CHAPTER VI

THE ATMOSPHERE AND THE ADVENT OF LIFE UPON THE EARTH

We saw in the preceding chapter that the gaseous envelope surrounding the earth is intimately related to the matter from which the earth has been formed. At the present time, the atmosphere is a mixture, the average composition of which being: nitrogen, 78·03% by volume; oxygen, 20·99; the "inert" or "noble" gases, 0·95; and carbon dioxide, 0·03. In spite of air being a mixture, the amounts of the various constituents present in the atmosphere in different parts of the world vary but slightly from the average figures. Another surprising fact is that the atmosphere grows less dense as we ascend, so much so that if we could travel upwards for but a few miles compared with the diameter of the earth we should soon find ourselves in a vacuum. At a height of ten miles above sea-level, the atmosphere is less than a quarter times as dense as that at the earth's surface, whilst at one hundred miles there exists so very little air that it exerts a pressure equal to about one-millionth of an atmosphere. Such a pressure might be compared with that prevailing inside an X-ray bulb. Hence when such a rarefied atmosphere, indeed a vacuum, is bombarded by electrons emitted from the sun, electric disturbances are set up within this vacuum which cause it to glow in various colours and thus give rise to the *aurora borealis*.

There is very good reason to believe that the primordial atmosphere was made up of a very different mixture of gases, and one that would have instantaneously asphyxiated any living creature. The gas, oxygen, which is essential to life was certainly absent. Much of the nitrogen, now in the air, was then in the earth in combination with oxygen and metallic elements, like sodium and potassium in the form of nitrates and nitrites which were not easily decomposed by heat. Besides vast quantities of water vapour, the chief constituents were carbon dioxide, carbon monoxide, chlorine and some hydrogen chloride.

The substitution of oxygen in our atmosphere for the carbon dioxide existing in the original atmosphere can be traced to the action of the sun's light on the surface of the earth, and the changes introduced in consequence of the appearance and maintenance of life upon the earth.

Vegetation has indeed had a very profound effect on the composition of the mixture of gases contained in the atmosphere. Through it, some of the carbon dioxide existing in the early atmosphere has been replaced by oxygen which is so necessary to animal and human life. It is highly possible, however, that a large proportion of the water vapour and carbon dioxide in the primordial atmosphere underwent chemical interaction by means of the sun's energy before life of any kind appeared on the earth. At the same time, vegetation and bacterial action have been largely responsible for the admission into the air from the soil of much of the vast amount of nitrogen. It has been estimated that the atmosphere contains 4,000,000,000,000,000 tons of nitrogen, compared with about 1,200,000,000,000,000 tons of oxygen. Vegetation is constantly enriching the air with oxygen and depleting it of its carbon dioxide. As stated before, the average content of carbon dioxide now in the atmosphere is 3 volumes per 10,000 volumes of air. Variations in this amount are found in towns where it tends to a higher value, especially during fogs when it may rise to 8 volumes, in badly ventilated rooms where it may be as much as 30 volumes, and in the air over sea. Over the Atlantic Ocean it is abnormally low, viz. 2 volumes.

This approximately constant composition of the atmosphere is maintained, on the one hand, by green vegetation which breathes in the carbon dioxide and emits oxygen, and, on the other hand, by animals and human beings which inhale the oxygen and then once again contaminate the air with carbon dioxide. For countless centuries, green plants have been scavenging the atmosphere for their carbon dioxide and replenishing it with pure oxygen. At the dawn of each new day, through the energising influence of the sun's light, fresh supplies of oxygen leave the green plants and trees. Such a process can only have taken place since the appearance of living vegetable matter upon the earth. During recent years, chemists have been able to trace the reactions which go on within the cells of the plant and cause oxygen to be released. Willstätter observed that the amount of oxygen transpired by a green leaf was exactly equal to the amount of combined oxygen contained in the carbon dioxide which had been assimilated. This was considered to point to the reaction :

$$\underset{\text{1 volume of carbon dioxide}}{CO_2} + H_2O \longrightarrow \underset{\text{formaldehyde}}{HCHO} + \underset{\text{1 volume of oxygen}}{O_2}$$

Such a reaction, whilst explaining why the volumes of assimilated carbon dioxide and transpired oxygen are equal, indicates that formaldehyde, often called formalin, should be formed in the living plant. No formaldehyde has, however, ever been detected in the living plant, though of course the plant juices contain sugar. Under the influence of certain light radiations in supplying the requisite energy, six molecules of formaldehyde combine with one another to form sugar, thus :

$$\underset{\text{formaldehyde}}{6HCHO} \longrightarrow \underset{\text{sugar}}{C_6H_{12}O_6}$$

But Professor Baly, in the University of Liverpool, has shown that sugar can be formed from carbon dioxide and water provided light energy in a suitable condition is supplied. Here is an example of the synthesis of an organic product without the aid of life, which formerly might have been considered necessary to a process taking place within the living plant. It is very probable, therefore, that before life of any kind appeared on the earth, photochemical reactions of the type, just alluded to, took place and the products became enmeshed in the soil. These carbohydrates and sugars became the humus of the original soil, which was drawn upon by the vegetation that subsequently appeared.

Two opposing types of bacterial actions take place in the soil which are responsible for the nitrogen content of the atmosphere. Thus there are the denitrifying bacteria which are present in the soil everywhere, and in the sea. These cause nitrates and nitrites of such metals as calcium and sodium to decompose and eventually to set free nitrogen. Simultaneously, sodium and calcium hydroxides tend to be liberated, but the ever-present carbon dioxide in the soil then combines to form sodium carbonate and calcium carbonate. The latter being limestone, is insoluble in water, and the former is soluble, which may be absorbed by vegetation and thence by animals, only to be rendered insoluble by interaction with calcium salts in the animal body where the calcium carbonate may take part in bone or shell formation. Eventually, this calcium carbonate passes back to the soil to form more limestone These reactions are always preceding in the soil and in the lakes, rivers and seas. If the effects of this denitrifying process were not counteracted by those of certain nitrogen-fixing processes, then a time would come when all the combined nitrogen present in the soil, so necessary as nutriment for vegetation, would have passed back to the atmosphere as free nitrogen. Then the soil would become sterile, vegetation would be at an end, and life generally would cease. Fortunately the evil effects of these denitrifying bacteria are approximately balanced by the activities of nitrogen-fixing bacteria, which locate their labours at the roots of certain plants, e.g., clover, alfalfa. These bacteria extract nitrogen from the air and cause it to combine with water to form either ammonia or nitrates in order that some might be absorbed by the plants.

Life is generally believed to have originated in or near the water of the primeval ocean in the form of protoplasm. Protoplasm is a semi-transparent colloidal liquid found in the animal cell. It may be either homogeneous or show evidence of a network structure. Although its composition may vary considerably, it always contains protein matter and a large amount of water; as much as 75%. In addition, the protoplasmic system of the living cell contains much essential inorganic or mineral matter such as the chlorides, bicarbonates and phosphates of sodium, calcium and potassium. Other salts are probably present, though in very small quantities, for it is known that salts containing iron, magnesium and iodine play important rôles in the phenomena of life. These organic substances may be produced, in all probability, without the aid of the living process. Yet, within these colloidal aggregates there is contained the nucleus or germ of life. That such a nucleus is present can be shown experimentally in the case of the larger single cell organisms by cutting the cell. The part that contains the nucleus lives whilst the other part dies. The chemical constitution of the nucleus differs from that of the protoplasm of a cell in that it is composed of a body formed from nucleic acid, a compound having a relatively high phosphorus content, and protein. The fact that the nucleus should contain a large amount of phosphorus is an important one in view of the use to which this element is put in the process of body-building by cell-division and sub-division.

We have seen so far, that many of these substances, which are essential to life, were in the first place either formed in the soil or deposited upon it. We shall now see that the action of the sun's light very probably caused the nitrogen-containing bodies, the proteins and the alkaloids, to be formed. It was stated that most of the nitrogen of the air was once in the earth as the nitrite or nitrate of sodium and other metallic bases. Very little evidence is available nowadays of such nitrates remaining in the earth for the simple reason that these salts dissolve in water and would be readily washed away, to be ultimately decomposed by bacterial action. It is true that there are extensive deposits of sodium nitrate in Chile (see page 186), but there the arid nature of the soil and the lack of rain provide just those conditions necessary to maintain the deposits intact. According to Professor Baly certain invisible ultra-violet light radiations, when allowed to fall on a solution of carbon dioxide and a nitrate or a nitrite, there is formed in the water an active form of formaldehyde which immediately reacts with any nitrite present to form an extremely reactive product, called by the chemist, *formhydroxamic acid*, oxygen being liberated at the same time. This acid is very closely related to the explosive acid, fulminic acid, which in combination as fulminate of mercury or fulminating mercury, was formerly used in the manufacture of detonators. It must be kept moist until used, for the slightest friction causes it to explode.

Formhydroxamic acid, once formed, combines with active formaldehyde to form a variety of compounds which are common constituents of plants, e.g., alkaloids and α-amino acids. The latter are closely associated with the proteins in that they can be prepared in the course of their decomposition, and are incidentally found in all living beings. So far, we have been able to offer some explanation for the formation of many of the chemical substances that are present in protoplasm in which life in its most primitive form is couched. What is more, we have not found it necessary to assume that the phenomenon of life was in any way linked up with the reactions which gave rise to them. But it has been necessary to believe that much of the energy to effect these reactions has been received from the light emitted by the sun. All the potentialities of life are therefore non-living. It is possible to imagine how the colloidal matter in which life first arose was formed into small aggregates encased in cell-like membranes, and how the comparatively large surfaces of the colloidal particles constituting these aggregates furnished ideal conditions for chemical reactions to take place, but one difficulty still remains. That difficulty is to explain how this non-living matter first became endowed with life. Although it is not possible to define "life," it is a fact that the continuance of life in the protoplasmic system is accompanied by the utilisation of energy derived from the interaction of oxygen with combustible organic substances, from certain organic substances alone, and from sunlight. The protoplasmic system is indeed an energy supplying machine, whose energy is required for the maintenance of life. Life and Energy are inseparable, but the actual secret of life still remains unknown. Though the problem of life remains unsolved, there is no doubt that the advances made in recent years have added considerably to our knowledge of this baffling problem.