

GENERAL BIOLOGY

~ INTRODUCTORY EDITION ~

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PART I.—INTRODUCTORY



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PREFACE

SEVERAL years ago it was our good fortune to follow as graduate students a course of lectures and practical study in General Biology, under the direction of Professor Martin, at Johns Hopkins University. Since that time we have ever been strongly of the opinion that beginners in Biology should be introduced to the subject by some similar method, following in the main the outlines marked out by Huxley and Martin more than ten years ago. The present work thus owes its origin to the influence of the authors of the "Elementary Biology," our deep indebtedness to whom we gratefully acknowledge.

It has not been our ambition to prepare an exhaustive treatise. We have sought only to lead beginners in biology from familiar facts to a better knowledge of how living things are built and how they act, such as may rightly take a place in general education or may afford a basis for further studies in General Biology, Zoölogy, Botany, Physiology, or Medicine.

It is still an open question whether the beginner should pursue the logical but difficult course of working upwards from the simple to the complex, or adopt the easier and more practical method of working downwards from familiar higher forms. Every teacher of the subject knows how great are the practical difficulties besetting the novice, who, provided for the first time with a compound microscope, is confronted with Yeast, Proto-coccus, or Amœba; and on the other hand, how hard it is to sift out what is general and essential from the heterogeneous details of a mammal or a flowering plant. In the hope of lessening the practical difficulties of the logical method we venture to submit a course of preliminary study, which we have used for some time with our own classes, and have found practical and effective. Believing that biology should follow the example of physics and chemistry in discussing at the outset the fundamental

properties of matter and energy, we have devoted the first four chapters to an elementary account of living matter and vital energy. In the six chapters which follow, these facts are applied by a fairly exhaustive study of a representative plant and animal, of considerable, though not extreme, complexity—a method which we believe affords, in a given time, a better knowledge of vital phenomena than can be acquired by more superficial study of a larger number of forms. We are satisfied that the fern and earthworm are for this purpose the best available organisms, and that their study can be made fruitful and interesting. The last chapter comprises a brief account of the principles and outlines of classification as a guide in subsequent studies.

After this introductory study the student will be well prepared to take up the one-celled organisms, and can pass rapidly over the ground covered by such works as Huxley and Martin's *Practical Biology*, Brooks's *Handbook of Invertebrate Zoölogy*, Arthur, Barnes and Coulter's *Plant Dissection*, or the second part of this book, which is well in hand and will probably be ready in the course of the following year.

The directions for practical study are intended as suggestions, not substitutes, for individual effort. We have striven to make the work useful as well in the class-room as in the laboratory, and to this end have introduced many illustrations. The generosity of a friend has enabled us to enlist the skill of our friend Mr. James H. Emerton, who has drawn most of the original figures from nature, under our direction. We have also been greatly aided in the preparation of the figures by Mr. William Claus of Boston.

NEW YORK, September, 1886.

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CHAPTER I.

INTRODUCTORY.

WE know from common experience that all material things are either dead or alive, or, more accurately, that all matter is either lifeless or living; and so far as we know, life exists only as a manifestation of living matter. Living matter and lifeless matter are everywhere totally distinct, though often closely associated. The most careful studies have on the whole rendered the distinction more clear and striking, and have demonstrated that living matter never arises spontaneously from lifeless matter, but only through the immediate influence of living matter already existing. And so, whatever may have been the case at an earlier period of the earth's history, we are at present justified in regarding the line between living and lifeless matter as one of the most clearly defined and remarkable of natural boundaries.

The contrast between living matter and lifeless matter is made the ground for a division of the natural sciences into two corresponding groups, viz.: the **Biological Sciences** and the **Abiological Sciences**, dealing with living matter and lifeless matter respectively. The biological sciences (p. 7) are known collectively as **Biology** (*βίος, life; λόγος, a discourse*), which is therefore often defined as the science of life, of living things, or of living matter. But living matter, as will shortly appear, is only ordinary matter which has entered into a peculiar state or condition. And hence biology is more precisely defined as *the science which treats of matter in the living state*.

The Relationship between Living and Lifeless Matter. Although living matter and lifeless matter present this remarkable contrast to one another, they are most intimately related, as a moment's reflection will show. The living substance of the human body, or of any animal or plant, is only the transformed lifeless matter of the food which has been taken into the body

and has there assumed, for a time, the living state. Lifeless matter in the shape of food is continually streaming into all living things on the one hand and passing out again as waste on the other. In its journey through the organism some of this matter enters into the living state and lingers for a time as part of the bodily substance. But sooner or later it dies, and is then for the most part cast out of the body (though a part may be retained within it, either as an accumulation of waste material, or to serve some useful purpose). Matter may thus pass from the lifeless into the living state and back again to the lifeless, over and over in never-ending cycles. A living plant or animal is like a whirlpool into which, and out of which, matter is constantly streaming, while the whirlpool maintains its characteristic form and individuality.*

How then is living matter different from lifeless matter? The question cannot be fully answered by chemical analysis, for the reason that this process necessarily kills living matter, and the

* We append Huxley's graphic comparison of a living organism to a whirlpool (*The Crayfish as an Introduction to the Study of Zoology*, pp. 84, 85. Appleton, N. Y., 1880), having made slight verbal changes so that the passage, originally applied to a particular animal, the crayfish, may be made general:—

“To put the matter in the most general shape, the body of the organism is a sort of focus to which certain material particles converge, in which they move for a time, and from which they are afterward expelled in new combinations. The parallel between a whirlpool in a stream and a living being, which has often been drawn, is as just as it is striking. The whirlpool is permanent, but the particles of water which constitute it are incessantly changing. Those which enter it on the one side are whirled around and temporarily constitute a part of its individuality; and as they leave it on the other side, their places are made good by newcomers

“Those who have seen the wonderful whirlpool, three miles below the Falls of Niagara, will not have forgotten the heaped-up wave which tumbles and tosses, a very embodiment of restless energy, where the swift stream hurrying from the Falls is compelled to make a sudden turn toward Lake Ontario. However changeful in the contour of its crest, this wave has been visible, approximately in the same place and with the same general form, for centuries past. Seen from a mile off it would appear to be a stationary hillock of water. Viewed closely it is a typical expression of the conflicting impulses generated by a swift rush of material particles.

“Now, with all our appliances, we cannot get within a good many miles, so to speak, of the living organism. If we could, we should see that it was nothing but the constant form of a similar turmoil of material molecules, which are constantly flowing into the organism on the one side and streaming out on the other.”

results therefore teach us little of the chemical conditions existing in the matter when alive. Analyses, nevertheless, bring to light several highly important facts. It appears that living matter is a tolerably definite compound of a number of the chemical elements, and it is probably too low an estimate to say that at least six elements must unite in order that life may exist. Moreover, only a very few out of all the elements are able, under any circumstances, to form this living partnership.

The most significant fact, however, is that there is no loss of weight when living matter is killed. The total weight of the lifeless products is exactly equal to the weight of the living substance analyzed, and if anything has escaped at death it is imponderable, and, having no weight, is not material. It follows that living matter contains no material substance peculiar to itself, and that every element found in living matter may be found also, under other circumstances, in lifeless matter.

Considerations like these lead us to recognize a fundamental fact, namely, that the terms living and lifeless designate two different STATES or CONDITIONS of matter. We do not know, at present, what causes this difference of condition. But so far as the evidence shows, the living state is never assumed except under the influence of antecedent living matter, which, so to speak, infects lifeless matter, and in some way causes it to assume the living state.

Distinctive Properties of Living Matter. Those properties of living matter which, taken together, distinguish it absolutely from every form of lifeless matter, are:

1. Its chemical composition.
2. Its power of waste and repair, and of growth.
3. Its power of reproduction.

Living matter invariably contains substances known as proteids, which are believed to constitute its essential material basis (see p. 35). Proteids are complex compounds of Carbon, Oxygen, Hydrogen, Nitrogen, Sulphur, and (in some cases at any rate) Phosphorus.

It has been frequently pointed out that each of these six elements is remarkable in some way; oxygen, for its vigorous combining powers; nitrogen, for its chemical inertia; hydrogen, for its great molecular mobility; carbon, sulphur, and phosphorus, for their allotropic properties, etc. All of these peculiarities may be shown to be of significance when con-

sidered as attributes of living matter. (See Herbert Spencer, *Principles of Biology*, vol. i.)

It is not, however, the mere presence of proteids which is characteristic of living matter. White-of-egg (albumen) contains an abundance of a typical proteid and yet is absolutely lifeless. Living matter does not simply contain proteids, but has the *power to manufacture them* out of other substances; and this is a property of living matter exclusively.

The powers of living matter are still more characteristic. It is continually wasting away by a kind of internal combustion, but continually repairs the waste by the processes of growth. Moreover, this growth is of a characteristic kind, differing absolutely from the so-called growth of lifeless things. Crystals and other lifeless bodies grow, if at all, by *accretion*, or the addition of new particles to the outside. Living matter grows from within by *intus-susception*, or taking in new particles, and fitting them into the interstices between those already present, throughout the whole mass. And, lastly, living matter not only thus repairs its own waste, but also gives rise by reproduction to new masses of living matter which become detached from the parent mass and enter forthwith upon an independent existence.

We may perceive how extraordinary these properties are by supposing a locomotive engine to possess like powers: to carry on a process of self-repair in order to compensate for wear, to grow and increase in size, detaching from itself at intervals pieces of brass or iron endowed with the power of growing up step by step into other locomotives capable of running themselves, and of reproducing new locomotives in their turn. Precisely these things are done by every living thing, and nothing in any degree comparable with them takes place in the lifeless world.

Huxley has given the best statement extant of the distinctive properties of living matter, as follows:—

“1. Its *chemical composition*—containing, as it invariably does, one or more forms of a complex compound of carbon, hydrogen, oxygen, and nitrogen, the so-called protein (which has never yet been obtained except as a product of living bodies), united with a large proportion of water, and forming the chief constituent of a substance which, in its primary unmodified state, is known as protoplasm.

“2. Its *universal disintegration and waste by oxidation, and its concomitant reintegration by the intussusception of new matter*. A process of

waste resulting from the decomposition of the molecules of the protoplasm in virtue of which they break up into more highly oxidated products, which cease to form any part of the living body, is a constant concomitant of life. There is reason to believe that carbonic acid is always one of these waste products, while the others contain the remainder of the carbon, the nitrogen, the hydrogen, and the other elements which may enter into the composition of the protoplasm.

"The new matter taken in to make good this constant loss is either a ready-formed protoplasmic material, supplied by some other living being, or it consists of the elements of protoplasm, united together in simpler combinations, which constantly have to be built up into protoplasm by the agency of the living matter itself. In either case, the addition of molecules to those which already existed takes place, not at the surface of the living mass, but by interposition between the existing molecules of the latter. If the processes of disintegration and of reconstruction which characterize life balance one another, the size of the mass of living matter remains stationary, while if the reconstructive process is the more rapid, the living body *grows*. But the increase of size which constitutes growth is the result of a process of molecular intus-susception, and therefore differs altogether from the process of growth by accretion, which may be observed in crystals, and is effected purely by the external addition of new matter; so that, in the well-known aphorism of Linnæus, the word 'grow' as applied to stones signifies a totally different process from what is called 'growth' in plants and animals.

"3. Its *tendency to undergo cyclical changes*. In the ordinary course of nature, all living matter proceeds from pre-existing living matter, a portion of the latter being detached and acquiring an independent existence. The new form takes on the characters of that from which it arose; exhibits the same power of propagating itself by means of an off-shoot; and, sooner or later, like its predecessor, ceases to live, and is resolved into more highly oxidated compounds of its elements.

"Thus an individual living body is not only constantly changing its substance, but its size and form are undergoing continual modifications, the end of which is the death and decay of that individual; the continuation of the kind being secured by the detachment of portions which tend to run through the same cycle of forms as the parent. No forms of matter which are either not living or have not been derived from living matter exhibit these three properties, nor any approach to the remarkable phenomena defined under the second and third heads." (*Encyclopædia Britannica*, 9th ed., art. "Biology," vol. iii., p. 679.)

Concerning the chemical composition of living matter and its significance, a few considerations should be borne in mind. For the purposes of biological study life must be regarded as a property of a certain kind of compounded matter.* But we are

* Herbert Spencer, *Principles of Biology*, vol. 1.

forced to regard the properties of compounds as the resultants of the properties of their constituent elements, even though we cannot well imagine how such a connection exists; and so in the long run we have to fall back upon the properties of carbon, hydrogen, nitrogen, oxygen, etc., for the properties of living matter. Reflections of this sort show how ignorant we are of the real properties of the elements, and how important further study of them is.

Consciousness. It cannot be doubted that the living form of matter alone manifests the phenomena of consciousness; and it is not generally believed to exist to any great extent, except in the higher forms of animal life. Because of the purely subjective nature of consciousness it is impossible to say with absolute certainty whether animals other than ourselves are really conscious, and many of the actions commonly supposed to indicate consciousness are simply reflex actions, even in ourselves.* We do not know, therefore, how widely consciousness is distributed among living things, though there is no reason to suppose that plants possess it. There is evidence, however, that it exists in different degrees of intensity among animals, keeping pace in a general way with the amount of organization which they exhibit, and shading off into simpler nervous conditions. The phenomena of consciousness are undoubtedly the least understood of all biological problems. From the scientific point of view it appears at present impossible to translate them into the terms of physical phenomena, though they are not known to occur apart from a living material basis with which they appear to be in some way closely connected.

Scope of Biology. Biology has already been defined as the science which treats of matter in the living state. Whatever pertains to living matter or to living things pertains to biology. The study of the forms of living things, of their habits, actions nutrition, surroundings, distribution; of their relations to the lifeless world, and to one another; of their sensations and social relations, their origin and their fate,—these and many other topics

* "It is really an open question whether a crayfish has a mind or not. Moreover the problem is an absolutely insoluble one inasmuch as nothing short of being a crayfish would give us positive assurance that such an animal possesses consciousness." (Huxley, *The Crayfish*, p. 89.)

lie within the province of biology. The science includes both zoölogy and botany, dealing with the phenomena of animal and vegetal life not only separately, but in their relations to one another. The term **General Biology** does not designate a particular member of the group of biological sciences, but is only a convenient phrase, which has recently come into use for the general introductory study of biology. It includes a description of the general properties of living matter as revealed in the structures and actions of living things, and may serve as the basis for subsequent study of more special branches of the science. It deals with the broad characteristic phenomena and laws of life as they are illustrated by the thorough comparative study of a series of plants and animals taken as representative types; but in this study the student should never lose sight of the fact that all the varied phenomena which may come under his observation are in the last analysis due to *the properties of matter in the living state*, and that this matter and these properties are the real goal of the study.

The Biological Sciences. The field covered by biology as thus understood is so wide as to necessitate a subdivision of the subject into a number of branches which are usually assigned the rank of distinct sciences. They are arranged in a tabular view on p. 8. The table shows two different ways of dividing the main subject, according as the table is read from left to right or *vice versa*. According to the more usual arrangement biology is primarily divided into zoölogy and botany, according as animals or plants respectively, form the subject of study. Such a division has the great advantage of practical convenience since, as a matter of fact, most biologists devote their attention mainly either to plants alone, or to animals alone. From a scientific point of view, however, a better subdivision is into *Morphology* (*μορφή*, *form*; *λόγος*, *a discourse*) and *Physiology* (*φύσις*, *nature*; *λόγος*, *a discourse*). The former is based upon the facts of form, structure, and arrangement, and is essentially statical; the latter upon those of action or function, and is essentially dynamical. But morphology and physiology are so intimately related that it is impossible to separate either subject absolutely from the other.

Besides the sub-sciences given upon the table a distinct branch called *Ætiology* is often recognized, having for its object the investigation of the causes of biological phenomena. But the

Biology.

The science of living things; i.e., of matter in the living state.

Morphology.

The science of form, structure, etc. Essentially statical.

Physiology.

The science of action or function. Essentially dynamical.

Anatomy.

The science of structure; the term being usually applied to the coarser and more obvious composition of plants or animals.

Histology.

Microscopical anatomy. The ultimate optical analysis of structure by the aid of the microscope; separated from anatomy only as a matter of convenience.

Taxonomy.

The classification of living things. Based chiefly on phenomena of structure.

Distribution.

Considers the position of living things in space and time, their distribution over the present face of the earth and their distribution and succession at former periods, as displayed in fossil remains.

Embryology.

The science of development from the germ. Includes many mixed problems pertaining both to morphology and physiology. At present largely morphological.

Physiology.

The special science of the functions of the individual in health and in disease; hence including *Pathology*.

Psychology.

The science of mental phenomena.

Sociology.

The science of social life, i.e., the life of communities, whether of men or of lower animals.

Botany.

The science of vegetal living matter or plants.

Biology.

The science of living things; i.e., of matter in the living state.

Zoology.

The science of animal living matter or animals.

scientific study of every phenomenon has for its ultimate object the discovery of its cause. *Ætiology* is therefore inseparable from any of the several branches of biology and cannot properly be assigned an independent place.

Psychology and *Sociology* are not yet generally admitted to constitute branches of biology, and it is customary and convenient to set them apart from it. The progress of these sciences has clearly shown, however, that their study is inseparable from that of biology in the ordinary sense.

It will be observed in the scheme that morphology and physiology overlap; that is, there are certain biological sciences in which the study of structure and of action cannot be separated. This is especially true of embryology, which considers the successive stages of embryonic structure and also the modes of action by which they are produced. And finally it must not be forgotten that any particular arrangement of the biological sciences must be in the main a matter of convenience only; for it is impossible to study any one order of phenomena in complete isolation from all others.

PRACTICAL STUDY.*

A. THE PARTS OF THE MICROSCOPE.

a. The Stand.

1. Stage.
2. Mirror.
3. Diaphragms.
4. Coarse and fine Adjustments.

b. The Optical Apparatus.

1. Objective.
2. Ocular or Eye-piece.
3. Draw-tube.

B. THE USE OF THE MICROSCOPE.

1. Illuminating.
2. Focussing.
3. Camera lucida.
4. Measurements by the camera and the stage micrometer.
5. The value of binocular vision.

C. THE EXAMINATION AND SKETCHING OF VARIOUS OBJECTS AS PRACTICE.

D. SIMPLE METHODS OF TEASING, MOUNTING, AND STAINING.

E. THE PRINCIPLES OF PHOTO-MICROGRAPHY.

* Since a knowledge of the microscope is an indispensable preliminary to the laboratory work, the student may now conveniently learn something of its use.

CHAPTER II.

THE COMPOSITION OF LIVING ORGANISMS.

Living and Lifeless Matter in the Living Organism. Since our own bodies and those of lower animals and of plants are composed of matter, it might be supposed, from what has been said in the last chapter, that they are composed of living matter. This, however, is true only in part. It is strictly true that every plant or animal contains living matter, but a little reflection will show that it contains lifeless matter also. In the human body lifeless matter is found in the hairs, the ends of the nails, and the outer layers of the skin,—structures which are not simply devoid of feeling, as every one knows them to be, but are really lifeless in every sense, although forming part of a living body. Nor is lifeless matter confined to the exterior of the body. The mineral matter of the bones is not alive; and this is true, though less obviously, of many other parts, such as the liquid basis of the blood, or plasma, the fat (which is never wholly absent) and various other forms of matter occurring in many parts of the body.

In lower animals examples of this truth occur on every hand. The calcareous shells of animals like the snail and the oyster; the skeletons of corals and sponges; the hard outer crust of insects, lobsters, and related animals; the scales of fish and reptiles; the feathers, claws, and beaks of birds; the fur of animals—these are a few of the countless instances of structures composed wholly or in part of lifeless matter, which nevertheless enter into the composition of living animals.

Among plants like facts are even more conspicuous. No one can doubt that the outer bark of an oak is devoid of life. The heart-wood of a tree is entirely dead, and even in the so-called live wood, through which the sap flows, not only is the solid part of the wood lifeless, but also the sap itself.

In short, it is a general truth that the living matter of plants and animals is almost invariably associated with lifeless matter.

and therefore the first step to be taken in the study of biology is to examine how the matter of a living organism is arranged. This may be done conveniently by a preliminary study of the

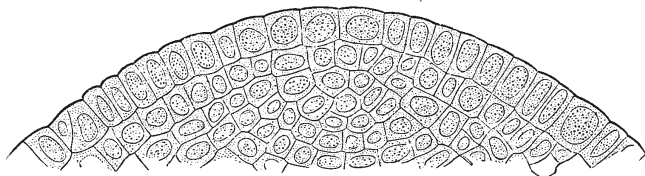


FIG. 1. (After Sachs.)—Longitudinal section through the growing apex of a young pine-shoot. The dotted portion represents the protoplasm, the narrow lines being the partition walls composed of cellulose ($C_6H_{10}O_5$). (Highly magnified.)

general composition of living organisms, leaving out of consideration, for the present, the lowest and simplest forms, and considering only those more highly organized plants and animals which are in a greater or less degree familiar to every one.

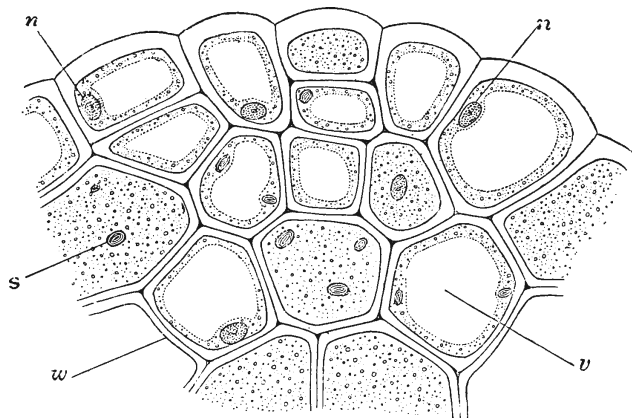


FIG. 2. Cross-section through part of the young leaf of a fern (*Pteris aquilina*), showing thick-walled cells; most of the walls are double. The granular substance is protoplasm. Most of the cells contain a large central cavity (vacuole) filled with sap, the protoplasm having been reduced to a thin layer inside the partitions. Nuclei are shown in some of the cells, and lifeless grains of starch in others: *n*, nuclei; *s*, starch; *v*, vacuole; *w*, double partition-wall. ($\times 500$.)

Organisms composed of Organs. Functions. It is characteristic of any living body—for example, a rabbit or a geranium—that it is composed of unlike parts, whose structure enables them to

perform various operations essential or accessory to the life of the whole. The plant has stem, roots, branches, leaves, stamens pistil, seeds, etc.; the animal has externally head, trunk, limbs, eyes, ears, etc., and internally stomach, intestines, liver, lungs, heart, brain, and many other parts having the most diverse structures. These parts are known as *organs*, and the living body is called an *organism* because it possesses them.

The word organism, as here used, applies only to the higher animals and plants. It will be seen in the sequel that there are forms of life so simple that organs as here defined can scarcely be distinguished or are entirely wanting. Such living things are nevertheless called organisms because of the existence of different parts which are analogous in function to the organs of plants and animals.

Since organisms are composed of unlike parts, they are said to be heterogeneous in structure. They are also heterogeneous in action, the different organs performing different operations called *functions*. For instance, it is the function of the stomach to digest food, of the heart to pump the blood into the vessels, of the kidneys to excrete waste matters from the blood, and of the brain to direct the functions of other organs. A similar diversity of functions exists in plants. The roots hold the plant fast and absorb various substances from the soil; the stem supports the leaves and flowers and conducts the sap; the leaves breathe and elaborate portions of the food; and the reproductive organs of the flower serve to form and bring to maturity seeds destined to give rise to a new generation.

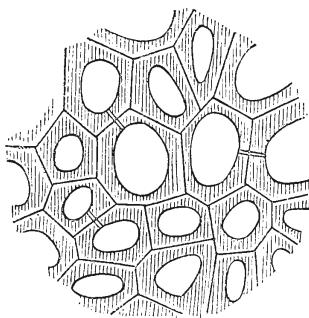


FIG. 3. (After Sachs.)—Cross-section through a group of dead, thick-walled wood-cells from the stem of maize. The cells contain only air or water. (Highly magnified.)

Heterogeneity of the kind just indicated is one of the most characteristic features of living things, and is not known in any mass of lifeless matter, however large and complex.

Organs composed of Tissues. **Differentiation.** In the next place it is to be observed that the organs themselves, when fully formed, are not homogeneous, but are in turn made up of different parts. The human hand is an organ which consists of many parts, differ-