# LIFE

## CHAPTER I

## INTRODUCTION

### DEFINITIONS OF LIFE—PROTOPLASM —ATTRIBUTES OF LIVING MATTER

"Sairey," says Mrs Harris, "sech is life. Vich likeways is the hend of all things."

Mrs Gamp. *Martin Chuzzlewit.* CHARLES DICKENS.

### DEFINITIONS OF LIFE

At the Dundee meeting of the British Association for the Advancement of Science held in 1912, the President introduced the subject of Life, and the topic proved undoubtedly interesting and even stimulating. It led to much discussion, but, as far as I am aware, no one tried to define life or even threw much new light on the question the savants so eagerly discussed:

Myself when young did eagerly frequent
Doctor and Saint and heard great argument
  About it and about; but evermore
Came out by the same door as in I went.

This seems to be the fate of anyone who tries to define life. *The Oxford Dictionary* tells us that life is "the condition or attribute of living or being alive; animate existence. Opposed to *death*." This definition at once begs the question and argues in a circle. Dr Johnson takes a more eighteenth century attitude and says life is "union and co-operation of soul with body; vitality; animation, opposed to an *inanimate state*." One would like to have heard Dr Johnson's opinion on protoplasm! Even Herbert Spencer's formula that life is "the continuous adjustment of internal relations to external relations..." omits the fundamental consideration that we know life only as a quality of and in association with living matter. When I was at school they used to tell me that a verb indicated "being, doing or suffering" and this certainly describes "life," though it does not define it. "Och, life's aye a laugh and a greet," as Sir Harry Lauder tells us. And then there's the well-known character who defined life as "one d—d thing after another"; but he was referring to a span of life—"Brief life is here our portion." It was probably the same pessimist who said, "The moment you're born, you're done for." For

Life lives on death; Death lives on life;
And so the circle runs,
Throughout a million teeming years,
And half a million suns.

Perhaps the best way to describe life is to enumerate those qualities which living organisms have and non-living objects have not, and then to say that life is the expression of these qualities. In the "Introductio" to his *Philosophia botanica* (1751) Linnaeus, who had named more plants and animals than anyone since Adam, states: *Lapides crescunt. Vegetabilia crescunt & vivunt. Animalia crescunt, vivunt, & sentiunt*, and roughly speaking this is true.

### Protoplasm

Living matter or, as Huxley phrased it, the "physical basis of life," is a substance called by Hugo von Mohl *protoplasm*. Since this protoplasm is always being added to from the outside world in the form of food and oxygen, and *per contra* is always giving up something to the outside world in the form of carbon dioxide breathed out and of other excreta, some might regard it more in the light of a space, in which various elements enter, combine, disintegrate and take their exit, than as a substance. Still, for the convenience of this book we will regard it as a substance never constant in composition for a single second.

To see this protoplasm in any mass and to form some idea of what the substance looks like it is better to study some of the larger of those animals which have but a single cell, or the contents of some of the larger cells among the plants, for here we can look at it, under the microscope, undifferentiated and, so to say, in bulk. If we do so look, we see a whitish substance, sometimes clear as crystal, but more often semi-opaque, like ground-glass. It contains many darker specks or granules, and some of these are particles of food. If the protoplasm be shut up in a vegetable-cell it flows hither and thither, usually up one side and down the other, or, like a Roger de Coverley dance, "up the side and down the middle." If the protoplasm be free, *i.e.* not confined by any surrounding cell-wall, it will be constantly changing its outline, on one side thrusting out a lobe or protuberance, on the other perhaps withdrawing one, and in this way the whole piece of protoplasm may move slowly forward. This whitish, soft substance, semi-jelly, semi-fluid, is living protoplasm, but so are our muscle cells and the cells of our brain and our blood corpuscles. All these, however, are more specialized and not so easily studied; still, all obey the same laws and do the same ultimate things.

### Attributes of Living Matter

What is it that this protoplasm does that non-living matter, such as rocks and stones, never does? To begin with, it is *motile*. We have seen that it can alter from time to time its outline or shape, and by doing this in a certain way it can move forward or progress, or move backward and regress. Therefore it is *motile*, and the slow protuberance of a lobe on one side of the body, and the equally slow withdrawal of another on the other side, is the first beginning of that muscular contraction which may ultimately produce a competitor for the Olympic Games. As far as we can judge, even this simple movement is not always the result of an external stimulus, but arises from something in the protoplasm itself, and certainly such is the case in the more complex instances of higher life. This initiation of action from within is called *automatism*, and protoplasm, unlike non-living matter, is *automatic*. But it also readily reacts to external impressions or stimuli. An electric current passed through the water in which our living matter is suspended will cause it to contract into a sphere, and thus to present for its bulk the smallest possible surface to the stimulus of the current; or, again, a piece of food will attract it, and towards that piece of food it will slowly move—in short it responds to external stimuli, and is, as the physiologists call it, *irritable*.

These activities and qualities imply a certain expenditure of energy; how is that energy supplied? What is the oil that drives this engine? It is the food already hinted at. Living protoplasm must have food. It takes to itself certain food substances of a high complexity and oxidizes and reduces these to simpler substances, and during this process, just as when gunpowder explodes, energy and heat are set free. It is also capable of building up the dead food into its own flesh (or into protoplasm), making the dead live, and this quality is called *assimilation*. Further, all protoplasm breathes; that is to say, it takes in oxygen and it gives out carbon dioxide. It is in effect *respiratory*. Should the supply of oxygen in this world of ours be suddenly withdrawn, all life would cease, and in the course of a few weeks or months the whole fabric of our earth would have become mineralized. Life would cease.

Living animals and plants *secrete*, that is to say, certain cells and organs bring forth products which play a large part in the life of the animal or plant in question. Examples of such glands or secretory cells in plants are found in the nectaries of flowers, which secrete a sugary fluid attractive to insects, who bring with them pollen from other plants to fertilize the flower. The glands of insectivorous plants produce a fluid which digests the proteins of the insects they catch, and other cells secrete certain solvents which render the starch in seeds soluble.

In the higher animals the products of the secretory glands play a large part in digestion. The salivary glands secrete saliva into the mouth, which moistens the food and turns starch into sugar. The walls of the stomach secrete gastric juice, which together with the products of the liver and the pancreas help to render undigested food soluble so that it may be taken up into the blood-stream. Then there are certain small glands which have no ducts and do not open anywhere. But their secretion passes into the blood and plays a large part in various functions of the body, such as growth, and they are also the cause of many obscure diseases. A secretion is a product which serves a useful purpose in the economy of the organism.

But with *excretion* we have to deal with the formation of bodies which are useless or injurious to plant or animal. Unless these are discharged from the body, the whole organism gets choked, just as ashes may put out, in time, the driving fire of a steam engine. Plants as a rule store away their excreta in parts of the body where it is harmless, although those plants that cast their bark and shed their leaves get rid of a good deal of excreta annually. Animals excrete sweat, urea, and certain products from the alimentary canal, but the great bulk of the last-named have never formed part of the organism which rejects them. They have passed through as undigestible portions of the food. In certain animals such as the ASCIDIAN, or sea-squirt, the urea is stored away where it is harmless to the body, but in most animals the urea is taken up from the blood by the kidneys and passed to the exterior. Carbon dioxide ($CO_2$) is another excretion which passes away from the gills or lungs, and out from the skin like the sweat. A certain amount of excreta is got rid of by ARTHROPODA (CRUSTACEA, INSECTA, etc.) when they cast their skin, and the same is true to a certain extent of some worms. Matter which is not living does not secrete or excrete.

Living matter grows and reproduces. Animals and plants give rise to successors and they, in their turn, reproduce. The most primitive method of reproduction is that the animal or plant splits or cleaves in two. Each of the two will then increase in size until it reaches a certain bulk—this is *growth*—and then again it will divide. No dead or non-living object behaves in this way.

Finally, living matter is *rhythmic*. It is always doing something or other at stated intervals. These intervals often seem to have no relation to outside influences, like breathing or the recurrent beats of a heart; but in many cases the intervals between the acts correspond with cosmic changes. Night and day control sleep; the tides have a marked influence on the habits of many of the shore-living Invertebrates, and so ingrained are these periodic habits that they are retained even when the animal showing them is removed inland and kept in a perfectly still aquarium. Summer and winter, seed-time and harvest play perhaps the greatest rôle in this rhythm. One has only to think of the breeding habits of most animals or of the annual appearance and disappearance of the foliage of deciduous trees to recognise this.

Yes; life, if undefinable, is rhythmic.

# CHAPTER II

## PROTOPLASM AND CELLS

### THE CONSTITUTION OF PROTOPLASM —THE AMOEBA—TISSUES

The remainder of the cell is more or less densely filled with an opaque, viscid fluid, of a white colour, having granules intermingled in it, which fluid I call protoplasm.

VON MOHL (1846).

### THE CONSTITUTION OF PROTOPLASM

ALL living organisms are built up of protoplasm and its products. Both plants and animals consist of this same protoplasm, the "physical basis of life," as Huxley called it. All modern evidence tends to show that protoplasm is an equilibrium mixture of a fluid and of a more solid jelly. The relative proportions of the liquid and the jelly are from time to time changed. Many cells are solidified at certain times to a high degree; and the change from the more fluid state to the more jellied state is reversible. Cells which are at one time very fluid may at other times be very solid, and *vice versa*. For instance, fertilization causes the protoplasm of the egg to become less solid and more liquid.

It is impossible to analyse by chemical or physical means *living* protoplasm, for any attempt at such analysis at once kills it.

By the analysis of dead protoplasm we find it contains *proteins*, and proteins are compound chemical substances which are never found apart from living matter. They contain carbon, hydrogen, nitrogen, oxygen and sulphur, and have the following percentage composition:

| | | | |
|---|---|---|---|
| Carbon | from 50 | to 55 | per cent. |
| Hydrogen | ,, 6·5 | ,, 7·3 | ,, |
| Nitrogen | ,, 15 | ,, 17·6 | ,, |
| Oxygen | ,, 19 | ,, 24 | ,, |
| Sulphur | ,, 0·3 | ,, 2·4 | ,, |

The proteins are tremendously important, and play a most prominent part in the building up of protoplasm. Proteins are never absent from living matter, and except for the fact that some of the simpler kinds can be synthetically produced in the laboratory they are never derived from any other matter than that which is living. The building up of proteins is the most important factor in life.

Proteins are highly complex, and are very varied in their nature; but all react in the same way to certain chemicals. Proteins in food differ from those in the living tissues. During digestion the former are broken up and then reconstructed, only to be finally broken down again into carbon dioxide, water, sulphuric acid, urea, and other products which are excreted from the body. Animals convert the protein of their vegetable food into the protein of their own body. But the building up of proteins in plants involves the combination of the soluble nitrogenous food taken up by the root with the complex carbon compounds formed by the green leaves in sunlight, and we thus have two circles or cycles, the cycle of carbon, which will be described in Chapter V under the title of Chlorophyll, and the cycle of nitrogen, which will be described in Chapter VI under the heading of The Nitrogen Cycle.

The molecules of the proteins are very large, certainly the largest and most complex that are known; and consisting as they do of thousands or even tens of thousands of atoms they afford a large scope for the slight variations which we find in the different classes of proteins. The variety in the arrangement of these numerous atoms in the complicated molecule may also explain the differences which exist between the different species of plants and of animals. The protoplasm of one species of animal or plant differs from the protoplasm of all others. "All flesh is not the same flesh; but there is one kind of flesh of men, another flesh of beasts, another of fishes, and another of birds."

It may be that differences between plant and plant and animal and animal depend on minute differences in the structure of their proteins, or possibly between the ways in which the protein molecule is built up. There are also minute differences, which are nevertheless perceptible, between the starches of one plant and the starches of another. There are similar differences between the haemoglobins of red-blooded animals and these differences are to some extent characteristic of the species concerned.

Other elements than those found in proteins also occur in the bodies of plants and animals. Phosphorus, chlorine, potassium, sodium, magnesium, calcium and iron are all found, having been taken in with the food or water.

Further, living protoplasm has not a constant composition. It is changing every moment, taking new matter into itself and discharging other matter. It is, in fact, like a stream or flame. Six centuries before Christ, Buddha, in his last re-incarnation, maintained that "Life is a flame," and, like a flame, protoplasm is never the same but always changing its composition. It is a living example of the saying of Alphonse Karr about the French Government under Louis Philippe: "Plus ça change plus c'est la même chose."

## The Amoeba

To form an idea of what protoplasm *looks* like one might examine with a microscope the uncooked white, *albumen*, of an egg, or a drop of fairly thin gum. Both are glairy, semi-transparent, full of particles: but neither of them is protoplasm. Perhaps the largest masses of more or less undifferentiated protoplasm easily visible to the naked eye are those curious slime-fungi, Myxomycetes, which are found several inches in diameter slithering about on dead and rotten wood in damp forests. But one cannot always find slime-fungi, and a better plan is to examine under the microscope the unicellular organism known as *Amoeba*. *Amoebae* are common enough in both fresh and salt water and in the soil. They are irregular in shape and their outline is

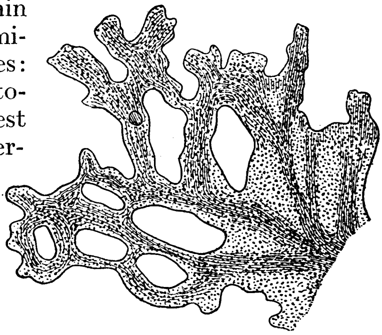

Fig. 1. A Myxomycete, *Chondrioderma difforme*. From Strasburger.

constantly changing. Their average diameter is about 100–250 $\mu$[1].

Lobes, *pseudopodia*, are constantly being thrown out from any part of the surface of the body and then withdrawn. The very thin outer surface coating of the minute creature is clear and free of granules, but the great bulk of the animal is slightly opaque and is full of granules of various sizes, some of which are food particles. The *Amoeba* will slowly crawl towards any small organism and around this it will thrust a couple of lobes or arms, forming a bay. The tips of the arms will unite, and then we have a small lake, in the centre of which the engulfed food-particle is now floating. Digestive fluids are passed from the protoplasm into this food-vacuole, and when the food is digested the refuse passes out of the *Amoeba* by a reverse process. The fluid surrounding the engulfed particle is at first acid and later it becomes alkaline, just as the contents of our stomach is acid and that of our intestine alkaline. This fluid dissolves the food so that it can be incorporated in the surrounding protoplasm. The pseudopodia of an *Amoeba* at times exert a surprisingly great force. They are even capable of nipping a *Paramoecium* in two, engulfing one half and leaving the other half outside, and a *Paramoecium* is a pretty tough organism.

Embedded somewhere near the centre of the little animal is a more solid ball which takes up stains more freely than the rest of the protoplasm; this is the *nucleus*. During life the nucleus is almost invisible, and it is larger in active, busy cells than in quiescent, inactive cells. Its functions include both the control of the building up of the food into protoplasm, *assimilation*, and the control of reproduction. If an *Amoeba* be cut in two, one half with, the other without, the nucleus, the nucleated fragment behaves as a normal *Amoeba*. The non-nucleated fragment also behaves quite normally *except* that it cannot divide and cannot digest its food, though food particles may be ingested. The life of such a non-nucleated

[1] A $\mu$ is the thousandth part of a millimetre. The smallest thing you can see with an ordinary microscope must have a diameter of 0·14$\mu$ and with an ultra-microscope about 0·005$\mu$. The smallest bacterium which has yet been seen has a diameter of about 0·5$\mu$.