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In *Diseases from Space* we shall be presenting arguments and facts which support the idea that the viruses and bacteria responsible for the infectious diseases of plants and animals arrive at the Earth from space. Furthermore, we shall argue that apart from their harmful effect, these same viruses and bacteria have been responsible in the past for the origin and evolution of life on the Earth. In our view, all aspects of the basic biochemistry of life come from outside the Earth.

Bacteria are living cells of a comparatively simple kind that exist and multiply by using similar nutrients to other more complex cells,such as those which make up our own bodies. Not all bacteria are harmful. Some have little or no interaction with plants and animals, while others serve useful functions. Bacteria in the gut of a sheep break down cellulose in the grass eaten by the sheep into its constituent sugar (glucose) molecules, and the sugar then becomes the animal's source of food energy. Unlike the sheep and the cow, we humans cannot usefully eat grass because we do not carry the right kind of bacteria in our stomachs. The useful bacteria that animals carry inside them maintain their numbers at more or less steady levels, whereas harmful bacteria seek to multiply their numbers uncontrollably. When this happens inside us the consequence is a drain on the materials which should go towards maintaining the normal cells of our bodies. Moreover, the bacteria themselves exude chemical wastes that may poison us severely, as happens for instance in the disease of botulism.

Although bacteria can cause extremely serious infections -pneumonia, tuberculosis and bubonic plague are other examples -their mode of attack is more straightforward than the attack of viruses; and as a general rule medical science has had greater success in coping with bacteria than with viruses. Viruses multiply by entering and destroying living cells,not by making use of comparatively simple materials. Whereas the harm that some bacteria do to us is in a sense a by-product of their activity, the attack of viruses on our cells is direct, and seemingly quite deliberate. Plainly, viruses have a close and intricate chemical connection with living cells. This raises the question of how a virus that evolved in some place other than the Earth could have become equipped with the ability to attack cells here on the Earth. The question is sharpened by the fact that specific viruses only attack specific kinds of cell. How, one may wonder, could a virus coming from a comet have foreseen the kind of living cell it was going to encounter after its arrival here on Earth?

There is obviously no direct answer to this question, but a decisive answer can be reached by turning the question around. The invading virus cannot know in advance about its terrestrial host, but the host can know about the virus, for the reason that terrestrial host cells have had a vast experience of invading viruses, an experience extending back in time over thousands of millions of years.

This experience could well have been imprinted in our genes and in the structure of our cells. The possibility of the host cell being adapted through long experience to receive certain types of bacteria and viruses, types for which the host cell has past knowledge, is entirely viable in theory. The reasons why critics of our point of view seem always to overlook this quite simple reversal of the problem lies undoubtedly in the deep-rooted conviction we all have that disease is bad for us. So it is for the individual, but not necessarily for the species as a whole. In Chapter 10 we shall argue that disease is essential to every species, because it is from invading viruses and bacteria that ultimately we derive all important changes, all worthwhile advances in our evolution, all improvements (paradoxical as it may seem) in our physique and in our mental capacity.

We turn now to a second very relevant question. Every cell, whether the simple forms of bacteria or the more complex cells of plants and animals, works on the same chemical system. So too do viruses. The system is exceedingly complex. In the past it was fashionable to compare the chemistry of life to a piece of precision machinery, like a watch, although no watch remotely approaches the subtlety of biochemistry in its construction. Now if the Earth derives its bacteria and viruses from not just one external body but from many, we have to suppose that exactly the same biochemistry exists in all such bodies. The question then arises of how this can be. Would one not expect the chemistry of life to evolve in different ways in different places - for example, through the use of some-what different amino acids in the construction of proteins? Our answer to these questions is an emphatic no. One would expect all systems to be the same, for the reason that, if external bodies can seed the Earth with life, they can also seed each other.

The most important quality of biology lies in its ability to increase numbers explosively. During the interval of two to three days between 'catching' a cold and the moment when you first begin to sneeze violently, the common cold virus multiplies its number inside you about ten thousand millionfold. And if the virus could keep on growing at the same rate for three weeks instead of three days, the eventual mass of it would exceed the combined masses of all the stars in the Milky Way. This means that in early days, when many chemical systems in many comets (there are thousands of millions of comets) were competing to produce the first working biological system, when they were shedding and scattering their products among each other, the first system to 'make it' scooped the pool. It was a case of winner takes all. The explosive power of biology forced biochemical unity on the solar system.

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As a matter of personal history, we did not arrive at our ideas at all light-heartedly. Over the past ten years, astronomers have discovered more than thirty organic substances present in the gas which lies between the stars, particularly in dense blobs of gas out of which new stars are continually being born. As well as the gas bet-ween the stars, there are also myriads of small solid particles, often called grains. We discovered two years ago that the heat emission properties of these grains are uncannily similar to the known heat properties of the commonest of all biological substances, the material cellulose, which gives strength to the stalks of ground plants and to the wood of trees. This work, which was discussed in more *Descent from space* detail in our previous book *Lifecloud,* is reviewed in the present book in Appendix 1.

These facts and clues forced us to ask ourselves whether the solar system might not have acquired a first supply of life-forming organic materials from its own parent interstellar cloud of gas and grains. It did not prove at all difficult to see how such materials could have been acquired by the solar system without suffering disruption by the early heat of the primeval Sun. The materials were simply swept up from the parent cloud, not directly onto the Earth itself, but into the cool distant outermost regions of the solar system, the regions occupied at present by the planets Uranus and Neptune. At that time, however, Uranus and Neptune had not yet formed; their material was divided up among avast swarm of much smaller bodies similar to the present-day comets.

We had long believed that the waters of the Earth and the gases of our atmosphere were not original to the Earth, but had been brought here from the outermost regions of the solar system by these same comet-type bodies. And now we had to consider that along with the water and the gases of the atmosphere there might have come great quantities of organic life-forming materials, an amount that might well have been as much as ten per cent of all the waters of the oceans. At first sight, this seemed a considerable help to the orthodox theory that life started here on the Earth, since it provided far more source-material for life than could have been generated locally on the Earth. Before accepting this position, how-ever, we felt it necessary to reconsider an old difficulty, which is that organic molecules are quickly destroyed in the presence of free oxygen. This oxygen problem is so important to the whole question of the origin of life that we shall now consider it at some length.

Imagine the Earth with its present oceans and atmosphere but without life. The higher ground on the land would be mostly bare rock and snow fields. There would be storms as we experience them now. Winds would blow, rain would fall, and rivers would flow along courses not significantly different from their present courses. There

would be weathering of rocks by wind and water, and sediments would continue to accumulate in river valleys, the beds of lakes, and on the shelves of the continents. But the sediments in the river valleys would not become soil as we understand it, because no organic humus would be added to it from year to year. The World would have a nightmarish topographical similarity to the present Earth. There would be Africa
and Asia, Europe and the Americas, but no life to soften the sharp outlines of the land-scape. In such a situation could we expect life to begin? The answer is that we could certainly not. The atmosphere and the oceans are made up of very stable inorganic molecules, mostly nitrogen, oxygen, carbon dioxide and water, which do not form themselves into the organic molecules needed for life. Indeed just the opposite. Even if the organic molecules needed for life should be formed in some way they would soon be degraded into simple stable inorganic molecules.

If the life which actually exists on the Earth were all suddenly to die, a very great deal of organic material would at first be left lying around. Yet even such a great quantity of organic material, much of it in the form of complex biomolecules, would not regenerate any life. The material would become degraded into simple inorganic molecules, much of it in a few months. Tree trunks would lie around for some years, and peat bogs in high geographical latitudes would persist for some centuries. But in a time exceedingly short compared to a geological epoch the whole of even such a large ini-tial supply of organic material would be gone.

Oxygen in the atmosphere would be the primary cause of this rapid degradation. Suppose we seek to stop the destructive effect of the oxygen by first adding hydrogen to the atmosphere. The oxygen would then be removed in combination with the hydrogen as water, which would wash out as rain to augment the oceans a little. With this precaution, what would happen if all life were again considered to die suddenly?

In our view the following sequence of events would take place. Any excess of hydrogen that might have been added to the atmosphere would evaporate in a time scale of a few thousand years away into space. The uppermost regions of the atmosphere are surprisingly hot (around the times when sunspots are most numerous in their cycle of about eleven years), and it is this high temperature of about 20000K that would cause the hydrogen to evaporate and to be lost from the Earth. The high temperature is generated by the absorption during daytime of hard ultraviolet light from the Sun.

While the hydrogen was thus evaporating, softer ultraviolet light from the Sun would penetrate through the Earth's atmosphere to ground level. In particular, ultraviolet that is normally absorbed by ozone (03) at a height of twenty-five to fifty kilometres above ground level would come through to the lower atmosphere, where some of it would dissociate water vapour into oxygen and hydrogen. For the several thousand years while hydrogen remained, the oxygen produced in this way would simply recombine with hydrogen back into water. After the hydrogen was gone, however, and with the hydrogen coming from the dissociation of water vapour also escaping into space, oxygen would begin to accumulate. To this point, the reservoir of organic materials would not on the whole have been much degraded. But now, with oxygen accumulating, the reservoir of organic material would again disappear, and we should reach the same final inert situation as before.

The critic will look for a loophole in this argument. Might not the organic materials have regenerated life during the few thousand years in which there was protection by the hydrogen? Our own answer to this question is no. Biologists, however, speak with a forked tongue on the matter. If they are reminded first of Pasteur's destruction of the ancient theory of the spontaneous generation of life, they too will emphatically answer no. Yet if they are asked the same question in the context of the origin of life4,000 million years ago they will answer yes, and they will do so in circumstances far less favourable than the situation we postulated above. It is there-fore ironical that Pasteur, after describing a particularly crucial experiment to the French Academy of Sciences, remarked: 'The theory of spontaneous generation will never recover from this mortal blow.' We provided complex molecules like chlorophyll, cellulose, and even the nucleic acids and proteins in the dead cells of plants and animals. For a proper understanding of the origin of life, the difficult problem of how these complex biomolecules were formed from very much simpler organic molecules must also be solved. Furthermore, we provided a vast quantity of organic material as a starting point.

How, one might ask, do biologists usually suppose that organic molecules were produced? By the effects of ultraviolet light and of lightning strokes in thunderstorms acting on simple inorganic molecules - water, carbon dioxide, methane, ammonia, hydrogen cyanide. These processes break up the simple organic molecules into atoms and radicals which overwhelmingly recombine back into the same simple stable inorganic molecules as before. Only a trickle of the atoms goes into less stable organic molecules. The resulting minuscule organic production on the primitive Earth would fall onto a land surface bare of vegetation, to run off quickly into rivers and thence to the sea, giving rise to no more than trifling concentrations of elementary organic molecules.

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We think there is little prospect of combating the above argument by claiming that an early protective hydrogen atmosphere persisted for ten million years or more, rather than for ten thousand years. Astronomical evidence shows that stars are more active at their surfaces when they are young than when they are middle-aged like the Sun. On astronomical grounds we should therefore expect a greater emission of hard ultraviolet light from the young Sun than the Sun emits at present, with the consequence that the protective influence of a hydrogen atmosphere would be shorter than ten thousand years. And in an issue that is really one of deep principle it is to be doubted that the time scale, so long as it was not obviously too short, is of any relevance at all.

Faced with this problem, it has been customary to take refuge in the assumption that ozone would form from the oxygen. An ozone layer in the high atmosphere, such as the Earth possesses at present, would absorb the damaging ultraviolet light from the Sun, thereby protecting all the water molecules lying below it. The trouble with this idea, however, is that neither oxygen nor ozone could persist in close association with easily burnable organic materials (or mixed with a combustable gas like methane, which is often taken to have been present in the Earth's early atmosphere). So not until *after* the life-forming materials had been destroyed could ozone begin to accumulate.

How is it then, the reader might wonder, that present day life manages to coexist with a present day atmosphere that contains free oxygen? Why does the oxygen not burn up the life? The answer is that it does, very quickly! But life also regenerates itself very quickly, as we emphasised above. Life is perpetually a race against being burned-up by the oxygen, a race that is balanced on a razor's edge and depends crucially on rainfall. When there is plenty of rain, life wins; the environment is everywhere green with grass and trees. When, however, there is only a little rain, burning-up wins, and the landscape is everywhere brown - we have the deserts of the Earth. But of course before there was any life capable of regenerating itself quickly there could have been no such race. In the presence of oxygen, burning-up would win in a canter.

If one had certain knowledge that life really had its beginning here on Earth it would of course be possible to infer an error in the seemingly persuasive argument of the previous paragraphs. The only way to arrive at such knowledge, we reasoned, would be to prove that life could not have begun anywhere else than on the Earth. So we set about seeking such a proof But instead of arriving at a proof that life could not originate except on the Earth, we found that conditions in comets seemed much better, better particularly in that the oxygen difficulty did not arise at all for comets.

So instead of the Earth being merely showered with life-forming materials by comets, we had now to contemplate the idea that the Earth might have been showered by life itself, by a profusion of living cells, some of which had managed to take root here.

If life began on the Earth some four billion years ago, there is not much to be predicted that we do not know already. But if life originated in comets, life must still be there, because the physical conditions in comets are very suitable to its preservation over vast intervals of time. And comets are still with us today - about ten of them come to the vicinity of the Earth each year. So if comets in the distant past shed life onto the Earth, we had to consider the possibility that comets were still doing so today. Suddenly therefore the ideas and theories about the origin of life, apparently rooted in the remote past, sprang for us into the immediate present. Was life in the form of primitive bacteria still reaching the Earth? And could viruses even be derived from comets? The idea seemed preposterous, but in science one must steel oneself not to decide the correct-ness or otherwise of ideas according to subjective prejudices. In science, fact reigns supreme. So what were the facts?

Our readings of medical history soon showed examples of dis-eases that fitted well with the infall onto the Earth of pathogenic viruses and bacteria from space, to a degree where we became convinced that the idea had to be taken quite seriously. We shall review this evidence in later chapters, for the common cold in Chapter 3, for influenza in Chapters 4, 5, 6, and for diseases more generally in Chapter 8. Indeed we found many situations, of which the famous historical incident described at the end of Chapter 2 is an example, where bacteria and viruses from space seemed the only explanation of the facts.

So it came about that the more we read and the more we probed many and diverse arguments, the more surely we were pressed to *Descent from space* the strange conclusion that it was in comets where we must seek for the early development of life. Let us return therefore to the addition of organic materials to the outermost regions of the solar system, addition from the particular interstellar cloud within which our solar system was born nearly 5,000 million years ago.

In the outer regions of the solar system there was already a vast swarm of hundreds of billions of comet-type bodies. The bodies were hard-frozen mixtures of simple substances, ordinary water, hydrogen cyanide, methane, hydrogen sulphide, to name a few of the commoner ones. It was on top of such hard-frozen mixtures that the interstellar organic materials were deposited. Typically, a cometary body would acquire an organic mantle about a kilometre thick. The organic mantles would initially be hard-frozen like the ices below them, giving conditions that were unsuited to the origin of life. Internal heating and liquification inevitably occurred, how-ever, as a result of chemical reactions among the organic materials, triggered perhaps by collisions of the comets with smaller bodies. Such reactions could release up to ten times the energy needed to melt cometary ices at a depth of a few hundred metres below the cometary surface, close to the inner boundary with the icy nucleus. High concentrations of organic materials in water solution, along with important in organics like hydrogen cyanide, would then be maintained for millions of years, because the rate of escape of heat to outside space can be shown to be very slow from regions buried some hundreds of metres below the surfaces of the cometary objects.

The situation then would be reminiscent of Charles Darwin's idea of a 'warm little pond': '... if (and oh what a big if) we could conceive in some warm little pond, with all sorts of ammonia and phosphoric salts present, that a protein compound was chemically formed ready to undergo still more complex changes .... ' The difference is that instead of just one warm little pond we now might have warm little ponds for thousands of millions of the cometary bodies, ponds which remained warm, not for a few months only, but for millions of years. A further difference is that instead of being supplied with ammonia and phosphoric salts our ponds are supplied with highly complex organics, perhaps with all the biomolecules that we discussed in our earlier book *Lifecloud* -polysaccharides as an energy source, sugar-phosphate chains and nucleotide bases for the building of proteins, porphyrins for assembly into chlorophyll. Yet another difference is that instead of being exposed to the damaging effect of oxygen in the Earth's atmosphere our ponds are each safely buried below a kilometre-thick protective skin.

It may be wondered if the actual chemical composition of comets accords at all with the idea that we have arrived at from argument. Recently, astronomers detected the presence in Comet Kohoutek of two organic molecules, methyl cyanide (CH_3CN) and hydrogen cyanide (HCN), as well as water (H_20). A further important connection with organic material has been deduced by A. H. Delsemme of the University of Toledo. By analysing various cometary data, Professor Delsemme has found that the overall atomic composition of volatile material is closely similar to that of living protoplasm , a property *not* possessed by terrestrial material, or by solar material, or by the material of planets in general.

Darwin's concept of a warm little pond is perhaps a little cosy. Rather should we think of each object as a vast laboratory with a floor area of some thousand square kilometres, with a height com-parable to the Empire State Building in New York, a laboratory chock-a-block with a high concentration in liquid water of organic molecules, a laboratory shielded from damaging radiations, a laboratory with a steady temperature maintained for millions of years. It was in such laboratories, a thousand million or more of them, that we shall suppose life in the solar system to have begun.

While the majority of the comet-type objects we have been dis-cussing went to form the planets Uranus and Neptune, a fraction must have been sprayed inward to the central regions of the solar system, and a fraction was very likely sprayed outward to form the giant halo around the solar system that we identify as the present-day comets. An inwardly deflected comet on which biological evolution had occurred could have seeded our planet with life some 4,000 million years ago. The seeding could have occurred in a large scale cometary landing, or it could have occurred more gradually through accumulations of cometary material that became dispersed into fine micrometeoritic particles. With each passage of a comet past the Sun, the outer layers are gradually peeled away, the process continuing until the one-time biochemically active ponds, now re-frozen, are eventually exposed at the surface. The freezing would ensure the preservation of cometary viruses and bacteria for almost indefinite periods. It is the eventual evaporation of such fro-zen surfaces that leads to the formation of the visible and famous 'tails' of comets, and also to the broadcasting of particles, some of which on our view contain viruses and some of which are bacteria.

Bacteria evolving within comets are of necessity anaerobic, i.e. out of contact with free oxygen. A small fraction of cometary bacteria which enter the Earth's atmosphere could conceivably make a transition from the anaerobic state to an aerobic one, although the vast majority may have perished. Aerobic bacteria on the Earth may have originated in this way, namely as the surviving members of the astronomically large number of cells which were shed from comets. Viruses could be carried within living cells, or they could be encapsulated in particles of either organic or inorganic composition.

From the arguments presented in this first chapter we find that the case for a cometary origin of life, as well as for a continuing infall onto the Earth of bacteria and viruses, is reasonably established on a preliminary basis. Accepting this position, at first tentatively, we shall proceed in succeeding chapters to discuss evidence and arguments that transform what at first seems an implausible hypothesis to a position with strong factual support.