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RUDIMENTS

OF

ANIMAL PHYSIOLOGY.

By Dr G. HAMILTON,

FALKIRK.

WILLIAM AND ROBERT CHAMBERS,

LONDON AND EDINBURGH.

sheds.

The function of a negro's black skin is supposed to be the conversion of the sun's light into heat. The heat thus generated remains in the skin, and does not penetrate to the deeper tissue. Being thus provided with a sun-proof armour, the negro can stand an amount of heat that would be fatal to a white man, and he runs hardly any risk of sunstroke.

Bellini's piano, on which he composed his earliest operas, has just been found in the possession of a widow lady of Catania, whose husband bought it for £1 10s. The Catanians have petitioned the owner to present the piano to the town—Bellini's birthplace—that the relic of their townsman may be preserved as a souvenir, and not pass into careless hands.

Edinburgh:
Printed by W. and R. Chambers.

EDITORS' PREFACE.

WHILE it has been justly objected to popular medical guides and dictionaries, that, read under the influence of imperfect knowledge, they tend rather to mislead than to instruct, and probably induce more diseases than they cure, a candid mind must regard in a very different light the various works which have been published of late years for the purpose of conveying a popular knowledge of Animal Physiology. The sole and certain result of these must be, by giving a familiar knowledge of the human organisation and its laws, to put individuals into the best possible condition for *avoiding* diseases—a very different thing indeed from the attempt to *cure* them. The utility of this knowledge to the non-medical community is now beginning to be generally felt, though still some perhaps require to be convinced of it. To such persons, it might be pointed out that, though almost all, from the communications made to them in childhood, or from their own sensations and experience, are enabled to observe some of the more obvious laws of organisation—as, for a familiar instance, those respecting simple overloading of the stomach—there are others of those laws which most persons, for want of knowledge, are constantly breaking, to the great injury of their health. The general prevalence, amongst men of business, of an overtasking of the brain, amongst ladies of a neglect of out-of-doors exercise; the almost universal over-indulgence in stimuli of various kinds; and the tight-lacing of young females; are but a scantling of the errors which we every where see around us, as the result of a want of knowledge of the structure and functions of our physical frames. It is only, indeed, where the infraction of any organic law is followed very immediately by its appropriate penalty, as simple over-eating is by indigestion, that ordinary knowledge observes and records the fact. In the far more numerous, and generally much more important class of cases, where the effect is not to be readily traced to its cause, popular knowledge is completely at fault: nothing can there be of avail but a knowledge to some extent of the human organisation and its laws. It may be true that the knowledge itself will not be sufficient to produce, in all, a proper attention to the rules of health; yet it is pretty clear that the knowledge *may* have such an effect, while, without it, nothing of the kind can be hoped for. It might also be expected, that, were a knowledge of our internal organisation thoroughly familiarised and made present to every mind, public opinion would become engaged in causing individuals of a negligent disposition to observe the laws of health. It would be thought wrong for a man, having a family depending on himself, to expose his life to hazard by daily-endured mental exhaustion; and a young lady, entering a room with a waist reduced to half its proper circumference, would be shrunk from as a kind of monster. Thus knowledge would operate, not only in a direct way upon individuals, but through one individual upon another.

It is for these reasons, and under these hopes, that the Editors of the present Educational Course have long been deeply impressed with the propriety of introducing Animal Physiology as a branch of study into schools. It is, at the very least, a section of natural science of a most interesting and enlightening kind, in as far as it shows a basis in nature for many of our most familiar impressions, otherwise apt to be themes of wondering ignorance. For this reason alone, it might deserve a prominent place in every liberal course of study. But its most important end is to afford a knowledge of the laws on which *health* depends—that element in life without which no one can be useful or happy, while the want of it often becomes a spreading evil. "It has been objected," says an eminent writer on the science, "that to teach any one to take care of his own health is sure to do harm, by making him constantly think of this and the other precaution, to the utter sacrifice of every noble and generous feeling, and to the certain production of hypochondriacal peevishness and discontent. The result, however, is exactly the reverse; and it would be a singular anomaly in the constitution of the moral world were it otherwise. He who is instructed in and familiar with grammar and orthography, writes and spells so easily and accurately as scarcely to be conscious of the rules by which he is guided; while he, on the contrary, who is not instructed in either, and knows not how to construct his sentences, toils at the task, and sighs at every line. The same principle holds in regard to health. He who is acquainted with the general constitution of the human body, and with the laws which regulate its action, sees at once his true position when exposed to the causes of disease, decides what ought to be done, and thereafter feels himself at liberty to devote his undivided attention to the calls of higher duties. But it is far otherwise with the person who is destitute of this information. Uncertain of the nature and extent of the danger, he knows not to which hand to turn, and either lives in the fear of mortal disease, or, in his ignorance, resorts to irrational and hurtful precautions, to the certain neglect of those which he ought to use. It is ignorance, therefore, not knowledge, which renders an individual full of fancies and apprehensions, and robs him of his usefulness." * Another not less eminent writer says—"The obvious and peculiar advantages of this kind of knowledge are, that it would enable its possessor to take a more rational care of his health; to perceive why certain circumstances are beneficial or injurious; to understand, in some degree, the nature of disease, and the operation as well of the agents which produce it, as of those which counteract it; to observe the first

* Preface to Dr Combe's Physiology.

beginnings of deranged function in his own person; to give to his physician a more intelligible account of his train of morbid sensations as they arise; and, above all, to co-operate with him in removing the morbid state on which they depend, instead of defeating, as is now through gross ignorance constantly done, the best concerted plans for the renovation of health." *

As the present little treatise—the first ever prepared in this country for use in schools—is the production of a gentleman not only of respectable acquirements in the science, but who has had much experience in teaching it to popular audiences, the Editors have no doubt that it will be found peculiarly well adapted to its proposed end.

AUTHOR'S PREFACE.

The method of teaching Physiology in Schools, which is recommended in this little treatise, originated from the following circumstances:—Some years ago, while the author was delivering, in Falkirk, a course of popular lectures on this science, he was waited on by the late Mr Downie, teacher of English in the Falkirk Parochial School, who wished to receive an explanation of some parts of the lectures which he did not quite comprehend. Dr Hamilton then learning from Mr Downie that he had attempted to give his pupils some lessons on Digestion and the Circulation, immediately furnished him with his diagrams on these subjects, agreeing, at the same time, to examine, in a few weeks, the progress made by the pupils. This was done, accordingly, and Dr Hamilton was astonished and delighted to find many of the boys well versed in the subject, and all the children evidently much pleased with explaining and copying the diagrams. After this period, instructions in different parts of Physiology were regularly given by Mr Downie, with a success which can be appreciated only by those who witnessed the proficiency of his scholars. In giving these instructions, it has been found that the effectual way to interest the children, and to make them comprehend the necessary descriptions, *is to show them the parts to be explained*. When this is done, a thorough comprehension of very intricate structures becomes quite easy; without it, Physiology never can be taught to children so as to be remembered.

It happens at present, however, almost universally, that before the pupil can be taught, the teacher must himself be instructed; and it is this circumstance that has induced the author to append to each section of the present work, instructions to the teacher. These, it is hoped, will be found both simple and requiring little pecuniary outlay. Almost the only instruments required to make

* Animal Physiology, Library of Useful Knowledge.

the preparations directed, are, a scalpel or good penknife, a pair of forceps (both to be had from the surgical-instrument makers), and a saw. Let the teacher only " put his hand to," and he will find that a few trials will make him quite an adept.

Numerous wood engravings have been interspersed with the text. The teacher should have copies of the principal of these made, of a large size, without letters of reference, to exercise the pupils. A good and very cheap mode of making large diagrams, is to get a frame of the size wished, and to stretch upon it strong smooth machine-made brown paper.* Give this a strong coat of whitening and size (or glue), and, when dry, draw the figures with water-colours and size, of whatever shades are desired. Then cut them off the stretching frame, and nail them, at the top, between a piece of tape and a slip of wood to hang by, and between tape and a roller below. When smaller drawings are wished, different-coloured chalks and cartridge or drawing paper may be used, giving them afterwards a coating of isinglass or skimmed milk. A good size for the larger sheets of diagrams (which are in general preferable) is four feet by six; and a good colour, where particular parts are not required to be distinguished, is burnt umber, to be had from any house-painter.

Additional figures and information may easily be had by referring to Dr Combe's Physiology, Dr Roget's Bridgewater Treatise, Dr Smith's Philosophy of Health, Animal Physiology in the Library of Useful Knowledge, Bell's Anatomy, Edwards's Elemens de Zoologie, Fletcher's Rudiments of Physiology, Caldwell on Physical Education, Prout's Bridgewater Treatise, Bell on the Hand, Brigham on the Influence of Mental Excitement on Health, and the various elementary systems of Physiology, &c. To the work of Dr Edwards the author has to acknowledge himself indebted for many of the illustrations in the following pages.

Both boys and girls received lessons on these subjects from Mr Downie, and the ages of the children generally ranged from nine to twelve years. The subject seems particularly fitted for interesting boys during the latter years of their classical studies, and it is hoped that the teachers of these branches will find that a few hours weekly may be profitably devoted to such lessons. If possible, the teacher should endeavour to make the lessons of one season include sections that have a close connexion with each other; such, for example, as those giving an account of the organic functions, or at least those of Digestion, Circulation, and Respiration. Section VII., giving an account of the parts employed in locomotion, and Section IX., of the Senses, contain lessons which, with a few explanations, may easily be understood separately.

* Furnished by Cowan, paper-maker, Edinburgh, at 4d. per yard, four feet broad, and of any length. In stretching, the sheet should be damped with a sponge, pasted on the frame, and then a hot smoothing-iron passed along the pasted part to dry it first.

ANIMAL PHYSIOLOGY.

SECTION I.

ORGANISATION—LIFE. CLASSIFICATION OF ANIMALS.

1. All natural objects are divided into two great classes, called the Organic and the Inorganic, the distinctive properties of each of which are in general readily recognised, but not easily explained. When the structure of animals and plants is attentively examined, parts are found to be included, to each of which some function or office has been assigned. To these parts the term *organs* has been given, and the whole structure is consequently said to be organised. Thus the heart and stomach of an animal are called organs, their functions being to circulate the blood and to digest the food. Animals and plants are hence said to be Organic Bodies. Inorganic bodies are such as rocks, air, water, &c., which do not possess a structure of the kind mentioned.

2. Organic bodies both possess different qualities from the inorganic, and fulfil different purposes in the economy of the world. Animals and plants are of certain determinate kinds, each kind having certain peculiarities, and each individual of each kind passing through a certain routine of existence, from what may be called its *birth* to its *death*. In the first place, *life* is indispensable to the existence of an animal or a plant. Of this quality we know little more than that it is one which appears essential to organisation, and that, while it is present, organic bodies are able, apparently through its means, to resist the action of various agents which would alter or decompose them if dead. Being in possession of the quality called life, a plant or animal commences the routine of existence—takes in nourishment from food and air, by virtue of which it grows to maturity—is afterwards supported for a certain space by the same means—and, finally, when its purposes in the world have been fulfilled, and it has reached the term allotted to its species, it ceases to live, and is resolved into the elements of which it was formed. In addition to these peculiarities, which attend plants and animals in common, animals possess parts, which give them what is called *sensibility*, and which enable them to fulfil certain purposes of a character quite apart from those ful-

filled by plants. In organic bodies, wherever there is sensation or voluntary motion, we have an animal; where these are wanting, a vegetable. Bichat, an eminent French anatomist and physiologist, has shown still further that this distinction forms a natural division of the complex parts combined in the animal system. Such parts as the heart, the intestines, &c., which act in general independently of our will, and without our consciousness, belong to what he calls the vegetative or organic life. The senses and parts that bring us into relation with our fellow beings and the external world, he calls the animal life. The division is so natural and comprehensive, that it has been adopted by almost all the best writers since the time of Bichat.

3. Animals, as well as plants, are distinguished from each other by peculiarities in their structure, some being of very simple forms, and possessing few organs or parts, while others are complicated in their figures and structure, and exercise a greater number of functions. Something like a regular progress or gradation has been observed from the most simple up to the most complicated, and the distinctions observed between different groups of animals have given rise to *classification*, or an arrangement for scientific purposes. The best existing classification is that formed by Baron Cuvier, usually called from its author the *Cuvierian System*, of which the following is an outline:—

4. The Cuvierian System supposes four Divisions of the Animal Kingdom, the first and simplest being the RADIATA, so called because some of the more remarkable creatures embraced by it have a rayed or branched figure. At the time, though it is still recent, when Cuvier formed his system, the animals placed by him in this division had not been very attentively observed; and it is probable that, as they become better known, the propriety of classifying them otherwise will be acknowledged. Cuvier represented them as composed of a simple homogeneous pulp, moveable and sensible, without any apparent apparatus for the senses; whereas parts different from pulp, and parts which some naturalists consider an apparatus for the senses, have since been in many cases ascertained.

5. The first of the so-called Radiata demanding attention are the Animalcules, or microscopic animals, so named as being only observable by means of the microscope. Apparently the simplest of these, and of all animals, is one termed the Monad, which seems to consist of merely a small round speck of animated matter, but is nevertheless found to possess at least organs of nutrition. It is one of a large class of animalcules, found in water in which decaying vegetable or animal matter

has been infused, and thence called *Infusoria*, or Infusory Animals. Some of these are small to a degree which the mind cannot conceive, being only the 24,000th part of an inch in diameter, and yet possess organs for feeding, breathing, and volition or will. Many hundreds of varieties have been described and classified by Professor Ehrenberg of Berlin, who has also discovered that large strata of siliceous or flinty rock under the earth's surface are composed of the hard parts of these minute creatures, no doubt deposited in remote ages from large bodies of water filled with them.

6. The Hydatid (Fig. 1), a parasitic worm, found in the human and other bodies, is larger, but has also a very simple structure. It has a head with four suckers, and a neck communicating with a bag, which forms its stomach. This sac, when distended with fluid, nearly obliterates the neck, and the animal then forms simply a globular bag. One species of this creature is sometimes found in the brain of the sheep, and gives rise to the disease called by shepherds *sturdy* or *staggers*. These bodies are so exceedingly simple, that it has been doubted whether they really are animals. An opportunity was afforded to many gentlemen in Edinburgh, a few years ago, of seeing a girl with one about the size of a pea within the ball of her eye, in which spontaneous motion appeared manifest. When at rest, it was nearly globular, but every few seconds it elongated itself into something like the form of a bottle of India-rubber.

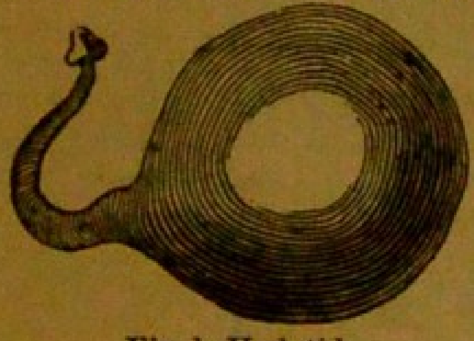


Fig. 1. Hydatid.

7. Of a structure a little more complex is the fresh-water Polype, of which two specimens, perched upon a stalk, are presented in Figure 2. It consists merely of a tube, with arms or tentacula at one extremity, with which it seizes small worms or insects, and conveys them into its interior to be digested; but of so little importance is the surface used for this purpose, that the animal may be turned inside out, like the finger of a glove, without apparently suffering the slightest inconvenience. It may also be cut into numerous pieces, when each separate piece will become a distinct animal; or parts of one polype may be grafted on the body of another.

Fig. 2. Polype.

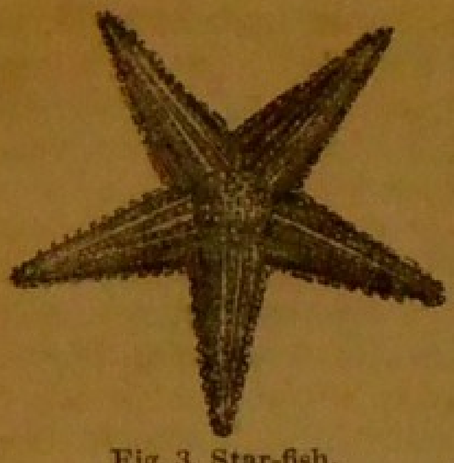


Fig. 3. Star-fish.

8. The Star-fish (Fig. 3), a well-known creature, often found on the beach when the sea has receded, is among the highest of the Radiata. In it we find a stomach distinct from the mass of the body, and teeth surrounding its entrance. We find, likewise, for the first time, parts having the form of feet, used in progression. In the five rays there are no less than 1520 feet of a very curious construction.

9. The next division is denominated MOLLUSCA (molluscous or pulpy animals), in which we find, gradually more and more developed, organs used for progression, a stomach and intestinal canal, a heart, and organs for breathing, as well as several of the senses. Indeed, in some respects the higher orders of this division are superior to the articulated animals which have been placed above them. In their senses and instincts, however, they are generally much inferior. The Oyster, Mussel, and different kinds of snails; the Clio Borealis, a small animal found in multitudes in the northern seas, and which forms the principal food of the Greenland whale; the Nautilus (Fig. 4); all belong to this division. The Sepia or Cuttle-fish (from which the paint of this name is got) is one of the highest of the molluscous division, being possessed of vision and several other senses, as well as a heart; besides parts that serve either as powerful arms for seizing its prey, or feet for walking with.

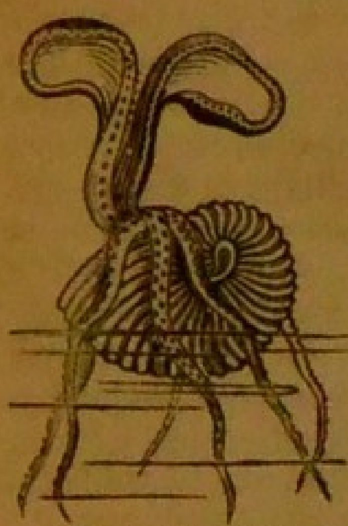


Fig. 4. Nautilus.

10. The third division includes the Articulated or Jointed Animals (ARTICULATA), which, like the Mollusca, may be said to be intermediate between the Radiated animals and the highest division, or Vertebrata. The Radiata and Mollusca are generally aquatic, and limited in their powers of motion; but the Articulata have often a very complete motive apparatus. Among them also are found all the senses, and, for the first time, a symmetrical form of the body, or that form in which two similar halves appear to have been, and really were, at one period of their growth, joined together. This form likewise obtains in man and all the higher classes of animals. In the Articulata, the solid parts or skeleton are always placed exter-

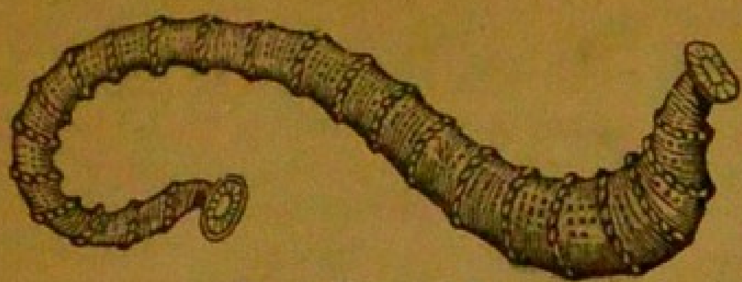


Fig. 5. Pontobdella.

nal to the rest of the body. The Pontobdella, a species of leech (Fig. 5), is a good example of a class of the Articulata, whose bodies consist of a succession of rings. The Crab (Fig. 6), the Spider, the Bee, Beetle, and Butterfly, are other specimens of this division.

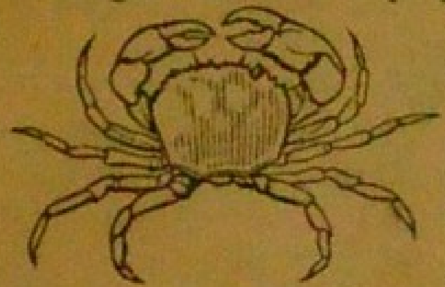


Fig. 6. Crab.

11. The fourth and last division includes a vast series of animals, among which are seen the most elaborate exertions of creative power. The members composing it vary exceedingly in their instincts, appearances, and other peculiarities, but all agree in possessing an internal skeleton. In the simplest form in which this skeleton ever appears, the vertebral column, or back-bone, as it is usually termed, is always present; and hence this, by far the most interesting and best defined division, has been called the VERTEBRATA. In such fishes as the lamprey, the back-bone is merely a continuous soft tube, with slight divisions marked upon it; but as we ascend in the scale, these divisions become more decided, until we arrive at the separate and solid vertebræ of man and the higher animals.

12. Fishes are placed at the bottom of the series of Vertebrata—Reptiles next—then Birds—and finally Mammalia, or suck-giving animals, at the head of which is the human race. Although less highly organised in other respects, fishes have a skeleton of superior character to some of the class of reptiles, which is in some instances very slightly developed. The skeleton of the serpent, one of the class of reptiles, is of a simple structure, though comparatively of great length. It consists merely of a vertebral column with ribs, and a head but slightly developed; but the vertebræ, or little bones composing the spine or vertebral column, are uncommonly numerous, being in some species three hundred, while man has but twenty-four, and the frog only eight. As we rise to higher orders, the offices of the vertebræ become subdivided, and new parts are added, for moving, and for seizing or holding objects (in scientific language, for progression and prehension), suitable to the wants of each species.

13. In the Mammalia, the division of the skeleton into its different regions is complete. Figure 7 is the skeleton of a man,

the highest order of the class. At the top we have the solid skull, to enclose and protect the important brain; the neck (*a′*)

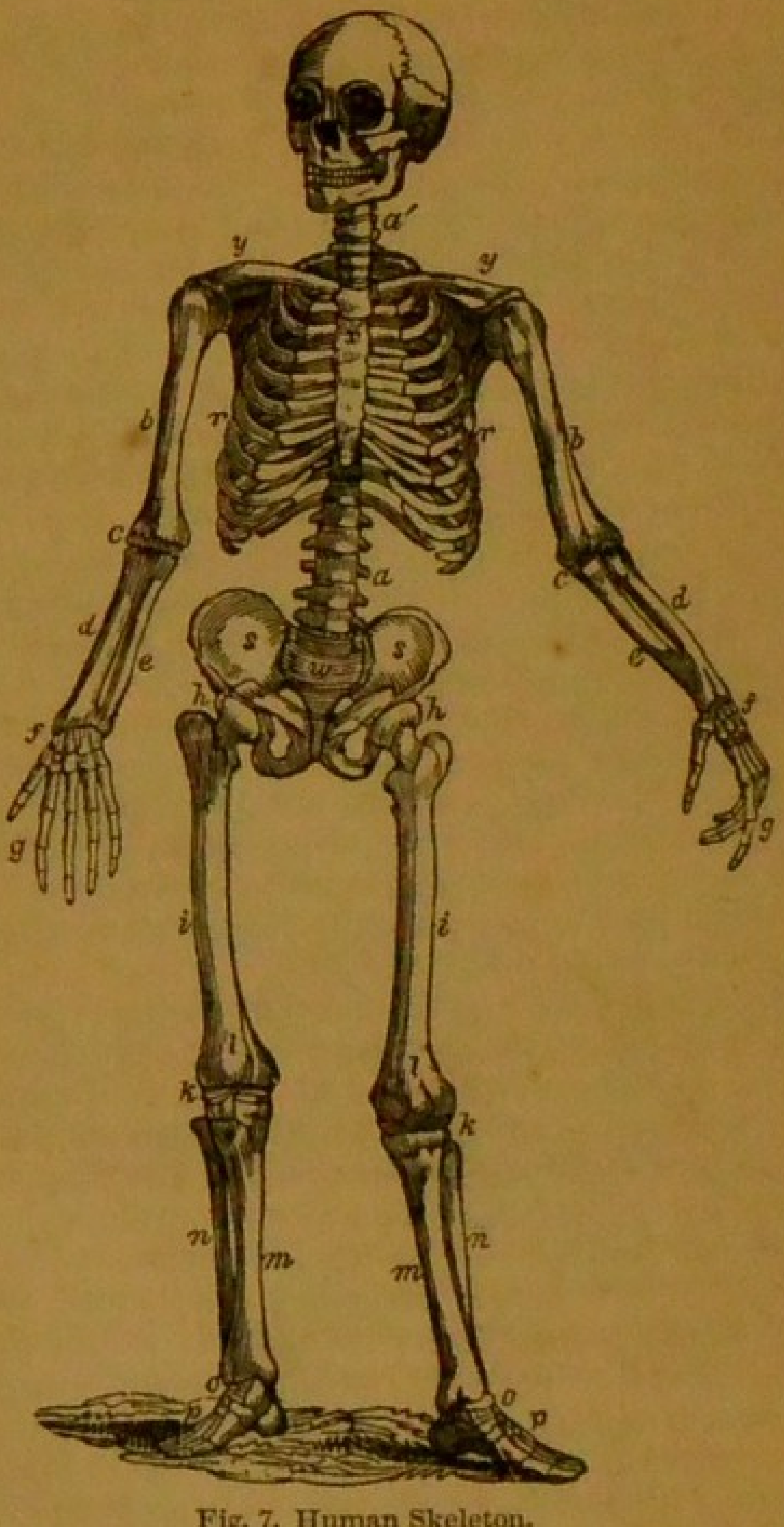


Fig. 7. Human Skeleton.

a′ a, vertebral column, on the top of which is the cranium. *r r*, ribs, most of which meet in the sternum, or breast-bone *x*, so as to form the thorax. *y y*, the clavicles, or collar-bones. *b*, the humerus, or upper arm-bone. *c*, the elbow. *d*, the radius. *e*, the ulna. *f*, the wrist-bones. *g*, the phalanges, or finger-bones. *s s*, the bones of the pelvis. *w*, the sacrum. *h i*, the thigh-bones. *l*, the patella, or knee-pan. *m*, the tibia. *n*, the fibula. *o*, the ankle. *p*, the metatarsal or foot bones.

invariably composed, in this class, of seven vertebræ,* showing the uniformity of nature's plan in forming different families; the dorsal vertebræ, or vertebræ of the back, with the attached ribs (*r r*) and breast-bone (*x*), constituting the chest or thorax, to which the anterior extremities are attached; below these, the lumbar vertebræ (*a*), forming the posterior boundary of the abdomen or belly; and, lower still, a strong circle of bones called the pelvis (*s s*), for connecting the inferior extremities with the trunk, and for supporting the bowels. In most of the Mammalia the vertebral column is still farther prolonged in the form of a tail, but in man it terminates by forming the posterior boundary of the pelvis.

14. These parts are variously modified in different species; but the general remark may be made, that the organs of each are connected so closely as to enable an anatomist to tell with certainty, from seeing a single bone, or even a part of a bone, the general form and habits of the animal to which it belonged. This may appear almost incredible, but may easily be illustrated by an example. Let us suppose a properly qualified person to find the broken off lower extremity of the bone called the radius (Fig. 7, *d*). He could easily tell, from examining its articulations, whether it was intended to be moveable or fixed. If fixed, as we find it in the horse or cow, then he would infer that it served as a solid support to the body, but was not meant to be used in seizing objects, as in man, the cat, monkeys, &c., in all of which it is moveable. But if the animal did not seize objects, it could have no use for claws, and would undoubtedly in their stead have hoofs. Hoofs, again, always imply a vegetable feeder, with grinding teeth, a particular form of alimentary canal, a certain conformation of the spine, &c.; so that it will thus be seen, that, from this broken piece of bone, a good general idea of the size, form, and habits of the animal, might be formed.†

15. Such reasonings as the above, it will be observed, are all grounded upon the supposition that the animal frame has been put together upon rational principles. This will become abundantly evident as we proceed with our subject. We shall

* The sloth appears, but only appears, to be an exception.

† Dr Buckland, in his Bridgewater Treatise, relates a fact admirably exemplifying what has been stated. A good many years ago, a few of the bones of an extinct species of animal had been found, before the general form of the animal was known. From these bones, Mr Connybeare, a celebrated geologist, set himself to construct an animal such as he supposed that to which the bones belonged would be. Some years afterwards, a complete skeleton of this singular animal, the Plesiosaurus, was discovered, with which Mr Connybeare's drawing was found in a surprising degree to correspond.

quickly discover that no organ stands isolated, but that each has intimate relations with the rest, always forming a harmonious whole; and that, whether we examine the structure of the individual parts, or their relations, we must equally feel that all has proceeded from the hand of an infinitely wise and good Creator.

[A proper acquaintance with the classes of the Vertebrata is so important, that we have appended the following table of their chief characters, taken from Edwards's "Elemens de Zoologie," an admirable work for the student of natural history. The teacher should have these tables transcribed on a large scale, and as the pupil gains a knowledge of the different organs, exercise him in the details by frequent examinations. In order, also, to render more intelligible our allusions to Cuvier's classification, we have given a condensed view of the vertebrate classes and orders, with examples.

An excellent plan for impressing on the minds of children Cuvier's four great divisions of the animal kingdom, is to make a large diagram, with drawings of each placed under their respective heads. Numerous appropriate figures may be found in Dr Roget's Bridgewater Treatise, vol. i., pages 165, 227, 258, 271, 283, 411, 441, 447, 530; in Grant's Comparative Anatomy; and in Edwards's Zoologie, &c.]

OUTLINE OF CUVIER'S CLASSES AND ORDERS OF THE VERTEBRATA.

Class I.—Mammalia.

Order.

1. Bimana (two-handed). Man.
2. Quadrumana (four-handed). Monkey, Ape, Lemur.
3. Carnaria.
   - Cheiroptera (wing-handed). Bat.
   - Insectivora (insect-eating). Hedgehog, Mole.
   - Plantigrada (foot-walking). Bear, Badger.
   - Digitigrada (toe-walking). Dog, Cat, Lion, Weasel.
   - Amphibia (doubtful, or belonging both to sea and land). Seal, Walrus.
4. Marsupialia (pouch-nursing). Kangaroo, Opossum.
5. Rodentia (gnawing). Rat, Hare, Beaver, Squirrel.
6. Edentata (wanting teeth). Sloth, Ant-eater, Armadillo.
7. Pachydermata (thick-skinned). Horse, Elephant, Hog.
8. Ruminantia (cud-chewing). Ox, Deer, Sheep, Camel.
9. Cetacea (whale-like). Whale, Dolphin, Narwhal.

Class II.—Birds.

1. Accipitres (hawk-like). Eagle, Vulture, Owl.
2. Passeres (sparrow-like). Sparrow, Thrush, Lark, Crow, Swallow.
3. Scansores (climbers). Parrot, Cuckoo, Woodpecker.
4. Gallinæ (hen-like). Peacock, Pheasant, Pigeon.
5. Grallæ (stilt-legged). Stork, Snipe, Plover.
6. Palmipedes (web-footed). Duck, Goose, Swan, Pelican.

Class III.—Reptiles.

1. Chelonia (tortoise-like). Tortoise, Turtle.
2. Sauria (lizard-like). Crocodile, Lizard, Chameleon.

3. Ophidia (serpent-like). Viper, Boa, Serpents.
4. Batrachia (frog-like). Frog, Newt, Salamander.

Class IV.—Fishes.

1. Acanthopterygii (thorn-rayed). Perch, Mackarel.
2. Malacopterygii (soft-rayed). Salmon, Cod, Herring, Eel.
3. Lophobranchii (loop-gilled). Pike-fish, Pegasus.
4. Plectognathi (jaw-joined). Sun-fish.
5. Chondropterygii (gristle-rayed). Shark, Lamprey, Sturgeon.

CHIEF CHARACTERS OF THE CLASSES OF THE VERTEBRATA.

Mammalia.	Birds.	Reptiles.	Fishes.
Viviparous.	Oviparous.		
With teats.	Without teats.		
Globules of blood circular.	Globules of blood elliptical.		
Blood warm.		Blood cold.	
Breathe by lungs.			Breathe by gills.
Respiration simple.	Respiration double.	Respiration simple.	
Circulation double complete.		Circulation double incomplete.	Circulation double complete.
Heart with four compartments.		Heart usually with 3 compartments.	Heart with 2 compartments.
Skin furnished with hairs.	Skin furnished with feathers.	Skin naked or furnished with scales.	
Members organised in general for walking.	Anterior members organised for flight.	Members organised in general for walking.	Members organised for swimming.

SECTION II.

MASTICATION—DEGLUTITION—DIGESTION.

16. The details which follow, refer, for the most part, to the sciences of Anatomy and Physiology, the former of which treats of the structure of animals, the latter of their functions, or of those phenomena which are peculiar to life. It is chiefly of the Physiology of the higher Vertebrate Orders, and particularly of Man, that we design at present to give some account; and in doing this we shall keep in view the important division of Bichat, into the organic or vegetative, and the animal or relative functions, although a slight departure from it will occasionally be necessary, to give connection, and to prevent repetition.

17. The first, because the most essential, processes which engage our attention, are those which relate to the introduction of food into the body, its digestion, and its assimilation.

18. It has hitherto been supposed that many of the lower and more minute creatures possess no cavity for the reception of nutriment, but are supported by the absorption of aliment through the outer surface. Of late, however, so many animals of this obscure kind, formerly thought stomachless, have been discovered to possess alimentary cavities, that it is now probable that no creature whatever is altogether deficient in a stomach. In the Infusoria, such an opening has been discovered, in some instances surrounded on the outside by *cilia*, or a series of hairs, the office of which seems to be to draw food towards the mouth. In the Polypes we find the orifice of the alimentary cavity surrounded in like manner by *tentacula*, or long string-like arms, with which they seize their prey, and convey it to its proper receptacle. In the star-fish the opening of the stomach is surrounded with teeth, and the cuttle-fish, of the division Mollusca, possesses, in addition to its numerous tentacula, a strong beak, like the parrot's, for crushing the shell-fish on which it lives. In Insects we find mandibles and a proboscis or trunk, with a thousand other modifications leading us up to the regular masticating apparatus of the vertebrate division.

19. This *masticating apparatus* consists of several parts. We have, 1st, the teeth for seizing or dividing the food; 2d, the glands which secrete the fluid for moistening the food

and mouth; and, 3d, the tongue and other muscles which move the food from side to side, or carry it backwards to be swallowed.

20. From what was formerly said, it must be evident that the *Teeth* are parts of great importance to the zoologist. They at once give him decisive indications of an animal's habits, conformation, and other qualities. In the adult man they are thirty-two in number, and consist of four different kinds, namely, 1st, of eight incisors, or cutting teeth, in front; 2d, of four cuspidati (pointed), or canine teeth ; 3d, of eight bicuspidati, or small grinders; and, 4th, of twelve molares, or proper grinders. The molares are flat-crowned in the horse, and in the other Herbivora, while the canine are either wanting, or, as in the horse, are rudimentary ; that is, imperfectly developed. The canine are largely developed in the lion (Fig. 8), and in the Carnivora, or flesh-eating tribes, generally, which have also the molares pointed instead of flat.

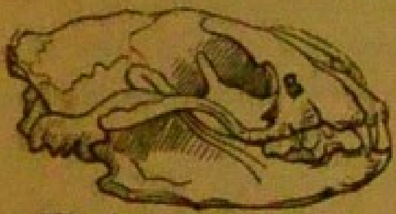


Fig. 8. Bones of Lion's Head.

In insectivorous animals, such as the mole and hedgehog, the molares are formed as in Fig. 9; while in the shark (Fig. 10), and other fishes, which swallow their prey entire, the teeth are all of the same pointed form, and are numerously set, even on the lips, sides of the mouth, and throat.

Fig. 9.

Even the degree in which an animal is carnivorous, or otherwise, is marked very accurately by the more or less pointed form of the teeth. Thus, among the Carnivora, the lion and others of the cat tribe are found to have all the molares pointed except two, which are rounded; while ferrets and polecats have four, and dogs eight, rounded. The teeth of man seem to approximate him, in this respect, to families such as we find among the Quadrumana, or monkey tribes, which, in their natural state, live principally upon fruits, but do not refuse also various kinds of animal food.

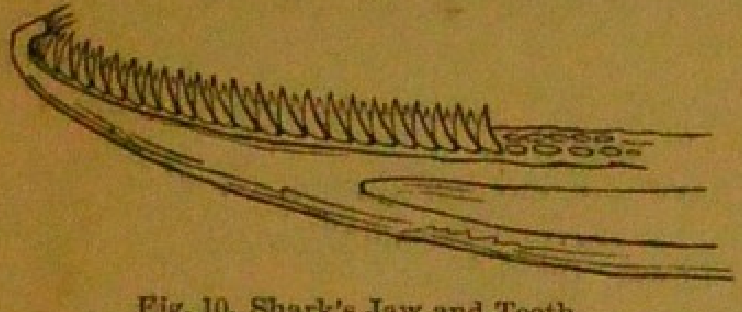


Fig. 10. Shark's Jaw and Teeth.

21. Nothing can be more plain than nature's intention in thus varying the forms of the teeth. Without any exception, these variations have the most precise relation to the instincts of each tribe. It is quite impossible that the sharp teeth of the tiger or shark could ever be used for grinding food, like that of the cow or the horse, or that the teeth of the latter could be

intended for seizing or tearing flesh; and this becomes still more striking, when we observe how the jaws in which the teeth are set have been articulated. In the Carnivora, as the teeth merely cut, the jaws are jointed like the blades of a pair of scissors; but the jaws of the Herbivora, and of Man, allow of a grinding motion. This motion, in the cow and horse, is from side to side, or nearly circular; in the Rodentia, as the rat, &c., the grinding motion is rapidly performed in a longitudinal direction.

22. The human teeth are composed principally of two substances, the *enamel*, and the *ivory*, or *bone*. The enamel is placed externally and on the body of the tooth, and forms only a thin layer. It has ninety-eight per cent. of earthy matter in its composition, is so hard as to strike fire with steel, and is viewed by physiologists as void of vitality, so that when once formed, the teeth never increase in size, and when any part of the enamel is destroyed it is never regenerated. The internal part of the tooth, or ivory, approaches more to the nature of bone, and is shown to possess vitality, from its capability of adhering to other vital structures. It was owing to this property that Duhamel, a physiologist of the last century, and others, were able to transplant the teeth of one person into the jaw of another, to make them grow upon the combs of cocks, &c. Transplanting sound for decayed teeth, threatened, indeed, at one time, to become but too common among the better ranks, until, happily for the interests of humanity, it was discovered that this practice produced disorders more serious than the deficiencies intended to be supplied.

23. Other animals have the enamel differently distributed. The horse, elephant, and other Herbivora, have layers of it which penetrate interiorly. These, from being harder than the surrounding ivory, are longer of wearing down, and hence form projecting ridges, of great importance in triturating their food. The incisors of the beaver, and other Rodentia, want the enamel posteriorly, and, for the same reason, wear soonest in that direction. As a consequence, they always preserve a sharp edge in front, which is of the greatest importance to this gnawing order.

24. The teeth furnish a beautiful example of what has been justly denominated a prospective contrivance. Their presence above the gums at birth would have been only an annoyance. Accordingly, they are then wanting; but nature, which anticipates our needs, places them deep in the jaw, even before birth, to appear in due season. If a section of the jaw of a young animal be made, some of the teeth may be seen just beginning to be formed—others cutting through the bone—while others are passing through their last covering, the gum.

In the child, the teeth generally begin to appear from the sixth to the twelfth month, and the first, or milk teeth, twenty in number, are usually completed about the third year. These again begin to be shed about the seventh year; and the second, or permanent set, is not complete until about the sixteenth or eighteenth year.

25. In the process of shedding, the crown, or that part of the tooth which is coming forward, presses upon the fang of the one already occupying the jaw, and causes its absorption. It is the impossibility of growth, in consequence of the non-vital nature of the enamel, which renders the renewal of the teeth necessary. In consequence, also, of the jaw, during youth, increasing its dimensions, mostly posteriorly, it is necessary that the number of the teeth should be increased, in that situation, in order that no part of the jaw may be unfurnished. For this reason, about the time when the human being reaches maturity, a new tooth rises at each extremity of the range, being four new ones in all, which, from the time of their appearance, are called the *wisdom teeth*. There are some teeth which animals of other species do not shed. The incisors of the Rodentia, and the grinders of the elephant, &c., continue to grow during the whole life of the animals.

26. The second part of the masticating apparatus, is that which moistens the food and mouth. The fluid employed for this purpose is tasteless, and is called *saliva*. It is produced by six bodies called glands, two of which are placed near the angles of the lower jaw (submaxillary), two under the tongue (sublingual), and one on each side, immediately before the ears (parotid). All these open into the mouth by means of small tubes or ducts—the four first under the tongue, the two latter on the inside of the cheeks, opposite the second or third molar teeth of the upper jaw. The fluid trickling from the latter may be seen at any time by turning out the cheeks, and watching their small openings. Its flow is seen to be increased by pressing with the finger from the ear forwards. The camel is supplied with additional salivary glands in its throat, which are of great service in its long journeys over burning deserts. Fishes, again, from living in water, and masticating but little, do not require, and are therefore destitute of, salivary organs.

27. The muscles of the tongue, cheeks, &c., which bring the food under the influence of the teeth, and pass it backwards into the gullet, form the third and most curious part of the masticating apparatus. Indeed, this, which we shall examine in connection with *deglutition*, or swallowing, is undoubtedly among the most admirable and wonderful of the bodily processes. During the comminution of the food, the mouth forms

a shut cavity, bounded by the closed lips anteriorly, the cheeks laterally, and the root of the tongue and the curtain of the palate brought together posteriorly. In Fig. 11, which represents the throat or pharynx cut open behind, *d* is the curtain (*velum palati*), with its central dependent part called the *uvula*, and *c*, the tongue. When the food has been properly moistened, and broken down, it is rolled into the form of a ball, and is passed backwards by the tongue and other muscles into the *pharynx*, which may be conceived of as a kind of bag, having the nostrils (*a a*) opening into it from above; the *mouth* (*b*) opening below these; the *glottis* (*e*), and the *gullet*, or *œsophagus* (*i*), still lower; besides two other openings, called *Eustachian tubes*, which open on its sides, and lead to the internal ear.

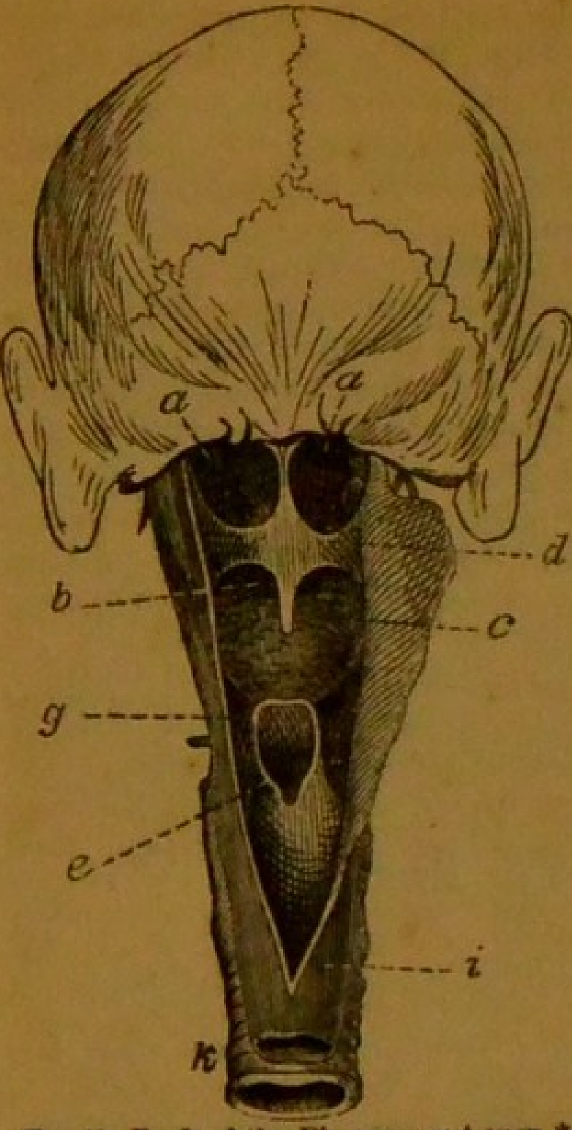


Fig. 11. Back of the Pharynx cut open.*

28. Before the food can get into the pharynx, the curtain (*d*), which we have said is, during mastication, applied closely to the root of the tongue, must be lifted up. But if nothing more were done, the food or drink might pass from the pharynx into any or all of the openings mentioned, the inconvenience attending which, every one has experienced when a morsel of food or a little fluid gets into the nostrils or the windpipe. This, however, is effectually prevented, for the curtain is not only lifted up, but is also instantly applied closely to the back of the pharynx, so as to cut off the communication with the nostrils, and close the Eustachian openings; while, at the same instant, the sides of the glottis, or opening into the windpipe (*e*), are drawn together, and a gristly substance, the epiglottis (*g*), is folded back over it. The food, being still forced backwards, passes rapidly over the epiglottis into the gullet (*i*), the only opening it can

* *a a*, the nostrils. *b*, the mouth. *c*, the tongue. *d*, the curtain of the soft palate. *e*, the glottis, opening into the windpipe. *g*, the epiglottis. *i*, the gullet. *k*, the windpipe.

now escape by, and from it is carried downwards into the stomach.*

29. Complicated as these different actions may appear, we know how accurately they are all performed many hundred times daily, in swallowing our saliva, and in taking food and drink. They may be divided into three kinds; first, those of the cheeks, tongue, and sometimes the curtain, which give us sensations, and are voluntary; secondly, those of the pharynx, which still produce a sensation, but which can be called into operation only when the food or drink comes into contact with the pharynx;† and, thirdly, those of the gullet, which are performed almost entirely without our consciousness.

30. In the examples hitherto adduced, we have found mastication to precede deglutition. Other animals, however, swallow their food first, and comminute it afterwards. This is the case

* It is exceedingly difficult for a person who has not made these parts and actions his study, thoroughly to comprehend them. The action of the curtain, perhaps the most interesting of the whole, may easily be exemplified in the following manner:—We have said first, that the mouth, during mastication, forms a shut cavity, the curtain being applied closely to the root of the tongue. The same takes place when the cheeks are distended with air. If the communication were not then cut off posteriorly, the air would escape by the nostrils. We may even feel the curtain forced back when the lips are kept firm and the distended cheeks are pressed with the fingers. Secondly, we have said that the curtain is lifted up and applied to the back of the pharynx during deglutition, in order to cut off the communication with the nostrils. To show that this is the case, attempt to swallow some fluid or saliva from the mouth, and at the same time keep the cheeks distended. This will be found impossible, because the moment the curtain is lifted up, the compressed air escapes by the nostrils. As an example of the curtain being applied to the back of the pharynx, blow smartly through the mouth, when it will be found that not a particle of air escapes by the nose. The communication with the nose must therefore be cut off. Again, when we blow through the nose, though the mouth be kept open, no air will escape by it. The curtain must therefore be applied to the tongue; nay, while blowing through the nose, we may even see this in the mouth of another, or feel it with our finger in our own. Children born without curtain and palate never can suck, because they cannot make the mouth a shut cavity; and, in this case, or where these parts have been destroyed by disease, deglutition is always difficult.

To form a proper conception of the other parts concerned in deglutition, a preparation, like the one described at the close of this section, must be seen.

† The simple experiment of swallowing our saliva several times in rapid succession, illustrates this well. As long as there is saliva to come into contact with the pharynx, deglutition can be performed; when the saliva is exhausted, our power over these parts is gone. Mr Mayo thinks the muscles in this case are fatigued, and cannot act. This is evidently incorrect, for they instantly act again with ease when saliva is furnished.

with the lobster, the grasshopper, &c., which have their teeth immediately connected with their stomachs. One species of the latter has no fewer than two hundred and seventy teeth. The same purpose is served by the gizzards of granivorous birds, only that the grain is ground between two hard horny surfaces, which act like millstones, their effect being increased by numerous small stones swallowed instinctively by the animal. As many as two thousand of these stones have been counted in the gizzard of a goose.

31. The processes which have been described are all preparatory to the *digestion of the food*, and this takes place in the stomach and intestines. Substances received into the stomach as food must necessarily undergo many changes in their composition before they are fitted to form part of the animal body, but the extent of the change required is proportionate to the difference between the qualities of the nutritive materials in their original and in their assimilated states. Thus, the conversion of vegetable into animal matter necessarily implies a more lengthened process, and a more complicated apparatus, than the assimilation of what has already been animalised. The cow eats grass, and converts it into flesh, by passing it through a series of very complicated organs; and we, in our turn, eat the flesh of the cow, and convert it into the substance of our bodies, but we employ for this purpose a much less complex machinery. As a substitute for such assistance as the cow lends in this case, man has invented the art of cooking, by which he is enabled to extract nourishment from substances that to him in their natural state are quite indigestible. Hence he has much greater variety in his food than any other animal.

32. The agent which nature employs to bring about the decomposition of the food when it arrives at the stomach, is called the *gastric juice*. When milk is taken into the stomach, the active principle of the gastric juice immediately separates the fluid from the solid parts, and this is the reason why milk is always curdled when it is vomited. This principle in the calf's stomach, called the runnet, when infused, is used for the same purpose in dairies.

33. A good many years ago, Dr Stevens of Edinburgh showed very satisfactorily the action of the gastric juice on various substances, by enclosing these in silver balls, perforated with holes, which were swallowed by an itinerant German, who went about exhibiting the singular power he had acquired of swallowing stones, &c. In one of these balls, divided by a partition, were enclosed four and a half scruples of raw beef, and five scruples of raw fish. In twenty-one hours the beef had lost one and a half scruples, and the fish two scruples. In another

ball was placed some beef which had been previously chewed; and in thirty-eight hours after it had been swallowed, it was found quite empty. The balls, in other experiments, contained pieces of roasted turkey, boiled salt herring, raw potatoes and parsnips, and apples and turnips, both raw and boiled, which disappeared in thirty-six hours. He also enclosed in the balls live leeches and worms, which were found, upon examination, not only dead, but completely dissolved. Most probably they were first killed by the high temperature of the body, and were then acted on by the gastric juice, for we observe that this fluid has no action on a body as long as it retains its vitality. Different kinds of worms which naturally inhabit the stomach and intestines, remain free from its influence so long as they are alive, but whenever they die, they are either digested or evacuated. In accordance with the same law, there is the curious observation made by Mr John Hunter, the truth of which has since received repeated confirmations, that the gastric fluid actually, in some cases after death, dissolves and perforates the stomach itself and surrounding structures. Dr Stevens, in another series of experiments, found that the gastric juice of dogs produced no effect upon vegetables, but easily dissolved flesh, bones, and even ivory, while the same fluid in the sheep or the ox made no impression on beef, mutton, or other animal bodies, but acted energetically on vegetable substances.

34. Dr Beaumont, of America, enjoyed a rare opportunity of observing the qualities of the gastric juice, and the process of digestion in the human body. A young Canadian, called Alexis St Martin, who had received the contents of a musket in his left side, after recovering from the effects of his wound, had an opening left into the stomach, through which its operations and contents could be seen and examined. At first this opening was attended with inconvenience, but afterwards a fold of the stomach became fitted to it and filled it up, acting like a valve, so that it could be pushed inwards at pleasure. Dr Beaumont having hired this young man as his servant, made a most elaborate and careful series of observations on different parts of the digestive process, which he has published, and which are well worthy of a perusal. To show the properties and action of the gastric juice, we shall here state a few of these. It had been noticed by previous observers that the fluid obtained from the stomachs of animals is sometimes not in the least acid; but Dr Beaumont has shown, that though this fluid may show no acidity at other times, during digestion, or even when the stomach is mechanically irritated by an India rubber tube, the bulb of a thermometer, &c., it is always acid; and the acidity, which is caused principally by a small quantity of

muriatic acid (spirit of salt), appears to be essential to the proper performance of digestion. Dr Beaumont frequently obtained at one time as much as an ounce of the gastric juice, which appeared to him to be poured out in the stomach of his patient by numerous minute clear points. He says it is a clear transparent fluid, without smell, slightly saltish, and very perceptibly acid. Its taste resembles that of thin mucilage, slightly acidulated with muriatic acid. It undergoes putrefaction with difficulty, and checks its progress in other animal substances. In one of the experiments, St Martin dined at one o'clock on roast beef, bread, and potatoes. In half an hour the contents of the stomach were found to be reduced to a mass resembling thick porridge, and by six o'clock the whole had been dissolved and carried out of the stomach. In other experiments, Dr Beaumont shows that vegetables are much more rapidly dissolved than animal substances, and some of the latter more quickly than others of the same kind. Thus, fried tripe was digested in one hour ; boiled cod, and likewise bread and milk, in two hours ; roasted beef, and also soft-boiled eggs, in three hours ; salted pork in four and a half hours ; hard-boiled eggs in five and a half hours ; and an unusually full meal of salted pork required six hours for digestion. Other experiments, similar to those of Dr Stevens, were also made, in which St Martin breakfasted on fried sausages with coffee and bread, while portions of the sausage, enclosed in a muslin bag, were placed in the stomach. In three hours the stomach was half empty, and the contents of the bag about half diminished ; and in five and a half hours the stomach was empty, and the bag contained only a few small pieces of gristle, and the spices of the sausage.*

35. We have occasionally examples of the power of the gastric juice over still more solid bodies. Cuvier opened the stomach of an ostrich, which contained nearly a pound of bits of iron, copper, pieces of money, &c., corroded and worn down by attrition. Even the human stomach has a similar power, though less frequently called upon to exercise it. An American sailor, who died in one of the London hospitals in 1809, had swallowed

* The gastric fluid has been found equally to produce its specific effects when substances are submitted to its action out of the body. It has lately been ascertained that a fluid very similar in its properties, may be produced by mixing the dissolved mucus of the stomach with a little muriatic acid. The mixture possesses different properties from either fluid singly. A brief account of the case of Alexis St Martin is given in Dr Combe's work on Digestion, and in Mayo's Physiology, and a larger account in a separate volume is published by Dr Beaumont in America, and republished in this country by Dr Combe.

during the ten previous years no fewer than thirty-five clasp-knives. Corroded fragments of upwards of thirty of these were found in the stomach after death. Other cases of the same description have since been recorded.

36. The intestinal canal is divided into the *stomach* (Fig. 12, *b*), *small intestines* (*d d*), and *large intestines* (*e e e*); all of

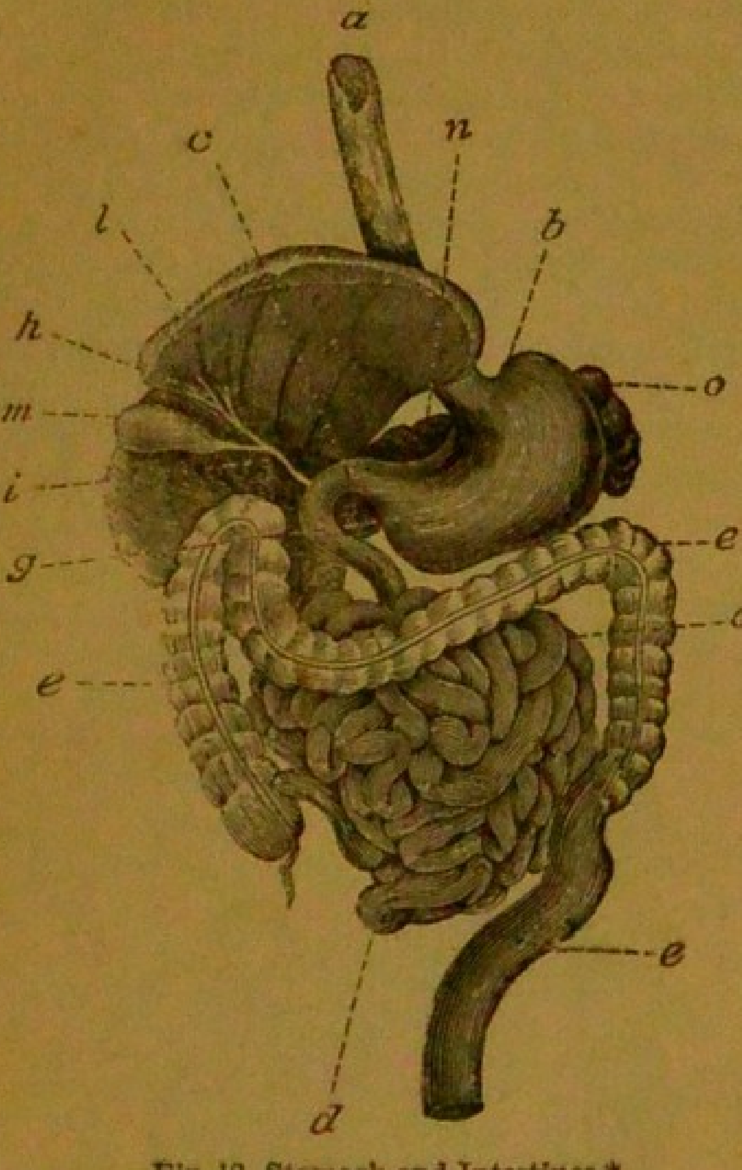


Fig. 12. Stomach and Intestines.*

which are contained in the abdomen or belly, and are seen in their natural situation in Fig. 21. They are all composed of three coats. The outer or serous coat is the smooth surface we see in opening the belly of an animal, the two layers of which unite behind the bowels to form the mesentery (Fig 13, *c c*),

* *a*, the gullet. *b*, the left or cardiac extremity of the stomach. *c*, the right or pyloric extremity of the stomach. *d d*, the small intestines. *e e e*, the large intestines. *g*, the duodenum or commencement of the small intestines. *l*, the liver. *h*, the duct from the liver. *m*, the gall bladder. *i*, the common duct. *n*, the pancreas or sweetbread. *o*, the spleen.

which attaches the intestines to the back-bone; the middle is the muscular coat, which produces what are called the peristaltic or vermicular (worm-like) motions which take place in the propulsion of the food downwards; the inner is the mucous coat, of a soft velvety texture, which produces all the fluids peculiar to this canal.

37. When food is taken into the stomach, it enters by the left or cardiac opening (Fig. 12, *b*). The more fluid parts are quickly absorbed, and the solids begin to be acted on by the gastric juice. A moderate portion of animal food, as has been stated, is dissolved in about two hours, and an ordinary meal generally in about double that time. As the solution advances, the dissolved parts are gradually moved by the action of the stomach towards the right opening (*c*). This portion is thicker than the rest, and is called the *pyloric orifice*, from its supposed resemblance to a porter, in preventing the escape of the undissolved food. The dissolved food, here gathered, receives the name of *chyme;* it is a greyish, pulpy matter, always, in a healthy state,

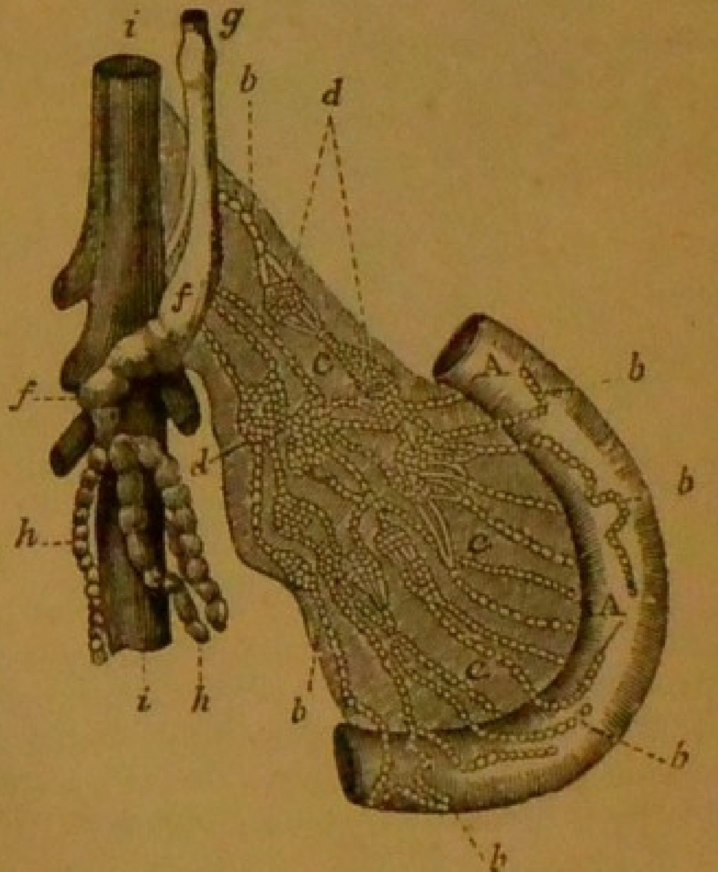


Fig. 13. Lacteals and Jejunum.

A A, a portion of the small intestines (jejunum). *b b b b*, lacteal vessels. *c c c*, the mesentery. *d d*, mesenteric glands. *f f*, the receptacle of the chyle. *g*, thoracic duct. *h h*, lymphatic vessels from other parts of the body. *i*, the aorta.

slightly acid. It passes, in successive portions, from the stomach into the first part of the intestines called the *duodenum* (Fig. 12, *g*), where it mixes with the bile, an alkaline fluid poured out by the *liver* (*l*), and with the *pancreatic juice*, a fluid somewhat resembling saliva, which comes from the *pancreas*, or sweetbread (Fig. 12, *n*), a gland that lies behind the stomach. Immediately after this mixture, an alteration takes place upon the mass, and it is found to separate into two parts, one of which is carried out of the system by the bowels, while the other, called the *chyle*, or the nutritious part of the food, is taken up, principally from the small intestines, by innumerable minute vessels. These have received the name of *lacteals*, from the milk-white appearance they present when distended with chyle, and they are said to terminate on the inner or mucous coat of the intestines by open mouths. Figure 13 shows the lacteal vessels (*b b*) coming from part of the small intestines named the *jejunum* (A). The membrane *c c*, named the mesentery, is that by which the intestine is confined to the spine. The lacteals have a beaded appearance, from the valves with which they are thickly furnished to prevent the return of the chyle. This fluid, in passing through them, traverses small bodies called mesenteric glands (*d*), in which it probably undergoes some alterations. As it advances, the lacteals unite more and more, until they terminate in a vessel called the *receptacle of the chyle* (*f*), where the chyle mixes with *lymph*, a fluid brought from other parts of the body. In the accompanying engraving, other absorbing vessels (*h h*) are seen coming from other parts of the body, also to unite in the receptacle of the chyle. The compound of lymph and chyle then passes through the terminating branch of this system of vessels, called the *thoracic duct* (*g*), a little larger in man than a crow-quill, and by it is poured into veins near the neck, to be mingled with, and to become, the blood.

38. The powers which move the chyle in this course are not well understood, but are considerable; for when the thoracic duct of a live animal is tied, the force from behind suffices to rupture it. The properties of chyle somewhat resemble those of blood. When poured from the thoracic duct, it has a slightly pink colour, and, like blood, separates, upon standing, into a solid and a watery part.

39. These details may serve to give some idea of the process of digestion in man, and animals like him. Among the Ruminantia, or those animals which chew the cud, there is not one, but a series of stomachs, the curious structure of which is familiar to every one in the article of our food called tripe.

Figure 14 represents the four stomachs of the sheep cut open.

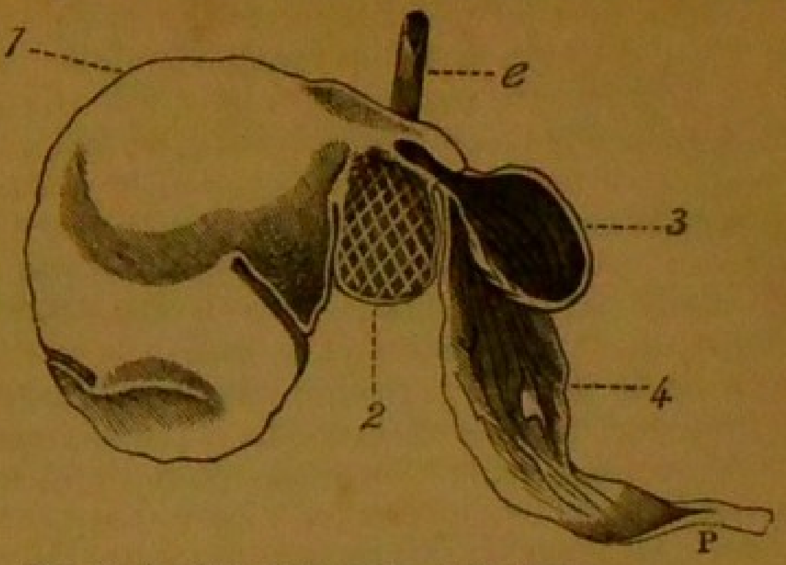


Fig. 14. Section of Stomachs of the Sheep.

e is the gullet opening into the first stomach or paunch (1); the second (2) is called the reticule or king's-hood; the third (3) the many-plies; and the fourth (4) the red, which is the only one having an inner surface like the human stomach. P shows the situation of the pylorus. The Ruminating family possess a voluntary power over their stomachs, which we and most other animals want. They are able, at pleasure, to bring up, into their mouths, the food which has been macerating in the fluids of the paunch and king's-hood, to be again masticated. They then pass it directly into the many-plies, to circulate between its leaves, before getting into the fourth stomach.

40. The object in view in the whole of this apparatus, is the detention of the vegetable food, and the exposure of it, to a large surface. The calf passes its animal food, the milk, directly to the fourth stomach. We can note a similar object constantly kept in view in the comparative lengths of the intestines in different tribes. Thus, the ram has these twenty-seven times the length of its body, the ox twenty-two times, man five and a half times, the lion three times, and the shark little more than three-fourths of its length.

41. The stomach may be regarded as a kind of centre, with which every part of the animal economy sympathises. It is well known that a violent blow in this region has frequently proved instantly fatal; a sudden draught of cold water, when the body is warm, sometimes has the same effect. Professor Christison mentions, that, when he injected a poison, called oxalic acid, into the stomach of a dog, death took place instantaneously, and before it could possibly have been absorbed into the system. It is from this extensive sympathy that the feelings of hunger and thirst must, for the most part, be regarded as indications

merely of the general state of the body. Grief and care, overtasking the brain by long-continued study, indolent inactivity, oppressive labour, every act or habit, in fine, that has a tendency to destroy health, also impairs our appetite for food. The stomach is, in general, a faithful monitor, serving to warn us when we are violating those laws which the Creator has prescribed as necessary to preserve in perfection the animal frame.

42. It can easily be understood how important is the proper performance of the digestive functions. The circumstances most essential in securing this are—1st, and above all, an originally sound constitution. Without this, some part of the animal machinery will continually be found going wrong, and, perhaps, more than any other, the digestive organs. 2d, Temperate habits, regular exercise, and a cheerful mind. 3d, A proper quality and quantity of food. The lower orders in this country suffer from the quality of their food, which is often very indigestible; the better ranks suffer more from the quantity taken. In both, the bad effects are most marked when combined with sedentary or intemperate habits.

43. The alimentary canal is liable to many diseases, and among the most common is inflammation, which affects it variously as its different coats are attacked. When the outer or serous coat is attacked, pain upon pressure is generally intense; when the muscular coat is attacked, there is generally violent twisting pain; but its principal effects are shown in impediments to the passage of the excrement, constituting what is commonly called iliac passion. When the mucous or inner coat is inflamed, it quickly becomes softened or ulcerated (eaten away), and vomiting, purging, or both, are its effects. In the cholera of this country, the whole extent of this coat is frequently affected; in dysentery it is principally the lower portion of it which suffers.

44. The mesenteric glands (Fig. 13, *d d*) occasionally become diseased in childhood, and prevent the chyle from properly entering the system. Children thus affected present the singular spectacle of eating voraciously, at the same time that they are becoming more and more emaciated.

[The teacher will increase the interest of this section, by exhibiting the arrangement of the teeth and jaws in the dog, cat, sheep, hare, haddock, &c. A horizontal section of a horse's molar tooth polished shows the enamel going into the interior. In preparing the skulls or bones of any animal, all that is required is to allow them to macerate in water till the flesh rots off, and then clean them.

To show the parts concerned in deglutition, take a sheep's head, being careful that the butcher has left the upper part of the wind-pipe uninjured. Saw through the whole of the skull and the brain perpendicularly downwards, half an inch anterior to the horns; forcibly separate these two portions of the skull, and detach the posterior from the articulations of the lower jaw and the soft parts with a scalpel, the finger being pushed upwards into the gullet as a guide to prevent the pharynx being injured. This being done, the back part of the pharynx and gullet may be laid open, and the parts seen as in Fig. 11. The lowest portion of the gullet should not be cut, and a cork may be placed in it to show its course. When this has been examined properly, the tongue may be detached from the lower jaw by cutting close to the latter, and its connections with the epiglottis, &c., seen. This preparation is easily made, and at once gives a perfect conception of these complicated parts even to children.

To see the intestinal canal, &c., the abdomen of a hare or rabbit may be opened. The mesentery, liver, stomach, small and large intestines, &c., may be seen; but the latter are considerably different from the human. The sheep's stomachs, as in Fig. 14, are easily got and examined. They should be cut open as shown, and merely well washed with cold water. Note in them the channel formed from the gullet, and the vicinity of the latter to all the stomachs, the great increase of surface produced by their internal structure, foldings, &c., and the thick pylorus at the extremity of the fourth stomach.

In the fowl, the gizzard is a curious object, with its glandular stomach above, and the intestines going off from it on one side.

A short intestinal canal is well seen in the haddock, &c.

As comparatively accessible books in which other appropriate figures to illustrate this section are to be found, we may mention Dr Roget's Bridgewater Treatise and Dr Smith's Philosophy of Health.]

SECTION III.

THE CIRCULATION.

45. In the preceding section we have traced the progress of the food during its mastication, deglutition, and digestion. We have seen it converted into chyle, taken up by the lacteals, and, through the thoracic duct, poured into the veins of the neck. Here we lose sight of it as chyle. In the new system of vessels into which it has entered, it undergoes alterations, all of which are not yet perfectly understood, but which completely assimilate it to the nature of the blood, of which it hereafter forms a part. We are thus brought to consider a second important department of our science, the circulation of

the blood; but first it is necessary to inquire into the nature of the blood itself.

46. With the appearance of *blood*, as it occurs in the higher classes of animals, every one is familiar. When drawn from one of the vessels which immediately receive it from the heart, and which are called arteries, it is of a bright scarlet colour; but when taken, as it usually is in the common operation of bleeding, from a vein, it is much darker, being of the shade called by painters Modena red. When first drawn from the vessel, it is a somewhat glutinous and apparently homogeneous fluid, but, after standing for a short time, it separates into two parts, one a watery part, called the *serum*, the other a more solid part, called the clot, or *crassamentum*. The serum is chiefly composed of water, with a considerable quantity of the same substance as the white of the egg (*albumen*) dissolved in it; so that, if it is exposed to a boiling heat, this coagulates and makes the whole solid. The clot, again, likewise consists of two principal substances, one of which gives it the red colour, and, by repeated washings, can easily be separated from the other, which is a white, tough, fibrous matter. It is known by the name of *fibrin*, and is said to be nearly identical in composition with the part that gives contractility to the muscles.*

47. Although the blood in all animals appears to be of essentially the same nature, separating when out of their bodies into a solid and a serous part, yet, in a large proportion of the lower classes, it has not the same florid appearance which it assumes in most of the Vertebrata. Thus, in insects, this fluid is nearly transparent, while in the caterpillar it has a greenish hue. In fishes, again, it is transparent in the bulk of the body, but it has a red colour in the gills, heart, and liver; and even in the human body, some textures, as the transparent parts of the eye, circulate only a colourless fluid. In certain diseased states of the system, indeed, nearly the whole blood becomes colourless. A man died in Leith about eighteen years ago, who for more than eight months before his death looked exactly like a person recovering from a fainting fit, and his body, after death, was found almost destitute of red blood. An alarming form of the same disease appeared in 1803 among the coal-miners at Anzain in France. Their faces assumed the appearance of

* The following, made by M. Le Canu, is the most recent analysis of the composition of the human blood:—Water, 786.500; albumen, 69.415; fibrin, 3.565; colouring matter, 119.626; crystallizable fatty matter, 4.300; oily matter, 2.270; extractive matter, soluble in alcohol and water, 1.920; albumen combined with soda, 2.010; chloruret of sodium and potassium, alkaline phosphate, sulphate and subcarbonate, 7.304; subcarbonate of lime and magnesia, phosphates of lime, magnesia and iron, peroxide of iron, 1.414; loss, 2.586. Total, 1000.

yellowish wax, and not a trace of blood-vessels could be seen even on the inner parts of the eyelids or mouth.

48. When the blood is examined with a microscope, its florid colour is perceived to arise from numberless extremely minute red globules supended in the watery serum. These have, in every species where they exist, a determinate size and form, being in man of a circular flattened shape, and from the 3000th to the 5000th part of an inch in diameter. In birds, reptiles, and fishes, they get progressively larger, assuming at the same time an elliptical form, and in the skate they are larger than in any other animal hitherto examined. Their number corresponds very constantly to the temperature of the animal, and hence the two divisions of warm and cold blooded. In birds the red globules constitute in general about fourteen or fifteen per cent. by weight of the whole mass, in man twelve or thirteen per cent., and both of these are warm-blooded animals. The red globules in fishes (which are cold-blooded, or only slightly warmer than the water in which they live) amount to about five or six per cent. It is also stated that these globules are in general more numerous in the blood of men than in that of females, and in persons of a sanguine than in those of a lymphatic temperament.*

49. One of the most singular properties of blood, is its power of coagulating. It has been supposed that the globules of blood are really vesicles or bags, the outer portion of which is composed of red colouring matter, while the centre consists of fibrin; and that, during coagulation, the vesicle is burst, and the particles of fibrin adhere to each other. But it has been more recently shown, by the experiments of Babington and Müller, that the fibrin is not contained in the red globules, but in the fluid part of the blood in which they float. When inflammation exists, the separation of the two parts is most complete, the yellow or upper buffy layer being the fibrin. Much beautiful design, as Dr Prout remarks, is probably concealed under this arrangement. One object of it is evident. If the blood did not coagulate, the existence of animals would be most precarious, as, on the slightest injury, they would be liable to bleed to death. Nor is the danger apprehended imaginary, for an unnatural state of fluidity in the blood has frequently, when the most trifling wounds were received, been attended with alarming bleeding, or even with death. A family in Oldenburg lost four children from this cause, and a daughter of the same family had three children who also died of this disease.

50. There must, therefore, evidently be a cause for the fluidity

* These terms will be explained immediately.

of the blood within the body, and many experiments render it highly probable that this depends, to a certain extent at least, upon the vitality of the veins and arteries circulating it. Even the vitality of the blood itself is made more than probable by the experiments of Mr John Hunter. Like the egg, it can within certain limits resist the influence of various agents, such as heat and cold, while it retains life, but yields to them when it dies. An electric shock passed through it, instantly extinguishes its vitality, and this is the reason why the blood in persons struck dead by lightning is always fluid.

51. While physiologists had yet but inaccurate ideas of the uses and structure of different organs, great benefits it was thought might follow from transfusing a healthy animal's blood into a diseased person's body, and some dangerous and even fatal experiments of this kind were performed in France, until the practice was interdicted by law. Of late years the practice has been successfully revived, in cases where great loss of blood has happened, and its previous failure has been shown to have arisen from transfusing the blood of one species into the body of another, in which the globules are of a different size or shape. The blood of a sheep, for example, transfused into a cat or rabbit, causes death in a short time ; and instantaneous death follows the transfusion of blood with circular globules into an animal which has these elliptical.

52. If other substances are mingled with the blood, equally serious effects follow. Farriers produce instantaneous death in horses by blowing air into their veins ; and a person in Paris, a few years ago, who was having an operation performed in which a large vein in the neck had to be cut, from the entrance of air fell over and expired. Many other cases have since been published, in which it is probable death occurred from the same cause.

53. Having made these observations regarding the blood, we must now explain the means employed for its circulation ; and in doing so, we shall first describe this as it takes place in man and in the other Mammalia; for though their circulating system is really the most complex, a knowledge of it forms a key to all the modifications which it sustains in the other classes.

54. The course of the circulation of the blood was unknown until the reign of James I., when it was discovered by Dr Harvey. The ancients knew of the existence of the veins and arteries, but thought that the blood was moved backwards and forwards in the veins, and that the arteries were filled with air. The name of the latter, indeed, is derived from *arteria*, or air-tube. Harvey publicly taught his new doctrines as early as 1616 ; but, with a caution worthy of one whose fame was to be

coeval with our race, spent no less than twenty-six years in amassing materials for his immortal work on the Circulation. The reception it met with, when published, is instructive. Derided by his own profession as a quack, he was looked upon by the vulgar as crack-brained; and in a letter written to a friend at this period, he complains that his practice had suffered seriously since the publication of his book. To the honour of mankind, however, it must be said that he lived long enough to see his system taught in every university in the world.

55. The circulating system in the Mammalia may be said to consist of four principal parts—first, the heart, which is the centre of the whole; second, the arteries, which receive the blood from the heart; third, the veins, which return the blood to the heart; and, fourth, the capillary (hair-like) vessels, which unite the termination of the arteries with the commencement of the veins.

56. Every one knows the appearance of the heart—an ox's or a sheep's, for example. When cut up, it is found to consist of four cavities, two on the right side that communicate with each other, and two similar ones on the left side, which also communicate with each other, but not directly with those

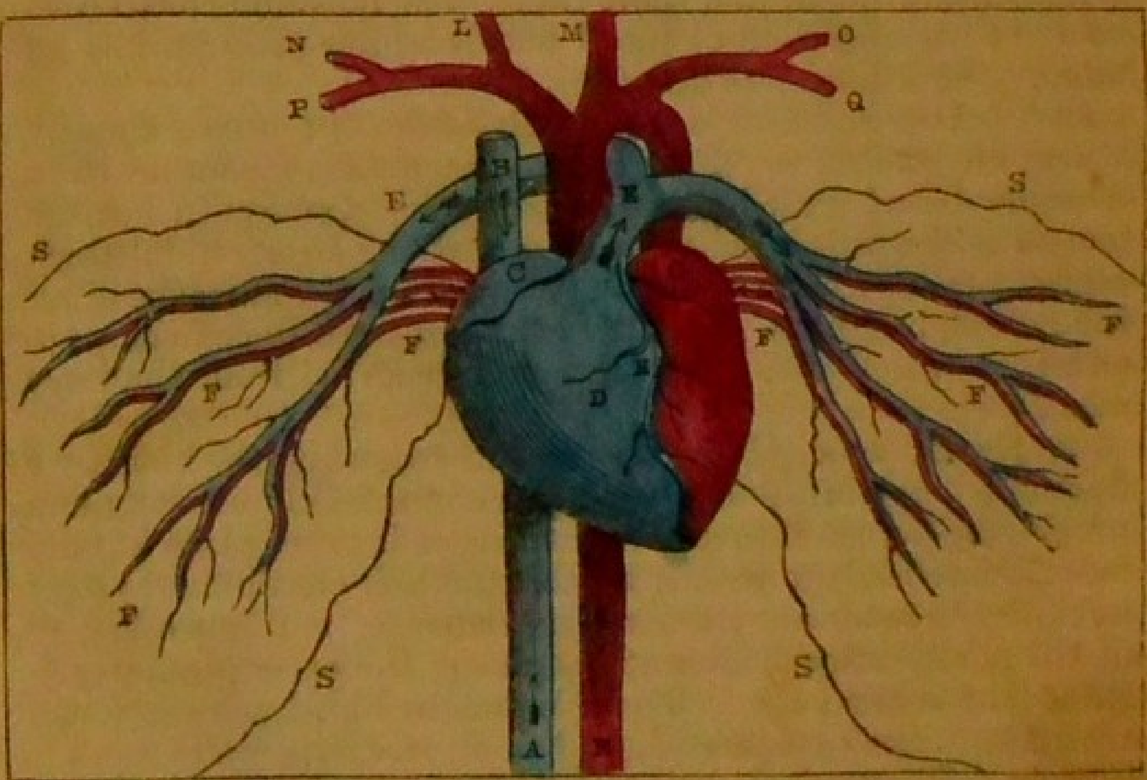


Fig. 15. Representation of the Human Heart, Vessels, and Lungs.

A Vena cava ascendens.
B Vena cava descendens.
C Right auricle.
D Right ventricle.
E Pulmonary artery.
F Pulmonary veins.
G Left auricle.
H Left ventricle.
I Aorta ascendens and branches.
K Coronary arteries.
LM Carotid arteries.
NO Vertebral arteries.
PQ Subclavian arteries.
R Aorta descendens.
SS Outline of lungs.

opposite. The diagram, figure 15, affords an exact representation of the human heart, with the circulation of the blood to and from the lungs on both sides.

57. To make the course pursued by the blood more plain, we take asunder the two sides or chambers of the heart, and represent them as separate from, and opposite to, each other, as seen in Fig. 16.

58. In this *ideal* plan of the circulation in the Mammalia, the arteries and veins are *supposed* to be thrown into continuous chains, with the capillaries as their connecting links. In describing this plan, we shall commence with the veins, which have been coloured blue, to indicate that they convey impure blood. It will be seen that they gradually unite, until those coming from above and those from below form two large vessels (*venæ cavæ*), that empty themselves into the upper cavity of the heart on the right side, called the *right auricle* (1). From the contraction or drawing together of this auricle, the blood easily passes downwards into the next cavity, called the *right ventricle* (2); and this, which is still more powerful, also in its turn contracting upon the blood, sends it through the vessel (*p a*) called the *pulmonary artery*. It is plain, however, that, if nothing hindered it, the blood could as easily go back to the right auricle, as forwards into the pulmonary artery; but this is effectually prevented by a valve that is placed between the right auricle and the right ventricle, and which allows the blood to enter, but prevents it going back. Another valve, which acts in a similar manner, is placed at the mouth of the pulmonary artery, so that the blood, by the successive contractions of the ventricle, is forced to go forward into the lungs. Here, as will afterwards be explained, it becomes purified, as is shown by its red colour, and is sent by the *pulmonary veins* (*p v*) to the *left auricle* of the heart (3), to pass, as on the other side, into the *left ventricle* (4). This last is the most powerful of all the parts described, as it is required to propel the blood into the artery called the *aorta* (*a o*), and from it into the whole of the body. Valves are placed on the left side, between the auricle and ventricle, and at the mouth of the aorta, which have a similar action and appearance to those on the right side. Those between the auricles and ventricles are called cuspid, that is, pointed valves; on the right side, from having three points, tricuspid; on the left side, from having two points, bicuspid. Again, those at the mouths of the pulmonary artery and aorta, are, from their shape, called semilunar valves.

59. The blue colour in the diagram, it will be noticed, at once gives an idea of the parts of the body in which impure or

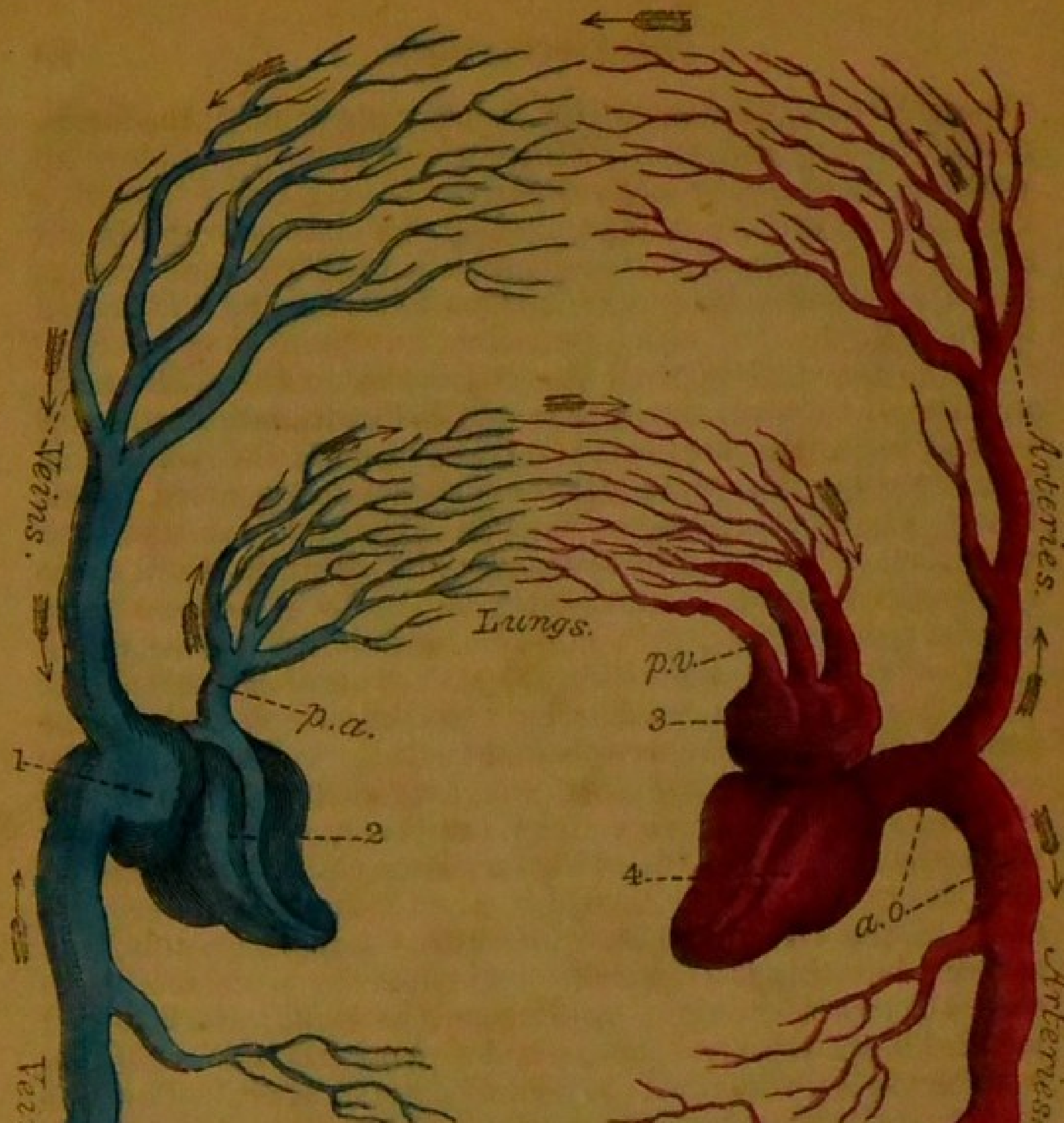


Fig. 16. Ideal Plan of the Circulation of the Mammalia

venous blood is circulated (the veins, right side of the heart, and pulmonary artery). The red colour also indicates in what part the blood becomes purified (the lungs), and where it is circulated as arterial or pure blood (the pulmonary veins, left side of the heart, and arteries). It is in the capillaries between the arteries and veins (which are too minute to be represented in the diagram, but which pervade every point in our bodies) that the blood parts with its vivifying qualities. The communication of these qualities to the different structures, may be said, indeed, to constitute the great object of the circulation. The arrows in the figure also show the course pursued by the blood. Figure 21 shows the situation of the heart in the chest, with the aorta (*h*) and its branches going off from it. *a* is the two ventricles united. *k* and *s*, the two auricles. *l l*, the carotid arteries going to the head. *m* is the superior vena cava (which empties itself into the right auricle), in which the jugular veins (*n n*) from the brain, and the subclavian veins from the arms (*o o*), are seen to terminate.

60. The course of the circulation, as shown in Fig. 15, will now be easily understood. The two venæ cavæ AB empty themselves into the right auricle C. From this the blood passes into the right ventricle D, which sends it into the pulmonary artery E, and this immediately divides in the lungs SS into innumerable branches, only a few of which are represented in the diagram. In the lungs, as already mentioned, the blood is purified, and the pulmonary veins FF are therefore represented as bringing back to the heart red or arterial blood. The pulmonary veins from both sides pour their supplies of blood into the left auricle G, from which again it passes into the left ventricle H, and is by the latter sent to all parts of the body through the aorta I and its branches, to be again conveyed by the veins to the right side of the heart. R is the continuation of the aorta, which carries the blood to the lower parts of the body. By attending to the directions indicated by the arrows, the course of the circulation in this and the other figures will be made very plain.

61. From the description given, it must be plain that the office filled by the heart, with its accurately-working valves, is essentially that of a forcing-pump. And with what inimitable precision and regularity does it perform this all-important duty! Unweariedly during the whole term of a long life it sends out daily its 100,000 waves of healthful fluid to refresh and renovate every corner of the system; and small as each wave may be individually, the aggregate amount is enormous. Thirteen thousand pounds of blood pass out of the left ventricle of the heart of an ordinary man every twenty-four hours. But the

aorta of man is not an inch in diameter, whereas the aorta of a whale, the skeleton of which is exhibited in Edinburgh, was three feet two inches in circumference. Well, therefore, might Dr Paley say, that the circulation is a serious affair in such an animal. "The aorta of a whale," says he, "is larger in the bore than the main pipe of the water-works at London Bridge; and the water roaring in its passage through that pipe, is inferior in impetus and velocity to the blood gushing through the whale's heart."

62. But if we are astonished in reflecting on what must take place in the aorta of the whale, our admiration will be not less excited on examining the circulation even in the web of a frog's foot. When this is brought under a moderately powerful microscope, we can perceive with ease through the transparent coats of the tiny vessels, the red globules of the blood—in some singly, with long intervals between—in others, two abreast—and, in others still, numbers crowded together—pursuing their beautiful course, like the trains of spectral figures that pass before us in our dreams—now moving onwards with the most steady regularity, and again hurried forward by the struggles of the little animal. This sight, an excellent writer well observes, "is one which no man who has once seen can ever forget; and he who has not seen it, has not beheld one of the most curious, and wonderful, and beautiful objects which animated nature presents."

63. Like most of the organs of organic life, the heart, in its usual state, gives us but slight indications of sensibility. Harvey met with an extraordinary opportunity of showing this. A young nobleman, from disease, had the heart exposed, so that it could even be handled while beating; and Harvey, to his astonishment, found that, unless his fingers came in contact with the outer skin, the young man was altogether unconscious of the heart being touched. Though nearly destitute of the sensations of touch, however, the heart is instantly affected by every powerful bodily excitement, or strong mental emotion. Upon the first of these depends the use physicians make of the pulse (which is just the heart's beat transmitted through the arteries) in judging of the different bodily ailments; while the power of emotions over the heart has furnished the poetry of all languages with some of its strongest images. The capillaries also share in the influence of emotions, of which we have a familiar example in blushing.

64. The greater or less vigour with which the blood is circulated through the system, gives rise to important effects. We see this particularly in two forms of constitution. In the one, the circulation is very vigorous; all the functions are performed

with energy; and the diseases, in general, are of an acute character. When the complexion is fair, this constitutes what has been called the sanguine temperament—when dark, the choleric. In the other variety, the circulation, and all the functions connected with it, are languidly performed; the surface is easily chilled, and the diseases have frequently a low insidious character. When the complexion is fair, this has been called the phlegmatic temperament, and the melancholic when the complexion is dark. With a feeble circulation, the general health never can be good; and hence we find the action of the heart weak in most delicate persons.

65. The arteries, like the intestines, are composed of three coats, and the middle one is generally considered to be muscular, in order to assist the contractions of the heart; but its muscularity is by no means so marked as is the muscularity of the intestinal canal. These coats possess, also, different degrees of distensibility, the inner one being least so. This gives rise to the remarkable circumstance, that when, as in those horrid accidents that are sometimes caused by machinery, a limb is torn off, frequently not a spoonful of blood will be lost. The reason is, that the inner coat, which is ruptured first, curls up, and, assisted by the outer coat, forms a plug in the blood-vessels. These coats are sometimes distended more gradually by the continued impulse of the heart, constituting the disease called aneurism. The sac thus formed, if on the largest vessels, occasionally attains the size of a child's head, and produces instantaneous death when it ultimately bursts.

66. The part of the circulating system most liable to disease is the valves, and especially those of the left side of the heart. Ossification, or the deposition of bone in their substance, is what most commonly affects them. As might be anticipated, the blood regurgitates and stagnates, and great distress in breathing, dropsy, &c., are the consequences. The only other valves in the circulating system are in the veins, and they seldom become diseased.

67. When the apparatus employed in the circulating system of man is understood, it will be easy, from a mere inspection of the coloured figures, to comprehend its modifications in other animals. Birds have a circulation similar to that of the Mammalia. An *ideal* plan of the circulation in reptiles is seen in Fig. 17. They have a right and a left auricle (*a b*), but only one ventricle (*c*). Commencing, as we did before, with the veins, we find that the whole venous blood is emptied, as in man, into the right auricle (*a*), and, from this, is sent into the ventricle (*c*). From the ventricle, the blood is sent into a large vessel (*d*), and is then distributed as follows:—

First, a small portion goes to the lungs by the vessel *e*, to be purified, and then brought to the left auricle (*b*), and from this

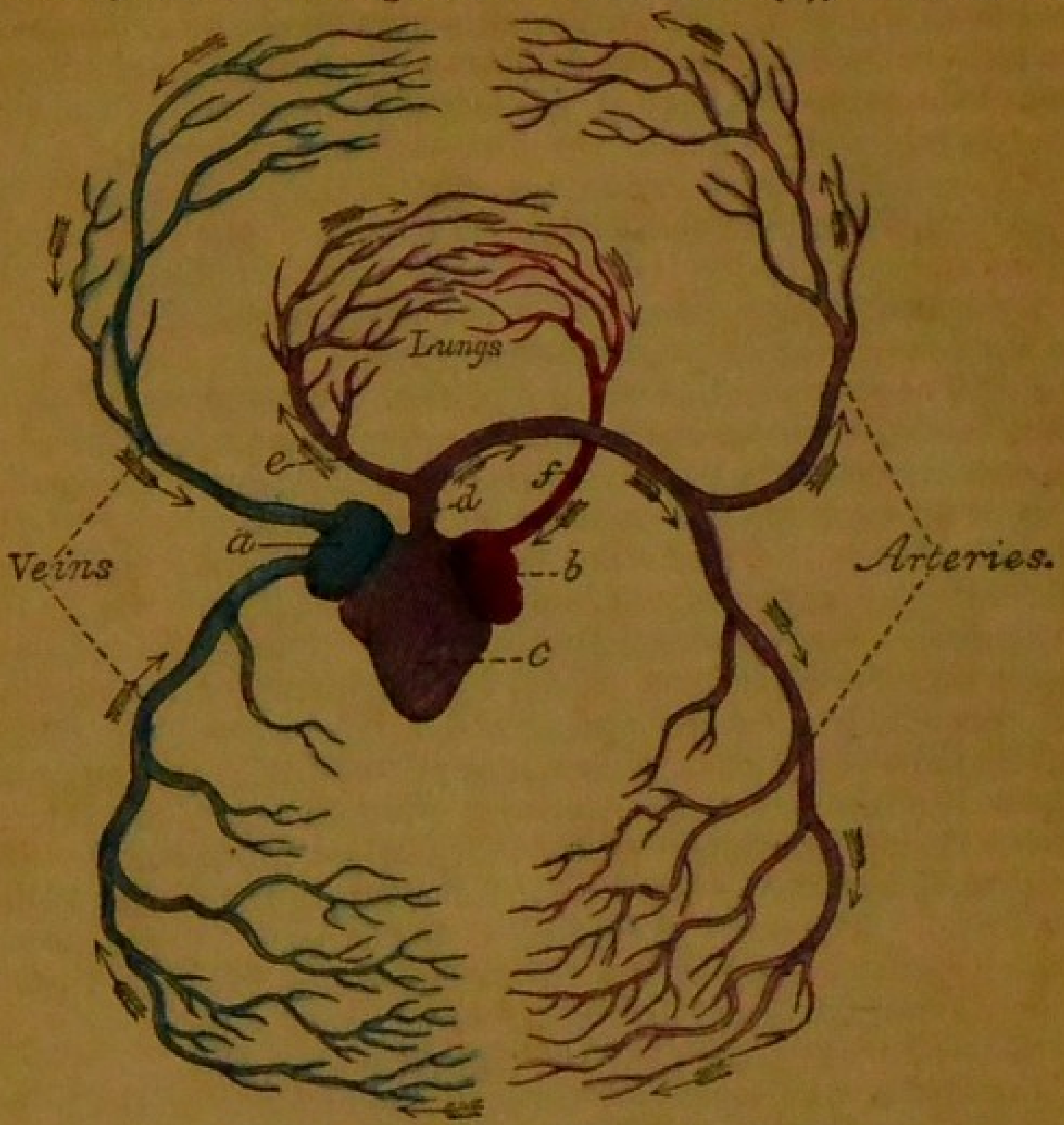


Fig 17. Ideal Plan of the Circulation in Reptiles.

to pass again into the ventricle, where it mixes with the impure blood coming from the right auricle; second, the rest of the blood goes to the upper and lower parts of the body by the arteries. The blue colour shows where the venous blood circulates (in the veins and right auricle). The red colour shows where it is arterialised (in the lungs), and where it circulates as red blood (in the pulmonary veins (*f*) and left auricle (*b*). The purple colour shows in what parts the mixed pure and impure blood circulates (in the ventricle (*c*), pulmonary artery (*e*), and all the other arteries).*

* The crocodile, one of the highest species of reptiles, has the ventricle divided like the Mammalia, and the venous is mingled with the arterial blood only in the hinder parts of the body, by a vessel which comes from the pulmonary artery, and joins the aorta low in the back. From this cause, pure arterial blood circulates in its brain and anterior parts, while mixed venous and arterial blood circulates posteriorly.

68. In fishes, as will be seen in Fig. 18, there are only two cavities in the heart, an auricle (*a*) and a ventricle (*b*), which are placed in the part of the circuit where the blood is venous; the gills, as will be explained afterwards, answering the purpose of the lungs.

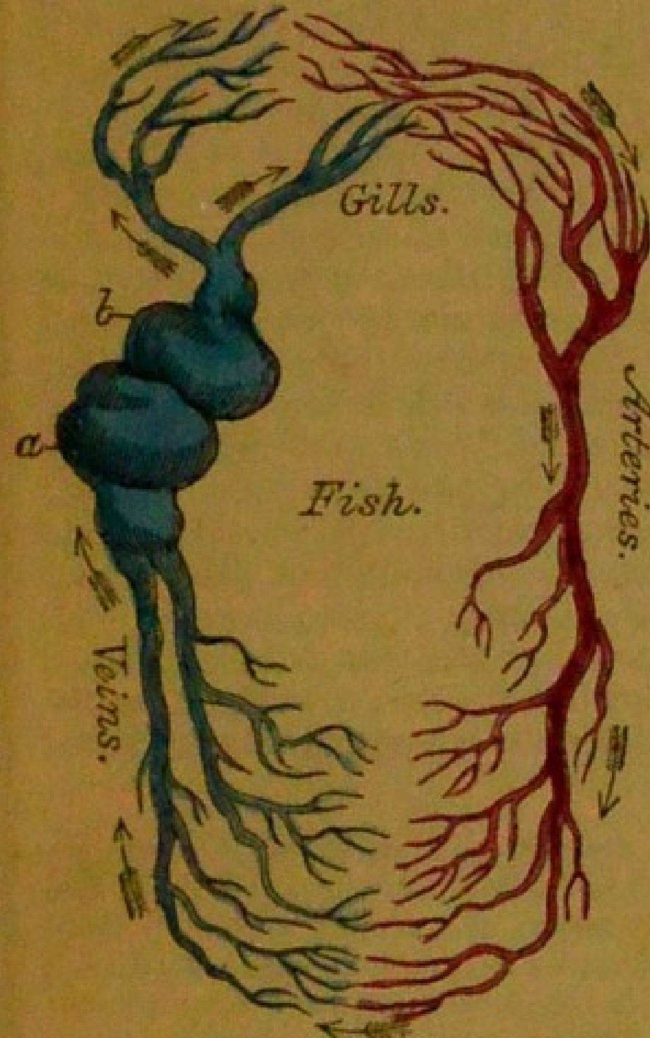


Fig. 18.

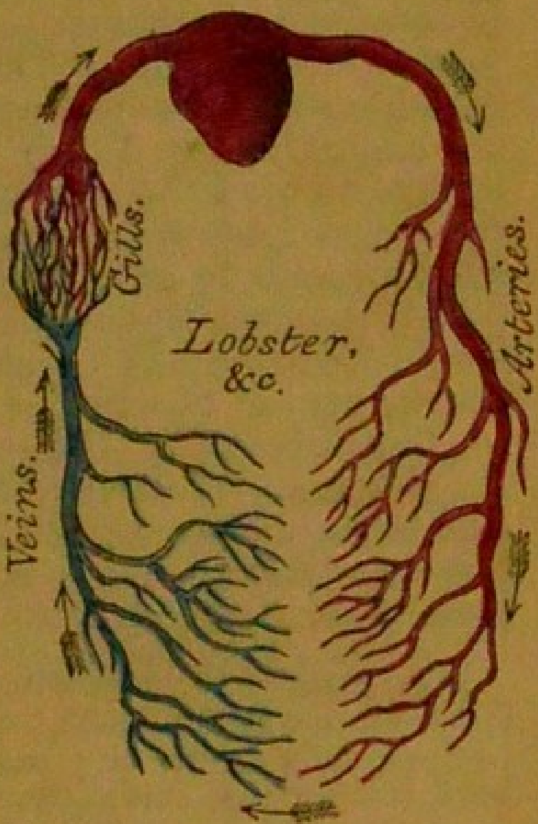


Fig. 19.

69. Among the Crustacea, again (as the crab, lobster, crawfish, &c.), there is only one cavity, like a fleshy ventricle, which, it will be seen in Fig. 19, is placed in the arterial part of the circuit.* In the orders below this, the heart is rudimentary, or wanting; and its duties, much simplified, are performed in many by a large vessel running along the back.

70. Looking at the whole figures in these diagrams of the circulation, we see, first, in man and the other Mammalia, parts equivalent to two hearts, which maintain a vigorous double complete circulation, corresponding to their high temperature,

* The Sepia has the heart likewise placed in the arterial part of the circuit, and the two veins that carry the blood to the gills also swell out into something like the rudiments of two other hearts in the venous part of the circuit. The two vessels connected with the auricle and ventricle of the fish, as may be observed, also swell out into what are called sinuses.

and to the activity of their habits and intellect. The following experiment may give an idea of the activity of the circulation in this class:—A fluid injected into one of the jugular veins in the neck of a horse, has passed through the right side of the heart, the lungs, the left side of the heart, the arteries, the capillaries, and been detected in the vein of the leg, within half a minute; secondly, we see, corresponding to the generally sluggish life of reptiles, that their blood is only partly purified; and we may observe, that this condition of the blood exists as a disease, in some of our own species, who are always, in like manner, very feeble and inert. The condition alluded to (called the blue disease) arises from parts of the heart, or its vessels, that are naturally open before birth, not closing afterwards, and hence allowing the venous and arterial blood to mingle; thirdly, in fishes we observe that the whole blood is purified, but is necessarily sent with decreased force into their bodies, the part corresponding to the left side of our heart being absent; while, fourthly, the Crustacea, which have the right side absent, present us with the most unfavourable modification of the heart's position. Before the impulse of the heart can reach the gills, it must evidently propel the blood through the arteries, capillaries, and veins; and the blood must, therefore, feebly enter the minute vessels in the gills, where purification takes place.

[The parts of the circulating system most difficult to be understood, are the valves of the heart and their action. Both these can be beautifully shown in a cow's heart, the vessels of which have been cut high up, and as little injured as possible. The hard suet being cleared from the base of the heart, to show the bicuspid valve between the left auricle and ventricle, pass the finger into the large opening of the aorta (which is the vessel butchers often hang the heart by) nearest the heart, when will be felt the semilunar valves at the mouth of the left ventricle. These must be broken down by cautiously introducing a scalpel, or penknife, and cutting and then forcibly rupturing them with the finger. Having done this, close all the openings on the sides of the aorta, by tying them, or transfixing them with a needle, and twisting thread round it, or putting a small cork in the largest, fastening with needles, and twisting thread round them, &c. Now pour water gently into the aorta, and notice where it escapes. This will be by the left auricle, which is to be cautiously removed (but not cut quite to its base), until the valves are exposed. If water is now poured quickly into the aorta, the bicuspid valve will be seen to be lifted up, and to prevent its escape; or, what is better, the air may be made to take the place of the water, by drawing in the breath and blowing forcibly, in quick succession, through the aorta. The action of the valve during life may thus be shown with tolerable accuracy.

When this has been examined, the heart should be cut through transversely, two or three inches above its apex, to show the greater thickness of the left than the right ventricle. The left ventricle and aorta may then be cut up to show their internal surface—the fleshy columns and tendinous cords, which assist the heart in contracting, the appearance of the bicuspid and semilunar valves, the grooves leading to the branches from the aorta, &c.

The action of the semilunar valves may now be shown by cautiously cutting away the right ventricle, till the valves at the mouth of the pulmonary artery are exposed. Take a pig's bladder, and cut about two inches off each extremity. Sew the narrower end round the inner surface of the pulmonary artery; pour a jugful of water quickly into the bladder, and the action of the valves, in preventing its return, will be seen.

By mixing Paris plaster (which may be got from any plasterer) bulk for bulk with the water, casts of the pulmonary valves, of the left ventricle, &c., may be made, and cut out when dry. To take a cast of the right ventricle, the pulmonary valves must be broken down, as above. These make very instructive preparations, when the valves, &c., are distinguished by being coloured.

Attention should also be directed to the great difference in muscularity between the auricles and ventricles, and to the sounds of the heart as they can be heard by applying the ear to the left side of the chest of a thin person. The first dull sound is supposed to be produced principally by the contraction of the ventricles; the succeeding sharp sound by the falling back of the blood on the semilunar valves. In disease, these sounds become louder and much altered—in some cases resembling the blowing of bellows, in others the rasping of a file, &c. The contraction of the heart is called its systolé, the time it rests its diastolé.

To show the fibrin of the blood, get some from the butcher (who extracts it by turning his fingers in the blood while coagulating), and wash it till it is pure white. The coagulability of the serum (which can easily be got from any surgeon) should be shown by heating it in a Florence flask.

As mentioned in the text, the microscope shows the circulation in a frog's foot.

Other figures to illustrate this section may be found in "Animal Physiology" in the Library of Useful Knowledge, pages 69, 70, 71, 73, 74; in Dr Roget's Bridgewater Treatise; in Dr Smith's Philosophy of Health; in Bell's Anatomy, &c.]

SECTION IV.

RESPIRATION.

71. We have seen, in the preceding section, the course which the blood pursues. We have now to consider the changes it

undergoes in that course. It will be recollected that the left side of the heart sends the blood into the general system: this is called the *systemic circulation.* The right side of the heart sends it into the lungs, and this has received the name of the *pulmonic circulation.* But if the blood that goes to the lungs were returned in the same state as it is sent, death would be the consequence, for venous blood is a poison to the body; and this is the reason why an animal dies when the air is prevented from getting into its windpipe by hanging or drowning. Bichat showed this very decisively. He connected, by a tube, the jugular vein of one dog with the carotid artery (which sends the blood to the brain) of another, and allowed the venous blood to flow into it. The immediate effect of this was, that the dog in whose brain the venous blood was made to circulate, became completely insensible, and would in a short time have died. On allowing the arterial blood, however, again to circulate in its brain, the dog was quickly restored.

72. What are the changes, then, that take place in the lungs, and how are these changes effected? These questions will be best answered by first knowing what the lungs are. The lungs (vulgarly called *lights*) are principally composed, 1st, of air-tubes (bronchi), of which the windpipe (trachea) is the commencement, and which divide and subdivide until they terminate, as has been supposed, in very minute bags or air-vesicles; and 2dly, of the pulmonary artery (Fig. 15, E, and Fig. 16, *p*, *a*), which branches out upon the sides of these air-tubes. Fig. 20 shows the windpipe, with the lungs entire on one side, and with the branches of the air-tubes dissected on the other. These tubes are said to terminate in vesicles, which vary in size from the 50th to the 100th part of an inch in diameter. The lungs are also seen in Fig. 21, in their natural situation in the chest.

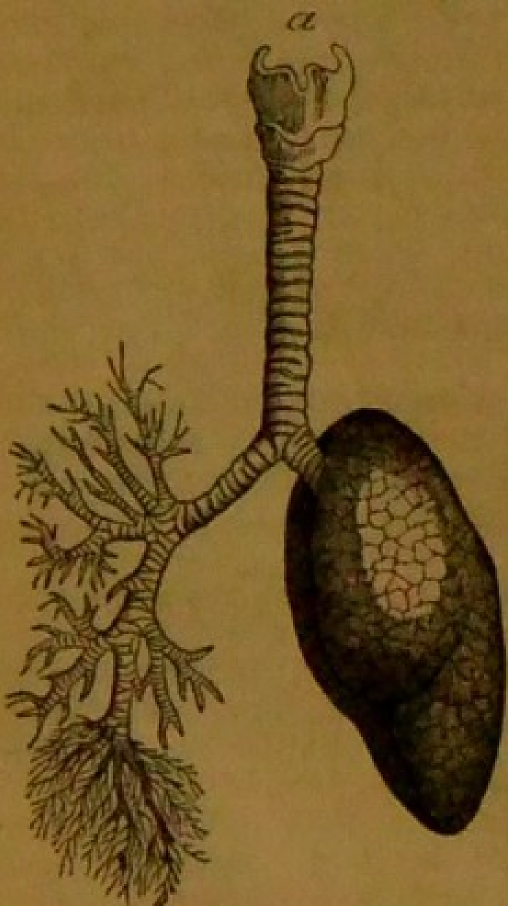


Fig. 20. Windpipe and Lungs.

73. If we tie up tightly in a bladder a quantity of venous or dark blood, we shall find, in a short time, that exposure to the air has changed the colour of the portion near the surface. The air has passed through the bladder, and has converted the

venous into red or arterial blood. Exactly the same thing takes place in the lungs; for the air, in the air-vesicles, is separated from the blood in its vessels by a membrane not more than the thousandth part of an inch in thickness. But we shall find, immediately, that it is not the blood alone that is altered in its qualities. The air also undergoes alterations. The blood in the lungs becomes fit for supporting life; the air becomes unfit for this purpose. We must, therefore, describe, 1st, the means by which the air is brought into, and then removed from, the lungs; and, 2dly, the changes of composition that thence occur in the air and in the blood.

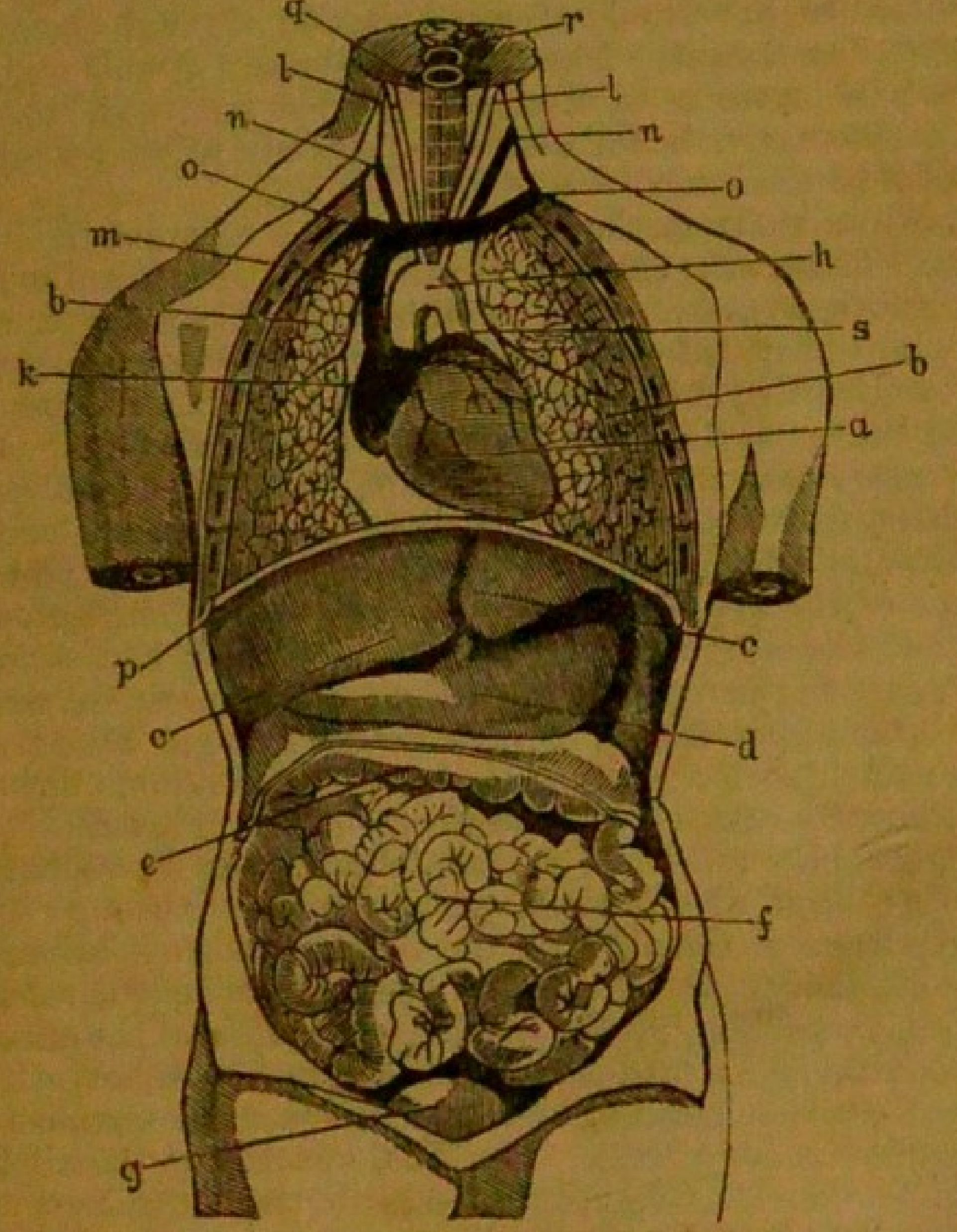


Fig. 21. Front view of the contents of the Chest and Belly.

a, the two ventricles of the heart. *k*, the right auricle. *s*, the left auricle. *h*, the aorta. *l l*, the carotid arteries. *n n*, the jugular veins; and *o o*, the subclavian veins, terminating in *m*, the superior vena cava. *b b*, the lungs. *q*, the windpipe. *r*, the gullet. *p*, the diaphragm. *c c*, the liver. *d*, the stomach. *e*, transverse arch of the colon, part of the large intestines. *f*, the small intestines. *g*, the bladder.

74. The lungs are contained in the chest or thorax (Fig. 7, *rxr*), a conical cavity formed by the breast-bone before, the back-bone behind, and the ribs above and on the sides. It is separated inferiorly from the abdomen or belly by a fleshy moveable partition called the *diaphragm* (Fig. 21, *p*), which is fixed to the bottom of the breast-bone and edges of the short ribs before, and extends downwards and backwards to be attached also to the back-bone behind. Through this the gullet, blood-vessels, &c., pass. The whole inside of the chest is lined by a thin smooth membrane called the *pleura*, which divides the chest into a right and a left side, and which likewise covers the lungs; but these are, nevertheless, on the outside of the pleura, in the same way as the head is on the outside of a double nightcap. There is no opening to admit the air between the lungs and sides of the chest, but it gets easily by the windpipe into the air-tubes of the lungs.

75. From these explanations it will be easy to understand the mechanism of *respiration* (breathing). Drawing in a breath is called *inspiration*. We do this, 1st, by raising the ribs, which are provided with numerous muscles for this purpose between the ribs, and attached to the ribs and neck; and, 2dly, and at the same time, by depressing the diaphragm. Of the latter movement we become sensible, by placing the hand on the abdomen during inspiration, when we notice the ribs raised, and find the belly pushed outwards at the same moment by the descent of the diaphragm. It is, therefore, evident that the cavity of the chest must be considerably enlarged by inspiration. But the cavity of the chest cannot be enlarged without something filling it up; and as no air can get between the lungs and sides of the chest, if the windpipe remain open, the air necessarily rushes by it into the air-tubes and vesicles of the lungs, and blows them up as we might blow up a bladder. The muscles that acted during inspiration having become relaxed, the expulsion of the air from the lungs is effected principally by the elasticity of the ribs, and by the contraction of the muscles of the belly pushing up the diaphragm. It is called *expiration*.

76. It must be manifest, from considering these arrangements, that the amount of blood and air brought together in the lungs must be very great. The whole extent of the air-tubes in man, taken collectively, has been calculated by Hales at about 20,000 square inches, and by Monro at twenty times the surface of the human body; the branches of the pulmonary artery, which ramify upon this surface, are so twined and interlaced that they have received the name, from anatomists, of *the wonderful net-work;* while the air received into and expelled from the lungs, and consequently brought into contact with

its air-tubes and blood-vessels, cannot be less, in an ordinary man, than between 3000 and 4000 gallons daily.

77. Fresh supplies of air, then, that the blood may be purified, are the essential objects of a respiratory apparatus; and from the necessity of having some modification of such an apparatus, no animal whatever is exempted, although the supply of air required varies much. A frog or a lizard, for example, will live a considerable time in air which a bird has been forced to breathe till it has died, and insects will live for a long period even in the air that has ceased to support both the bird and the lizard. Fishes, again, whose gills, it was formerly mentioned, perform the same office as our lungs, can exist upon the small portion of air they extract from the water in which they swim. But, however small the quantity required, none can want it altogether; and if any of them be placed under the receiver of an air-pump, and the air be exhausted, they immediately become distressed, and die in a short time.

78. There is one remarkable circumstance that may be noted when the motions of the heart, or intestines, and those of respiration, are contrasted. The motions of the former are entirely removed from the influence of the will, and usually do not excite in us any consciousness of their existence; while those of respiration are always accompanied by a sensation, if not also by an act of volition. Before air is drawn into the chest, we have always a peculiar sensation, reminding us that a fresh supply of this material is required. At first, this sensation is merely a gentle intimation; but if neglected, it becomes so intolerably painful as to compel us to relieve it by breathing. When an individual becomes partly insensible, the sensation requires to be considerable before he attends to it; and accordingly we find, that, instead of breathing, as we ordinarily do, fifteen or twenty times in a minute, he will breathe only once in half a minute, a minute, or a minute and a half. When insensibility increases still further, this and all other feelings become extinct, and then he dies. Upon this principle an explanation has been given of sighing. When a person sighs, the mind has been intensely fixed on some object. The consequence is, Dr Darwin supposes, that he forgets for a short time to breathe, until the sensation in the chest becomes so importunate as to oblige him to make a more than usually full inspiration to relieve it.

79. The mechanism of respiration is considerably modified in other classes. Whales (which breathe air) have parts that are thought to serve as reservoirs, both of venous and arterial blood; and this is conjectured to be the reason why they are able usually to remain under water twenty minutes, and sometimes upwards of an hour, without breathing. The lungs of

birds, instead of being free in the chest, are fixed to its sides, and also have openings in them which allow the air to pass into air-cells that pervade almost every part of their bodies. As a proof of this, if the windpipe of an eagle be tied, and the largest bone of its wing (humerus) be broken, it can breathe through the broken bone instead of its windpipe. It is this arrangement that causes the respiration of birds to be called double, for the air acts on the blood, 1st, in passing through the lungs to the air-cells; 2dly, in passing out of these, and probably also while it remains in the air-cells. Hence, they consume more air than any other class of animals.

80. Reptiles can act but imperfectly on the air, from the cells of their lungs being very large, and, from this cause, of course diminishing the surface upon which the blood-vessels have to be distributed. The frog has no ribs, nor has it any diaphragm, the abdomen and chest forming but one cavity. As a substitute for these, the air is forced into the lungs by a species of deglutition. A frog perishes if its mouth is kept open, because, before this deglutition can be accomplished, the mouth must be closed.

81. The surface occupied by the gills of fishes is often very considerable. Those of the skate are said to have a surface nearly equal to that of the human body. The reason why air cannot usually be directly breathed by gills, is believed to be principally because they become collapsed and dry. The eel, the crab, and some other species, that breathe by gills, can, however, breathe in air for a considerable time.

82. The only other modification of the respiratory apparatus we shall refer to, is that of insects. The veined appearance of the wings of the butterfly is produced by what are called tracheæ, that have openings on the surface (stigmata) for admitting the air, and extensive ramifications over the body. There are similar openings on the sides of the bee-worm and in other species. If these are closed, the animal immediately dies. In all the lowest classes of animals, and even as high as the class of reptiles, the skin is also an active respiratory organ.

83. What has been said may render intelligible the mechanism by which the air is introduced into the body. It will now be necessary to describe the changes that take place there. The atmospheric air, when it goes into the lungs, is composed of about four parts of a gas called nitrogen, and one part of another gas called oxygen.* But the air which comes out from the lungs is not the same in composition, for a considerable quantity of oxygen is found to have disappeared, and in its

* We omit mention of the small quantity of carbonic acid in the air.

stead we find another gas, called carbonic acid, which is produced by the union of a portion of oxygen with the carbon which forms a large ingredient in the composition of the blood and of the body in general. Carbonic acid is a gas which is fatal to animal life, and it is therefore discharged from the lungs. If an animal is made to inhale it, insensibility and death follow in a very few minutes. We have already seen that the venous blood is a poison to the animal body, and it is probably this same carbon, or the carbonic acid, that makes it noxious. It appears that about 45,000 cubic inches of oxygen are consumed by an ordinary man in twenty-four hours, and that 40,000 inches of this gas go to form the carbonic acid produced during the same period, the remainder of the oxygen probably combining with other ingredients of the blood. Under different circumstances, however, the consumption of oxygen varies. It is considerably greater when the temperature is low than when it is high, and during digestion the consumption has been found one-half greater than when the stomach is empty. By violent exercise, when the stomach is empty, it has been found to be augmented to three times its usual quantity, and to four times its usual quantity when food has been taken after this.

84. When we thus see the great quantity of pure atmospheric air which a single individual requires to carry off the noxious parts of the venous blood, and to convert this into arterial blood, we can easily comprehend why such dreadful consequences should follow the breathing of a highly vitiated atmosphere. The most melancholy instance of this kind on record, is the well-known one that occurred in the Black Hole at Calcutta. In this dungeon, 18 feet square, and having only two small windows on the same side to admit air, 146 men were immured. In six hours 96 of them had died from suffocation, after the most horrible sufferings; and in the morning, when the doors were opened, only 23 out of the whole number remained alive.

85. From the same cause we can understand how hurtful it must be continually to breathe the air of ill-ventilated rooms, confined sleeping apartments, crowded low-roofed schools, or other places in which numbers are assembled together, and where ventilation is not particularly attended to. A long-continued and constant residence in such places most certainly shortens life by several years, and not unfrequently terminates it rapidly, by giving rise to consumption and other fatal disorders.

86. It must not be supposed, however, from what has been said, that the carbonic acid given off from the lungs is to be viewed as a merely noxious material. If it were retained,

death would undoubtedly take place; but if no carbonic acid were formed, we shall find that the heat of our bodies could probably not be maintained. When charcoal is burned in atmospheric air, the changes which occur seem to be almost precisely similar to those that are produced by respiration. Oxygen disappears, and carbonic acid is formed. It seems reasonable, therefore, to conclude, that the heat produced in both cases is connected with these changes. That the production of animal heat bears some resemblance to combustion, is rendered probable by the following considerations:—1st, It has been determined by experiment that the charcoal contained in the carbonic acid formed during a given period by respiration, would give out, when burned, fully more than half the heat produced by the animal in that period. It takes no less than about eleven ounces of carbon to form the carbonic acid of an ordinary man's daily respiration. Dr Milne Edwards thinks that this, and the superabundant oxygen which is absorbed by the blood (which probably combines in great part with hydrogen to form water), will account for nine-tenths of the heat an animal produces, the remaining tenth probably being the product of the friction of the different parts of the body, the changes occurring in secretion, &c. 2dly, This view is supported by the fact, that the temperature, in the different classes of animals, very accurately corresponds to the quantity of oxygen consumed. The temperature of birds is highest, and they consume most. The young, among the Mammalia, consume the least, and have the temperature lowest. Indeed, it may be remarked, that the young of most of the Mammalia, including children, have much difficulty in supporting any great degree of cold when separated from their parents; and where incautious exposure takes place, the mortality among them is found to be very great. Reptiles, which consume little oxygen, have a temperature only a few degrees above the medium in which they live; and the same may be said of fishes, with the remarkable exception of the Cetacea (whale, porpoise, &c.), which have a high temperature, but consume much oxygen, as they breathe air by lungs.

87. It has been thought, however, that as the carbonic acid is given off in respiration, and the oxygen disappears at the same time, the temperature of the lungs ought to be much higher than that of other parts, and it was to meet this difficulty that Dr Crawford proposed his celebrated *Theory of Animal Heat*. He maintained that the capacity for heat (as chemists call it) is greater in arterial than in venous blood;* that

* What is meant by capacity may be rendered intelligible thus:—If we mix one pound of water at the temperature of 60 degrees, with

as this enlargement of capacity takes place in the lungs, at the same moment as the heat is generated, a considerable portion of it must be absorbed; and that this latent heat comes to be given out, as the arterial, in its course, is again gradually converted into venous blood.

88. It will be observed, that Dr Crawford's theory supposes, 1st, that the capacity for heat in arterial is greater than in venous blood, which subsequent observation has not shown to be the case. Dr Davy states the capacity of both to be very nearly the same. 2d, It supposes that the carbonic acid given off during respiration is *formed in the lungs*, from the direct combination of the oxygen of the atmosphere with the carbon of the blood, which also appears to be incorrect, for it has been shown, by Dr Edwards and others, that carbonic acid is produced in large quantities, even when an animal is made to breathe a gas containing no oxygen. A frog can be made to breathe nitrogen or hydrogen gas, even for several hours together, without losing its vitality; and in such cases, it is found that nearly as much carbonic acid is formed as when the animal is allowed to breathe atmospheric air. It therefore seems probable that the carbonic acid is *formed in the blood*, and is merely given off or separated at the lungs. There is another theory that has been proposed by Lagrange and Hassenfratz, two German physiologists, and which is supported by the fact ascertained by Professor Magnus, that venous and arterial blood both contain carbonic acid and oxygen, but that the carbonic acid is in larger and the oxygen in less quantity in the venous than in the arterial blood, which seems to avoid the difficulties involved in Dr Crawford's theory. The oxygen, these physiologists suppose, when it is absorbed by the blood in the lungs, exists there only in a loose state of combination; as it circulates, the union with the carbon, &c., of the blood is supposed to become more intimate, the carbonic acid being thus formed probably in the capillaries; and the heat comes thus also to be gradually disengaged, and diffused through every part of the body. Professor Müller calculates that the quantity of carbonic acid which has been ascertained to exist in each cubic inch of venous blood, is sufficient to account for the whole quantity exhaled from the lungs. Professor Liebig, a high authority, takes nearly the same view of this subject.

another pound at 91 degrees, the resulting temperature will be exactly the medium, or 75½ degrees. But if we mix a pound of water at 60 degrees with a pound of quicksilver at 91 degrees, the resulting temperature will be only 61 degrees, because the capacity of water is so much greater than that of quicksilver, that the heat which raises the quicksilver 31 degrees will raise the water only 1 degree.

Many other facts, however, prove that both secretion and the nervous system are connected, directly or indirectly, with the production of animal heat. We can only state generally, also, that the body possesses the power of keeping down its heat to nearly the natural standard, even when exposed to a very high temperature. Sir Charles Blagden remained, without any great inconvenience, in a room, the temperature of which was 52 degrees above that of boiling water, until eggs were roasted hard, and a beefsteak made ready by blowing air on it. Indeed, the heat of his body, though the temperature of the apartment was 264 degrees, rose only three or four degrees above 98 degrees, its natural standard. It has been found that the principal agent in keeping down the temperature, is the immense evaporation that takes place from the lungs and skin. Accordingly, when the skin is varnished, or the air of the apartment is saturated with moisture, so as to prevent evaporation, a temperature one-half so high can hardly be borne.

89. Having now given a short but connected account of the physiology of the circulation and respiration, we cannot but remark how varied and how complicated are the agents employed, and yet how accurately each of these performs the part assigned it. Such investigations as those with which we have been occupied, form the proper foundations of natural religion. No one can rise from the study of these parts of the animal frame, without intensely feeling that *design*, and design of a kind the most exquisite, guides every motion and change of the vital fluid. Never did any piece of machinery invented by man, indicate with greater precision the intentions of its maker.

90. The voice is produced in what is called the larynx, at the top of the windpipe (Fig. 20, *a*). The air, in passing through its opening (*glottis*, Fig. 11, *e*, and Figs. 22 and 23), causes parts called vocal ligaments to vibrate, and to give out the different varieties of sound. These sounds can be further modified by the parts in the mouth, &c., so as to produce articulate speech. Singing-birds have a simple larynx at the top, and a complicated one at the bottom, of the windpipe.

91. When foreign bodies, such as cherry or plum stones, get into the larynx or windpipe, they cause excessive irritation, and not unfrequently death. A few years ago, a woman came under the care of Mr Liston, who stated, that six months previously she had been nearly choked by a piece of bone, while eating some hashed meat; that when she was almost suffocated it had passed downwards into the windpipe, and that she could since then feel it lodging at the top of the chest, on the right side. Her statement was so precise that Mr Liston resolved to

attempt its extraction. He cut down into the windpipe at the bottom of the neck, passed his instrument downwards three or four inches towards the right lung, and felt the bone. But he found his instrument opened in a wrong direction to seize it. This difficulty had, however, been anticipated by the accomplished operator. Another pair of forceps, opening differently, was produced; the bone was seized and extracted, and the woman left the hospital in a few days quite recovered.

92. Other affections of the top of the windpipe produce suffocation, and, among these, by far the most common and fatal is *croup*. This disease consists in inflammation and swelling of the inner or mucous lining of the larynx and windpipe. When allowed to gain ground for even a few hours, the surgeon meets with few more rapidly fatal diseases. The cause of this will easily be understood, from looking at Figure 22, which shows the natural size of the opening (rima glottidis) through which all the air had to pass, in a weakly child 11 years old. Figure 23 is the same seen from within. The least diminution of this opening is fatal.

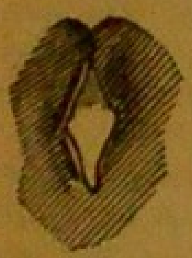


Fig. 22.

Fig. 23.

93. When the inner or mucous membrane of a few of the larger branches of the windpipe is slightly inflamed, it is called *a common cold;* when the inflammation is greater, and extends to the lesser air-tubes (bronchi), it is called *bronchitis,* and is often denoted by considerable wheezing in the breathing;* when the air-vesicles, and the substance which connects them, become inflamed, it is called inflammation of the lungs (*pneumonia*). The last is a very fatal disease, if not early checked. The importance of early attention to it will be understood from this, that it consists of three stages, in the first of which the part of the lungs affected is merely engorged with the watery serum of the blood. A smart bleeding will frequently at once remove this. But if allowed to remain, this rapidly passes into the second stage, in which the lung becomes solid like a piece of liver (*hepatization*), and ultimately into the third stage, when the solid portion is infiltrated with matter

* Millers, masons, sawyers, grinders, and others who are exposed to the inhalation of various kinds of dust, are very subject to this disease, and have their lives much shortened by it. Dry grinders seldom live beyond 30 or 35 years. In M. Lombard's returns for Geneva, the average longevity of stone-cutters is stated at 34 years, of sculptors at 36 years, and of millers at 42 years; while painters live, on an average, to 44, joiners to 49, butchers to 53, writers to 51, surgeons to 54, masons to 55, gardeners to 60, merchants to 62, protestant clergymen to 63, and magistrates to 69 years.

(*pus*). The two latter stages are comparatively seldom recovered from.

94. When the membrane (pleura) covering the lungs and lining the inside of the chest is inflamed, it is called *pleurisy*, or *pleuritis*, and is denoted by the sharp cutting pain which is felt when we draw a breath. If uncombined with pleuritis, the pain in pneumonia (inflammation of the lungs) is not great. It is rather tightness of the chest, and oppression of the breathing, that are felt. These are caused by the difficulty the air finds in getting admission into the condensed air-vesicles. From the same cause, pneumonia is generally attended by rapid and heaving breathing. As the quantity of air that can be brought into contact with the blood is diminished, fuller and more frequent inspirations require to be made. If the hepatization extends to the whole of one lung, then there can be no motion of the chest on that side, as the air enters only to the other lung. These signs are of especial importance in children. Whenever the breathing of a previously healthy child becomes rapid and heaving, alarm should be felt for its safety.

95. The branches of the windpipe have another coat below the inner or mucous one, which, like that of the intestines, is muscular, and can, it is thought, contract and diminish their size. This contraction is supposed to be the cause of the sudden difficulty in breathing, so often felt by asthmatic persons. In asthma, however, other causes combine to produce this difficulty; for, 1st, there is generally more or less habitual inflammation of the larger air-tubes; and, 2dly, from the repeated violent fits of coughing, the air-vesicles become distended or ruptured, so that the cavity of the chest is permanently filled to a considerable extent with these distended vesicles (*bullæ*). The surface of the lungs of old asthmatic persons may be seen studded with these, like little bladders, sometimes as large as walnuts.

96. The only other disease of the lungs we shall notice, is the almost invariably fatal one, consumption (*phthisis pulmonalis*). This disease consists in the formation, in the lungs, of a peculiar substance called tubercle. Tubercles are at first small semi-transparent bodies, like pins'-heads; but as they increase in size and number, they unite, and form masses generally like yellowish cheese, occasionally as large as a walnut or an orange. At a later period, this cheesy matter becomes softened, and is coughed up, leaving cavities in the lungs more or less extensive, under the irritation of which the patient sinks. Consumption, from very accurate calculations, is known to cause about one in every five deaths in Great Britain, so that some knowledge of the causes which produce it, is important to almost every one.

From extensive statistical inquiries made in Geneva by Dr Lombard, he has found that the average number of consumptive cases occurring in all the different professions of that town, is 114 in the 1000. In some it rises much above, while in others it falls greatly below, this average number. Thus, among varnish-painters no less than 37 out of the 100 were found to have died of this complaint, while of gardeners only 4 in the 100 fell a sacrifice to it. The causes which principally tend to produce consumption, Dr Lombard finds, are, 1st, breathing air in which mineral, vegetable, or animal powders are floating: among polishers, sculptors, stone-cutters, plasterers, watch-hand-makers, &c., the proportion of consumptive complaints is 177 in the 1000. 2d, Sedentary occupations seem to have a great effect in producing this disease, the mortality among clerks, printers, tailors, engravers, &c., being 141 in the 1000; while among such active professions as carpenters, blacksmiths, slaters, agriculturists, &c., the average proportion is 89 in the 1000. 3d, Indigent persons seem about twice more liable to consumption than those living in easy circumstances: annuitants in Geneva, who may be reckoned as generally leading an easy, comfortable life, average only 50 consumptive persons in the 1000. 4th, The more or less impure state of the air breathed, its temperature, dryness, &c., seem to influence considerably the production of consumption. In professions in which life is spent in shops or manufactories, the proportion of cases is 138 in the 1000; while in those professions in which life is spent principally in the open air, only 73 in the 1000 become its victims. An atmosphere loaded with animal emanations, such as is breathed by butchers, tanners, candlemakers, &c., seems to act rather as a preventive to this complaint, the average among these professions being only 60 in the 1000. Breathing a moist air seems also a preventive circumstance, as weavers, dyers, bleachers, watermen, &c., are found liable to it only in the proportion of 53 in the 1000; while those who breathe a hot dry air, such as toolmakers, enamellers, file-smiths, &c., have 127 in the 1000 affected. These deductions may be considered as, at least, approximations to the truth, and they in general agree with what might have been expected, as we know that even in the lower animals consumption can be produced at pleasure by general debilitating causes, or by irritants applied directly to the lungs. A large proportion of the monkeys brought from their own warm to this cold and changeable climate, die of this scourge of our race; and M. Flourens, a French physiologist, has shown, that by keeping chickens in a dark and damp cellar, and upon a scanty diet, they are rapidly carried off by this affection. Though the lungs are the parts most usually affected by this disease, it is a mistake to suppose that it is a merely local complaint. Very commonly, the cheesy matter is found, at the same time, in the liver, mesentery, and many other parts; and there can be little doubt that the essential cause of the whole is a particular form of constitution, either inherited from parents, or brought on by irregular habits, want of fresh air and exercise, or other diseases and circumstances that enfeeble the body. Where the predisposition to this disease is very great, we see whole families cut off by it; but when the predisposition is less, we often notice only those affected that follow occupations, or have contracted habits, that impair their health.*

97. In concluding the subject of respiration, we may mention that a French physician, named Laennec, invented a simple instrument, called the stethoscope, which enables us to ascertain very accurately, from the sounds of the air passing through the lungs, what is going on within. Different diseases are denoted by the modifications of sound they produce, often with as much precision as if we saw through the walls of the chest.

[The mechanism of respiration may be beautifully seen in the hare. After skinning, &c., open the belly, take out the intestines, liver, &c., and cut through the back-bone high up with a strong

* We have said that consumption is a hereditary disease, or arises from a peculiar constitution transmitted from parents to children. This is what is called the scrofulous constitution, which can often be detected by a practised observer, but of which it is not easy to give any definition, except that the formation of tubercular (cheesy) matter in any part always denotes it. When much developed, and when it affects the glands of the neck, it is vulgarly termed "king's evil." Constitutions are variously tainted with it, however, from a very slight to a very high degree; and it may easily be conceived how generally the taint is diffused, when we have stated that one in every five dies in this country from one of its forms. There are many other diseases, the tendency to which is derived from parents, such as asthma, insanity, gout, &c.; and there can be little doubt that this class of diseases constitutes the great bar to the physical improvement of the human stock. Until correct views on this subject become more general, little hope of improvement can be entertained. At present, persons in every rank make eager inquiries as to the worldly condition, &c. of those who are likely to form their partners for life; but how seldom does it happen that the tendency to even serious hereditary disease forms a bar to their union, or that persons even take the least pains to satisfy themselves whether such exists! The great part of mankind neglect far too much the fact that they are animals, and that they are therefore subject to those general laws which regulate the transmission of peculiarities or diseases to their children. Hence, from this serious error, they fail to take the precautions which are necessary to secure an approach towards physical perfection in their own progeny, and the neglect of which they would be ashamed of, even in regard to their dogs and their horses.

knife. The diaphragm, separating the belly from the chest, will then be seen. To show the parts contained in the chest, next take away the fore-legs, and cautiously detach the ribs from the breast-bone, on each side, except at the top and bottom, breaking or snipping through with scissors the detached ribs near the back-bone, and removing them. The breast-bone will thus be left in its place, supported by a rib or two at the top and bottom, and the division of the chest into two halves by the pleura—the heart lying in its bag or pericardium—as well as the appearance and position of the lungs, will be seen. Great care must be taken in opening into the chest, and in cutting the ribs posteriorly, not to injure the lungs. To show the action of the lungs, the windpipe must now be cut down upon in the neck, cut through, and detached, and a small tube tied into it. When this is gently blown into, the lungs will be seen to be inflated. A much more elegant mode of showing their action, however, is, carefully to take out both windpipe and lungs, and to attach them as represented in Fig. 24, where *a* is a bottle, six or seven inches high, and about three wide, such as is used by druggists, with the bottom cut off; *b* is the hare's lungs (with the windpipe left moderately long) tied to a notched tin tube (*c*), that passes through a cork accurately fitting the neck of the bottle; *d* is a wooden piston, three-fourths of an inch thick, covered with soft leather, which is stuffed with hair, and oiled to make it fit accurately. When the handle of the piston is drawn quickly down, the air rushes by the tube and windpipe into the lungs, and inflates them, and this can be repeated by pushing the piston gently up, and then again drawing it quickly down. The bottle must be of the same width throughout, and the lungs must not be cut or injured in any part. The lungs should be in the bottle, and the windpipe tied on the tube, before the cork is fitted into the bottle. This is a remarkably striking experiment, and should be seen by every one who wishes to form a just conception of respiration.

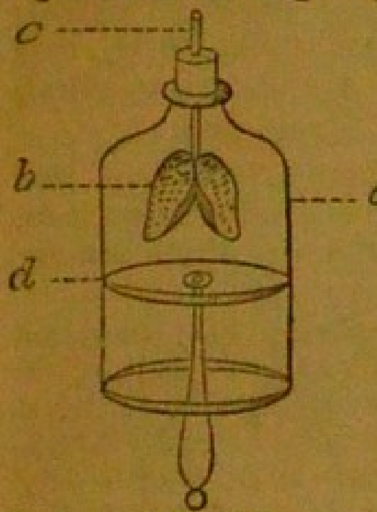


Fig. 24.
Hare's lungs in a bottle.

The power of oxygen in supporting combustion, and of carbonic acid in extinguishing it, should also be shown by introducing a lighted candle, fixed to a wire, into jars of these gases.

That the expired air contains carbonic acid, may easily be shown by breathing through a tube immersed in newly prepared lime water. The carbonic acid throws down the lime in the form of carbonate of lime.

By placing the ear to the upper part of the chest of a young person, the murmur produced by the air rushing through the air-vesicles may be heard; or the stethoscope may be used for hearing this, as well as the sounds of the heart.

The air-cells of birds may be seen in the pigeon, by opening the belly on one side, and then (while pressure of the fingers on the ribs prevents any escape of air from the lung on that side) blowing air into the windpipe, as directed above.

The gills of a cod or haddock (recent or dried) should also be examined.

Preparations of the bronchial tubes are generally made by anatomists with wax. These, however, have the disadvantage of being easily broken. We have used, instead of wax, some of the metals. Equal parts of tin and lead answer well for the larger bronchi. Take a sheep's lungs, clear away fat, &c., but taking care not to injure them, and cut off the windpipe three or four inches above the lungs; dry the interior of the windpipe by introducing pieces of lint on the end of a stick, and afterwards allowing it to remain exposed to the air for a few hours. Then transfix the windpipe at the upper part with two darning-needles crossed, to hang the lungs by; fasten the needles to the ring of a retort-stand; fasten a wide-mouthed tin funnel, supported by another ring of the retort, in the windpipe, and pour in the melted metal; boil the lungs for two hours, cut out the preparation, and varnish with wax dissolved in boiling spirits of wine. A much more delicate preparation can be made in the following manner:—Instead of tin and lead, take the composition called the *fusible metal*,* and pour it into the lungs, and then place these in a large pot of water, to be kept boiling for an hour. The air is thus in a great measure expelled; and as the metal melts at the boiling point of water, it finds its way into the most minute ramifications. When heated, the air in the air-tubes causes the lungs to become buoyant, which prevents the metal getting properly into the lower bronchi. To obviate this, the lungs may be enveloped in a cloth, which should be loaded with heavy weights, to keep them in the upright position. As the metal is extremely brittle when hot, the lungs should not be taken out of the pot till they are cold; then hang them in some place where flies can deposit their eggs, moistening the outside daily, and allow them to remain until the maggots eat away all the flesh; after this, hang them in water until the preparation can be easily cleaned. In making both preparations, about one and a half pounds of metal are required, and the tin filler should be heated to make the metal run the easier. If any of the large branches are broken, any tinsmith will easily solder them. When well managed, preparations we have made in this way have a truly wonderful appearance; the bronchial tubes, though beautifully distinct, and as fine as hairs, presenting almost a solid mass. The existence of air-vesicles has been doubted by some authors, and these preparations seem to us to support this opinion.

Other illustrative figures for this section will be found in Bell's Anatomy, vol. i. page 599; Dr Smith's Philosophy of Health, vol. i. page 243; "Animal Physiology," in the Library of Useful Knowledge, pages 88, 89, 90, 92, &c. &c.]

* The *Fusible Metal* may be composed of two parts bismuth, one lead, one tin, and one quicksilver, to be all melted together and well mixed.

SECTION V.

SECRETION AND NUTRITION.

98. We have seen, in the preceding sections, that there are arrangements for circulating the blood and for keeping it pure. The great object in these arrangements seems to be, that the substances required in the different parts of the system may be separated from the blood in a proper state. There is a class of bodies, known by the name of glands, whose office appears to be principally to form different secretions. Thus, the liver is a gland, which is said to secrete (separate) bile: the salivary glands, we have seen, secrete saliva; and so on with the others. It would be a mistake, however, to suppose that secretion is performed only by glands, for thin membranes, without any glandular structure, produce numerous secretions; and the deposition of the solid parts of the body takes place without the intervention of any thing like glands. It seems to be the capillary vessels, themselves, in these cases, that are employed; and even in glands, however minutely we examine their structure, there can be detected almost nothing but endless subdivisions of circulating vessels, and ducts for collecting and carrying off the secreted fluid.

99. It will be impossible for us even to refer individually to the numerous substances produced by secretion. We shall, therefore, mention particularly only a few, and make some general observations regarding the whole.

100. The liver (Figs. 12, *l*, and 21, *c*) is the largest gland in the body. We have seen that it secretes the bile, which probably serves important purposes in digestion. The numerous ducts of the liver unite and form one large duct, called the hepatic duct (Fig. 12, *h*), from which the bile passes into the common duct (*i*), or into the gall-bladder (*m*), to be poured, when required, into the upper part of the intestinal canal. The bile is an alkaline fluid, which contains, besides other substances, a peculiar resinous principle. Unlike other secretions, it is formed from the venous blood. The whole veins of the stomach and intestines, instead of going directly to the right side of the heart, first unite to form one great trunk (vena portæ), which divides, like an artery, in the substance of the liver; and these branches, by which the bile is secreted, again unite, and join the veins going to the heart in the ordinary way. In some species the veins going to the kidneys have a similar distribution. From this, and

for various other reasons, it is strongly conjectured that the liver assists the lungs in purifying the venous blood, by depriving it of a portion of its carbon; and, accordingly, we always notice the liver larger in animals in proportion as the activity of their lungs diminishes. The carbon uniting with oxygen forms the carbonic acid given off from the lungs; it seems to escape from the liver in union with another gas called hydrogen, forming the resinous and other principles of the bile. We have before stated that less oxygen is consumed, and of course less carbonic acid is produced, when the temperature is high, than when it is low. Hence, probably, a chief cause of the diseases of the liver Europeans are liable to in warm climates; for if less carbon be given off at the lungs, more will have to be secreted by the liver; and any part required to do more than its ordinary duty is apt to become deranged. It is thought that about six or eight ounces of bile are ordinarily secreted daily. Another analogous substance, called *urea*, is secreted by the kidneys, which are glands that also probably assist in purifying the blood. It is probable that both the resinous matter in the bile, and the urea in the urine, exist ready formed in the blood, and are merely separated by their respective glands; as, when the kidneys of dogs have been taken away, urea has been detected in the blood, which could not be the case if the kidneys formed it. It sometimes happens, especially in drunkards, that one or both of these glands become diseased, and are incapable of separating the peculiar fluids mentioned; and then these, being retained in the system, act as poisons, producing insensibility and death. In the case of the liver, this forms one cause of jaundice; but jaundice is more commonly caused by an obstruction to the flow of the bile through its ducts. The passage of gall-stones (which are only bile solidified) from the gall-bladder through the common duct (Fig. 12, *i*), is a common cause of obstruction. When the substance of the liver becomes diseased, the flow of blood through its veins is also often obstructed, and this very generally gives rise to dropsy.

101. What has been said must suffice in regard to the larger glands; smaller ones are scattered in almost every part of the body. The whole extent of the intestinal canal, and of the skin, is found to be studded with bodies having a glandular structure, and producing secretions.

102. Some secretions are evidently produced only in particular emergencies, as we see with the increased secretion of bony matter when a limb is broken; other secretions are uncommon in their nature, as in the case of such fishes as the torpedo or of the firefly, the former of which can produce at pleasure powerful electrical discharges, and the latter a substance that gives

out light; while in other instances, again, secretions become unusual in their situation, or of a morbid kind. Of a secretion unusual in its situation, a curious instance occurred some years ago in France. A woman who was suckling had the secretion of milk transferred from her breasts to one of the lower extremities, from which her child continued to be supplied. Of morbid secretions we have examples in ossification of the valves of the heart, in consumption, in cancerous, brainy, and other tumours, and, unfortunately, in too many other cases.

103. The secretions are much influenced by our mental states. Every one has felt the flow of saliva increased from savoury odours, or the flow of tears from distressing feelings. A cheerful state of mind is peculiarly favourable to the proper performance of the function of secretion; and we therefore learn how important it is to avoid such things as distract, or agitate, or harass us.

104. As to the agent which produces or directs the different secretions, we have no very accurate information. In one instance, at least, Dr W. Philip found that its place could be supplied by galvanism. He cut the principal nerves going to the stomach, and the secretion of gastric juice was completely stopped; but the secretion was restored when a galvanic pile was made to communicate with the lower extremities of the nerves. Of late years it has been discovered that the operations of galvanism are much more various and subtle than was formerly supposed, and it therefore seems not unreasonable to conjecture that its agency may be important also in secretion.

[Suitable views of the liver will be found in Lizars's Coloured Plates, page 86, and of the kidneys, at page 88.]

SECTION VI.

EXHALATION AND ABSORPTION—THE SKIN.

105. By exhalation is meant the escape of some portion of the contents of the blood-vessels (generally little altered), probably through pores in their sides. When a fluid, coloured with vermilion, is injected into the blood-vessels of a dead animal, the fluid portion will pass out of them, and is said to be exhaled, while the vermilion is retained; or when a solution of phosphorus is thrown into the veins of a living animal, in a few seconds fumes of phosphorous acid are given off from its lungs. By absorption is meant the removal of the soft or hard parts of

the body, or of substances placed in contact with these parts. When a fat person becomes lean, or the fluid in a dropsical person's belly has disappeared, the fat and the fluid are said to have been absorbed.

106. The three most important exhaling and absorbing surfaces, are the intestinal canal, the lungs, and the skin; but these processes are active also in the chest, belly, and other cavities. We have already explained the structure of the intestinal canal and lungs, and the skin will be treated of at the close of this section, so that it will be necessary at present only to say, that the skin has a thin outer covering, called the cuticle, or epidermis (the part raised by blistering), which has no feeling, and little vitality; and another thicker part underneath, called the true skin (the part which tanners convert into leather), which is plentifully supplied with nerves, blood-vessels, &c.

107. From what has been said, it will be seen that the mechanism of exhalation is very simple, the fluid merely passing through the sides of its vessels. In every part of the system an active absorption is carried on by the same means, the fluid removed merely passing through the sides of the veins, to be carried off by the internal current. It was at one time supposed that absorption was exclusively carried on by a system of vessels, which received the name of absorbents; but this is now known to be quite incorrect. Allusion has already been made to one portion of these absorbent vessels, connected with digestion, which are called lacteals (Fig. 13). Similar vessels in other parts of the body (some of which are seen in Fig. 13, *h*) receive the name of lymphatics, from a fluid called lymph, which they convey; and in their course towards the thoracic duct (Fig. 13, *g*), in which they almost all terminate, they pass through glandular bodies, found in numbers in the hams, groins, armpits, on the sides of the neck, &c. It is these glands about the neck that so often swell and inflame when there is disease of the gums, or eruptions on the head, or when there exists a highly scrofulous habit of body.

108. The veins appear to take up all fluid matters indiscriminately that are brought in contact with them; the lacteals take up principally (if not solely) chyle; the office of the lymphatics seems to be chiefly to mould the different parts of the body into their proper forms, and the lymph contained in them is probably the removed animal matters, which, it is supposed, may undergo some changes while passing through the lymphatics and their glands, that render them fit to be mingled with the blood. From the late researches of Fohmann, Panizza, and Lanth, it would appear that the lymphatics commence by

minute plexuses, and that these at their origin do not communicate with the arteries and veins, but begin by shut extremities. In the frog, and in some other reptiles, there have been discovered parts, connected with the lymphatics, that pulsate irregularly, like hearts. The frog has four of these, which seem to be used for propelling the lymph.

109. Absorption and exhalation, in a healthy state, generally balance each other, so that a full-grown person's weight, notwithstanding the quantity of food consumed, will frequently for years vary only a few pounds. The conditions which promote the one, generally impede the other. When the body is saturated with fluid, absorption goes on slowly; but exhalation, under the same circumstances, takes place rapidly. M. Magendie found that when a quantity of water was thrown into an animal's veins, absorption was either much impeded, or altogether suspended; and, on the other hand, when the blood-vessels were partly emptied by bleeding, the effects of a poison, that usually showed themselves at the end of the second minute, were distinctly perceived before the thirtieth second. A frog, kept for some time previously in dry air, when its legs are immersed in water, will in a short time absorb nearly its own weight of the fluid.

110. We have already spoken of the absorbing powers of the intestinal canal. The next in importance, as an absorbing surface for external substances, is the lungs, and, of course, the matters absorbed are generally conveyed in the form of vapour. When a fluid poison, however, is injected into the windpipe, it acts with fearful rapidity. It is through this surface that substances diffused in the atmosphere usually produce their effects on the system. The vapour of turpentine, breathed along with the air of a room, may be detected in the urine within a short time afterwards, and the concentrated vapour of such poisons as prussic acid will instantly kill an animal if inhaled. It is probable also that the various poisons which produce fever, measles, small-pox, and other infectious disorders, are in this way introduced into the body, the smallest quantity frequently sufficing for this purpose. We can conceive the small quantity of the poison required, when we notice that the least particle of the matter of small-pox, placed in a scratch on the skin, gives rise to the same disease. In proof of the action of poisons, when inhaled by the lungs, the following facts may be stated:

111. M. Magendie contrived some experiments, in which dogs were confined in the upper part of a barrel, the lower part being filled with putrifying animal substances, which were separated from the dogs by a grating. Confinement in this situation, from the absorption of the putrid effluvia, produced

death generally about the tenth day. The animals took food, and were even lively, but became much emaciated before death. The same physiologist produced symptoms exactly resembling those of yellow fever, by injecting a few drops of putrid water into the veins of dogs.

112. A nurse in one of the Dublin hospitals, apparently in excellent health, was desired by the physician to assist a patient, labouring under fever, to turn in bed. Being very feeble, he endeavoured to support himself by placing his arms round the nurse's neck, when she suddenly drew back, struck by the offensive odour from his person, and exclaiming that she had caught fever. She instantly became cold, pale, and ghastly, and, appearing about to faint, had to be removed to her room. Malignant fever, of a very severe description, succeeded, and lasted for thirteen days.

113. In the island of St Lucia, in the West Indies, two boatmen were employed hauling their canoe up on the beach, close to a dangerous swamp, when they perceived a small cloud of vapour approaching, which gradually enveloped them. One immediately fell down insensible, and the other was so much affected as to be unable to render him any assistance. The vapour soon passed away, and both men recovered so far as to be able to walk home. The one most affected, however, was seized with fever, and died within forty hours afterwards.

114. Repeated instances occur in the West Indies of twenty or thirty workmen being employed in cutting drains or canals in these infectious swamps, nine out of ten of whom will be seized in a few days with the most dangerous forms of tropical fever. Chiefly from these pestilential fevers, also, the probability of life to Europeans in the West Indies is very low. It appears, from the most accurate army returns, that a young man's chance of life, which in this country would probably be about forty years, is reduced in Jamaica to about seven years.

115. In such marshy districts as the fens in Lincolnshire, or the Pontine marshes near Rome, the poison diffused in the atmosphere operates with intensity chiefly after sunset, and produces dreadfully fatal fevers and agues. We see also, in the natives of these districts, the effects which the slow operation of the poison produces on the health. Their appearance in highly infected districts is miserable in the extreme. Stunted in their growth, with swollen bellies, stupid expression, and jaundiced complexions, they linger out a miserable existence, and can any where, at a glance, be recognised. Happily their sufferings terminate life quickly. In Rome, chiefly from this cause, the annual mortality of the whole population is stated at one in twenty-five, while in the whole of England and Wales

Mr Rickman states that it is only one in sixty. It is a curious circumstance that these poisons generally lie latent or inactive in the body for some time. In the fevers of this country, the latent period may vary from a few days to some weeks; while in marsh fever, a person will often have left the infected district, six, twelve, or more months, before he is seized with it.

116. We have entered into these details in order that it may be seen, 1st, that unnecessary exposure to air infected with the poison of fever, is both improper and highly dangerous; and, 2dly, to show how important to health is pure air, attention to cleanliness, and the removal of all putrifying animal and vegetable matters from the vicinity of our dwellings. In a very filthy part of Constantinople, called the Jews' quarter, the plague constantly prevails more or less, and the same may be said of typhus fever in some confined and dirty parts of London, Edinburgh, Glasgow, and most other large towns.

117. In man, the absorbing powers of the skin are much more limited than those of the lungs. When the cuticle is entire, indeed, it appears to absorb almost none, unless the substance be rubbed on it with force, or be of a very irritating nature. When the cuticle is removed, however, it absorbs readily. This is the reason why the most virulent poisons can be handled with impunity, only while the cuticle is entire. Surgeons often suffer severely from this cause, when, in opening dead bodies, they accidentally puncture or cut themselves, even in the slightest degree. The poison introduced by the cut part inflames it dreadfully, and death not unfrequently occurs within a few days. It is for the same reason that a slight scratch must be made through the cuticle before a child can be inoculated.

118. The exhaling powers of both the skin and the lungs are very considerable. In winter, we notice the watery vapour coming from the lungs condensed by the cold air; in summer, we see how much fluid escapes from the skin in the form of perspiration. Independently of this, however, from thirty to sixty ounces of watery fluid are calculated to pass off daily from the skin in the form of insensible perspiration. This insensible perspiration may be seen to be condensed, when the point of the finger is moved along the surface of a looking-glass, at about the distance of an eighth of an inch, and also when we handle any polished steel instrument; or, still more decisively, when the arm is confined in a glass jar. It is the condensation of this insensible perspiration that makes the inner surface of a M'Intosh cloak damp when worn in frosty weather. Dr Smith has performed some interesting experiments on the subject of

exhalation, from the skin and lungs jointly. Eight workmen in the Phœnix Gas-works, London (where they must work hard, and be exposed to a high temperature at the same time), were weighed before going to work, and immediately afterwards. In one experiment, in November, they continued to work for an hour and a quarter, and the greatest loss sustained by any one man was two pounds fifteen ounces. In another experiment, in the same month, one man lost four pounds three ounces in three quarters of an hour; and in an experiment of the same kind, in June, one man lost no less than five pounds two ounces in an hour and ten minutes.

119. We shall conclude this section, by stating a few other circumstances connected with the structure and functions of the skin. We have mentioned that the external layer of the skin is called the cuticle. M. Breschet, a French author, who has very carefully investigated the structure of the skin, considers the cuticle to be of the same nature as the horny matter which forms the nails, the hairs, feathers, horns, &c., of animals. It is secreted by particular organs, and when intended to be coloured, it is mixed with colouring matter (which also is secreted by distinct organs) while in a fluid state. The arrangement of the cuticle, in different parts of the human body, is well worthy of attention. Where feeling is to be exercised, it is thin and delicate; over the joints it is lax and moveable; on the palms of the hands and soles of the feet, even in the infant, it is thick and hard, and these properties are greatly increased by constant use. Simple as this last provision may appear, it seems doubtful whether the want of it would not have interfered materially with the exercise of many of our most useful arts.

120. Between the cuticle and the true skin, formerly mentioned as the part of animals that is tanned, is found the layer that gives the colour to the different varieties of the human species, &c. (*rete mucosum*). In Europeans it is generally of a light colour, in Negroes it is black, and in other races it is intermediate, or of other shades. The colour of the Negro does not depend on the blackening of the cuticle by the sun, for his cuticle is seen to be as transparent as a European's when raised by a blister; and we observe, also, that the secretion of the black colouring matter does not take place in the Negro child until a day or two after birth.

121. The *cutis*, or true skin, is the third and most important layer. Besides its uses already referred to, it has a very large supply of blood sent to it; is a surface of great sensibility, intimately sympathising with the internal organs; and, from its exposed situation and extent, is peculiarly liable to be affected

by external influences. Perhaps no other surface in the body is so much concerned in the production of internal inflammatory disorders, and perhaps the agents that above all others tend to produce these, are the various degrees, and especially the sudden applications, of heat and cold. When heat is applied suddenly and extensively, so as to give rise to a burn or scald, the heart's action is frequently extinguished within a few hours, even although the burn, in any one portion, is altogether superficial and unimportant. Mr John Hunter gives a striking proof of the effects produced by a sudden change of temperature on the skin. He took an eel, which was swimming in water a little above 30 degrees, and plunged it into water about 60 degrees, a temperature in which it habitually lives with ease. The sudden change, however, gave such a shock to its system, that the animal instantly expired.* In these cases the effect seems to be produced principally through the agency of the nervous system, for an account of which we must refer to Section VIII.; but when the application of cold produces its injurious effects, the blood that is forced, by the constricted vessels, from the surface, upon the internal parts, probably also overloads them, and impedes the due performance of their functions. When the body is exposed for some time to a great degree of cold, the tendency to sleep becomes almost irresistible. Under these circumstances, to use the words of Dr Solander, quoted by Captain Cook, "whoever sits down will sleep, and whoever sleeps will wake no more." These words were used by Dr Solander during an excursion in Terra del Fuego, with Sir Joseph Banks and nine other individuals, when the cold was intense. Notwithstanding Dr Solander gave the precaution, he was the first to feel the effects of the cold, and his companions were obliged to yield so far to his entreaties as to allow him to sleep for five minutes. With the utmost difficulty he was roused. Two black servants also slept, and perished. Exposure to a lesser degree of cold acts differently. Every one knows the power of cold draughts of air, of cold or damp feet, the wearing of damp clothes, or sleeping in damp sheets, in giving rise to inflammations, even in persons whose surface has a vigorous circulation, and is therefore not easily chilled. When the circulation on the surface is languid, these causes act with tenfold force; and hence in all such constitutions it is of the utmost moment, 1st, that the skin should at all

* We lately met with a case exemplifying the effect of sudden change of temperature. A person who had been treading snow in an ice-house felt his feet uncommonly cold. To remedy this, he plunged them into water somewhat heated. The consequence was, the little toe of one foot and part of the great toe of the other mortified, and had to be cut off.

seasons be protected from sudden chills by warm (the best are flannel) coverings; and, 2dly, that sea-bathing, a generous diet, and all other means that give permanent vigour to the circulation, should be specially attended to. Under all circumstances, indeed, frequently cleansing the skin, by removing noxious excretions, and allowing the proper exercise of its functions, has a much more important influence on health than is generally imagined.

[Good views of the lymphatic vessels will be found in Lizars's Coloured Plates, page 99, and of the skin, at page 82 of the same. Connected with the subject of the skin, the teacher may introduce some instructive lessons on the five varieties of the human species and their distribution. We have found that these lessons are rendered much more impressive by having drawings of these varieties, and also a skeleton map of the globe, of a large size (say six feet by four), coloured so as to indicate their different localities. Thus, the European, or Caucasian, may be left white, the Mongolian coloured yellow, the American red, the Malay brown, and the Ethiopian black. The drawings, and the requisite information as to localities in making this map, will be found in the latter part of Lawrence's Lectures on Man, 8vo. edition.]

SECTION VII.

LOCOMOTION—THE BONES, MUSCLES, &c.

122. Having now given a short account of the most important functions of the organic or vegetative life, we shall here consider shortly the parts that are immediately concerned in producing the motion of the body. These are the bones and their articulations (joints), and the muscles.

123. The most important of the hard parts in animals are shells, crusts, and bones. The two former, however, are void of vitality, while bone gives every indication of possessing life. In shells, almost no animal matter is found; they are nearly the same in composition as a piece of marble. Crusts (as the lobster's) have a larger proportion of animal matter; and in the composition of bones there is much more. Not only, however, is the earthy matter less in bones; it is also differently combined. In shells and crusts the earth is carbonate of lime (chalk), while in bones the lime is principally united with an acid composed of phosphorus and oxygen, forming phosphate of lime; and it may be remarked, that it is from bones that phosphorus is usually obtained.

124. The quantity of animal matter in different bones, and, consequently, their hardness, varies. In infancy and youth the animal matter predominates; in old age the earthy matter. On an average, perhaps, in mature age, about two-thirds are animal (mostly gelatin and albumen), and one-third earthy matter. Mere hardness, however, is not all that is wanted, for the hardest are often the most brittle substances. The composition of bone, therefore, is such, that the earthy matter may give stability to the framework, on which all the other parts are to hang and work, while the animal matter imparts to it adhesiveness and toughness.

125. It is found that all the parts which afterwards become osseous (bony) are originally in the state of cartilage or gristle; that this is gradually removed, and bone deposited in its stead; and that ultimately, in its highest state of developement, the bone is hollowed out internally, and is filled with marrow, or, in birds, with air.* Some of our bones are completely ossified at birth, as is the case with the bones of the ear; most of the others become more or less so in a few years afterwards; but some parts continue cartilaginous even in manhood, and become perfectly ossified only in old age. This is the case with the cartilages that join the ribs to the breast-bone; and as the elasticity of the cartilage materially assists in breathing, it is easy to understand that the change is not an advantageous one.

126. Perhaps the most rudimentary form of an internal skeleton, exists in the sepia, or cuttle-fish. It is merely a collection of bony plates, which gives support to its soft body, and forms a ring superiorly, through which part of its nervous system passes. The first object, in laying the foundation of the skeleton, appears to be, to provide for the security of the brain and spinal marrow, as protection to these from injury, we shall afterwards find, is of the very highest importance. Accordingly, whatever other parts of the skeleton are wanting, it has been already mentioned that the back-bone, or spine, is always present; and further, in the human race, and in all the other Vertebrata, this is invariably the first part of the osseous structure which nature developes.† It is composed of a series

* When thus hollowed, the bone is found to be much stronger than if the same amount of hard substance had been disposed in the solid form.

† We may here mention, that the various organs of animals are quite different when first developed, from what they afterwards are in their perfect state. On this subject have, of late years, been made perhaps the most astonishing discoveries in modern science. It appears that the organs of the different beings, before they can attain to the rank assigned them in the animal scale, must first pass through many of the phases which the same organs assume in the classes beneath them. Thus, the

of rings or vertebræ, variously joined together in the different classes. Each side of a vertebra, in fishes, forms a cup, and, consequently, when the whole vertebræ are joined, two cups are always opposed to each other—the cavity left being filled by a thickish jelly. In reptiles, the junction is what is called, by mechanics, of the ball and socket kind—the ball of the one vertebra fitting into the socket of that above it. The surfaces of the vertebræ in the Mammalia are nearly flat, and between each, in man especially, there is placed a thick, tough, and highly elastic gristle, which is of great use in breaking the shocks that would otherwise be sustained in running, leaping, &c. The mode of articulation in the fish and reptile allows of much more extensive motion than that of the Mammalia; but some parts of the spine in the latter possess much greater capabilities of motion than others. Figure 25 shows one of the lower vertebræ in man. *a* is the surface by which it is joined; *b* the ring through which the spinal marrow passes, which, Mr Earle has shown, is, in the various species, of a width proportionate to the extent of motion enjoyed by the part.

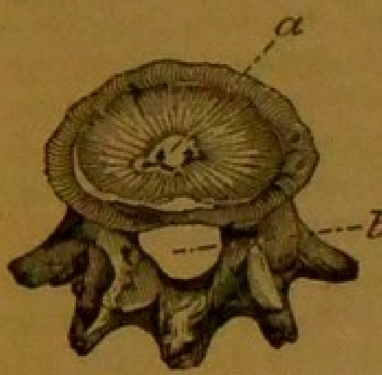


Fig. 25. A Vertebra.

whole body of man is at first little larger than a pin's head, and has the simple pulpy structure of the lowest zoophyte; the brain at first is wholly wanting, and is subsequently like a fish's, a reptile's, a bird's. About twenty-one weeks after its developement, the human brain has a close resemblance to that of the Rodentia (marmot, &c.)

The human heart also, as in animals low in the scale, is at first wanting; then it is like a fish's; and even at birth, we have already remarked that communications exist between the venous and arterial circuits, as in reptiles. In the same way, what afterwards become bones, are at first a mere jelly, like the bodies of the Radiata; subsequently they are gristly, like the skeleton of the Chondropterygii (shark, ray, &c.); and ultimately they pass through the different stages of ossification. The same happens with all the other organs. It has even been found that the human embryo, at one period of its growth, is furnished, like a fish, with gills.

The transformations of insects afford beautiful examples of the same law; and every one has observed that the frog, before it becomes a reptile, remains for some time as a tadpole in the lower class of fishes. It has then gills, and is indeed in every essential a fish.

These discoveries give a most satisfactory explanation of certain of the cases called monstrosities. For example, a person or quadruped born without posterior extremities, may be said, in regard to these, to have remained in the state of developement represented by the Cetacea; a person with hare-lip or cleft pallet represents the condition, in these particulars, of the hare, birds, reptiles, &c.; and so on with the heart, brain, and other organs.

127. The articulation of the spine with the skull, in the Mammalia, exhibits one of the most curiously artificial contrivances to be met with in the body. The object contemplated is to produce a hinge that will allow of two kinds of motion, namely, 1st, such a motion as takes place when we turn the head from side to side; and, 2dly, such a motion as we employ in nodding the head, or one backwards and forwards. The mechanism by which this object is attained is of a most admirable kind, but at the same time of a kind which does not readily admit of description. It involves a great regard for the protection of the spinal marrow at the top of the neck, this being perhaps the most vital portion of the whole body. Injury to it, or pressure upon it, is instantly fatal.

128. Taken as a whole, the human spine is a most curious and perfect piece of mechanical art. It combines the two apparently almost incompatible requisites of great strength and sufficient flexibility. The flexibility is principally produced by the number of pieces employed, which are so firmly knit together, that dislocation of them, without fracture, is a very rare case. Let any one, as Dr Paley observes, try, by main force, to separate the vertebræ even of a hare or a rabbit, and he will soon learn how firmly they are united.

129. The spine is surmounted by the cranium, or skull (see Fig. 7), which consists of a number of separate pieces joined together, forming a strong case for the brain, constructed on the principles of the arch. Connected with the skull are the organs of the principal senses and of mastication, which, amounting, in large animals, to a considerable mass, render necessary various contrivances. In the bird the head is at the end of a long neck, but the skull is made extremely light. The skull and bill of a common fowl are only about the weight of a sixpence. In the cow, camel, &c., the neck, from the food on which they live, is necessarily long, and the head is heavy; and hence there are powerful muscles, that are attached to the skull, and to long spines projecting from the back of the vertebræ of the neck, and an elastic rope, or ligament, fixed also to the same parts, that assists to raise or to support the head.* In the elephant the weight of the head is so enormous, that nature has had, besides these contrivances, to shorten the neck so much as to necessitate the formation of a proboscis, or trunk. One of these sagacious creatures died of a lingering disorder a few years ago in Paris. It was never seen to lie down till the day of its death, and, when very feeble, what seemed to give it the greatest distress, was the effort requisite to support its head.

* Vulgarly called pax-wax, or maiden's hair.

130. The other parts of the skeleton are less essential. They are modified in numerous ways in different species to suit particular purposes, and some are occasionally wanting altogether.

131. The clavicle, or collar-bone (Fig. 7, *y*), is one which has obvious and interesting relations. This bone is perfect in man; it is imperfect in the tiger, &c.; and is wholly wanting in most of the herbivorous tribes. Now, what can be the reason for these differences? The reason is perceived from knowing the uses of the bone, for it is of service only where the upper extremities are much used in laying hold of objects, as in the monkey, squirrel, man, &c.; and to them it serves the important purpose of separating the limbs, and thus allowing sufficient extent of motion. Would it not, then, have been of service to the cow or the horse? Certainly not: quite the reverse. When, in running down a hill, we fall on our hands or shoulder, or stop ourselves with our hands against a wall, one of the most common accidents is dislocation or fracture of the collar-bone, because this bone is directly connected with the arm and breast-bone, and, of course, sustains a great part of the shock. But when a horse gallops down a hill, or leaps, the shock is greatly more violent, and yet no bone is broken. The reason of this is learnt by inspecting its skeleton, for we find that the fore-legs are not connected with the trunk by bones at all, but by two enormous fleshy muscles attached to the shoulder-blades (Fig. 7, between the situations of the letters *y* and *r*), between which the heavy body safely swings.

132. The breast-bone (Fig. 7, *x*) is almost rudimentary in fishes, as they have properly no chest, the gills and the heart being placed under the head. The same bone in birds is very large, to give an extensive surface on which the muscles that move the wings may be fixed. In the tortoise and turtle its size is enormous, forming a covering to the whole of the under part of the body.

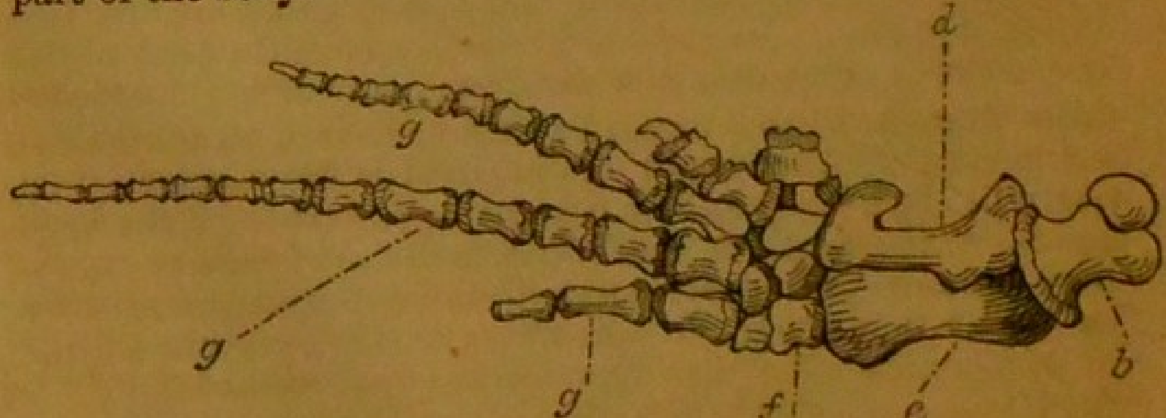
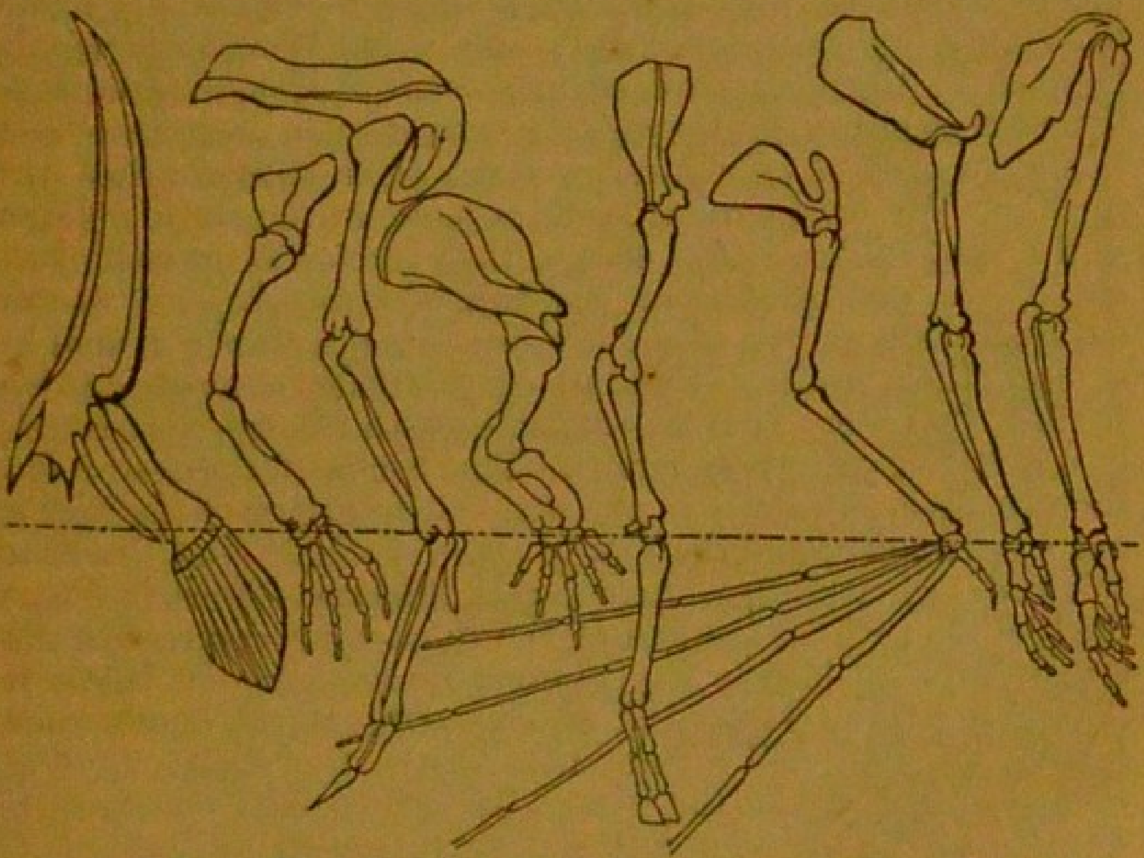


Fig. 26. Paddle, or fin, of the Porpoise.

133. The extremities are parts in which it is very interesting

to trace the modifications which nature employs to fit the same bones for different uses. In Fig. 7 we see the human arm and hand, composed of the humerus, or principal bone (*b*), the two bones of the fore-arm (radius and ulna, *d*, *e*), the bones of the wrist (*f*), and the fingers (*g*). Fig 26 represents the paddle, or fin, of the porpoise, which might almost be taken for some burlesque representation of the hand and arm of man. The parts are marked with the same letters, from which it will be seen that the humerus and bones of the fore-arm are short, flat, and strong, and that the joints of the fingers have been greatly increased to give extent of surface. Almost the whole body of the skate and of the ray-fish is composed of what represent the two hands, immensely expanded. In Fig. 27,

Fig 27. Anterior Extremities of Various Species.



Fish. Frog. Bird. Dolphin. Deer. Bat. Ape. Man.

taken from Dr Fletcher's Rudiments of Physiolgy, the anterior extremities of different species are sketched, and a mere inspection will show at once the general resemblance of the parts and their modifications. As the extremities of the deer, horse, cow, &c., are formed for solidity, we find, in different parts, that there is only one solid piece for two, three, or more bones, in the corresponding parts of man, but even these solid pieces are found originally to have been several distinct bones, that have afterwards united. Of all the modifications which the different portions of the extremities undergo, the human hand is undoubtedly the most beautiful. Marks of the greatest care are every where visible in the formation of this most admirable structure; and whether we regard its fine sensibility, or the power, rapidity, and delicacy of its movements, we must acknowledge that no similar part in other animals can be compared with it. Its chief superiority, as an instrument of prehension, arises from the length, mobility, and strength of the thumb, which can act as an antagonist to all the other fingers, giving us something like the power of two hands conjoined. Indeed, we notice that monkeys, squirrels, the opossum, &c., which most resemble us in these parts, always use both extremities when they take up and examine any object.

134. It is not possible, on the present occasion, to say more than a few words regarding the joints, although there are many things connected with them well worthy of attention. The bones forming joints are firmly knit together by parts called ligaments; the bones are covered with a smooth gristle at their extremities, that they may move easily on each other, and there is a kind of oil poured into the joint to assist this still further. We have various kinds of joints in the body. There is the hinge-joint at the elbow, that admits of motion only backwards and forwards; the ball and socket joint at the shoulder, that allows of motion in every direction; as well as several other kinds. We shall only further observe, on this subject, that there is a part connected with the hip-joint which is worthy of particular notice. The bones of the lower extremity are constructed on the same plan as those of the upper, but are stronger; and the hip, like the shoulder joint, is of the ball and socket kind. There is this difference, however, that the socket in which the ball of the thigh-bone moves, is made much deeper, evidently to give greater security against dislocation, in a part on which the whole weight of the trunk must press. To show still further that this is the object in view, we find, on examining the joint, a part added, that is altogether wanting at the shoulder. It is a strong rope, fastened by its one end to the top of the thigh-bone, and by the other to the socket in which this moves. Dr Paley (whose graphic remarks have been already more than once quoted), in speaking of the proofs of a designing Creator exhibited in our body, observes of this part, that nothing can be more mechanical, no proof of contrivance stronger. "It is," says he, "an instance upon which I lay my hand. One single fact, weighed by a mind in earnest, leaves oftentimes the deepest impression. For the purpose of addressing different understandings and different apprehensions —for the purpose of sentiment—for the purpose of exciting admiration of the Creator's works, we diversify our views, we

multiply our examples; but, for the purpose of strict argument, one clear instance is sufficient; and not only sufficient, but capable, perhaps, of generating a firmer assurance than what can arise from a divided attention."

135. Having got the solid skeleton, the agents employed in producing its motion are the muscles. By a muscle is meant a fleshy body, possessing the peculiar property of contractility, or of shortening itself. When we cut a piece of meat, it is the flesh we notice which is the muscular part. When we move our fingers, and look at our fore-arm, we can see the muscles that move them contracting; or we can feel the muscles in strong contraction when we press a finger on each side of the cheeks, near the angles of the lower jaw, and firmly close the jaws; or when we place one finger in the armpit, and the other on the breast, and then draw the arm downwards and across the chest with a jerk. This contractile power of muscles is quite different from elasticity. The first is an original source of power, while elasticity merely modifies its distribution. Thus, it is the elasticity of the mainspring of a watch that keeps it going for twenty-four hours, but the muscles of the hand which winds it up, is the true moving power.

136. The muscles are generally collected into bundles, which are found, when examined, to consist of lesser and lesser bundles, bound together by firm sheaths. Those employed for moving the skeleton are fixed by their ends to the bones, and are very various in their shapes, but commonly terminate in tendons, or sinews, which are of a very intricate structure, and of great strength. Taken together, the tendon may be viewed as a strong rope, and the muscular fibres, when contracting, as so many hands that are pulling at it. Fig. 28 shows the bundles of fibres of which a muscle is composed; Fig. 29 the zigzag state into which these are thrown during contraction, and which, indeed, is the cause of contraction.*


Fig. 28.


Fig. 29.

137. Professor Ehrenberg states, that even in animalcules, when these minute creatures are darting through the fluid, he has seen parts contracting which he thinks are muscular bands. The bodies of the other Radiata seem almost wholly contractile, but no distinct muscles have hitherto been discovered, and their powers of locomotion are generally very limited. Except in the highest of the Mollusca, the locomotive powers are not much

* Prevost and Dumas, two eminent French physiologists, describe this as the appearance of the muscle when contracting, but the accuracy of their description has lately been rendered doubtful by other researches.

greater; but many of these have distinct and strong muscles. It is by powerful muscles that the oyster and the mussel so firmly close their shells. The muscular system of the Articulata is particularly well marked, and their activity and power are proportionately great. Lyonet has counted, in some species of caterpillar, not less than 4000 muscular bands. A beetle, placed under an ordinary candlestick, is able to move it; a fact which shows a wonderful degree of muscular energy in so small an animal. Ants will carry loads forty or fifty times heavier than their own bodies; and a small insect, called the *Cicada spumaria*, will leap five or six feet—at least two hundred and fifty times its own length. Dr Roget remarks, that this, if the same proportions were observed, is equal to a man of ordinary stature vaulting through the air a quarter of a mile.

138. It is, however, in the vertebrated division that the action and arrangement of the muscular system have been studied with the greatest care. Anatomists have given names to between 400 and 500 muscles in the human body; but the parts of what is called a single muscle by anatomists, often have different and even opposite uses. Professor Grant states, that, in the proboscis of the elephant alone, there are nearly 1000 muscles.

139. The covering of the skin hides from our view the busy scene beneath. Could we behold properly the muscular fibres in operation, nothing, as a mere mechanical exhibition, can be conceived more superb than the intricate and combined actions that must take place during our most common movements. Look at a person running or leaping—or playing on a harp or piano—or watch the motions of the eye! How rapid, how delicate, how complicated, and yet how accurate, are the motions required! Think of the machinery necessary to articulate distinctly 400 words, most of them requiring several separate movements, in the space of a minute; or of the endurance of such a muscle as the heart, that can contract, with a force equal to sixty pounds, eighty times every minute, for eighty years together, without being tired.

140. To muscular contraction are principally owing the infinitely varying shades of expression in the human countenance; and even in the lower animals, we see that the feelings to be expressed, and the parts that are to express, are in unison. A cow or a horse not only does not snarl like a dog or a tiger, but is absolutely incapable of doing so; and for this plain reason, that the latter are furnished with express muscles for drawing up the sides of the mouth, which the cow and horse altogether want.

141. The muscles are generallv arranged in sets, which are

opposed to each other, like workmen in a saw-pit. We have thus a set that bends the limbs, and a set that extends them; sets that lower the body or head, and sets that raise them up; and it is even in the same manner that the mouth is kept in the centre of the face. When palsy affects the muscles on one side of the face, those opposite, having no counterbalancing power, draw the mouth to that side.

142. It is exceedingly interesting to note the many modes nature employs to accomplish progressive motion among the Vertebrata—making use of two legs in man, four in quadrupeds, the legs and tail in the kangaroo, the tail in fishes, &c. &c. We can say only a few words as to her greatest achievement in locomotion, that of flight—a feat which it has foiled all man's ingenuity to imitate. When an animal has to pass rapidly through the air, nature seems to have bestowed her chief care upon two circumstances; 1st, to lighten the whole fabric as much as possible, which is principally accomplished by making the solid parts thin and hollow, at the same time that the whole body is filled with air like a sponge. Thus, the skeleton of a pelican, five feet long, was found to weigh only twenty-three ounces. And, 2dly, by concentrating the muscular power in those parts that are to be the chief instruments of motion. The two pectoral muscles which move the wings of the swallow, have been estimated to possess more power than all the others in the body put together. A flap from a swan's wing has been known to break a man's leg, and a similar blow from an eagle has been instantly fatal. This great power will appear absolutely indispensable, when we consider that a swallow, as well as many birds of prey, will probably often pass through not much less than 1000 miles daily. All the functions, indeed, contributing to locomotion, exist in the highest intensity in the bird. Its skeleton, of all animals, is the most highly ossified; its muscles act with the greatest energy; its blood, to support this energy, is richest in red globules, and the respiration, to arterialise the blood, in it alone is double.

143. Perhaps no ordinary circumstance has so much influence on the general health, as due attention to the state of the muscular system. We may be convinced of this in two ways; for, 1st, we see persons, whose system no means can prevent continually running into disorder, evidently because they persist in leading an indolent, inactive, or sedentary life, in which the exercise of the muscles is totally neglected; and, 2dly, we see others, who neglect almost all the rules considered essential for securing health except this, that they incessantly exercise their bodies in the open air, and who yet pass through life almost without a bodily

ailment. Under ordinary circumstances, and with a moderately good constitution, in a country like our own, we may say, that the condition above all others which can secure and preserve the inestimable blessing, health, is varied exercise in the open air. With this, our food, however plain, is sweet, our body is light, our digestion easy. Without it, the salt that gives relish to every dish is absent—we live the prey of a thousand tormenting sensations—our diseases become intractable, our secretions morbid, our children are weakly and stunted, and the term of life is materially shortened.

144. Among the poorer classes, those who suffer most from neglecting muscular exercise, are the various artisans who follow sedentary occupations, and females who are constantly employed in different kinds of needle-work, &c. Among the more wealthy classes, literary persons, and those engaged in engrossing occupations, suffer much from neglect of it; but, above all, females suffer from this cause, and especially young females attending school, who are often at once enormously overtasked, in acquiring what are considered the necessary

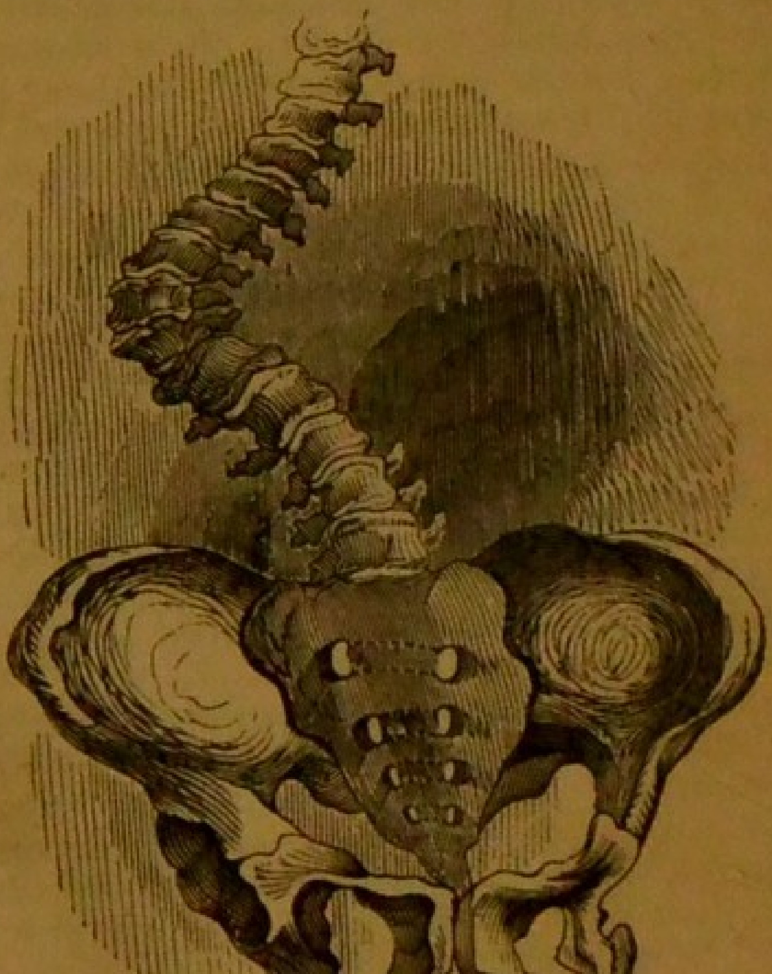


Fig. 30. Deformed Spine.

branches of education, and denied those playful sports, which alike nature and common sense dictate as agreeable and proper. In all the classes of persons referred to, the effects of neglected muscular exercise are shown in a general increased susceptibility to disease; and in the females of the better classes, inability of the muscles to support the spine, and consequent curvature of it, are but too common. Dr Forbes states, that in a boarding-school, containing forty girls, which he inspected, he did not find one, who had been at the school for two years, whose spine was not more or less crooked. A greatly deformed spine of this kind is represented in Fig. 30. The spine (by which all the upper parts of the body are supported), it should be recollected, is composed of twenty-four pieces, that are kept in a straight position by the contraction of its muscles; and if these are not exercised, like all other parts, they become weak and shrivelled, and are thence unable to support their burden. In Fig. 31, A shows the natural upright line the spine presents when viewed from behind; B shows the deviation a girl's spine sustained after the muscles had been weakened by a fever, but which went nearly off in a few weeks from proper exercises; C shows the line the spine then presented; D shows a case in which this deformity had become inveterate. To show what an extent of injury is thus inflicted on young females, in the more wealthy ranks, we may mention, that the late Mr Shaw, of London, who had great experience in this disease, states, that for one poor child twenty rich ones are affected; that among the poor children, the proportion of boys and girls is about equal; but that, among the rich, for one boy a hundred girls have crooked spines. It must be obvious, therefore, that there is something greatly wrong in the system of training to which these girls are generally subjected.*

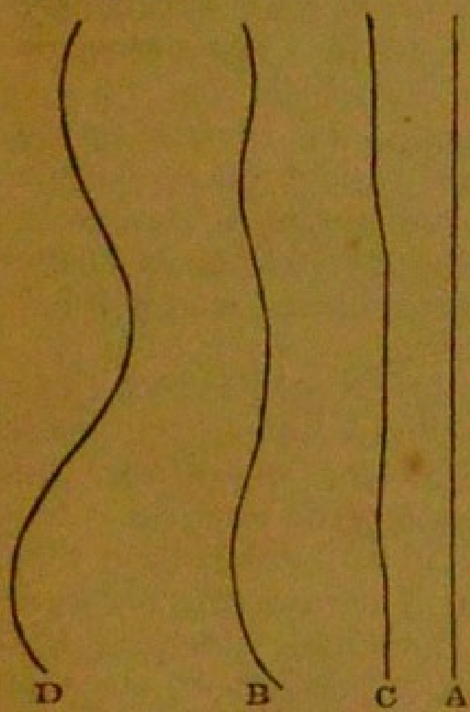


Fig. 31. Deformities of Spine.

* No doubt, want of exercise is the main cause of this, but the pernicious fashion of lacing tight the stays also contributes to produce distortion of the spine; for besides that this prevents the natural supports, the muscles, being exercised, it is a physiological law that all parts much pressed on become absorbed. Perhaps, also, something is due to the false taste that prevails among the higher classes, as to a certain delicacy of habit being necessary to gentility. Nothing can be more unnatural, or more injurious in its consequences.

145. We can but very briefly refer to the kinds of exercise that are most proper. These, indeed, must vary with the condition, the opportunities, and the inclinations of individuals. In general, when the weather permits, three or four at least out of the twenty-four hours should be spent in some out-of-door exercise. Let this be persevered in, and there are few who will not acknowledge its benefits. Such exercises as engage the mind at the same time are to be preferred. Games and sports, gardening, botanical and geological excursions, hunting and shooting, &c., are of this kind. Where it can be had, perhaps one of the best, for both sexes, is exercise on horseback; but of whatever kind it may be, let this be remembered by all, that if it is wished to possess health, and properly to enjoy life, a sufficient amount of muscular exercise must be taken.

146. There is one state of the bones called rickets, in which the earthy matter is deficient, and which often proceeds from original weakness of constitution. The bones are consequently soft and yielding, and are sometimes bent in a most extraordinary way. There is another state, in which the amount of earthy matter in the bones is too great, and then they are very brittle. This happens generally in old and in young people. We lately saw a girl whose thigh-bone broke from merely turning in bed. Dr Good saw an old lady who broke both her thigh-bones merely from kneeling in church, and who had her arm broken on being lifted up.

147. The bones, joints, and muscles, are all subject to various other diseases. In scrofulous habits, the bones and joints are particularly liable to low, obstinate affections, which wear out the constitution, and often render necessary the removal of the limbs. Rheumatism is a particular kind of inflammation that attacks the joints or muscles, and which occasionally becomes excessively dangerous from leaving these and attacking the valves of the heart, and the bag (pericardium) in which it is contained.

[To show the animal without the earthy matter of bones, steep the rib of a sheep, or other slender bone, in one part of muriatic acid (spirit of salt), and eight of water, for a few hours. It will then bend in any direction. To show the earthy without the animal matter, place a bone in a clear fire for about ten minutes.

A vertebra or two of the horse or other quadruped should be seen to form a proper idea of the spinal canal, &c.; and also the back-bone of a cod or haddock. A section of a cod's spine should be made to show the cup-like cavities in the bodies of the vertebræ. The articulations of the two upper vertebræ referred to in the text, can be well seen in the calf. Give the butcher directions to preserve attached to the head the two upper vertebræ; clear off the flesh from the fore part of these, cut into the first and second articulations, and separate the vertebræ from the head. The tooth-like process, the ligaments, &c., will then be seen. At the same time may be shown the ligament that supports the head, by cutting away the flesh behind the vertebræ.

To give a clear idea of what a muscle is, it is interesting to take off the skin from a pigeon's breast, and show the extent of its immense pectoral muscle. On the other side, the muscle may be cut through to show its thickness; and its attachment to the first bone of the wing (humerus) should be shown. A small muscle (lesser pectoral), having a different insertion, will be found beneath the great pectoral. The comparatively small size of the muscles of the leg, the tendons going to the toes, &c., may also be easily shown.

A stucco cast, showing the superficial muscles of the human body, may also be made very interesting, when their uses can be explained.

The inspection of a few skeletons or parts of skeletons of any of our common animals—a dog, cat, squirrel, weasel, mole, cock, swan, cod, &c.—adds greatly to the interest of this section; and it is still better, where there is an opportunity, to visit such collections as the Anatomical Museum belonging to the University or Royal College of Surgeons in Edinburgh.

For appropriate figures to illustrate this section, see Penny Cyclopædia, vol. viii. page 57;* Roget's Bridgewater Treatise, vol. i. pages 129, 178, 333, 337, 411, 437, 441, 447, 465, 530, 559; Bell on the Hand; Dr Smith's Philosophy of Health, vol. i. pages 171, 189, 196, 205, 237, 312, 321; Bell's Anatomy, vol. i. pages 254, 258.]

SECTION VIII.

THE NERVOUS SYSTEM.

148. We have now to enter on the consideration of those parts that essentially distinguish an animal from a vegetable, and the organs of the animal from those belonging to the organic life; or, in other words, we have to speak of the parts that give us the power of voluntary motion, and which enable us to feel and to think.

149. In all but the most simple animals, it is quite certain that sensation and voluntary motion depend on the nervous system. The nervous system of man consists of the brain, the spinal marrow, and the nerves. As these are all composed of nearly the same kind of substance, we may view the spinal marrow and brain as nervous matter collected into masses, and the nerves as the same matter diffused over every part of the

* A figure taken from the London Fashions answers better than the "modern beauty."

body. The brain, as has already been mentioned, is contained in and protected by the cranium or skull. It is also enclosed in three layers of fine membrane, the outermost of which (dura mater) is strong and tough, and adheres to the skull at different points; the middle layer (arachnoid) is so fine as scarcely to be visible; and the innermost one (pia mater) not only envelopes the brain, but also penetrates into certain parts in its interior. The spinal marrow has similar coverings, and is contained in the canal formed by the rings of the united vertebræ, represented in Fig. 25, *b*. The nerves are cords, attached to the brain and spinal marrow, which are composed of brainy matter enclosed in numerous minute sheaths, bound together by a strong covering (neurilema), as seen in Fig. 36, *g*.

150. When we examine the outer surface of the brain, we ob-

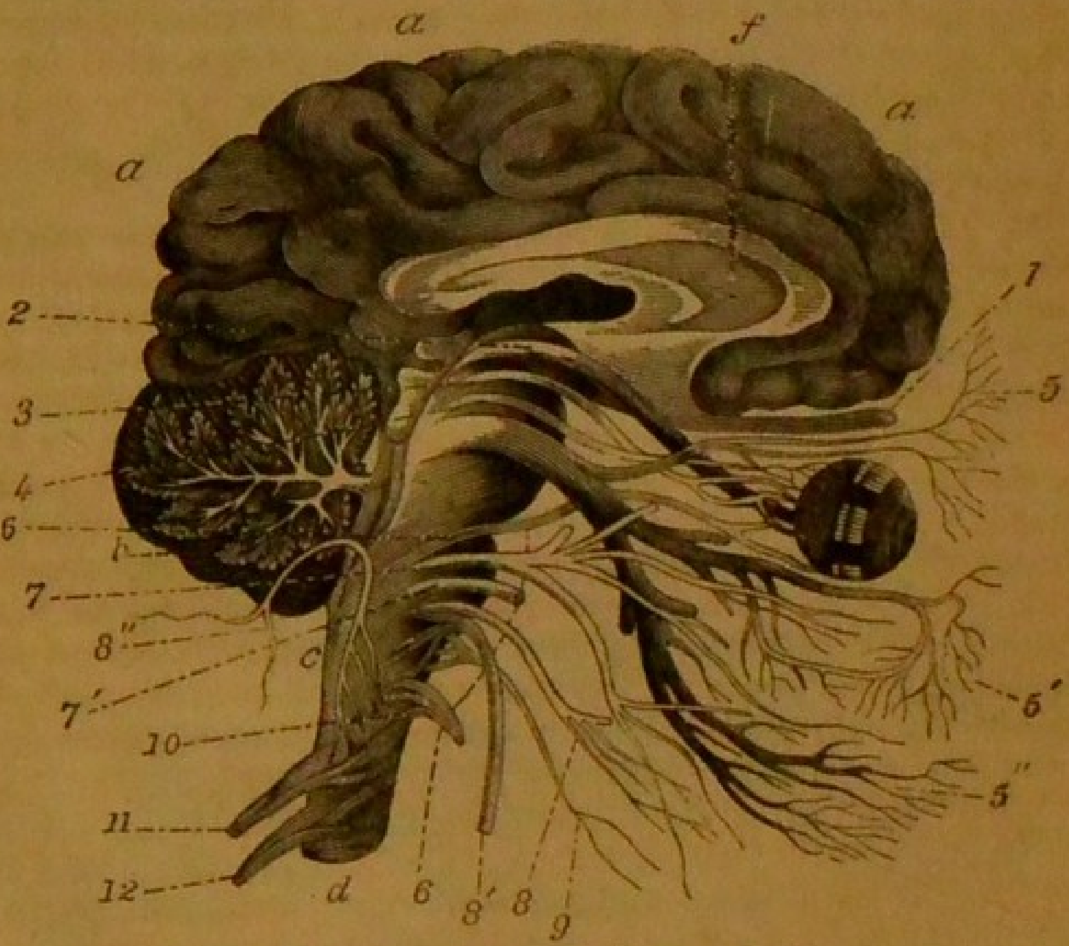


Fig. 32. Side View of the Human Brain.

Longitudinal section of the cerebrum, cerebellum, and medulla oblongata. *a a a*, the cerebrum. *b*, the cerebellum. *c*, the medulla oblongata. *d*, the spinal marrow. *f*, the lateral ventricle. 1, the olfactory nerve. 2, the optic nerve. 3, 4, 5, 6, the 3d, 4th, 5th, and 6th nerves. 7, the portio dura of the 7th nerve. 7′, the auditory nerve. 8, the glossopharyngeal nerve. 8′, the par vagum. 8″, the spinal accessory nerve. 9, the hypoglossal nerve. 10, the suboccipital nerve. 11, 12, spinal nerves.*

* The functions of the different nerves, which will immediately be adverted to, may be made plain by having a large drawing of

serve it folded or convoluted, as seen in Fig. 32, *a a a* (which shows a longitudinal section of the brain and upper part of the spinal marrow, with the nerves attached to them); and when it is cut into, we find it composed, 1st, of a grey pulpy substance, mostly placed externally, and, 2dly, of a similar white substance, placed internally. The same materials exist in the spinal marrow, but the white matter is external, while the grey is internal. What is commonly called the brain, is divided by anatomists into the cerebrum or proper brain (Figs. 32, *a*, and 33, *a*), and the cerebellum or lesser brain (Figs. 32, *b*, and 33, *b*), which presents in its interior the branched appearance of a tree (arbor vitæ), as may be observed in Fig. 32. Both these parts are divided longitudinally into two halves or hemispheres, and also transversely into lesser parts called lobes. The connections of the two are clearly seen in Fig. 35, in which the convolutions are supposed to be unfolded, and the parts separated. *a a* is the cerebrum, *b b* the cerebellum. Fig. 33 represents the base of the brain (*a*) and cerebellum (*b*), the anterior surface of the spinal marrow (*c*), and the nerves going off from these.

151. In the interior of the brain there are several cavities called ventricles, two of which are of considerable size. Into these cavities, one of which is seen in Fig. 32, *f*, there is continually poured out a clear fluid, which, in the healthy state, is immediately absorbed; but in a diseased state, this sometimes accumulates until it amounts to gallons, forming one variety of the disease called hydrocephalus, or water in the head. There are also other parts found in the brain, which have received names from anatomists, some of which will be noticed afterwards.

152. The spinal marrow is found to be composed of six columns, as represented in Fig. 36. Two are anterior, two lateral, and two posterior: in the cut one of each is marked respectively *a*, *b*, and *c*. These columns, again, when minutely

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Fig. 32, so coloured as to distinguish each kind; or, what will answer equally well, perhaps, the pupil can colour the nerves in the cut. The following may be placed beneath the drawing:—

NERVES OF SENSATION (coloured red). No. 1, olfactory—No. 2, optic—No. 5, 5′, branches of the 5th nerve—7′ auditory nerve.

NERVES OF MOTION (coloured blue). Nos. 3, 4, 6, go to the muscles of the eye—No. 7 (portio dura) goes to the sides of the head and face—8″, the spinal accessory nerve, goes to the muscles of the shoulder—9, goes to the muscles of the tongue.

NERVES BOTH OF SENSATION AND MOTION, OR MIXED NERVES (coloured brown). 5″, the lowest branch of the 5th nerve (the brown colour to commence where the upper branch of 7 crosses it) —10, 11, 12, and all below this.

DOUBTFUL NERVES (coloured black). 8, the glossopharyngeal—8′, the par vagum.

examined, are found to consist of bundles of fibres,* that can be traced upwards into, and are found to be continuous with, similar fibres composing the brain and cerebellum. The upper portion of the spinal marrow (Figs. 32, *c*, 33, *f*), which receives the name of the medulla oblongata, is composed, 1st, of two parts called the corpora pyramidalia (Fig. 35, *e*), which appear to be chiefly continuous with the anterior columns of the spinal cord (Fig. 36, *a*), and to run upwards to the cerebrum (Fig. 35, *a*); 2dly, of two similar parts (Fig. 35, *f f*), called the corpora olivaria, chiefly continuous with the lateral columns of the spinal cord (Fig. 36, *b*), and likewise principally running up to the cerebrum; and, 3dly, of two other parts, called corpora restiformia, behind the corpora olivaria, continuous with the posterior spinal columns (Fig. 36, *c*), and chiefly running to the cerebellum (Fig. 35, *b*).† The two lobes of the cerebellum are also connected with each other by a part (Fig. 35, *g*) called the bridge of Varolius.

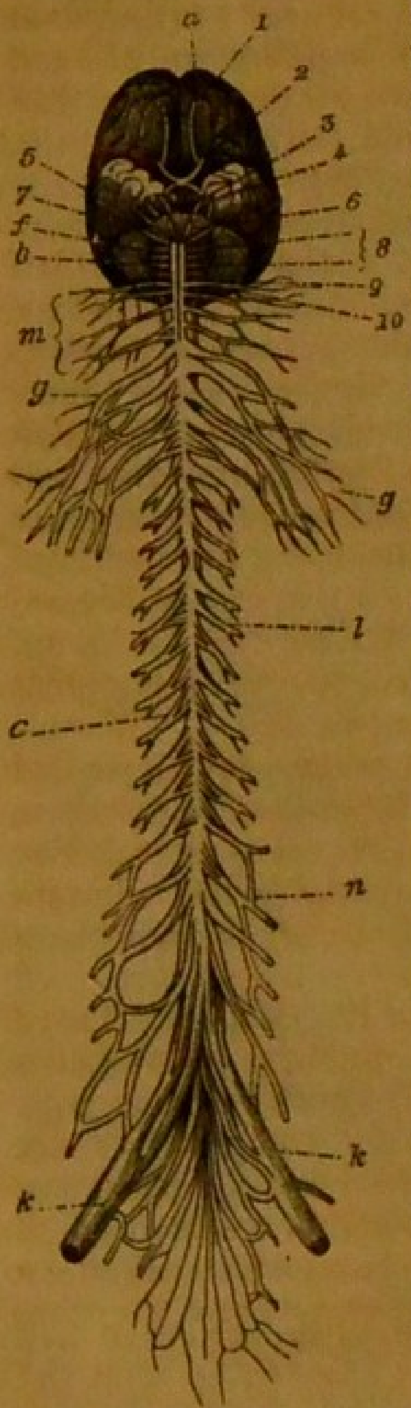

Fig. 33. Base of the Brain and Spinal Cord.‡

* The interesting discovery has been made within these few years, by German anatomists, that these fibres, and all the fibres composing the nervous matter, are tubes filled with a fluid. The annexed sketch (taken from the British and Foreign Medical Review, No 12, in which a detailed account of this discovery is given), shows the fibres of one of the nerves magnified, with the fluid contained in them escaping from their extremities. It is probable that this discovery may be the means of throwing some light upon the functions of this hitherto little understood part of the animal frame.

Fig. 34.

† Sir C. Bell has described another part, which he calls the respiratory column, but it has not been generally admitted by physiologists. On separating the two corpora pyramidalia, the fibres can be seen very distinctly to cross from the right and left sides, and this is thought to be the reason why palsy, from injury or disease of the one hemisphere of the brain, frequently affects the opposite side of the body.

‡ View of the base of the brain, anterior part of the spinal marrow, and attached nerves. *a*, Cerebrum; *b*, cerebellum; *c*, spinal marrow; *f*, medulla oblongata.

153. These descriptions are necessary to make intelligible the functions of the different parts of the nervous system. We shall now state a few of these. When the spinal marrow is divided in the loins, sensation and all power of voluntary motion are immediately lost in the lower extremities; when the spinal cord is divided above where the nerves (Fig. 33, *g*) come off to the arms, the latter, and all the parts below, suffer in the same manner, but the animal can still breathe; when the medulla oblongata (Figs. 33, *f*, and 32, *c*) is divided or injured, respiration immediately ceases, and death of course is instantaneous. If, again, the division is made above the medulla oblongata, and below the bridge of Varolius (Fig. 35, *g*), respiration continues, and the animal may live for a longer or shorter time. Chossat, a French physiologist, who performed some experiments of the latter kind on dogs, thinks they die from an inability to keep up their natural temperature. Tortoises, however, in which the brain has been taken out, have lived for four or six months afterwards. The brain of a young puppy was removed, and it not only continued to breathe, but also sucked, when applied to the teat, or when the finger, moistened with sugar, was put in its mouth. There have also been many cases of children born almost wholly without nervous matter, above the medulla oblongata, which yet have lived and thriven for days, or even for several months.

154. The parts above the medulla oblongata, viz. the cerebrum and cerebellum, are generally considered as the especial seat of intellect and moral feeling. Upon the different functions supposed to be performed by different parts of these, is founded the modern science of phrenology. They are thought to be no further necessary to sensation and voluntary motion, than as receptacles to treasure up the one, and an organ to direct the other. The brain itself is not possessed of sensibility, for when the skull has been fractured, and the brain has protruded, part of it has been repeatedly shaved off, without occasioning the least pain, and, in some of the lower animals, the whole of the upper nervous mass has been cut away, without the animal manifesting any uneasiness, until the instrument came close to the medulla oblongata. Cases of disease of the brain have been recorded which lead to the same conclusion. Dr Abercromby mentions having seen a lady who died suddenly without almost a single symptom, and who was so well the evening before death

1, Olfactory nerves; 2, optic nerves; 3, 4, 5, 6, 3*d*, 4*th*, 5*th*, and 6*th* nerves; 7, portio dura of the 7th and auditory nerves; 8, glossopharyngeal nerves and pneumogastric nerves; 9, spinal accessory and hypoglossal nerves; 10, suboccipital nerves; *m*, cervical plexus of nerves; *g*, plexus of nerves going to the arms; *l*, dorsal nerves; *n*, lumbar nerves; *k*, plexus of nerves going to the lower extremities.

as to have been at a dancing-party, one half of whose brain was ascertained, after death, to have been completely destroyed.

155. M. Magendie has made some curious discoveries connected with the effects of lesions of the parts situated above the medulla oblongata. When parts situated in the ventricles (corpora striata) are cut, the animal immediately darts forward and runs with rapidity. This phenomenon, he says, is particularly remarkable in young rabbits, the animal appearing to be impelled forward by a power within, which it cannot resist. It is a curious fact connected with this observation, that horses are subject to a disease that produces similar effects. The diseased animal easily goes forward, and will even trot or gallop quickly, but seems incapable of going backwards, and appears to have difficulty in arresting its progressive motion. On the other hand, when the cerebellum or medulla oblongata was injured in a certain manner, the tendency always was to move backwards. Some pigeons which had been thus injured, constantly moved backwards in walking for more than a month,

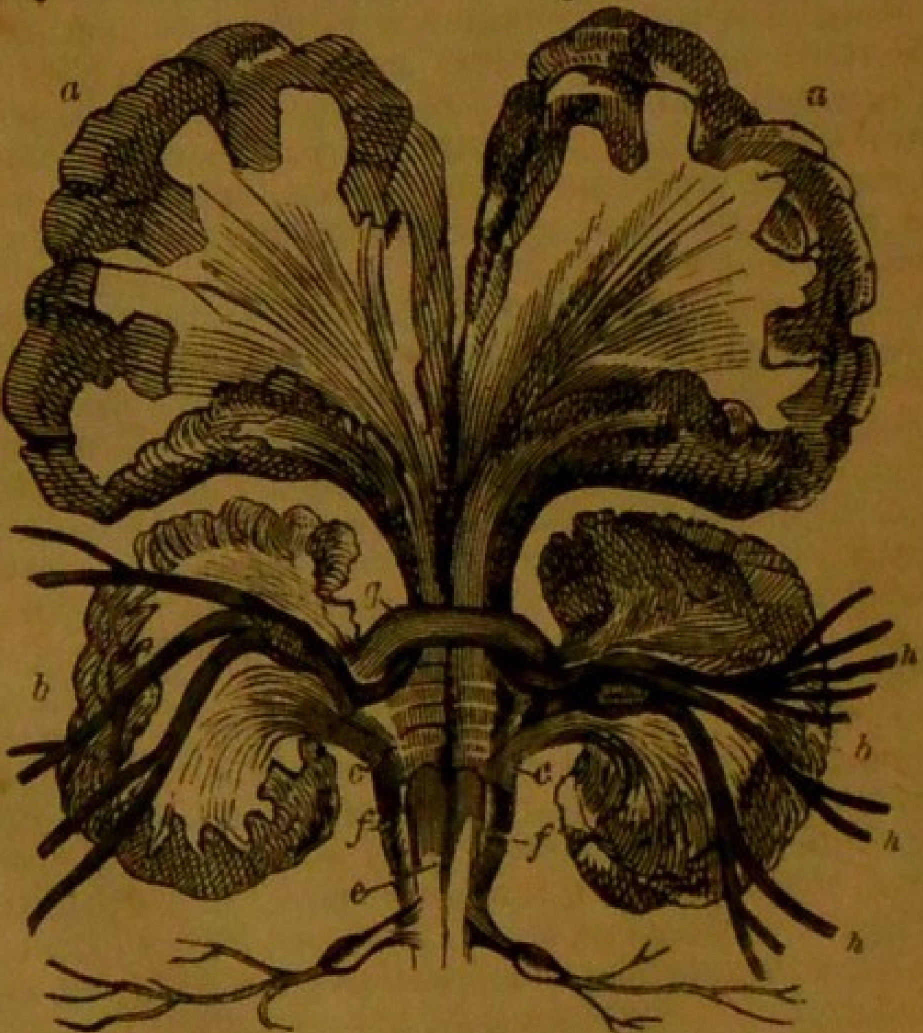

Fig. 35. Connection of the Cerebrum and Cerebellum.

and even flew backwards when thrown into the air. Another singular movement took place when the parts leading from the spinal cord up to the cerebellum (crura cerebelli), Fig. 35, *c*, were cut. When the one on the right is cut, a whirling motion takes place on that side, and sometimes with such rapidity that sixty turns are made in a minute. M. Magendie says he has seen this continue for eight days, without stopping, to speak properly, for a single instant. When the opposite crus cerebelli is cut, rotation takes place on the opposite side; and when both are cut, motion in both directions ceases. Probably some disease of these parts existed in an insane person who was some years ago confined in one of the Edinburgh asylums, and who incessantly occupied himself in turning round in one direction. He might be stopped, or forced to turn in an opposite direction, but when left to himself, immediately turned as before.

156. We are indebted to our countryman Sir Charles Bell, however, for perhaps the most brilliant discovery ever made connected with the functions of the nervous system. We refer to his discovery of the different parts upon which motion and sensation depend. This distinguished physiologist was led to his investigations partly from considering the distribution of certain nerves, and partly from cases in which a person wholly loses the power to move a part of the body, and yet retains perfect sensation in it, or where the reverse of this happens—that is, where the power of motion remains while sensation is gone. Of such cases, the following may be taken as an example:—Francisco Cæsario, living at Rio Janeiro, fell from a scaffold twenty feet high. On recovering from the shock, it was found that his left side, from the shoulder downwards, was deprived of all power of motion, but that sensation remained in it; whereas, on the right side, his powers of motion were perfect, but sensation was then and afterwards so completely gone, that a lancet might be thrust deep into the flesh without giving him the slightest pain. From the middle of the neck upwards, motion and sensation on both sides were uninjured, and the line of demarcation was so exactly drawn, that it might be defined by a pack-thread surrounding the neck.

157. Now, of such cases as the above, Sir Charles Bell's experiments afford a most satisfactory explanation; for though a limb is deprived both of the power of motion and sensation by dividing the spinal nerves that go to it, Sir Charles Bell showed, that by tracing these nerves to their origin, they are each found to be composed of two parts, one of which comes from the anterior column of the spinal cord (Fig. 36, *a*), while the other comes from the posterior column *c*, and, as represented, has always a small ganglion or swelling on it. He further showed, that if the anterior root *d* be cut, the power of motion in the part supplied by the nerve is extinguished, as is also

sensation, by dividing its posterior root *e*. In his experiments, when the posterior or sensitive roots of the nerves in a newly

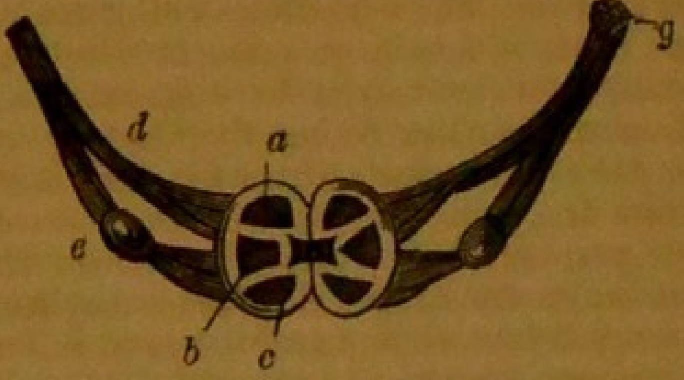

Fig. 36. Section of Spinal Marrow.

killed animal were irritated with a sharp instrument, no effect was produced; but when the anterior or motive roots were irritated, the parts of the body to which these nerves went, were thrown into convulsions. An ass was killed, and immediately the motive nerve which supplies the muscles of the jaw was irritated. The muscles contracted strongly, and closed the jaw with a snap; but when the same nerve was divided in a living animal, the jaw fell relaxed.

158. These explanations will render intelligible the account we shall now give of the functions of the different nerves derived from the brain and spinal cord.* They come off in pairs, as represented in Fig. 33. Figure 32 shows, as already mentioned, a longitudinal section of the brain and medulla oblongata. No. 1 (in both Figures) is the 1st or olfactory nerve, which goes to the nose, and gives the sense of smell; and No. 2 (also seen in both figures) is the 2d or optic nerve, that goes to the eye, and gives the power of vision, both of which will be considered when we come to speak of the senses.

No. 3 (seen in both Figures) is a nerve that goes exclusively to the muscles of the eye. It has its origin from the anterior column of the spinal cord, which runs up to the cerebrum, and is, therefore, only a nerve of motion.

No. 4 (seen in both Figures) is the smallest nerve in the body, being, in man, little thicker than a sewing thread. It goes to a single muscle which moves the eye (trochleator); it is a nerve of motion, and probably has an origin similar to the last, though this has not been distinctly shown.

No. 5 (seen in Fig. 33, but best in Fig. 32 and in Fig. 35, *h*) is a most extensive and important nerve. It is the highest that arises by double roots, and is, as shown by Sir C. Bell, both a

* The derivation of the nerves from the brain is considered only apparent, many physiologists believing that they can be traced to the spinal cord, as may be partly seen in Fig. 32.

motor and a sensitive nerve. Its first branch (Fig. 32, 5), which goes to the eye, eyebrows, forehead, &c., comes only from the posterior or sensitive root, and gives to the parts mentioned the sense of touch or common sensation. If this nerve were destroyed, we might have sensations from light, but we could have no feeling when any thing else came in contact with the eye. The second branch (Fig. 32, 5′), like the first, comes from the posterior root, and gives sensibility to the upper jaw, palate, upper lip, &c. The third branch (Fig. 32, 5″) has its origin from both the motor and sensitive roots, and hence gives both sensibility and the power of motion. It goes to the muscles, skin, &c., connected with the lower jaw, tongue, and mouth. The sensitive branches of the 5th nerve are those that are so painfully affected in toothache and tic doloureux.

No. 6 (Figs. 32 and 33) is the 6th nerve. It has only one root from the anterior part of the spinal cord, and is hence exclusively a motor nerve. It goes to a single muscle of the eye.

No. 7 (Figs. 32 and 33) is the motor, or hard portion, as it is sometimes called (portio dura), of the 7th nerve. It is extensively distributed to the muscles of the face and forehead. When it is cut, the muscles on that side are paralysed, and the mouth, as formerly noticed, is drawn to the other side.

No. 7′ (Fig. 32) is called the soft portion of the 7th nerve. It goes to the internal ear, and is the nerve of hearing.

No. 8 (Figs. 32 and 33) is called the glossopharyngeal nerve, from being distributed to the root of the tongue and pharynx. The functions of this nerve are at present the subject of dispute. It is considered by some physiologists as a motor nerve, by others as motor and sensiferous, while Panizza, a continental physiologist, contends, that from it is derived exclusively the sense of taste, and adduces several experiments which he thinks conclusive on this point. According to his view, this nerve gives the sense of taste, while the third branch of the 5th nerve (5″ Fig. 32) gives only common sensation or touch to the mouth and tongue, although physiologists have hitherto generally thought common sensation and taste might both be derived from this branch of the 5th nerve. Taste, according to the latter view, is considered a mere modification of touch. Professor Reid of St Andrews, one of the most accurate experimenters on the functions of this and the two following nerves, is of opinion that the glossopharyngeal is certainly a nerve of common sensation, and that, although it may be concerned in giving us sensations of taste, Penizza is mistaken in supposing that taste is destroyed when this nerve is cut. Dr

Reid has also shown that this nerve is concerned in the motions of deglutition. Its motor power, however, is different from that of the ordinary motor nerves. When an ordinary motor nerve is cut, it is the part connected with the muscles it supplies which causes contraction in these, when its extremity is irritated, whereas, when the glossopharyngeal is cut, it is *the extremity connected with the brain* which excites muscular contractions in the throat when it is irritated. Physiologists have therefore latterly called this a *reflex* motion, or one which takes place probably by first producing an impression on the brain or spinal marrow. The proper motor nerves in this case are the branches of the next or pneumogastric nerves. The subject of reflex nervous action is at present exciting much interest among physiologists.

No. 8′ (Figs. 32 and 33) are called the pneumogastric nerves, from being distributed principally to the lungs and stomach. These are large nerves that run behind the carotid arteries in the neck. Although they have been very frequently experimented on, their functions are still a subject of dispute. There seems no doubt that they give motor branches to the top of the windpipe, the pharynx, the œsophagus, and probably also to the lungs, and they also seem to furnish us with some of the sensations from the lungs. When the pneumogastric nerves are cut below the branches to the windpipe, the effect is, as formerly mentioned, generally, though not uniformly, to suspend the process of digestion, the food remaining in the stomach nearly unaltered. It was to these nerves that Dr Philip, under these circumstances, applied galvanism, and found that the power of digestion was then restored.

No. 8″ (Fig. 32) is called the spinal accessory, and is considered to be a motor nerve. It is distributed to the muscles of the neck and shoulder. This is called by some anatomists the third branch of the 8th pair, the glossopharyngeal and pneumogastric being considered its first and second branches. The next or hypoglossal nerves, in this way, come to be called the 9th pair.

No. 9 (Figs. 32 and 33) is a nerve of motion, called the hypoglossal from going to the muscles, and consequently producing the movements of the tongue.

No. 10 (Figs. 32 and 33) is called the suboccipital nerve, from coming out immediately below the occiput or back of the head. It goes to the back of the neck, &c., and belongs to the strictly regular nerves, or those which have both sensiferous and motor roots. All the spinal nerves below this, as seen in Figs. 32 and 33, also have sensitive and motor roots. They become interwoven in their course, forming, in different parts, what is called a plexus. The principal of these are, 1st, the cervical plexus (Fig. 33, *m*), which gives off, among others, two important nerves, one of which goes to the diaphragm, and is called the phrenic or internal respiratory nerve, and the other, from being also concerned in respiration, is called by Sir Charles Bell the external respiratory nerve. *g*, Fig. 33, is called the brachial plexus, from supplying nerves to the arm. Below this are the dorsal nerves (*l*), the lumbar nerves (*n*), and the sacral plexus (*k*), which last furnishes the large nerves that go to the lower extremity.*

159. Besides the nerves described above, there is a most extensive system of nerves called ganglionic (from small ganglia or swellings with which they are connected), that are principally distributed to the lungs, bowels, and other viscera. Their functions are not precisely ascertained, but they do not confer either sensibility or the power of voluntary motion. They are generally supposed to be chiefly connected with secretion, and, from their connections with the spinal nerves, to form a bond of union between the rest of the nervous system.†

160. By whatever parts effected, there can be no doubt that a union or sympathy of the different organs does exist. The effects, in paralysing the heart's action, of a blow on the region of the stomach, of extensive burns, &c., have already been stated. If the brain of a rabbit be merely removed, the heart may beat for an hour or more afterwards, but suddenly crushing the brain instantly stops its action. Tickling of the soles of the feet, causing the action of the diaphragm that takes place in laughing, tickling of the throat causing vomiting, &c., are examples of a similar connection.

161. A subject of the utmost interest to the physiologist is

* We have spoken of the nerves enumerated, as merely motor and sensiferous. Sir C. Bell thinks, however, that the motor power conferred is not the same in all. He contends that the 4th nerve (4), the portio dura of the 7th (7), the glossopharyngeal (8), the pneumogastric (8′), the spinal accessory (8″), and the external and internal respiratory, that arise from the cervical plexus (*m*), all come off from one tract of the spinal cord, which presides only over instinctive actions, such as respiration, acts caused by emotions, &c. Although Sir C. Bell's system has been supported with great ingenuity, its correctness in many points is not admitted by a large portion of both British and Continental physiologists. For much interesting information on this subject, see the works of Sir C. Bell, Dr Marshall Hall, Dr Fletcher, Dr Reid in Edinburgh Medical Journal for 1838-39, &c.

† Some physiologists have thought that the functions of the ganglionic system are to confer on the muscles and other structures the property of irritability. The power the heart has of contracting when blood flows into it, is called its irritability. This opinion, however, is not generally admitted.

presented in the modifications which the corresponding parts of the nervous system undergo in the different classes of animals. In none of the lowest tribes of the Radiata have any traces of a nervous system been discovered, though these creatures seem to possess both feeling and voluntary powers. In the long round worm which infests the human intestines, a slender nervous filament passes along the lower part of the belly, and is divided by the gullet into two branches. The nervous filaments in the star-fish (Fig. 3) encircle the mouth, and radiate to its five divisions. In the Articulata the nervous cords are interrupted by knots or ganglia, which, it is probable, perform functions analogous to the brain and spinal marrow of the Vertebrata. The nervous system of the Mollusca contrasts with that of the Articulata, in assuming more of a circular form. In that of the sepia, there is a large ganglion, which is enclosed in something like a rudimentary cranium, and probably performs functions analogous to those of the brain. The parts from which the optic nerves are derived in this animal, are even larger than the part representing the brain.

162. In the vertebrated division, a brain and spinal marrow are always present, but the size of the parts composing the brain especially, is relatively so much altered, as almost to prevent them from being recognised. Among animals of this division, fishes have the most simple nervous system. From these there is a regular gradation in complexity of organisation up to man, in whom all the parts belonging to the other classes are found, besides some that are peculiar to himself.

163. The nervous system of man is particularly distinguished by the ample developement of the cerebral hemispheres. The human cerebrum extends so far backwards as to cover the whole of the cerebellum; the orang-outang's cerebrum allows the cerebellum to be seen behind it, and the otter's and sheep's do so still more decidedly. In the marmot, and other Rodentia, not only the cerebellum, but also the parts from which the optic nerves arise (optic tubercles, also called corpora quadrigemina), are partially exposed, and the convolutions on the surface of the brain have disappeared. In birds the exposure is still greater, and becomes complete in reptiles and in fishes.

164. It was at one time thought that the brain of man was not only relatively, but absolutely, larger than that of any other animal; but it is now known that the amount of nervous matter in the elephant's brain, and in some others, is greater. Relatively, however, to the size of their bodies, the comparison is more in our favour. For example: in man, the ratio of the weight of the brain to that of the whole body is about 1 to 28, while in the dog it averages about 1 to 160, in the horse 1 to

400, and in the elephant 1 to 500. But again, on the other hand, it is curious to remark, that the brain of the canary bird, compared with its body, is as high as 1 to 14; and there is a species of monkey in which the proportion is even 1 to 11. For various reasons, however, comparisons of this kind are not considered as furnishing a fair estimate. Another method has been proposed by Soëmmering, an eminent physiologist, to which hitherto few if any exceptions have been found, and which depends on the ratio which the size of the brain holds to the aggregate bulk of the nerves that proceed from it. As an illustration of this method, the example of the horse may be cited. The absolute size of the brain of the horse is only about half that of the human brain, while the mass of the nerves of the horse, at their origin, is no less than ten times greater than that of man.

165. By adopting this principle, we are able, in most instances at least, to trace a correspondence between the cerebral developement and the amount of intelligence, and we pass, by easy gradations, from one class of animals to another upwards to man, between whom and all the rest there exists a great gap. Between the two extremes the difference is very striking. To show this, we weighed a cod, and found it to be 27 pounds. We then weighed its brain (including all the nervous matter above the medulla oblongata), and found it to be 44 grains. As a comparison we weighed a child, which died four days after birth, and found it to be 7 pounds. Its brain was also weighed, and was found to be no less than 6912 grains. A similar comparison may be made with the adult brain. Mr Scoresby found the brain of a young whale (whose body weighed 11,200 pounds) to be 3 pounds 12 ounces. The body of Byron or Cuvier would probably not weigh more than 200 pounds, and yet the brain of the former is said to have weighed 4½ pounds, while Cuvier's brain weighed 4 pounds 13½ ounces*—the heaviest we believe upon record.

166. From the great mass of nervous matter which man's brain contains, it is necessarily a very active organ. It is to it, as the organ of the mind, that we owe our pre-eminence as moral beings, as well as all that has been accomplished in the arts, in science, and in literature. While we cannot but be proud of what has thus been done, it must be confessed that the too great activity of this organ often leads to melancholy consequences. A large proportion of those who devote themselves to intellectual occupations, irreparably injure their health. This arises from two causes. 1st, Because these persons often do not mingle a due amount of bodily exercise with their studies. Many young

* Brigham on the Influence of Mental Cultivation on the Brain.

students, especially, fall a sacrifice to this error. Where proper out-of-door exercise is regularly taken, we are inclined to believe that moderate study will in most instances be found the reverse of hurtful. But, 2dly, by far the most injurious consequences follow from such engagements or studies as continually excite, and agitate, and harass the mind, and consequently the brain. The constitution must be good, indeed, in which such a course does not give rise to impaired appetite, habitually painful digestion, or some more serious disease. The brain, like every other organ, if its powers are continually put upon the stretch, almost necessarily becomes itself deranged, or deranges some other organ.*

167. The diseases of the brain are too numerous to allow of even a reference to them individually. The one most commonly met with in practice, is perhaps that particular species of inflammation which gives rise to hydrocephalus, or water of the head. This fatal disease occurs most commonly in childhood, and the physician can usually trace it to the variety of constitution termed the scrofulous. The tendency to it is generally derived from parents; and hence, when it has once occurred or is suspected in a family, very great attention to the general health of the other members of it is called for. Another disease of the brain, unfortunately of frequent occurrence, is called delirium tremens. It arises from the continued abuse of ardent spirits. There are three organs especially affected by this baneful habit—the brain, the liver, and the kidneys. The two latter slowly, but surely, become diseased, and their diseases as certainly prove fatal. Delirium tremens, however, though a dangerous, is not usually a fatal disease. The person affected is in a high state of excitement, thinks he is surrounded by evil spirits, imagines all his friends are plotting against him, and a thousand other fancies. The mind, in certain other states and diseases, is also very singularly affected, which it would be curious to refer to, did our space permit. Dr Abercromby's

* Every physician has melancholy experience of such cases. We lately met with a painful one, which may be mentioned as an example. A young gentleman, a student of divinity, of not a very strong constitution originally, met with a favourable opening for commencing a school in April 1837. Anxious for the success of his school, as well as for the progress of his studies, he made the harassing duties of the former the only relaxation from the latter. The consequence was, as might have been naturally anticipated, that his health sank under it, and he was obliged to give up his school in April 1838. His health continued in the most precarious state until June 1838, when he was seized with inflammation of the membranes of the brain, which proved fatal. After death, not only the brain, but most of the other important organs, were found in a highly diseased state.

work on the intellectual powers, the works of phrenologists, those on somnambulism and animal magnetism, &c., contain some very interesting facts on this subject.

[To illustrate this section, the brain of a sheep should be exhibited, which can easily be done by sawing through the skull from behind the eyes down to the opening for the spinal marrow (taking care not to saw too deep), and then wrenching it off with a screw-driver or other strong lever. The membranes covering the brain will be observed. These should be slit open, and the brain lifted up anteriorly, when the different nerves, commencing with the olfactory, will come into view, and must be cut through, and the brain taken out and placed in spirits for a few hours to harden it. The nerves, as seen in Fig. 33, the ventricles in the interior of the brain, and the other parts described here, and in anatomical works, may then easily be seen. A cod's or haddock's brain and spinal marrow may easily be shown, by cutting with a strong pair of scissors the spinal rings and skull.

Besides these, if wished, the progressive developement of the brain in different species may, with a little care and patience, be shown in the fowl, the hare or rabbit, the adder or frog, &c.

A few casts, showing the size and appearance of the human brain, that of the orang-outang, of idiots, &c., and casts of the heads of the Carib, Negro, European, &c., form excellent illustrations of this section, and can easily be got from O'Neil in Edinburgh, and other stucco dealers.

Appropriate figures for illustrating this section will be found in Fletcher's Rudiments of Physiology, Part 1, pages 47 and 48; in Lizars's coloured plates, pages 64, 67, 68; in Roget's Bridgewater Treatise, vol. ii. pages 547, 550, 552.]

SECTION IX.

THE SENSES.

168. The senses are the means by which the mind becomes acquainted with external objects. Without the materials which they furnish, its exercise would be impossible. When the mind has once experienced various sensations, the memory can recal them when they are gone; the judgment can compare them, and can perceive their relations, and the imagination can combine them into endless varieties; but still, with all this, we are incapable of figuring to ourselves any image, the elements at least of which have not first been made known to us through sensation.

169. The senses generally enumerated are five, viz. touch, taste, smell, hearing, and vision. There are other sensations, however, such as those of thirst, hunger, nausea, sneezing, &c. which cannot properly be classed under any of these heads.

170. The sense of *touch* is diffused over almost the whole external surface of the body, but is possessed in greatest delicacy by certain parts, such as the lips and the ends of the fingers. When the innermost layer of the skin is examined with a microscope, it presents numerous projecting points or papillæ, to each of which it is probable a branch of a sensitive nerve is sent, as they are seen in greatest numbers where the sense is most acute. To exercise this sense in perfection, it is requisite that the organ should be so constructed as to be capable of being readily applied to bodies, in a variety of directions; and it is in the human hand that this quality, the distribution of the sensitive nervous filaments, and a thin cuticle covering these, are united in the highest degree.

171. The late eminent Dr Thomas Brown, professor of moral philosophy in Edinburgh, contended that touch gives us no, or at least very imperfect, ideas of extension or space, and of hardness or solidity. Our ideas of these, he thought, are principally derived from what he calls muscular sensations. Connected with this point, we may remark, that Francisco Cæsario, whose case has been before referred to, although entirely deprived of sensation on one side, so that even cutting it gave him no feeling, could yet, with the same, judge of the weight and consistence of bodies.

172. A similar conjecture, as to the feelings derived from temperature, seems to be supported by such cases as the following:—A physician of Geneva, after an attack of palsy, could be pricked or scratched in the right hand or arm, without giving him any sensation. When, however, he took a cold body into his hand, he felt it, but it appeared to him lukewarm. Here the feelings of touch seem to have been lost, but a deranged perception of temperature existed.

173. The soft bodies of the lowest classes of animals are well fitted for the exercise of the sense of touch, and it is doubtful whether many of them possess any other. The organs of touch in insects, if, indeed, they are not allotted to some higher sense, are especially their antennæ or feelers, which, though in themselves minute, are generally feathered or radiated, so as to include parts too small for human vision, and the sensations of which must be of an exquisitely delicate nature. Huber, in his interesting work on bees, states, that it is by feeling with the antennæ that they seem to direct their various works in the interior of the hive. If an insect be deprived of its antennæ,

it either remains motionless, or, if it attempts to fly, appears bewildered. A queen bee, thus mutilated, ran about, without apparent object, as if in a state of delirium.

174. Spallanzani discovered that bats could thread their way with ease through the darkest and most intricate passages, where obstacles had been purposely placed in their way, even when their eyes were put out or covered over, and hence thought that they must have some other sense to direct them. It has been rendered probable, however, that they owe this power to the delicacy of the sense of touch in their wings and other parts.

175. The senses of *taste* and *smell* may be spoken of together, as they appear in many cases to be intimately connected. The sense of taste resides in the tongue and mouth, and has generally been considered by physiologists as little more than a modification of touch. The 5th nerve was supposed to confer both touch and taste. Panizza, however, as was mentioned, has recently disputed this. The papillæ, already spoken of, are particularly well seen in the tongue. If a fluid, such as strong vinegar, be applied with a hair pencil, they will be seen to become curiously elongated.

176. The tongue is covered with a thin cuticle, and the nostrils are lined by a soft membrane, called, from a celebrated anatomist, the Schneiderian membrane. It is upon this that the olfactory nerve (No. 1, Figs. 32 and 33) ramifies; not, however, covered by it, but protected from the air that passes through the nostrils merely by the natural secretion, called mucus. The vapour of different bodies thus comes directly into contact with these nerves.

177. Substances tasted must be either naturally fluid or must be dissolved by the saliva. When this condition is observed, we are sensible of certain feelings, commonly supposed to be produced in the mouth. A large proportion, however, of the feelings conveyed by the tongue, are little more than different degrees of pungency, which we may almost conceive capable of being felt by the ends of the fingers, had their cuticle been fine enough. The flavour of bodies, generally included when we speak of their taste, is a sensation entirely owing to the action of their vapour on the back part of the nostrils; so that, when the membrane that lines these is inflamed, or otherwise diseased, whisky, vinegar, mustard, and many other substances, can with some difficulty be distinguished from each other. Any one may easily satisfy himself of the indefinite nature of the sensation of taste, by pushing out the tongue, accurately closing the mouth and nostrils, and then applying to it different substances.

178. In the savage state, the sense of smell is much used, and becomes proportionately acute. The American Indians can easily distinguish different tribes and nations by the odour of their bodies. The blind and deaf boy, James Mitchell, whose history has been recorded by Mr Wardrop and Professor Dugald Stewart, knew his friends, and at once detected strangers in a room, by this sense.

179. These senses are very acute in some of the lower animals, and particularly in the carnivorous Vertebrata. The olfactory nerves of most birds are small. In the duck and similar tribes, however, they are large, and are much used. The nostrils of fishes do not communicate with the mouth, and smell becomes with them more like taste, from the substance being dissolved in water instead of air.

180. The sense of *hearing* results from vibrations in an elastic substance, such as air or water, being communicated to the ear. When a bell is shaken in the exhausted receiver of an air-pump, no sound is heard, because the air which usually carries the vibrations to the ear is absent. Sound travels through air at the rate of about twelve and a half miles in a minute; through water its velocity is four or five times greater; and ice and other solid bodies are known to transmit it even more quickly.

181. The organ of hearing in man may be divided into external, middle, and internal parts. The external consist of the gristle of the ear (Fig. 37, *c*), of use in most animals for collecting the sounds; and of a funnel-shaped canal (*m*), which leads to the middle part or drum (*t*). The external and middle parts do not communicate directly, there being interposed between the two a thin membrane (*d*), attached to the bony sides of the canal, exactly like the parchment on a real drum. On this membrane the vibrations of the air strike, and to it there is attached a chain of small bones (*b*), which are also

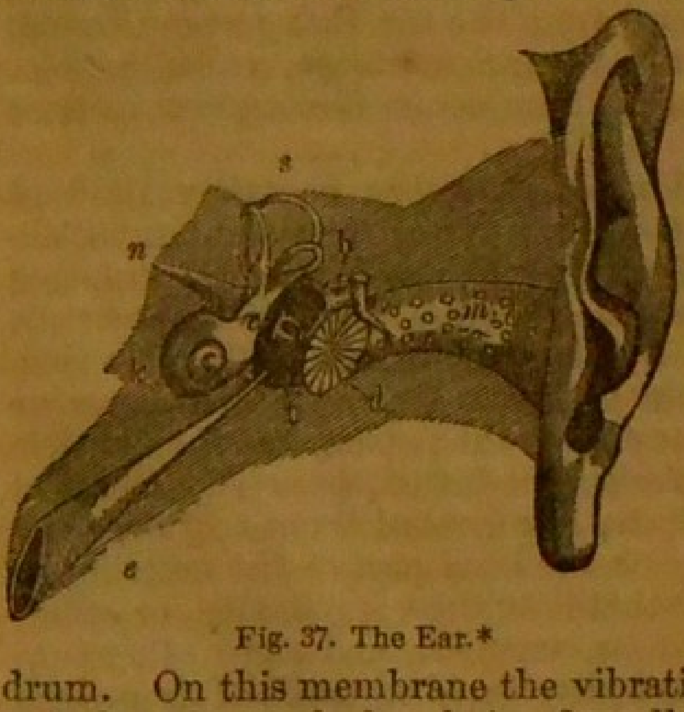

Fig. 37. The Ear.*

* *c*, concha or external gristle. *m*, canal leading to *t*, the tympanum or drum. *d*, membrane of the drum. *b*, small bones of the drum. *v*, vestibule, *s*, semicircular canals. *k*, cochlea. *n*, auditory nerve. *e*, Eustachian tube.

connected with the internal ear, in which last is placed the nerve of hearing. The vibrations, therefore, first strike the membrane of the drum, and then pass along these bones to the auditory nerve, seen in Fig. 37, *n*. The cavity of the drum (*t*), though it does not communicate with the external ear, yet has air admitted to it. This passes through a canal (Fig. 37, *e*), called the Eustachian tube, which opens into the back part of the throat or pharynx. Most persons have felt their hearing become dull when inflammation of the throat closes this tube, and prevents the passage of the air. The internal ear is very intricate, and the uses of its different parts are not well known. In Fig. 37 are seen parts of it called semicircular canals (*s*), the cochlea (*k*), the vestibule (*v*), which are all filled with a fluid, and there is also seen the auditory nerve (*n*), going to these parts.

182. Of the parts described, it would seem that the internal ear is the only one that is essential, for cases have occurred in which disease has destroyed both the membrane of the drum and the small bones, and yet hearing has remained. It is a curious observation, made by Dr Wollaston, that there are persons, of whom he himself was one, who are insensible to very acute sounds, though all others are perfectly heard. Some cannot hear the note of the bat or the chirp of the grasshopper, while others are insensible even to the chirping of the sparrow.

183. The Radiata, and almost all the Mollusca, appear to want this sense, but it is possessed acutely by many insects, though the organ used is not accurately known. In the sepia is found the simplest organ of hearing. It is merely a sac filled with fluid, with the nerve expanded in it, and having a hard body attached to its extremity. Fishes have this organ a little more complicated, but in neither these nor the sepia is there any external opening. They hear as we do when a hard body is held between the teeth, the conducting power of water for sound being much greater than that of air. When the Abbé Nollet sank his head under water and struck two stones together, the shock to the ear was almost insupportable. This organ becomes progressively more complicated in Reptiles, Birds, and the Mammalia. Among the last we first find external cartilages, which, as well as the internal tube, are directed forwards in those which pursue their prey, and backwards in timid animals, such as the hare, rabbit, &c.

184. The next and last sense we have to treat of is *vision*. All the affections of this sense are derived from the action of light. We think we see the bodies themselves that are scattered round us, but this is a mistake, for they themselves have no colour. The colour, or, more properly speaking, the

power to produce the sensation we call colour, resides entirely in the rays of light that are thrown off or reflected from these bodies to our eyes. In spite of our convictions, however, we cannot help conceiving of our sensations as abiding qualities in these different objects.

185. If a ray of light be admitted through a small opening into a dark chamber, it appears white, but by causing it to pass through a three-sided piece of glass called a prism, it is seen to be composed of different-coloured rays. These, according to Dr Wollaston, are red, yellowish green, blue, and violet. In this way a ray of light is decomposed: when these colours are all uniformly blended, as when a card on which they are separately painted is rapidly whirled round, the resulting colour is again white. Now, it is from the power bodies possess of throwing off or of absorbing special rays out of the number, that they appear to us differently coloured. If a body appears blue, the blue rays alone have been reflected; and so on with red, green, and other colours. We do not notice any interval between looking at an object and the impression on our eye (as we can do with distant objects in the case of sound), from the rapidity with which light travels, and from not having any other sense that can give us information more quickly. There is always an interval, however, and in the case of the distant heavenly bodies this has been calculated. We have said sound travels at the rate of between twelve and thirteen miles in a minute, but light passes through 195,000 miles in the sixtieth part of the same time.

186. As the eye is strictly an optical instrument, we must state that it is a law of optics that the rays of light, while passing through the same medium, proceed in straight lines, but that they are turned out of their course when they pass from a less into a more dense medium. They are then said to be refracted. This takes place when the rays of light pass from air into water, and it is by virtue of the same law that a common magnifying or double convex glass collects the sun's rays into a focus or point.

187. The eye has various appendages, which require some explanation. The first to be noticed are the eyelids. These are composed chiefly of a gristly substance placed under the skin that accurately fits the ball of the eye, and which is lined internally by a thin membrane called the conjunctiva, that turns over on the globe of the eye, and keeps it in its socket. Attached to the eyelids are the eyelashes, which protect the eye from too great a glare of light, from particles of dust, &c. Persons without eyelashes have always tender eyes. The chief purposes served by the eyelids are, 1st, to protect from

external injury, and to exclude the light when they are closed; and, 2dly, to distribute equally over the eyeball the fluid which moistens it. This fluid is usually carried off as quickly as it is formed; but when the eye is irritated, or the mind affected by various emotions, it is then secreted in such quantity as to run over the eyelids in the form of tears. The source of this fluid is a gland, named the lachrymal gland, situated above the outer angle of the eye. Tears, there secreted, pass downwards to the eye, whence they flow, through two small holes (puncta lachrymalia), near the inner angle of the eyelids, into a small receptacle called the lachrymal sac, placed immediately behind the inner angle, and from which there is a communication to the nostrils by what is called the nasal duct. This is the reason why, when tears are copious, a necessity for blowing the nose is felt. When the nasal duct is obstructed, as often happens, the nostril on that side is dry, and the tears run over the eyelids. The puncta lachrymalia may easily be seen by everting the eyelids, and looking at their inner angle; and the opening of the nasal duct may be seen by looking into the nostril of the horse. The two edges of the eyelids, when closed, form a channel, along which the tears flow. Birds have a third eyelid, at the inner angle of the two others, which they may often be seen moving. Fishes have neither eyelids nor lachrymal apparatus.

188. Others of the appendages are the muscles that move the eye, six in number. There are, besides these, two that move the eyelids. A broad circular one, which closes the eyelids, lies immediately under the skin. The other, which raises the upper eyelid, is a long muscle, and is attached to the bone deep behind the eyeball.

189. We now come to consider the globe of the eye, the parts composing which are seen in Fig. 38, representing a horizontal section of it. C, the cornea, is the transparent part of the eye in front, which, it will be seen, forms part of a lesser circle, and therefore projects more than the rest of the globe. It is set into the white part of the ball of the eye, and after steeping, can be taken out of it like a watch-glass. S, the sclerotic or hard coat, is the outermost one, or the white part of the eye seen in front. It extends over the whole ball posteriorly, and, from its toughness, forms its principal support. In the tortoise and in birds this part anteriorly has bony matter in its composition; and in the immense eye of the extinct reptile called the ichthyosaurus, it appears to have been composed of bony plates. The coat (X), which lies internal to the sclerotic, is called the choroid coat. It is lined on its inner surface, in the human eye, by a brownish-black paint (contained in hexagonal cells), which we see when we look deep into the eye. Its use seems

to be to absorb the rays of light not required in vision. The colour of this paint is, as every one has seen, yellowish-green in the eye of the cat. It is chocolate-brown in the hare and rabbit, silvery-blue in the horse, and pale golden yellow in the lion and bear. In general, it is of a light shade in such animals as prowl by night. This paint is wanting altogether in albino animals, such as white rabbits or ferrets, and the red blood-vessels can then be seen in the eye. This coat seems to be continuous with a number of foldings called ciliary processes (K). The innermost of the coats of the eye (R) is called the retina, from its netted appearance. It consists of a very fine membrane, with the pulpy, half transparent substance, which is continuous with the optic nerve (O),† expanded upon it. This is the seat of vision. All visual impressions must, in the first place, be made upon this expansion, and are then conveyed by the optic nerve to the mind.

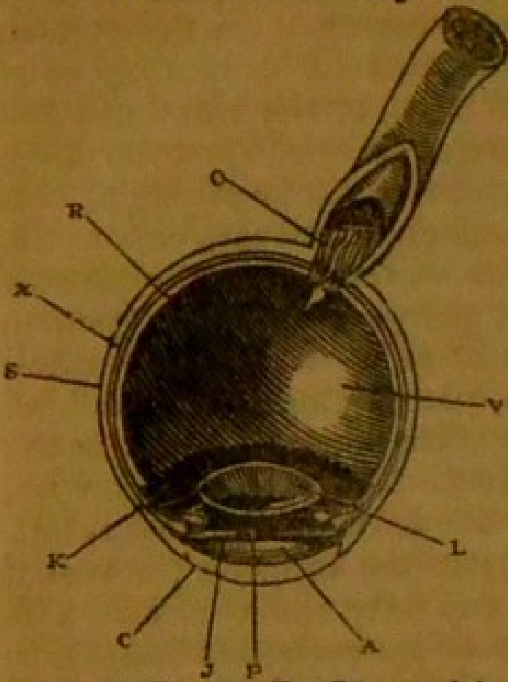

Fig. 38. Human Eye Dissected.*

190. The parts of the eye remaining to be described are the humours and the iris. A is the aqueous or watery humour, placed immediately behind (C) the cornea. It is divided into an anterior and a posterior chamber by (J) the iris, which floats like a curtain in it. The iris is the part that gives the blue, grey, or black colour to our eyes, and which has in its centre an opening (P) that enlarges or contracts according to the quantity of light to be admitted. It is supposed to possess a circular and a radiated set of fibres to effect this. Behind the aqueous humour lies the lens (L), the firmest of the three humours. Its form in the human eye, as seen in the figure, is something like a highly convex magnifying-glass. In fishes it is globular, and it is it that falls out like a pea when the eye is boiled.‡ Behind this, again, is placed the largest or vitreous

* C, cornea. S, sclerotic coat. X, choroid coat. R, retina. O, optic nerve. V, vitreous humour. L, lens. A, aqueous humour. P, pupil. J, iris. K, ciliary processes.

† Also seen in Figs. 32 and 33. In Fig. 33 the two optic nerves are seen to join, and the fibres at this point are supposed partially to cross.

‡ A globular form of the lens (which refracts light in the highest degree) is rendered necessary from the greater refraction required, this being less when the rays of light pass from a dense medium like water to the eye, than when they pass from air to it.

humour (V), which appears of rather greater consistence than the white of an egg, and is enclosed in a very fine transparent membrane, ramifying also into its interior.

191. By the united action of all these parts, vision is produced. The cornea serves the purpose of a convex or magnifying-glass, to collect into foci or points the rays of light that pass from an object to the eye, and this effect is still further assisted by the lens placed behind it. The point where these foci are thus formed, is the retina; and the eye may be compared to the optical instrument called the camera obscura, which is, indeed, but an imitation of the eye itself. Those who have seen this instrument will know, that when the part corresponding to the cornea is presented to a landscape, there is an exact picture of it formed on the back part of the box. Kepler, the great astronomer, made the interesting discovery that the same thing may be seen in the eye. If the eye of a recently killed bullock be carefully stripped of its sclerotic and choroid coats posteriorly, and the retina be supported by a piece of transparent silk, it may be placed in the hole of a window shutter looking out upon a landscape, and a diminutive but distinct picture of the whole may be seen depicted on the retina. From the thinness of the coverings of the eye in albino animals (such as the white rabbit), this exquisitely beautiful experiment may be performed even without removing any of the coats.*

* The course of the rays of light coming from an object, and passing through the eye, is shown in Fig. 39, from which it will be seen that the object represented on the retina is inverted. The cause of this is, that the rays from different points (as may be observed in the figure) cross, and that those coming from the lower part of the object (*c*) have their focus on the upper part of the retina (*d*), while those from the upper part of the object (*a*) have their focus on the lower part of the retina (*b*). It must be understood that a double convex glass, or the eye, has the power of converging rays of light not merely to one focus or point, but to many foci. What is commonly called *the focus* of a glass or lens is merely its principal focus. Although, however, the objects are inverted on the retina, we see them in their proper position, that is, in a position corresponding with the sensations of touch. Various explanations of this fact have been attempted, but our space does not allow us to enter upon the subject.

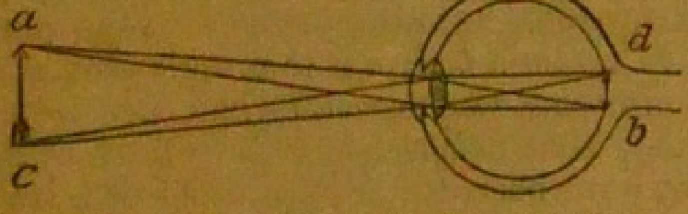

Fig. 39. Inversion of Rays on the Retina.

It may be mentioned here, also, that the reason why humours of different densities, and consequently different refracting powers, are used, appears to be, that the eye may be rendered what is called an

192. It is truly wonderful to think that all the accurate perceptions of this sense are derived from the images of a crowded picture formed at the bottom of the eye, on a space so small that it may be covered with the point of the finger. What can be more astonishing than the fact, that the image of the sail of a windmill, six feet in length, seen at the distance of twelve paces, occupies only the twentieth part of an inch on the retina, and that the image of the same sail, when removed to the limits of distinct vision, occupies, according to the calculations of M. de la Hire, only the eight thousandth part of an inch, or less than the sixtieth part of the breadth of a common hair! "We can never," to quote again Dr Paley's words, "reflect without wonder upon the smallness yet correctness of the picture formed at the bottom of the eye. A landscape, of five or six square leagues, is brought into a space of half an inch diameter, yet the multitude of objects which it contains are all preserved—are all discriminated in their magnitudes, positions, figures, colours. The prospect from Hampstead Hill is compressed into a compass of a sixpence, yet circumstantially represented. A stage-coach, travelling at its ordinary speed for half an hour, passes in the eye over only one twelfth of an inch; yet is this change of image distinctly perceived throughout its whole progress, for it is only by means of that perception that the motion of the coach itself is made sensible to the eye."

193. After what has already been said of the proofs of design furnished by other parts of the body, it is almost unnecessary, in that point of view, to direct attention to this admirable organ. Its mechanism is so clear that no one can mistake its objects. A celebrated philosopher held (and with good reason) that an examination of the eye was a cure for atheism; and he might have added, that it not only proves, beyond all doubt, the existence of a great first cause, but also, perhaps, more than any other organ, that our Creator's design is to mingle pleasure with our existence. If only what was necessary had been done, it has been well remarked, that nothing but the tame, dull, outlines of objects might have been made sensible to us. But colour, endless in its shades, ever variegated in its tints, has been spread over the face of nature—for what purpose, it

achromatic instrument; that is, one that gives a clear picture of an object, without coloured fringes. These fringes used to annoy opticians and astronomers much, until the year 1729, when the happy thought struck a gentleman of the name of Hall to ask himself how nature obviated the difficulty in the eye. By using the same means, namely, constructing telescopes with lenses of different refracting powers, his success was complete.

may be asked, if not to convey to us delight, and to prove that He who made us, also wishes us to be happy.

194. Among even the lower tribes of the Radiata, indications of sensibility to light have been observed, but no distinct organs for this sense have been discovered. Ehrenberg has lately described some small spots in the rays of the star-fish, which he conceives answer the purpose of organs of vision. As we rise higher, visual organs are seen, but the Sepia is the lowest that has eyes constructed like those of the Vertebrata. The eyes of insects are called compound, being, in truth, immense aggregations of eyes, apparently to compensate for their want of mobility. The common house-fly has 8000 of these eyes; the dragon-fly 12,544; and some other species have upwards of 25,000.

195. The diseases of the eye are very numerous. The conjunctiva, lining the eyelids and reflected on the eyeball, the sclerotic coat (S, Fig. 38), and the iris (J), are particularly liable to inflammation. The ophthalmia that affected our soldiers in Egypt, generally commenced in the conjunctiva, and destroyed the eyes of great numbers. The lens (L) often becomes opaque, especially in old people, and causes blindness. When this happens, it is called cataract, and very frequently an operation is performed to restore vision. The Duke of Sussex was successfully operated on a few years ago. The operation consists either in taking out the opaque lens, by cutting the cornea, or in pushing the lens downwards into the vitreous humour (V), out of the course of the rays of light. Blindness also arises from opacity of the cornea, closure of the pupil, disease of the retina or optic nerve, called amaurosis, &c.

[To illustrate the sense of smell, a longitudinal section of the nose of a sheep can be easily made, keeping the saw as much as possible to one side, when the spongy or turbinated bones, which are covered with the Schneiderian membrane, and are convoluted to increase the extent of surface, may be observed. The structure of the nose of the cod or haddock is also curious. It does not communicate with the mouth, and ought to be shown. The olfactory nerves going to it from the brain, may easily be exposed in the fish with a strong pair of scissors.

The organ of hearing lies deep in the bone, and is not easily got at. However, the membrane of the drum in a sheep can be very nicely shown, by taking off the bone containing the ear from the skull, and then cutting away the external bony canal leading to it, until it is exposed. The small bones of the ear may also be got at by breaking into the drum with a strong pair of cutting pliers. They should be taken out, and fastened with gum on a card covered with a piece of black velvet.

A simple apparatus to show the vibrations of the air, in imitation of the external ear, may be constructed by forming two pieces of firm Bristol board into a shape like a common funnel used for decanting liquors, cutting the narrower extremity slopingly, so as to leave an opening about two inches by one and a half, and gumming *loosely* over this a piece of goldbeater's skin. The other extremity may be made about seven inches in diameter. When this funnel is supported on a wire-stand, so as to bring the goldbeater's skin into a horizontal position, and some fine sand is placed on it, the vibrations produced by the air may be seen, by beating on a sheet of tin, or other strongly vibrating body, at the larger extremity. Any tinsmith will give the shape for the Bristol board.

The structure of the eye can be admirably shown. Direct attention to the puncta lachrymalia; to the appearance of the pupil, contracting and dilating as more or less light is directed on the eye; to the correspondence of the motions of the two eyes; the colour of the iris, &c. The muscles of the eyeball can be beautifully seen in the sheep, but they require a good deal of dissection. The globe of the eye may be easily shown, however. Get a bullock's or sheep's eye, clear off the fat, &c., and observe the optic nerve entering it posteriorly. Take hold of the optic nerve, introduce a pair of sharp scissors through its coats, rather more posteriorly than the middle of the globe, and cut the coats round transversely. The exterior sclerotic coat, the pulpy retina (often curled up) interiorly, and the choroid coat between these, will then be seen. Some of the vitreous humour will probably escape in making the section, and both it and the lens, lying behind the pupil, will be seen when the posterior section of the eye is removed. A number of lines on the choroid coat, radiating from the circumference of the lens, and called ciliary processes, may also be seen. The aqueous humour may be seen to escape when the eye is made tense (when entire), and the cornea is punctured. The iris may be examined when the humours are removed. A similar section of a cod's eye should be made to show the globular lens. The eye of a fowl may also be examined, and its bony sclerotic, third eyelid, &c. observed.

Such a section as has been mentioned should of course always be made, but the anatomy of the eye is made much more simple by having a horizontal section model of it. In this its coats, humours, &c., are all seen, and their relations may be comprehended with the utmost ease by young pupils.

To show the inverted image on the retina, the eye of a white rabbit answers well. It is seen best by candle light, and when two or three lights are moved before the eye. All the muscles and fat must first of course be removed posteriorly.

A prism, to show the decomposition of light, and a small camera obscura, should be exhibited.

Fig. 39 is rendered more plain by colouring the upper rays red, and the under ones blue, or the reverse.

For figures to illustrate this section, see Lizars's Coloured Plates pages 75, 76 ; Roget's Bridgewater Treatise, vol. ii. pages 384, 400, 401, 425, 464, 467.]

SECTION X.

REPRODUCTION.

196. As the law throughout the whole of animated nature is, that each individual shall, after a period more or less limited, die, so also have arrangements been made to secure the reproduction of the various tribes of animals. The modes adopted by nature, in accomplishing this object, vary much, in some cases being very simple, in others more complicated. Among the simplest modes of propagation is that in which an animal divides into two similar halves, each half becoming a separate creature, which also, in due time, undergoes the same process. This takes place among monads and other animalcules. Another very simple mode of propagation is seen in the polype (Fig. 2), on the body of which a small bud appears, grows, and ultimately separates from the parent, to become an animal of the same kind. As we rise higher in the scale of creation, we observe that animals are either *oviparous*, that is, produced from an egg, or *viviparous*, that is, born alive. Three classes of the vertebrata—fishes, reptiles, and birds—as well as the great proportion of the inferior divisions of animals, are all *oviparous ;* but the animals composing the highest of the vertebrate classes, the mammalia, are all viviparous. In both these divisions, however, we do not find that the animal produced has always the form which it is ultimately destined to assume. Among *oviparous* animals we have already mentioned the frog as being, when hatched from the parent egg, essentially a fish before it becomes a reptile, and the fly and moth as being at first a maggot or a caterpillar ; while, among *viviparous* animals, we find that the Marsupialia, including the opossum and kangaroo, are, when born, minute half-formed masses, totally unlike what they afterwards become. When born, the opossum, which, at its full growth, is an animal larger than a cat, is little larger than a pea ; and the kangaroo, an animal at its full size as large as a sheep, is at birth hardly an inch in length. At this stage of its existence, the animal

is transferred by its mother to a pouch which nature has formed in the skin of the belly of these singular creatures, and there becomes firmly fixed to a small nipple, to which it remains attached until its growth has greatly increased. The pouch continues to be the dwelling-place of the young animal until it can subsist independently of the parent, and many may have seen in our menageries the young ones gamboling about the mother, but escaping to the pouch upon the least alarm of danger. Something analogous to this arrangement is found among certain *oviparous* tribes, in which the eggs are hatched within the body of the animal. These are called *ovo-viviparous.* The shark is said to be *oviparous* in some circumstances, and *ovo-viviparous* in others.

END OF ANIMAL PHYSIOLOGY.

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