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ANIMAL LIFE AND INTELLIGENCE

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PREFACE.

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There are many books in our language which deal with Animal Intelligence in an anecdotal and conventionally popular manner. There are a few, notably those by Mr. Romanes and Mr. Mivart, which bring adequate knowledge and training to bear on a subject of unusual difficulty. In the following pages I have endeavoured to contribute something (imperfect, as I know full well, but the result of several years' study and thought) to our deeper knowledge of those mental processes which we may fairly infer from the activities of dumb animals.

The consideration of Animal Intelligence, from the scientific and philosophical standpoint, has been my primary aim. But so inextricably intertwined is the subject of Intelligence with the subject of Life, the subject of organic evolution with the subject of mental evolution, so closely are questions of Heredity and Natural Selection interwoven with questions of Habit and Instinct, that I have devoted the first part of this volume to a consideration of Organic Evolution. The great importance and value of Professor Weismann's recent contributions to biological science, and their direct bearing on questions of Instinct, rendered such treatment of my subject, not only advisable, but necessary. Moreover, it seemed to me, and to those whom I consulted in the matter, that a general work on Animal Life and Intelligence, if adequately knit into a connected whole, and based on sound principles of science and of philosophy, would not be unwelcomed by biological students, and by that large and increasing class of readers who, though not professed students, follow with eager interest the development of the doctrine of Evolution.

Incidentally, but only incidentally, matters concerning man, as compared with the dumb animals, have been introduced. It is contended that in man alone, and in no dumb animal, is the rational faculty, as defined in these pages, developed; and it is contended that among human-folk that process of natural selection, which is so potent a factor in the lower reaches of organic life, sinks into comparative insignificance. Man is a creature of ideas and ideals. For him the moral factor becomes one of the very highest importance. He conceives an ideal self which he strives to realize; he conceives an ideal humanity towards which he would raise his fellow-man. He becomes a conscious participator in the evolution of man, in the progress of humanity.

But while we must not be blind to the effects of new and higher factors of progress thus introduced as we rise in the scale of phenomena, we must at the same time remember that biological laws still hold true, though moral considerations and the law of duty may profoundly modify them. The eagle soars aloft apparently in defiance of gravitation; but the law of gravitation still holds good; and no treatment of the mechanism of flight which neglected it would be satisfactory. Moral restraint, a higher standard of comfort, and a perception of the folly and misery of early and improvident marriage may tend to check the rate of growth of population: but the "law of increase" still holds good, as a law of the factors of phenomena; and Malthus did good service to the cause of science when he insisted on its importance. We may guide or lighten the incidence of natural selection through competition; we may in our pity provide an asylum for the unfortunates who are suffering elimination; but we cannot alter a law which, as that of one of the factors of organic phenomena, still obtains, notwithstanding the introduction of other factors.

However profoundly the laws of phenomena may be modified by such introduction of new and higher factors, the older and lower factors are still at work beneath the surface. And he who would adequately grasp the social problems of our time should bring to them a mind prepared by a study of the laws of organic life: for human beings, rational and moral though they may be, are still organisms; and man can in no wise alter or annul those deep-lying facts which nature has throughout the ages been weaving into the tissue of life.

Some parts of this work are necessarily more technical, and therefore more abstruse, than others. This is especially the case with Chapters III., V., and VI.; while, for those unacquainted with philosophical thought, perhaps the last chapter may present difficulties of a different order. With these exceptions, the book will not be beyond the ready comprehension of the general reader of average intelligence.

I have to thank many kind friends for incidental help. Thanks are also due to Professor Flower, who courteously gave permission that some of the exhibits in our great national collection in Cromwell Road might be photographed and reproduced; and to Messrs. Longmans for the use of two or three illustrations from my text-book of "Animal Biology."

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ANIMAL LIFE AND INTELLIGENCE.

CHAPTER I.
THE NATURE OF ANIMAL LIFE.

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I once asked a class of school-boys to write down for me in a few words what they considered the chief characteristics of animals. Here are some of the answers—

- 1. Animals move about, eat, and grow.
- 2. Animals eat, grow, breathe, feel (at least, most of them do), and sleep.
- 3. Take a cat, for example. It begins as a kitten; it eats, drinks, plays about, and grows up into a cat, which does much the same, only it is more lazy, and stops growing. At last it grows old and dies. But it may have kittens first.
- 4. An animal has a head and tail, four legs, and a body. It is a living creature, and not a vegetable.
- 5. Animals are living creatures, made of flesh and blood.

Combining these statements, we have the following characteristics of animals:—

- 1. Each has a proper and definite form, at present described as "a head and tail, four legs, and a body."
- 2. They breathe.
- 3. They eat and drink.
- 4. They grow.

- 5. They also "grow up." The kitten grows up into a cat, which is somewhat different from the kitten.
- 6. They move about and sleep.
- 7. They feel—"at least some of them do."
- 8. They are made of "flesh and blood."
- 9. They grow old and die.
- 10. They reproduce their kind. The cat may have kittens.
- 11. They are living organisms, but "not vegetables."

Now, let us look carefully at these characteristics, all of which were contained in the five answers, and were probably familiar in some such form as this to all the boys, and see if we cannot make them more general and more accurate.

1. *An animal has a definite form.* My school-boy friend described it as a head and tail, four legs, and a body. But it is clear that this description applies only to a very limited number of animals. It will not apply to the butterfly, with its great wings and six legs; nor to the lobster, with its eight legs and large pincer-claws; to the limbless snake and worm, the finned fish, the thousand-legs, the oyster or the snail, the star-fish or the sea-anemone. The animals to which my young friend's description applies form, indeed, but a numerically insignificant proportion of the multitudes which throng the waters and the air, and not by any means a large proportion of those that walk upon the surface of the earth. The description applies only to the backboned vertebrates, and not to nearly all of them.

It is impossible to summarize in a sentence the form-characteristics of animals. The diversities of form are endless. Perhaps the distinguishing feature is the prevalence of curved and rounded contours, which are in striking contrast to the definite crystalline forms of the inorganic kingdom, characterized as these are by plane surfaces and solid angles. We may say, however, that all but the very lowliest animals have each and all a proper and characteristic form of their own, which they have inherited from their immediate ancestors, and which they hand on to their descendants. But this form does not remain constant throughout life. Sometimes the change is slight; in many cases, however, the form alters very markedly during the successive stages of the life of the individual, as is seen in the frog, which begins life as a tadpole, and perhaps even more conspicuously in the butterfly, which passes through a caterpillar and a chrysalis stage. Still, these changes are always the same for the same kind of animal. So that we may say, each animal has a definite form and shape or series of shapes.

2. *Animals breathe.* The essential thing here is that oxygen is taken in by the organism, and carbonic acid gas is produced by the organism. No animal can carry on its life-processes unless certain chemical changes take place in the substance of which it is composed. And for these chemical changes oxygen is essential. The products of these changes, the most familiar of which are carbonic acid gas and urea, must be got rid of by the process of excretion. Respiration and excretion are therefore essential and characteristic life-processes of all animals.

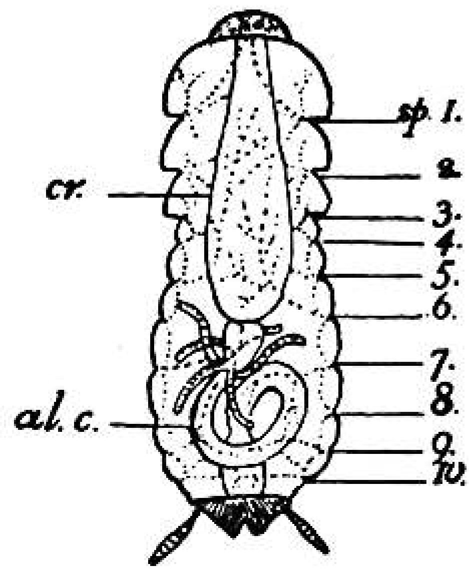

Fig. 1.—Diagram of spiracles and air-tubes (tracheæ) of an insect (cockroach).

The skin, etc., of the back has been removed, and the crop (*cr.*) and alimentary canal (*al.c.*) displayed. The air-tubes are represented by dotted lines. The ten spiracles are numbered to the right of the figure.

In us, and in all air-breathing vertebrates, there are special organs set apart for respiration and excretion of carbonic acid gas. These are the lungs. A great number of insects also breathe air, but in a different way. They have no lungs, but they respire by means of a number of apertures in their sides, and these open into a system of delicate branching tubes which ramify throughout the body. Many organisms, however, such as fish and lobsters and molluscs, breathe the air dissolved in the water in which they live. The special organs developed for this purpose are the gills. They are freely exposed to the water from which they abstract the air dissolved therein. When the air dissolved in the water is used up, they sicken and die. There can be nothing more cruel than to keep aquatic animals in a tank or aquarium in which there is no means of supplying fresh oxygen, either by the action of green vegetation, or by a jet of water carrying down air-bubbles, or in some other way. And then there are a number of animals which have no special organs set apart for breathing. In them respiration is carried on by the general surface of the body. The common earthworm is one of these; and most microscopic organisms are in the same condition. Still, even if there be no special organs for breathing, the process of respiration must be carried on by all animals.

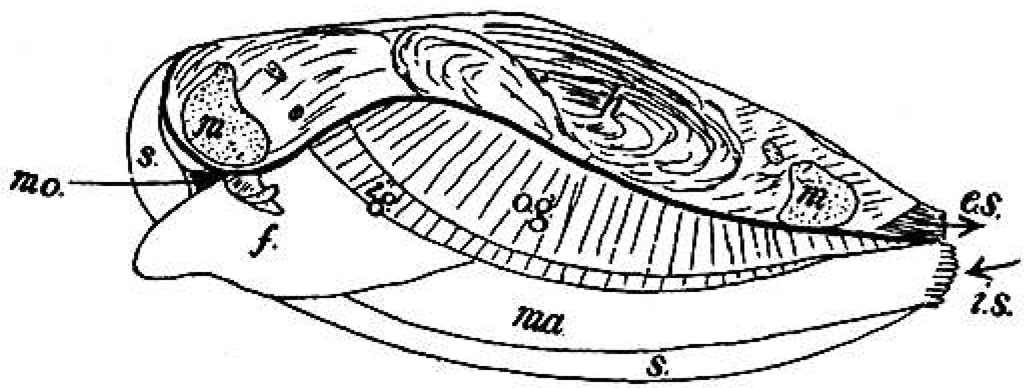

Fig. 2.—Gills of mussel.

o.g., outer gill; *i.g.*, inner gill; *mo.*, mouth; *m.*, muscles for closing shell; *ma.*, mantle; *s.*, shell; *f.*, foot; *h.*, position of heart; *e.s.*, exhalent siphon, whence the water passes out from the gill-chamber; *i.s.*, inhalent siphon, where the water enters.

The left valve of the shell has been removed, and the mantle cut away along the dark line.

3. *They eat and drink.* The living substance of an animal's body is consumed during the progress of those chemical changes which are consequent upon respiration; and this substance must, therefore, be made good by taking in the materials out of which fresh life-stuff can be formed. This

process is called, in popular language, feeding. But the food taken in is not identical with the life-stuff formed. It has to undergo a number of chemical changes before it can be built into the substance of the organism. In us, and in all the higher animals, there is a complex system of organs set aside for the preparation, digestion, and absorption of the food. But there are certain lowly organisms which can take in food at any portion of their surface, and digest it in any part of their substance. One of these is the amœba, a minute speck of jelly-like life-stuff, which lives in water, and tucks in a bit of food-material just as it comes. And there are certain degenerate organisms which have taken to a parasitic life, and live within the bodies of other animals. Many of these can absorb the material prepared by their host through the general surface of their simple bodies. But here, again, though there may be no special organs set apart for the preparation, absorption, and digestion of food, the process of feeding is essential to the life of all animals. Stop that process for a sufficient length of time, and they inevitably die.

4. *They grow.* Food, as we have just seen, has to be taken in, digested, and absorbed, in order that the loss of substance due to the chemical changes consequent on respiration may be made good. But where the digestion and absorption are in excess of that requisite for this purpose, we have the phenomenon of growth.

What are the characteristics of this growth? We cannot, perhaps, describe it better than by saying (1) that it is organic, that is to say, a growth of the various organs of the animal in due proportion; (2) that it takes place, not merely by the addition of new material (for a crystal grows by the addition of new material, layer upon layer), but by the incorporation of that new material into the very substance of the old; and (3) that the material incorporated during growth differs from the material absorbed from without, which has undergone a preparatory chemical transformation within the animal during digestion. The growth of an animal is thus dependent upon the continued absorption of new material from without, and its transformation into the substance of the body.

The animal is, in fact, a centre of continual waste and repair, of nicely balanced constructive and destructive processes. These are the invariable concomitants of life. Only so long as the constructive processes outbalance the destructive processes does growth continue. During the greater part of a healthy man's life, for example, the two processes, waste and repair, are in equilibrium. In old age, waste slowly but surely gains the mastery; and at death the balanced process ceases, decomposition sets in, and the elements of the body are scattered to the winds or returned to mother earth.

There are generally limits of growth which are not exceeded by any individuals of each particular kind of animal. But these limits are somewhat variable among the individuals of each kind. There are big men and little men, cart-horses and ponies, bloodhounds and lap-dogs. Wild animals, however, when fully grown, do not vary so much in size. The period of growth is also variable. Many of the lower backboned animals probably grow during the whole of life, but those which suckle their young generally cease growing after a fraction (in us from one-fourth to one-fifth) of the allotted span of life is past.

5. But animals not only grow—*they also "grow up."* The kitten grows up into a cat, which is somewhat different from the kitten. We speak of this growing up of an animal as its *development*. The proportion of the various parts and organs progressively alter. The relative lengths of the arms and legs, and the relative size of the head, are not the same in the infant as in the man or woman. Or, take a more marked case. In early spring there is plenty of frog-spawn in the ponds. A number of blackish specks of the size of mustard seeds are embedded in a jelly-like mass. They are frogs' eggs. They seem unorganized. But watch them, and the organization will gradually appear. The egg will be hatched, and give rise to a little fish-like organism. This will by degrees grow into a tadpole, with a powerful swimming tail and rounded head and body, but with no obvious neck between them. Legs will appear. The tail will shrink in size and be gradually drawn into the body. The tadpole will have developed into a minute frog.

There are many of the lower animals which go through a not less wonderful, if not more wonderful, metamorphosis. The butterfly or the silkworm moth, beginning life as a caterpillar and changing into a chrysalis, from which the perfect insect emerges, is a familiar instance. And hosts of the marine invertebrates have larval forms which have but little resemblance to their adult parents.

Such a series of changes as is undergone by the frog is called *metamorphosis*, which essentially consists in the temporary development of certain provisional embryonic organs (such as gills and a powerful swimming tail) and the appearance of adult organs (such as lungs and legs) to take their place. In metamorphosis these changes occur during the free life of the organism. But beneath the eggshell of birds and within the womb of mammals scarcely less wonderful changes are slowly but surely effected, though they are hidden from our view. There is no metamorphosis during the free life of the organism, but there is a prenatal *transformation*. The little embryo of a bird or mammal has no gills like the tadpole (though it has for a while gill-slits, pointing unmistakably to its fishy ancestry), but it has a temporary provisional breathing organ, called the allantois, pending the full development and functional use of its lungs.

All the higher animals, in fact—the dog, the chick, the serpent, the frog, the fish, the lobster, the butterfly, the worm, the star-fish, the mollusc, it matters not which we select—take their origin from an apparently unorganized egg. They all, therefore, pass during their growth from a comparatively simple condition to a comparatively complex condition by a process of change which is called development. But there are certain lowly forms, consisting throughout life of little more than specks of jelly-like life-stuff, in which such development, if it occurs at all, is not conspicuous.

6. *They move about and sleep.* This is true of our familiar domestic pets. The dog and the cat, after periods of restless activity, curl themselves up and sleep. The canary that has all day been hopping about its cage, or perhaps been allowed the freedom of the dining-room, tucks its head under its wing and goes to sleep. The cattle in the

meadows, the sheep in the pastures, the horses in the stables, the birds in the groves, all show alternating periods of activity and repose. But is this true of all animals? Do all animals "move about and sleep"? The sedentary oyster does not move about from place to place; the barnacle and the coral polyp are fixed for the greater part of life; and whether these animals sleep or not it is very difficult to say. We must make our statement more comprehensive and more accurate.

If we throw it into the following form, it will be more satisfactory: Animals exhibit certain activities; and periods of activity alternate with periods of repose.

I shall have more to say hereafter concerning the activities of animals. Here I shall only say a few words concerning the alternating periods of repose. No organism can continue in ceaseless activity unbroken by any intervening periods of rest. Nor can the organs within an organism, however continuous their activity may appear, work on indefinitely and unrestfully. The heart is apparently restless in its activity. But in every five minutes of the continued action of the great force-pump (ventricle) of the heart, two only are occupied in the efforts of contraction and work, while three are devoted to relaxation and repose. What we call sleep may be regarded as the repose of the higher brain-centres after the activity of the day's work—a repose in which the voluntary muscles share.

The necessity for rest and repose will be readily understood. We have seen that the organism is a centre of waste and repair, of nicely balanced destructive and reconstructive processes. Now, activity is accompanied by waste and destruction. But it is clear that these processes, by which the substance of the body and its organs is used up, cannot go on for an indefinite period. There must intervene periods of reconstruction and recuperation. Hence the necessity of rest and repose alternating with the periods of more or less prolonged activity.

7. *They feel—"at least some of them do."* The qualification was a wise one, for in truth, as we shall hereafter see, we know very little about the feelings of the lower organisms. The one animal of whose feelings I know anything definite and at first hand, is myself. Of course, I believe in the feelings of others; but when we come to very lowly organisms, we really do not know whether they have feelings or not, or, if they do, to what extent they feel.

Shall we leave this altogether out of account? Or can we throw it into some form which is more general and less hypothetical? This, at any rate, we know—that all animals, even the lowest, are sensitive to touches, sights, or sounds. It is a matter of common observation that their activities are generally set agoing under the influence of such suggestions from without. Perhaps it will be objected that there is no difference between feeling and being sensitive. But I am using the word "sensitive" in a general sense—in that sense in which the photographer uses it when he speaks of a sensitive plate, or the chemist when he speaks of a sensitive test. When I say that animals are sensitive, I mean that they answer to touches, or sounds, or other impressions (what are called stimuli) coming from without. They may feel or not; many of them undoubtedly do. But that is another aspect of the sensitiveness. Using the term, then, with this meaning, we may say, without qualification, that all animals are more or less sensitive to external influences.

8. *They are made of "flesh and blood."* Here we have allusion to the materials of which the animal body is composed. It is obviously a loose and unsatisfactory statement as it stands. An American is said to have described the difference between vertebrates and insects by saying that the former are composed of flesh and bone, and the latter of skin and squash. But even if we amend the statement that animals are made of "flesh and blood" by the addition of the words, "or of skin and squash," we shall hardly have a sufficiently satisfactory statement of the composition of the animal body.

The essential constituent of animal (as indeed also of vegetable) tissues is protoplasm. This is a nearly colourless, jelly-like substance, composed of carbon, hydrogen, nitrogen, and oxygen, with some sulphur and phosphorus, and often, if not always, some iron; and it is permeated by water. Protoplasm, together with certain substances, such as bony and horny matter, which it has the power of producing, constitutes the entire structure of simple organisms, and is built up into the organs of the bodies of higher animals. Moreover, in these organs it is not arranged as a continuous mass of substance, but is distributed in minute separate fragments, or corpuscles, only visible under the microscope, called cells. These cells are of very various shapes—spherical, discoidal, polyhedral, columnar, cubical, flattened, spindle-shaped, elongated, and stellate.

A great deal of attention has been devoted of late years to the minute structure of cells, and the great improvements in microscopical powers and appliances have enabled investigators to ascertain a number of exceedingly interesting and important facts. The external surface of a cell is sometimes, but not always in the case of animals, bounded by a film or membrane. Within this membrane the substance of the cell is made up of a network of very delicate fibres (the *plasmogen*), enclosing a more fluid material (the *plasm*); and this network seems to be the essential living substance. In the midst of the cell is a small round or oval body, called the nucleus, which is surrounded by a very delicate membrane. In this nucleus there is also a network of delicate plasmogen fibres, enclosing a more fluid plasm material. At certain times the network takes the form of a coiled filament or set of filaments, and these arrange themselves in the form of rosettes and stars. In the meshwork of the net or in the coils of the filament there may be one or more small bodies (nucleoli), which probably have some special significance in the life of the cell. These cells multiply or give birth to new cells by dividing into two, and this process is often accompanied by special changes in the nucleus (which also divides) and by the arrangement of its network or filaments into the rosettes and stars before alluded to.

Instead, therefore, of the somewhat vague statement that animals are made of flesh and blood, we may now say that the living substance of which animals are composed is a complex material called protoplasm; that organisms are formed either of single cells or of a number of related cells, together with certain life-products of these cells; and that each cell, small as it is, has a definite and wonderful minute structure revealed by the microscope.

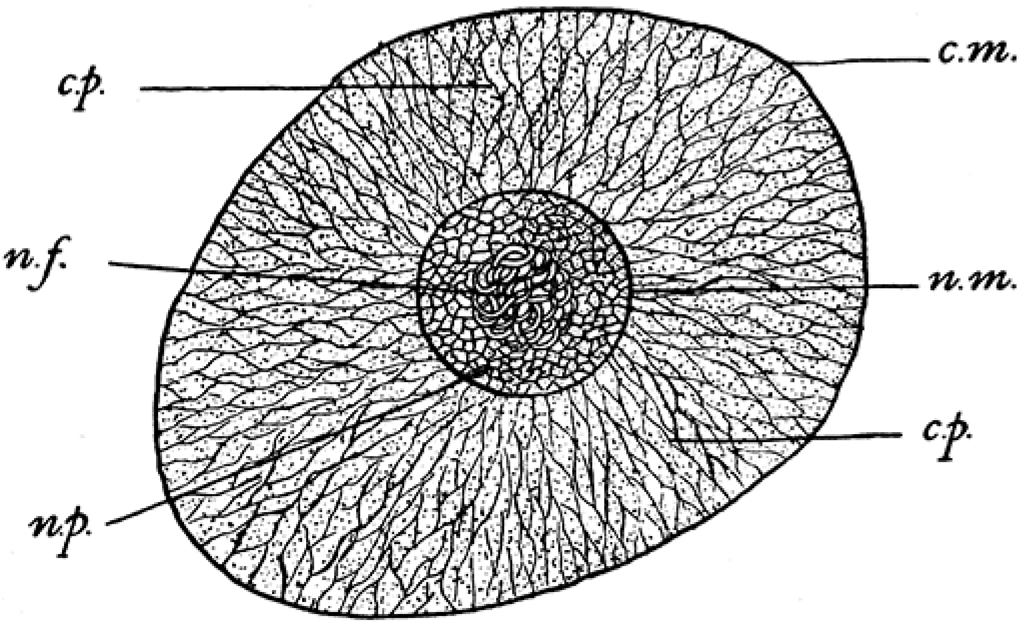

Fig. 3.—A cell, greatly magnified.

c.m., cell-membrane; *c.p.*, cell-protoplasm; *n.m.*, nuclear membrane; *n.p.*, nuclear protoplasm; *n.f.*, coiled nuclear filament.

9. *Animals grow old and die.* This is a familiar observation. Apart from the fact that they are often killed by accident, by the teeth or claws of an enemy, or by disease, animals, like human beings, in course of time become less active and less vigorous; the vital forces gradually fail, and eventually the flame of life, which has for some time been burning dimmer and dimmer, flickers out and dies. But is this true of all animals? Can we say that death—as distinct from being killed—is the natural heritage of every creature that lives?

One of the simplest living creatures is the amœba. It consists of a speck of nucleated protoplasm, no larger than a small pin's head. Simple as it is, all the essential life-processes are duly performed. It is a centre of waste and repair; it is sensitive and responsive to a stimulus; respiration and nutrition are effected in a simple and primitive fashion. It is, moreover, reproductive. First the nucleus and then the protoplasm of the cell divide, and in place of one amœba there are two. And these two are, so far as we can tell, exactly alike. There is no saying which is mother and which is daughter; and, so far as we can see at present, there is no reason why either should die. It is conceivable that amœbæ never die, though they may be killed in immense numbers. Hence it has been plausibly maintained that the primitive living cell is by nature deathless; that death is not the heritage of all living things; that death is indeed an acquisition, painful indeed to the individual, but, since it leaves the stage free for the younger and more vigorous individuals, conducive to the general good.

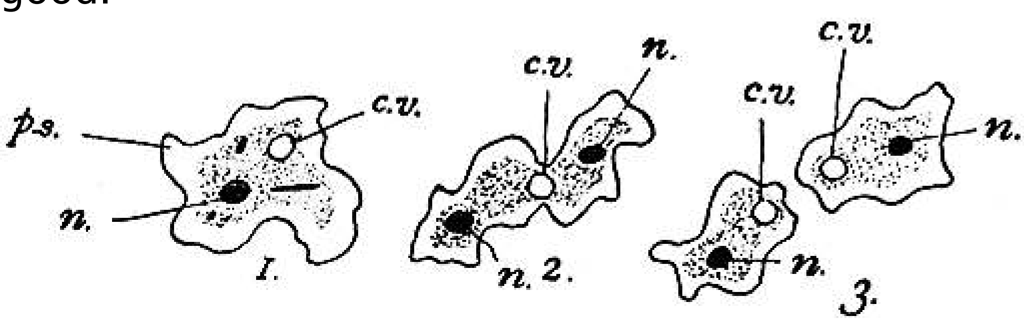

Fig. 4.—Amœba.

1. An amœba, showing the inner and outer substance (endosarc and ectosarc); a pseudopodium, *p.s.*; the nucleus, *n.*; and the contractile vesicle, *c.v.* 2. An amœba dividing into two. 3. The division just effected.

In face of this opinion, therefore, we cannot say that all animals grow old and die; but we may still say that all animals, with the possible exception of some of the lowest and simplest, exhibit, after a longer or a shorter time, a waning of the vital energies which sooner or later ends in death.

10. *Animals reproduce their kind.* We have just seen the nature of reproduction in the simple unicellular amœba. The reproduction of the constituent cells in the complex multicellular organism, during its natural growth or to make good the inevitable loss consequent on the wear and tear of life, is of the same character.

When we come to the higher organisms, reproduction is effected by the separation of special cells called egg-cells, or ova, from a special organ called the ovary; and these, in a great number of cases, will not develop into a new organism unless they be fertilized by the union with them in each case of another cell—the sperm-cell—produced by a different individual. The separate parents are called male and female, and reproduction of this kind is said to be sexual.

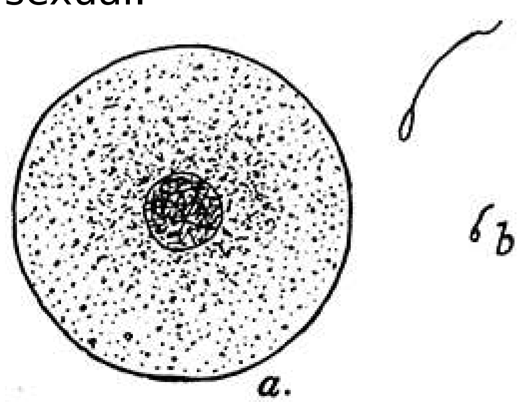

Fig. 5.—Egg-cell and sperm-cell.

a, ovum or egg; *b*, spermatozoon or sperm.

The wonderful thing about this process is the power of the fertilized ovum, produced by the union of two minute cells from different parents, to develop into the likeness of these parents. This likeness, however, though it extends to minute particulars, is not absolute. The offspring is not exactly like either parent, nor does it present a precise mean between the characters of the two parents. There is always some amount of individual variability, the effects of which, as we shall hereafter see, are of wide importance. We are wont to say that these phenomena, the transmission of parental characteristics, together with a margin of difference, are due to heredity with variation. But this merely names the facts. How the special reproductive cells have acquired the secret of developing along special lines, and reproducing, with a margin of variability, the likeness of the organisms which produced them, is a matter concerning which we can at present only make more or less plausible guesses.

Scarcely less wonderful is the power which separated bits of certain organisms, such as the green freshwater hydra of our ponds, possess of growing up into the complete organism. Cut a hydra into half a dozen fragments, and each fragment will become a perfect hydra. Reproduction of this kind is said to be asexual.

We shall have, in later chapters, to discuss more fully some of the phenomena of reproduction and heredity. For the present, it is sufficient to say that animals reproduce their kind by the detachment of a portion of the substance of their own bodies, which portion, in the case of the higher animals, undergoes a series of successive developmental changes constituting its life-history, the special nature of which is determined by inheritance, and the result of which is a new organism in all essential respects similar to the parent or parents.

11. *Animals are living organisms, and "not vegetables."* The first part of this final statement merely sums up the characteristics of living animals which have gone before. But the latter part introduces us to the fact that there are other living organisms than those we call animals, namely, those which belong to the vegetable kingdom.

It might, at first sight, be thought a very easy matter to distinguish between animals and plants. There is no chance, for example, of mistaking to which kingdom an oak tree or a lion, a cabbage or a butterfly, belongs. But when we come down to the simpler organisms, those whose bodies are constituted by a single cell, the matter is by no means so easy. There are, indeed, lowly creatures which are hovering on the boundary-line between the two kingdoms. We need not discuss the nature of these boundary forms. It is sufficient to state that unicellular plants are spoken of as *protophyta*, and unicellular animals as *protozoa*, the whole group of unicellular organisms being classed together as *protista*. The animals whose bodies are formed of many cells in which there is a differentiation of structure and a specialization of function, are called *metazoa*, and the multicellular plants *metaphyta*. The relations of these groups may be thus expressed—

Animals.		Plants.	
Metazoa.	Protozoa.	Protophyta.	Metaphyta.

Protista.

There are three matters with regard to the life-process of animals and plants concerning which a few words must be said. These are (1) their relation to food-stuffs; (2) their relation to the atmosphere; (3) their relation to energy, or the power of doing work.

With regard to the first matter, that of food-relation, the essential fact seems to be the dependence of animals on plants. Plants can manufacture protoplasm out of its constituents if presented to them in suitable inorganic form scattered through earth and air and water. Hence the peculiar features of their form, the branching and spreading nature of those parts which are exposed to the air, and the far-reaching ramifications of those parts which are implanted in the earth. Hence, too, the flattened leaves, with their large available surface. Animals are unable to manufacture protoplasm in this way. They are, sooner or later, dependent for food on plant-products. It is true that the carnivora eat animal food, but the animals they eat are directly or indirectly consumers of vegetable products. Plants are nature's primary producers of organic material. Animals utilize these products and carry them to higher developments.

In relation to the atmosphere, animals require a very much larger quantity of oxygen than do plants. This, during the respiratory process, combines with carbon so as to form carbonic acid gas; and the atmosphere would be gradually drained of its oxygen and flooded with carbonic acid gas were it not that plants, through their green colouring matter (chlorophyll), under the influence of light, have the power of decomposing the carbonic acid gas, seizing on the carbon and building it into their tissues, and setting free the oxygen. Thus are animals and green plants complementary elements in the scheme of nature.[A] The animal eats the carbon elaborated by the plant into organic products (starch and others), and breathes the oxygen which the plant sets free after it has abstracted the carbon. In the animal's body the carbon and oxygen recombine; its varied activities are thus kept going; and the resultant carbonic acid gas is breathed forth, to be again separated by green, growing plants into carbonaceous food-stuff and vitalizing oxygen. It must be remembered, however, that vegetable protoplasm, like animal protoplasm, respires by the absorption of oxygen and the formation of carbonic acid gas. But in green plants this process is outbalanced by the characteristic action of the chlorophyll, by which carbonic acid gas is decomposed.

Lastly, we have to consider the relations of animals and plants to energy. Energy is defined as the power of doing work, and it is classified by physicists under two modes—potential energy, or energy of position; and kinetic energy, or energy of motion. The muscles of my arm contain a store of potential energy. Suppose I pull up the weight of an old-fashioned eight-day clock. Some of the potential energy of my arm is converted into the potential energy of the weight; that is, the raised weight is now in a position of advantage, and capable of doing work. It has energy of position, or potential energy. If the chain breaks, down falls the weight, and exhibits the energy of motion. But, under ordinary