AN INTRODUCTION TO SOCIAL BIOLOGY

LIFE IN SPACE AND TIME	MAN AND EVOLUTION
MAN AS AN ANIMAL	MAINTAINING THE HUMAN SPECIES:
(*a*) SEX (*b*) INHERITANCE	(*c*) REPRODUCTION
MAN AND HIS HEALTH	SOCIAL HYGIENE
HISTORY OF MEDICINE	FOOD AND DRINK
THE BALANCE OF NATURE	POPULATION
SOCIAL LIFE AMONG ANIMALS	SOME REASONS FOR MAN'S SUCCESS
THE NATURE OF LIFE	BIBLIOGRAPHY

by ALAN DALE B.Sc.

"It is to be placed on the same high level as those famous outlines by Wells and Huxley, Hogben and Sherwood Taylor."

AN INTRODUCTION TO SOCIAL BIOLOGY

TO MY PARENTS

WHO MADE EVERYTHING POSSIBLE

AN INTRODUCTION TO
SOCIAL BIOLOGY

ALAN DALE, B.Sc.

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INTRODUCTION

THERE is an increasing tendency in teaching modern science to try, as it were, to take it out of its laboratory context and set it against the background of human activity, where it properly belongs. Biology, the science of life, particularly lends itself to this treatment.

There is a growing belief that every pupil who leaves school should take with him some knowledge of certain biological facts and principles. And this for two reasons : (1) a knowledge of these facts is essential in order to live a satisfactory physical life, and (2) appreciation of certain broad biological principles enables the individual to use rightly that raw material from which he gradually constructs a personal philosophy of living.

In so far as these two issues may be separable, the first is dealt with mainly in Chapters IV to IX inclusive, while the second is more the concern of the remainder of the book.

This book is the outcome of a series of discussions held with the combined Sixth Forms (Arts, Science, and Modern) of a large boys' secondary school, and devised with this twofold object. As the discussions proceeded it became apparent that boys of this age had their interests both in the biological aspects of existence, and in man as an animal, already broadly conceived. Consequently the scope of the discussions tended to become ever wider ; and, though the primary object of the course was not lost sight of, much material not strictly biological was discussed. Aspects of politics, theology, morality, spiritualism, propaganda, philosophy, and kindred subjects, came under review. The author soon realised that a degree course in biology was a not altogether adequate preparation for the task he had undertaken, and a considerable amount of supplementary reading had to be done to enable some measure of authoritativeness to be brought to the discussions.

It is hoped that this book will help to satisfy a definite need for Sixth Form " General Courses " in schools, and cultural courses in adult education. Obviously a work of this nature must necessarily be experimental. Criticisms and suggestions from teachers and others as to how the book may be improved will therefore be most welcome.

A. D.

BAKEWELL, 1958.

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CONTENTS

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CHAPTER I

LIFE IN SPACE AND TIME

IT is a peculiarity of the human mind that familiar everyday things are taken for granted and are rarely the subject of speculation. Familiarity breeds indifference and mental blindness. For instance, when the water is run out from a bath a whirlpool forms over the plug-hole. Everyone has baths, yet few people will have pondered on the whirlpool and wondered what causes it, or thought whether the direction in which the water rotates can easily be changed, or what factors determine the direction of swirl. Similarly, gardeners who sow parsnip seed expect parsnip plants to come up, and when the parsnips do come up the gardeners do not bother to think why this should always be so, because they find nothing remarkable in the fact that parsnips always beget parsnips. If seeds gathered from a broad bean plant gave rise to a crop of onions, or if a doe rabbit gave birth to a litter of kittens, it would be considered wonderful, yet the fact that plants and animals always reproduce their own kind is equally wonderful. Again, the passage of time is a familiar experience for everyone ; so familiar, indeed, that its nature is rarely considered, except by the most penetrating thinkers.

That is how it is with the phenomenon of Life. Everyone is born alive into a living world, and soon recognises that there are two kinds of matter : the living and the non-living. The difference is simply explained by the assumption that the former possesses a property called Life which the latter lacks. Here, for most people, speculation stops. Life for them is a fundamental, and they are not concerned with an exact definition or a close examination of its attributes. They accept it as they find it. It can be stated at once that precise ideas on the nature of life have not yet been arrived at. Neither the experimental biologist nor the philosopher has obtained a satisfactory answer to the question : " What is Life ? " ; nor can either explain exactly wherein lies the difference between a sparrow chirping under the eaves and that same sparrow dead on the garden path. It may be that there is no answer beyond the simple statement that the one has life and the other has not ; in other words, Life may be a fundamental incapable of explanation in terms of other phenomena.

Here all that can profitably be said is that Life is an attribute possessed by certain things (living organisms) for a certain period (from the time of their origin until death), and that it appears to be intangible, massless, and invisible, and can only manifest itself by utilising matter. It would thus seem to be a kind of abstraction, like Beauty. The matter imbued with life, which is, of course, a different thing from Life itself, is still susceptible to the ordinary laws of physics and chemistry, but in addition seems to have certain attributes of its own. It is not impossible that Life may exist " neat " so to speak, without permeating matter at all. The idea of a centralised pool of Life, to which all Life returns after the death of the host-matter, is attractive in this connection.

All living bodies are derived from other living bodies by some form of reproduction, which is essentially the separating off from a parent organism of a bit of material with its contained Life. It is significant that, as far as we know, Life never enters into possession of previously non-living matter and makes it " come alive ", although living material may grow by incorporating into itself non-living food. Whether the Life in a grown man is the same Life that was in him when he was a child it is impossible to say ; and whether it is necessary for the " Life essence " in a child to " grow " to keep pace with the growth of body substance also cannot be determined, because there is no means of measuring " quantity " of Life. All that is known for certain is that the manifestations of Life certainly go on at different rates, both in the same organism and in different ones. A dry pea seed, for instance, is not growing at all, and only respiring very slowly ; but when it begins to germinate, both these functions increase in intensity, though this cannot be taken to imply that its Life Essence is changed in any way. Also, there are cases of suspended animation to be considered, where, under such adverse conditions as drought, a living organism may enter a state in which it manifests no vital activities at all. And yet it can hardly be said to be dead, because the restoration of appropriate conditions will make it renew its vital activities. Organisms in the state of suspended animation have been likened to watches wound up and in perfect mechanical condition, but awaiting that little shake which will set the flywheel in motion and start the whole mechanism working. The danger of such an analogy is that it tends to create an over-simplified idea of what must be a very complex problem, and of course it does not supply an explanation.

Since we cannot define Life itself, we must content ourselves with a description of the properties of living things, that is, of matter which is invested with Life. They are :—

(1) The power of deriving energy from food.
(2) The power of growth and repair.
(3) The possession of irritability (power of response to stimuli).
(4) The power of reproduction.
(5) The power of automatism (or sometimes called self-regulation).
(6) The power of movement.

(1) and (2) All living things possess the property of being able to obtain from their environment certain chemical substances which they can either utilise in the process of respiration as a source of energy, or incorporate into their own body-substance as new living material. The new material thus made is used for growth or for the repair of damaged tissues, and this power of growth and repair is a second property of all living things.

The growth of living things involves the deposition of newly-formed particles of body substance in between previously existing body substance, and in this way differs fundamentally from the accretionary growth which non-living materials, such as a crystal in a saturated solution, or a snowball rolling down a hill, may exhibit due to further layers of " mother " substance being added to the outside surface. Repair is merely local growth. A crab will grow a new claw if one becomes broken off during a fight, but a man cannot grow a new hand, though he can regenerate bone, nervous tissue, skin or hair. Generally speaking the higher an animal is in the evolutionary scale, the more limited is its power of repair.

$$\mathbf{0} + \mathbf{0} + 000 \longrightarrow 0\mathbf{0}0\mathbf{0}0 \quad \text{. . . . .} \quad \text{(a)}$$
$$\mathbf{0} + \mathbf{0} + 000 \longrightarrow \mathbf{0}000\mathbf{0} \quad \text{. . . . .} \quad \text{(b)}$$

FIG. 1. This shows (a) how living things actually incorporate new material into the structure of the body substance, while (b) non-living things can only increase in size by the addition of new layers of material on the outside. O represents pre-existing body material, and **O** new material.

(3) The power of responding to stimuli is a very familiar characteristic of living things. The stem of a runner bean plant responds to the stimulus afforded by contact with a solid support and produces fibrous materials in the stem once a hold is obtained. A kitten will respond quite markedly to the smell of fish in a shopping basket, or to small moving objects such as leaves.

The responses made by living things are usually appropriate ones such as will tend to promote the welfare of the individual or of the species to which it belongs, two concepts not always identical. An important feature of the responses made to stimuli by living things is that in general the magnitude of the response bears no obvious relation to the intensity of the stimulus. The kitten mentioned above will respond to a faint smell of fish as well as to a strong one if it is hungry. It may not respond at all to the smell of fish if it is replete.

Many non-living things respond to stimuli also, but here the response seems to have no connection with the " welfare " of the responding object, or to the class of objects to which it belongs, and the same response is always made to the same stimulus if other conditions are equal. This predictability of the response of non-living things is the basis upon which rest science and the modern way of life.

It must be admitted that there are, particularly among the lower organisms, many responses of living things which are similarly mechanical or " reflex," where the same stimulus is followed time after time by the same response. The prawn *Palæmonetes* will change colour to blue every time it is placed on a blue background, or the pupil of the human eye will contract every time a strong light is shone into it, and expand again when the light is removed. Similarly, the sensitive tips

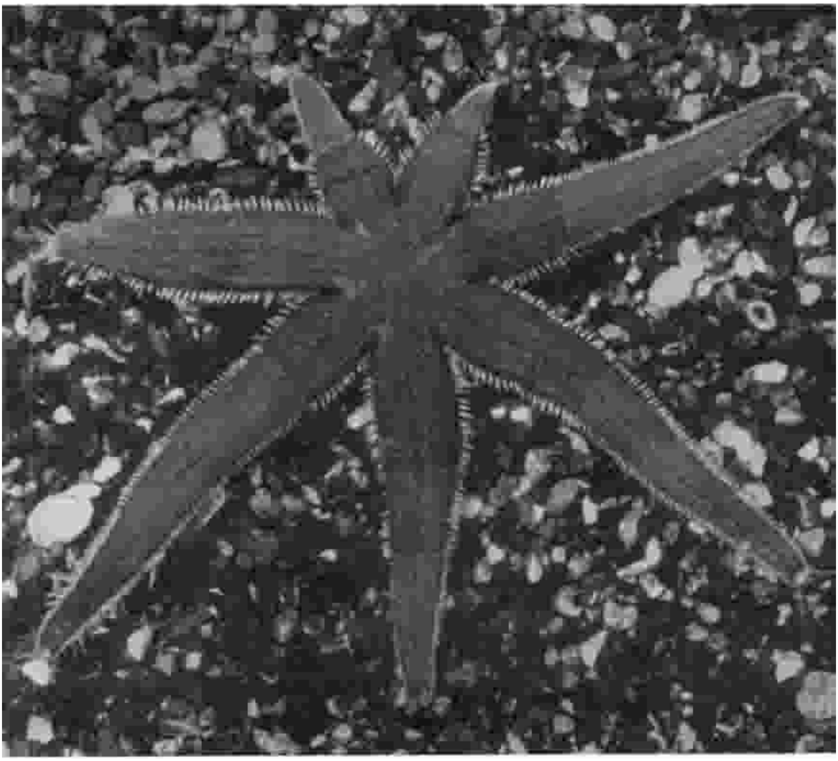

FIG. 2. Long-armed Starfish (*Luidia ciliaris*), showing regeneration of arms. (*Photo : D. P. Wilson.*)

of the tendrils of a pea plant will always respond to the lightest touch of a solid object by curling, provided that the stimulus is allowed to act for a certain minimum time. The difference between such mechanical responses of living organisms and the mechanical responses of non-living things is again that the former usually have an adaptive significance *when considered in relation to the needs of the organism concerned.*

(4) The power of reproduction is one possessed by nearly all living things (see Chapter IV). There are a few organisms which do not

have this power, notably the sterile worker castes found among ants, bees, and termites, but in these insects the real reproductive unit is the complete colony and not the individual member. Hybrids, too, are usually incapable of reproduction, though exceptions do occur, especially in plants. A famous case is that of the Rice Grass, *Spartina Townsendii*, which first appeared in Southampton Water in 1870, and is the hybrid between *S. stricta* and *S. alterniflora*. This grass reproduces itself freely and has become established at several places along the south coast.

(5) Automatism, or the power of self-regulation, is another attribute of living organisms. It means that the possessor can originate some form of behaviour (which may range from the birth of an idea in man to the shedding of the leaves of a tree), having no immediate relation to an outside stimulus. It is commonly believed that deciduous trees drop their leaves in direct response to the colder days of autumn. That this is not so is shown by the fact that when grown in warmer climates the trees still discard their leaves at regular intervals. This type of behaviour is the reflection of some internal determinant—a reflection of the Life that is in the organisms.

(6) Movement, though not necessarily locomotion, is another feature commonly possessed by living things. It varies from the rapid wing beats of many insects (often as rapid as a thousand times a second), to those slow twining movements of plants which are imperceptible to the unaided eye, but which can be very clearly shown by "stop-motion" cinematography, where single exposures of a growing plant are made on a cine-film at intervals of an hour or so. Such a film of a germinating pea plant shows it writhing and twisting in a most striking fashion.

Some plants exhibit very remarkable movements indeed. The sensitive plant (Mimosa) literally shrinks away at a touch, while Venus' Fly Trap, one of the insect-eating plants, also makes very rapid movements (Fig. 3).

Other plants, such as the lichens which form encrustations on stone walls and branches of trees, move incredibly slowly as they gradually extend their boundaries. However, the protoplasm inside the fungal and algal cells which compose these plants would presumably show slow streaming movements if it could be observed under the microscope. Of course, many non-living things exhibit movement—the earth itself, the atmosphere, and the flames from a fire—but the movements of living things are generally purposive, directed to some end which contributes to the organism's welfare, whereas the movements of non-living things are not.

It will be seen from the foregoing that living things have certain very definite characteristics, some of which, however, are also shared by some non-living things. To sum up, the real difference between the two classes seems to be that in living things processes go on which on the whole serve to preserve and perpetuate them, processes which are not directly evoked by the environment nor related in any simple manner to it, but which at the same time enable the organisms to fit very precisely into their environment.

It is now possible to discuss those conditions which life will require in order to be able to exist. Of first importance is a suitable temperature, because all living things are made up of complex chemical

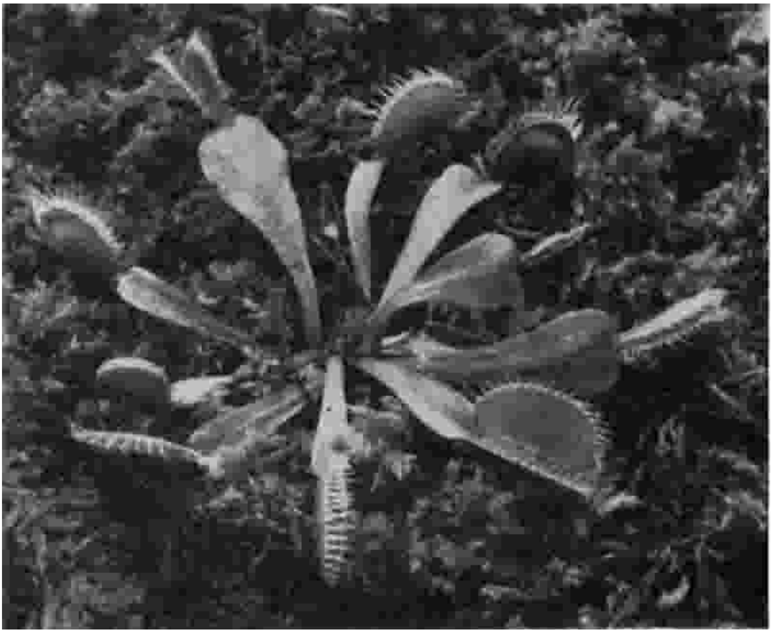

FIG. 3. Venus' Fly Trap. The midrib of the leaf acts as a kind of hinge, about which the two parts of the leaf blade can turn. When an insect alights on the open leaf it touches sensitive hairs which cause the two parts of the leaf to move together to trap the insect, which is subsequently digested. Both open and closed traps are shown here. (*By courtesy of Messrs. Flatters and Garnett.*)

units called molecules, and their life processes are a reflection of innumerable chemical reactions which go on between these molecules. At normal temperatures the molecules are relatively stable and their inter-reactions take place at a suitable rate. If the temperature is raised unduly, many of the molecules break down (*cf.* vitamins which are destroyed in the cooking of food), and also, what is probably more important, the rates of the various chemical reactions become altered disproportionately, and may even have different end-products when equilibrium is reached.

It is certainly true that most organisms cannot tolerate large variations in their body temperatures. In man, for instance, a degree or two variation from the normal is accompanied by a feeling of illness, and a variation of as little as 8° F. is usually terminated by death. It has been suggested, too, that this raising of the body's temperature when it is attacked by disease germs, helps to make the germs themselves feel ill, so to speak, and thus, by weakening *their* resistance, make them more susceptible to any measures the body may be able to make in an effort to overcome them.

Low temperature, for a time, may be endured by the less specialised forms of life quite well, but they become inactive and cease to exhibit the normal manifestations of life. Hence, in a region where the temperature is for ever low, such as in Central Greenland, or in the centre of Antarctica, life does not exist. Round the edges of these regions, where the temperature comes above the freezing-point for a while, specialised forms of life do manage to maintain themselves.

The presence of water in the liquid state is essential for the existence of life, firstly because water plays an integral part in the structure of protoplasm, and secondly because the chemicals which interact in the body must do so in the dissolved state. The need for liquid water further implies that there must be a certain atmospheric pressure, for at 1/170th of the normal atmospheric pressure on the earth, ice would evaporate at once to form water vapour, without forming liquid water at all, just as naphthalene moth-balls evaporate.

The value of light to living things is its ability to bring about certain chemical changes, as, for instance, the conversion of ergosterol into vitamin D_2. One such chemical change is of paramount importance. It is that known as photosynthesis, whereby carbon di-oxide from the atmosphere is combined with water to form a simple sugar which is the starting-point of all the foodstuffs elaborated by green plants. It is only by the oxidation of foodstuffs so obtained that the higher plants and animals can obtain vital energy, as explained in Chapter X, p. 348. Without light, and without carbon di-oxide in the atmosphere, there could be no foodstuffs for the higher plants and animals ; and without free oxygen in the atmosphere such organisms would be unable to liberate the energy present in their foods. It is perhaps significant that during photosynthesis oxygen is liberated into the atmosphere, so that if carbon di-oxide, light, water, and green plants are present, a supply of oxygen is assured because free oxygen will be produced by this photosynthetic action of the green plants (see p. 11 for the relevance of this to the atmosphere of Mars).

$$\underset{\text{Carbon di-oxide}}{6CO_2} + \underset{\text{water}}{6H_2O} = \underset{\text{sugar}}{C_6H_{12}O_6} + \underset{\text{oxygen}}{6O_2}.$$

Many lower organisms, however, can obtain energy without utilising free oxygen by breaking down normal foodstuffs such as sugar only partially. Yeasts do this in accordance with the equation—

$$\text{Sugar} \rightarrow \text{Alcohol} + \text{Carbon di-oxide} + \text{Energy.}$$

This is the ordinary process of fermentation and is carried on by all forms of yeasts. The different yeasts do, however, produce traces of different by-products which have a marked influence on the flavour of the beverage they produce. The yeast used in beer-making, *Saccharomyces cerevisiæ*, occurs in many distinct varieties, each of which confers on the beer it produces a distinctive taste, and the famous breweries go to considerable trouble to keep their strains of yeast pure.

As explained in Chapter X (p. 348) the energy liberated by the oxidation of foodstuffs by both plants and animals is ultimately derived from light. The only exceptions are a small number of organisms which obtain their energy without utilising the foodstuffs elaborated by the green plants. They usually oxidise some relatively simple inorganic substance. Examples are the sulphur and iron bacteria. The former oxidise hydrogen sulphide to sulphuric acid and derive a small amount of energy in accordance with the following equation :—

$$\underset{(H_2S)}{\text{Hydrogen sulphide}} + \underset{(2O_2)}{\text{Oxygen}} = \underset{(H_2SO_4)}{\text{Sulphuric acid}} + \underset{\text{115 Calories}}{\text{Energy.}}$$

The energy thus obtained is used to make formaldehyde, by combining hydrogen from hydrogen sulphide with the carbon di-oxide of the air, and free sulphur is liberated—

$$\underset{(CO_2)}{\text{Carbon di-oxide}} + \underset{(2H_2S)}{\text{Hydrogen sulphide}} = \underset{(HCHO)}{\text{Formaldehyde}} + \underset{(H_2O)}{\text{Water}} + \underset{(2S)}{\text{Sulphur}}$$

The iron bacteria obtain their energy by oxidising iron in the ferrous state to the ferric state.

There are animals which dwell in subterranean waters of pitch black caverns, but the food supply in such cases must ultimately be brought by the waters, or in some other way, from the outside world. Similarly, in the abyssal depths of the sea perpetual darkness prevails, illumined only by the phosphorescent displays of the denizens. Animals living there depend for their sustenance on the continual rain of bodies which slowly descend from the surface waters, bodies of animals which have fed directly or indirectly upon the microscopic plants floating at the surface.

On the other hand, it must be pointed out that many bacteria are actually killed by light—hence the value of airy, well-lit rooms, into which the sunshine may enter—and ultra-violet light of very short wavelength proves exceedingly harmful, if sufficiently intense, to all protoplasm. The ultra-violet wavelengths in sunlight are largely filtered out by a layer of ozone in the earth's atmosphere about twenty miles up, otherwise it is possible that life would not have been able to exist on the earth.

A suitable temperature, light, free oxygen, carbon di-oxide, water, and a pressure above a certain minimum, will all be present if life as we know it exists and flourishes. It has been suggested that other types of organised matter might exist with silicon instead of carbon as the characteristic element, and that such a kind of "silicon-life" might be able to flourish in the absence of one or more of these factors. That may indeed be so, but such a phenomenon could not properly be called life ; nor could it be profitably discussed, as it is impossible to surmise the properties it might have. It is, however, permissible to speculate upon the possibility of life existing on worlds other than our own.

The solar system contains nine known planets revolving around the central sun, and their relative positions are shown in Table I. Further, it is possible to gain much information about the conditions prevailing on their surfaces, about the temperature, the nature of the chemicals present, and whether the planets have an atmosphere or not.

The temperatures of the planets can be measured directly by means of telescopes of large aperture used to concentrate as much heat as possible upon such sensitive physical instruments as the bolometer and thermopile. Table I gives the measured temperatures for the planets and moon.

TABLE I. TEMPERATURES OF THE PLANETS AND MOON

	Temperature in °C.	Mean Distance from the Sun.
Mercury (mean, sunlit side) .	400	36 million miles
Venus (bright side) . . .	55	67·2 ,, ,,
Venus (dark side) . . .	− 20	
Earth	14	92·9 ,, ,,
Moon (centre of sunlit side) .	120	
Moon (centre of dark side). .	− 150	
Mars (hottest portions) . .	20	141·5 ,, ,,
Jupiter (average) . . .	− 140	483·3 ,, ,,
Saturn (average) . . .	− 155	886·1 ,, ,,
Uranus (average) . . .	− 180	1,783 ,, ,,
Neptune	—	2,793 ,, ,,
Pluto	—	3,666 ,, ,,

(*From "Life on Other Worlds," by Spencer Jones : E.U.P.*)

The temperatures of Neptune and Pluto have not been measured, They are very far away from the sun, and calculations of their temperatures give values below — 200° C.

It is seen that only Venus (55° C.), the earth (14° C.), and Mars (20° C.), have temperatures which would allow liquid water to exist, so on this issue alone all other planets may be dismissed at once as unsuitable for life. Life certainly occurs on the earth ; what of Venus and Mars ?

Seen through the telescope, Mars has a general orange colour with superimposed misty brown-grey markings which were thought at first to be seas. In addition there are white polar caps which grow larger in winter and shrink in summer. As long ago as 1877, Schiaparelli, a very competent Italian observer, noticed fine lines running over the surface of the " seas " and later he announced that they could also be seen on the " continents " as a fine criss-crossing network. Where the lines intersected he saw dark spots which he termed lakes ; the lines he called *canali* (channels), but by mistranslation they came to be known as the canals of Mars. The appearance of the channel network changed periodically, the altered appearance being due, according to Schiaparelli, to their being flooded with waters from the melting polar caps, which he assumed to be made of snow.

Mars is a difficult planet to observe satisfactorily. The most favourable opportunities occur during a month or two every few years, and, of course, many nights during this period will be unsuitable for observations. Owing to disturbances in the earth's atmosphere, really clear views can be obtained only for very brief periods of about a second's duration. Satisfactory photographs have not been obtained. Hence it is that information about the existence of Schiaparelli's *canali* depends on the personal equation of the observer.

At the end of last century, Lowell, in America, set up an observatory for the sole purpose of studying Mars. His observations confirmed and extended Schiaparelli's, and after some years he came to the conclusion that the so-called seas were really areas of vegetation and that their changes in colour and position were seasonal variations depending on the water supply liberated by the thawing of the polar caps. He asserted that the straightness of the canals pointed to the activities of intelligent animals, which had presumably constructed them to utilise to the full the water supply from the polar caps. Since in some canals the water must inevitably flow uphill, he suggested that this intelligent life had built huge pumping stations.

Unfortunately for this attractive theory, most observers have failed to confirm the existence of the canals, at least as sharply defined straight lines forming an intersecting network, and nothing like the elaborate systems drawn by Lowell has been recognised. Also, it has been calculated that the quantity of water locked up in the polar caps would be insufficient to fill the canals if they really do exist.

Mars has an atmosphere, but neither free oxygen nor carbon di-oxide has been detected. The ruddy appearance of the surface indicates the presence of oxides among the surface rocks, and suggests that free oxygen has been present in the atmosphere at some previous time. The only reasonable explanation of free oxygen in the atmosphere of a planet is that it has been given out during photosynthesis by plants, because oxygen, if originally present, would have been absorbed avidly by the molten rocks as they cooled. Hence it is not unreasonable to suppose that life, at any rate plant life, has existed on Mars. The present daily temperature range, from 70° F. to — 130° F., renders it unlikely that any life still exists there, or at least any forms of life as we know it.

Alternative suggestions have been made to account for the dusky patchwork regarded as vegetation by Lowell. Possibly it is due to a superficial deposit of hygroscopic salts which, when water becomes available, absorb it strongly and become a semi-liquid sludge, thus changing the light-reflecting properties of the regions in which it occurs. Alternatively, it may be due to layers of mist lying in the valleys and depressions in the ground, and moving from pole to pole in accordance with the seasons. If either of these two views is correct, there remains no evidence for the present-day existence of life on Mars. The question must therefore remain, for the time being, an open one.

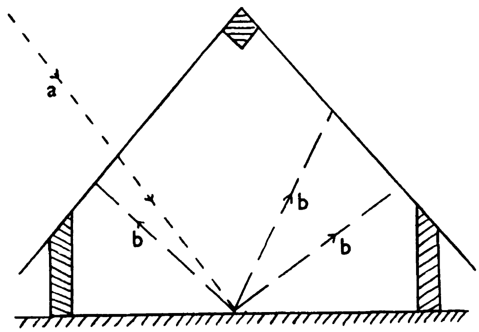

FIG. 4. Greenhouse effect. The glass allows the relatively short wavelength heat rays (*a*) from the sun to pass through. These are absorbed by objects inside the greenhouse and radiated as relatively long wavelength heat rays (*b*) which cannot pass through the glass.

Venus, although the nearest planet to the earth, possesses an atmosphere which prevents direct observation of its surface. The conditions prevailing on the surface have consequently to be inferred from the facts ascertainable about its atmosphere.

The atmosphere was formerly thought to be composed of clouds of ice crystals, but recently it has been suggested by Dr. Wildt that the " clouds " are crystals of a compound formed between formaldehyde and water.[1] There is abundant carbon di-oxide present, but no trace of oxygen has been detected. Probably the surface of Venus, like the surface of the earth, is incompletely oxidised and, at the high temperature existing there, would rapidly absorb any free oxygen.

The measured temperature of the outer layer of the atmosphere of Venus is about 60° C., but the " cloud " layer and the carbon di-oxide

[1] Polyoxymethylene hydrates $HO(CH_2O)_xH$ such as separate out when aqueous solutions of formaldehyde are allowed to evaporate.

would presumably exert a greenhouse effect (Fig. 4) and cause the temperature at the surface to be well above 60° C. Consequently life is unlikely to exist there, though as Venus cools down conditions should become more favourable for life, which may then possibly arise on this planet.

Little can be said about the multitudes of stars with their planetary systems which occur in our universe. The planets of stars are all too far away to be observed, and consequently no data are available. It may well be that on many of them conditions are suitable for life, and when the vast extent of time, and the numbers of the stars, are contemplated, it would be exceedingly foolish to hold that our solar system alone is the seat of life. The probability is that the conditions obtaining on the earth when life first had its origin will have occurred on other worlds, and it remains now to see whether the mode of origin of life may have been such as to permit it arising elsewhere under similar conditions.

Historically, the first theory of the origin of life was that of spontaneous generation held by the Greeks, and first clearly formulated by Aristotle. It is a matter of everyday experience that in certain kinds of matter life will appear, apparently coming from nowhere. This is particularly true of matter which is likely to putrefy, such as manure heaps, dead animals, or stagnant ponds. The life may be observable only under a microscope, or it may be very obvious to the naked eye like the pullulating masses of maggots found in the corpses hung up on a gamekeeper's gibbet,[1] or the rich earthworm fauna which appears in and near manure heaps. According to the theory of spontaneous generation, these forms of life are directly created in the non-living matter and do not arise as the offspring of other living creatures. Some credence is given to the theory by the account of the swarm of bees which arose in the body of the lion killed by Samson in the vineyards of Timrath. " And after a time he returned to take her, and he turned aside to see the carcass of the lion : and, behold, there was a swarm of bees and honey in the carcass of the lion " (Judges xiv, 8). Other support can be found in the writings of savants of early times. Kircher, a learned man of the seventeenth century, gives specific directions for the making of particular kinds of snakes :—" Take some snakes, of whatever kind you want, roast them and cut them in small pieces, sow those pieces in an oleaginous soil : then, from day to day, sprinkle them lightly with water from a watering-pot, taking care that the piece of ground is exposed to the spring sun, and in eight days you will see the earth strewn with little worms, which

[1] Many gamekeepers hang up the corpses of predaceous animals which they have shot, on hurdles or trees, in the belief that the gibbet will serve as a warning to other vermin. It is a common sight to see jays, crows, weasels, and owls, hung up thus in regions where game is preserved.

being nourished with milk diluted with water, will gradually increase in size till they take the form of perfect serpents."

The present writer himself, when a boy, often went with playmates to put horsehairs into the River Meese, believing that they would change into eels and so improve the fishing prospects, and the sight of swarms of blackish elvers wriggling their way up the river only served to strengthen this conviction. A somewhat similar idea was formerly very popular. This was that water fowl were derived from the swollen buds of certain trees which overhung the water; and Sebastian Munster, in his book "Cosmography", gives a drawing made by himself depicting this animal generation actually in process (Fig. 5).

FIG. 5. The Bird Tree (from Sebastian Munster's "Cosmography"). The head of a duck is seen emerging from the bud on the extreme left.

Nowadays the theory of spontaneous generation is known to have had its origin in faulty observation or faulty interpretation. The work of Schroeder, Pasteur, and others, has conclusively demonstrated that the organisms which appear in decaying matter are the progeny of other living things which are usually carried into the matter by air currents, or, as in the case of maggots, laid as eggs. In the case of Samson's lion, the phrase "after a time" supplies the explanation, for, in the hot atmosphere, the lion's body would rapidly become desiccated, and other instances are known where bees have made a nest in the dried body of a dead animal.

The disproof of the theory of spontaneous generation can apply only to the conditions existing on the earth at the present time. It will never be possible to say that under different conditions relatively high forms of life may not arise ; but acceptance of the theory of evolution considered in the next chapter makes it seem probable that life, when it originated on the earth, did so at a low level, and other forms of life have steadily developed from this primeval living matter by a process of gradual complication. Hence some explanation of the origin of this " first-life " becomes necessary.

In 1871, Sir William Thomson, later Lord Kelvin, advanced the view that life had arrived on the earth from some other heavenly body where life originally existed, being carried on meteors in the form of very resistant spores. The objections to this theory, as originally proposed, was that it would take far too long, a time of the order of 62,000,000 years being required for a meteor travelling at 40 m.p.h. to come from *alpha Centauri*, which is probably the sun of the nearest solar system. The life, of course, would not come from the hot sun, but from one of its planets. Furthermore, when the meteor rushed headlong into the earth's atmosphere, terrific heat would be generated by friction and this would almost certainly destroy any life which had managed to survive the immense lapse of time.

The theory was not generally accepted, but, in 1903, Arrhenius proposed a modification, depending on the pressure which light is known to exert. He suggested that light pressure could propel minute quantities of living dust through space with very considerable velocity, and, according to him, such particles would reach the earth from *alpha Centauri* in about 9,000 years, which is more reasonable. The temperature of inter-stellar space is -220° C., and this would reduce vital activity to a minimum, so the organisms would not use up an appreciable quantity of energy, but travel in a latent condition. It is known that life in this latent form is very resistant to adverse factors, including heat, so the temperature to which it would be subjected on entering the earth's atmosphere might not destroy it. The theory is probably still untenable, because, apart from the temperature question, there is also the influence of the unscreened effect of solar radiation which, as stated before, is extremely harmful to life, and which, if it were free to operate for such a long period, would almost certainly destroy even the most resistant spores. In any case, the theory does not explain the ultimate origin of life as a phenomenon, it merely removes the place of origin from this planet to some other place in the universe, leaving the essential problem unsolved.

A much more satisfying solution, which has been called the *Palæogenetic* theory, has gradually replaced the two preceding ones. This is based on a consideration of the chemical and physical conditions which may be supposed to have existed as the original mass of hot matter which was to form our world cooled down, and the water vapour gradually condensed from the atmosphere to form liquid.