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Experiments and Observations

IN ORDER TO

ASCERTAIN THE MEANS EMPLOYED

BY THE

ANIMAL ECONOMY,

IN THE

FORMATION OF BONE.

By JOHN HOWSHIP, Esq.

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1815.

FORMATION OF BONE.

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By JOHN HOWSHIP, Esq.

COMMUNICATED BY

DR. ROGET.

Read Feb. 14, 1815.

THE following inquiry was principally suggested by the very beautiful results of the elaborate series of experiments on the composition of Bone and Cartilage, by Mr. Charles Hatchett; and the interesting nature of the subject engaged me to pursue it to the extent I have done.

In order to obtain correct representations of whatever might appear curious in the minute structure of parts, I constructed an instrument on the principle of the solar microscope, by the assistance

of which I was enabled to trace with perfect accuracy as many figures as I thought necessary.

§ I. ON THE FORMATION OF THE CYLINDRICAL BONES OF ANIMALS.

Examinations of the Human Fœtus.

Exam. 1. An embryo eight weeks old was prepared by spreading out the limbs upon slips of glass, and allowing them to dry.

Upon examining these by the compound microscope, the following appearances presented themselves. Rings of bone had been formed in the situation of the metacarpal bones, and of the first and third phalanges. The diameters of these pieces of bone were much larger in proportion to the length of those parts of the limbs within which they were forming, than at the future stages of their growth.

This was most evidently the case in the bones of the hand and foot: it appeared to be a provision for admitting of a considerable increase to the length of the cylinder, before it became necessary to enlarge its diameter.

The soft parts in the situations of the joints, consisted of a yellowish transparent gummy matter*,

* See Fig. 1.

in which no appearance of cartilage could be discerned.

Exam. 2. In the embryo ten weeks old, the extremities of the bones were found connected together by a cartilaginous substance. The rings originally formed, having in the mean time gradually increased in length, had now reached the cartilaginous portions at the extremities. The cartilage connected to the upper end of the bone of the arm was divided into thin sections for examination under the microscope. Several irregular cavities were discovered in the substance of the cartilage, filled with a mucilaginous fluid. In one of these sections a smooth cavity was detected, which extended into an even canal or tube, passing down to the surface of union, between the cartilage and the bone*.

Exam. 3. An embryo about thirteen weeks old, was injected with size and vermillion, and afterwards examined. The cavities within the cartilage, as well as the cancellated parts of the bones, had received the injection freely, but the parts were still too minute to admit of any satisfactory conclusion being drawn from the examination.

Exam. 4. A fœtus of seven months was finely injected, and sections from the cartilages and ossifying surfaces of the thigh-bone were examined by

* See Fig. 2.

the microscope. The cartilage had acquired a comparative firmness in its structure. All the cavities were now formed into canals, traversing the substance of the cartilage in various directions, and several of the largest passed down to the surface of ossification.

In all the sections the ossifying surface was observed to have received a slight tinge of colour, from the general diffusion of the finer particles of the vermillion*.

Exam. 5. Sections from the cartilage of the lower end of the thigh-bone of a child at birth, were next laid in the field of the microscope. A great number of tubular canals were found, many of which terminated immediately upon the surface of ossification. Every canal was filled with a peculiar colourless glairy or mucilaginous fluid.

The edge of the newly formed bone, examined with a strong magnifying power, exhibited an appearance of small short pointed villi, shooting forwards from the surface of the bone into the substance of the cartilage. These villi were only sufficiently opaque to be just visible when a strong light was cast upon them.

All the sections exhibited an apparent alteration in the texture of the cartilage, upon the surface

* See Fig. 3.

connected with the bone. In many instances the cartilage seemed to be more opaque here than elsewhere, this slight opacity forming a line equal to one-twentieth of an inch in breadth.

Exam. 6. In order to ascertain more clearly the primary arrangement of the ossific matter, the lower extremity of the thigh-bone of a child three weeks old was macerated and cleaned. A longitudinal section of the bone was then made, and the surface of the section, including the margin of ossification, pared very smooth with a knife. The piece was afterwards calcined, with a view to remove the remaining animal matter.

In the examination of this, and many successive sections of a similar description, it was observed that in proceeding from the middle of the cylindrical bones, where the medullary spaces are larger, and the cancellated structure stronger, towards the more recently formed extremities of the bone, the ossific masses become more numerous, of a lighter substance, and a thinner texture; the same gradation being continued up to the margin of the newly ossified surface, where the structure is most curiously wrought, and so exquisitely fine as scarcely to admit of description.

From these examinations it was ascertained that the first and earliest state in which the particles of ossific matter become apparent, after they have

formed a mass by their cohesion, may be considered as an assemblage of the finest and thinnest fibres, moulded into the form of short tubes, arranged nearly parallel to each other, and opening externally upon the surface connected with the cartilage. These tubes appeared to correspond in their number to the villi noticed in the last examination. They presented at the surface the appearance of numerous foramina, similar to the smaller set exhibited in Fig. 4. The larger set of foramina seen on the same surface, apparently corresponded in number and situation to the canals already described as existing at an early period in the cartilage, and extending into the bone beyond the surface of ossification.

Exam. 7. In order to observe the changes that occur towards the latter periods of growth, sections were taken from the lower end of the thigh-bone; these were selected from subjects of various ages, and the following were the appearances under the microscope.

In a child eleven months old, the canals within the cartilage were very few in number. At the age of four years these canals were still more thinly scattered, and those that were observed were of comparatively small diameter. When the sections became partially dry, a line one-sixteenth of an inch in breadth, was seen towards the margin of ossification, where the particles of the cartilage had

apparently taken on a new arrangement, so as to resemble parallel lines or fibres. This curious circumstance has been noticed by Haller *.

At the age of eleven years the cartilaginous canals were found to be still diminishing, both in point of size and number; and in the examinations made at seventeen years, it was with great difficulty that a section could be found in which there was any remaining trace of them.

Examinations in Quadrupeds.

Exam. 8. Sections taken from the cartilages and ossifying extremities of the bones of the slink or fœtal calf, were examined in the microscope. The cartilaginous canals were found to be very numerous. They were all filled with a clear mucilage, and the sides of the canals in many parts of the cartilage had the appearance of being stained with blood, although no distinction of blood-vessels could be detected in any of them.

By a series of these examinations it was ascertained, that the cartilages upon which the flat bones of the scapula and ilium are produced, possess a similar organization to that which obtains in the cylindrical bones.

* Prim. Lin. Physiolog.

The posterior extremities were injected with coloured size, and the cartilage then examined in sections, under the microscope. The membranes covering the cartilages and bones externally were beautifully injected; the canals within the cartilage also were equally well injected. Wherever the canals appeared, they were observed to have received the vermillion.

Several oblique sections of canals fell under observation, and in these a membranous lining was very readily discerned, the injected state of the parts rendering the divided edge of the membranous tube very obvious. In some instances this membrane became still more evident, by its having been partially separated from the divided edge of the canal.

Where the canals were found to be divided longitudinally, the membranous lining was in general still attached to the sides of the tube, and the beautiful appearance of the injected membrane was rendered still more brilliant by the abundance and crystalline transparency of its natural mucous secretion.

In many parts of the cartilage where the lining of the canals was finely injected, there was still no appearance of distinct vessels, although in those canals that were opened at their origin upon the external surface of the cartilage, a distinct artery

full of the injected matter might generally be traced, passing inwards to some extent.

In the more internal canals, the usual appearance of the membranous sheath under the microscope was such as it would have been if the injection had passed out from the vessels, and become dispersed in the cellular texture of a fine membrane: had so peculiar an appearance arisen from the accidental rupture of the coats of the arteries, the injected matter must have been detected in masses, which was not in any instance the case.

In those canals that were divided obliquely, the finely and equally injected membrane had the appearance of an uniformly scarlet tube; and by increasing the magnifying power to a very high degree, the individual particles of the vermillion not only became visible, but were seen most distinctly; they were every where found to be very thinly and evenly scattered, indicating the most equal dispersion of the colouring matter throughout every part of the membrane.

In prosecuting this part of the inquiry, a considerable difficulty at first arose out of the following circumstance. The heat of the water in which the preparation was laid previous to its being injected, had so far loosened the membranes from the sides of the canals, that in the subsequent operation of dividing the cartilage into sections, they

were torn from their natural situation, and were consequently found in many parts more or less collapsed. These collapsed membranes had under the microscope very much the appearance of injected arteries, and were at first considered as such, but subsequent and more attentive observation soon enabled me to correct this mistake.

Exam. 9. Sections taken from the cartilages of the thigh-bone of a calf, three weeks after birth, were examined by the microscope, and in order to preserve, as far as possible, the natural appearance of the parts, the blood had been previously coagulated by the application of a heat of boiling water.

The cartilaginous canals were large and numerous. The membranous sheaths also were very distinctly seen. In many of the sections the red blood in the fine structure of the membrane, was evidently continued forward by an extension of the canal for some distance in the bone beyond the surface of ossification.

In order to trace the exact appearance of this ossifying surface, a small cube was cut out from the bone, and calcined. This piece of bone placed in the microscope afforded very distinct appearances. The large canals were seen entering, some at right angles, and others more or less obliquely into the ossifying surface; the intermediate spaces

being perforated by an infinite number of small foramina *.

A similar cube from the femur of the ox, was found on examination, to retain no one character of the above appearances: the surface of the bone beneath the cartilage being uniform and compact in its structure, and without any appearance of the foramina above described.

Exam. 10. In the sucking-pig, the kitten, the young rabbit, and the fœtal lamb (examined at two periods of its growth), the appearance of the cartilages and ossifying bones was in every respect precisely similar to those above-mentioned.

Having thus seen that in the human body, the ox, the sheep, the rabbit, the cat, and the hog, the same purpose of ossification is accomplished by one and the same means, a question naturally occurred, whether the rule might not be a general one, and whether it did not apply also to the larger species of the mammalia?

The cartilages of the whale and elephant, however, are not easily obtained during the progress of their growth; but upon reflection it appeared, that if by examining the surface of ossification the osseous portions of the canals were clearly made

* See Fig. 4.

out, we might fairly infer the existence of the corresponding tubes in the cartilage at an earlier period.

Exam. 11. With this view a section was taken from the extremity of the thigh-bone of a young elephant, and was calcined for examination in the microscope. The two classes of foramina were found, and were exactly correspondent to those before ascertained in the calf.

Examinations in the Cetacea.

Exam. 12. A section taken from the ossifying margin of the scapula of a piked whale, in a young fish only eighteen feet in length, was calcined and examined with the microscope. The two classes of foramina were seen very distinctly, and bore a close resemblance to those found in the elephant and calf *.

Exam. 13. Was made from a corresponding slip of bone from the ossifying margin of the scapula of a young porpoise. This specimen exhibited the double set of foramina very distinctly; they resembled exactly, in all material respects, the appearances observed in the bones of the animals before mentioned †.

* See Fig. 5. † See Fig. 6.

Examinations in Birds.

Exam. 14. Some thin sections were carefully taken from the lower extremity of the injected femur of a goose, at twenty-one days old. The parts were so divided as to include the cartilage with the newly ossified bone. In dividing these sections it was observed, that they could be cut more readily, and were of a more soft and tough consistence than any bone yet examined. Under the microscope these sections appeared remarkably clean and well defined at the edges of their cavities.

A great number of highly injected membranous sheaths were found in all these sections, occupying the canals, and passing from the cartilage into the newly ossified portion of the bone *.

It was observable, however, that these sections, although they gave less resistance to the knife than other bones, had at the first glance an appearance of greater solidity than any bone formerly examined. But when by exposure to the air, these sections became partially dry, a roughness upon the surface became perceptible, even to the naked eye.

Exam. 15. The injected cartilages and bones

* See Fig. 7.

from a duck at seven days *, and a chick at five days old †, were treated as above, and afforded in every respect precisely the same appearances as were noticed in the goose.

Upon consideration, it seemed probable that the superior softness observed, might depend on an excess in the proportion of the animal matter in the bones of growing birds. I was even led to suspect this excess might be so considerable, that the minute structure of the bone would be unable to support itself, if exposed to a strong heat. To determine this point I made the following experiment.

The end of the thigh-bone of a goose was divided, and the surface of the section pared smooth. A part of this surface one-eighth of an inch square was then marked, by cutting away a notch from the surrounding part of the bone. This square piece was magnified to the diameter of two inches by the solar microscope, and the figure accurately traced. The bone was then removed, and calcined till the surface was fair and white. It was then replaced in the microscope, and the shade projected was found to be of the same dimensions in all its parts as the outline taken from the same bone previously to its exposure to heat; having neither gained nor lost in any sensible degree even when thus magnified, by the action of the fire.

* See Fig. 8. † See Fig. 9.

This experiment served to unfold the true nature of the ultimate structure, which in the compound microscope appeared to be a light, even, reticulated texture. The interstices by the aid of a considerable magnifying power, became very large and remarkably distinct. From the appearance it was also evident that the particles of the phosphat of lime were in a state of very loose cohesion *.

Every part of these sections gave precisely the same appearance, whether the surface was natural or artificial; nor were the interstices materially larger or deeper in one situation, than they were in another.

In order to contrast the appearance of the ossifying surface of bone in birds, with that in quadrupeds, the cartilage covering the lower end of the femur of a goose, was carefully separated from the injected surface of the bone. The bone was then placed in the solar microscope, and exhibited a very clear and well defined figure, including a larger and a smaller series of foramina. The larger set contained membranous sheaths brightly coloured with the injected matter, of which the smaller set appeared to have received none, or scarcely any.

The openings of the larger series of tubes were

* See Fig. 11.

observed to be uniformly marked by a slight depression, while those of the smaller series were as constantly distinguished by an elevation above the general surface *.

In the goose three months old, the ossific surface assumes a new appearance. It is now laid out so as to present but a single series of foramina, of equal size and comparatively close arrangement. The sections, at this period, exhibit tubes corresponding to the openings found upon the surface, but the more internal parts of the bone are moulded into a new form, and are cavernous, preparatory to the complete establishment of the general cancellated structure of the bone †.

In the full-grown bird, the ends of the bones display a close and even surface. There are now neither foramina upon the surfaces, nor tubes within, the extremities of the bones being converted throughout into an extremely fine, light, cancellated texture.

§ II. ON THE FORMATION OF THE BONES OF THE HEAD.

Examinations in the Human Fœtus.

Exam. 16. In an embryo at about ten weeks, the teguments covering the head were found to be

* See Fig. 10. † See Fig. 12.

extremely vascular, and of a deep crimson colour. On removing the scalp, a part of the superior margin of the frontal bone, covered by its membrane, was cut out with a pair of scissars, and laid upon glass to dry. On examining it by the solar microscope, many small portions of bone were observed, which had been deposited in points entirely detached from the larger ossific radii. These minute nodules of ossific matter, together with the radiated margin of the bone, were comparatively thick, but towards the central part of the bone, the plate was thinner, and consequently more transparent.

This specimen was examined with attention, first as an opaque, and then as a transparent object, for each of these modes has its advantages. To procure a perfectly exact outline, and to shew the precise figure of all the little ossific radii, it was necessary that a strong light should be transmitted; and on the other hand, to ascertain the superior thickness of the smaller masses of the ossific matter, contrasted with the more evenly disposed structure towards the centre of the bone, as well as to shew the earliest appearance of the phosphat of lime, which is deposited in minute granules dispersed through the intermediate cellular structure of the membranes, required that the surface should have a brilliant light cast upon it obliquely, for when the light was transmitted, the smaller granules were not discernible.

Exam. 17. In the injected embryo, about thirteen weeks old, the membranous coverings of the head were found replete with the finest arterial ramifications, passing in every direction through the open structure of the ossific radii, between the scalp and dura mater. The reticulated texture connecting the membranes to the bone, with the spaces between the ossific fibres, were abundantly stored with a stiff, glairy, colourless, mucilaginous fluid; a secretion perfectly similar in its sensible properties, to that furnished by the membranes lining the canals in the cartilages of the long bones.

Exam. 18. In a fœtus injected, at about seven months, the integuments of the head were found still highly vascular. On making a division down to the bone, a quantity of gelatinous fluid was found deposited between the scalp and the skull. This matter was effused equally over every part of the cranium, separating the integuments to the distance of a quarter of an inch from the surfaces of the bones.

This jelly was transparent, but had a slightly red tinge, and was readily removed from its situation. Laid upon glass, it very soon lost a part of its bulk, by the oozing of a clear limpid fluid. Upon placing this mass under the microscope, it was found to be beautifully and most abundantly vascular. A numerous assemblage of the finest capillary arteries

very variously inflected, was suspended in this bed of transparent matter.

Seeing that this substance lay in immediate contact with the bones of the cranium, and was furnished with a vascular arrangement peculiar to itself, there could no longer be any doubt of its being the loose cellular state of the fœtal pericranium, loaded with a serous exudation from the vessels in consequence of their being injected; although the greatest magnifying power afforded no distinct trace of cellular web or membranous structure.

By way of experiment, a part of this vascular jelly was laid upon a slip of glass, and exposed to a gentle heat: an aqueous vapour soon arose, and continued to pass off, till at length the gelatin assumed the form of a dried membrane. On examination under the microscope it was found, contrary to expectation, that the brilliancy of the injected vessels, which it had been supposed would be obscured, was not diminished by the evaporation of the moisture.

The dura mater was next examined, and as I had just been contemplating the extensive anastomosis, and continual inflexions of the vessels on the outside of the skull, I was forcibly struck with the contrast in the appearance of the arteries des-

tined to circulate the blood on the inside of the same fabric.

The whole series of the smaller ramifications were found to be disposed nearly at right angles to the principal branches of the arteries, resembling so many straight lines crossing the course of the larger blood-vessels.

It was remarkable, that in many points the smaller vessels had yielded more or less to the injection; some were over distended, and others had been ruptured, allowing the injected matter to escape into the cellular texture. This last-mentioned appearance was equally obvious upon all parts of the dura-matral surface, and was observed to be equally general, even without the aid of glasses, in a former examination, where this membrane had been injected at an earlier period of its growth.

§ III. CONCLUSIONS.

From the foregoing observations, I think myself warranted in drawing the following conclusions.

1. That in the mammalia, the first rudiments of ossification in the long bones are the effect of a secreting power in the arteries, upon the internal surface of the periosteum, which produce a portion of a hollow cylinder; this form of bone having been found antecedent to the evolution of any cartilaginous structure.

2. That at a certain stage of the process, the mode of operating is changed, in order that it may proceed more expeditiously. A cartilage is formed, which, by the nature of its organization, and by admitting of a specific provision of cavities and canals lined with vascular membranes, which secrete an abundant store of gelatinous matter, is adapted to this particular purpose; while at the same time it serves to determine the future figure of the extremity of the bone, by establishing and conducting the ossification, within its own substance.

3. That from the appearance and texture of cartilage, when examined under the microscope, it may be defined,—an even and finely granulated albuminous matter, deposited in the interstitial spaces of an exceedingly elastic bed of a semi-transparent

reticulated structure, which is apparently a modification of gelatin.

4. That from the period when the ossification proceeds in the mode above described, by the medium of cartilage, the process is continued in the same uniform manner till it has completed the growth of the bone. The growth of the epiphyses, and their union with the ends of the bone, are also effected by the same means.

5. That the ossific matter in the cylindrical bones is deposited primarily in the form of fine thin tubular plates: a mode of deposition of all others the most favourable for their being subsequently remodelled, and for facilitating all the subsequent changes of structure they are destined to undergo.

6. That while the circulation in the capillary arteries situated between the cartilage and bone must provide the phosphat of lime; the principal agent in extending the cylinder, and in effecting the subsequent progressive changes of structure, which in a growing bone are continually taking place, appears to be simply the mechanical pressure exerted by the fluid secretions within the medullary cavities of bone, this power operating successively in different directions, according to the particular determination given by the circulation *.

* This opinion, however extensively it may bear, will not appear strained to those who will for a moment consider the general incompressibility of fluids.

7. That the mode of circulation most favourable for ossific action, is a very slow and uniform motion of the blood through the capillary system; and that the numerous inflexions of the minute arteries in the pericranium, and the great weakness, and rectangular mode of giving off the smaller arteries upon the dura mater, as well as the extremely curious appearance of the blood and injected matter, upon the fine membranous linings of the canals in cartilage, indicating, as I believe, something beyond a mere capillary circulation, are to be considered as so many evident provisions for securing this condition.

8. That in the formation of the cylindrical bones, the ossific surface is arranged into tubular plates of two different sizes, constituting a larger and a smaller series; an arrangement by no means essential to the increase of a bone, because in many of the early stages of ossification, and also where the growth is very slow, the larger series is found to be entirely wanting.

9. That the only apparent use of the larger series of tubes, is that of augmenting the quantity of blood circulated through the ossifying structure, so as to increase the rapidity of growth; for they are abundant in animals of quick growth, less numerous in those that reach maturity slowly, and in the same animal I have observed they are employed by nature, or laid aside, in conformity with the

quick or slow developement of structure, which we know actually takes place at the particular period when the examination is made.

10. That in the growth of the cylindrical bones, and of those flat bones that are formed upon cartilage, the deposit of the ossific secretion is in the first instance made around the external openings of the smaller series of tubes, and upon these only. This opinion derives support from the recent appearances of the bones of quadrupeds, but is most clearly established by the characters found upon the ossific surface in the bones of birds, where the gradations of progressive evolution are more readily traced.

11. That in the flat bones of the skull, the circumstances under which ossification takes place, differ materially from those above described. In these the phosphat of lime in combination with the animal mucilage, is occasionally deposited in small detached unequal masses, without regularity, as if merely laid in the way, preparatory to their subsequent application; that these soon become connected with the more central parts of the bone, and are found to decrease in thickness, as they increase in breadth, until they are finally consolidated with the original plate of bone.

12. That the particular simplicity observable in the mode of production of the bones of the skull,

affords a strong argument in favour of the opinion, that pressure variously modified, constitutes one of the most efficient instruments in the hand of nature: for in this instance, the uniform though gentle pressure from the impulse of the circulation, and the constantly increasing volume of contents in the head, must be admitted to be the sole agents in completing that process, which in its commencement had the appearance of being conducted in a comparatively imperfect manner.

13. That the ultimate texture of bone is not laminated, but reticulated, the phosphat of lime being deposited as an interstitial substance; for although from the greater compactness necessary to the bones of quadrupeds, the ultimate structure is not in them so readily traced, yet in the more delicately constructed bones of birds, this mode of arrangement is sufficiently obvious, and may at any time be readily ascertained.

This opinion agrees perfectly with that lately given by a most excellent physiologist*. His experiments were made by the removal of the earthy matter of bone, while mine have turned principally upon the destruction of the gelatinous, or animal principle.

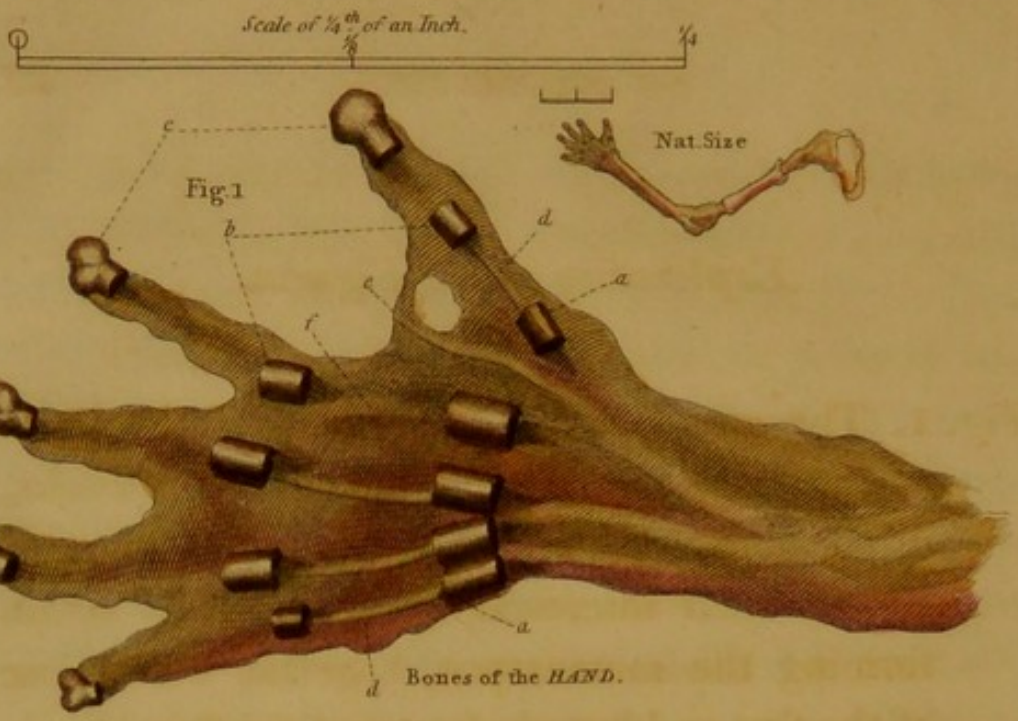
I cannot submit the above experiments and observations to the attention of this Society, without

* Anton. Scarpa de penitiori ossium structura.

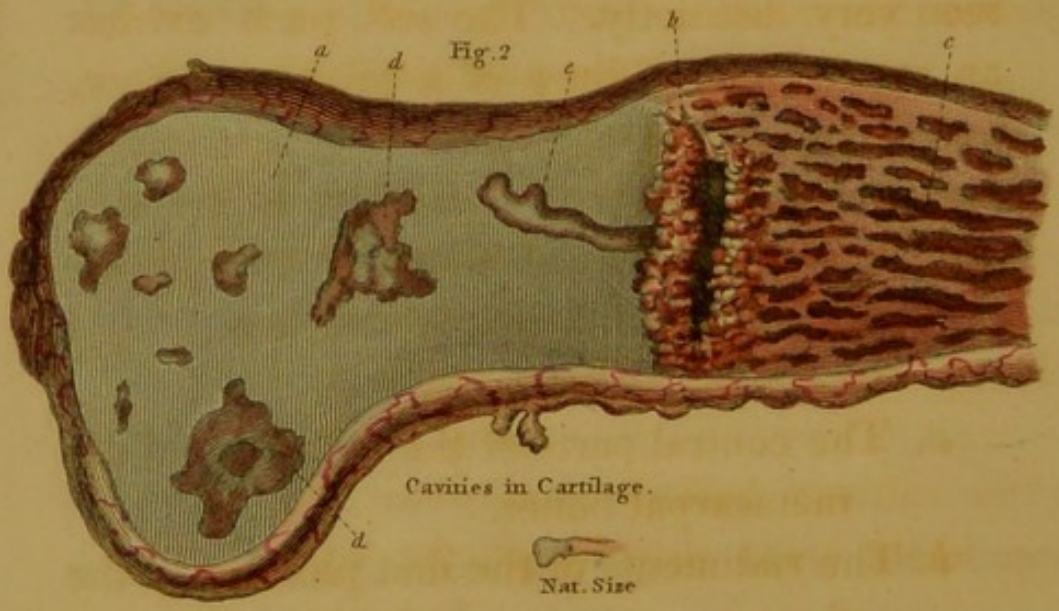
feeling a desire to excuse their numerous defects. The examinations that I have hitherto made, are extremely few in number, and very imperfect. But when the extent of the subject is considered, together with the great uncertainty of the weather in this country, which renders the application of the solar microscope, even in the summer season, extremely precarious, it will be admitted that many years of persevering labour are yet necessary, in order to complete the circle of this inquiry.

Some of the points connected with the above conclusions, are the result of observations already made by others, but it appeared to me difficult, if not impossible, to pass over in absolute silence all those circumstances with which we were before acquainted, and yet explain intelligibly, certain particulars which I believe to be new; for the existence and the organization of the membranous sheaths in cartilage, and their office in furnishing a peculiar secretion, together with the regular arrangement of the foramina upon the ossific surface, and the purposes they are destined to fulfil in the animal economy, are points, which as far as my reading extends, no author has ever mentioned or even glanced at; so that should the evidence of my experiments be deemed sufficiently conclusive, I may perhaps be allowed to consider, that in what regards those particulars, my observations are not altogether devoid of novelty and interest.

PLATE I.

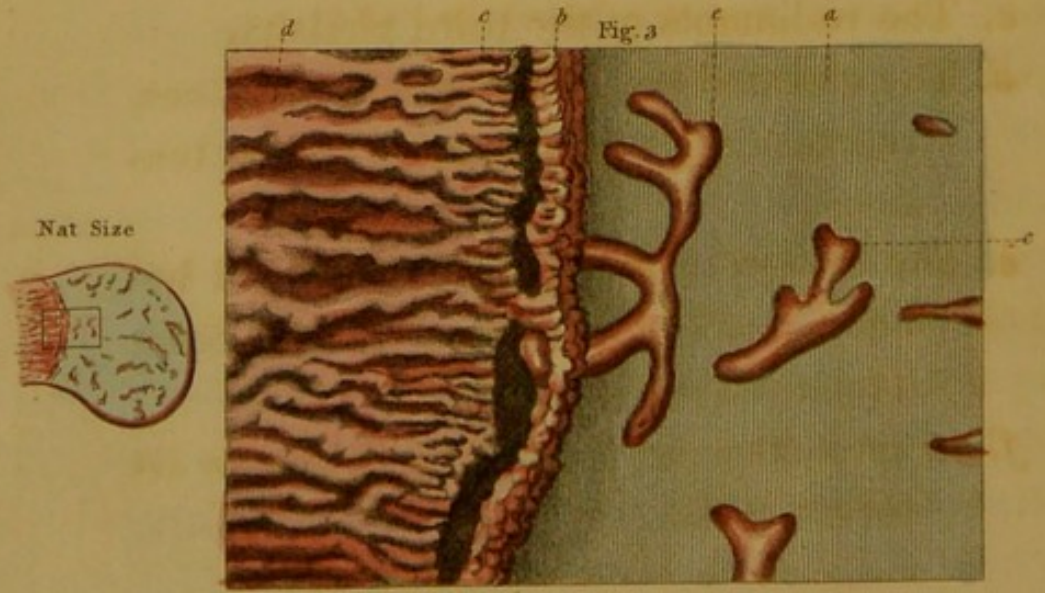


Bones of the *HAND*.



Cavities in Cartilage.

Nat. Size



Canals in Cartilage.

Explanation of the Figures.

Fig. 1. The appearance of the bones of the hand of the human embryo, at about eight weeks, dried upon glass, and as projected on a screen by the solar microscope. The set of bones forming the metacarpus, together with those of the first and last phalanges of the fingers, are seen very distinctly. The soft parts exhibit an appearance of lines of a brighter colour, and firmer consistence than the gelatin; these appear to be the early rudiments of the tendons of the fingers, although at this period there is no trace of muscular structure.

a. The central parts of the cylinders of the metacarpal bones.

b. The rudiments of the first phalanx of the fingers.

c. The rudiments of the third phalanx.

d. The elevated and brighter coloured lines, representing the rudiments of the tendons.

e. The tendon of the indicator, which I believe was accidentally displaced from its natural situation at

f. in spreading out the object, while in its recent state.

Fig. 2. A section from the upper end of the bone of the arm, with the cartilage, from a human fœtus, at about ten weeks; exhibiting the appearance of the cavities that exist prior to the formation of canals in the cartilage.

This figure was traced while the specimen was recent, but the heat of the solar rays had begun to act before the outline could be finished, producing some contraction in the cartilage, and a partial separation of the ossific surface, from the remaining part of the bone.

a. The section of the cartilage.
b. The appearance of the newly ossified surface.
c. The larger cavities within the cylinder of the bone.
d. The irregularly formed cavities within the cartilage, with their membranes injected.
e. One of these cavities, formed into a regular tube, passing down to the ossifying surface.

Fig. 3. The central part of a section from the lower end of the femur, from a human fœtus in the seventh month, injected. At this period, the membranous canals every where received the injection; and the membranes in the

PLATE II.

Fig.4

The two Sets of Foramina. Ossifying Surface.

CALF

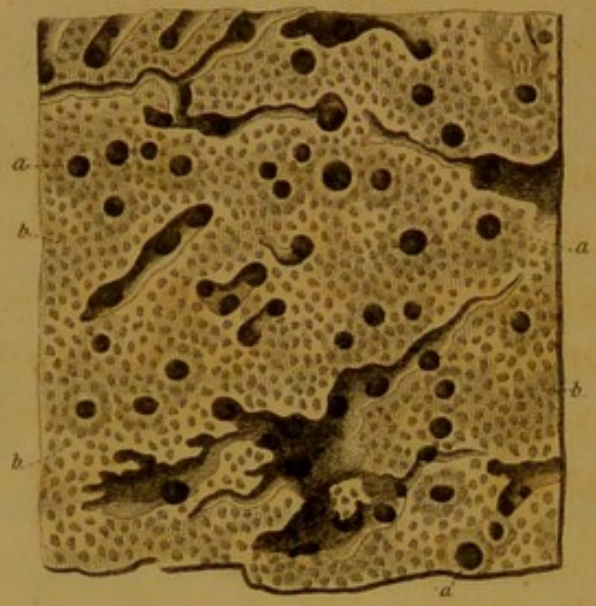
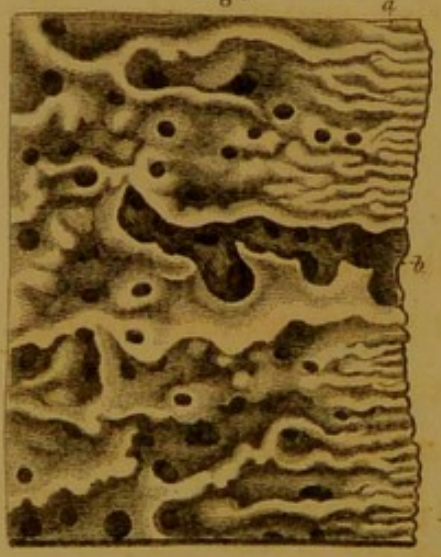
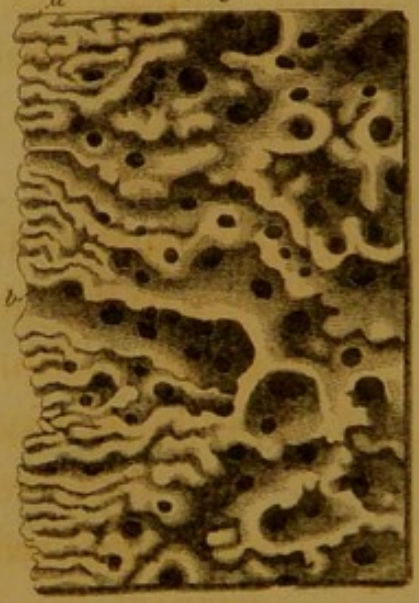


Fig.5



Section from the *WHALE*.

Fig.6

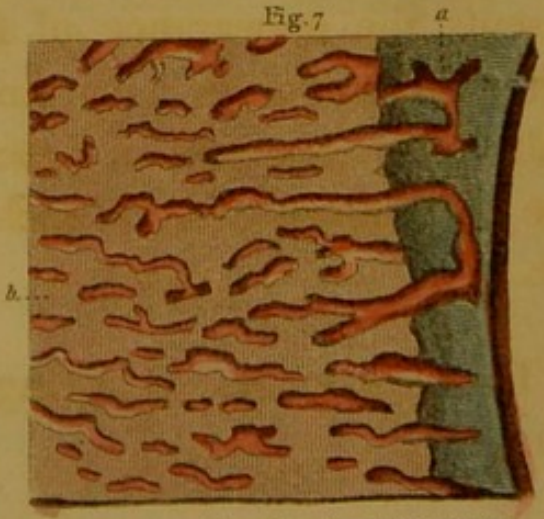


Section of Bone.

PORPOISE

Fig.7

Nat.Size



Membranes injected in Bone & Cartilage.

GOOSE

large canals were injected completely down into the ossifying surface.

The edge of the newly formed bone is seen separated, as in Fig. 2.; and behind this separated margin there is an appearance of an imperfect portion of an osseous tube, in a line continuous from one of the injected cartilaginous canals, into the substance of the bone.

The tubular appearance of the superficial ossific structure is very distinct.

a. The cartilage.
b. The margin of ossification.
c. The parallel tubular arrangement immediately behind the surface of the bone.
d. The larger cavities within the bone.
e.e. The tubes within the substance of the cartilage, with their injected membranes.

Fig. 4. Represents the appearance of the ossific surface after calcination in a specimen taken from a calf. The two sets of foramina may readily be distinguished from each other in this figure.

a.a.a. The larger, or circulating series of foramina.

b.b.b. The smaller, or secreting series of foramina.

Fig. 5. Exhibits the appearance of a section including one of the large canals, in the ossifying margin of the scapula of a piked whale. The internal communications of this canal must have been very extensive. The primary tubular arrangement, and the progressive change in structure from thence into larger spaces and thicker masses, may be readily traced upon this figure.

a. The tubular arrangement of the newly formed bone, the openings of which upon the ossific surface form the smaller series of foramina.

b. The section of a canal belonging to the larger series of foramina.

Fig. 6. Represents a section, similar to the above, from the scapula of a young porpoise. The appearances are very exactly the same as those above noticed.

a. The tubular arrangement.

b. The section of one of the larger series of foramina.

Fig. 7. A part of a section of injected cartilage from the femur of a goose, three weeks

PLATE III.

Canals in Cartilage & Bone.

DUCK

Nat. Size

Fig. 8

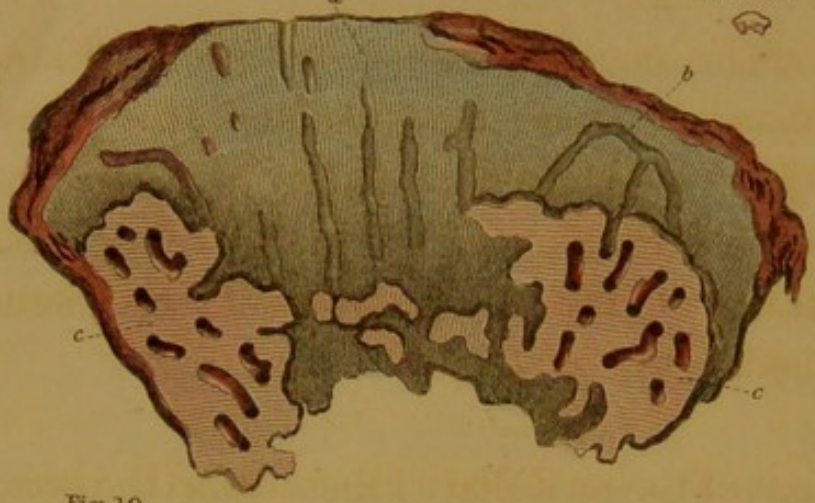
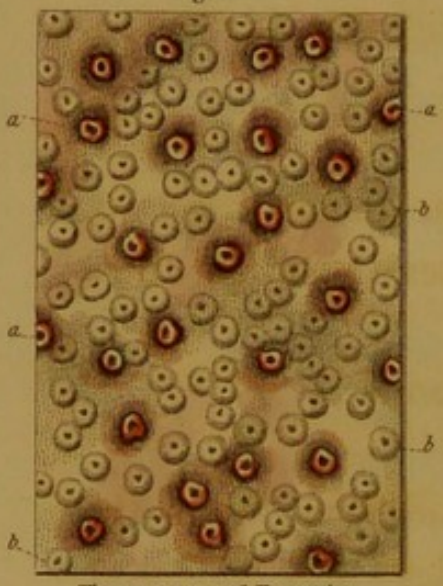


Fig. 10

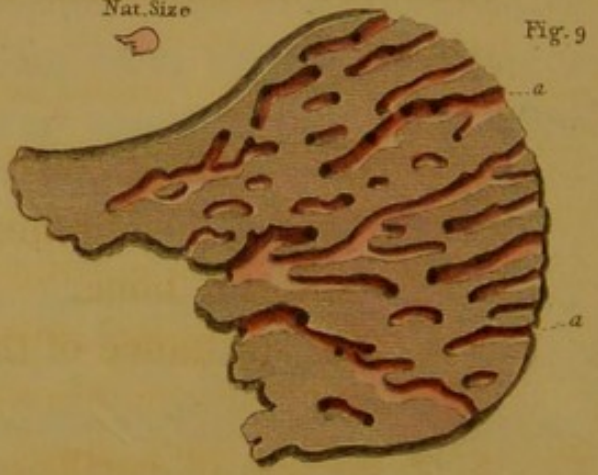


The two sets of Foramina.

GOOSE

Nat. Size

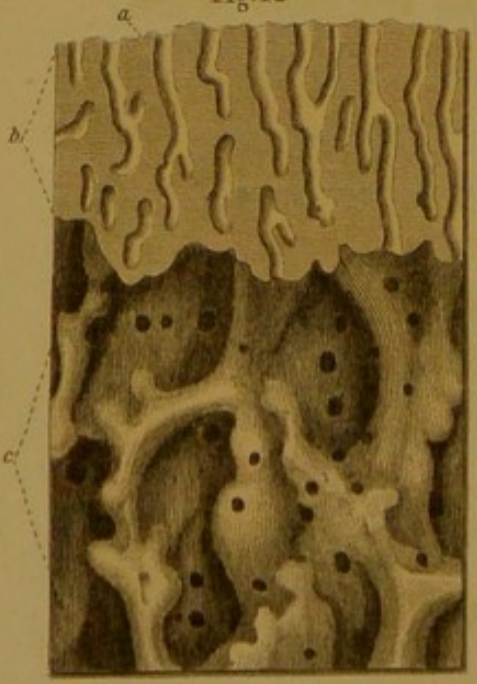
Fig. 9



Canals in Bone.

CHICK

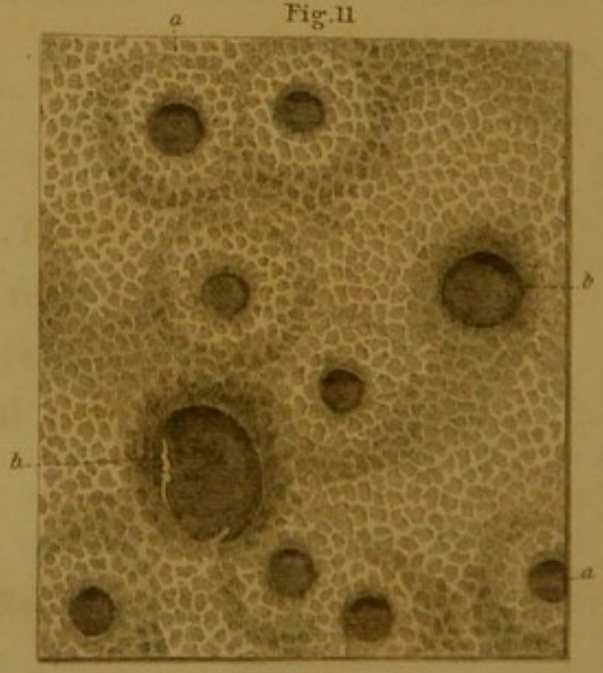
Fig. 12



Canals & Cavities in Bone.

GOOSE

Fig. 11



Reticulated Texture of Bone.

GOOSE

old. The membranes have the same striking peculiarity in their appearance as the corresponding membranes in other animals; for, however great the magnifying power applied, no trace of distinct vessels could be distinguished in any of them.

The sections of the medullary tubes within the bone, shew the membranous lining was highly injected.

a. The cartilage, with the canals, and injected membranes, seen passing down into the bone.
b. The substance of the bone.

Fig. 8. A section of cartilage and bone, from the femur of a duck at seven days old, injected. The membranes lining the canals in the cartilage had not received the injection; those, however, within the cavities of the bone were very well injected.

a. The cartilage.
b. The canals within the cartilage, seen passing down into the bone.
c.c. The bone with its canals, the membranes of which had received the injection.

Fig. 9. A section from the head of the humerus of

a chick, five days old. It shews the tubes within the ossific structure. The corresponding thin section of cartilage exhibited canals answering to each of those entering the bone, but this appearance soon vanished by the drying and shrinking of the cartilage.

a.a. The openings of the canals upon the surface of ossification.

Fig. 10. The injected ossifying surface of bone, from a goose, at three weeks old. This view includes a portion, the extreme length of which was one-eighth of an inch. The larger set of openings are marked by a depression upon the surface, and an injected membrane which in drying has in most of the canals suffered some degree of collapse, exposing more or less of the true circumference of the tube.

The smaller set of foramina may be distinguished by a flattened elevation, which forms a circular border round each of these openings. As to arrangement, these foramina have much less regularity, than is observed upon the bones of quadrupeds.

a.a.a. The openings of the larger or circulating series of foramina.

b.b.b. The openings of the smaller or secreting series of foramina.

Fig. 11. The same surface, exhibited in the last figure, as it appears subsequent to calcination. This view displays the reticulated structure so clearly as scarcely to require an explanation. The image was faint, from its being magnified to an extreme degree, but the character was nevertheless perfectly distinct and satisfactory.

a.a. The elevated openings from the smaller foramina.

b.b. The depressed openings from the larger series.

Fig. 12. Represents the ossific structure in a goose, at three months old. The section is exhibited in its calcined state. This figure demonstrates the progressive change that takes place in the structure of the bone, the more internal parts of which have already assumed the form of large cavernous cells.

a. The surface of ossification.

b. The remaining part of that structure which exists during growth.

c. The appearance of the ultimate or cavernous structure, which extends itself from the centre towards the extremity of the bone.

THE END.

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