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 connection 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.

ANIMAL PHYSIOLOGY.

SECTION I.

ORGANIZATION—LIFE. CLASSIFICATION OF ANIMALS.

[Anatomy is chiefly the subject of the following section, and for the reason that this lies at the foundation of Physiology. The learner should, however, first become familiar with the signification of these and collateral terms.

Anatomy may be defined, the science of organization in the healthy or physiological state. It is called *Human* anatomy, when restricted to the structure of man; *Comparative* anatomy or Zootomy when it includes the inferior animals, and *Vegetable* anatomy when it teaches the structure of plants.

Physiology may be defined strictly as the science of nature, and hence it was originally synonymous with Physics, or Natural Philosophy, and comprehended both animate and inanimate beings. This term is now, however, restricted to signify living organization, or the functions of living bodies; literally, therefore, the science of life, or *living anatomy*. It is hence subdivided into Animal and Vegetable Physiology, the former of which only is the subject of this volume.

Until very lately, "the three kingdoms of nature," *animal*, *vegetable*, and *mineral*, were uniformly considered separately. The two former, however, being endowed with life, and analogous to each other in many respects, both by structure and function, are now classed together as the *organic* kingdom, in contradistinction to the *inorganic* world, which comprises the mineral kingdom.]

1. All natural objects are therefore 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 organized. Thus the heart and stomach of an animal are called organs, their functions being to circulate the blood and 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 organization, 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

1. Define organic and inorganic, organ and function, with examples of each.
2. Name individual bodies belonging to the organic and inorganic world.
3. Points of analogy between plants and animals.
4. Distinctions between plants and animals.

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 fulfilled 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

5. The doctrines of Bichat.
6. Differences between animals.
7. Whose classification?
8. His first division and the objections to it.

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, movable 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 or 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 Hytadid (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

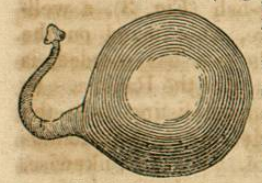

Fig. 1. Hytadid.

9. Describe the first of these, and their different names.
10. What is wonderful in these?
11. Define parasitic.

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. 2. Polype.

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. 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

12. Describe the hytadid.
13. What of the polype?
14. Describe the star-fish.

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 Sepio 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

Fig. 5. Pontobdella.

15. The second division of the Cuvierian system.
16. Describe these with examples.
17. What is the third division called?

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 external 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 organized 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,

18. The points of difference among these.
19. Give examples of these.
20. What is the fourth and last division?
21. Name the fourth subdivision of these.
22. Describe their peculiarities of structure.

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') 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.

[As the human skeleton here represented is one of the most interesting objects of study for young people, it is desirable that one should be procured for exhibition in every school in connection with anatomical and physiological instructions. The following additional items of information should be imparted upon this subject.

A natural skeleton is one in which the bones are con-

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

23. Define "progression and prehension."
24. To which series does man belong?

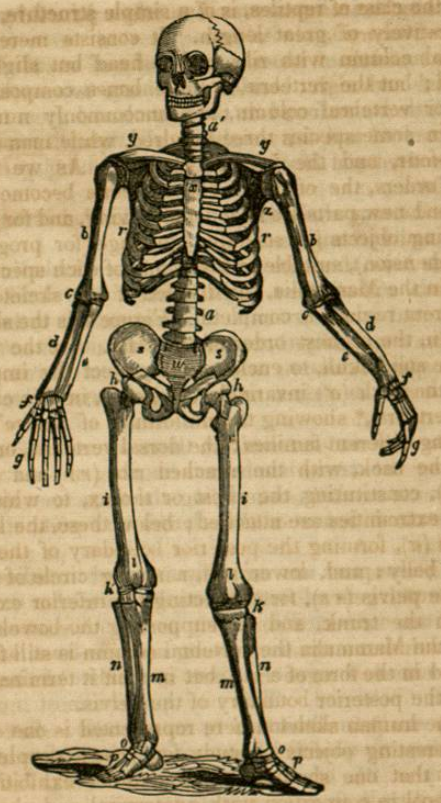

Fig. 7. Human Skeleton.

$a'\ a$, 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.

25. Describe the human skeleton, as here explained.

nected by their ligaments: but when joined by wires, it is called an artificial skeleton.

The number of bones in the body of an adult are two hundred and eight, besides the thirty-two teeth and the eight little bones found in the thumb and great toe, being two hundred and forty-eight in all, though some reckon two hundred and fifty-two, by distinguishing parts of the same bones.

The human skeleton is usually divided into the head, trunk, and extremities.

In the *head*, there are sixty-three bones, including thirty-two teeth, and of these eight belong to the skull, eight to the internal ears, fourteen to the face, and one to the tongue.

In the *trunk*, fifty-three bones are found, viz. twenty-six to the spinal column, twenty-five to the thorax or chest, and two to the pelvis, or basin found at the base of the trunk.

In the *superior extremities*, there are sixty-four bones, including the arms, hands, and fingers; and sixty in the *inferior extremities*, comprising the legs, feet, and toes; the sesamoid bones of the thumb and great toe being counted.

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 movable 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 movable. But if the animal did

26. Can the form of an animal be conjectured by a single bone?
27. What illustration is cited, and what inference is authorized?

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 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.

* 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.

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). Sunfish.
5. Chandropterygii (gristle-rayed). Shark, Lamprey, Sturgeon.

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28. What classes and orders in this table?

CHIEF CHARACTERS OF THE CLASSES OF THE VERTEBRATA.

<table>
<tr><td>Mammalia.</td><td>Birds.</td><td>Reptiles.</td><td>Fishes.</td></tr>
<tr><td>Viviparous.</td><td colspan="3">Oviparous.</td></tr>
<tr><td>With teats.</td><td colspan="3">Without teats.</td></tr>
<tr><td>Globules of blood circular.</td><td colspan="3">Globules of blood eliptical.</td></tr>
<tr><td colspan="2">Blood warm.</td><td colspan="2">Blood cold.</td></tr>
<tr><td colspan="3">Breathe by lungs.</td><td>Breathe by gills.</td></tr>
<tr><td>Respiration simple.</td><td>Respiration double.</td><td colspan="2">Respiration simple.</td></tr>
<tr><td colspan="2">Circulation double complete.</td><td>Circulation double incomplete.</td><td>Circulation double complete.</td></tr>
<tr><td colspan="2">Heart with four compartments.</td><td>Heart usually with 3 compartments.</td><td>Heart with 2 compartments.</td></tr>
<tr><td>Skin furnished with hairs.</td><td>Skin furnished with feathers.</td><td colspan="2">Skin naked or furnished with scales.</td></tr>
<tr><td>Members organized in general for walking.</td><td>Anterior members organized for flight.</td><td>Members organized in general for walking.</td><td>Members organized for swimming.</td></tr>
</table>

29. Enumerate the chief characters in the vertebrata.