CHAPTER IV.

Differences between different Organisms—Divisions of Biological Science—Morphology, Physiology, and Distribution—The Differences in "Function"—"Specialisation of Function"—Illustrations and Deductions.

Our work, so far as it has proceeded, partakes in character of the analytical, inasmuch as we have been endeavouring to separate out and to distinguish the great groups of natural objects; and to clearly set before us the special characteristics of each division. We have thus defined, so far as is possible, the two great series of organic or living beings. The next step in our process of analysis and separation consists in the endeavour to discover the most philosophic and trustworthy mode by which any individual organism, or group of organisms, can be separated or distinguished from another organism or group.

And the progress of biological science has in no case left clearer proofs of its advance, than in the improved and thoroughly scientific basis on which the principles of mapping out the differences between different organisms have been founded. The older systems of noting these differences were crude and unsatisfactory, and were founded on supposed distinctions, drawn from mere external configuration, and without any regard to internal structure or organisation. As a consequence, the ultimate scheme of separation or classification of the organic series was, as we shall hereafter see, a thoroughly artificial one; based on self-constituted principles, and entirely ignoring the details of structure and function, on which alone it is possible to construct a true and reliable system of classification.

Two great principles aid us in obtaining a sure idea of the differences between the members of either animal or

plant series. The first of these is termed *Morphology*, and relates to those distinctions which we may draw between two organisms, by simply investigating their *structure*. The second principle is known as that of *Physiology*; and this latter bases its grounds of distinction on the differences which it elucidates from a consideration of the mode in which the *functions* of life are carried on in each organism respectively. Given two organisms, then, concerning which we wish to decide as to the proper place of each in the scale of being, we can thus consider each from two distinct yet connected points of view. We may compare the *structure* of the one with the structure of the other, and determine their relations by a study of their *Morphology*; or we may observe how the processes or *functions* of life are carried on in each, and by aid of *Physiology* arrive at a conclusion as to which is to be regarded the more highly organised of the two.

Before proceeding to note the chief ideas involved in each process, it may be well to observe the subordinate divisions, which are included under the several departments of Morphology, Physiology, and Distribution. The tabular view appended will serve to show at a glance the classification of these sciences :—

BIOLOGY—"SCIENCE OF LIVING BEINGS."

Differences between different organisms or groups of organisms investigated under the sciences of—

I.—MORPHOLOGY (Science of Form)
1. Anatomy.
2. Embryology or Development.
3. Taxonomy or Classification.

II.—PHYSIOLOGY (Science of Function)
1. Function of Nutrition or Alimentation.
   - Digestion,
   - Absorption,
   - Circulation,
   - Respiration.
2. Function of Reproduction.
3. Function of Correlation, Innervation, or Irritability.

III.—DISTRIBUTION
1. In Space (Geographical).
2. In Time (Geological).

The science of *Morphology*, then, includes three subdivisions, each of which deals with a subordinate part of the *structural* relations of the organism. (1) *Anatomy* thus investigates for us the structure of the adult being—of the organism in its fully-grown state. Our knowledge of its structure, however, cannot be said to be completed with a review of its adult state; and accordingly we trace its early life-history, by aid of the second branch of the science, that of (2) *Embryology* or *Development*. We now know the organism thoroughly as to its structure; as the perfect animal, and in its various stages of development also. The third division of Morphology is that of (3) *Taxonomy* or *Classification*, and this principle is brought into use, when, knowing the structure of several organisms, we compare them together, with a view to determine their relative place in our scheme of arrangement. This latter head might in this respect be termed "*Comparative Morphology*." To these three divisions of Morphology some authorities add a fourth—namely, *Histology*; by which branch we investigate the minute structure of the tissues or intimate parts of the organism. This latter science might therefore be appropriately named "*Microscopic Morphology*," since in its pursuit we employ the microscope and allied modes of investigation.

The science of *Physiology* similarly divides itself into three subdivisions, by means of which we gain a complete knowledge of the processes or *functions* of life in the animal or plant. Firstly, we observe how the organism nourishes itself—(1), Function of *Nutrition*—and under this branch of physiological knowledge we investigate the processes of digestion, absorption, circulation, and respiration; or, in other words, those functions which administer to the growth of the being, by providing for the due elaboration of the food. The function of (2) *Reproduction* provides for the propagation of the species; or for the production of new individuals, by which the specific peculiarities of the organism are carried on, and perpetuated in time. Then, lastly, we have the function of (3) *Correlation*, or as it is sometimes termed,

of *Innervation* or *Irritability*. This latter subdivision investigates the relations which an organism maintains with the world in which it lives, which relations are manifested through the nervous system, or through analogous media.

The terms "functions of animal life," and "functions of organic or vegetative life," so frequently occur in connection with the present subject, that it may be well to explain what is meant by these terms. The functions of "organic or vegetative life" are those of *Nutrition* and *Reproduction;* and these latter functions are so called because they are common to all living beings, whether animals or plants. The functions of *Correlation*, on the other hand, are generally regarded as distinctively and essentially peculiar to the *animal* series, and hence these latter functions are spoken of as those of "animal life."

The *Distributional* aspect of biological science divides itself into a twofold arrangement. We ascertain by its (1) *Geographical Distribution* how an organism is distributed in the world as it now exists. We observe under this head the particular tracts or regions it inhabits, or conversely, in what districts it may be or is unknown. And lastly, through (2) *Geological Distribution*, or by means of its *Distribution in Time*, we ascertain if the organism existed in past periods of our earth's history; and if so, whether or not the conditions of the past differed from those under which it may exist in the present day.

To know an animal or a plant fully and completely, we must know it according to the mode and principles of investigation I have just pointed out. In no sense can our knowledge of an organism be said to be complete and final, unless we are fully aware of its Morphology, its Physiology, and its Distribution. Its early life; its period of full development; its functions as a living being: its habitat now and in time past—these are the points which a complete life-history should contain, and which it is the province of a reliable system of examination to furnish.

Resuming the consideration of those distinctions which

separate different organisms from one another, we now note how morphology and physiology, respectively investigating for us the details of structure and function, enable us to form a correct idea of the relations which exist between the members or groups of either life-series. We observe without difficulty very many differences between animals on the one hand, or between plants on the other. Differences these, which we may include under the heads of form, colour, size, etc., and which may readily enough serve the purposes of a popular classification or arrangement. But, scientifically regarded, we must endeavour to ascertain such differences after a reliable mode; and thus we call to aid the generalisations which a correct system of Morphology and Physiology alone can give.

The differences between different living beings are therefore capable of being investigated under either or both of these divisions: in other words, the differences either relate to the *form* and *structure* of the organism, or to the manner in which the *functions* of its body are carried on. Or, lastly, we may employ both of these means, conjointly, to aid us in our work.

The *morphological* or structural differences are investigated under the head of "Morphological Type;" and the *physiological* or functional differences collectively constitute what is known as "Specialisation of Functions." We shall most profitably and readily arrive at a clear understanding of both, if we commence with the consideration of the differences in "function."

By "specialisation of functions" we conveniently and shortly mean to express the fact that an organism is physiologically simple when the functions of its body are simple, and are subserved by organs or tissues of correspondingly elementary character. Hence the organism physiologically increases in complexity and in perfection of organisation, according as its *functions* are more complex; or, to use the more expressive term, as its functions become more and more "specialised." At the one extremity of either organic series we have organ-

isms physiologically simple, and with functions "unspecialised:" at the other extremity "specialisation of functions" attains its maximum in the most highly organised forms. Let us briefly trace the progress of the specialisation of the nutritive function, as materially assisting us to understand the meaning and application of the term.

The first stage finds a convenient illustration in such a *Protozoic* form as the *Amœba* (Fig. 1, *a b*), or better still in its nearly allied neighbours the *Foraminifera* (Fig. 2, *a b*). In either case, the phenomena of life are primitive and simple to the last degree, and in the *Amœba* these phenomena may be very conveniently studied. Its body is composed of a minute shapeless mass of sarcode or protoplasm, destitute of any defined outline, and exhibiting but the faintest traces of organisation. We look in vain for any defined or even rudimentary stomach-sac, or digestive apparatus of any kind. When the function of nutrition is brought into play, we see it thrusting out its protoplasmic body into finger-like processes (Fig. 1, *a*), by means of which it seizes any particles of nutrient matter. These nutrient particles are drawn into the interior of the body, and the extemporised arms or fingers soon disappear. Around each particle of food thus thrust into the substance of the body, a little clear space forms, and gradually the minute morsel is digested in this temporary and extemporised "stomach." We cannot be certain of the existence in the *Amœba* of any definite organs for the circulation of the nutrient fluid which we may suppose to be thus elaborated from the food; although the function of hearts has been ascribed to certain little clear spaces, termed "contractile vesicles," and which are seen to contract and expand in a regular and defined manner. The innutritious or indigestible portions of the food, or the waste matters of the system, are simply cast out of the body from any portion of its surface; that is, no defined channel for the conveyance of such material from the system is found in the present instance. No distinct respiratory

or breathing organs exist in the *Amœba*, which thus presents us with a form, lingering as it were, on the very verge of existence.

Now let us clearly understand the state of matters observable in the *Amœba*. Firstly, then, we find that no part of the body is "specialised," or set aside to perform the special functions of a stomach; and no specialised organs for seizing the food are present. Any part of the body serves the animal as a stomach, just as any portion of the body-wall can be thrust out to grasp or entangle the particles of food. And as the digestive function is not specialised, so neither are the respiratory, nor, in all probability, the circulatory systems. Specialisation of functions, in short, has not commenced in the *Amœba*. The simple functions of its body are subserved by means apparently and infinitely more simple than the functions themselves.

A step higher in the scale brings us to a form in which we find a certain degree of specialisation of the nutritive function. The common Fresh-Water Polype, or *Hydra*

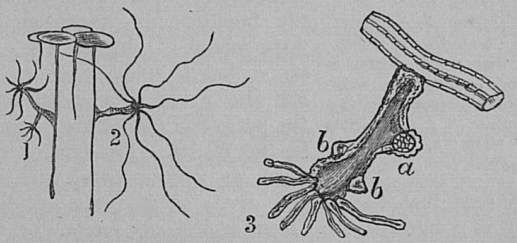

Fig. 7. HYDROZOA.

1. *Hydra viridis*, attached to root of duckweed, with young *Hydra* budding from the side of the parent. 2. *Hydra fusca*, the "long-armed" *Hydra*. 3. *Hydra viridis* (greatly magnified), showing tentacles, ovarium (*a*), and spermatozoic receptacles (*b b*).

(Fig. 7, 1 2 3), found attached to the roots of duckweed and other aquatic plants in most of our ponds, exemplifies the second stage in our investigation. This organism consists of a minute tubelike body, attached by a

root-like extremity to any fixed object, and possessing at its free or unattached end a mouth surrounded by a circle of tentacles.

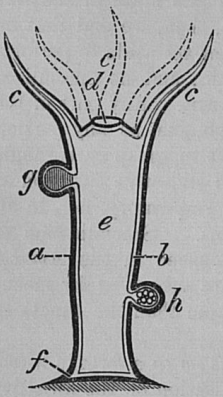

Fig. 8. SECTION OF HYDRA. (*Cœlenterata*).

a, Ectoderm; *b*, endoderm; *c c c*, tentacles; *d*, mouth; *e*, "somatic" cavity, or general cavity of the body; *f*, attached portion or "hydrorhiza;" *g*, spermarium or testis; *h*, ovarium or ovary.

A diagrammatic section of the *Hydra's* body (Fig. 8) reveals a very simple and primitive organisation. We find this body to be composed of a simple tube, with double walls (*a b*), terminating superiorly in a mouth (*d*), and tentacles (*c*). The tentacles serve to grasp the food and convey it to the mouth, whilst the general and simple cavity of the body (*e*) serves the purpose of a stomach. We therefore observe in the present case an advance on the *Amœba's* primitive structure. We find the function of prehension, or that of seizing the food, subserved by special organs, the "tentacles" — in other words, the function of prehension is "specialised;" and we also observe that a distinct mouth exists and is specialised, but here the process of differentiation ends in the *Hydra*. No distinct stomach as yet is found, and we have seen that the general cavity of the body (*e*), does duty as a digestive sac. Neither does any special channel exist for the elimination from the body of the innutritious products of digestion; the refuse material of the body being rejected by the oral aperture (*d*).

A further stage awaits our examination in the *Flustra* or Sea-mat (Fig. 6, *a b*), the structure of which has already been described. If we magnify and diagrammatise a single cell of the *Flustra*, as in Fig. 9, we shall find a very important and marked advance on the *Hydra*. We find a mouth (*b*), and tentacles (*a*) as before, but we also

observe that in addition a distinct stomach (*d*) is specialised or differentiated from the general cavity of the body; and we further notice that from the stomach an intestine (*e*) is continued, terminating by a distinct anal aperture (*f*), and serving for the conveyance from the system of the effete or useless digestive products. Specialisation has advanced in the present case in a marked degree, although as yet we find no distinct circulatory or respiratory organs. In the *Flustra*, the nutritive fluid elaborated from the food simply passes from the digestive system into the cavity of the body (*h*), and is kept circulating throughout the body-cavity by means of the constant action of the little hair-like bodies or "cilia" which line the inner wall of the cell. The function of respiration is in all probability subserved by the ciliated tentacles (*a*) of each little "polypide."

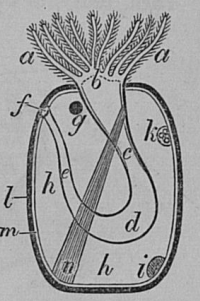

Fig. 9. FLUSTRA.

Diagrammatic section of a single cell of *Flustra* or "Sea-mat" (greatly magnified); *a a*, ciliated tentacles; *b*, mouth; *c*, gullet; *d*, stomach; *e*, intestine; *f*, anus; *g*, nervous ganglion; *h h*, general cavity of body; *i*, testis; *k*, ovary; *l*, ectocyst, or outer membrane of body; *m*, endocyst, or inner membrane of body; *n*, retractor muscle, by the action of which the animal can withdraw the ciliated tentacles.

In the *Snail* or *Whelk* (Fig. 10), we reach a further stage in the process of differentiation of the nutritive function. A complicated organisation is here presented to our notice, and we find that, in addition to the simple stomach and intestine of the *Flustra*, many organs and structures, each fulfilling a definite part and share in the digestive process, are now added. Salivary glands (*e*); a large liver (*i*), furnishing bile, one of the most important of the digestive fluids; a distinct heart (*s t*) and blood-vessels circulating the elaborated products of digestion; and highly developed gills (*p*) or breathing organs for purifying the blood — all testify to the extent and degree

of complication to which the function has, in the present instance, attained.

Then, lastly, if we advance to the consideration of a

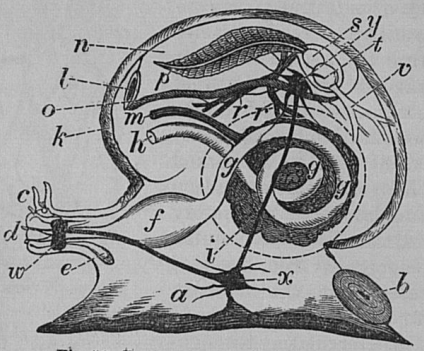

Fig. 10. Diagrammatic Section of Snail.

a, foot; *b*, operculum; *c*, tentacles; *d*, mouth; *e*, salivary gland; *f*, stomach; *g g*, intestine; *h*, anus; *i*, liver; *l*, aperture of gill-chamber; *m*, oviduct; *n*, gill-chamber; *o*, floor of gill-chamber; *p*, gill or breathing-organ; *s t*, heart; *w*, "cephalic," *x*, "pedal," and *y*, "branchial" ganglia.

form high in the scale, such as a *Mammal* (Fig. 11), we shall find the process of specialisation still further improved upon and advanced.

Let us now take a retrospective view of these various stages, and endeavour to gain a true idea of the significance of the process of differentiation. In the *Amœba* any part of the body subserved the nutritive function, and its specialisation in that animalcule could hardly be said to have commenced. In the *Hydra* we found the presence of a distinct mouth, tentacles, and body-cavity, to evince a primary, but still decided, stage of advance on the simplicity of the *Amœba's* organisation. In the *Flustra* the process was observed to be truly specialised; distinct organs and parts being devoted to the performance of the nutritive function. And lastly, in the complicated organisation of the *Whelk*, or *Mammal*, the process reached, respectively, a great and the

highest degree of differentiation to which it could attain. What, then, is the essential difference which physiology will teach us between the simple *Amœba* and the complicated Mollusc or Mammal? The *Amœba* and Whelk nourish themselves equally well. The process of nutrition is as perfect in the *Amœba*, so far as its result goes, as it is in the Whelk. But the *mode* in

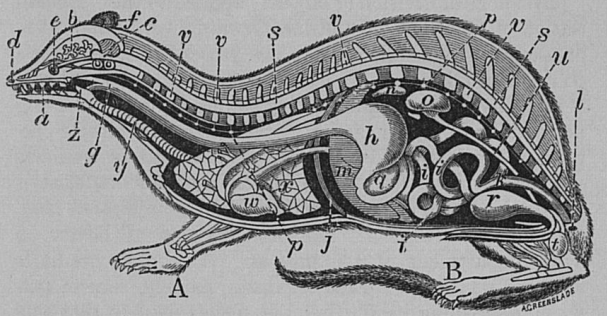

Fig. 11. IDEAL SECTION OF MAMMAL. (Owen.)

A, fore-limb; B, hind-limb; *a*, mouth; *b c*, brain; *d*, nostril; *e*, eye; *f*, ear; *g*, gullet; *h*, stomach; *i i*, intestine; *j*, midriff; *k*, terminal portion of intestine; *l*, anus; *m*, liver; *n*, spleen; *o*, kidney; *p p*, sympathetic nervous system; *r*, urinary bladder; *s s*, spinal cord; *v v v*, vertebral column; *w*, heart; *x*, lung; *y*, windpipe; *z*, epiglottis.

which the result is attained varies greatly in the two cases, and it is exactly this variation which physiology expresses as the *functional* distinction between different organisms.

The simple function in the *Amœba*, subserved by its equally simple protoplasmic body, is broken up in the Whelk, for example, into a complicated series of secondary functions; these secondary functions being subserved by organs which are specialised or set aside, each for the performance of a special duty. Thus it is clear that with the growth in complexity of a function we must also have a corresponding increase in the complexity of our apparatus. It would be obviously useless to suppose or expect that the simple protoplasm of the *Amœba*

should perform the complex functions subserved by the special organs and systems of the Whelk; and therefore it is that we find specialisation of functions and specialisation of organs going "hand-in-hand." Nature, in this view, never employs a physiological "maid-of-all-work" or "Jack-of-all-trades." Where the duties are many and varied, the apparatus is also varied; and hence the term "physiological division of labour," applied to the "specialisation of functions" by Milne Edwards, very happily expresses a just generalisation of the process. The Amœba's body, indeed, is comparable to a factory where raw material is perfectly prepared after a very simple fashion, involving no division of labour, and to serve an equally simple purpose. The body of the Whelk or Mammal is similarly comparable to a factory, in which the raw material is prepared after a different fashion, in a complicated manner, and involving an immense division of labour in every department of the process. The same result is attained relatively to each organism, namely, that of perfectly nourishing itself; but the means used to that end are widely different in the two cases. It is this difference which the principle of the "specialisation of function" expresses; and, physiologically speaking, therefore, an animal is high or low, according as its functions are specialised to a greater or less degree.

To use Huxley's words — "In the lowest organism all parts are competent to perform all functions, and one and the same portion of protoplasm may successively take on the function of feeding, moving, or reproducing apparatus. In the highest, on the contrary, a great number of parts combine to perform each function, each part doing its allotted share of the work with great accuracy and efficiency, but being useless for any other purpose."

What has just been illustrated by aid of the function of nutrition might equally well have been exemplified by that of "reproduction," and, though perhaps not with so strict a result, by the function of "innervation" also. We know so little concerning the conditions determining the function of relation in the lowest organisms,

that we could not, with ease or certainty, employ this particular function to illustrate the process of specialisation through its various stages. At the same time, we are not at all inclined to believe with those who assert that the comparison between the function of relation in the highest and in the lowest animal organisms is one hardly fair or admissible. We do not doubt that such forms as the *Amœba* and *Foraminifera* possess a general sensibility in lieu of the more localised sensations indicative of and dependent upon the presence of a distinct nervous system. This idea is strengthened, as will hereafter be shown, by the results of recent investigations into the nature of "bioplasm;" and we appear to be on the verge of the demonstration of the elements of a sensory apparatus even in the lowest organisms.

There is certainly nothing unreasonable in the idea that the lower animal organisms possess means for carrying on the function of innervation; these means being present and exercised, in an imperfect degree no doubt when compared with the definite nervous apparatus of higher forms, but partaking, in common with the other systems and functions, of that general want of specialisation which we have seen to characterise the *Protozoa* generally.