge. It is shaded off into a thinner edge, which projects into the joint between the head of the femur and the capsule, is inclined a little inwards so as to embrace the head of the femur, and is retained in close contact with it by the pressure of the capsule. The synovial membrane is reflected from the capsule upon it and is lost upon its free edge. It fills up the minor inequalities observable in the mar-

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DESCRIPTION OF PLATE XLII.

Fig. 1. Transverse ligament and notch of right acetabulum seen from below. *A*, cut surface of pubes. *B*, ditto of ischium. *C*, edge of bone between acetabulum and obturator hole, forming the bottom of acetabular notch. *D*, fibres of transverse ligament, arising from anterior, or pubic, corner of notch, crossing beneath those (*E*) which arise from posterior, or ischiatic corner, and becoming blended with (*F*) the cotyloid ligament, which is continued across the notch in front of the transverse ligament. *G*, vacant space in notch which is occupied by fat continuous with that in the round ligament.

Fig. 2. Front view of right hip-joint. *A*, anterior inferior spine of ilium. *B*, pubes. *C*, ischium. *D*, lesser trochanter of femur. *E*, tendon of rectus femoris. *F*, anterior accessory ligament. *G*, superior accessory ligament. *H*, inferior accessory ligament. *I*, space covered by tendon of psoas magnus. *K*, interlacing fibres of obturator ligament.

Fig. 1.

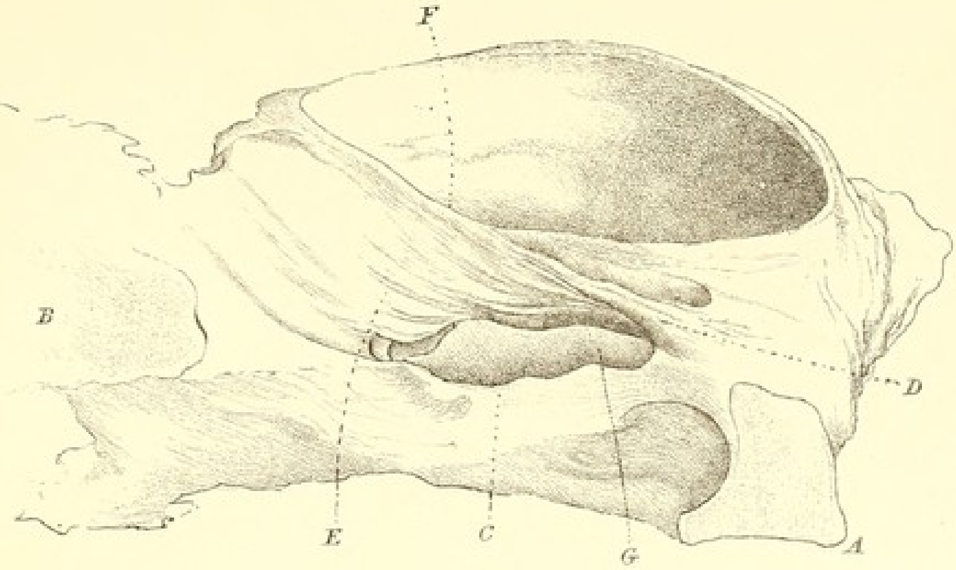
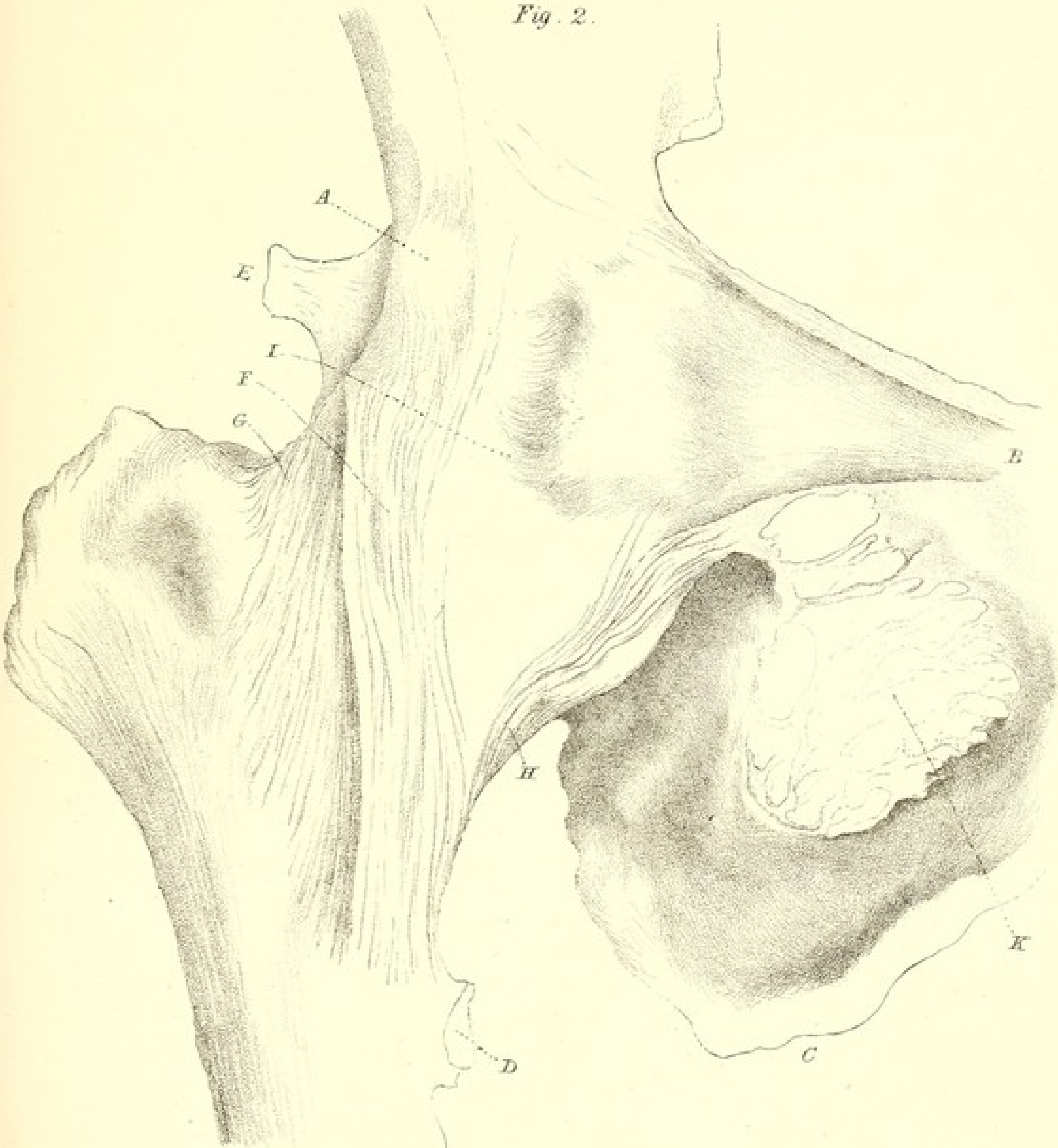


Fig. 2.



gin of the acetabulum, and is continued across the notch, thus forming a complete circle or collar, which, closely surrounding the head of the femur, and, like a valve, preventing the entrance of air into the joint, holds the thigh-bone in its place, after the capsule has been quite divided. Owing to its soft cushiony quality it does not interfere with the movements of the joint, and it prevents any chipping of the acetabulum or injury to the head and neck of the thigh-bone, which would have been likely to occur had the place of the ligament been supplied by a prolongation of the edge of the cup itself. Even when the head of the thigh-bone is driven over the edge of the acetabulum, as in dislocation, the bones generally escape injury.

The influence of this fibrous ring, combined with that of atmospheric pressure, is exerted upon the head of the femur under all circumstances and in every position of the joint. The articular surfaces are thus maintained in apposition with sufficient force to meet all ordinary contingencies; and this is done without any hindrance to the movements of the joint. The head of the thigh-bone, though securely held in its socket, is free to revolve in any direction with a scarcely appreciable amount of friction; and the lower extremity swings, like a pendulum, from the pelvis.

Transverse ligament.

The cotyloid ligament is not entirely confined to the margin of the acetabulum; for some of its fibres are, as just said, continued across the notch, completing the circle of the acetabulum. It is strengthened in this situation by a layer of strong fibrous bundles (*D*), passing, from the external surface of the pubes, just in front of the anterior or pubic cornu of the notch, downwards and backwards to the posterior or ischiatic cornu; also by deeper bundles (*E*) arising from the ischiatic cornu, and crossing the others obliquely. Some of the fibres of both these bundles are continuous with those of the cotyloid ligament; and they combine with it to make the *Transverse ligament*. The transverse ligament does not fill up the acetabular notch, but merely bridges it over, leaving a space (*G*) beneath it, through which vessels pass to the bottom of the acetabulum, and into which the fat, contained in and about the base of the round ligament, is pressed in certain positions of the joint.

Capsular ligament.

The *Capsular ligament* (Pl. XLIII.), as in the case of other ball-and-socket joints, extends from the edge of the "cup" to the circumference of the neck upon which the "ball" is carried. It encloses the cotyloid ligament, and its fibres run, for some distance, upon the exterior of the acetabulum, the uppermost becoming blended with some of the fibres of the *rectus femoris* (*N*), near the anterior inferior spine of the ilium. At the notch it is connected with the cotyloid ligament; but is thin at that part. Externally the capsule is attached to the base of the great trochanter, beneath the digital fossa, to the prominent ridge of the inner and fore part of the great trochanter, to the anterior inter-trochanteric line, and to a line which ascends from the lower end of the latter, in front of the lesser trochanter, and which then passes behind the middle of the neck of the femur to the digital fossa. This line, especially where it passes behind the neck of the femur, is very faintly marked. The attachment of the capsule at this latter part is slight; it is chiefly effected by means of a thin external layer (*H*), which passes towards the trochanter, and by a thin internal layer (*G*) which is reflected upon the back of the neck of the femur.

Is most tight when the thigh is extended upon the pelvis.

Most of the fibres of the capsule pass, not directly from one bone to the other, but obliquely, and are so arranged that the greater number of them are tightened when the thigh is extended upon the pelvis. The effect

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DESCRIPTION OF PLATE XLIII.

Fig. 1. Transverse section through left hip-joint viewed from above. *A*, *A*, acetabulum. *B*, great trochanter. *C*, depression at bottom of acetabulum devoid of cartilage. *D*, most prominent part of head of femur. *E*, *E*, cut edges of cotyloid ligament. *F*, back part of capsule. *G*, layer of capsule reflected upon back of neck of femur. *H*, thin layer passing on to back of neck of femur near great trochanter. *I*, fore part of capsule pulled away from front of neck of femur.

Fig. 2. Back view of right hip-joint. *A*, acetabulum. *B*, great trochanter. *K*, spine, and *L*, tuber, of ischium. *M*, pubes. *N*, tendon of rectus femoris. *O*, zonular band. *P*, edge of capsule lightly connected with hinder part of neck of femur, *Q*, fibres of superior accessory ligament, interlacing with those of rectus tendon, passing into back of capsule and continuous with zonular band.

Fig. 1.

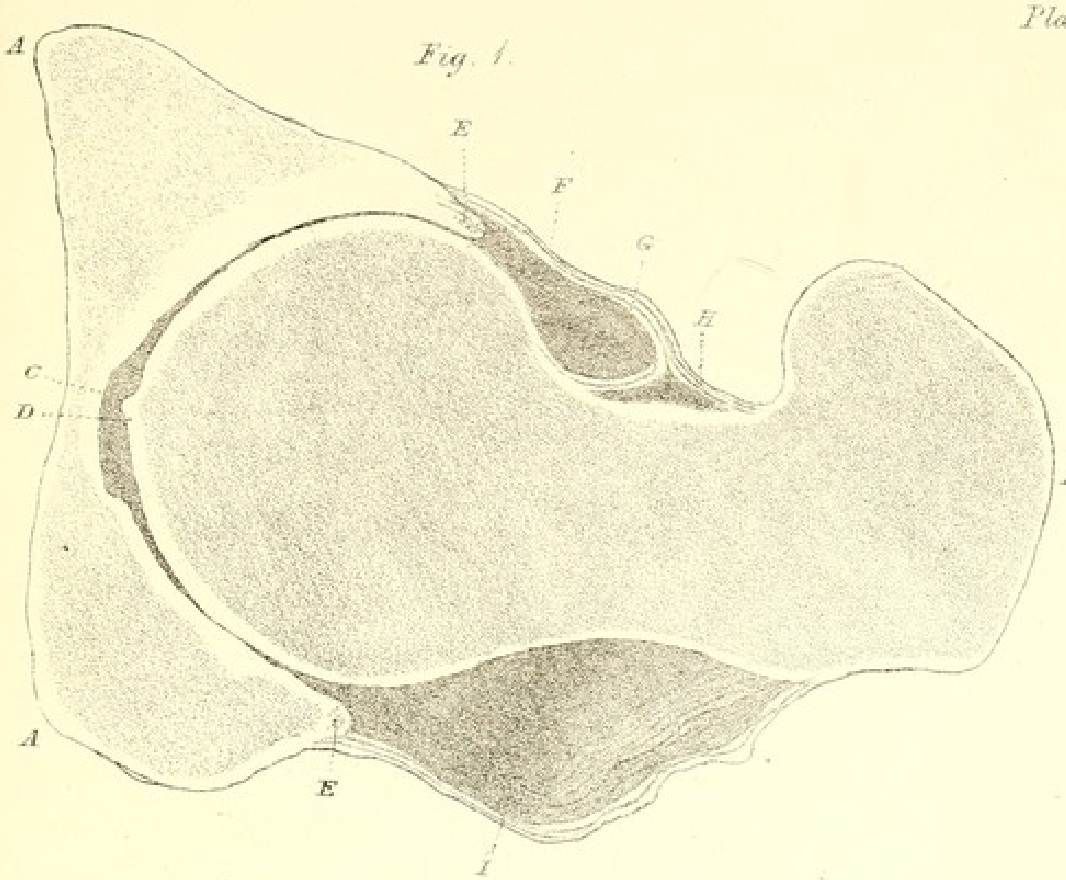
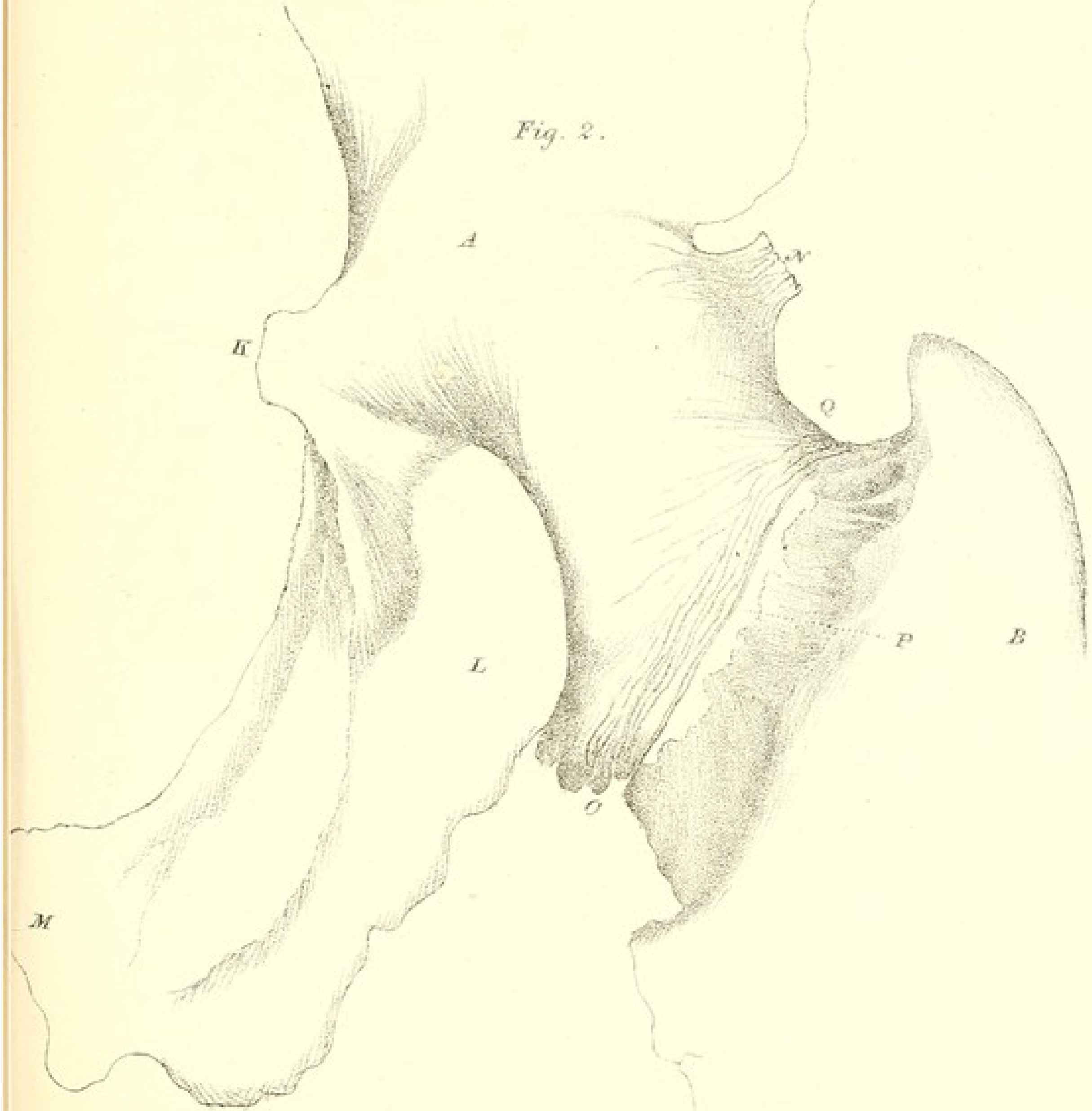


Fig. 2.



of this is to press the head of the thigh-bone tightly against the acetabulum, and to give a certain amount of steadiness to the joint in that position. For the same reason, if the joint be tender from inflammation of the synovial membrane, or if fluid be effused into its cavity, the extended position becomes painful or impossible; the patient, therefore, keeps the thigh a little bent upon the pelvis, and, when he stands, the whole of the affected extremity is placed in advance of the other; the pelvis is, at the same time, inclined downward on the affected side, to assist in the bending of the hip-joint, and to enable the foot to rest upon the ground, so that an apparent elongation of the limb is produced.

Its varying thickness.

The capsule varies very much in thickness in different parts. It is thin near the back of the neck of the femur, also near the transverse ligament and where it is covered by the psoas tendon. It is of very great thickness at the front of the joint, and between the upper edge of the acetabulum and the fore part of the great trochanter[1].

Accessory ligaments:

the anterior

The great thickness, at these parts, is due to *accessory* ligamentous fibres, which pass from the anterior intertrochanteric line in three directions. One division, which may be called the *Anterior accessory ligament* (Pl. XLII. fig. 2, *F*), runs from the middle and greater part of that line, obliquely upwards and a little inwards, to the lower edge of the anterior inferior spine of the ilium, and to the thick ridge that descends from the spine to the acetabulum. The component bundles are not all disposed in parallel lines; for those which arise from the lowest part of the inter-trochanteric line ascend to the highest part of the iliac ridge, and are, therefore, less oblique than the others, which arise from the higher part of the line, and pass to the lower part of the ridge.

limits extension of hip.

It is a ligament of great strength and great importance. Its office is to limit the extension of the hip-

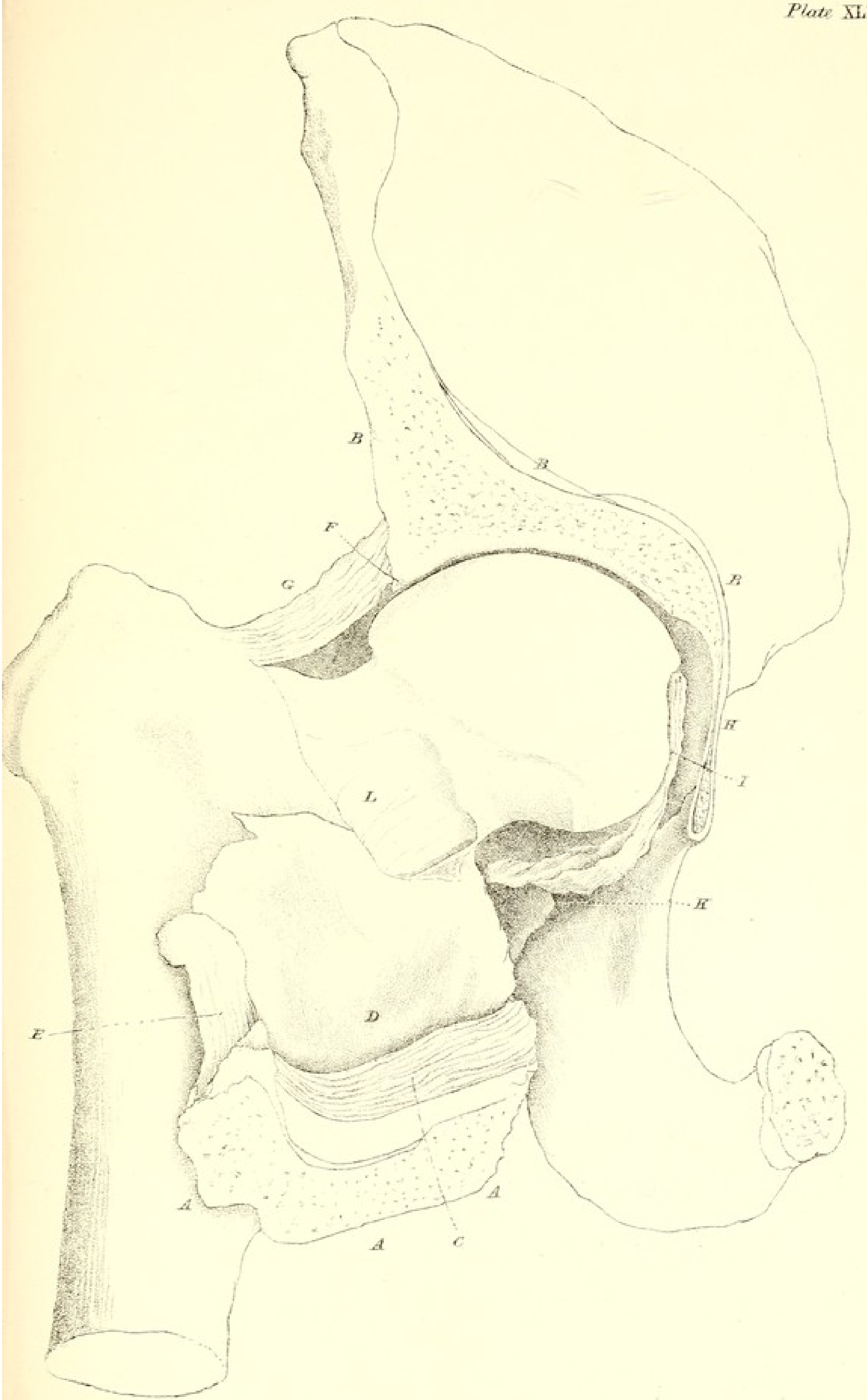
[1] It must be understood that the capsule is, at all parts and in all positions of the joint, closely applied to the neck of the thigh-bone, being separated from it only by synovial membrane and sufficient synovial fluid to lubricate the opposed surfaces.

joint. When the joint is so far extended that the thigh is brought into a line with the vertebral column the ligament is rendered quite tense, and further movement in that direction is prevented. It is, accordingly, tense when we stand upright; and we are, in consequence, then unable to throw either thigh further backward, without at the same time rolling the pelvis upon the other thigh. And, what is more important, it resists the tendency which the powerful extensor muscles have to roll the pelvis and trunk back upon the thigh beyond a given point. When their action has brought the trunk into a vertical position, so that the line of gravity, falling through the spine, bisects a line drawn transversely between the heads of the thigh-bones (page 148), this ligament operates as a check, and enables those muscles, with slight effort, to fix the pelvis and the trunk steadily in that position. Without some such check it would be almost impossible for the pelvis to be balanced, for any length of time, and with any thing like security, upon the slippery spherical heads of the thigh-bones; the trunk would be continually swaying to and fro, and the erect posture would be one of great difficulty and fatigue. The several fibres of the ligament all become tense at the same time, and combine to effect this important purpose. They do not distinctly limit either rotation, abduction, or adduction, in any position of the joint; but when quite upon the stretch they do, more or less, impede these movements, particularly the latter.

and so gives steadiness to the erect posture.

DESCRIPTION OF PLATE XLIV.

Hip-joint, in extended position, viewed from the front, with the fore part of the acetabulum (*A*, *A*, *A*) reflected from *B*, *B*, *B*. *C*, part of reflected cotyloid ligament. *D*, reflected front of capsule. *E*, part of superior accessory ligament reflected. *G*, cut edge of ditto. *F*, cut edge of cotyloid ligament. *H*, thin part of acetabulum; the fat which should cover it has been removed. *I*, posterior band of ligamentum teres, arising from (*K*) the ischiatic corner of the notch. The wavy disposition of its fibres shows that it is not tense. *L*, fibres passing from fore part of capsule upon neck of femur.


B
B
F
G
B
H
I
L
K
E
D
A
A
A
C

The superior accessory ligament

The uppermost fibres of the accessory ligament, which may be called the *Superior accessory ligament*, (Pl. XLII. fig. 2, *G* and XLIV. *E*, *G*) are attached, externally, to the bold ridge that stands out from the fore part of the great trochanter, at its junction with the neck. The greater number of them, forming a very powerful ligament, nearly half an inch thick, the thickest and strongest in the body, run inwards, with a slight inclination upwards and backwards, to the upper edge of the acetabulum and to the outer side of the ridge which ascends from it to the anterior inferior spine of the ilium. Other fibres—the upper and hinder (Pl. XLIII. fig. 2, *Q*)—radiate backwards, over the neck and head of the femur, to the outer surface of the acetabulum, between the ridge before mentioned and the neighbourhood of the tuber ischii. Some of them are entwined with the fibres of the rectus tendon (*N*). The hindmost of all, passing downwards and backwards, over the back of the joint, are interlaced with fibres derived from the inferior spine of the ilium and the exterior of the acetabulum, and thicken the outer edge of the capsule at this part, so as to form a zonular band (*O*) which encircles the hinder part of the neck of the femur, somewhat in the same manner as the orbicular ligament encircles the head of the radius. They are finally lost in the capsule near the tuber ischii.

limits extension of the thigh

Nearly all the fibres of the superior accessory ligament are, like those of the anterior ligament, put on the stretch when the thigh is extended, and contribute with them to antagonise the action of the glutæi and other extensor muscles, and to give steadiness to the joint. They act also in a more direct manner than the anterior ligament, in limiting adduction of the thigh, or, more properly speaking, in limiting lateral inclination of the pelvis upon the thigh, such inclination as is caused by the weight of the body bearing upon the sacrum when we rest upon one foot. In proportion as the pelvis is bent upon the thigh so does the range of its lateral inclination, at the hip, become more free; and the limit to that movement is set either by the fibres of this ligament or by those of the round ligament which now come

and lateral inclination of the pelvis;

into play. First, when the hip is a little bent, the office is performed by the enormously thick bundles of the superior accessory ligament, which pass from the trochantral ridge to the upper edge of the acetabulum; and in the "stand-at-ease" position of drill, when the soldier rests upon one leg, with the hip a little bent, the pelvis and trunk are, as it were, slung upon this ligament, the muscles being left almost entirely at rest. As the flexion increases the office is transferred, more and more, from these strong anterior fibres, to the hinder and weaker fibres of the ligament, which pass to the upper and posterior surface of the acetabulum and to the hinder part of the capsule; and when the flexion has reached to a certain degree (when the thigh is bent to somewhat less than a right angle), assistance is rendered by the *Ligamentum teres.*

in the latter aided by "round ligament."

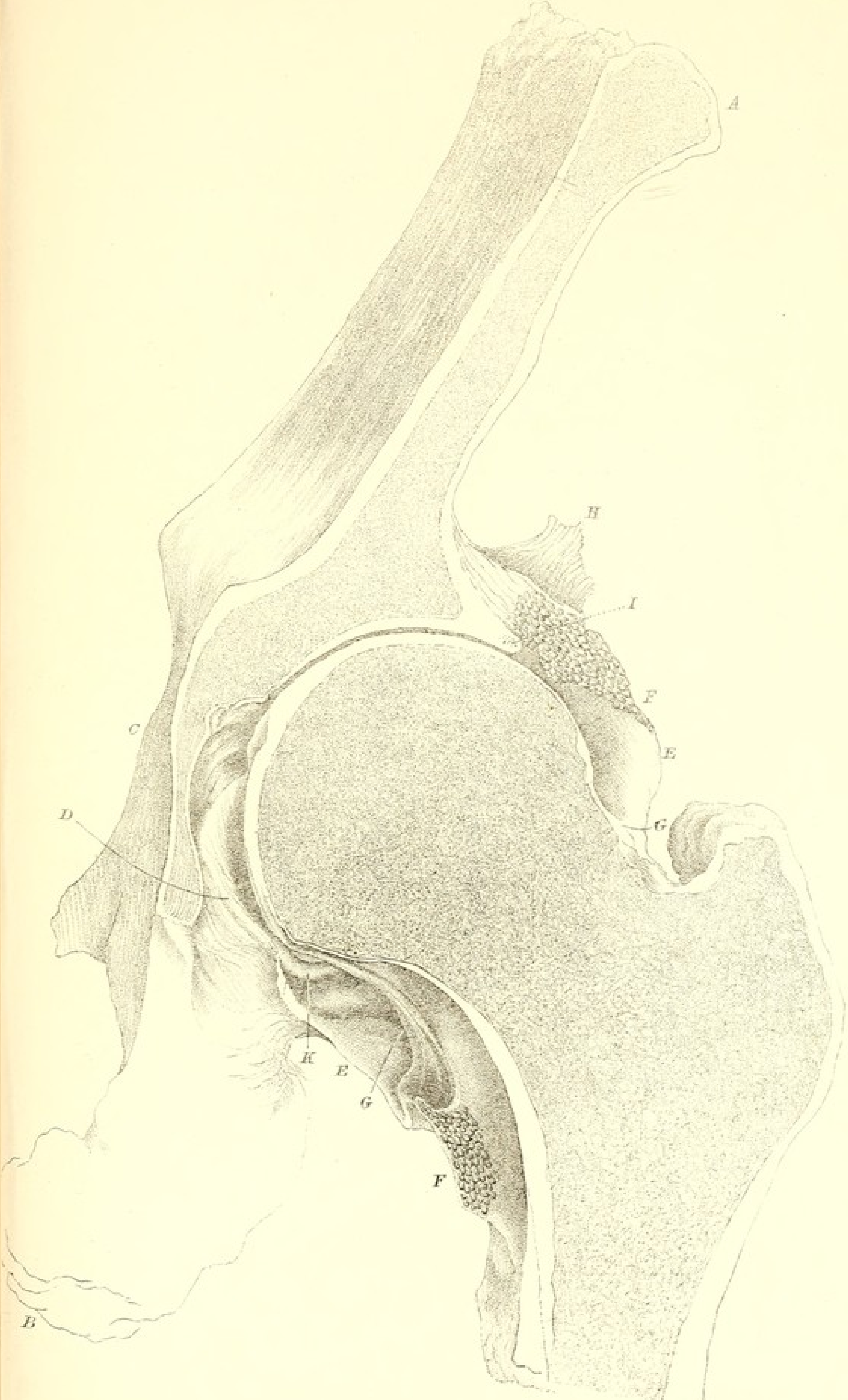
The inferior accessory ligament

The inferior portion of the accessory ligament, forming what may be called the *Inferior accessory ligament* (Pl. XLII. fig. 2, *H*), arises from the lowest point of the inter-trochanteric ridge, from the ridge which ascends from the latter in front of the lesser trochanter, and from the angle between these two ridges. It runs obliquely, upwards and forwards, to the pubic edge of the acetabulum, just above the notch, where some of its fibres become blended with the fibres of the transverse ligament.

DESCRIPTION OF PLATE XLV.

Vertical section from side to side through left hip-joint, with thigh extended upon pelvis and adducted, and with toes directed straight forward. *A*, cut edge of crest of ilium. *B*, tuber ischii. *C*, thin part of acetabulum. *D*, round ligament springing from hinder corner of notch and ascending in a waving line to dimple in head of femur. *E, E*, cut edge of capsule. It is thickened near acetabulum above, and near its attachment to femur, below, by the addition of the anterior accessory ligament (*F, F*). Some of its fibres are reflected, with synovial membrane at *G, G*, upon upper and under surfaces of neck of femur. *H*, rectus tendon turned back. *I*, upper cut edge of cotyloid ligament. *K*, lower edge of same, with some of its fibres continued into round ligament.

The capsule is relaxed above and below, because its fibres, which run from the ilium downwards and outwards to the femur, are cut obliquely in the section.


A
H
I
F
E
C
G
D
K
E
G
F
B

limits abduction of the thigh.

It limits abduction of the thigh, or rotation of the pelvis outwards upon the femur. Thus, when, in standing upon one leg, we incline the body and the pelvis a little to that side, so as to maintain the balance, a check to the movement is given by this ligament, at the right time, just as we have seen that a check to extension of the hip is given by the anterior accessory ligament when the erect posture has been attained; and the muscles which have caused the movement are enabled by this assistance to fix the pelvis steadily upon the thigh.

In the erect posture the inferior accessory ligament is soon rendered tense, and the movement just mentioned is, accordingly, soon stopped. If the thigh be a little bent the points of attachment of the ligament are brought more nearly into the same line, and are, therefore, approximated a little, so that a greater range of movement is permitted.

Thin part of capsule.

Near the attachment to the femur this ligament is united with the anterior accessory ligament; but they diverge from one another as they pass to the pelvis, and, in the interval (*I*) which is left between them, the capsule is thin and is covered by the psoas tendon; indeed there is often a communication here between the bursa appertaining to that tendon, and the cavity of the hip-joint.

Ligamentum teres.

The offices of the *Ligamentum teres* have been variously stated; but never, I think, quite correctly. They are rather difficult to ascertain with precision, because the ligament, lying in the interior of the joint, is entirely hidden from view; and when once the capsule has been cut, or a section of the joint has been made, it is not easy to retain parts in their proper position while the bones are moved upon one another. The best opportunity of observing the ligament is afforded by removing with a trephine, from the bottom of the acetabulum, the portion of bone which is not covered by cartilage. This may be easily effected from the inside of the pelvis, after one os innominatum has been taken away; and it should be done while the capsule remains entire. When the piece of bone has been thus cut out, and the fat which lies upon it has been dissected away, the ligament is seen in its whole length,

Best mode of exposing it to view.

and its condition in the various positions of the joint can be observed[1].

The round ligament consists of two bands, a posterior, moderately thick and strong, and an anterior, thin and weak. These are attached, respectively, to the ischiatic and pubic margins of the acetabular notch; they are connected together by areolar and fatty tissue, and by a synovial sheath; and they are inserted together into the bottom of the dimple in the head of the femur, so as to form one triangular ligament. It will be observed, on looking at a thigh-bone (particularly a recent thigh-bone), that the outline of this dimple is not circular but rather of trefoil shape, or three-cornered (Pl. XLVI. fig. 5), the lower edge being nearly flat. Each of the lower two corners corresponds with one of the bands of the ligament; and the hinder one is the larger and deeper, in accordance with the greater size of the posterior band; the upper corner is

[1] I had resorted to this means of ascertaining the use of the round ligament, and had demonstrated it to my pupils, before seeing, from a brief report of a paper read by Dr Struthers, *Ed. Med. Journal*, April, 1847, that he had, by a similar process, arrived at somewhat similar results.

DESCRIPTION OF PLATE XLVI.

Figs. 1, 2, 3, and 4, are views of ligamentum teres in different positions of the hip, obtained by cutting out a circular portion of the bottom of the acetabulum. *A, A,* cut edge of ilium. *B,* ditto of pubes. *C,* spine of ischium. *D,* tuber ischii. *E,* femur. *F,* lower surface of the capsule. *G,* opening into acetabulum beneath transverse ligament. *H,* ligamentum teres; *I,* small pad of fat lying upon it, and assisting to fill up dimple in head of femur. The pelvis is in the erect position in all. In fig. 1 the thigh is extended and adducted; ligamentum teres is not tight. In fig. 2 the thigh is bent; and ligamentum teres is still relaxed. In fig. 3 the thigh is bent and adducted; the fibres of ligamentum teres are straight and tight. In fig. 4 the thigh is bent and rotated outwards; the fibres of ligamentum teres are now also tight. In the last two positions the small pad of fat (represented at *I,* in figs. 1 and 2) is carried out of sight.

Fig. 5. A view of the dimple in the head of the femur, shewing its triangular form.

Fig. 1.

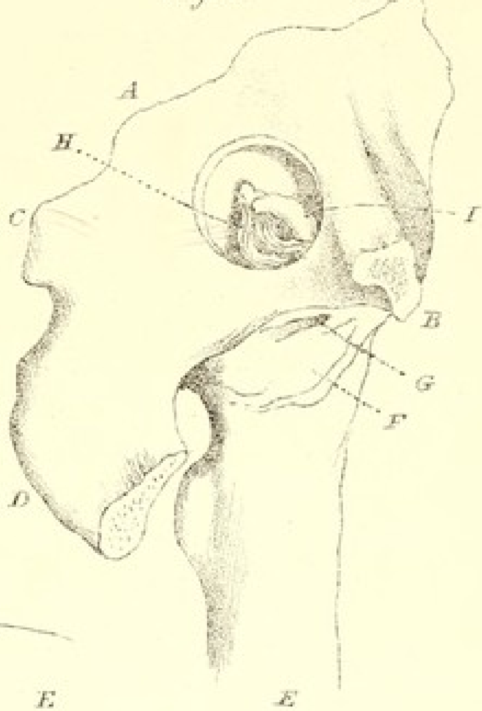
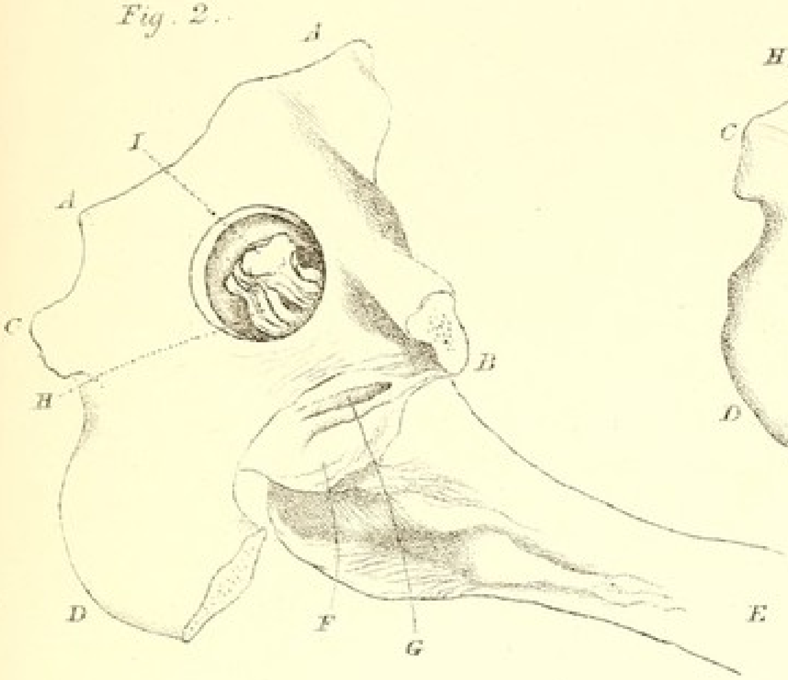


Fig. 2.



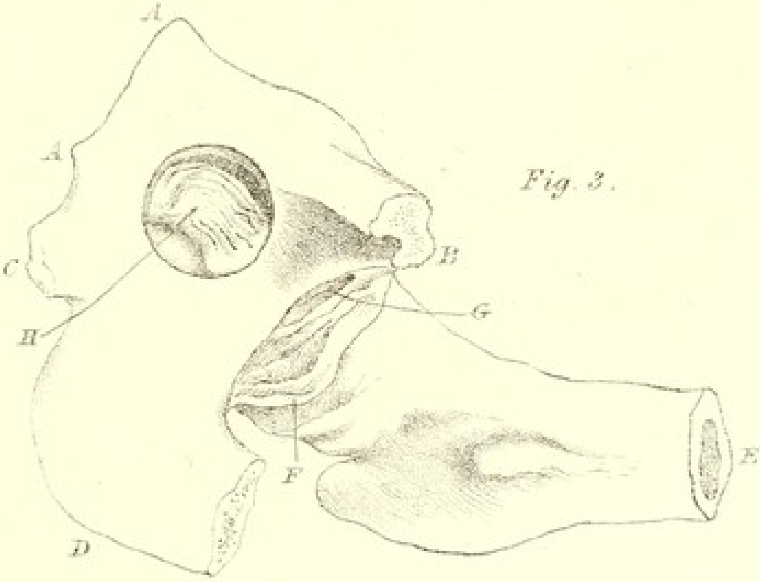


Fig. 3.

Fig. 4.

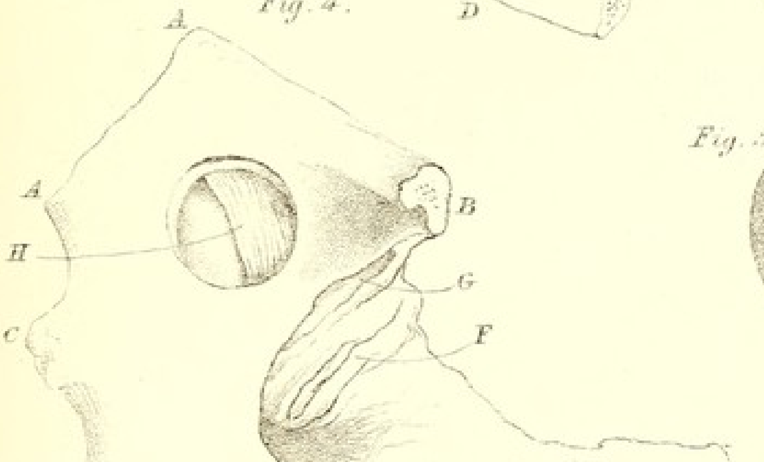
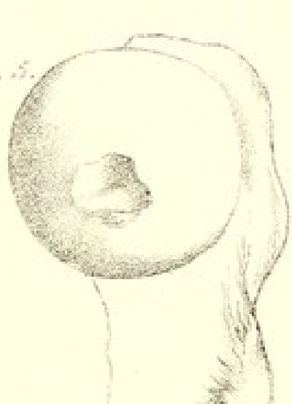


Fig. 5.



occupied only by fat. When the hip is bent the lower two corners of the dimple are brought opposite to the edges of the acetabular notch; that is to say, the respective points of attachment of the two bands of the ligament are brought opposite to each other.

Use to limit inclination of the pelvis in flexed position of the joint.

This, together with the fact that the bands do not occupy the corners of the dimple at all times, but only when they are on the stretch, at other times lying upon any part of the lower edge of the dimple, indicates that the bent position of the hip is that in which the ligament is tense, and is, therefore, the position in which it is called into service.

The inference, thus drawn from the anatomy of the parts, is quite confirmed by the observation of the ligament through the trephine hole just mentioned (Pl. XLVI.). In the extended position of the joint (fig. 1) the ligament is seen to be quite loose; and it cannot be rendered tense by any adduction or rotation of the thigh. If, however, the thigh be bent upon the pelvis (fig. 2), and be then adducted (fig. 3); or if, when bent, it be rotated outwards (fig. 4); or, which amounts to the same thing, if the opposite side of the pelvis be inclined downwards, the ligament is rendered tense, and its two bands are drawn tightly over the two corners of the dimple in the head of the femur, which are now opposite to the two edges of the acetabular notch.

Round ligament is compressed into acetabular notch in certain positions of the joint.

In the bent position of the thigh, with the other side of the pelvis inclined downwards, the round ligament is drawn its full length into the acetabular cavity; and the areolar and fatty tissue, enclosed in its synovial sheath, are drawn up with it. But when the rotation of the thigh or pelvis is effected in an opposite direction, or when the thigh is abducted in the erect posture, the ligament is driven, in wrinkles, down to the lower part of the acetabulum; and its areolar and fatty tissue are compressed into the notch, and are made to project externally beneath the transverse ligament. Thus we learn that one of the uses of this notch is to afford room for the components of the round ligament in certain positions of the joint.

Torn in dislocation.

Anatomical and experimental observation combine, therefore, to shew that the office of the ligamentum teres is the same with that of the hindmost fibres of the superior accessory ligament, viz. to prevent too great inclination of the pelvis in the bent position of the hip. That the assistance it affords is far from being superfluous is proved by the fact that the hip-joint is more frequently dislocated by a strain in the direction which these ligaments are intended to resist than in any other. The accident is commonly caused by the sufferer being thrown violently upon one knee with the hip bent; the upper and back part of the capsule, together with the hinder fibres of the superior accessory ligament and the ligamentum teres, are torn, and the head of the femur, driven from the acetabulum, is lodged upon the dorsum of the ilium or in the neighbourhood of the sciatic notch.

It does not limit adduction of thigh in the erect position.

Weber[1] considers that the ligamentum teres co-operates with the thick anterior fibres of the superior accessory ligament, to restrain adduction of the thigh in the erect position; because a vertical section, carried through both hip-joints when the thighs are extended, divides the ligamentum teres in its whole length, shewing that it takes a vertical direction. It does not appear to have occurred to him to open the joint from the pelvis in the way I have described, or he would have seen that, though the hinder fibres of the ligament are nearly vertical when the joint is extended, they are not then tense, and that they cannot be made tense by any attempt at adduction or rotation, till the joint is bent, which proves, with certainty, that it is in the bent position of the joint only that the ligament comes into use. Weber remarks that when the joint is straight, no adduction is possible because this ligament is tight. It is true that adduction in that position is very limited; this is not, however, in consequence of the tension of the round ligament, but because many of the fibres of the capsule are then on the stretch. Indeed, if this ligament prevented adduction of the thigh in the extended position, as Weber says that it does, it would do the same in all other positions of the joint, because its attachment to the dimple of the femur being in the line of the transverse axis of rotation of the thigh upon the pelvis, it would necessarily be tense in the flexed and extended position of the joint alike. Hence adduction would be altogether impossible in all positions.

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[1] *Gehwerkzeuge*, s. 144.

Condition as seen in vertical section of joint.

To assure myself further of the condition of the ligament in the erect posture, I made a vertical section through the joint when the thigh was extended upon the pelvis with the toes directed straight forward; and found that although the section was parallel with the fibres of the ligament they were not tense, neither could they be made so till the joint was bent (Pl. XLIV. XLV.).

Always torn in dislocation.

The ligamentum teres is torn in each variety of dislocation, even in the dislocation into the obturator hole. For though, when the joint has been opened after death, the head of the thigh-bone can be removed from the socket and laid in the obturator hole without dividing the ligament, yet the force which causes a dislocation is always sufficient to rend the ligament from its dimple in the femur. The separation takes place the more easily because the drag upon it in this displacement is made, downwards, in the direction in which it is not calculated to offer resistance. In the other dislocations of the hip, the force is applied in an opposite direction; and the ligament is not separated from the dimple, but is rent across a little below it.

May be absent.

Although a valuable assistant to the other ligaments, it may be wanting, without any éspecial weakness of the joint being observed to result from its absence. Perhaps the deficiency in such cases is compensated for by additional strength in the upper part of the capsule, or in those fibres of the accessory ligament which are associated in function with the ligamentum teres. I have remarked the ligament to be comparatively thick in fœtal and early life, especially near the head of the femur, and to be comparatively thin in some elderly persons; but I have not made sufficient observations to be sure that it undergoes any regular decrease in size in advancing years.

Wanting in some animals.

It is generally present, and sometimes is very strong, in those animals, as the horse and ox, in which the hinder extremities are inclined inwards from the pelvis, and in which such assistance, as the round ligaments afford, is required to limit the degree of that inclination. When, on the other hand, the lower extremities descend more vertically, or are inclined a little outwards, it is commonly absent, as in the elephant, the seal, and the tortoise. In the orang outan it is very small, or wanting altogether. In the chimpansé and other monkeys it is present. In the frog, as before stated, a similar structure is found in the shoulder as well as in the hip-joints.

To sum up what has been said respecting the offices of the various ligaments of the hip:—Extension of the joint is arrested, at the erect position, by the anterior accessory ligament; and, by the antagonising assistance of this ligament, the extensor muscles are enabled to hold the pelvis steady in that position. Flexion is limited, not by any particular ligament, but by the muscles and by the bulk of soft parts in front of the joint[1]. The inclination of the opposite ilium upwards (which corresponds with abduction of the thigh) is limited by the inferior accessory ligament. The inclination downwards in the erect, and slightly bent, positions of the joint (which corresponds with adduction of the thigh) is limited by the anterior fibres of the superior accessory ligament; and by the hinder fibres of the same ligament, as well as by the ligamentum teres, when the joint is more bent. The inclination of the opposite side of the pelvis forwards in the erect posture (which corresponds with rotation of the thigh inwards) is limited by the hinder part of the capsule; and the inclination of the same backwards (which corresponds with rotation of the thigh outwards) is limited by the fore part of the capsule.

Synovial membrane.

The *Synovial membrane* covers the fibrous tissue of the neck of the femur, is reflected from it upon the interior of the capsule (Pl. XLV. *G*), and is again reflected from the latter upon the exterior of the cotyloid ligament. It also covers the round ligament and the fat at the bottom of the acetabulum.

Disease frequent and persistent in the hip.

Owing to the extent, the vascularity, and the inflections of the synovial membrane, as well as the variety and range of movements of the hip, this joint is often the seat of inflammation, causing the well-known symptoms of "hip disease," which, in young persons, lingers so long in each of its several stages. In the middle-aged it is common, but is more acute and more quickly followed by ulceration of the cartilages. In elderly persons it is apt

[1] Weber found that, in the dissected joint, flexion could be carried to 139°, whereas, in the living person, it was limited to 86° by the presence of the muscles and other soft parts. His experiments shew the range of adduction, or abduction, to amount to 90°, and that of rotation to 51; it is greatest in the half-bent position of the joint.

to assume the characters of "chronic rheumatic arthritis," and is productive of a slower removal of the cartilages, and of those various alterations in the shape of the head of the femur and of the acetabulum which have been so often described. When once disease has been fairly established in the hip, whatever the period of life may be, the free use of the joint is rarely regained. Hence we find so many examples of ankylosis of the hip; more, I think, than of any other joint. The obstinate manner in which disease adheres to the structures of the hip is probably explained by the great pressure upon the articular surfaces, caused by the weight of the body and by the contractions of the powerful muscles which are required to wield the long and heavy lower extremity upon the trunk, as well as to move and support the latter upon the thigh. The hip is, perhaps, also more frequently the seat of congenital malformation than any other joint[1].

THE KNEE-JOINT (Plates XLVII. to LIII.)

is one of the most difficult of the joints to understand thoroughly; it is, however, one of the most interesting to study; and it presents a high claim to our careful consideration, inasmuch as it is so frequently the seat of disease.

Apparently weak, really strong.

Its articular surfaces are little adapted to one another; and they are in contact only to a comparatively slight extent in any position of the limb. So far as it depends on them, therefore, it is a most insecure joint. It has, nevertheless, to bear great weight, has a considerable range of movement (as much as 150° of flexion and extension), and the movement takes place between the two longest bones of the body, so that it has to withstand the influence of greater leverage than any other joint. Experience tells us, however, that, in spite of these disadvantages, it is, really, one of the strongest of the joints; at least, it is very rarely dislocated. The sources of its strength are to be found in the size of the articular ends of the tibia and femur, which are the largest in the body; in the number and

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[1] See *Cycl. Anat.* Art. *Hip-joint.*

strength of the ligaments, and in the powerful muscles and fasciæ by which it is invested.

Movements apparently simple, really complex.

Its movements are, apparently, simple, consisting only of flexion and extension, with the superaddition of rotation in the bent position. But if we come to examine the joint carefully, when these movements are made, we shall find that they are by no means so simple as they, at first, seem to be.

Differs from a hinge-joint.

In most other joints flexion and extension take place in an almost simply hinge-like manner; that is to say, the same part of one articular surface, whether it be the whole or a portion only, is applied against the other articular surface, and revolves upon it in every stage of the movement; and the centre or axis of the motion is a fixed one. Thus, in the elbow-joint, the sigmoid cavity of the ulna, and the cup-like cavity in the head of the radius, are applied upon the lower end of the humerus, and remain in contact with it in every position of the joint; and, during movement, they revolve round an axis drawn through the lower

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DESCRIPTION OF PLATE XLVII.

Vertical section through outer condyles of femur and tibia, shewing their relations to one another in different positions of the knee-joint.

Fig. 1. The section was made when the bones were in this—the semi-extended—position, and the cut surfaces are therefore in the same vertical plane. The cartilage is thickest where the two articular surfaces are in contact. *A, B, C,* the line described by the shifting axis of motion of the tibia upon the femur in extension and flexion. *A* corresponds with a line drawn between the points of attachment of the lateral ligaments. The lines from *A* to 1, 2, 3, and 4, indicate the distance of the line of attachment of the lateral ligament to different parts of the articular surface of the condyle. *D,* the groove upon the under surface of the condyle of the femur, which receives the semilunar cartilage in complete extension. *E,* the hinder cut edge of the external semilunar cartilage.

Fig. 2. The same bones placed in the flexed position. The cut surface of the femur has acquired a slightly oblique direction with regard to that of the tibia, owing to the rotation of one bone upon the other which accompanies flexion. The *hinder* part of the articular facet of the tibia is in contact with the condyle of the femur; and the semilunar cartilage (*E*) is pushed quite upon the hinder edge of the articular facet. *F,* the anterior crucial ligament.

Fig. 3. The same bones placed in the extended position. The slant of the cut surfaces, with regard to one another, is in an opposite direction to what it was in the flexed state, and the *fore* part of the articular surface of the tibia is in contact with the femur.

Fig. 1.

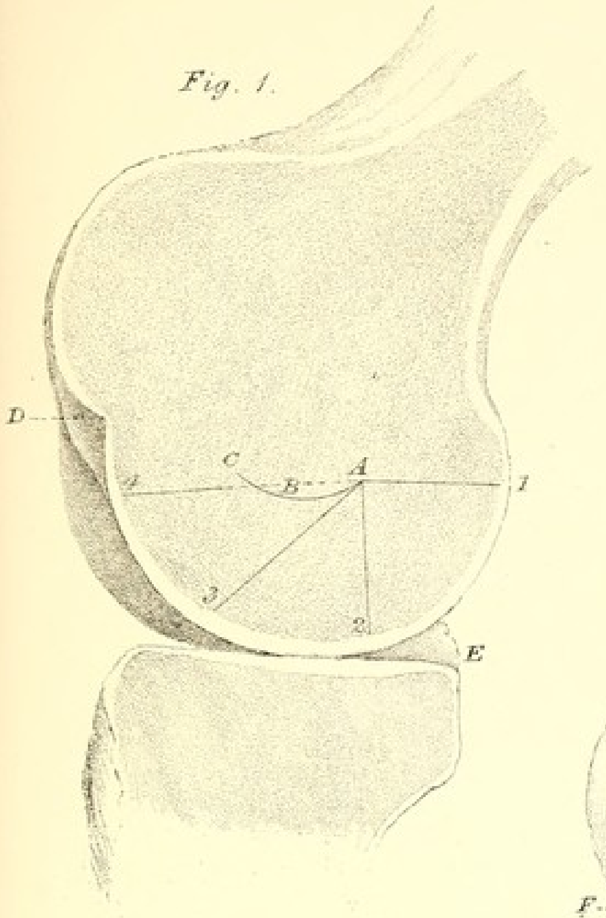


Fig. 2.

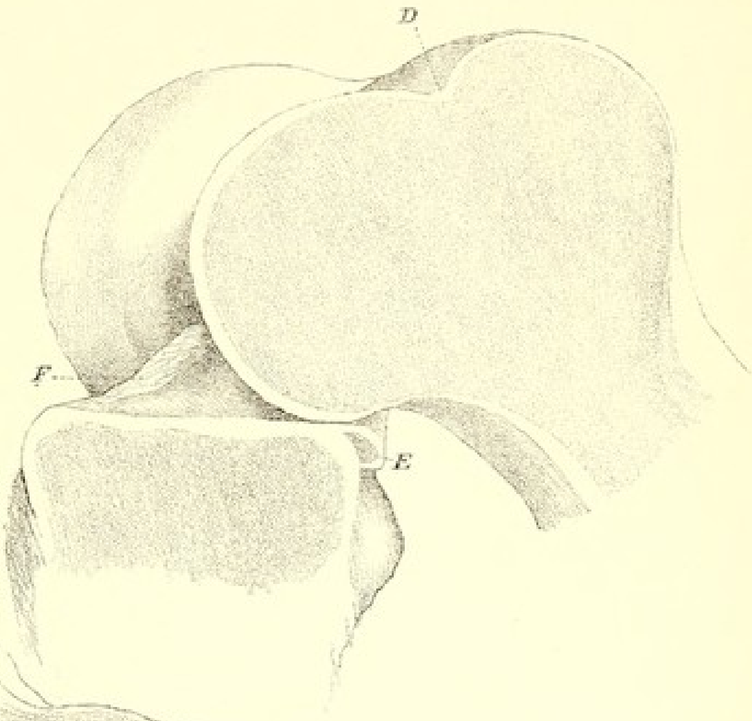
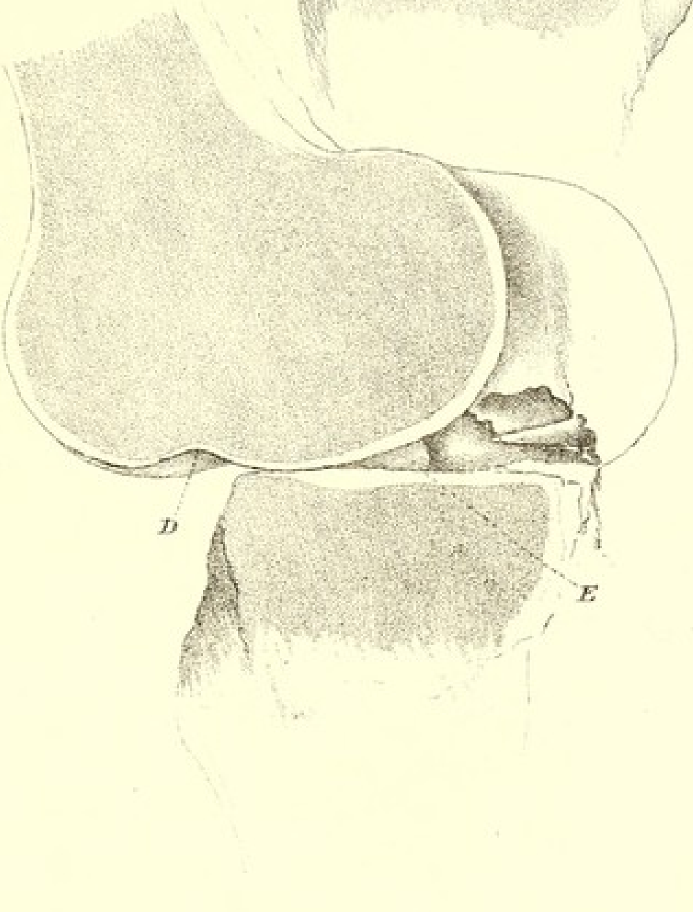


Fig. 3.



end of the humerus, between the points of attachment of the lateral ligaments. Accordingly, if the movement at the knee were also of the true hinge kind, the whole, or one part, of the articular surface of the tibia would remain applied against some portion of the condyles of the femur in the flexed, as well as in the extended, position.

Turning of tibia upon itself accompanies its revolution upon femur in flexion and extension.

But an examination of the knee in its recent state (Pl. XLVII.) shews that the part of the tibia which is in contact with the condyles of the femur varies according to the position of the joint; in the flexed position (fig. 2) it is the hinder part of the articular surface alone; in the semiflexed position (fig. 1) it is the middle part; and in the extended position (fig. 3) it is the anterior and middle part. To effect this change there must be a *turning of the tibia upon a transverse axis* drawn through its own upper end, in addition to the revolution of its articular surface round an axis drawn through the lower end of the femur.

Shifting of axis of motion.

Secondly, the knee differs from an ordinary hinge-joint in the fact that, in flexion and extension, the tibia does not perform the whole revolution round one axis drawn transversely through the lower end of the femur; inasmuch as the revolving movement is accompanied by a *sliding* of the articular surface of the tibia, forwards in extension and backwards in flexion; and the axis of its revolution is, therefore, continually shifting. Suppose the joint to be flexed as in fig. 2; when extension begins, the axis, round which the revolving movement of the tibia takes place, is in the back part of the condyle (fig. 1, *A*); as the movement continues the tibia slides forward beneath the condyle, and the axis upon which it revolves, in like manner, travels forward to *B* and *C*; and, in flexion, a retrograde shifting of the axis, along the same line, accompanies the sliding back of the tibia to its former position.

The effect of the turning of the tibia in extension and flexion counterbalanced by the sliding.

One effect of the *former* of these concomitants of flexion and extension—the *turning of the tibia upon its own axis*—would be to make the lower end of the tibia travel through a larger segment of a circle than the upper end, to increase, that is to say, the range of extension and flexion of the lower part of the leg in greater proportion than that of the upper part; were it not that the *second* concomitant, viz. the *sliding* of the tibia upon the femur, would tend to produce just the opposite effect, reducing the range of flexion and extension at the lower part of the leg below that of the upper; and it appears that the one of these influences about counterbalances the other, and leaves the segment of the circle described by the foot corresponding with that of the smaller circle described by the upper end of the tibia.

Rotation of tibia accompanying flexion and extension.

Thirdly, an observation of the dissected joint, when flexion and extension are made, shews that, in addition to the sliding under the condyles and the turning upon its own transverse axis, the tibia undergoes a slight *rotation upon a vertical axis*, outwards during extension and inwards during flexion. This is most observed in the nearly extended state of the joint, that is to say, near the termination of extension and also at the commencement of flexion; and it gives a prominence to the head of the fibula, at the back of the joint, when the limb is straight. The centre of this motion corresponds with a nearly vertical axis drawn through the outer condyles of the tibia and femur near their middle. It is more correct to speak of it as a rotation of the thigh upon the leg, than of the leg upon the thigh; because, in

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DESCRIPTION OF PLATE XLVIII.

Fig. 1. Upper surface of head of left tibia. *A*, inner articular facet. *B*, outer ditto. *C*, point of attachment of posterior crucial ligament. *D*, ditto of hinder extremity of internal semilunar cartilage. *E*, ridge to which hinder extremity of external semilunar cartilage is attached. *F*, foramina for vessels in front of spine. *G*, points of attachment of anterior extremity of external semilunar cartilage. *H*, point of attachment of anterior crucial ligament. *I*, ditto of anterior extremity of internal semilunar cartilage. *K* and *L*, internal and external tubercles of spine.

Fig. 2. Upper surface of head of tibia, shewing attachments of semilunar cartilages and crucial ligaments. The patella (*P*) and the tendon of the rectus femoris (*R*) are turned down. *C*, the posterior crucial ligament. *D*, the posterior extremity of the internal semilunar cartilage. *E*, ditto of the external semilunar cartilage. *F*, foramina for vessels. *G*, anterior fibres of external semilunar cartilage. *H*, anterior crucial ligament. *I*, anterior part of internal semilunar cartilage. *M*, transverse ligament. *N*, mass of fat beneath ligamentum patellæ. *O*, roll of fat surrounding edge of patella.

Fig. 1.

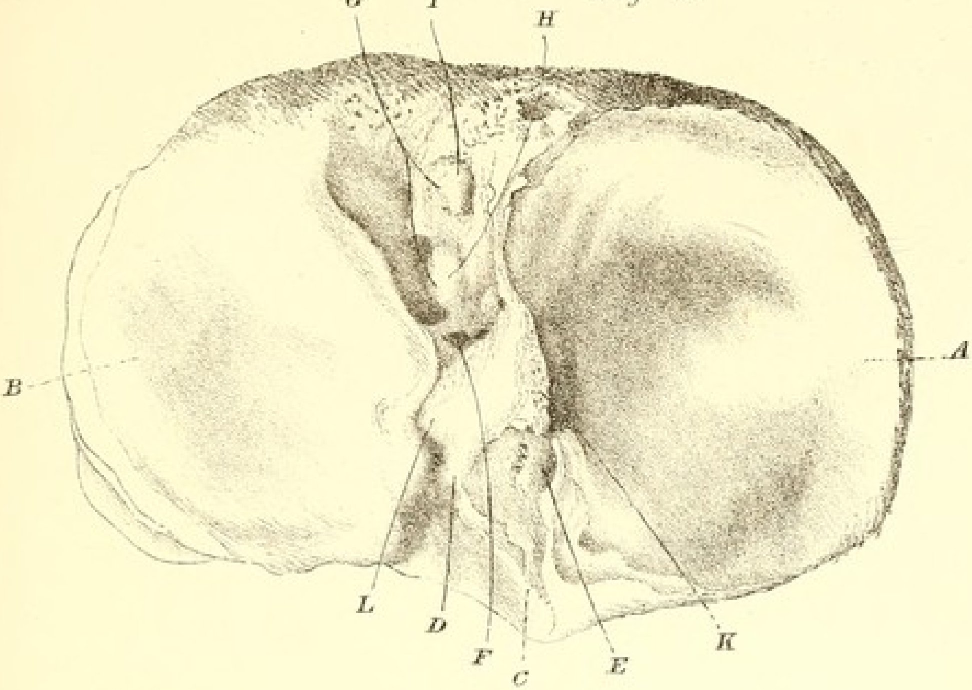
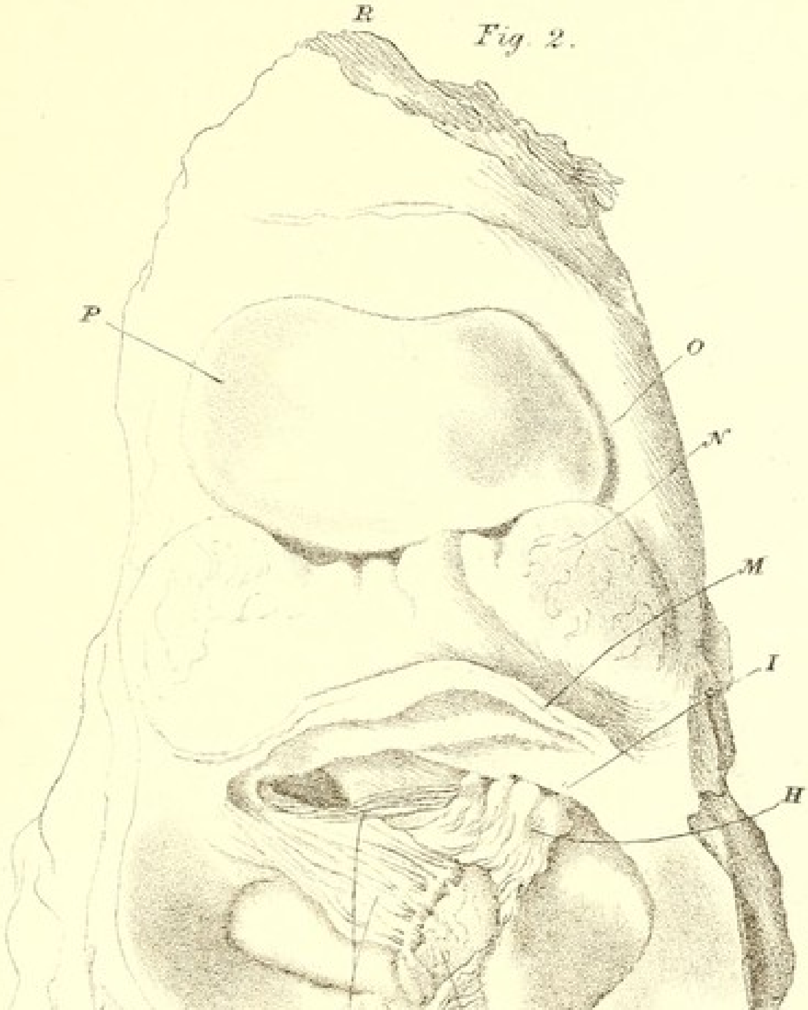


Fig. 2.



the nearly extended state of the knee, the lower part of the extremity is generally fixed by the planting of the foot upon the ground, which prevents any rotation of the leg in the further straightening of the joint. One effect of this slight rotation of the femur inwards, in the nearly extended condition of the lower extremity, is to produce a slight relaxation of the anterior accessory ligament of the hip, and so to increase, in a corresponding degree, the range of movement of that joint.

Pronation and supination of leg in flexed position.

These three movements, I may repeat, are all accompaniments of flexion and extension; and the rotation just described, as occurring in the nearly extended state of the joint, must not be confounded with the more *free rotation* of the leg, also upon a *vertical axis*, which may be effected when the joint is *bent*. This latter variety of rotation is sometimes called *pronation* and *supination* from its partial similarity to that motion in the forearm; and these terms are convenient, inasmuch as they serve to distinguish it from the rotation described in the last paragraph. But, whereas, in the instance of the forearm, one end of the radius revolves round the ulna, and the movement is equally free in every position of the elbow-joint, in the case of the leg the tibia and fibula revolve *together* upon the femur, and the movement cannot be effected at all in the extended state of the joint. It begins to be practicable when the knee is bent to about an angle of 150°; and it becomes more easy, and more free, as the joint becomes more bent. The axis of rotation in this pronatory and supinatory movement passes through the spine of the tibia nearer to the inner than to the outer articular surface, in other words, through the inner tubercle of the spine of the tibia; and the outer condyle of that bone, consequently, moves in the segment of a larger circle than does the inner one.

Shape of the articular surfaces of the tibia.

The two *Articular facets* upon the upper surface of the tibia resemble one another in being almost flat and of oblong shape with the greatest diameter from before backwards; and they are nearly parallel. The *inner* one is, however, rather longer, rather narrower, and rather more concave; and its inner edge rises more suddenly into the inner tubercle of the spine (Pl. LII. fig. 1). The *outer* facet is almost flat. It is slightly concave in the transverse direction; but it is slightly convex from before backwards (Pl. XLVII.), inasmuch as its hinder edge is rounded off, to permit the semilunar cartilage and the tendon of the poplitæus to slide upon it when the joint is bent, and its anterior edge is flattened to permit the semilunar cartilage to pass forwards upon it during the slight rotation that accompanies complete extension of the joint. It rises more gradually than the inner articular facet into the spine; and this increases the antero-posterior convexity of its inner part. The comparative flatness of the outer facet, and the rounding of its anterior and posterior edges, permit it to be moved forwards and backwards upon the femur in the pronation and supination of the leg, more easily than the inner articulating facet. This corresponds with the statement just made that the centre of that motion is nearer to the inner than to the outer facet. There is a slight depression in each facet on the side of the spine; the cartilage is thickest at this part; it is particularly thick on the outer facet (Pl. LII. fig. 1); the chief weight is borne here when the foot is planted on the ground; and the outer condyle of the femur rotates upon this part of the outer facet of the tibia in the last stage of extension.

The spine and space between the articular surfaces.

The *Spine* of the tibia (Pl. LII.), called also the *Eminentia intermedia*, is situate nearer the hinder than the anterior edge of the upper surface, and at the point where the two articular facets approach nearest to one another. It stands up into the interval between the condyles of the femur so as to prevent lateral displacement. Its *inner tubercle* (*O*) is larger and rises higher and more abruptly than the *outer* (*P*), and, consequently, presents a larger surface of contact to the side of the inner condyle; this is probably one reason that displacement of the tibia *in*wards from the femur, in the course of disease, takes place so very rarely, in comparison with the displacement *out*wards. Immediately in front of the spine are two or three foramina for vessels (Pl. XLVIII. *F*) marking the spot where ossification of the epiphysis commenced. Between the two tubercles, and in front of them, is a large space for the attachment of the anterior crucial ligament (*H*), and of the anterior extremities of the semilunar cartilages (*G* and *I*), and for the lodgement of the fat which lies at the fore part of the joint. Behind the spine is a smaller space for the attachment of the posterior extremities of the semilunar cartilages (*D* and *E*) and of the posterior crucial ligament (*C*).

Shape of the condyles of the femur.

The *Condyles of the femur*, like the articular facets on the tibia, present a general *resemblance* to one another. They are oblong from before backwards; and their under surface is convex from before backwards and from side to side. They are separate behind, but run together in front, uniting there to form a *trochlear* surface upon which the patella plays. The antero-posterior curve of their cartilaginous surfaces is by no means uniform, but increases in sharpness as we trace it from before backwards. The under parts of the condyles, upon which the weight is borne, in the erect posture, present large and comparatively flat surfaces to the tibia; while the hinder parts, which are in contact with the tibia in the flexed position, when there cannot be much weight resting upon them, are round, and present surfaces favourable to the pronation and supination of the tibia.

Differences between outer and inner condyles.

There are many points of *difference* between the two condyles. The outer is directed nearly straight, from behind, forwards; if it presents any lateral curve, the convexity is directed towards the other condyle. The inner is inclined, from behind, obliquely outwards towards the outer condyle, with which its articular surface becomes blended in the trochlea; it presents a distinct lateral curve with the concavity towards the other condyle. This concavity receives the inner tubercle of the spine of the tibia, and revolves round it in the slight rotatory motion that occurs during the last stage of extension. The outer condyle is broad, increases in width from behind forwards, is sharply curved from before backwards, behind, but is comparatively flat upon its under surface, both in a transverse, and in an antero-posterior direction; and its under surface is inclined, from within, outwards and downwards, in adaptation to the slope of the external articular facet of the tibia (Pl. LII. fig. 1). The inner condyle is narrower than the outer; it decreases in width from behind forwards; its under surface is more convex transversely, as well as antero-posteriorly; and its hinder part is less sharply curved from before backwards, but is more convex from side to side[1]. The external margin of the outer condyle, in front, is more prominent than the corresponding part of the inner condyle; which is for the purpose of resisting the tendency of the extensor muscles to drag the patella outwards. Indeed, the outer condyle is, in front, altogether more prominent than the inner, and its articular surface has a wider sweep; whereas the reverse is the case behind, the inner condyle being there more prominent and forming part of a larger circle.

Each crossed by a superficial ridge.

Just behind the trochlea each of the condyles is crossed by a superficial *Ridge* passing, from its intercondyloid or apposed edge, obliquely outwards and forwards. These ridges are placed in front of superficial *Grooves* (Pl. XLVII. *D*) which receive the interarticular cartilages when the joint is extended. They mark off the part of the joint belonging to the tibia from that which belongs to the patella, and they are not subject to much pressure, either from the tibia or the patella; accordingly, the cartilage is thin here, and we not unfrequently find, when the movements of the joints have been impeded by disease, that the cartilage is, at this part, covered, or replaced, by a band of connective tissue. This occurs mostly upon the inner condyle[2]. The ridge and groove upon the inner condyle are in a plane anterior to those of the outer condyle, which disposition has relation to the greater prolongation forwards of the inner articular

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[1] The comparative flatness of the hinder part of the *outer* condyle, as compared with that of the *inner*, in a transverse direction (Pl. LII.), favours the difference in the movement of the two articular surfaces of the tibia in pronation and supination; inasmuch as the outer surface *slides* to and fro upon the outer condyle, whereas the inner surface *rotates* upon a vertical axis drawn through the outer part of the inner condyle.

[2] "In connection with this partial division of the synovial cavity, by means of transverse ridges, aided by the *Ligamentum adiposum*, and in connection also with the closer relation of the patella to the inner condyle of the femur in the lower animals (mentioned at p. 482), it is interesting to find that in the Ornithorynchus Paradoxus the knee-joint is divided into two compartments by an extension of the ligamentum adiposum, from the back of the patella, to the crucial ligaments; there being one synovial cavity, common to the patella and anterior part of the femur with the internal condyles of the femur and tibia, which contains the internal semilunar cartilage; and a second common to the external condyles of the femur and tibia with the head of the fibula, in which is contained the external semilunar cartilage."—*Catalogue of Museum of Coll. of Surgeons.*

facet of the tibia, as well as to the slight rotation of the femur inwards in extension, forasmuch as that movement causes the inner facet of the tibia and the internal semilunar cartilage to advance, forwards, beyond the level of the corresponding parts on the outer side.

The ligaments.

It is in the strength and disposition of the ligaments that we are to look chiefly for the agents by which the movements of the joint are determined, and by which its security is provided for. Their arrangement is such as to adapt them to the peculiar combinations of movements that take place in this joint. Four of the ligaments—the two "lateral" and the two "crucial"—are attached to the condyles in, or nearly in, a line with the axis round which the tibia revolves during a considerable part of the movement of flexion and extension; so that they may be compared with the lateral ligaments of true hinge-joints; and they are placed one on either side of each condyle. The crucial ligaments are nearly tense in every position of the joint; and they assist to regulate and limit each of the movements. On these accounts, as well as from their great strength, they are the most important of the ligaments. The two "lateral ligaments" are tense only in one position; and their office is to limit extension and the movements attendant upon it. Herein they differ from the lateral ligaments of the elbow and other true hinge-joints, which are tight in every position of the joint, and which prevent all movements except those of flexion and extension. A fifth ligament—the "posterior ligament"—limits extension and contributes much to the steadiness of the joint in that position. There is no ligament in front of the joint, and none which has the direct effect of limiting flexion; the stop to this movement is, under ordinary circumstances, given by the bulk of the soft parts behind the joint, before either of the ligaments are put upon the stretch. Besides these ligaments, there are the "semilunar-cartilages" and the "synovial ligaments;" the office of which is not so much to limit the movements of the joint, as to fill up the intervals between the articular surfaces of the bones in different positions.

Internal lateral ligament.

The *Internal lateral ligament* (Pl. XLIX.) is connected, above, with a slight depression upon the "tubercle" on the inner side of the internal condyle of the femur, and, below, with the rough ridge which descends from the inner side of the inner condyle of the tibia. It is flat, and about 3½ inches long; its anterior edge (*D*) is thicker and more defined than the posterior (*E*), which is continuous, in the upper part, with the fibres of the "posterior ligament." It is closely applied along the sides of both the bones[1] and the interarticular cartilage, and is connected with the latter and with the tibia by fibrous tissue, so that it accompanies them in the movements of the joint. It is free from the side of the femur below the point of its attachment, to permit the lower part of the condyle to slide to and fro beneath it[2].

External lateral ligament. The "tubercle" on the external condyle of the femur presents, on its elongated posterior edge, which forms the anterior boundary of the groove for the tendon of the *poplitæus* muscle, three superficial depressions. The upper and hindmost of these (Pl. L. *A*) receives some of the tendinous fibres of the

[1] Except just beneath the head of the tibia, where the incurvation of the side of the bone leaves a space between it and the ligament, which is occupied by fat, and which transmits the "inferior internal articular artery."

[2] A *Posterior internal lateral ligament* has been described passing from the inner edge of the tibia, just in front of the *semimembranosus* tendon, to the femur behind the internal lateral ligament; it is closely connected with the internal semilunar cartilage, and is stretched in extension.—Meyer, in Müller's *Archiv*, 1853, s. 506. It may be regarded as a part (*F*) of the internal lateral ligament, and scarcely deserves separate mention.

DESCRIPTION OF PLATE XLIX.

Fig. 1. Inner side of left knee-joint. *A*, tendon of adductor magnus. *B*, tendon of gastrocnemius. *C*, internal lateral ligament. These are attached, near together, to the internal condyle of the femur. *D*, thick defined anterior edge of internal lateral ligament. *E*, hinder fibres of the same, radiating backwards and blended with posterior ligament. *F*, a portion of the internal ligament ascending, upwards and backwards, from the tibia to the posterior ligament; it is sometimes called the posterior internal lateral ligament. *G*, the semi-membranous tendon. *H*, detachment of latter passing down hinder surface of tibia. *I*, fibrous band which connects internal semilunar cartilage with fore part of head of tibia. *K*, tendon of rectus femoris. *L*, tendo-patellæ, with a mass of fat (*M*) between it and head of tibia.

Fig. 2. Inner side of knee-joint bent. *A*, *B*, *C*, *D*, *E*, *F*, *G*, *I*, the same as in preceding. *K*, the posterior ligament thrown into folds.

Fig. 1.

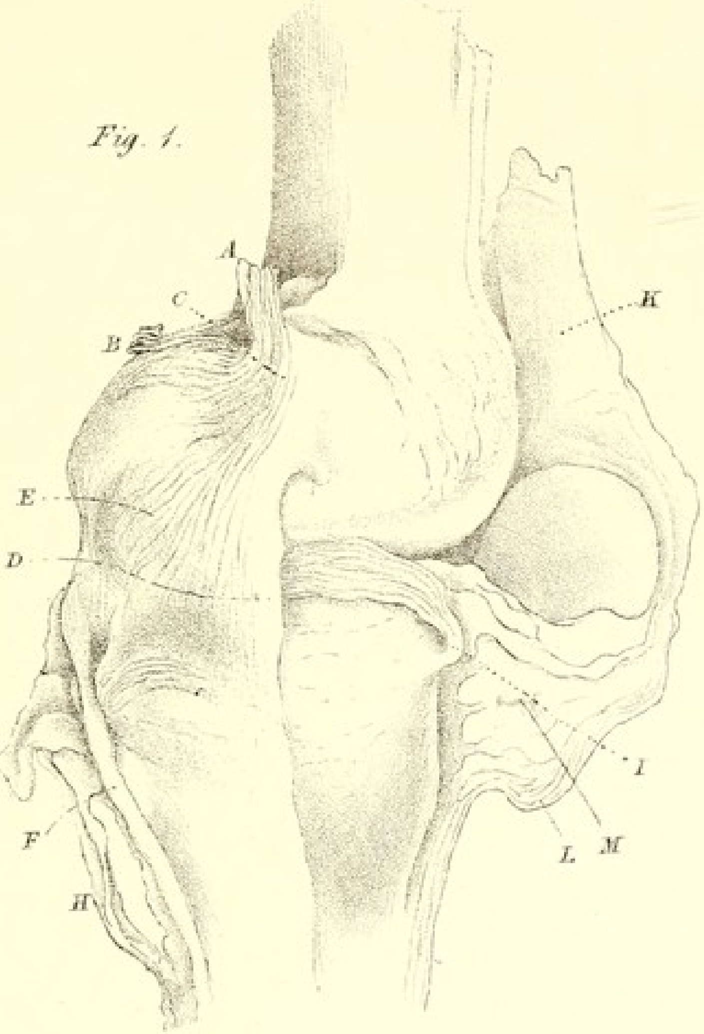
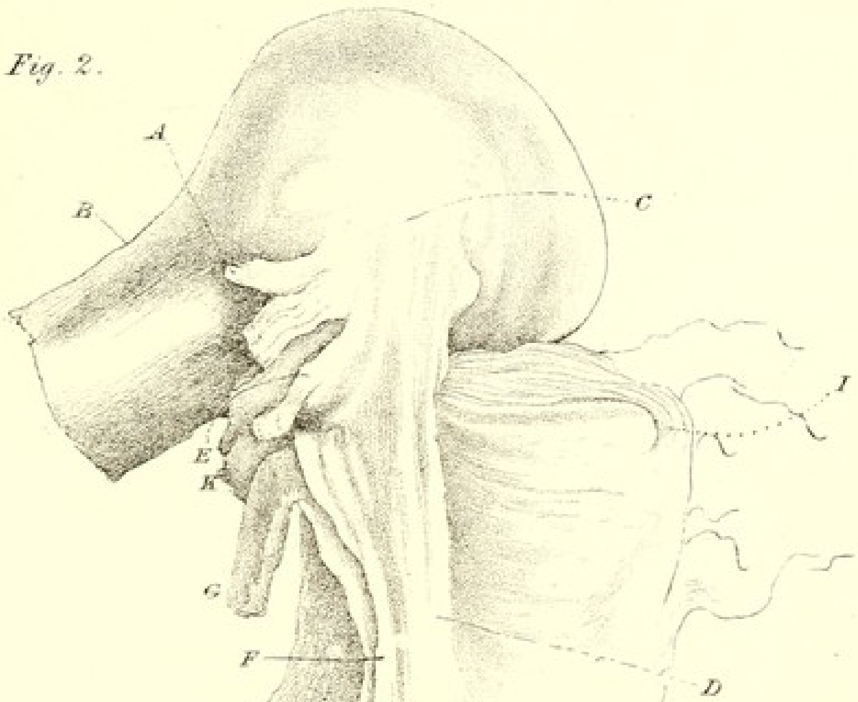


Fig. 2.



gastrocnemius; the lower and and foremost (*C*) gives attachment to the tendon of the *poplitæus*, and the middle one (*B*) gives attachment to the *External lateral ligament.* This ligament is of cylindrical shape, and 2½ inches long; it is attached, below, to the depression on the head of the fibula, which is just external to the middle of its articular facet, and which is partly surrounded by the prominence for the insertion of the biceps tendon. The points of attachment of the ligament stand out more wide of the joint than do those of the internal lateral ligament; and it is separated from the joint, from the interarticular cartilage, and from the head of the tibia, by an interval containing fat and areolar tissue. The tendon of the *poplitæus* (*C*) intervenes between it and the lower edge of the femur, except in the completely flexed state of the joint, when the tendon lies along its own groove. Some of the fibres of the *biceps* tendon pass over the lower part of the ligament, in their course to the fore part of the fibula and to the adjacent part of the tibia. The tendon is closely united to the ligament by tough fibro-areolar tissue, so as to exert an influence in giving it some tension while the joint is being bent.

Difference between the two lateral ligaments.

The external lateral ligament, therefore, differs from the internal in the following respects. It is of rope-like shape; is an inch shorter; the point of its attachment to the fibula is higher than that of the internal ligament to the tibia; and its point of attachment to the condyle of the femur is a little lower and a little further back[1]; it is more free from the joint; and has no direct connection either with the head of the tibia or with the interarticular cartilage.

The external most relaxed when joint is bent.

Both lateral ligaments lie nearer to the hinder than to the fore part of the joint, which alone is sufficient to make them tight in the extended, and relaxed in the flexed, position of the knee. The relaxation is more marked in the external ligament than in the internal, which permits to the external condyle of the tibia the free movement required

[1] A pair of compasses will shew this at once, and will prove that the sweep of the outer condyle round the point of attachment of the external lateral ligament is smaller —is part of a smaller circle—than that of the inner condyle round the corresponding point of attachment of the internal lateral ligament.

for its revolution round the internal condyle in pronation and supination of the leg (page 527).

Axis of flexion and extension of knee is oblique.

The point of attachment of each lateral ligament to its condyle represents, nearly, the centre around which the corresponding articular facet of the tibia revolves during a part of the movement of flexion and extension of the knee; and a line drawn between the points of attachment of the two ligaments represents the axis of motion of the tibia. This line is oblique, in consequence of the point of attachment of the external ligament being a little lower and more backward than that of the internal ligament. The direction in which the movement takes place is, therefore, also oblique. The arrangement is such that the plane which is occupied by the tibia in the most bent position of the knee about corresponds with that of the femur; that is to say, it slants obliquely upwards and outwards, and the leg is folded up against the thigh. This also accords with the fact that the hinder part of the external condyle is smaller than that of the internal—i. e. forms a segment of a smaller circle. When, however, the knee is extended, the upper surface of the tibia comes into contact with the under part of the femur, where the surfaces of the two condyles are on the same horizontal level; and the plane in which the leg is then placed is perpendicular to the ground, though oblique with regard to the thigh. In the extended position, therefore, each leg is vertical, and in a plane, parallel with that of the opposite leg, but oblique with regard to that of the thigh; in the flexed position, it is in the same plane with the thigh, but is

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DESCRIPTION OF PLATE L.

Outer side of left knee-joint extended. *A*, point of attachment of gastrocnemius. *B*, external lateral ligament. *C*, poplitæus. *D*, external semilunar cartilage, having no distinct fibrous connection with fore part of head of tibia. *E*, biceps tendon attached to head of tibia; it has been separated from top of fibula (*F*) and turned down. *G*, tendo-patellæ.

The same bent. *A*, *B*, *C*, *D*, *E*, *F*, *G*, the same as in preceding. *H*, fibrous tissue connecting external semilunar cartilage with poplitæus. The external lateral ligament is relaxed; and the semilunar cartilage, following the femur, has left the fore part of the articular surface of the tibia.

Fig. 1.

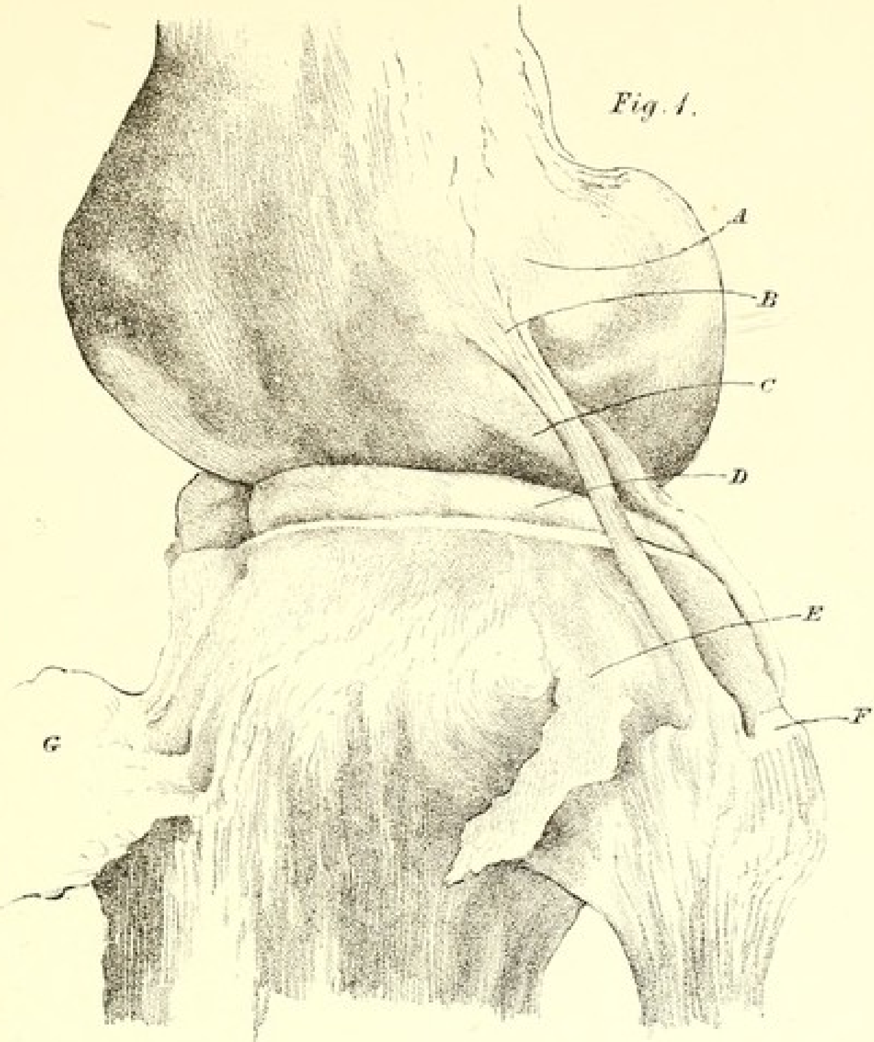
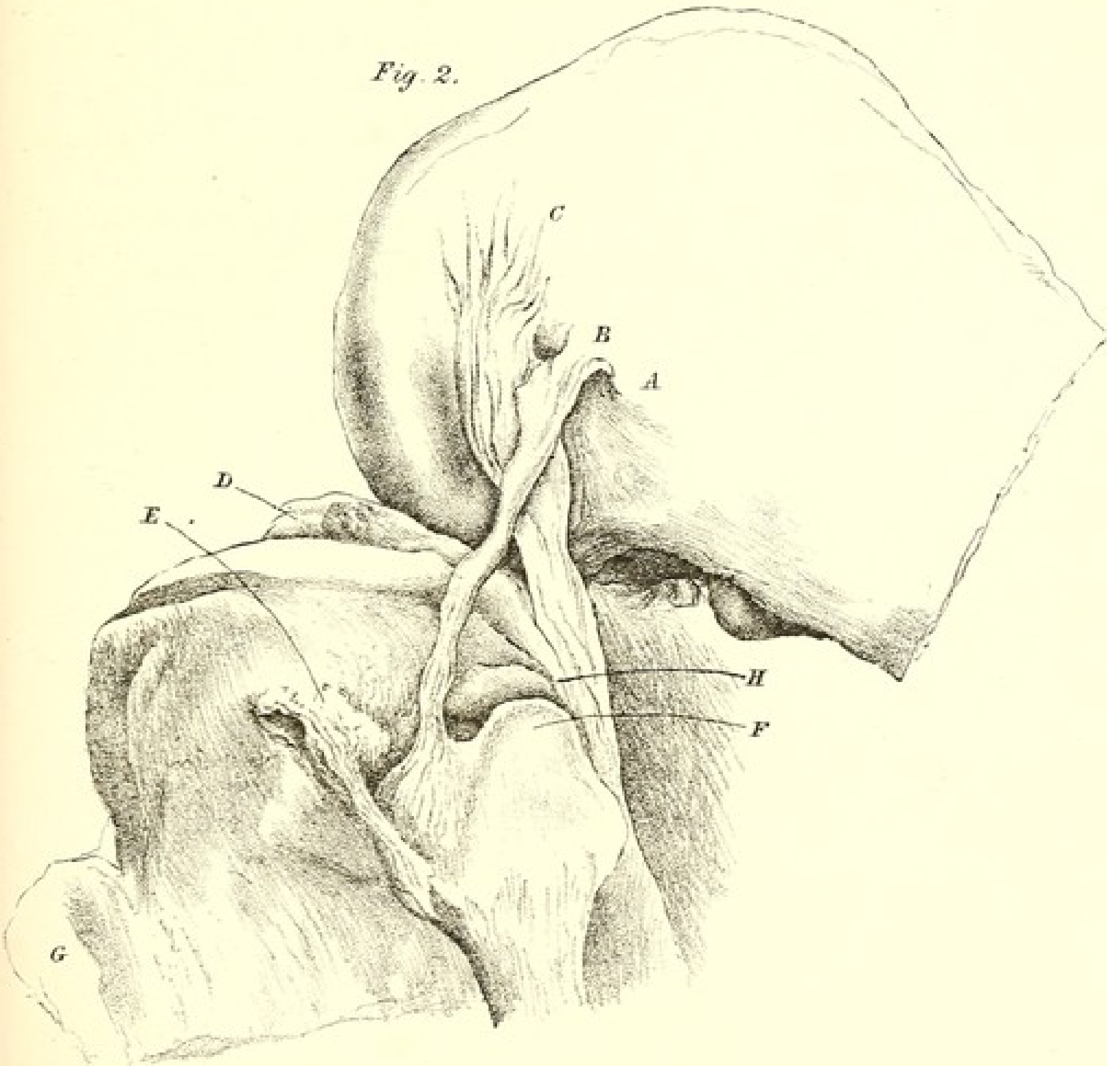


Fig. 2.



oblique with regard to the opposite leg; and the line of its movement from one position to the other is oblique both with regard to the thigh and to the opposite leg.

Knock-knee and bandy-leg.

This, at least, is the case in the natural condition of the knee, when the condyles of the femur retain their proper form and relative size. Suppose, however, that the whole surface of the outer condyle has not descended to the same level with that of the inner condyle (p. 476), or, which is no uncommon thing, has been flattened by the weight of the body; then, although the leg may occupy its natural position when the knee is bent, it will, during extension, slant more outwardly, instead of becoming vertical, and will attain its greatest obliquity when the joint is straight. This is what occurs in cases of "knock-knee." In "bandy-leg" the slant of the leg is in the opposite direction, in consequence of the relative shortness of the internal condyle.

Office of the lateral ligaments.

If the relations of the various parts of the articular surface of either condyle with the axial line, or, what is the same thing, with the point of attachment of its lateral ligament, (Pl. XLVII. fig. 1, *A*), be examined, by means of lines drawn from that point to the surface, it will be found that the hindermost extremity of the condyle approaches nearest to it (as indicated by the line *A* 1); accordingly when the tibia is brought into contact with this part (as in fig. 2) the distance between the points of attachment of the lateral ligament is diminished, and the ligament is relaxed. It is still further relaxed, in this position, by the fact of its being the hinder part of the tibial facet which is now in contact with the femur. The distance of the articular surface of the condyle from the point indicated as the axial line increases as we trace it forwards; quickly at first, till we reach the most prominent posterior point of the condyle (2), then slowly, till we come to a point (3) which is situated nearly vertically beneath the attachment of the ligament to the femur in the straight position of the limb. After this the distance again increases, more quickly, to the point indicated by fig. 4. It follows, accordingly, that as, during the extension of the joint, the tibia glides beneath the lines *A* 2, *A* 3, and *A* 4, the lateral ligaments gradually become tense. The tension is also increased by the slight turning of the tibia upon a transverse axis, which accompanies extension; and, in the case of the external lateral ligament, by the rotation of the tibia upon a vertical axis, which occurs in the last stage of extension. Hence the ligaments are quite relaxed in the bent position of the joint; and do not interfere with its rotatory or other movements; as extension proceeds they are gradually tightened, and finally become quite tense, holding the articular surfaces firmly together. In the straight position they resist additional *extension* by not permitting the tibia to slide upon the condyles to a point more distant from their attachment to the femur; they resist additional *turning* of the tibia upon a transverse axis by not allowing any further separation of the hinder part of the articular facets of the tibia from the femur; and they resist any further *rotation* of the tibia outwards upon a vertical axis by the direction which they have now assumed, the outer one (Pl. L. fig. 1) slanting backwards from its condyle to the fibula, while the inner (Pl. XLIX. fig. 1) slants a little forwards to the tibia.

They are relaxed in flexed state; limit extension, and turning of tibia, and rotation.

It is sometimes stated that the external lateral ligament limits *pronation* and *supination* of the leg, by checking the play to-and-fro of the fibula and of the outer condyle of the tibia which take place in that movement; but this is not the case, for, when the joint is sufficiently bent to permit pronation and supination of the leg, the ligament is too much relaxed to exert any restraining influence; and after it has been cut the movement is quite as restricted as it was before, being, in reality, limited, as we shall find, by the crucial ligaments.

External lateral ligament does not limit pronation or supination.

The *Posterior ligament* of the knee-joint (Pl. LI. fig. 2) is so closely united with the surrounding tendons that it is difficult to define its precise limits. Below, it is connected, in the middle, with the head of the tibia, just behind the posterior crucial ligament; on the outer side, it is connected with the *poplitæus* muscle (*F*), and, on the inner side, with the *semimembranosus* tendon (*B*). Above, it is connected, in the middle, with the poplitæal space of the femur, and, on either side, with the heads

Posterior ligament.

of the *gastrocnemii* (*C* and *E*). It is composed of crossing and interlacing fibres, with large orifices between them for the passage of the posterior articular vessels. A strong band (*A*), passing from the *semimembranosus* tendon, obliquely upwards and outwards, to the outer head of the *gastrocnemius* (*C*), forms the hinder layer of the ligament; sometimes, indeed, it is the chief constituent. Where this band joins the gastrocnemius, upon the outer condyle of the femur, is, commonly, a thick mass of fibrous tissue; and, sometimes, a sesamoid bone (*D*) is here developed[1]. The posterior ligament strengthens the back of the knee-joint, is tightened during extension, and assists the other ligaments in limiting that movement. Its connection with the various adjacent flexor muscles serves to bind them together, and to ensure that its own fibres, and the contiguous glands and other structures, are kept from being caught between the articular surfaces when the knee is bent.

This ligament presents an obstacle to the eruption, into the synovial cavity, of abscesses forming in the ham. It is liable to become contracted in consequence of disease, or from other cause; and it may thus prevent extension of the joint after the disease has subsided. I have known it to be torn, and rent away from the femur, by forcible attempts to straighten a limb under these circumstances.

Crucial ligaments.

The *Crucial ligaments* are situated, in great measure, out of sight. Like the ligamentum teres of the hip, they have been the subject of much discussion; and very conflicting accounts of their use have been given by different anatomists. Weber's[2] description is, on the whole, more accurate than any other. The following account is derived from careful examinations of the joint, dissected, and prepared in various ways for the purpose.

The anterior

The *Anterior crucial ligament* is connected, below, with the fore part of the inner tubercle of the spine of

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[1] A sesamoid bone, in the origin of the external portion of the gastrocnemius, was noticed by Vesalius, Lib. I. cap. 28 and 30, I. There is one of considerable size in the hare (Cambridge Museum).

[2] *Gehwerkzeuge*, s. 184.

the tibia, and with an oblong eminence, or rough space, continued forwards, from the spine, alongside the margin of the inner articular facet. (Pl. XLVIII. *H*, and LI. *B*.) Its fibres here lie between the fibres of insertion of the anterior extremity of the external semi-lunar cartilage, which splits to make way for it. From this point the ligament passes obliquely, upwards, backwards, and outwards, to the hinder part of the inner side of the external condyle of the femur, and is inserted into a nearly perpendicular line along the side of the ascending articular facet of the condyle. Its component fibres do not run in parallel lines. Those which pass from the foremost point of the tibia ascend to the highest point of the line on the condyle, and are, consequently, the longest (Pl. LII. figs. 2 and 3 *G*); they are also the strongest. The fibres (*H*), which arise from the lowest point of the condyle, are shorter and more oblique, inasmuch as they cross behind the others to reach the spine of the tibia, and are inserted close to it. We shall find it convenient to call these the "short fibres" of the anterior crucial ligament, to distinguish them from the others or "long fibres."

resists displacement of tibia forwards and limits extension,

The obvious use of the anterior crucial ligament is to prevent the tibia from being carried too far forwards upon the femur, either by the pull of the extensor muscles or by any external force; and it does this, more or less, in all positions of the joint. In the extended position, when its services are most needed, all its fibres, the "long" as well as the "short," are put upon the stretch, and they all combine to resist any further extension as well as any further sliding forward

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DESCRIPTION OF PLATE LI.

Fig. 1. Anterior view of left knee-joint bent. *A*, posterior crucial ligament. *B*, anterior ditto. *C*, internal semilunar cartilage. *D*, external ditto. *E*, external lateral ligament relaxed. *F*, tendon of biceps running forwards to tibia between (*I*) upper and (*K*) lower portions of anterior peroneo-tibial ligament. *G*, tendo-patellæ turned down. *H*, tendon of poplitæus.

Fig. 2. Left knee-joint extended, seen from behind. *A*, ligamentum posticum; the thickest portion of it ascends from (*B*) the semimembranosus to (*C*) the outer head of gastrocnemius; *D*, a sesamoid bone at its junction with the latter. *E*, inner head of gastrocnemius, also connected with lig. post. *F*, poplitæus muscle, raised a little to shew (*G*) the posterior peroneo-tibial ligament. *H*, external lateral ligament.

Fig. 1.

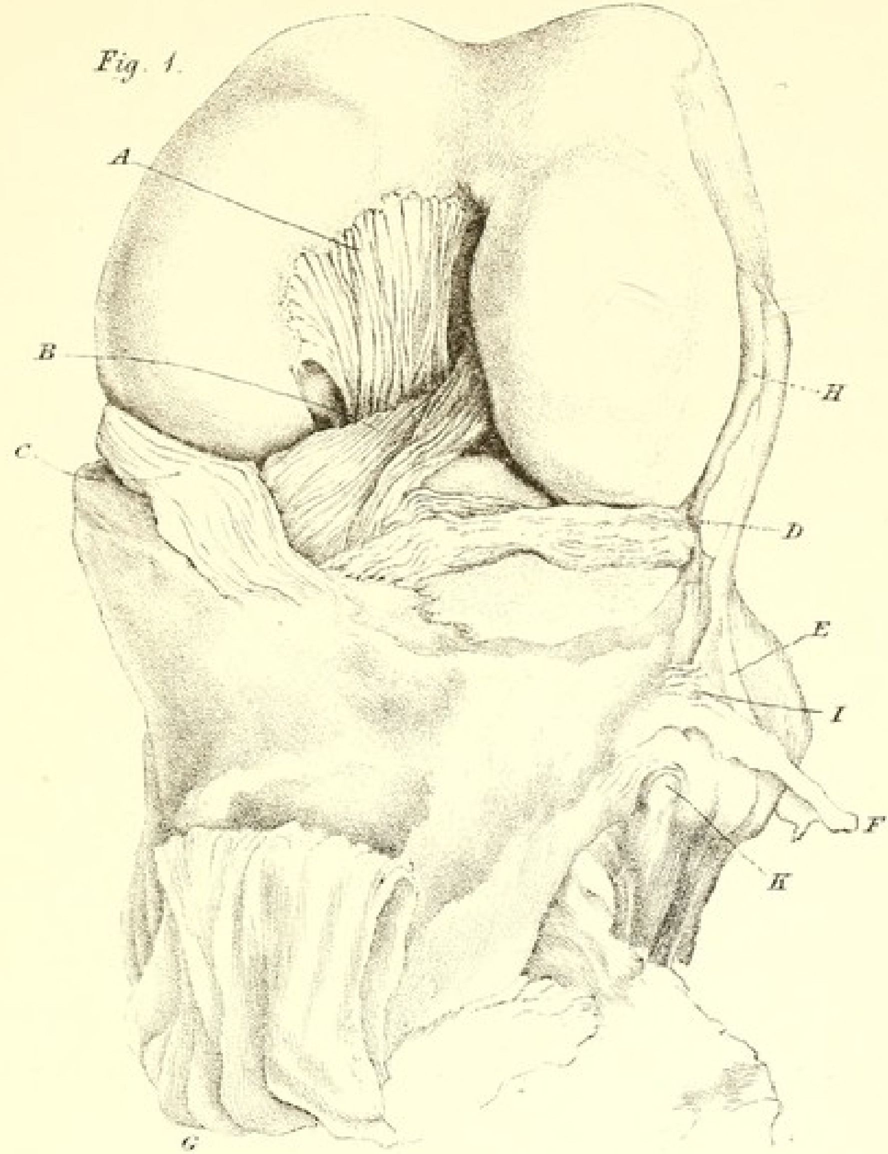
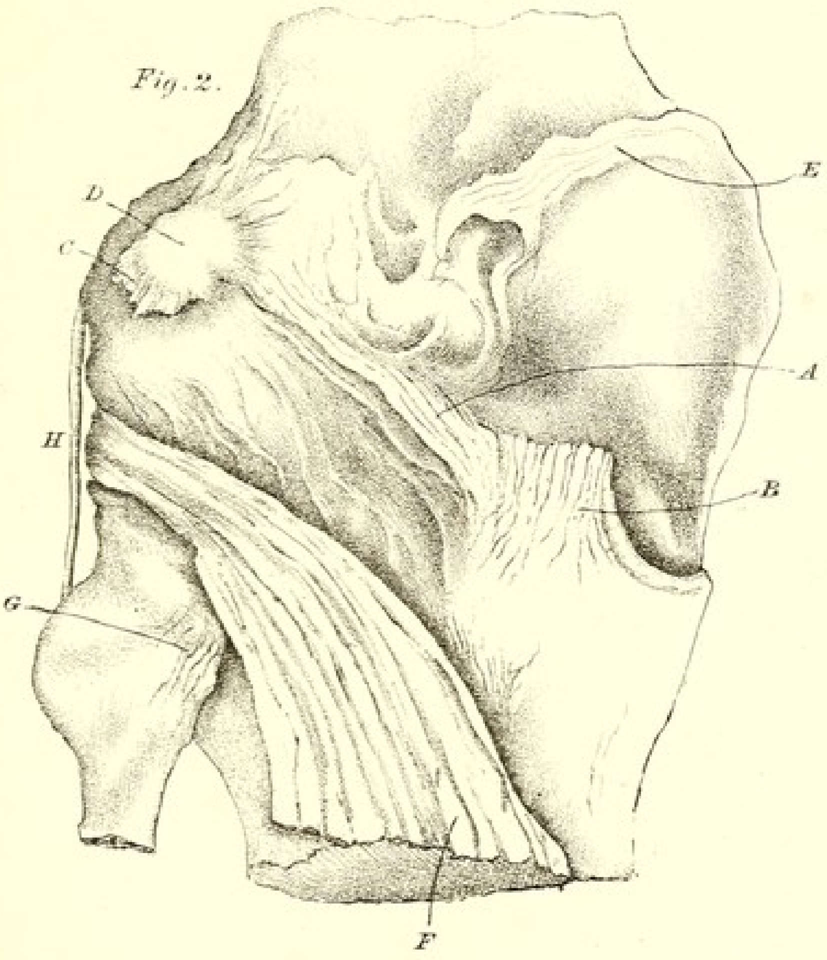


Fig. 2.



of the tibia upon the femur. Indeed they would not permit the extension and sliding movement to go quite so far as they do, if the fibres were not a little relaxed by the accompanying rotation of the tibia outwards. When the joint is bent the fibres of the ligament gradually become somewhat relaxed, first the "short" fibres and then the "long;" but the relaxation of the latter is very slight.

and pronation.

It is necessary to the *pronation* of the leg that the ligament should be a little relaxed; for when it is on the stretch the disposition of its fibres, particularly of its "short" fibres, is such as entirely to prevent that movement; accordingly, in the extended position, the fibres of the anterior crucial ligament combine with the lateral ligaments to resist pronation as well as any further extension of the leg. During flexion, the fibres being somewhat relaxed, pronation, within a certain range, is permitted; and the range is increased with the flexion of the joint, because the fibres of the ligament are more and more relaxed. The relaxation, however, under any circumstances, as just stated, is but slight, and, in all positions of the joint, the extent to which pronation can be carried is limited by this ligament.

Is kept nearly tense in all positions of the joint,

It is essential, therefore, to the movements of the knee that the anterior crucial ligament should be somewhat relaxed in the flexed condition; it is essential, also, to the proper limitation of these movements, and to the security of the joint, that that relaxation should be slight; and it is by the peculiar combination of movements which takes place that the requisite condition of the ligament is maintained. For these combined movements have, to a certain extent, the effect of neutralizing each other's influence upon the ligament, in the following manner. The flexion, and the attendant sliding back, of the tibia upon the femur would approximate the anterior inter-articular space of the former to the hinder part of the condyle of the latter; that is to say, would approximate the points of attachment of the anterior crucial ligament, and would, consequently, relax it; but the other movement which takes place at the same time—the turning of the tibia upon a transverse axis (page 525)—would have the contrary effect, and, by distancing the points of attachment of the ligament, would increase its tension. So nicely are these opposing influences regulated that, although, during flexion, the ligament is sufficiently relaxed to permit the necessary pronation and other movements of the knee, it is maintained in such a condition that it still serves to restrain those movements and to assist in preventing any separation of the bones.

does not especially limit flexion.

The idea that the anterior crucial ligament is the especial agent in limiting flexion of the knee has probably arisen from an observation of the fact that, in the dissected joint, flexion cannot be carried beyond an angle of 40° or 35° without tearing the ligament from its point of attachment to the femur. The manner, however, in which its fibres are inserted into the bone sufficiently proves that it is not intended to bear a strain in this direction; and it has been already observed (page 532) that the limitation to bending of the knee is given, not by any particular ligament, so much as by the bulk of soft parts in the ham.

Posterior crucial ligament.

The *Posterior crucial ligament* crosses the anterior, and is, in many respects, the converse of it. It passes from the hindermost part of the fossa between the articular facets

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DESCRIPTION OF PLATE LII.

Fig. 1. Vertical section from side to side through left knee-joint, in the nearly extended position. *A*, inner condyle of femur. *B*, outer ditto. *C*, internal lateral ligament. *D*, cut edge of internal semilunar cartilage; *E*, fibro-synovial fold from its upper margin to side of condyle of femur, and reflected upon the latter; *F*, similar fold from its lower margin to side of head of tibia. *G*, external lateral ligament. *H*, cut fibres of tendon of poplitæus muscle. *I*, cut edge of external semilunar cartilage; *K*, fibro-synovial fold passing from its upper margin to side of condyle of femur; *L*, similar fold from its lower edge to side of head of tibia. These folds mark the extent of the cavity of the joint in this direction. *M*, fibres of anterior crucial ligament. *N*, ditto of posterior crucial ligament. *O*, inner tubercle of spine. *P*, outer ditto.

Figs. 2 and 3 are views of anterior crucial ligament obtained by removing the internal condyle of the femur. Fig 2 is in the extended, and fig. 3 is in the flexed position. *A*, cut surface of femur between the condyles. *B*, internal articular surface of tibia, with internal semilunar cartilage (*C*) lying upon it. *D*, external semilunar cartilage. *E*, transverse ligament. *F*, posterior crucial ligament divided and turned back. *G*, "long" fibres of anterior crucial ligament. *H*, "short" ditto; the upper end of these, in the extended position (fig. 2), are behind the others; but, during flexion, they pass on the outer side, and in fig. 3 are seen in front of the long fibres.

Fig. 1.

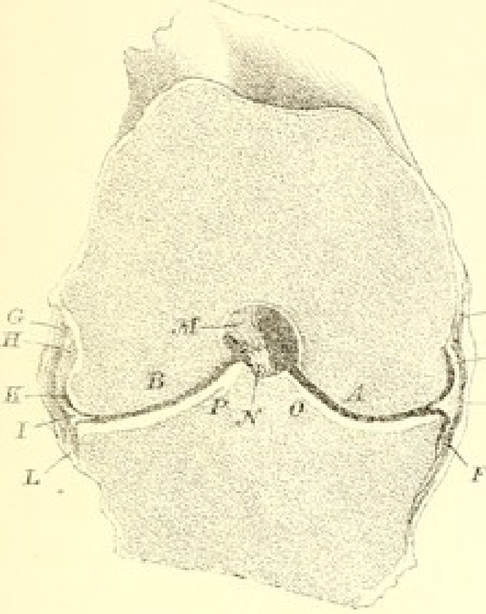


Fig. 2.

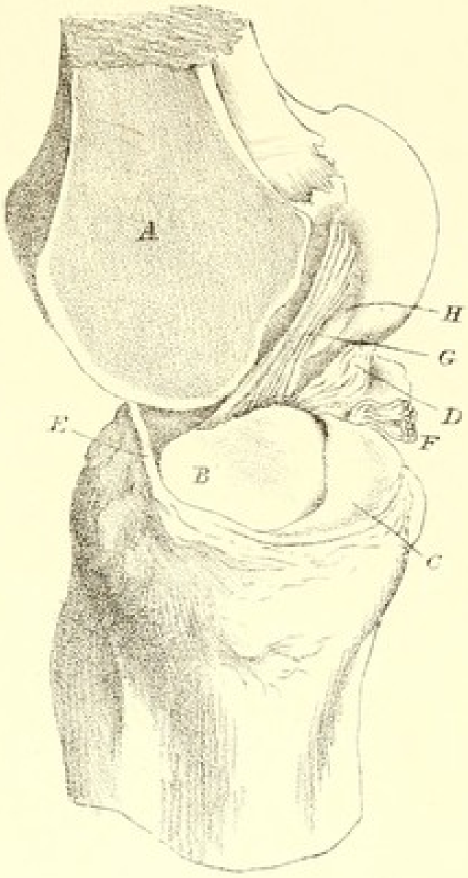
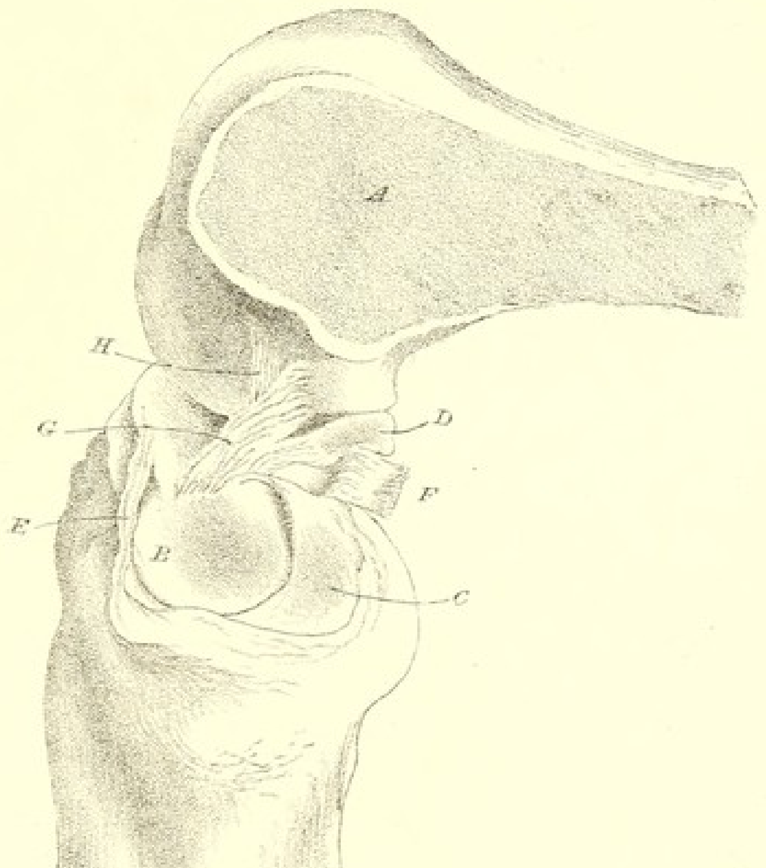


Fig. 3.



for resistance. In the dissected joint the posterior crucial ligament sets a limit to *flexion* when the knee is bent quite to an acute angle; but in the living subject the soft parts of the ham put a stop to the approximation of the leg and thigh, before the point at which the ligament is in a condition to do so. During

limits extension

the first stage of *extension* the ligament is a little relaxed; it becomes less loose in the latter stage of the movement; and when the joint is straight, all, or nearly all, of the fibres are tense, and resist any further revolution of the condyle; indeed they would not permit the requisite degree of extension to take place, if they were not somewhat relaxed by the simultaneous sliding forwards of the tibia upon the femur.

and supination.

The posterior crucial ligament exerts little or no influence upon *pronation* of the leg, that movement being checked by the anterior crucial ligament before the posterior is tense. It serves, however, to limit *supination* by means of its "long" fibres. These hold the articular surfaces closely together, and fix the inner condyle of the femur against the side of the spine of the tibia in such a manner as to constitute a very effectual lock, which prevents supination being carried beyond a certain point in any position of the knee, and renders the movement impossible when

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DESCRIPTION OF PLATE LIII.

Views of posterior crucial ligament, in right knee, obtained by removing the external condyle of the femur. Fig. 1 is in the extended; fig. 2 is in the flexed position. *A*, cut surface of femur between the condyles. *B*, external articular facet of tibia with external semilunar cartilage (*C*) lying upon it. *D*, internal semilunar cartilage. *E*, transverse ligament. *F*, anterior crucial ligament; the upper part has been removed with the condyle. *G*, "short" internal fibres of posterior crucial ligament, which are tense in all positions of the knee; in the extended position (fig. 1) they are behind the others; but during flexion their upper ends are carried forwards beside the others, and in fig. 2 appear quite in front of them. *H*, "long" external fibres of the same; these are somewhat relaxed in fig. 1 in consequence of the joint being extended a little beyond the natural limit. *I* and *K*, fibres of external semilunar cartilage passing into hinder and fore part of posterior crucial ligament. *L*, cut end of poplitæus muscle; *M*, fibres passing from latter to semilunar cartilage. *N*, upper, and *O*, lower, fibres of anterior peroneo-tibial ligament; the space between them was occupied by the part of the biceps tendon which passes on to the head of the tibia (Pl. L. *E*).

Fig. 1.

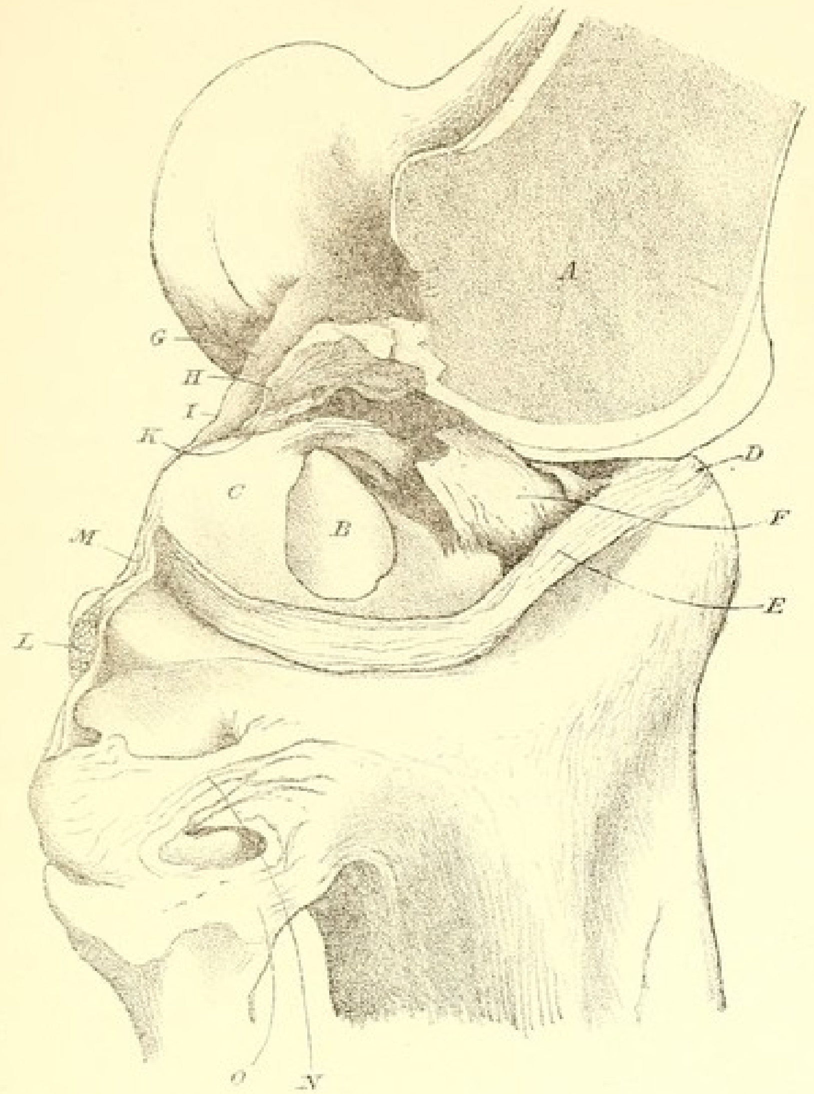
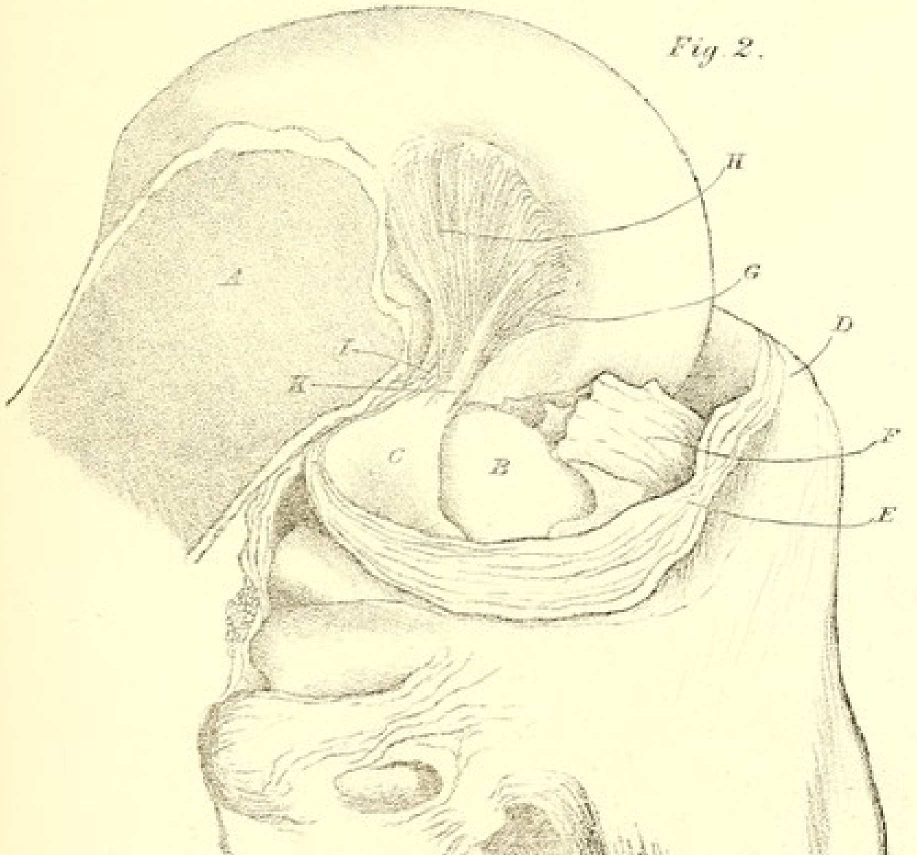


Fig. 2.



the knee is quite straight. In the first stage of flexion, the ligament is a little relaxed, and some supination may be effected; and when the joint is bent, the movement is more free, although the ligament is then tight, because the spine of the tibia is not, in this position, so closely applied against the surface of the condyle, and because the inner articular surface of the tibia revolves, upon the ball-like hinder part of the condyle, on an axis which nearly corresponds with the ligament.

Is nearly tense in all positions of the joint.

It is therefore essential to the movements of the joint that the fibres of this ligament, like those of the anterior crucial ligament, should be somewhat relaxed in certain positions of the joint; and it is also essential to the proper limitation of the movements, and to the security of the joint, that the relaxation should be slight; and, in this instance, as in the case of the anterior crucial ligament, the requisite condition is maintained by the counteracting influences which the simultaneous movements of the joint exert upon the ligament. Thus, in extension, when the sliding of the tibia forwards, by approximating the hinder edge of the tibia to the fore part of the condyle of the femur, tends to relax the fibres, so, in nearly the same proportion, does the distancing of the hinder edge of the tibia from the condyle, by the concomitant turning of the bone upon a transverse axis, tend to maintain the tension of the ligament; it does this enough to give steadiness to the joint, and to limit its movements, though not enough to prevent the latter altogether.

Combinations of movements necessary to proper condition of crucial ligaments and necessitated by them.

The proper combination of movements in the knee not only maintains that condition of the crucial ligaments which is requisite for the play and security of the joint, and proves, in this way, a cause of the efficiency of the ligaments; but it may be regarded also as a necessary *consequence* of the manner in which those ligaments are arranged. For instance, owing to the disposition of the anterior crucial ligament, flexion, and turning of the tibia on a transverse axis, could not take place without being accompanied by the sliding of the tibia backwards; and, owing to the disposition of the posterior crucial ligament, the sliding of the tibia backwards, in flexion, could not take place without the attendant turning of the tibia. Again, the posterior crucial ligament requires the sliding forward of the tibia to be an attendant on extension; and the anterior crucial ligament does not permit the sliding movement to take place unless it be accompanied by the turning of the tibia upon a transverse axis, and a slight rotation of the same bone upon a vertical axis (page 526). It is evident, therefore, that the ligaments and the articular surfaces bear such relation to each other in their construction, that the proper tension of the former, and the proper movements of the latter, are mutually dependent. The crucial ligaments possess all the advantages of the lateral ligaments of an ordinary hinge-joint, inasmuch as they maintain a uniform, or nearly uniform, tension in all positions of the joint, and possess the additional advantage of not restricting the movements to those of flexion and extension[1].

Interarticular or semilunar cartilages.

The *Interarticular fibro-cartilages*, called also the *Semilunar cartilages*, are appendages to the tibia, being connected with it by both their extremities and accompanying it in its chief movements upon the femur. They are bands of fibro-cartilage curved so as to be adapted to the shape of the articular facets between which they are interposed. Their con-

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[1] Examining the undissected knee-joints of a male adult subject, I found the tension of the anterior crucial ligament not decidedly affected by position :—only a little diminished by flexion. The posterior crucial ligament was tight when the joint was extended, a little relaxed in semiflexion, and again tight in the completely bent state. Division of either ligament alone made very little difference to the joint, except that, in the extended position, it was rather less firm after the posterior crucial ligament had been cut, in consequence of the back part of the tibia not being held so firmly to the femur. When both ligaments were cut there was, in addition, preternatural looseness of the joint in the flexed position; the tibia could be moved backwards and forwards upon the femur, as well as rotated more freely, but lateral displacement was still prevented by the projecting spine of the tibia, aided by the lateral ligaments and other soft parts. I did not find that the crucial ligaments were tightened alternately, the posterior in flexion, and the anterior in extension, as stated by Weber, *Gehwerkzeuge*, s. 185; but that some fibres of each were tense, or nearly tense, in all positions.

Dr. Stark, *Ed. Med. and Surg. Journal*, LXXIV. has related two cases of "rupture of the crucial ligaments." In each the accident was attended with an audible snap, and the patient lost the power of supporting the body on the limb, in consequence of the knee-joint bending backwards. The recovery was slow, though nearly complete. The exact nature of the injury could not, of course, be certain in those cases; it must have involved some stretching, at least, of the lateral and posterior ligaments, if the bending backwards took place to any great extent.

vex edges are thick, and united to the synovial membrane and surrounding tissues; their inner edges are thin and free; their under surfaces are comparatively flat to rest upon the facets of the tibia; their upper surfaces are concave to receive the condyles of the femur. They are thickest and deepest at their hinder parts, and gradually become thinner and narrower as they pass forwards. In the greater part of their extent their structure is very compact and gristly; near their extremities it becomes looser and more fibrous.

The internal.

The *Internal semilunar cartilage* (Plate XLVIII.) is attached, behind (*D*), to a short oblique ridge, which runs from the inner tubercle of the spine of the tibia, backwards and outwards, to the outer articular facet; also to the space immediately behind the ridge, between it and the posterior crucial ligament (*C*). Anteriorly (*I*), it is attached to an eminence between the articular facets, in front of the anterior crucial ligament (*H*). Its extremities are, therefore, separated by a considerable interval, in which are situated the tubercles of the spine (*K* and *L*), the two extremities of the external semilunar cartilage (*G* and *E*), and the anterior crucial ligament (*H*). Its thick convex edge is connected with the synovial membrane, with the internal lateral ligament, and with the tendon of the semimembranosus muscle (Pl. XLIX. *I*; LII. fig. 1, *D*).

The external.

The *External semilunar cartilage* (Plate XLVIII.) is small and much more sharply curved than the internal, forming almost a complete circle. It is attached, behind (*E*), to the hinder edge of the outer "tubercle" of the spine of the tibia, and sends a prolongation inwards, along the front of the ridge to which the inner semilunar cartilage (*D*) is attached, as far as the inner tubercle of the spine (*K*). In front of this prolongation it is separated from the anterior crucial ligament (*H*) by loose areolar tissue, and by vessels passing into the foramina of the bone (*F*). Anteriorly (*G*), the external semilunar cartilage is attached to the tibia, just in front of the outer tubercle (*L*) of the spine, its fibres passing beneath those of the anterior crucial ligament (*H*). One narrow strip, detached from the rest, runs in front of this ligament and separates it from the extremity (*I*) of the internal semilunar cartilage. The external semilunar cartilage is less closely connected with surrounding tissues than the internal, and, consequently, slides more freely than it upon the articular facet of the tibia, the flatness of which is favourable to such movement. Behind, the external semilunar cartilage is attached, by means of fibrous and synovial membrane (Pl. LIII. *M*), to the tendon of the poplitæus (*L*), which lies close upon it and separates it from the external lateral ligament; it is attached, also, to the posterior ligament; and some of its fibres pass into the hinder part (*I*), and others into the fore part (*K*), of the posterior crucial ligament. These connections are not sufficiently close to prevent its being pressed backwards over the edge of the tibia during flexion, and drawn forwards upon the articular facet during extension (Pl. L.). The anterior part of its circle is even more free than the posterior, which permits it to be drawn far back upon the articular facet of the tibia, and to be kept in close contact with the condyle of the femur, when the joint is bent.

Office of the semilunar cartilages;

The chief use of the semilunar cartilages is to deepen and extend the space for the reception of the condyles of the femur, and so to relieve the articular surfaces, both of the tibia and femur, from undue pressure at particular points. They adapt themselves to the varying shape of the surface of the femur, which rests upon the tibia; being squeezed out into a larger circle during extension, and again contracting so as to cling round the smaller hinder parts of the condyles in flexion. The fore part of each is less fixed than the hinder, so that it may be free to follow up the condyle as the latter recedes from the front of the tibia in flexion, and be pressed back again into its place in extension. This change of position, to and fro with the condyle, is most marked in the outer semilunar cartilage.

they move with the tibia in flexion and extension, with the femur in supination and pronation.

In flexion and extension the cartilages follow the tibia, and move with it upon the femur; but in supination and pronation they adhere to the femur, and move with it upon the tibia. The flat surface of the outer facet of the tibia, and its slight connection with the external semilunar cartilage, are particularly favourable to the sliding of the facet beneath the cartilage and the condyle of the femur; and it will be remembered that the movement is more free on this than on the inner side, in consequence of the centre of the motion being internal to the spine of the tibia (page 527).

Fill up intervals between surfaces of femur and tibia.

Further, the semilunar cartilages serve to occupy the angular intervals between the articular surfaces of the condyles of the femur and tibia, which vary in size and depth very greatly in the different positions of the joint, owing to the fact that the condyles present, at one time, a nearly flat, and, at another, a nearly spherical, surface to the tibia; and had these intervals been occupied, like similar spaces in other joints, merely by processes of the synovial membrane, such processes would have been very liable to injurious squeezing between the articular surfaces, during the free, rapid, and varied movements of the joint. The tough structure and the shape of the semilunar cartilages admirably adapt them to serve this purpose; for, closing in upon the condyles in flexion, and sliding forwards again in extension, they fill up the intervals between them and the tibia, prevent the entrance of other structures, and suffer no injury themselves. Their tough elastic structure also enables them to assist the articular cartilages in interrupting the transmission of the jarring vibrations that must take place between the long bones of the leg and thigh in walking and running. They do this most effectively when they are flattened out between the articular surfaces in the extended position of the joint; and it is then that such jars are most likely to occur. The adjustment of the fibro-cartilages to the varying shape of the articular surface of the femur during flexion is due, partly, to their elastic quality, and, partly, to their connections and the pressure of surrounding parts.

We frequently hear of dislocation of these fibro-cartilages; but I am not aware that the displacement has been proved in any case by dissection, and can scarcely understand how it should take place, their convex edges being connected with the synovial membrane all round. Slight derangements of them, or of some of the structures of the knee-joint, are, however, not unfrequent, as the result of sprains or sudden twists of the joint; they are attended with great lameness, and with inability to flex or extend the limb; and the symptoms may, sometimes, be suddenly relieved by manipulation, such as quickly and forcibly bending or extending the joint, or pressing the leg to one side. Mr Hey[1] first drew attention to these cases. I have seen several instances of the kind, but can form no more distinct idea of the exact nature of the derangement that takes place than that eminent surgeon appears to have done.

Synovial membrane, The *Synovial membrane* of the knee is of great extent; and the cavity which it encloses is more spacious than that of any other joint. It forms a large cul de sac on the fore part of the femur, beneath the quadriceps muscle; it invests the circumference of the lower end of the femur, and is reflected from it upon the tendons of the gastrocnemii behind, and upon the internal lateral ligament and the tendinous expansion of the quadriceps in other parts, and a process covers the fore part of the crucial ligaments; it passes upon the upper and lower surfaces of the semilunar cartilages, and extends a short way round the circumference of the head of the tibia. It bulges out a little above and below the semilunar cartilages (Pl. LII. *D*, *E*, *F*, *I*, *K*, *L*); so that the latter occupy a circular depression in the contour of the joint, which becomes much more manifest when the membrane has been long distended with fluid, or has undergone thickening of its substance. One process of the synovial membrane invests a great part of the circumference of the poplitæus tendon, and extends downwards upon it to a variable distance. This process sometimes reaches and is blended with the fibular joint, and so establishes a communication between it and the knee.

its internal processes, Besides the numerous sheaths and bulging sacs, investing and passing between the various structures that enter into the composition of this complicated joint, the synovial membrane furnishes very large processes, which project into the interior of the joint, and which, being occupied by fat, serve as padding to assist in filling up the spaces between the articular surfaces of the bones. One of these forms a fold round the patella, encircling and often overlapping the edge of the bone (Pl. XLVIII.

[1] "On internal derangement of the knee-joint," *Practical Observations in Surgery*, 1803.

fig. 2, *O*). Another large process covers a great lobulated mass of fat (*N*), which lies below the patella, beneath, and on either side of, the ligamentum patellæ; it is, in the middle, prolonged into a narrow strip which reaches the fore part of the intercondyloid space of the femur, and is attached there; on either side it is spread out into an angular fold which occupies the interval between the articular surfaces of the tibia and femur. This median process and the lateral folds are called the *Alar ligaments.* A narrow fibrous crescentic band (*M*) running beneath the alar ligaments, from the fore part of one semilunar cartilage to the other, is called the *Transverse ligament;* it serves to keep the semilunar cartilages and the fatty and synovial processes in their places.

Alar and transverse ligaments.

The numerous folds of the synovial membrane, giving rise to so great an extent of surface, the variety and range of movements of the joint, the size of the articular surfaces, and the exposed position of the knee render diseases here very common and very intractable, more so than in any other joint. When the synovial membrane becomes thickened, which is so often the case, its outline may be clearly distinguished in the front of the knee; and the depressions occupied by the semilunar cartilages may often be traced.

SUMMARY.

It will have been remarked that, in the knee, each ligament fulfils two or more purposes, and that some of the movements are limited by two or more ligaments. The joint is never entirely dependent upon atmospheric pressure for the apposition of its articular surfaces, inasmuch as one or more of the ligaments is tight in every position; hence each movement (the knee not being a true hinge-joint) has a tendency to relax certain ligamentous fibres while it gives tension to others; and it is by the peculiar combination of movements that take place, and the peculiar adaptation of the articular surfaces and the ligaments to one another and to these movements, that the requisite tension of some fibres, and the relaxation of others, is effected, and effected in such a manner that, in certain positions, the greater number of the ligaments are tense, to give more resisting power to the joint, and, in others, the greater number are relaxed, to permit more movement.

All the ligaments rendered tense in extended position.

In the nearly straight position of the joint—the position in which it usually is when the limb is placed upon the ground in walking—the lateral ligaments and the anterior crucial ligaments are tense, holding the articular surfaces closely together and preventing any pronation or supination. In the further straightening of the joint, which takes place as the trunk is brought perpendicularly over the limb, these ligaments are still maintained in a uniform state of tension by the combination of the four movements (the revolution of the tibia upon the femur, the turning of the tibia upon a transverse axis, the rotation of the tibia upon a vertical axis, and the sliding of the tibia forwards upon the femur) which take place, and which affect each of the four ligaments in a somewhat different way. Thus; the continuance of the revolving of the tibia upon the femur tends to increase the tension of all four; the turning of the tibia upon a transverse axis tends to increase the tension of the lateral ligaments but to relax the crucial; the sliding forwards of the tibia tends to relax the lateral and to tighten the crucial; and the rotation of the tibia upon a vertical axis has little or no effect upon the internal lateral, but tends to tighten the external lateral ligament, and to relax the anterior crucial. The movements are, however, so combined, that the tension of all four is preserved; and as, owing to the shape of the condyles, a continuance of extension beyond the straight line would be attended with an increased tension of them all, without any compensating relaxation of any, it is checked by their united force, aided by the posterior ligament. Thus the extension of the knee beyond the straight line is more or less resisted by all the ligaments of the joint[1].

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[1] In a case of dislocation of the tibia forwards upon the femur which I dissected, the crucial ligaments were torn through, the anterior near its connection with the tibia, the posterior near its connection with the femur; the external lateral ligament, the tendon of the biceps, and the head of the fibula, were separated together from the shaft of the bone; the internal lateral ligament remained entire; the semilunar cartilages retained their connection with the head of the tibia; the posterior ligament was much torn. The accident was caused by a heavy weight falling upon the limb. In

and bear the weight of the body, relieving the muscles.

This provision is important, inasmuch as in the completely extended position of the knee (owing to the inclination forwards of the neck and head of the femur and of the lower part of the tibia) the line of gravity falls, from the middle of the hip, to the middle of the ankle, in a plane a little in front of the point of bearing of the femur upon the tibia. The tendency of the weight of the body in this position, therefore, necessarily is to increase the extension of the knee; but, being resisted by all these ligaments, the practical effect is to keep the joint straight, without the aid of any muscular exertion. Hence we find this to be a position of ease; in the "stand at ease" posture of drill, the knee of the limb upon which the soldier rests is in its most extended condition, the weight is borne entirely by the bones and ligaments, and the muscles are allowed to be at rest. If now, during this inactive condition of the muscles, a sudden and unexpected, though slight, pressure be made in the ham, the joint easily yields and becomes a little bent; and, the line of gravity now falling behind the point of bearing of the tibia upon the femur, the man will drop, unless the muscles come quickly to the rescue —a fact which has not escaped the observation of school-boys.

Flexion, pronation, and supination; how limited.

Flexion of the knee is limited by the bulk of soft parts situated behind the joint. When these have been removed it is limited by the crucial ligaments. Pronation and supination are prevented, in the extended position, by the shape of the articular surfaces, and by the close manner in which they are held together by the several ligaments. When the knee is bent, pronation is limited by the anterior crucial ligament, and supination is limited by the long fibres of the posterior crucial ligament. In the latter movement the crucial ligaments are untwisted or separated from one another: in the former they are twisted more closely together; but it does not appear that the mutual pressure of the ligaments, caused by this twisting, has so much influence in limiting pronation as the cause I have assigned, viz. the tension of the fibres of the anterior crucial ligament.

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a similar case quoted in *Cycl. Anat.* from *Lond. Med. Gaz.* May 14, 1836, the lateral ligaments on both sides were perfect; the other ligaments were torn.

PERONEO-TIBIAL JOINTS.

The mode of connection of the fibula with the tibia is such as to permit very little movement between the bones. There is a regular synovial joint above; but, below, they are united only by ligaments; and in the interval between their upper and lower ends there is the *Interosseous membrane*, the fibres of which take, for the most part, an oblique direction, downwards and outwards, from the tibia to the fibula.

Upper peroneo-tibial joint.

The upper end of the fibula is placed beneath the overhanging hinder edge of the outer condyle of the tibia, so as to afford some support to the latter; and the joint between the two is constructed with the same view. The articular surface of the fibula, placed upon the upper and inner aspect of the head of the bone, is oblong, with the greatest diameter from above downwards and inwards, is slightly concave in the same direction, and looks upwards and inwards. That of the tibia, placed upon the hinder and under aspect of the condyle, looks downwards and outwards, is slightly convex from above downwards, and is of oval shape, but the longest diameter is from before backwards. It is larger than that of the fibula, exceeding it in the antero-posterior diameter and equalling it in the vertical, or oblique, diameter. Hence the head of the fibula may be made to slide a little backwards and forwards upon the tibia, but cannot be moved in any other direction. There is an *Anterior* (Pl. LIII. fig. 1, *N*, *O*,) and a *Posterior ligament* (Pl. LI. fig. 2, *G*) which pass obliquely over the joint, but the chief bonds of union are the fibres of the biceps tendon (fig. 1, *F*), which are spread over nearly all the fore part of the joint.

Occasionally communicates with knee-joint.

The synovial cavity of the tibio-fibular articulation is sometimes found to communicate with that of the knee-joint, through the medium of the sheath of the poplitæus tendon. The occasional occurrence of such a communication is an objection to the practice, which has been adopted by Larrey and others, of removing the head of the fibula in amputation just below the knee. The joint not unfrequently participates in diseases affecting the knee.

Lower peroneo-tibial joint.

The lower end of the tibia is, on its outer side, hollowed to receive the convex inner side of the fibula (Pl. XL. fig. 7); and the bones are held firmly and closely together by three ligaments—an *Anterior peroneo-tibial* (Pl. LV. fig. 6, *F*), a *Posterior peroneo-tibial* (Pl. LIV. fig. 2, *I*, LVI. fig. 2, *G*), and an *Inferior interosseous* (Pl. LIV. fig. 4, *C*)—which all descend obliquely from the tibia to the fibula. They are very strong, and prevent any forward or backward movement of the lower end of the fibula upon the tibia; moreover they combine to hold the fibula up firmly against the outer condyle of the tibia. The *Inferior interosseous ligament* forms a cushion between the two bones, where they are in closest contact; thus answering some of the purposes of cartilage, while, in addition, it forms a firm bond of union. Its fibres are thick and directed, for the most part, from the tibia, downwards and outwards, to the fibula. These ligaments had need be strong, because, owing to the position of the lower end of the fibula and the manner in which the leg is placed upon the foot, they have to bear much stress when the weight of the body is thrown obliquely from one foot upon the other in walking and running; and they are so effective that, although the fibula is often broken above them, and is sometimes broken below them (in fracture of the external malleolus), it is very rarely separated from the tibia; indeed I am not able to refer to a single example of such an accident.

Dislocation very rare.

Dislocation of the upper end, also, of the fibula seldom takes place. I have seen it driven forwards upon the tibia; and it has been dislocated backwards. Sir A. Cooper once saw the dislocation connected with compound fracture of the leg[1].

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[1] *Cooper's Dislocations*, by B. Cooper, 1842, p. 222.

THE ANKLE. (Plates LIV. to LVII.)

The movements of the foot upon the leg are varied; and they are rather difficult to analyse, because they pass easily into one another, because two, or more, are generally combined together, and because they are divided between three distinct joints which are placed near to one another. These are; *first*, the joint between the tibia fibula and astragalus, in which there is one synovial cavity; *secondly*, the joint between the astragalus and the os calcis, which is a double joint having two separate synovial cavities; and *thirdly*, the joint between the first and second rows of tarsal bones, between, that is to say, the astragalus and os calcis behind, and the scaphoid and cuboid in front. The latter is also a double joint, the synovial cavity between the os calcis and the cuboid bone being quite distinct from that between the astragalus and the scaphoid.

The joint between the leg and the astragalus permits flexion and extension only.

The most obvious movement is that of flexion and extension, which is effected at the joint between the tibia and fibula and the astragalus. It takes place, in a perpendicular plane, upon an axis which passes, from left to right, through the lower part of the astragalus, and which is the centre of the circle of which the upper articular surface of the astragalus forms a segment. It will be observed that the shaft of the tibia is twisted, so that when the bone is laid upon a table, on its hinder surface, it rests on the posterior edges of *both* its condyles, but upon the *hinder* and *outer edge* only of its lower articular end; the inner malleolus being quite turned away from the table. This twist in the tibia gives an outward slant to the foot, from the heel, causing the great toe to incline away from that of the opposite side, when the heels are placed in contact. A line drawn from the point of the heel, through the middle, or longest, toe, coincides with the plane in which the foot moves in flexion and extension upon the leg. The direction of this movement is, therefore, oblique with regard to that of the knee-joint, and to that of the plane in which the leg-bones descend from the knee. The degrees of flexion and extension are nearly equal; the two together amounting to about 80°. The joint does not admit of any other movement than flexion and extension upon the one axis just mentioned; it is therefore a simple hinge-joint.

Shape of the articular surfaces.

The *Shape* of the *Articular surfaces* corresponds with this movement. The upper surface of the astragalus is convex from before backwards, so as to permit the slightly concave surface of the tibia to revolve backwards and forwards upon it. Transversely, it presents a wide shallow groove—a sort of *trochlea*—adapted to a broad superficial ridge on the tibia. This increases the surface of contact between the bones, by giving a wavy outline to it, and, therefore, contributes to the steadiness and security of the joint and resists the liability to lateral displacement. From the groove the surface mounts on either side to a prominent ridge; that on the inner side is received into the retiring angle formed by the inner malleolus with the rest of the tibia; and that on the outer side, which is the higher and sharper of the two, is received into the retiring angle between the tibia and the fibula. The manner in which these projecting ridges are embraced by the corresponding surfaces of the tibia and fibula is such as quite to prevent any rotatory or lateral motion in the joint.

Differences between outer and inner facets of astragalus.

The *inner side* of the articular surface, which corresponds to the internal malleolus, increases in depth towards its fore part, so as to present the greatest area for contact with the tibia in the *flexed* position of the joint; it is also sloped from above, inwards and downwards (Pl. LIV. fig. 3), so as to receive a share of the weight of the body transmitted to it through the inner malleolus. The facet on the *outer side* of the astragalus is of different shape. It is somewhat triangular, corresponding with the facet on the inner side of the fibula; the apex is directed downwards; it is slightly convex from before backwards, and a superficial ridge, ascending from the apex, divides it into two unequal portions, of which the hinder is the larger, so that this facet presents the greatest area for contact with the fibula in the *extended* position of the joint. It is, moreover, situated in a plane posterior to the internal facet; and is continuous with the upper articular surface nearly as far as the posterior border of that surface. Whereas, between the anterior border of the facet and the anterior edge of the upper articular surface is an interval covered by fibrous tissue and synovial membrane (Pl. LIV. fig. 2, *F*).

Reason of these differences.

These differences between the articular facets on the two sides of the astragalus have relation to the fact that, in walking, when we plant the limb on the ground the ankle is in the extended position; and the weight of the body is received by the foot in a direction downwards, *forwards*, and *inwards*, in consequence of the twist in the tibia just mentioned, and also in consequence of the inclination of the leg-bones inwards in their lower third. The lower end of the fibula is, accordingly, placed behind the plane of the inner malleolus; and the articular surface of the astragalus is extended far back on its outer side, for the purpose of receiving and transmitting the weight when the foot comes in contact with the ground. On the contrary, when the foot is about to be withdrawn from the ground, and when the trunk is being thrown diagonally, forwards and inwards, upon the other limb, the ankle is in the flexed position; and the weight is then received by the foot in a direction downwards, *backwards*, and *outwards*. The inner malleolus is, accordingly, situated near the fore part of the joint; and the internal articular surface of the astragalus advances further forwards than the outer one, for the purpose of receiving and transmitting the weight in the last stage of the step.

The outer one descends lower than the inner.

A further difference between these two facets is caused by the outer one descending to a considerably lower level than the inner; indeed it descends so low that its apex, or lowest part, and, with it, the lowest part of the articular facet of the fibula, is traversed by the axial line upon which the leg revolves, in flexion and extension, upon the foot. The inner malleolus, on the other hand, does not descend so low as the axial line, and does not, therefore, revolve upon a line drawn through any part of itself, but is carried forwards, and backwards, in the segment of a circle the centre of which lies beneath it. This makes no real difference in the movement of the two malleoli, but it makes some difference in the disposition of the lateral ligaments.

Articular surface wider in front than behind.

The upper articular surface of the astragalus is one-fourth wider in front than behind; the cavity between the tibia and fibula, into which it is received, is shaped in a corresponding manner; and the articular facets, on either side, are, consequently, sloped a little outwards from behind, which is most marked in the hinder part of the outer facet[1]. This conformation is to prevent the leg being driven forwards upon the tarsus when we alight upon the ground in running, jumping, or walking; and, for the same purpose, the posterior edge of the articular surface of the tibia descends a little lower than the anterior.

In spite of these provisions dislocation of the tibia forwards does, sometimes, occur. Whereas, the dislocation backwards, which the shape of the bones would rather favour, is a far more rare occurrence; because the weight of the body is scarcely ever brought to bear upon the limb in such a direction and with such force as to induce it.

How socket is adapted to astragalus in different positions of the joint.

It is not enough to say that the socket of the leg-bones is shaped in conformity with this configuration of the articular surface of astragalus. For, if that had been all, and if the fibula had, like the inner malleolus, formed a part of the tibia, so that the socket had been hollowed out of the solid bone and had maintained an unvarying size, it could not have been adapted to the astragalus in the different positions of the limb. It would have been either too large when the joint was extended or too small when it was bent. But the outer malleolus, being a little moveable, permits a slight alternate widening and narrowing of the socket in flexion and extension; so that freedom of movement is combined with the maintenance of an exact co-aptation of the articular surfaces. This yielding of the outer malleolus in a lateral direction, under the pressure of the articular surface of the astragalus during flexion, and its recoil in extension, depend, not so much upon a yielding of the ligaments that bind it to the tibia, as upon the elasticity of the bone itself. Hence a careful examination will shew that, during

[1] The section in fig. 2, Pl. LIV. is not quite low enough to shew these points.

flexion, when the malleolus is pressed outwards, the shaft of the fibula is, at its narrowest part, just above the ankle, bent a little inwards; and *vice versâ*, when the joint is extended, the shaft recoils to its former distance from the tibia.

The experience which we have of the effect of severe injuries is in accordance with this observation; for we know that if the outer malleolus be driven outwards with unwonted force, as in cases of dislocation of the leg forwards, or of subluxation of the ankle, the peroneo-tibial ligaments remain entire, but the fibula is commonly broken in the lower part of its shaft.

DESCRIPTION OF PLATE LIV.

Fig. 1. Vertical section, made obliquely from within, outwards and forwards, through hinder joint between (*A*) astragalus and (*B*) os calcis, to shew the shape of the articular surfaces. It is viewed from before. *C*, point of heel. *D*, ligament uniting the bones on the inner side. *E*, ditto, on outer side. The ascending outer part of the opposed surfaces is not covered with cartilage, but with fibrous tissue.

Fig. 2. Horizontal section of ankle-joint, with leg in upright position. *A*, inner malleolus. *B*, outer malleolus. *C*, cut surface of astragalus. *D*, hinder edge of cartilaginous surface of astragalus, extending further back on the outer side than it does on the inner. *E*, fore part of cartilaginous surface of the same, extending on the inner side, below the level of the section, further forwards than it does on the outer side. *F*, process of synovial membrane and fibrous tissue running up the astragalus, in the interval between the outer articular facet and the anterior cartilaginous surface. *G, G, G, G*, synovial membrane, turned downwards and forwards. *H*, roll of fat, beneath the synovial membrane, lying upon neck of astragalus. *I*, posterior peroneotibial ligament.

Fig. 3. Vertical section, from side to side, through middle of ankle, and through joint between astragalus and os calcis. *A*, inner malleolus. *B*, outer malleolus. *C*, astragalus. *D*, os calcis. *E*, deltoid ligament. *F*, external lateral ligament. *G*, ligamentous fibres passing from outer side of astragalus to external lateral ligament and outer malleolus. *H*, inner part of interosseous ligament between astragalus and os calcis. *I*, articular surfaces of hinder joint between astragalus and os calcis; *K*, ditto of anterior joint between the same.

Fig. 4. Vertical section, from side to side, through lower ends of tibia (*A*) and fibula (*B*) seen from the front. *C*, inferior interosseous ligament. *D*, fatty process which fills up interval between cartilaginous surfaces of tibia and fibula.

Fig. 5. Transverse section through (*A*) internal, (*B*) middle, (*C*) external cuneiform, and (*D*) cuboid bones, with (*E*) metatarsal bone of little toe resting upon the cuboid. *F*, transverse ligaments between the cuneiform; *G*, ditto between the external cuneiform and cuboid. *H*, superior ligaments between cuneiform bones and between external cuneiform and cuboid.

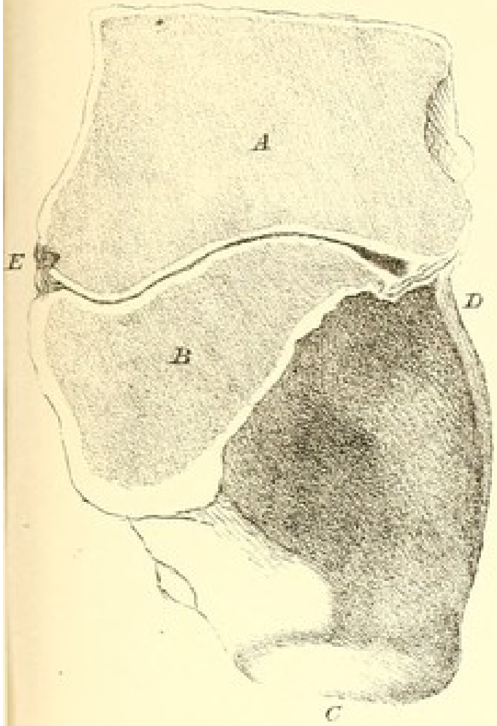
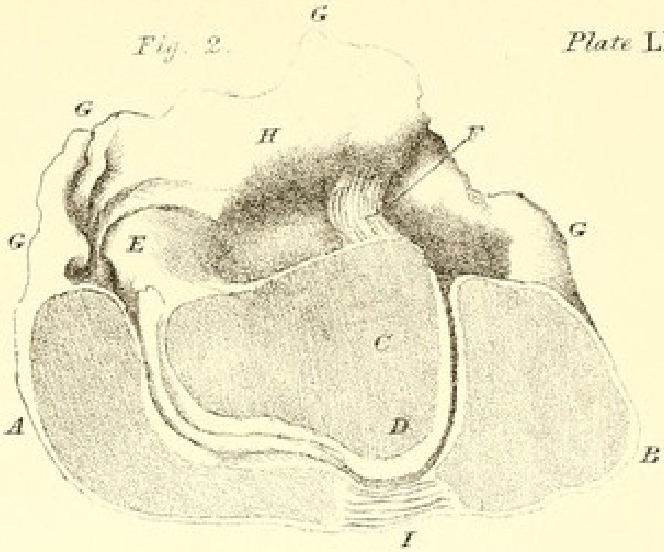


Fig. 1.



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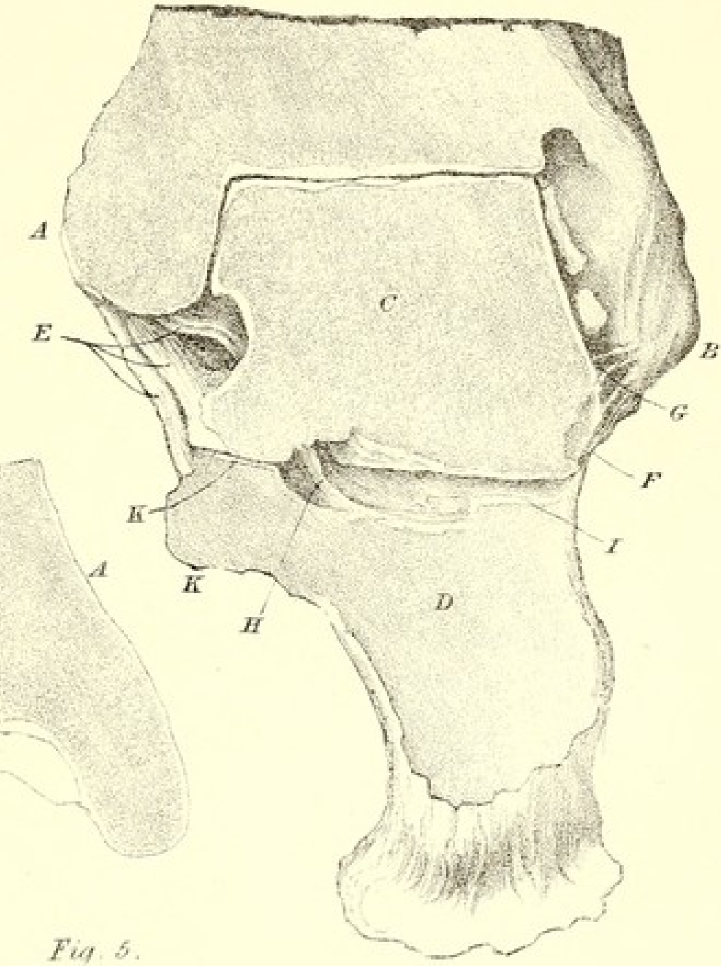

Fig. 3.

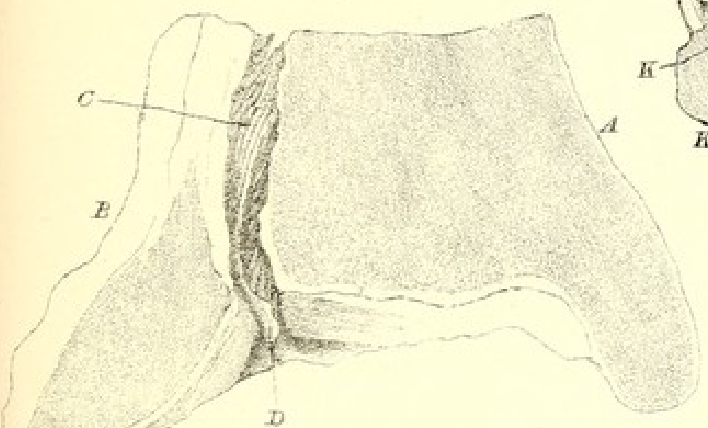

Fig. 4.

Fig. 5.

External lateral ligament.

The ligaments of the ankle-joint pass from the malleoli. Those from the outer malleolus are three in number. First; the *External lateral ligament* (Pl. LV. fig. 6, *E*) is attached to a smooth space on the fibula, just outside the apex of its articular facet, between the latter and the tip of the bone. It runs, backwards and downwards, to a superficial depression, between two rough eminences that are seen on the exterior of the os calcis, a little behind the joint with the astragalus. Being connected with the fibula in the line of the axis of motion of the joint this ligament is tense in every position of the bones; and the direction of its fibres is such as to prevent the fibula from being driven forwards upon the tarsus.

Posterior peroneo-tarsal ligament.

Secondly; the *Posterior peroneo-tarsal ligament* (Pl. LVI. fig. 2, *F*) is attached to a deep pit behind the apex of the articular facet of the fibula, and runs, almost horizontally inwards, with a slight inclination backwards. Its lower fibres, constituting the strongest part of the ligament, descend a little to the ridge which forms the outer edge of the groove in the astragalus for the *flexor longus pollicis.* Its middle fibres pass to the upper part and outer edge of this groove; and its uppermost fibres pass, behind the ankle-joint, to the lower margin of the tibia and the hinder edge of the inner malleolus. It aids the external lateral ligament in preventing displacement of the fibula forwards; and the two are so strong that in dislocation of the ankle they sometimes hold the malleolus in its place, and cause the bone to be snapped above the line of their attachment. The posterior peroneo-tarsal ligament can scarcely be said to be relaxed in any position of the ankle; but it is most distinctly tense when the joint is bent. It helps, therefore, to limit flexion of the ankle. It binds the lower end of the fibula to the tibia; and its uppermost fibres, deepening the hinder part of the socket for the astragalus, render the position of that bone more secure.

Anterior peroneo-tarsal ligament.

Thirdly, the *Anterior peroneo-tarsal ligament* (Pl. LV. fig. 6, *G*), a flatter and broader ligament than either of the other two, is attached along the lower part of the ridge that stands out in front of the articular surface of the fibula, and passes obliquely forwards, inwards, and a little downwards, to the astragalus, to be inserted in front of the facet upon which the fibula plays. It tends to prevent displacement of the outer malleolus backwards or outwards. It also limits extension of the ankle-joint. Being a little relaxed in flexion it permits that slight yielding of the fore part of the malleolus which takes place when the latter advances upon the anterior broader part of the astragalus.

The deltoid ligament. On the inner side of the joint there is only one ligament, the *Deltoid.* This, however, in extent, disposition and strength corresponds with and equals, or more than equals, the three ligaments connected with the outer malleolus. It is attached along the whole of the lower edge of the internal malleolus; the greater number of its fibres pass from the depression or notch in the under part of that edge, and some from the anterior and poste-

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DESCRIPTION OF PLATE LV.

Fig. 1. Oblique section, from above, downwards and inwards, (that is, in the plane of movement) through joint between astragalus (*A*) and scaphoid bone (*B*). *C*, calcaneo-scaphoid ligament.

Fig. 2. Section, in same direction, through joint between os calcis (*C*) and cuboid (*D*). *F*, calcaneo-cuboid ligament.

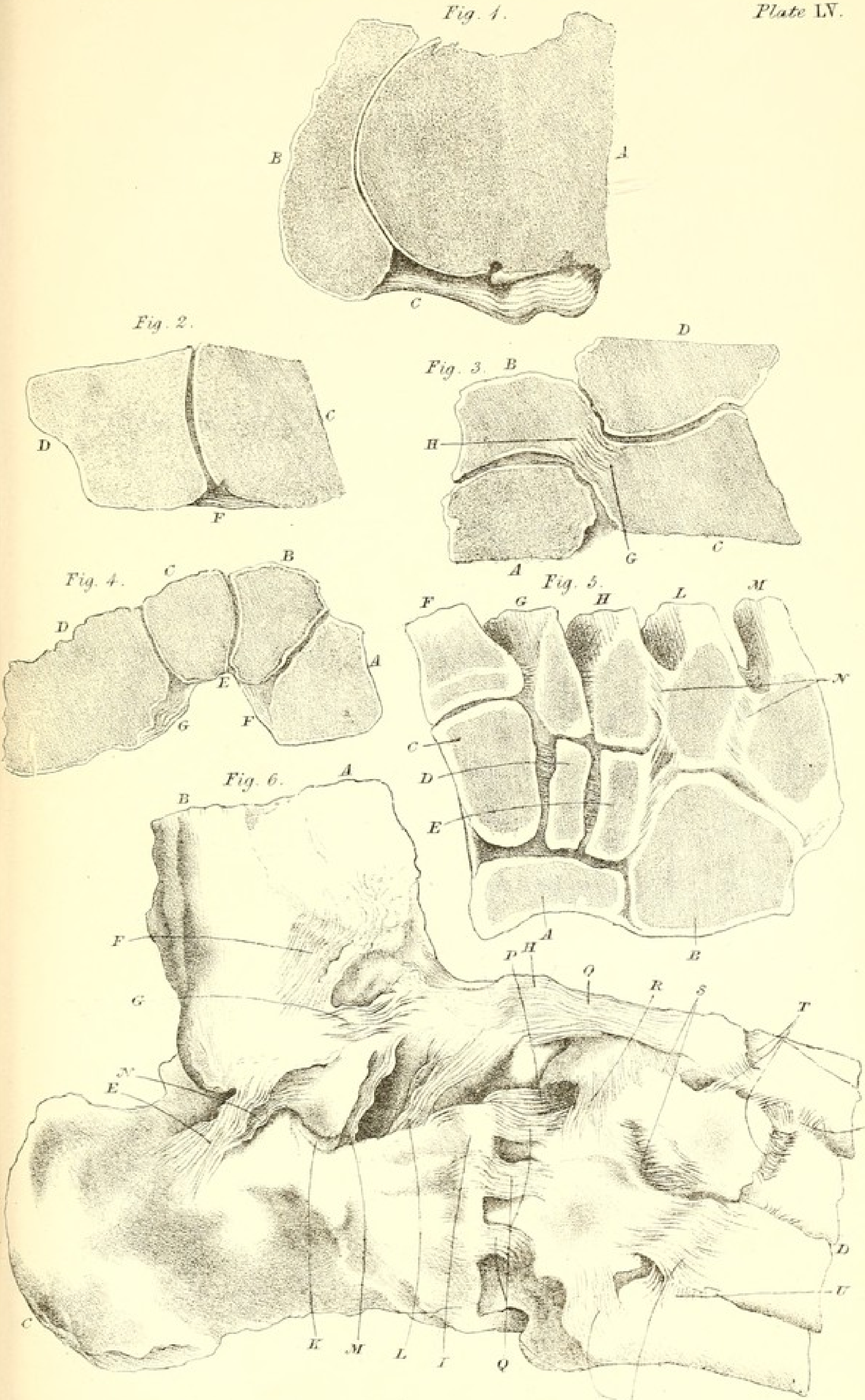
Fig. 3. Horizontal section through the joints between (*A*) astragalus and (*B*) scaphoid, and between (*C*) os calcis and (*D*) cuboid. *G*, process of os calcis projecting between the two joints and giving attachment to (*H*) external calcaneo-scaphoid ligament.

Fig. 4. Transverse section through joints between (*A*) internal, (*B*) middle, and (*C*) external cuneiform, and (*D*) cuboid bones. *E*, hollow space beneath middle and external cuneiform bones, which contains fat. *F*, ligament between internal and middle cuneiform. *G*, ditto between external cuneiform and cuboid.

Fig. 5. Horizontal section through the joints between (*A*) scaphoid, (*B*) cuboid, (*C, D, E*) cuneiform bones and (*F, G, H, L, M*) metatarsal bones. *N*, transverse ligaments between outer three metatarsal bones.

Fig. 6. View of ligaments on outer side of ankle and foot. *A*, tibia. *B*, fibula. *C*, os calcis. *D*, cut ends of metatarsal bones. *E*, external lateral ligament. *F*, anterior peroneo-tibial ligament. *G*, anterior peroneo-tarsal ligament. *H*, head of astragalus. *I*, fore part of os calcis. *K*, outer part of hinder joint between astragalus and os calcis. *L*, anterior interosseous ligament between astragalus and os calcis. *M*, posterior ditto. *N*, external lateral ligament between astragalus and os calcis. *O*, superior ligament between astragalus and scaphoid and between latter and internal cuneiform. *P*, external calcaneo-scaphoid ligament. *Q*, superior calcaneo-cuboid ligament. *R*, superior ligaments between scaphoid and cuneiform and cuboid. *S*, superior ligaments between scaphoid and external cuneiform and between latter and cuboid. *T*, dorsal tarso-metatarsal ligaments. *U, U*, dorsal transverse metatarsal ligaments.

Plate LV.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rior border of the process. They radiate as they descend, so as to cover the whole of the inner side of the ankle-joint; the foremost (Pl. LVI. fig. 2, *O*) run over the neck and head of the astragalus, and are inserted into the hinder and inner border of the scaphoid; the middle fibres (O^1) are attached to the depression beneath the inner articular facet of the astragalus, to the prominence which separates that depression from the groove on the under surface of the astragalus, and to the adjacent projecting inner process of the os calcis; the hindmost fibres (O^2) are attached along the inner side of the hinder part of the astragalus. The middle and thickest part of the ligament is tense, or nearly tense, in every position of the joint, and is a very important agent in supporting the ankle under the weight of the body and in preventing dislocation of the foot inwards. The foremost and hindmost fibres, respectively, limit extension and flexion of the ankle. The anterior and middle fibres, being attached to the os calcis as well as to the scaphoid, serve to limit abduction of the foot.

Synovial membrane and fatty mass in front of joint.

There are no true anterior and posterior ligaments. There is a thick roll of fat (Pl. LIV. fig. 2, *H*) upon the fore part of the joint, which causes the synovial membrane to project into, and to fill up, the retiring angle between the margin of the tibia and the astragalus, and which also gives a thickness and rounded contour to the synovial fold, and prevents its being caught between the articular edges of the bones in flexion of the joint. A prolongation of this fatty mass occupies the depression upon the neck of the astragalus (Pl. XLI. *A*), and forms a soft cushion to receive the anterior edge of the tibia in forced flexion of the ankle.

JOINT BETWEEN ASTRAGALUS AND OS CALCIS.

The other joints which are concerned in the movements of the foot upon the leg; viz. the two between the astragalus and the os calcis, and the two between the first and second row of tarsal bones, are so closely connected, and so intimately associated in their movements, that they might be described together as one

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joint composed of four separate articulations; but it will somewhat simplify the description to consider,

The joints between the astragalus and os calcis permit adduction and abduction with some rotation,

First, the joints between the astragalus and the os calcis. Between these two bones adduction and abduction of the foot upon the leg are chiefly effected. The movements take place upon an axis drawn, from behind forwards, through the astragalus, at right angles to the axis of motion in the ankle-joint; they do not, however, occur alone, but are always accompanied by rotation of the os calcis, and of the remainder of the foot, in a horizontal plane, upon an axis descending vertically through the middle of the astragalus. The movements of the foot upon the astragalus may, therefore, be described as a combination of adduction or abduction with rotation; and they take place in such a manner that *adduction*, or inclination of the sole inwards, is attended with a *turning* of the *toes in*wards and of the *heel out*wards; and, *vice versa*, *abduction* is accompanied with

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DESCRIPTION OF PLATE LVI.

Fig. 1. Ligaments on plantar surface of toes. *A*, sesamoid bones of great toe, with channel between them for flexor tendon. *B*, ligamentous fibres uniting them to head of metatarsal bone. *C*, ditto uniting them to phalanx. *D*, ligament running forward to (*E*) sesamoid body of phalangeal joint. *F*, ligaments uniting sesamoid body to 1st phalanx. *G*, ditto uniting it to 2nd phalanx. *H*, ridge on terminal phalanx for attachment of flexor tendon. *I*, tubercle at extremity of phalanx. *K*, a bristle passed beneath ligamentous fibres that run from the ridge to the tubercle. *L, L, L, L*, sesamoid bodies beneath four outer metatarso-phalangeal joints, united by cross bands (*M, M, M, M*). *N, N*, sesamoid bodies beneath the phalangeal joints. *O*, cut ends of flexor tendons projecting from their sheaths.

Fig. 2. View of ligaments on inner and under surfaces of ankle and foot. The ankle is in a state of extreme extension. *A*, tibia. *B*, fibula. *C*, heel. *D, D*, cut ends of metatarsal bones. *E*, groove in astragalus for tendon of flexor longus pollicis. *F*, posterior peroneo-tarsal ligament. *G*, posterior peroneo-tibial ligament. *H*, inner edge of astragalus. *I*, inner edge of os calcis overhanging groove for flexor longus pollicis. *K*, scaphoid bone. *L*, internal cuneiform. *M*, external cuneiform (the middle cuneiform is hidden from view). *N, N*, cuboid, with groove for tendon of peroneus longus between the two letters. O, O^1, O^2, anterior, middle, and posterior portions of deltoid ligament. P, inferior calcaneo-scaphoid ligament; P^1, smooth surface of the same upon which tendon of tibialis posticus plays. *Q*, inferior calcaneo-cuboid ligament. *R*, inferior scapho-cuboid ligament. *S*, plantar ligaments between cuneiform bones, and between cuneiform and cuboid bones. *T, T*, plantar tarso-metatarsal ligaments. *U, U, U, U*, plantar transverse metatarsal ligaments.

Fig. 1.

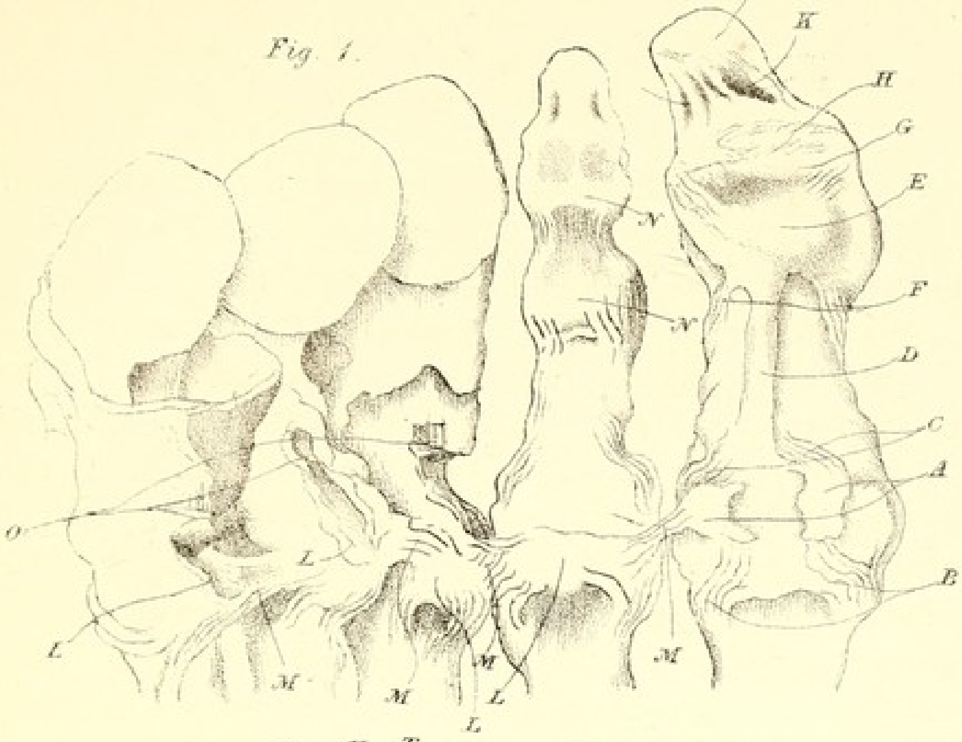
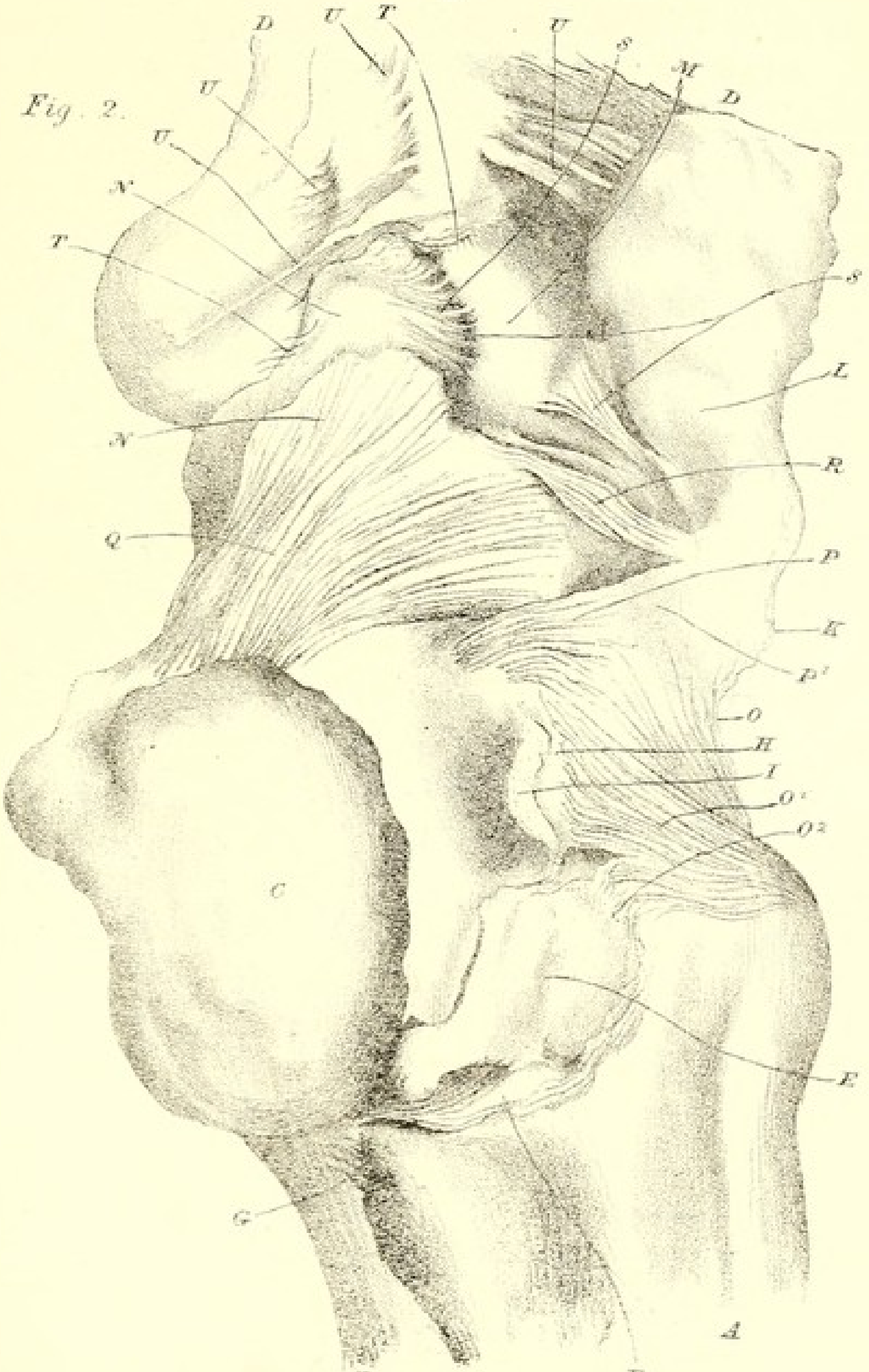


Fig. 2.



a *turning* of the *toes out*wards and of the *heel in*wards. The effect of the rotation is much more evident upon the toes than upon the heel, in consequence of their greater distance from the centre of motion. In these movements the other bones of the foot are carried with the os calcis, the scaphoid revolving upon the round anterior end of the astragalus.

Very little abduction possibly.

Although we speak of *adduction* and *abduction* of the foot, it is not strictly correct to do so; because, when the foot is planted upon the ground, in the position in which it has to bear the weight of the body, *abduction* (or inclination of the leg outwards, which is equivalent to abduction of the foot) is scarcely possible, being prevented by the tension of the deltoid and of the several ligaments which lie between the astragalus and the os calcis. If the ligaments were loose in that position, so as to permit abduction of the foot, the astragalus and the inner ankle would be dependent entirely upon the support of the surrounding tendons, and would be liable to be driven inwards by the heavy weight to which they are subjected[1]. Owing, however, to the tension of the ligaments, and to the strength of the tendons which pass beneath the inner ankle, the astragalus is so securely held upon the os calcis, that displacement at this joint, or even a strain, rarely occurs when the weight of the leg is received in the usual direction.

Displacement of the astragalus.

If, however, by accident, the foot be in a state of adduction, with the outer edge upon the ground, when the weight falls suddenly upon it; or if the weight of the body be received by the foot in an oblique line, from within *out*wards, so that the foot is thrown into a state of adduction, then, in consequence of the ligaments being partially relaxed, a displacement of the astragalus may take place, or a strain is very likely to occur. In some persons these ligaments are weak and permit abduction to take place; and then the weight of the body is likely to increase the abduction, and to drive

[1] It must always be borne in mind in considering the anatomy of this, and of the other adjacent joints, that the weight of the body is transmitted to the foot in an oblique direction, from above, downwards, and *in*wards.

the inner malleolus and the head of the astragalus inwards; thus depressing the arch of the instep and causing "flat foot." If to this condition be superadded, as is often the case, a tension of the peronei muscles, which prevents the return of the foot to the proper position, the permanent deformity called "talipes valgus," is induced.

Flat foot.

Valgus.

Shape of the articular surfaces.

The *Articular surfaces* of the two joints between the astragalus and the os calcis differ from one another in shape. Those of the hinder joint are broad and oval, with the longest diameter, from within, forwards and outwards. The facet of the os calcis is, from side to side, flat, or a little concave, near the middle. From before backwards it is convex. The degree of its curvature differs, however, in different parts, so that it is not a portion of one circle; and its greatest prominence and its sharpest curve are towards the inner side, where it approaches nearest to the anterior facet. Towards the outer side the curvature is less; indeed the anterior and posterior parts of the facet, which are prolonged further on the outer than on the inner side, are nearly flat. The apposed facet of the astragalus is shaped in a corresponding manner; and the width and disposition of the two surfaces render the joint well suited for the transmission of weight, from the astragalus, to the heel-bone.

DESCRIPTION OF PLATE LVII.

Fig. 1. Vertical section, from before backwards, through distal part of great toe. *A*, skin. *B*, ligamentous fibres radiating from bulbous extremity of phalanx (*C*) through soft cushion of fat to skin. *D*, fibres passing from upper surface of phalanx to nail. *E*, flexor tendon. *F*, sesamoid bone.

Fig. 2. Vertical section, from before backwards, through extremity of heel, from a lad æt. 10, to shew the thick stratum of cartilage (*B*) under the bone (*A*). *C*, tendo achillis. *D*, Plantar fascia.

Fig. 3. Vertical section, from behind forwards, through tibia, inner side of tarsus, and great toe. *A*, skin of heel. *B*, ligamentous fibres passing obliquely backwards, from extremity of os calcis, through cushion of fat, to skin. *C*, tendo achillis. *D*, plantar fascia. *E*, capsule in front of ankle. *F*, ditto behind, and posterior peroneo-tarsal ligament. *G*, anterior and posterior interosseous ligament between astragalus and os calcis. *H*, depression in upper part of neck of astragalus occupied by fat. *I*, scaphoid bone. *K*, middle cuneiform. *L*, internal cuneiform. *M*, metatarsal bone of great toe. *N*, sesamoid bone. *O*, first phalanx. *P*, second phalanx.

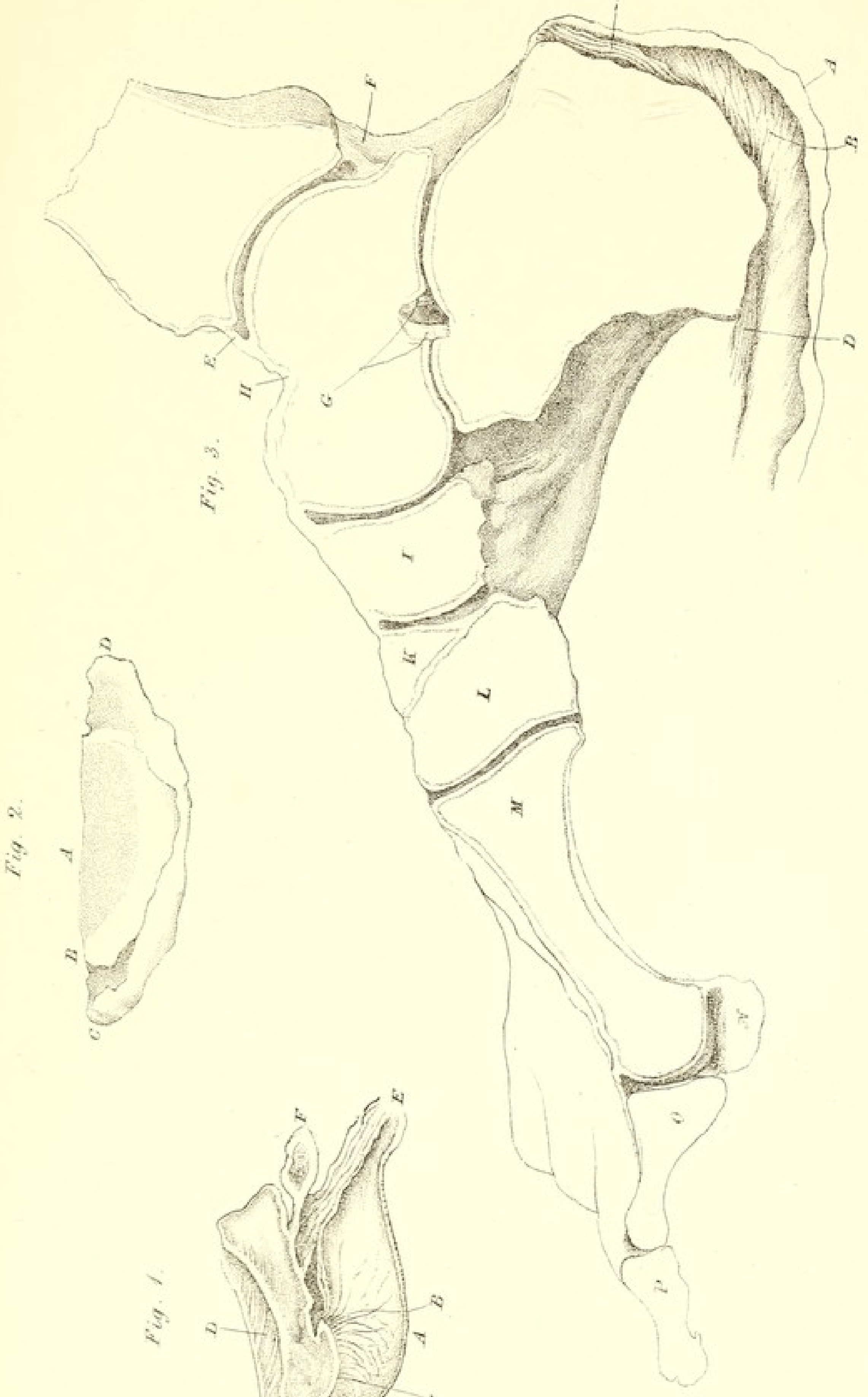


Fig. 1.
A
B
C
D
E
F
Fig. 2.
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Fig. 3.
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The other articulating surface on the os calcis for the astragalus is narrow, elongated from behind forwards and outwards, and concave in the same direction. Sometimes it presents two flat, or slightly undulating, facets, which are united at an obtuse retiring angle; the inner of these facets constitutes two-thirds, and the outer one-third, of the surface.

Four facets on head of astragalus.

The anterior portion—or "head"—of the astragalus presents four facets separated from one another by slight ridges; and both the facets and the intervening ridges are entirely covered by cartilage. The uppermost, which is also the foremost and largest of the facets, is convex, and is received into the cup on the hinder aspect of the scaphoid bone; it is part of a true sphere. The two facets on the under surface are flat or a little concave; they, together with the ridge which intervenes between them, are adapted to the articulating surface of the os calcis just described. The larger of the two is separated from the convex facet for the scaphoid bone by a fourth facet, which rests upon the inner part of the calcaneo-scaphoid ligament.

If the astragalus and os calcis be placed together, it will be perceived that the articulating surfaces of the two connecting joints are so constructed as not to permit either direct adduction, or true rotation in a horizontal plane; they permit only an oblique movement, compounded of adduction and rotation, which I have described to be the movement that takes place between the two bones. Adduction cannot take place without rotation of the toes inwards; abduction cannot take place without rotation of the toes outwards; neither can rotation take place without some amount of adduction or abduction.

The ligaments.

The ligaments are disposed in accordance with these movements, and with the especial object of preventing abduction of the foot when the sole is placed upon the ground.

Interosseous.

The *Interosseous* is the most powerful, forming a very strong bond of union between the bones. It occupies the interosseous groove or channel; and its fibres, being disposed in two planes, may be regarded as forming two ligaments—an anterior and a posterior. The *Anterior interosseous ligament* (Pl. LV. fig. 6, *L*) is situated chiefly in the outer, and wider, part of the interosseous groove. It arises from the middle of a rough space on the os calcis, which intervenes between the posterior articulating surface and the anterior extremity of the bone; and it runs *for*wards, upwards, and inwards, to a depression in the outer and under side of the head of the astragalus, just behind the projecting edge of the articular facet for the scaphoid. The *Posterior interosseous ligament* (*M* and Pl. LVIII. fig. 9, *E*) is situated, chiefly, in the inner, and narrower, part of the interosseous space. It arises from the bottom of the groove in the os calcis, and runs *back*wards, upwards and inwards to the hinder side of the groove in the astragalus, in front of the edge of the posterior articular surface. Towards the middle of the interosseous space the fibres of the anterior and posterior ligaments are near together, and take a nearly parallel, and straight, course from one bone to the other (Pl. LVII. fig. 3, *G*); and towards the outer side of the interosseous space, the fibres of the posterior ligament (Pl. LV. fig.

DESCRIPTION OF PLATE LVIII.

Figs. 1 to 5. Vertical sections, from before backwards, through the five tarso-metatarsal joints, showing the different shapes of the articular surfaces. *A*, metatarsal bone. *B*, internal cuneiform. *C*, middle ditto. *D*, external ditto. *E*, inner part of cuboid. *F*, outer part of cuboid. *G*, and *H*, upper and lower ligaments connecting metatarsal with tarsal bones.

Fig. 6. Vertical section, from before backwards, through joint between scaphoid (*S*) and internal cuneiform bone (*C*).

Fig. 7. Ditto, between scaphoid (*S*) and middle cuneiform (*C*).

Fig. 8. Ditto, between scaphoid (*S*) and external cuneiform (*C*).

Fig. 9. Ligaments on inner side of foot. *A*, astragalus. *B*, scaphoid. *C*, internal cuneiform. *D*, metatarsal bone of great toe. *E*, posterior interosseous ligament, *F*, internal lateral ligament, and *G*, posterior ligament between os calcis and astragalus. *H*, fibres of deltoid ligament attached to scaphoid and forepart of os calcis. *I*, edge of os calcis overhanging groove for tibialis posticus. *K*, under surface of head of astragalus appearing between two portions (*L* and *M*) of inferior calcaneo-scaphoid ligament; it is here supported by the tendon of tibialis posticus. *N*, *N*, long inferior calcaneo-cuboid ligament. *O*, internal ligament between scaphoid and internal cuneiform; *P*, ditto between internal cuneiform and metatarsal of great toe. *Q*, portion of internal lateral ligament connecting phalanx with metatarsal bone; Q^1, ditto with sesamoid bone. *R*, ligament connecting sesamoid with metatarsal bone. *S*, portion of internal lateral ligament connecting second phalanx with first; S^1 ditto with sesamoid body. *T*, fibres connecting sesamoid body with first phalanx.

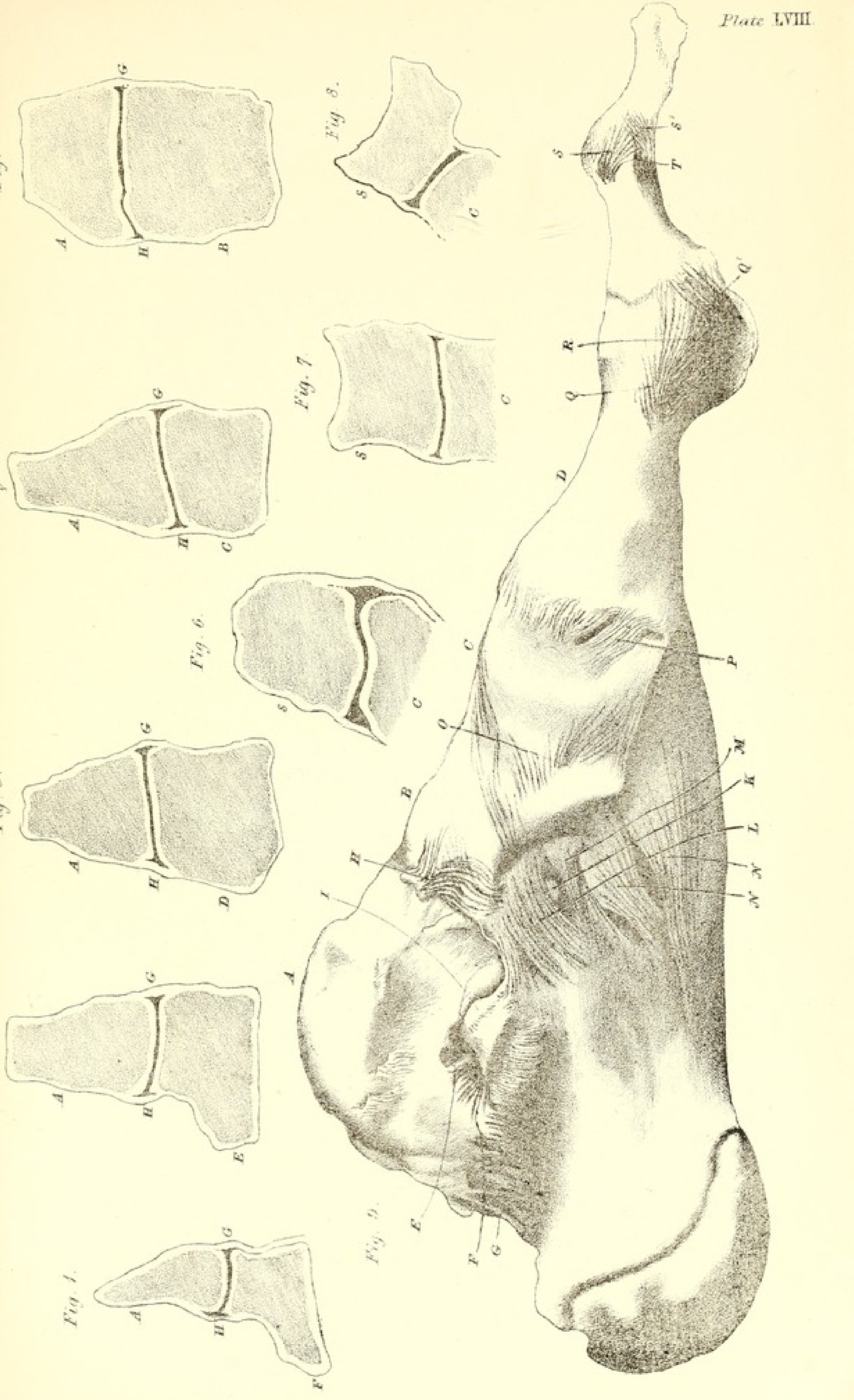
Fig. 1.
Fig. 2.
Fig. 3.
Fig. 4.
Fig. 5.
Fig. 6.
Fig. 7.
Fig. 8.
Fig. 9.

6, *M*) take nearly the same direction as those of the anterior, though they are at some distance behind them. All the fibres of the interosseous ligament are so disposed as to retain their tension in the different positions of the bones; and they all combine to limit abduction of the foot, and the accompanying rotation of the toes outwards.

Lateral.

The *Internal lateral ligament* (Pl. LVIII. fig. 9, *F*) passes, from the hinder edge of the projecting internal process of the os calcis, almost directly backwards, to the adjacent inner edge of the groove in the astragalus for the tendon of the flexor longus pollicis. The *External lateral ligament* (Pl. LV. fig. 6, *N*) arises from the outer side of the os calcis, in company with the external lateral ligament (*E*) of the ankle, and accompanies it to the outer surface of the astragalus, where it is attached just in front of the apex of the articular facet for the fibula. Both these ligaments limit adduction of the foot. The *Posterior ligament* (Pl. LVIII. fig. 9, *G*) is not very strong; it consists of short bundles passing between the adjacent hinder edges of the astragalus and os calcis. Its fibres are nearly vertical, and, therefore, have little influence either upon abduction or adduction of the foot.

Posterior.

The deltoid, and the external lateral ligament of the ankle, both of which pass from the leg-bones, over the astragalus, to the os calcis, contribute to the strength of the joint between the astragalus and the heel-bone.

JOINT BETWEEN FIRST AND SECOND TARSAL ROW.

Joint between first and second row of tarsal bones permits flexion and slight rotation.

The joint between the first and second row of tarsal bones, *i. e.* between the astragalus and os calcis, behind, and the scaphoid and cuboid in front, admits of flexion and extension of the second row upon the first in an oblique plane. The axis of the movement is a line drawn obliquely from within, outwards, backwards, and downwards, through the astragalus and os calcis; and the direction of the movement corresponds with the long diameter of the anterior convex facet of the astragalus. The joint permits also a slight rotatory movement of the fore part of the tarsus, upon an antero-posterior axis drawn through the scaphoid and the head of the astragalus. This is productive of adduction and abduction of the sole: and the two movements—viz. flexion or extension, and rotation—take place together; flexion and adduction of the sole, and extension and abduction of the sole, being, respectively, contemporaneous. They also take place in harmony with the movements in the astragalo-calcaneal and the ankle-joints. Thus flexion and adduction of the sole, and turning of the toes inwards, which are performed in the joints between the astragalus and the os calcis, and between the first and second row of tarsal bones, are associates of extension[1] of the ankle; and extension and abduction of the sole, and turning of the toes outwards, are the associates of flexion of the ankle. The four movements, being divided between the three sets of joints, are allowed to take place in sufficient range, and with great facility, while the foot retains the strength required to enable it to bear the weight of the body.

Although I have spoken of *extension* and *ab*duction of the sole as well as of flexion and adduction, it must be understood that, as in the case of the joint between the astragalus and os calcis (p. 563), the two former of these movements are arrested, at the position in which the foot rests upon the ground, by the tension of the various ligaments that have to sustain the arch of the instep against the pressure of the superincumbent weight.

Shape of the articular surfaces.

The inner of the two joints, viz. that between the astragalus and the scaphoid, is a true ball-and-socket joint, so that the cup of the scaphoid might revolve upon the ball of the astragalus any way; but it moves most freely in the direction in which the articular surfaces are most prolonged, that is, from above, downwards and inwards. Measured in this line the convex facet of the astragalus exceeds the cup of the scaphoid by two or three lines; the latter bone, therefore, may revolve upon the former to that extent. Moreover,

[1] The movement of the ankle, which is attended with elevation of the heel, is, strictly, *flexion;* but it is usually described as *extension.*

the movement between the first and second row of tarsal bones is nearly restricted to the direction in which the scaphoid has freest play upon the astragalus, by the presence, and by the mode of construction of the outer of the two joints, viz. that between the os calcis and the cuboid.

For, the articular surface of the os calcis (Pl. LV. fig. 3, *C*) is concavo-convex from side to side; and this shape necessarily prevents any rotation upon a vertical axis, as well as any lateral motion of the cuboid (*D*), which is accurately adapted to the os calcis. Whereas, from above downwards and inwards, that is to say, in the direction corresponding with the greatest diameter of the head of the scaphoid (fig. 1, *A*), the articular surface of the os calcis (fig. 2, *C*) presents a uniformly convex outline, and permits the concave facet of the cuboid (*D*) to revolve upon it round the oblique axial line which I have described to be the centre of motion of the second row of tarsal bones upon the first. This, with the exception of the slight rotation upon an antero-posterior axis above mentioned, is the only movement that can take place between the os calcis and the cuboid; and, forasmuch as the scaphoid and the cuboid are bound together by ligaments, and by the shape of their apposed surfaces, the movement of the scaphoid upon the astragalus is limited to the same direction.

The ligaments; All the ligaments uniting the first and second row of tarsal bones are connected, behind, with the os calcis; except one (Pl. LV. fig. 6, *O*) upon the joint between the astragalus and the scaphoid, the fibres of which pass, with slight obliquity, forwards and inwards, from the neck of the former bone to the upper surface of the latter, and run on to the internal cuneiform. They are

the inferior calcaneo-scaphoid. 1. The *Inferior calcaneo-scaphoid ligament* (Pl. LV. fig. 1, *C*; Pl. LVI. fig. 2, *P*), which extends, from beneath the margin of the anterior facet on the os calcis for the astragalus, forwards and inwards, to the groove between the projecting inner process, and the posterior articular surface of the scaphoid. It becomes narrower and thicker as it approaches the scaphoid; its hinder edge is in contact with, and indeed is blended with, the deltoid ligament (*O*); its under surface is flat, and presents a smooth facet *P′*, covered by synovial membrane, upon which the tendon of the tibialis posticus plays; its upper surface is also flat, or a little concave, is covered by synovial membrane, and contributes to form the socket which supports the under part of the head of the astragalus. It is sometimes divided into an inner portion (Pl. LVIII. fig. 9, *L*) and an outer (*M*); and the head of the astragalus (*K*) appears between the two, in an interval which is occupied by the tendon of the tibialis posticus. The oblique direction of the fibres prevents their being relaxed in any position of the bones. Even when the sole is bent, and the under surface of the scaphoid is approximated to the os calcis, the slight rotation of the scaphoid, inwards, which accompanies that movement, is sufficient to maintain the tension of the ligament; and the ligament, by limiting the rotation which is a necessary attendant on flexion, limits the flexion also. In the opposite movement, likewise, the relaxation, caused by rotation of the scaphoid outwards, is compensated for by the distancing of that bone from the under surface of the os calcis, which occurs in the accompanying extension; and, by limiting extension of the sole, the ligament limits, also, the outward rotation of the fore part of the foot. But its office is not confined to this limitation of the movements of the sole; for, by binding together the lower edges of the scaphoid and os calcis, and by underlying the head of the astragalus, it supports that bone and maintains the arch of the foot. It is assisted in this important office by the tendon of the *tibialis posticus*, which comes into action just at the time when the heaviest duty is devolving upon the ligament, viz. when the heel is being raised and the weight is being thrown forward, over the instep, upon the other foot.

Yields in "flat foot."

In "flat foot" this ligament is weakened, and a little lengthened; and in consequence of this condition, too much extension and outward rotation of the fore part of the foot is permitted, the head of the astragalus descends below its proper level, and the patient, unable to carry the weight of the body steadily forwards over the metatarsus, directs it over a line to the inner side of the great toe. He thereby shortens the step and contrives to move along in an easier manner, but with an ungainly and unsteady gait.

External calcaneo-scaphoid ligaments.

2. The *External calcaneo-scaphoid ligaments*, sometimes called the *superior* (Pl. LV. fig. 6, *P*) and *inferior* (fig. 3, *H*) *interosseous ligaments*, are also very strong. They are attached to the os calcis, above and below the ridge (fig. 3, *G*) which projects forwards between the anterior articular facet for the astragalus (*A*) and the facet for the cuboid (*D*); and they are connected together by a thin strip of fibres attached along the edge of the ridge. They run obliquely, forwards and inwards, to the scaphoid (*B*); but a few of their fibres are connected with the adjacent edge of the cuboid. They hold the bones very firmly together; and the oblique direction in which they run is, like that of the inferior calcaneo-scaphoid ligament, so arranged, with reference to the obliquity of the movements of the one bone upon the other, that, while they assist to limit each of these movements, their tension is maintained in every position of the joint.

The calcaneo-cuboid ligaments.

3. The *Superior calcaneo-cuboid ligament* (Pl. LV. fig. 6, *Q*) consists of two, three, or more, bands, which pass from the upper edge of the articular surface on the os calcis, with varying obliquity, to the tubercles on the upper surface of the cuboid, about a quarter of an inch distant from its hinder edge. The obliquity of their course, and the distance of their insertion from the edge of the cuboid, are so adjusted that they permit the movements of that bone upon the os calcis to take place within the required range, and, at the same time, prevent their exceeding it. 4. The *Inferior calcaneo-cuboid ligament* (Pl. LVI. fig. 2, *Q*, and LVIII. fig. 9, *N*) is of considerable strength; it radiates, from the tubercle on the under and fore part of the os calcis, to the ridge on the middle of the under side of the cuboid bone; and some of its fibres extend, beyond the ridge, beneath the *peroneus* tendon, to the heads of the outer two metatarsal bones. It is the main support of the outer part of the arch of the instep; and it limits the extension of the cuboid upon the os calcis, that is to say, it limits the extension of the second row of tarsal bones upon the first. The space enclosed by this ligament, beneath the calcaneo-cuboid joint, between the projecting tubercle of the os calcis and the ridge of the cuboid, is occupied by soft fat. The immediately contiguous edges of the os calcis and cuboid are

united by thin fibrous bands which form (5) a *Short inferior calcaneo-cuboid ligament.* These are strongest near the outer edge of the foot; and they are hidden by the long inferior calcaneo-cuboid ligament, except at the part where they are strongest.

Talipes plantaris and vulgus.

The preternatural curve of the sole, which sometimes exists alone, constituting *talipes plantaris,* but which is generally an attendant upon *talipes varus,* depends almost entirely upon a permanently, and it may be a preternaturally, flexed condition of the joint between the first and second row of tarsal bones. It is maintained by the contracted state of the plantar fascia and the ligaments. The other joints of the foot are, usually, not much disturbed. A similarly contracted condition of the foot may be induced by any disease of the foot which long suspends the influence of volition.

Connexion between scaphoid and cuboid.

There is not usually any synovial joint between the scaphoid and the cuboid bones. Nevertheless they move a little upon one another; and the movements are restricted by fibrous bands—*Superior* and *Inferior scapho-cuboid ligaments*—which pass obliquely between the respective dorsal and plantar surfaces. Some fibres connecting the opposed surfaces of the bones form an *Interosseous ligament.*

OTHER TARSAL JOINTS.

Joints between third row of tarsal bones.

The movements of the cuneiform and cuboid bones upon one another are very slight, and are of such a kind as merely to deepen, and widen, the transverse tarsal arch. It is interesting, however, to observe that the external cuneiform, which is the central element of the tarsus, and may be compared with the os magnum of the wrist, is the most fixed in this row of bones, and constitutes the pivot, as it were, upon which the internal and middle cuneiform, on the one side, and the cuboid, on the other, perform their slight revolutions; the axis of their movement being a line drawn, from before backwards, through this bone. The structure of the several articulations of the cuneiform and cuboid bones with one another and with the scaphoid, indicates that this is the case; the surfaces of the joint between the internal and middle cuneiform (Pl. LV. fig. 4, *A* and *B*) are flat, and permit only a slight sliding of one bone upon the other; that of the middle cuneiform (*B*) presents a distinctly concave facet, capable of revolving in a limited range upon the convex facet of the outer cuneiform (*C*); and the facet of the cuboid (*D*) is also slightly concave, though less so than that of the middle cuneiform. The cuboid and the internal cuneiform lie very obliquely; and the narrowing or widening of the plantar arch is, therefore, effected by their sliding up and down, as well as by their revolving upon the other cuneiform bones.

Joints between scaphoid and cuneiform.

With regard to the connexion of the cuneiform bones with the scaphoid, the articular surfaces between that bone and the two internal cuneiform (Pl. LVIII. figs. 6 and 7) are comparatively elongated and flattened from above downwards, or slightly undulating, so as to permit very little motion; whereas the joint between the external cuneiform and the scaphoid (fig. 8) is of the ball-and-socket kind—a slightly projecting spherical facet of the former bone being received into a superficial cup in the latter—; so that the conformation of these three joints corresponds with that of the joints described in the last paragraph, inasmuch as it permits the two inner cuneiform and the scaphoid bones to revolve together upon the external cuneiform, during the widening and narrowing of the sole of the foot.

The joints between the cuneiform, the cuboid, and the scaphoid bones, are strengthened by dorsal (Pl. LV. fig. 6, *R. S*), interosseous, and plantar (Pl. LVI. fig. 2, *S*) ligaments, which pass, with varying degrees of obliquity, between the several bones. They are so arranged as to permit very little movement and to retain their tension in the varying positions of the joints. The stronger ones are on, or near to, the plantar aspect.

TARSO-METATARSAL JOINTS.

The joint between the 5th, or small, metatarsal bone and the tarsus resembles the corresponding joint in the hand, inasmuch as it permits a certain amount of flexion and extension; and the 4th metatarsal bone may be moved in the same way, but in a more limited range. This provision has the effect of deepening or widening the metatarsal arch, and of adapting the balls of the toes to inequalities on the surface of the ground. The 2nd and 3rd are almost immoveable, and the first admits only slight rotation. The shape of the articular surfaces exhibits corresponding differences. The head of the 5th metatarsal bone (Pl. LVIII. fig. 1 *A*) is convex from above downwards, and is received into the concave facet of the cuboid (*F*). The head of the 4th metatarsal bone (fig. 2, *A*), and the corresponding facet (*E*) of the cuboid, present a similar conformation; but the degree of curvature is less. The heads of the 2nd and 3rd metatarsal bones (figs. 3 and 4 *A*), and the facets of the cuneiform bones (*D* and *C*) upon which they rest, are quite flat, and are lengthened from above downwards. The head of the 1st metatarsal bone (fig. 5, *A*), and the facet of the internal cuneiform bone (*B*), are prolonged in the same direction as those of the two contiguous joints; and they have, in addition, a slightly undulating outline.

The dorsal, plantar, and transverse ligaments, uniting the several tarsal and metatarsal bones, need no particular description (Pl. LV. fig. 6, and LVI. fig. 2, *T*, *U*). Those connecting the 4th and 5th metatarsals with the cuboid are more oblique in their direction than those connecting the other metatarsals with the cuneiform; this position has relation to the greater freedom of movement of the outer two toes.

THE METATARSO-PHALANGEAL JOINTS

resemble the metacarpo-phalangeal. The concave facet of each phalanx revolves upon the convex head of its metatarsal bone in flexion and extension; and there is also slight movement, of a similar kind, in a lateral direction, which is called adduction and abduction. The head of each metatarsal is prolonged towards the sole in the form of two tubercles overhanging the shaft and covered by cartilage. These support and give prominence to the sesamoid bodies, and assist in distancing the flexor tendons from the centre of motion.

The sesamoid bodies.

The *Sesamoid bodies* are the chief feature in these joints. They consist, in the case of the outer four toes, of square, flat plates of cartilage, situated upon the plantar aspect of the joints; their upper surfaces are in contact with the heads of the metatarsal bones, and are covered by synovial membrane; their under surfaces are in contact with the flexor tendons, and are covered by the synovial sheaths of these tendons; their anterior edges are connected, by strong, short, ligamentous fibres, with the adjacent parts of the phalanges; and their hinder edges are connected, by weaker, ligamentous fibres, and areolar tissue, with the heads of the metacarpal bones, just behind the overhanging edges of the articular surfaces; their lateral margins receive fibres from the lateral ligaments, above, and are closely united with the sheaths of the flexor tendons, beneath.

Transverse ligaments.

The several sesamoid bodies are also united together by short ligaments (Pl. LVI. fig. 1, *M*), which extend transversely, from one to the other, across the interspaces between the joints. The innermost of these transverse ligamentous bands runs to the external sesamoid bone of the great toe. Thus, by means of the sesamoid bodies and their connecting ligaments, is formed the *Transverse ligament*, which extends from the pollex to the little toe, and which holds the distal ends of the metatarsal bones together.

Lateral ligaments.

Each joint is provided, on either side, with a *Lateral ligament*, which radiates, from the tubercle on the side of the head of the metatarsal bone, to the side of the proximal extremity of the phalanx, and to the adjacent edge of the sesamoid body. Its origin from the metatarsal bone is rather above the centre of motion of the joint; hence it becomes most tense during flexion, and tends to limit that movement, as well as the adduction and abduction of the phalanx. During extension the lateral ligaments become a little relaxed, and permit a slight amount of adduction and abduction to take place. They are connected together, above, by thin fibres, which extend across the dorsal aspect of the joint and form a capsular, or superior, ligament; on the plantar surface they are united only by the sesamoid bodies.

THE PHALANGEAL JOINTS

are simple hinge-joints, permitting only flexion and extension. The articular surfaces are transversely elongated, and slightly undulating. Each is provided, upon its plantar aspect, with a sesamoid body (Pl. LVI. fig. 1, *N*), which is connected, like those of the metacarpo-phalangeal joints, closely with the bone in front, loosely with the bone behind, and, on the sides, with the lateral ligaments and the sheaths of the tendons.

THE JOINTS OF THE POLLEX

differ but little from those of the other toes. They are on a larger scale; and, in the case of the metatarso-phalangeal joint, two *sesamoid bones* (Pl. LVI. fig. 1, *A*) are substituted for the sesamoid body. The sesamoid bones are united to one another by strong ligamentous bands, forming a channel in which the flexor tendon plays; they are connected, behind, with the head of the metatarsal bone by ligaments (*B*), and with the short flexor muscle; and, in front, they are connected with the phalanx by strong short ligaments (*C*). A strong fibrous band (*D*) runs forwards from them, beneath the middle of the first phalanx, to the sesamoid body (*E*) which is situated under the phalangeal joint[1].

Liability to disease.

The distal end of this metatarsal bone is naturally large and prominent, its whole circumference projecting beyond the rest of the bone; it is very liable to be still further enlarged by chronic inflammatory affections. I suppose the pressure to which the joint is subjected by tight and ill-fitting boots, added to the extent

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[1] A small sesamoid *bone* is sometimes developed in this body (Pl. LVII. Fig. 1, *F*), as in the case of the corresponding part of the thumb, (p. 436). Haller, *Icones Anat.* fasc. v. p. 49, note 35, speaks of a sesamoid bone belonging to the little toe; and Krause, *Handbuch der Menschlichen Anatomie,* s. 207, mentions two sesamoid bones under the 1st joint of the great toe, a third under the 2nd joint, a fourth at the outer end of the tuberosity of the cuboid, a fifth, often, at the inner side of the 1st cuneiform bone, and a sixth at the inner side of the head of the astragalus.

of the cartilaginous surface of the head of the metacarpal bone, and its liability to sprains, and other injuries, are the causes of this joint being so liable to acute and chronic diseases of the cartilages and bones, to gout and other affections.

Deformity frequent in the metatarso-phalangeal joint.

It has been remarked (p. 503), that the metatarsal bones, slant inwards from the tarsus. In the well-shaped foot the phalanges are directed, not quite in the same line with the metatarsal bones, but nearly straight forwards, so as to form a very obtuse angle with them; and the natural effect of the unrestrained action of the various muscles connected with the phalanges is to lessen the obtuseness of this angle, and to make the toes slant more outwards. This tendency is too commonly assisted by the tight hard heavy shoes in which the foot is confined, or by the bruising to which it is subjected in those who go shoeless upon hard roads and paved streets. Hence the great toe often loses its proper direction and acquires a slant outwards, thus obliterating the interval between it and the next toe. Sometimes it not only presses upon the latter, but crosses quite over or under it. Such displacement is necessarily attended with detriment to the other toes; and it leaves the metatarsal bone of the great toe prominent on the inner side of the foot, and liable to be inflamed and covered with bunions and corns.

STANDING, WALKING, RUNNING. (Plate LIX.)

In erect posture skeleton is disposed in six curves between head and feet.

When a man stands erect, with both heels close together upon the ground, and with the knees and hips fully extended, (fig. 1), the centre of gravity of the head is directly over a point midway between the two astragali; and the skeleton is arranged in a series of six alternating antero-posterior curves, which extend from the occiput to the astragali. Of these, the upper three, formed in the cervical, dorsal, and lumbar portions of the spine, have been described at length (page 146); and we found that the line of gravity falls through the points at which they meet, and coincides with their several arcs. Next below these follows the curve formed by the sacrum and iliac bones. It has its convexity backwards, and terminates, above, by joining the lumbar curve at the promontory of the sacrum. Below, it is continuous with the next succeeding curve; which has its convexity in the opposite direction, and which is formed by the union of the heads of the thigh-bones with the iliac bones in the acetabula. The sixth curve, with its convexity backwards, is at the knee. The lower three curves are less marked than the upper three; but in the former, as well as in the latter, the transverse plane of gravity cor-

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DESCRIPTION OF PLATE LIX.

Fig. 1. Diagram of skeleton in upright posture. Line of gravity falling from head traverses points of junction of three spinal curves, passes behind head of femur, in front of knee, through ankle.

Fig. 2. Stooping posture. Hips projected behind line of gravity.

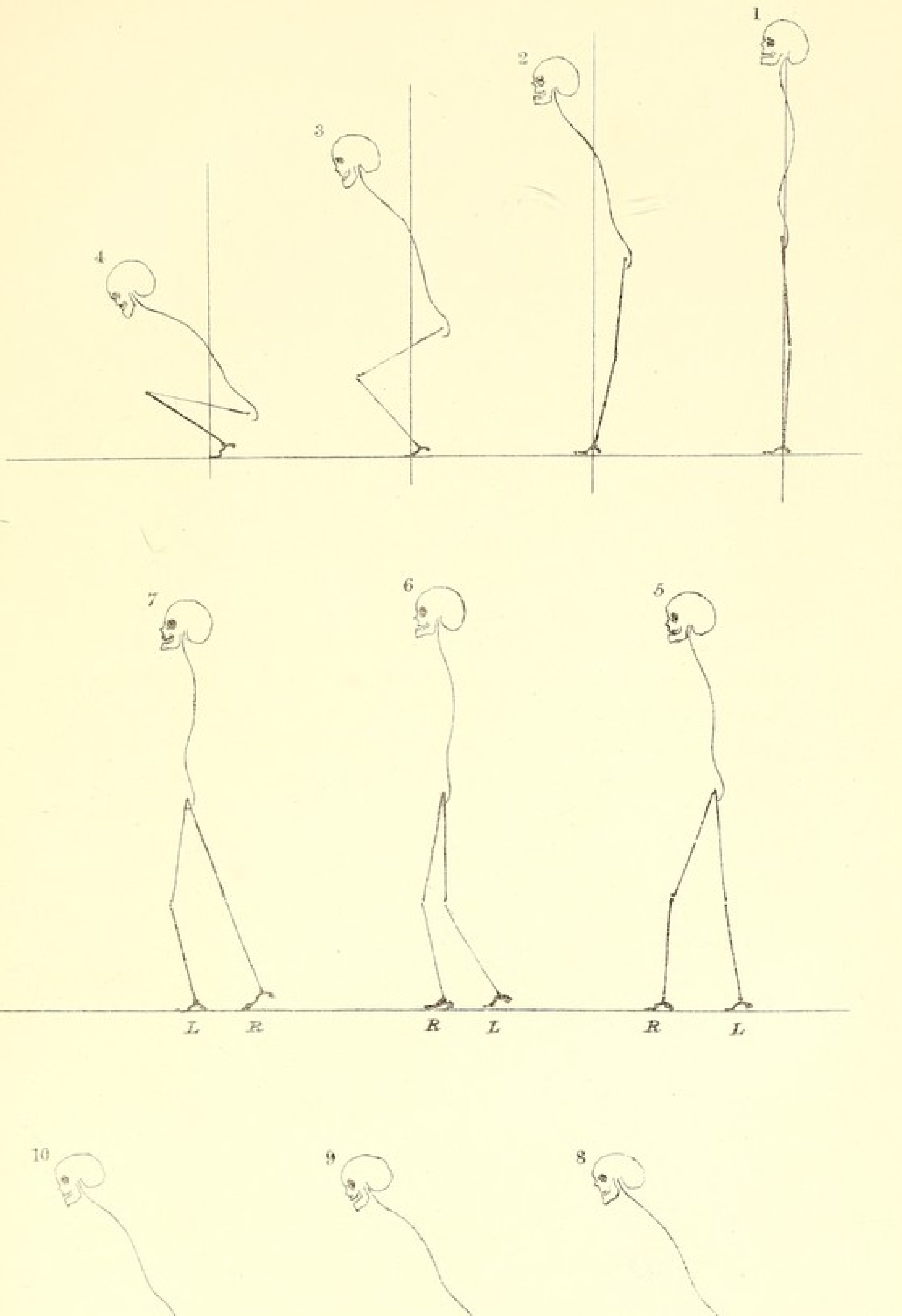
Fig. 3. Squatting ditto.

Fig. 4. Ditto ditto.

Figs. 5, 6, 7. Walking.

Figs. 8, 9, 10. Running.

Plate LIX.



responds with the arc of each[1]; and the weight of the body has, therefore, a tendency to increase the degree of the several flexures.

Those in lower extremities the means of saving muscular effort.

It is interesting to observe the effect which this tendency practically has. In the pelvis it produces no effect at all; because the sacrum and the iliac bones are so firmly united at the synchondrosis that they may be regarded as one bone, and the curve formed between them is of unvarying shape. At the hips, where the bones which form the curve are more moveable, the line of weight, falling in the arc of the curve, that is, behind the joints, tends to produce further extension of the pelvis upon the thighs. This is, however, resisted by the "accessory ligaments" (page 513); and, owing to that resistance, the effect of the weight is simply to maintain the joints fixed and steady in a state of extension. The strain is thrown upon the accessory ligaments; and the muscles are, in great measure, relieved. In like manner, in the case of the knees, the ends of the leg and thigh-bones are thrown back when the limbs are fully extended; so that the plane of gravity falls a little in front of the joints, a fixed state of extension is maintained, and the weight is borne by the crucial, lateral, and posterior ligaments, which are then tense, to the complete relief of the various extensor muscles. By these provisions, therefore, in the form, position, and direction of the several curves, steadiness is given to the lower extremities in the erect posture, and muscular force is greatly economised.

The curves are slight.

In each of these two instances the curve is formed only in the completely extended state, and is very slight; it is only sufficient to throw the plane of gravity in front and behind the respective joints, and just attains the object desired. Had the flexures been greater the joints would have been weakened, the ligaments would have been subjected to far greater strain, and other inconveniences would have resulted, without any compensating advantage.

Body falls forward when muscles are paralysed.

The various curves, and the parts of the skeleton which form them, are so disposed that, in the erect posture, the head is *nearly* balanced upon the trunk, the trunk is *nearly* balanced upon the thighs, and the latter, with the legs, are nearly balanced upon the astragali. In the case of the head, however, as mentioned at page 316, when it is in the ordinary position, with the eyes looking straight forward, or downward, the weight preponde-

[1] In other words, the arcs of the curves and the line of gravity lie in the same plane.

rates a little in front of the balancing point upon the spine; and, in the case of the trunk, as we commonly stand, the line of gravity falls a little in front of the axis of rotation of the pelvis upon the thighs, and is continued, downwards, a little in front of the centre of the ankle-joint. Hence, a continuance of muscular action, to a greater or less amount, is required to hold the body up; and if all muscular aid be suddenly suspended by a severe impression upon the great nervous centres, or, in any other way, the head commonly falls forwards upon the chest, and the body falls forwards upon the ground[1].

Base of support afforded by the feet.

The feet are placed at right angles to the legs, and are spread out upon the ground so as to afford a wide basis of support to the extremities; and the area of this basis in front of the ankle, which is provided by the length of the metatarsus and phalanges, as well as by the divergence of the toes, is partly for the purpose of preventing the overbalancing of the body in this direction, and of enabling the gastrocnemii and other muscles to fix the legs firmly in the perpendicular position. When we stand upon both feet, the base of support is the area of the two soles, together with the space included between them. When we stand upon one leg, the base of support is reduced to the area of one sole; and the difficulty of maintaining the equilibrium is proportionately increased. Still greater is the difficulty of balancing the body upon the balls of the toes, or, upon the heels.

Lateral balance how maintained.

Muscular aid is required to maintain the *lateral* as well as the antero-posterior *balance* of the trunk upon the extremities; for the trunk is ever ready to slip sideways upon the heads of the thigh-bones. Hence the standing straight upright on both legs is attended with some constraint and fatigue; and we are provided with a means of varying the posture, and of obtaining partial rest, while the trunk is still maintained erect, by allowing the weight to fall upon the lower limbs alternately. When this is done the hip of the side to which the weight is transferred is thrown a little outwards, the thigh and leg of the same side are inclined outwards,

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[1] Herein we may find the explanation of the cases of "toppling forwards," which are occasionally met with. The peculiarity of the attack probably does not depend, as has sometimes been supposed, upon a particular portion of the nervous system being the seat of disease, or upon any particular group of muscles being paralysed, but upon the sudden suspension of the force of all the voluntary muscles together, so that the body is left to fall in the direction to which gravity inclines it.

and the pelvis, retaining its proper level, is in a proportionate degree adducted to the thigh. By this means the line of gravity of the trunk is placed perpendicularly over the ankle, the pelvis is slung upon the strong fibres of the "superior accessory ligament" of the hip (page 515), and the other limb, a little bent and placed "at ease" upon the ground, serves to maintain the balance of the body.

Stooping.

In *Stooping* (fig. 2) the trunk is inclined forwards by the rotation of the pelvis upon the thighs, the lower limbs are inclined backwards from the feet by extension of the ankle-joints, and the buttocks are, thereby, made to project backwards, so as to assist in maintaining the balance. Nevertheless, if the movement be carried beyond a certain point, the centre of gravity passes, forwards, to some point between the ankles and the balls of the toes; and the position is, consequently, difficult to maintain.

Squatting.

In a further degree of stooping (or, as it may be called to distinguish it from stooping, *Squatting*) (figs. 3 and 4) the trunk and the extremities are bent in a zigzag manner by flexures, in alternate directions, at the hip, knee, and ankle; and the weight is thrown upon the balls of the toes. The amount of flexure, forwards, at the knee, nearly equals that of the flexure, backwards, at the ankle and hip taken together. If it did so quite, and if the leg and thigh were of equal length, the head of the femur would still be maintained over the ankle, and the pelvis would descend in a vertical plane. There would, then, have been great difficulty, or even an impossibility, in maintaining the balance upon the fore part of the foot; because, in this movement, the trunk is inclined considerably forwards, partly, for the purpose of directing the eyes downwards, and the arms are also generally thrown forwards to handle or pick up objects on the ground; so that the weight of the head, trunk, and arms would have preponderated considerably in front of the resting point upon the ground, and a great muscular effort would have been required to prevent the body from falling forwards. In consequence, however, of the thighs being made longer than the legs, the buttocks are thrown *behind* the ankles when the extremities are bent, and tend, in some measure, to counterbalance the weight of the head and upper part of the trunk which are advanced in *front* of the ankles. This is one of the objects attained by the great proportionate length of the femur, which has been mentioned (pp. 90 and 466) as constituting one of the peculiarities of the human skeleton.

WALKING.

In walking, the feet not off the ground both together.

In walking, the lower extremities are moved forward, one after the other, in a succession of steps, and the trunk is borne upon them alternately. Both feet are upon the ground at the commencement, and at the termination, of each step; but they are never both off the ground together. The period, therefore, during which each foot is upon the ground is greater than that in which it is in the air; and the proportion between the two periods varies with the quickness of the step. The quicker the step, the shorter is the period in which each foot is upon the ground, not only actually, but in comparison with that in which it is swinging in the air; and in the fastest walking the one foot is lifted from the ground nearly at the same moment that the other is placed upon it.

Period in which the foot is upon the ground;—first stage,

Let us examine what takes place in each of these two periods. That in which the foot is upon the ground may be divided into three stages. In the first stage (fig. 5), the foot (*R*) is in front of the head of the thigh-bone, and, therefore, the limb is advanced a little in front of the trunk, so as to be in a favourable position to receive the weight of the trunk, which is being pushed forward upon it by the other limb (*L*). The heel comes upon the ground a little before the rest of the sole and the balls of the toes; but the difference is scarcely appreciable. The ankle is slightly extended, and the hip and knee are slightly bent, which prevents any jar being communicated to the body by the sudden contact of the foot with the ground. The other foot (*L*) still rests upon the ground, and is employed in pressing the trunk onward.

second stage,

In the second stage (fig. 6), which quickly succeeds the first, the head of the thigh-bone, and the trunk, are carried perpendicularly over the foot (*R*), which now bears the whole weight of the body, while the other foot (*L*) is being swung beside it and advanced in front of it. The sole accordingly rests firmly, in its whole length, upon the ground. The ankle is changed from the extended to the intermediate position. The knee and hip remain a little bent.

third stage.

In the third stage (fig. 7), the head of the thigh-bone, and the trunk, are advanced in front of the foot (*R*). The limb is lengthened, first, by the straightening of the knee and hip, and, then, by the continued extension of the ankle, whereby the heel is raised, so that, at last, only the balls of the toes and the phalanges rest upon the ground. By this lengthening of the limb a sufficient impulse is given to the trunk to carry it forward upon the other extremity (L), which is now placed upon the ground to bear it; and, whereas, in the first stage, the limb was inclined *for*wards from the trunk, to be ready to receive the weight of the body, it is, now, inclined *back*wards from the trunk, to be in a favourable position to communicate an onward impulse to the trunk.

The turning, or revolving, movement which the foot makes upon the ground, in these three stages, has been not inaptly compared to that of the segment of a wheel passing over a horizontal plane; although the comparison is not very exact, forasmuch as, besides other differences, the whole length of the foot rests upon the ground during one part of the process, and the centre point, or astragalus, which would correspond with the axle, describes, not a horizontal, but, a curvilinear movement, in consequence of its distance from the toes being greater than that from the heel.

Period in which the foot is off the ground;—

When this rotatory motion of the foot has been completed, and the last impulse, derived from the straightening of the limb, has been communicated to the trunk, so that the forward movement of the latter is continued, the toes are raised from the ground by the flexion of the ankle, and the extremity, a little shortened by the bending of the knee, is swung, from behind, close beside the other limb, and is advanced in front of it, so as to be again planted upon the ground ready to receive the weight of the body.

first stage,

In the first stage of the swinging movement, while the foot is behind the other, the toes are pointed towards the ground (fig. 6, L), in consequence of the ankle retaining some of the extension which it had before the movement began; the leg and foot may also be, sometimes, observed to undergo a slight rotation at the knee, in such a manner as to cause a turning of the toes *in*wards.

second stage,

In the second stage of the swinging, when the foot is beside the other, and hangs vertically beneath the trunk, the sole has become parallel with the ground, and the toes are directed straight forward, the ball of the great toe passing beside, and beneath, the internal malleolus of the other leg, so as just to avoid it.

third stage.

In the third stage, the ankle is a little extended, and the leg is again rotated at the knee; but in a direction opposite to that in the first stage, so that the toes have a slight inclination *out*wards. The rotation of the leg *in*wards in the first stage of the movement, and *out*wards in the last, which is more evident in some persons than in others, is for the purposes of preventing the toes catching against foreign bodies when the foot is withdrawn from the ground, and of widening the basis of support when it again reaches the ground.

Causes which induce the swinging forwards of the leg.

The *swinging forward* of the leg, while it is suspended in the air, is due to three causes. First, the limb partakes of the impulse which its own muscles have been the means of communicating to the trunk, and which have the effect of carrying it through a distance equal to that which is traversed by the trunk. This, however, is not sufficient to account for the whole movement; forasmuch as when the foot is first raised from the ground it is behind the plane of the acetabulum, and when it again comes into contact with the ground it is in front of the same plane, having traversed a distance two or three times as great as it. Secondly, the weight of the limb, acting like that of a pendulum, causes it to swing upon the pelvis; this, added to the first cause, would, at a moderate rate of walking, be sufficient to accomplish the movement. Thirdly, there is the force of the psoas and other muscles, which are brought into action in proportion as the step is quickened. Hence, the more rapid the movement, the greater is the fatigue attendant on it[1].

The trunk is carried in a nearly straight line:

The transfer of the weight of the body from one limb to the other, and its propulsion forwards, in walking, are so managed, that there is no unnecessary movement; and, consequently, no needless expenditure of muscular power. The trunk is carried along in a nearly straight line, with very little rising and falling, without any swinging backwards and forwards or to either side, and without rotation. This is effected; partly, by the varying position, and the varying degree of flexion, of the limb which rests upon the ground; partly, by the mode in which the pelvis is borne upon the

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[1] The statement (*Cyclopedia of Anat.* III. 466) that the limb swings forward by the force of gravity alone, independently of muscular action, cannot be strictly correct, because if that were the case it would always swing at the same rate.

heads of the thigh-bones; and, partly, by the mode in which the different sets of muscles, of the opposite sides, are made to assist and counterbalance one another.

It rises and falls very little,

For instance, it has just been said that each lower limb, when first placed upon the ground, is a little bent at the knee and extended at the ankle; that, when the trunk is passing vertically over it, the knee is still bent, and the hip and ankle are also slightly bent; and, further, that as the trunk is advanced forwards, the limb is gradually lengthened by the extension of the knee and the raising of the heel. Now, the shortening of the limb in one stage of the step, and the lengthening of it in another, are so regulated, with regard to the perpendicular and oblique positions of the limb in the several stages of the step, as to maintain the head of the femur, and with it the trunk, almost at a uniform level. Hence, when we walk with a deliberate easy step the head is not moved up and down, so much as we might suppose that it would be, but *describes nearly a straight line*, and is carried at a somewhat lower level than the height of the person when standing erect. If, however, the step be long and measured, and the knee be straightened before the foot is placed on the ground, as in the case of soldiers marching, the body is moved in a more distinctly wavy line; it may be seen to rise when it passes vertically over each limb, and to descend in the interval between those periods. This is attended with more muscular effort, and is consequently more fatiguing.

is not swayed from side to side,

The body is not *swayed from side to side* when the weight is transferred from one leg to the other; because the extremities are slanted inwards from the pelvis, in such a manner that each foot is placed upon the ground very nearly in the antero-posterior plane of gravity; and any tendency of the trunk to be inclined to the opposite side, in consequence of the foot not being exactly beneath the centre of gravity, is neutralized by the impulse, in an opposite direction, which has just been received from the other leg, and by the contraction of the muscles which steady the pelvis upon the thigh. The rolling ungainly movement of the shoulders, which we sometimes observe in persons as they walk, is an acquired habit; or it results from great width of pelvis, or from the extremities descending in too vertical a manner, or, which is perhaps the most frequent cause, from the legs slanting outwards, from the knees, to the ground.

nor rolled backwards and forwards.

Rolling of the trunk backwards and forwards, and *rotation* upon a vertical axis, under the influence of the alternate action of the muscles which are employed in propelling it, are prevented, partly, by the muscles being so arranged as to antagonise each other's tendency to rotate the pelvis upon either a horizontal or a vertical axis. In this way they render the pelvis steady and preserve the proper direction of the trunk; and, in addition, they provide a mutual *point d'appui*, so that the whole force of each may be employed in the desired manner. Thus, when the glutæi and other extensor muscles, of the one side, are engaged in straightening the limb which is upon the ground, their tendency to rotate the pelvis *back*wards upon a horizontal axis is prevented by the action of the psoas and other muscles, of the opposite side, which are engaged in swinging that limb, and which have a tendency to rotate the pelvis *for*wards. The power of the latter set of muscles is, it is true, considerably less than that of the former set; but it must be remembered that they are, in this duty, assisted by the inclination forwards of the upper part of the trunk, and by the consequent tendency of the weight of the trunk to increase the horizontal rotation of the pelvis. In the like manner, the tendency which the extensor muscles would have to cause rotation of the pelvis upon a vertical axis in *one* direction, is resisted by the anterior fibres of the glutæus medius and by the impulse in an *opposite* direction, which the trunk has just received from the other limb.

Swinging of the arms.

The balance of the trunk is still further preserved by the swinging of the arms upon the scapulæ; the movement of each arm being in an opposite direction to that of the lower extremity of the same side.

Inclination of the trunk forwards assists progression.

The *inclination of the upper part of the trunk forwards*, which is maintained in walking and running, and which increases in proportion to the rate of progression, serves to advance the line of gravity in front of the ankle, and, therefore, to diminish the amount of force required to elevate the heel.

This forward inclination of the trunk is further necessary to preserve the balance of the body, in consequence of the direction in which the propelling impulses are received from the lower extremities, and in consequence of the resistance of the air. Just as when we balance a stick upon the finger, and wish to move it, we must give it an inclination in the direction towards which it is to be carried, and proportionate to the velocity of the movement; so must the trunk be bent upon the pelvis, more or less, according to the rate of progression[1]. The distance from the acetabula to the top of the head being one half of the height of the whole body, and the upper half being the heavier[2], the requisite inclination of the trunk forwards could not be carried to any great extent without danger of frequent overbalancing of the body, were it not for the fact that the knee is always more or less bent when the body is moved onward; and this, owing to the great proportionate length of the human thigh, throws the pelvis backward, as has been just mentioned, and the weight of the buttocks in part counterbalances that of the head and shoulders. Moreover, when the pace is quickened, and the inclination of the trunk is increased, the knee is always more bent; and the pelvis is, consequently, thrown further back, as well as maintained at a lower level.

Relation between length and quickness of step.

It is found that the *rapidity* with which the several stages of each step are conducted is proportionate to the *length* of the step; that is to say, the longer the step the quicker is it made. Hence the rate of progress is accelerated by an increase of both the length and the celerity of the step at the same time. The quicker the movement the longer is the step, and the shorter also is the period during which the two feet are upon the ground together. The fastest walking is when this period is reduced to a minimum, the one foot being withdrawn from the ground directly the other is placed upon it; and the rate at which the body can be moved along,

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1 "It is well known that when any portion of a rigid body receives motion from a neighbouring body, all the parts of the rigid body will partake of the same motion, only when the direction of the force passes from the point of contact through the centre of gravity. If this is not the case, as, for example, when the upper extremity of the propelling leg acts on the lower part of the trunk of the human body in the erect position, the lower part would be propelled forwards and upwards, whilst the centre of gravity of the trunk would be left behind, and fall backwards; but if this centre be inclined forwards at the beginning of the step, the weight of the body and its required momentum will propel it forwards and downwards; hence the resultant of the several forces will be a force which propels the body forwards in a direction which, by experience, is found to be nearly horizontal: but there is also another force which affects the trunk, namely, the resistance of the air, which tends to turn the trunk backwards, and must be counteracted by the force of gravity, through the inclination of the trunk forwards. The amount of this constant inclination of the trunk must be estimated by the resistance which it encounters from the air in walking and running." John Bishop in *Cycl. Anat.* III. 459.

2 The horizontal plane of the centre of gravity was found by Weber to lie about half an inch above the promontory of the sacrum.

in walking, is limited by the length of the stride and the celerity with which the several stages of the step can be conducted.

Running; both feet off the ground at the same time.

If greater rapidity be required, *Running* is substituted for walking. The difference is that the trunk, instead of being quietly delivered over from one leg to the other which is already upon the ground to receive it, is thrown forward, with a spring, by the muscles of the leg which is leaving the ground, and remains, for a time, suspended in the air, or, rather flying through the air. Hence, in running, *both feet are in the air at the beginning and end of each step*, that is, in the periods corresponding to those in which both are upon the ground in walking; and the length of the step is no longer limited by the length of the stride, which can be taken while both feet are upon the ground, but superadded to that is the distance to which the body can be driven through the air while both feet are off the ground. It need scarcely be remarked that this propulsion is attended with great effort, and that running is, therefore, considerably more fatiguing than walking.

Period in which the foot is on the ground.

In running, the period during which each foot is upon the ground (fig. 9, *R*) is shorter than that in which it is in the air; and the disproportion increases with the quickness of the step. Indeed, in fast running the foot is on the ground only during the short time in which the trunk is passing vertically over it, and during the first part of the time in which the trunk is being advanced in front of it. The limb is at first bent at the knee and hip, and becomes quickly straightened; the changes which take place corresponding with those in the second and third stages of the same period in walking. Though the first stage can scarcely be said to exist in running; for, as just mentioned, by the time the foot has reached the ground the trunk is already vertically over it, or nearly so; whilst the heel scarcely touches the ground, and the foot revolves, almost exclusively, upon the balls of the toes. The impulse which is communicated by the sudden and forcible lengthening of the limb is sufficient to drive the whole body through the air for a certain distance, and to urge it onwards during the chief part of the period in which the other leg is upon the ground.

Period in which the foot is off the ground.

When the limb has completed its extension and has given to the body the impulse resulting therefrom, it is raised from the ground (fig. 8, *L*), partly, in consequence of its being carried on by the forward movement of the trunk, and, partly, in consequence of the flexion of the hip and knee, which results from muscular action; and it begins to be swung forward before the other foot reaches the ground. The swinging takes place quickly; the limb (fig. 9, *L*) is thereby carried beside, and to the front of, the other limb (*R*), which is upon the ground; and the forward movement is continued for a short time after the latter (*R*, fig. 10) has left the ground. The foot (*L*, fig. 10) does not advance so far in front of a perpendicular line falling through the hip-joint, as if it had been (*L*, fig. 8) situated behind the same line; because the rapid progress of the trunk does not give sufficient time for the completion of the pendulum-like movement and the extension of the limb. The quicker the progress of the trunk the greater is the disproportion between the angles formed by the extremity in front and behind the perpendicular line; and in the fastest running the anterior angle is lost altogether, the foot being just brought up to, but not advanced in front of, the perpendicular. It follows from this, as well as from the fact of the two limbs swinging in the air at the same time, that a greater number of steps can be taken in a given time in running than in walking.

Limbs more bent than in walking.

Both the carrying and the swinging limb are more bent in running than in walking, when they are placed vertically beneath the trunk; whereby the swinging movement, and, consequently, the step, is still further quickened, the propulsive power is increased, and the body is carried at a lower level.

Trunk carried in a straight line.

The trunk is carried along, by virtue of the same provisions as in walking, nearly in a straight line, with scarcely any rising and falling[1], without swaying forwards and backwards, or to either side, and without rotation. The inclination of the trunk forwards is regulated according to the velocity of the movement; and its balance is preserved by the proportionate resistance of the atmosphere, by the projection of the buttocks, which is an attendant on the flexure of the knees and hips, and by the powerful contractions of the several muscles.

Walking and running are the common modes of progression, and the most important movements, of the body. It would be entering on too wide a field, however interesting the subject, to attempt to explain the mode in which the various other movements of the human frame (such as hopping, leaping, turning, &c.) are effected.

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[1] Weber says that the vertical movement is even less than in walking; and that the trunk is lowest when passing perpendicularly over each limb, instead of being then highest, which he finds from his experiments to be the case in walking.

THE HOMOLOGY OF THE SKELETON[1]. (Plate LX.)

In the preceding pages scarcely any mention has been made of the Homology of the several parts of the skeleton; because, after a careful review of the subject, which is undoubtedly a very difficult one, I found that, although I could quite assent to, and adopt, the general features and most of the particulars of the plan laid down, with so much ability, by Professor Owen, and commonly adopted in our schools, yet that I could not acquiesce in certain of the details of that system. It would be foreign to the scope of the present work to enter into any lengthened disquisition, which might be necessary to explain my reasons for dissenting, in some important points, from the views of one whose authority is so deservedly esteemed. Nevertheless, it does not seem right to pass over, with mere occasional allusions, a branch of our science which is deeply interesting, and which has received more or less attention at the hands of most of the philosophical anatomists of modern times. I propose, therefore, to give here a brief account of the conclusions to which I have been led respecting the homology of the human skeleton; but must be content to defer all the reasons upon which those conclusions are based to a short account of the "Morphology and Homology of the Vertebrate Skeleton," which, I hope, will soon follow as an Appendix to this Volume. The following remarks have reference to the human skeleton only; though they are the results of observations and comparisons of the several vertebrate classes.

I think it is to be regretted that so much new and difficult nomenclature has been introduced; and shall, therefore, endeavour to avoid that, and shall use familiar terms as far as possible.

Centra.

The Bodies of the vertebræ, arranged in front[2] of one another, and connected, in most instances, by fibro-cartilage, form the centre, or axis, of the skeleton, which is interposed between

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[1] This was the subject of a communication to the British Association at Leeds, September, 1858.

[2] In this section the skeleton is supposed to be placed with the dorsal surface uppermost, to facilitate the comparison with that of the lower animals.

the cerebro-spinal nervous axis, above, and the circulating, digestive and respiratory viscera, beneath; they are, therefore, well named the *centra*. They are in close relation to, and are developed in close connection with, the ganglia which form the primitive constituents of the cerebro-spinal neural axis; each centrum corresponding, apparently, with a pair of these ganglia. Their shape usually approximates to that of a sphere; but sometimes deviates from it very considerably. One of the modifications is caused by out-growths from the superior or inferior surface of the centrum. Those in the former situation—such as the posterior clinoid processes of the sphenoid bone, and the crista galli of the æthmoid—may be called *Supra-central;* those upon the under surface—such as the prominences on the fore part of the cervical vertebræ, and the rostrum or azygos process of the sphenoid—may be called *Sub-central*. They are usually mere out-growths; but it appears that, when large, they may be developed from separate osseous nuclei; and it is probable that the inferior arch of the atlas is of this nature.

Supra- and sub-central growths.

Neural arches.

The neural axis lies upon the upper surface of the centra, enclosed in a tube which is formed by a series of bony arches called *neural Arches* (fig. 1). Each of the neural arches rests by a pedicle, on either side, upon one of the centra, and, with it, constitutes a complete transverse segment of the *neural Tube;* and each neural arch is composed of lateral portions, or alæ—the *neural Alæ*—which spring from the sides of the centrum, and which may be confluent in the middle line, above, or may be united by one, or two, mesial portions—the *neural Spines*. In the spinal column the neural spines are often absent, or are merely small osseous nuclei formed at the tip of the process which runs from the point of union of the neural alæ (p. 121); in the cranium, however, they form an important part of the covering of the brain.

Neural spines.

Intervertebral foramina.

Between the pedicles of the neural alæ of contiguous vertebræ are spaces — the *Intervertebral foramina*—which transmit vessels and nerves to and from the neural canal. In the cranium the nerves and vessels, which are more numerous than in the spine, pass not only through the intervertebral foramina, but through perforations in the pedicles.

Articulating processes.

Processes grow out from the neural alæ, on either side, in front and behind, which come into contact with, and are jointed with, corresponding processes of the contiguous vertebræ—these are the *Articulating processes.* In the cranium, where the edges of the adjacent alæ are united in nearly their whole length, special articulating processes are not required; and their representatives can be distinguished only in the cartilaginous jugular facets of the occipital bones, and, perhaps, in the so-called spinous processes of the sphenoid bone.

Transverse processes. *Transverse processes* also grow out from the neural alæ, one or two on either side. When there are two, as in the cervical vertebræ, they are usually placed one above the other, the lower one springing from near the inferior extremity of the pedicle, close to the attachment to the centrum; and they enclose between them a space, which contains an artery. This space may be closed on the distal side by the confluence of the two transverse processes; it is thus converted into a foramen—the *transverse foramen.*

Ribs. Or, a separate piece of bone may be appended to the transverse processes on either side, to one or both as the case may be. It may become ankylosed with them, as in 7th cervical vertebra; or it may remain separate, as in the dorsal region. It may be called the *Transverse Ala.* Where it remains separate it is most commonly inclined downwards (fig. 2), on the side of the visceral cavity; and, contributing to form the lateral wall of that cavity, it is called a rib. In some parts of the cranium, however, where the size of the neural cavity preponderates over that of the visceral, it is directed upwards (fig. 3) and assists the neural arches to form the covering of the brain. Under these circumstances it may be appended, directly, to the neural ala, without the intervention of the transverse process.

The so-called "viscera of organic life" are placed beneath the vertebral centra, and bear a relation to them similar to that of the brain and spinal cord, but not nearly so intimate. They are also, more or less completely, enclosed in an osseous tube, which is formed upon the inferior surface of the vertebral axis. This may be called the *Visceral Tube,* to distinguish it from the neural tube; with which it corresponds, inasmuch as it is formed of a series of arches—the *Visceral arches*—which descend from the sides of the centra, and unite in the middle line, below.

Visceral tube. Visceral arches.

Each visceral arch is an appendage to one of the centra; but the several visceral arches do not preserve their relations with their respective centra quite so regularly as do the neural arches; indeed it is sometimes difficult to tell to which of the centra a particular visceral arch belongs. They are subject also to considerable varieties, in accordance with the variations of the number, size, and shape of the organs they have to protect, and the different uses to which they are made subservient.

Hæmal elements.

The most regular components of the visceral arches are the *Hæmal parts* of the vertebræ. They correspond, apparently, with the neural parts, being formed, like them, of lateral portions, or *alæ*, one on either side, which are approximated at their distal extremities, and are united in the mesial line, either directly, or by the intervention of one or more separate portions—the hæmal *Spines*. In the caudal region of many animals the hæmal elements are applied, directly, to the under surface of the centra, forming with them the whole of the visceral tube, which, in that region, contains only the caudal vessels: hence the name "Hæmal." Commonly, however, for the purpose of enlarging the visceral tube, and of giving more space to the various organs contained in it, the hæmal elements are removed to a considerable distance from the centra, and are appended to the extremities of the transverse alæ, or ribs, which, as we have seen, are bent downwards to assist in forming the visceral arches. In the parts of the cranium in which the transverse alæ are devoted to the construction of the neural, instead of the visceral, arches, the hæmal elements are still appended to them.

The limbs.

An important office performed by the hæmal parts of the vertebræ at the anterior and posterior regions of the trunk, is to afford a basis for the *Limbs*, which, it appears to me, should be regarded as appendages to the hæmal, and not to the pleural, components of the skeleton.

We will proceed to consider the several regions of the skeleton homologically, commencing from behind and travelling forwards.

The coccyx.

The hindmost segment of the skeleton—the terminal bone of the Coccyx—is an illustration of the fact that the various elements just mentioned are not, necessarily, all present in each vertebra; inasmuch as, in this instance, the centrum only is present, represented by a little pisiform bone, and all the other parts are wanting. In the anterior portions of the coccyx the neural alæ (Pl. XXXVI. fig. 1, *I*) are superadded; but they project upwards only a short distance from the centra, and do not close the neural canal, above.

The sacrum.

The Sacrum represents five segments, being composed of five vertebræ (Pl. XXXVI. figs. 2 and 3), which become ankylosed. The BODY of each is the *centrum* (Pl. LX. fig. 7). The neural alæ arch over the neural canal, except in the instance of the hinder two vertebræ, where they do not quite meet; and neural spines may be formed upon them, though they are commonly absent. Stunted articulating processes may be recognised; but, for the same reason as in the cranium, they are almost abortive. Two transverse processes from each vertebra, on either side—an upper and a lower—and the transverse ala, or rib, are united together to form the septa between the intervertebral foramina and the lateral parts, or "alæ," of the sacrum. The transverse processes grow out together; and are not separated by any interval, as they are in the neck. The rib is developed from a distinct nucleus (Pl. IV. fig. 5, *H*).

Ossa innominata.

The OSSA INNOMINATA constitute the *visceral arches* of the pelvis, enclosing the urinary and genital organs, the terminal portion of the alimentary tube, and the blood-vessels. They appear to be composed of the hæmal elements of two of the sacral vertebræ; the PUBES being the *hæmal spine* of one, the ISCHIUM of the other, with the obturator foramen—or inter-hæmal space—between them; and the ILIUM being the conjoined *hæmal alæ* of the two. The latter rests upon two or three sacral ribs (p. 451). The hinder LIMBS are *appendages* diverging from the points of junction of the hæmal alæ with the hæmal spines.

Lumbar vertebræ.

In the LUMBAR portion of the skeleton (Pl. LX. fig. 4) the centra, neural arches, and neural spines, the articulating processes, and the upper transverse processes, are present. Separate alæ, or ribs, are occasionally formed upon the latter. The lower transverse processes are absent, or are represented only by slight prominences (this seen on the side of *D*, Pl. IV. fig. 8. *C* is the upper tr. pr.). The visceral arches, extending from the extremities of the transverse processes, are membranous; and the LINEÆ TRANSVERSÆ in the recti muscles are the only representatives of the *hæmal* elements in this region.

Dorsal vertebræ.

In the DORSAL region (Pl. LX. fig. 5) the same vertebral elements are present as in the loins. The inferior transverse processes are rudimentary (Pl. IV. fig. 7); but the separate *transverse alæ*, or RIBS, which form the chief distinguishing feature of the dorsal vertebræ, are developed to a considerable extent, and descend on the sides of the trunk as parts of the visceral arches. In the case of the hinder dorsal vertebræ the ribs are jointed only with the rudimentary inferior transverse processes; and their lower extremities are free, the visceral arches being incomplete below. Further forwards, the ribs are attached to the upper, as well as to the lower, transverse processes; and the visceral arches are completed, below, by the presence of *hæmal elements*—the STERNUM and COSTAL CARTILAGES. The COSTAL CARTILAGES represent the hæmal *alæ;* and the STERNUM is composed of a number of hæmal *spines* (indicated by the nuclei of ossification, one in the middle line, or one on either side, Pl. XXII.), which are fused together into one bone.

Cervical vertebræ.

In the NECK (Pl. LX. fig. 6) a tendency to subcentral growths is evinced in slight projections on the under parts of the bodies of the vertebræ. The neural arches completely enclose the vertebral canal, above, as in the sacral, lumbar, and dorsal regions; and, at the point of their confluence, two neural spines are formed in each vertebra. The articulating processes project from the neural alæ less than in the back and loins. Both the inferior and the superior transverse processes grow out (Pl. IV. fig. 6, and VI. fig. 2) from the neural pedicle, enclosing between them the foramen for the vertebral artery. The superior process, which is the larger, grows downwards so as to form the outer part of the circumference of the foramen; and it meets, and becomes united, with the inferior process. A separate piece of bone, or distinct rib, is very seldom seen here in man and mammals, though very common in birds and reptiles. In the 7th cervical vertebra, however, the place of the anterior transverse process is often supplied by a distinct ala (Pl. V. fig. 1, *E*), which may remain separate, forming a cervical rib (Pl. VI.).

The axis.

In the AXIS the subcentral formation is more marked than in the vertebræ which are situated further back. The ODONTOID process is the *centrum* of the atlas, detached from that bone and united to the centrum of the axis. It may have an epiphysis at its summit (Pl. VII. fig. 4, *B*); and epiphyses (fig. 3, *A*) may be developed at the under parts of the neural alæ, which run to some distance between the body of the vertebra and the odontoid process.

The atlas.

In the ATLAS it may be a question whether the UNDER part of the RING, against which the odontoid is applied, should be regarded as corresponding with the lower part of the body of the vertebra—that is to say, as a *subcentral* formation; or whether it is an extension of the under parts of the neural alæ. Many circumstances indicate the former to be the correct supposition; but the specimens represented in Pl. VIII. suggest that the part may be a derivative, either from the centrum, or from the neural alæ; just as the uppermost part of the neural arch of the atlas may be formed either by a confluence of the neural alæ alone, or by them with the addition of a neural spine interposed between them (p. 132).

The scapular arch.

The SCAPULAR ARCH, like the pelvic, appears to me to consist of the *hæmal* elements of two vertebræ; the BLADE of the Scapula being composed of two hæmal *alæ* united together; the CLAVICLE representing one hæmal *spine*, and the CORACOID process the other. This arch is connected, beneath, through the medium of the clavicle, with the hæmal spine of the first dorsal vertebra; above, it is quite free. We have, therefore, no osseous clue to assist us in deciding to which of the vertebræ it more especially belongs. Various considerations induce me to assign it to the hinder two of the cervical group; and I believe that it forms the incomplete *visceral arches* of these vertebræ.

Cranium.

In the SKULL the several bones are so locked together, and so modified in shape, in consequence of the sudden expansion of the neural tube and the different uses to which the components of the visceral tube are applied, that it is difficult to recognise, with certainty, the homological relations of the several parts. An additional, and very considerable, difficulty is occasioned by the fact that certain elements of two vertebræ, besides other bones, are united together into that which we call the temporal bone. There seems good reason for the opinion, maintained by Owen and others, that four vertebræ are combined in the construction of the skull. They are, to a certain extent, indicated by the names "Occipital," "Posterior Sphenoid," "Anterior Sphenoid," and "Æthmoid[1]."

Occipital vertebra.

The BASILAR portion of the occipital bone is the *centrum* of the OCCIPITAL VERTEBRA (figs. 9 and 10). It is superficially channelled, upon its upper surface, for the medulla oblongata; and it presents, beneath, in the tubercle to which the pharyngeal muscles are attached, and in other less marked projections, some indications of subcentral growths. The SIDES of the FORAMEN MAGNUM are the *neural alæ*. They are joined to the centrum, beneath: above, they coalesce to complete the circle of the neural arch; or a process of the neural spine

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[1] They may be also called "Occipital," "Parietal," "Frontal," and "Nasal;" or "Auditory," "Gustatory," "Optic," and "Olfactory."

may be interposed between them; or a separate piece may be developed at the point of their junction (p. 238, footnote). The CONDYLES are the *posterior articulating processes;* and the CARTILAGINOUS SURFACE of the JUGULAR PROCESS, on either side, may be the representative of the *anterior articulating process.* The JUGULAR PROCESSES themselves appear to be *transverse processes.* The EXPANDED PART of the bone is the *neural spine.* This may be formed from one or from several centres (p. 238). The MASTOID and STYLOID portions of the temporal bones represent the *transverse alæ.* The LESSER CORNUA of the HYOID bone are the *hæmal alæ;* the BODY of the hyoid is the *hæmal spine;* and the GREAT CORNUA of the hyoid are *diverging appendages,* corresponding probably with the limbs which I have described as appendages to the hæmal parts of the vertebræ. Thus, the hyoid bone, with the stylohyoid ligaments, and the styloid processes[1], complete the visceral arch.

Posterior spenoid vertebra.

The hinder part of the BODY of the sphenoid is the *centrum* of the POSTERIOR SPHENOID VERTEBRA (figs 9 and 11). Its interior is hollowed out, on either side of the middle line, to form the sphenoid sinus. Above, it is prolonged, by means of *supracentral growths,* into the POSTERIOR CLINOID PROCESSES, and the hinder edge of the OLIVARY TUBERCLE; beneath, a slight ridge, which forms the commencement of the ROSTRUM, and upon which the vomer is applied, is a rudimentary *subcentral* growth. The GREAT ALÆ are the *neural alæ;* and the PARIETAL bones are the *neural spine.* The PTERYGOID PROCESSES, both of which grow from the neural alæ, are the *transverse processes.* The SQUAMOUS parts of the temporal bones seem to stand in the same relation to this vertebra that the mastoid parts do to the occipital vertebra, that is to say, they are the *transverse alæ;* and they are connected, beneath, with the LOWER JAW, which is the representative of the *hæmal* elements, and which forms the visceral arch. In the CONDYLOID portions of the lower jaw we may, probably, recognise the hæmal *alæ,* in the RAMI the hæmal *spines,* and in the ANGLES the *diverging appendages.*

Anterior sphenoid vertebra.

The FORE part of the BODY of the sphenoid, which is developed separately from the hinder part, though it subsequently coalesces with it, is the *centrum* of the ANTERIOR

[1] It may be a question whether the styloid processes of the temporal should not be regarded as belonging to the hæmal, rather than to the transverse, elements of the vertebra.

SPHENOID VERTEBRA (figs. 9 and 12). Superiorly, it forms the anterior part of the olivary tubercle. Its lateral parts are so hollowed out, or rather removed, to increase the size of the sphenoid sinus, that the chief constituent is the median plate, which is continuous, behind, with the median plate of the posterior sphenoid centrum, and is prolonged, beneath, into the ROSTRUM, which may be regarded as a *subcentral* growth. The LESSER ALÆ of the sphenoid are the *neural alæ;* and the FRONTAL bone is the *neural spine.* From the under surface of the neural ala, on either side, a bony plate descends, which forms the lateral boundary of the fore part of the sphenoid sinus, and corresponds in position with the pterygoid processes of the posterior sphenoid vertebra. I regard this to be a *transverse process.* From it hangs the PALATE bone, which appears to be the *transverse ala,* and which is connected, in front, with the SUPERIOR MAXILLARY bone. The latter represents the *hæmal* parts of this vertebra, and sends off the MALAR bone as a *diverging appendage*[1]. The visceral arch of the anterior sphenoid vertebra is formed therefore by the palate and superior maxillary bones. The fore part of the respiratory tube alone is enclosed by it, and is separated by it from the fore part of the alimentary tube, which passes between the hæmal portions of the two sphenoid vertebræ, to the oral orifice.

Æthmoid vertebra.

The median plate of the ÆTHMOID bone, which is in a line with the median plates of the two preceding centra, may be regarded as the *centrum* of the ÆTHMOID VERTEBRA (figs. 9 and 13). It is prolonged, superiorly, into the CRISTA GALLI, which is *supracentral.* The CRIBRIFORM PLATES are indicated to be the *neural alæ* by their perforation for the transmission of nerves and by their position; and the NASAL bones are the *neural spines.* The LATERAL MASSES of the æthmoid are the united *transverse* and *pleural* elements. The VOMER, which is in a line with, and forms a continuation of, the rostrum of the sphenoid, I regard to be the inferior, or *subcentral* part of the æthmoid centrum. It carries, at its extremity, the INTERMAXILLARY bones, which represent the *hæmal* elements. In this vertebra, therefore, a complete neural arch exists only at the fore part, where the neural alæ just come into contact with the neural spines; it is very small, and transmits the

[1] The LACHRYMAL is regarded by Owen as a *Muco-dermal* bone; but its size and connections in lower animals lead me to think that it is a member of the vertebrate skeleton. Perhaps it may be regarded as a second appendage to the superior maxilla.

nasal branch of the fifth pair of nerves. The visceral arch is still more incomplete, the transverse elements being connected with the hæmal elements of the anterior sphenoid vertebra, which run on, beneath them, to join the vomer and the intermaxillaries.

Sense- and splanchnic-cartilages and bones.

There are some other cartilages and bones in the skeleton, which have not been included in the above summary, and which do not belong, directly, to the vertebral system, but are developed in connection with the organs of sense or with the viscera, and the office of which is to minister, especially, to those organs and viscera. Such as are related to the organs of special sense are commonly called "*Sense Capsules*" or "*Sense Bones.*" They lie in the head; and some of them are closely united with the other cranial bones. In connection with the EAR are the PETROUS and TYMPANIC portions of the temporal bone, the OSSICLES and the external CARTILAGES. In connection with the EYE are the TARSAL CARTILAGES; and in connection with the NOSE are the TURBINATE bones, and the CARTILAGES of the nasal orifice. The cartilages and bones which are developed in connection with the viscera are called "*Splanchnic.*" They are the TEETH (unless these be regarded as parts of the dermal skeleton), and the CARTILAGES of the LARYNX, TRACHEA and BRONCHI.

Homology of the limbs.

The key to the exact homology of the upper and lower LIMBS (figs. 7 and 8), I apprehend, is furnished by the fact that they are placed at opposite ends of the trunk, and that the apposed surfaces of their upper segments have, consequently, been made to correspond with one another. The hæmal constituents of the visceral arches upon which they rest are modified accordingly. Thus the scapula is inclined backwards and the ilium forwards; the hinder edge of the scapula corresponds with the anterior edge of the ilium; and the rough projection near the glenoid cavity, for the attachment of the long portion of the *triceps*—the extensor of the fore-arm—corresponds with the anterior inferior spine of the ilium, which gives attachment to the *rectus femoris*—the long portion of the extensor of the leg; the coracoid process is homologous with the pubes, and the clavicle with the ischium. The posterior surface of the femur corresponds with the anterior surface of the humerus. The upper flexure in the former bone is backwards; the lower flexure is forwards; whereas in the humerus it is just the reverse. The lesser trochanter of the femur, which receives the *iliacus* muscle coming from the inner surface of the ilium, looks backwards; and the lesser tubercle of the humerus, which receives the *subscapularis* muscle coming from the inner surface of the scapula, looks forwards. The outer and inner surfaces of the two bones respectively correspond with each other: thus, the great trochanter of the femur and the great tubercle of the humerus are, both, directed outwards; the rough space for the great *glutæus,* which comes from the tuber ischii and the sacro-ischiatic ligament, is upon the outer side of the shaft of the femur; and the rough space on the humerus for the *deltoid,* which comes from the clavicle and the acromion, is upon the outer side of the shaft of the humerus; the rough space for the long *adductor* muscle, which comes from the spine of the pubes, is on the inner side of the shaft of the femur; and the rough space for the *coracobrachialis,* which comes from the tip of the coracoid process, is on the inner side of the shaft of the humerus; the outer condyle of the femur corresponds with the capitulum of the humerus; and the inner condyle of the femur corresponds with the trochlea of the humerus.

The knee bends backwards, and the elbow bends forwards; the flexure in each case bringing the limb more under the middle of the trunk. The patella, which receives, or is developed in, the extensor of the leg, is on the anterior surface of the knee; and the olecranon, which receives the extensor of the arm, is on the posterior surface of the elbow.

Thus far the homology of the two limbs is easily made out by the application of the principle I have mentioned; but in the distal segments a difficulty arises from the fact that the *corresponding* surfaces of the two limbs are, under ordinary circumstances, directed the *same* way; the palmar and plantar aspects being both directed backwards. And, further, the fibula lies upon the outer side of the leg, and is not articulated with the femur; whereas the ulna, which so many circumstances indicate to be the homologue of the fibula, lies on the inner side of the fore-arm, and is articulated with the trochlea of the humerus.

These three points admit, I think, of explanation from the manner in which the parts are developed. The distal segments of the limbs—the hands and feet—first bud out from the sides of the trunk; and the palm and sole are both directed *down*wards (towards the centre of the embryo). The pollex in each looks forwards—towards the head—the fibula and ulna look backwards, and the knee and elbow would bend upwards. Subsequently, as the proximal segments are formed, the limbs undergo a quarter turn, but in opposite directions. The hinder limb is rotated on its long axis *for*wards; the result of which is that the sole becomes turned backwards, and the fibula outwards, and the bend of the knee is forwards. In the anterior limb the rotation is *back*wards. Consequently, the bend of the elbow is backwards, and the ulna is turned inwards. When the rotation affects the entire limb in the same direction,—that is, when the fore-arm and hand are supine,—the whole of the radius is on the outer side, the thumb is also on the outer side, the palm is turned forwards, and the antagonism between the anterior and posterior surfaces of the two limbs is complete. But in this limb the *distal* segments are made to undergo a slight rotation *for*wards, or in an opposite direction to that of the proximal segments, for the purpose of bringing the hand into the prone position, and of turning the palm towards the ground. This is attended with a twist in the fore-arm. The radius retains its connection with the outer condyle of the humerus, but crosses over the ulna so as to reach the inner side; and, together with the hand, which is carried with it, undergoes a rotation on its axis, so as to give the requisite direction to the palm. Pronation should be regarded as the ordinary or natural position, because it is the most easy, and the one which we assume when placed, upon all fours, on the ground; and we have found it to be the one which is permanent in most of the lower animals (p. 379).

To permit pronation and supination of the fore-arm and hand the radius is confined to the capitulum of the humerus; and, to maintain the strength of the part, the upper end of the ulna is large, and, extending beyond the limits assigned to its homologue, the fibula, plays upon the trochlea of the humerus, and sends up a process—the olecranon—to receive the extensor of the fore-arm.

With regard to the remaining constituents of the limbs—The SCAPHOID bone of the carpus is homologous with the SCAPHOID of the tarsus, although the position is different in the two cases, the scaphoid being placed, in the foot, between the two rows of tarsal bones: the SEMILUNAR bone of the carpus is homologous with the ASTRAGALUS; the CUNEIFORM and PISIFORM, with the OS CALCIS and its Epiphysis; the TRAPEZIUM with the INTERNAL CUNEIFORM; the TRAPEZOIDES with the MIDDLE CUNEIFORM; the OS MAGNUM with the EXTERNAL CUNEIFORM; and the UNCIFORM bone with the CUBOID. The METACARPAL and METATARSAL bones, and the PHALANGES of the two limbs, correspond with one another almost exactly.

TABLE OF CRANIAL BONES.

Sense Bones.	Auditory.			Optic.	Nasal.		
	Tympanic and petrous parts of temporal.	Ossicula auditus.	External cartilages.	Tarsal cartilages.	Turbinate bones.	Cartilage of septum.	External cartilages.

Cranial Vertebræ arranged homologically.

Vertebræ	Central parts.			Neural.			Transverse			Hæmal.		
							Process.		Ala.			
	Central.	Supra-Central.	Infra-Central.	Ala.	Spine.	Articulating processes.	Superior.	Inferior.		Ala.	Spine.	Diverging appendage.
1. Occipital	Basilar part.		Pharyngeal tubercle.	Side of foramen magnum.	Expanded part of occipital.	Condyles.	Jugular process.		Mastoid.	Lesser cornu of hyoid.	Body of hyoid.	Great cornu of hyoid.
2. Post-sphenoid	Post-sphenoid body.	Posterior clinoid. Hinder part of olivary tubercle.	Hinder part of Rostrum.	Great ala of sphenoid.	Parietal.		External pterygoid.	Internal pterygoid.	Squamous.	Condyle of lower jaw.	Ramus of lower jaw.	Angle of lower jaw.
3. Pre-sphenoid.	Pre-sphenoid body.	Fore part of olivary tubercle.	Fore part of Rostrum.	Small ala of sphenoid.	Frontal.		Laminæ on sides of sphenoid sinus.		Palate.	Superior maxilla.		Malar and Lacrymal.
4. Æthmoid	Median plate of æthmoid.	Crista Galli.	Vomer.	Cribriform plate of æthmoid.	Nasal.		Lateral portion of æthmoid.			Intermaxillary bone.		

	Centrum.			Neurapophysis.	Neural spines.	Zygapophysis.	Diapophysis.	Parapophysis.	Pleurapophysis.	Hæmapophysis.	Hæmal spine.	Diverging appendage.
1. OCCIPITAL	Basilar part.			Side of foramen magnum.	Expanded part of occipital.	Condyle.		Jugular process.	*Scapula.*	*Coracoid.*	*Episternum.*	*Fore limb.*
2. PARIETAL	Post-sphenoid body.			Great ala of sphenoid.	Parietal.			*Mastoid.*	*Styloid.*	*Lesser cornu of hyoid.*	*Body of hyoid.*	*Great cornu of hyoid.*
3. FRONTAL	Pre-sphenoid body.			Small ala of sphenoid.	Frontal.			*External angular process of frontal.*	*Tympanic.*	*Condyle of lower jaw.*	*Ramus of lower jaw.*	*Malar and Squamous and Pterygoid.*
4. NASAL	*Vomer.*			*Median and cribriform plates of æthmoid.*	Nasal.				*Palate.*	*Superior maxillary.*	*Inter-maxillary.*	

On this page the terms used by Professor Owen are given; and the bones are arranged according to his plan, the differences from that in the preceding page being indicated by Italics.

DESCRIPTION OF PLATE LX.

Fig. 1. Diagram of an ideal vertebra. *C*, centrum. *NP*, neural process. *NA*, neural ala. *NS*, neural spine. TP^S, superior transverse process. TP^I, inferior transverse process. TA^S, superior transverse ala. TA^I, inferior transverse ala. *HP*, hæmal process. *HA*, hæmal ala. *HS*, hæmal spine.

Fig. 2. Diagram of a human dorsal vertebra, shewing the transverse ala directed downwards and contributing to the formation of the visceral arch (as in fig. 5). *AP*, articulating process. The other letters in this and the following figures indicate the same as in preceding.

Fig. 3. Diagram of a cranial vertebra (post-sphenoidal, see fig. 11), shewing the transverse ala directed upwards and contributing to the formation of the neural arch.

Fig. 4. Lumbar vertebra.

Fig. 5. Dorsal vertebra. *TA*, rib. *HA*, costal cartilage. *HS*, sternum.

Fig. 6. Cervical vertebra.

Fig. 7. Pelvic vertebra, with left lower extremity. *C*, body of sacrum. *TA*, ala of ditto. *TP*, part connecting ala with body of ditto. *HA*, ilium. HS^1, pubes. HS^2, ischium. 1, anterior inferior spine of ilium. 2, great trochanter. 3, rough surface for attachment of gluteus. 4, point of attachment of adductor longus.

Fig. 8. Left scapula and clavicle, with upper extremity. The fore-arm and hand are semi-prone. *HA*, blade of scapula. HS^1, coracoid. HS^2, clavicle. 1, rough surface for attachment of long head of triceps. 2, great tubercle of humerus. 3, rough surface for attachment of deltoid. 4, point of attachment of coraco-brachialis.

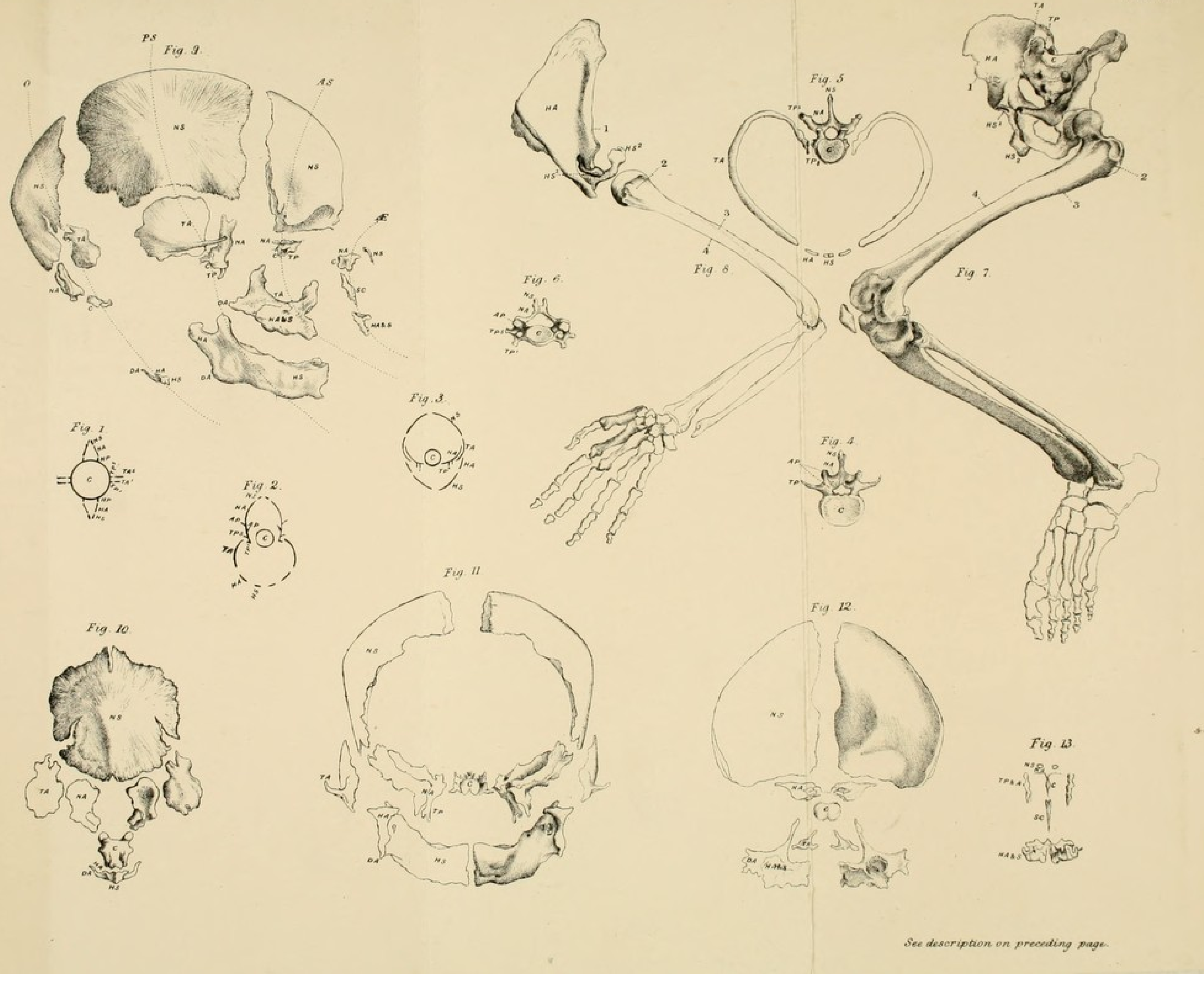
Fig. 9. Cranial bones, at birth, separated. The dotted lines from *O*, *PS*, *AS*, and *Æ*, traverse, respectively, the components of the occipital, the posterior and anterior sphenoid, and the æthmoid vertebræ. The several parts are indicated by the same letters as in the following figures.

Fig. 10. Occipital vertebra. *C*, basilar part. *NA*, side of foramen magnum. *NS*, expanded part. *TA*, mastoid part of temporal bone. *HA*, lesser cornu of hyoid bone. *HS*, body of ditto. *DA*, great cornu of ditto.

Fig. 11. Post-sphenoid vertebra. *C*, hinder part of body of sphenoid. *NA*, great ala. *TP*, pterygoid process. *NS*, parietal bone. *TA*, squamous part of temporal bone. *HA*, condyloid part of lower jaw. *HS*, ramus of ditto. *DA*, angle of ditto.

Fig. 12. Pre-sphenoid vertebra. *C*, fore part of body of sphenoid. *NA*, lesser ala. *NS*, frontal bone. *TA*, palate-bone. *HA*, and *S*, upper jaw. *DA*, malar bone.

Fig. 13. Æthmoid vertebra. *C*, median plate of æthmoid. *NA*, cribriform plate of ditto. *NS*, nasal bone. *TP*, and *A*, os planum and lateral parts of æthmoid. *SC*, vomer. *HA*, and *S*, intermaxillary bone.



See description on preceding page.

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Sutura 160 Fig. 3

§ Post. transverse processes
Sacral ribs (new nuclei of ossifying cartilage) 125, 6

3. M. 1