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851ST ORDINARY GENERAL MEETING

HELD AT THE ALLIANCE HALL, WESTMINSTER, S.W., ON MONDAY, APRIL 12TH, 1943, AT 4.30 P.M.

DOUGLAS DEWAR, Esq., B.A., F.Z.S., in the Chair.

The Minutes of the previous Meeting were read, confirmed and signed.

The CHAIRMAN then called upon Dr. R. E. D. Clark to read his paper entitled "Evolution and Entropy" (being the Langhorne Orchard Prize Essay, 1942).

The Meeting was later thrown open to discussion, in which Dr. Farmer and Mr. McAdam Eccles took part.

Written communications were received from Sir Ambrose Fleming, Lt.-Col. L .M. Davies, Rev. Principal Curr and Mr. E. A. Mobberley.

The following election has been made :—W. E. H. Stokes, Esq., Member.

EVOLUTION AND ENTROPY.

By ROBERT E. D. CLARK, M.A., PH.D.

(*being the Langhorne Orchard Prize Essay,* 1942).

AT first sight entropy and evolution appear to have little to do with one another. The one reminds us of the steam tables in the handbook of engineering, the other of the past history of life upon our planet. Yet, for all their dissimilarity, their interconnections form a fascinating study which is intimately connected with the philosophy of modern science.

Let us start by seeking to understand the meaning of entropy. Deep down in the subconscious minds of us all certain ideas lie enshrined, ideas which we have taken for granted as far back as we can remember, and which we have learned to include in the all-embracing term "common sense." These ideas are so much a part and parcel of ourselves that to most of us it seems the height of stupidity to drag them out into the open and seek by recondite reasoning to justify ourselves for accepting them uncritically.

Among a group of ideas of this kind—the idea that events are connected by cause and effect, that the outside world exists and is intelligible to our minds, and so on—there is one of more than usual importance, notwithstanding the fact that philosophers have often overlooked its existence. It is not easy to put the idea in words; simplified definitions have a way of omitting scores of exceptions, and making us doubt from the start the existence of the thing we define, while long involved statements suggest a complexity which we are apt to suppose resides in the things we describe, instead of in the words we use to describe them. So let us resolve the difficulty by reminding ourselves of a familiar

story. In the book of Genesis (xliii, 33) we read of a lord of Egypt who entertained eleven men who were brothers. The men so the story goes, " marvelled one with another " when they found themselves seated at table in the exact order of their ages.

Let us seek to face the question: why was it that they marvelled ? For answer we can only say that such an event seemed to contradict one of the basic ideas entailed in " common sense." The men had never heard of the laws of probability, of entropy, or of the second law of thermodynamics, but they rightly suspected that the long arm of coincidence would hardly have arranged them in just that way. Somehow, they guessed that intelligence was at work, though to all appearances this could hardly have been the case. In the end, so it would seem, they decided to trust to appearances instead of intuition. Nevertheless, they soon learned that their intuition had not deceived them.

Now let us span the centuries. We find at once that the same intuition has been at work in every age ; but while a majority of people have always taken it for granted, there have always been those who, like Joseph's brothers, have sought to bring it into consciousness, and then, with clever arguments, to convince themselves of its falsity. At this, however, we need feel no surprise. Every intuitive idea has suffered a similar fate ; philosophers have doubted causality, have doubted the existence of a physical world, have doubted interaction between mind and matter, have doubted every conceivable dictate of common sense. And so, right up to modern times, men and women are to be found who suppose that by the working of some inscrutable principle, nature is in the habit of producing order where chaos existed before.

This denial of a common sense intuition formed a part of the Platonic philosophy, which exerted an enormous influence on medieval thought.* For Plato, nature was ever tending to produce the ideal *eidos* or form—that is to say, she was able to produce order of herself. It was this notion which for so long prevented the birth of modern science, and it is possible to trace the way in which science after science was able to come into existence only as the notion of the Platonic *eidos* was overthrown. To-day it is difficult indeed to imagine ourselves back in a medieval world in which slime generated eels, flies, mammals and (so Aristotle said) even men, in which mice could be

* R. O. Kapp, *Science Versus Materialism*, 1940, p. 182 ff.

made from a soiled shirt and some flour, and fossils came into existence as a result of " formative virtues " in the rocks.*

The early scientists abandoned the medieval attitude. Again and again we find them dissatisfied with the idea of a self-ordering principle in nature. Instead, they make the tacit assumption that order does not arise of its own accord and that, in fact, if things are left to themselves, order may diminish, but cannot increase.

In the science of heat it was soon found that a hot body and a cold body, placed near to one another, both reached a uniform temperature; but it was quite impossible to take a body at uniform temperature and divide it into hot and cold parts. This, put in simple language, became known as the law of *entropy*, and it clearly showed that something irreversible took place in nature. Indeed, were this law to be proved wrong, perpetual motion machines would become possible.

Later, two important points became clear. First of all it was realised that the actual event taking place in nature when hot bodies warmed cold ones was a general disordering of the molecules; secondly, it was found that literally hundreds of well-known laws in physics and chemistry were reducible to the law of entropy, thus demonstrating the enormously wide scope of what had hitherto appeared to be a law in that rather specialised branch of engineering—the study of the steam engine.

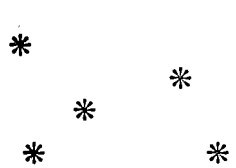
It seems advisable, therefore, to extend the meaning of the word " entropy " so as to make it a synonym for " disorder." In this sense the " law of entropy " must be understood to mean the law that disorder will tend to increase, but that order can never arise spontaneously from chaos.† It is in this form only, of course, that the law is related to the theory of evolution.

Not only has the law of entropy been vindicated again and again in every science, but scientific workers of to-day almost invariably assume the law in their work, though they do not always notice the fact. So much is this the case that modern science makes no attempt whatever to explain natural phenomena *in general*, but only such phenomena as exhibit order, whether in

* As J. M. Mecklin has recently pointed out (*The Passing of the Saint* 1941, p. 36), it was generally supposed in medieval times that nature responded, almost automatically, to man's emotional needs—and naturally enough these required an organising power in the inanimate world.

† In order to avoid confusion with the specialised law of entropy of the physicist and engineer, it was suggested by the present writer (in 1936) that the wider law should be referred to as the *Law of Morpholysis* (*luo*= to loose; *morphe*= form). Prof. R. O. Kapp (*loc. cit.*) has recently suggested the term *adiathesis* for the same principle.

space or time.* If, for instance, a group of meteorites were seen to fall upon the moon, making craters in the arrangement shown :—



the precise arrangement of these craters would universally be regarded by astronomers as being at random, and no one would be concerned to discover why the crater A, for instance, was not situated slightly to the left or to the right of its actual position. If, on the other hand, a group of craters arranged in a precisely similar way had previously been formed upon the earth, the lunar craters would at once be recognised as possessing order, and so explanation would become necessary. Astronomers and mathematicians, knowing instinctively that the order could not have arisen by chance, would at once try to " explain it away " by proving that, for instance, the known laws of force between small free objects moving in space are such as to necessitate the very configuration which had been observed on the moon.

In short, the business of science is to explain instances of the apparent production of order which are observed to occur in nature. Moreover, this process of " explaining " is nothing other than " explaining away " ; it is the attempt to show that in the last resort a given instance of order did not arise of itself, but because it was there already in nature in a latent form. In the world of physics chaos is constantly increasing, energy is becoming less and less available. But while some of the still ordered energy is turning into energy in a less ordered condition, it will chance now and again that groups of atoms will arrange themselves in what *appear* to be new ways. It will seem to the uninitiated as if atoms and molecules have arranged themselves and created something new ; but the scientist tries to show that however startling the novelties that emerge, they were really present all the time : they are the logical and deducible consequences of what was already in existence.

* Prof. P. W. Bridgman (*The Nature of Thermodynamics*, 1941, p, 172) is one of the few writers who have realised this fact. "It is strange," he writes, " that we do not seem to require any explanation for the tendency of a system of many members to increase in the disorder of its arrangement, but this tendency is such a universal property of the systems of ordinary experience that we know intuitively when to expect it and do not require any explanation, unless we are unusually critically minded."

The simplest possible example of this is to be found in the steam engine, and since the physical explanation of the working of this machine is typical of all physical explanations of the production of new order, it is worth discussion in detail. The remarkable fact about the steam engine is that by its means we may convert the purely random movements of molecules of water into useful work—the ordered movement of a piston along a cylinder against an opposing force. It is as wonderful as if millions of fireflies, flitting aimlessly in any and every direction, should suddenly produce a stream of tiny points of light moving in the same direction and exactly parallel to one another. How is the miracle performed ?

The physicist has found a simple and adequate answer. He has discovered that, despite appearances, the miracle is *not* performed at all. The cylinder and piston simply behave as a sorting machine. Molecules which happen to be moving towards the piston are alone able to give up their energy—the rest just rebound repeatedly from the cylinder walls until they too chance to be moving in the right direction. If the process stops before the whole of the energy of the molecules has been given up—before the absolute zero of temperature is reached—only a part of the energy of the moving molecules can be converted into useful work.

Again, if we watch a crystal in the process of formation, we see an apparently structureless liquid or vapour producing complex and beautiful patterns. How comes it that the molecules arrange themselves in this ordered manner ?

Crystallisation takes place in two stages. Firstly, invisible " seeds " or " nuclei " come into existence and, secondly, these grow into larger crystals. There is no need to discuss the technicalities of the subject here. Suffice it to say that arrangements of the atoms or molecules in the crystal are determined wholly by their shapes, polarisability, and other properties. In a few simple cases (the rare gases) the crystal structure has been successfully predicted as a result of observations made upon a gas, and there is little doubt that in time this achievement will be accomplished in countless other instances. Thus the arrangement of the atoms or molecules in a crystal nucleus is *determined* before the crystal has come into existence. Just as the shape of a knitting needle determines the fact that knitting needles, when shaken together, will collect in long thin bundles, so the order of the crystal is already " present " in the liquid or vapour in the form of the properties of the molecules. The fact that, supposing we could see them, molecules do not " look like " the crystals

to which they give rise is, of course, irrelevant. In just the same way the sound track on a cine film does not " look like " the waves of sound which we hear as music or speech ; but all would agree that the whole organisation of the resulting sound was ultimately present in the sound track. Or, to anticipate somewhat, chromosomes and genes do not " look like " full-grown animals—as the pre-formationists used to suppose—but they none the less contain the organisation of biological organisms.*

We come now to discuss the bearing of these ideas upon biology. Do biologists make the same presuppositions about order as do scientists working in other fields ? Undoubtedly they do. Most modern advances in biology have been based upon the law of entropy. Hereditary factors, leading finally to the idea of physical genes, were postulated to account for the resemblance between offspring and parent, simply because the biologist could not believe that the organisation of an animal could arise *de novo* with each generation, but must have been present in some form in the egg or sperm. Subsequent research has vindicated this bold step ; to-day it seems likely that genes have actually been rendered visible in the salivary glands of the drosophila fly. Biologists have sought to interpret the growth of the embryo with the help of the concept of a " field " for the same reason. Biological mechanisms by the score—the digestion of food or the circulation of oxygen by means of the blood—have been interpreted according to the rules of physics and chemistry, which in their turn depend upon the law of entropy. Biologists have themselves pointed out that the processes of growing old and dying are clear manifestations of the law of entropy.† And so the list might be continued.

The detailed study of evolution has again and again revealed the working of the same law. Many years ago Dollo formulated the generalisation that if, during the course of evolution, an organ was reduced it never again regained its original importance, while if it disappeared altogether it never reappeared. Even if an organ is lost which was valuable in a previous environment,

* The point of view here expressed is, of course, radically opposed to the philosophical doctrine known as *emergence* (C. Lloyd Morgan, *Emergent Evolution* 1923 etc.). It need only be said that this doctrine is wholly without factual evidence in its support and that scientific advance has ultimately depended upon its falsity.

† L. von Bertalanffy, *Das Gefüge des Lebens*, Leipzig, 1937, p. 116. H. Pictet (*Arch. de Sc. phys. et naturel*, 1915, pp. 181–200) believes that old age and death are connected with the progressive stabilisation of protein molecules with the consequent production of highly stable cyclic compounds.

and that environment is again restored, the organ does not reappear—at best some other organ takes its place.

More recent research has shown that Dollo's law applies not only to visible bodily structures, but to scores of biochemical and physiological adaptations. To cite but two striking instances: the Mexican axolytl has lived for centuries in iodine-free water, and has lost the power to synthesis thyroxine from this element. Since metamorphosis in amphibia is dependent upon the action of thyroxine, the axolytl has long since ceased to turn into a salamander. To-day the amphibian breeds true even when iodine is available, and will not metamorphise. When, however, it is treated with ready-made thyroxine, it turns into a salamander. Again, a culture of *Bacillus pyocyaneus* on one occasion lost its power to make the usual bluish-green pigment. For thirty-nine years the new strain was cultivated, but never recovered its original colour.

Dollo's law, in fact, has been found to hold both in anatomy and in biochemical mechanisms over an exceedingly wide range of species, nor has any definite exception to its operation been discovered.* Its relation to the law of entropy is manifest: complex structures naturally cannot arise by chance when they have once been lost.

Again, Blagovenschenki,† in an exceedingly interesting monograph, has shown that biochemistry is intimately related to evolution. Simple substances—amines, amino-acids, glycocoll-betaine, simple terpenes, etc.—are widely distributed in plants. Complex substances—alkaloids, resins, etc.—on the other hand, are very restricted in their distribution, but are formed by the condensation of simple substances into rings. Once formed, the latter are very stable, and are therefore no longer able to play a part in metabolism, so that they eventually cause the death of the plant and often of the species. The chemical evidence thus makes it possible to recognise in every phylogenetic series stages of juvenility, maturity and senility. In short, the evolutionary process always proceeds from the highly improbable—the long chain unstable compounds of simple structure—to the highly probable stable cyclic compounds which are ill-adapted to the life of the species, and often even cause its death. Blagovenschenki compares this to the process of disordering of energy in which free energy always diminishes in physical changes, that is to say, less stable arrangements become more stable.

* J. Needham, Reversibility in Evolution. *Biol. Reviews*, 1938, 13.
† A. V. Blagovenschenki. *Biologia Generalis*, 1929, 5, 427.

The evidence of genetics points in a similar direction, as modern geneticists have not been slow to point out. The remarkable changes which occur in the genes as a result of bombardment by X-rays, α-particles, electrons, quanta of ultra-violet light, etc., all appear to be of a destructive nature. That this *must* always be the case is generally regarded as a debatable question, but at least no known case of an increasing organisation as a result of mutations is yet to hand.* Moreover, the view that mutation followed by natural selection is the raw material of evolution is quickly gaining ground, and if this is so we have yet further reason for believing that evolution is consistent with the law of entropy. In this connection we must bear in mind that the types of mutations produced by artificial means are statistically identical with those produced by nature, showing, apparently, that artificial ways of inducing mutations only have the effect of hastening the natural process.

On the basis of this and similar evidence, some biologists have boldly identified the law of evolution with the law of entropy, though not all have realised the implications of this identification.

Taken at their face value, these facts seem to suggest that evolution is simply the unfolding of organisations which are already present and that, despite appearances, it cannot involve any real rise in the degree of organisation of an organism. As is well known, a number of biologists have stated this conclusion boldly. Eimer's original conception of " orthogenesis " involved the view that each species could only evolve along specified directions which were already determined by the structure of its germ plasm. Berg's famous work, *Nomogenesis*, involved the same view, which was supported by a wealth of research material. Lotka, whose *Principles of Physical Biology* is stated by Needham to be " one of the three or four greatest contributions to biological thought in the present century," simply denies that any rise

* Some instances are known in which a gene is *apparently* lost as a result of such bombardment, but may be regained again as a result of a later mutation. It is *possible* (with H. J. Muller, *Biol. Rev.* 1939, 14) to urge that the second mutation shows a rise of organisation, but more likely that the original gene was not, in these cases, destroyed at all but its development simply blocked. Muller is forced to admit that apart from these dubious cases, mutations involving a rise in organisation (*hypermorphic mutations*) have not been proved to occur. R. Goldschmidt (*The Material Basis of Evolution*, 1940), frankly abandons all hope that mutations of the ordinary kind will convert one species into another, but supposes that novelty may arise by a single very extreme (*systemic*) mutation. He produces no evidence that such mutations are possible, other than those involving loss of structure.

occurs in organisational level during evolution. H. F. Blum* openly confesses that, but for the fear of giving away ground to the theologians, such conclusions would certainly have had a far greater impact upon biological thought than they have, in fact, exerted. D'Arcy Thompson† shows how all the classical evolutionary changes found by the paleotologists can be connected together by slowly changing the geometrical co-ordinates and finally concludes that the great organisational gaps in evolution are to-day unbridged and likely to remain so for ever.

Now let us turn to see how far those who still believe in a rise in the organisational level during evolution have attempted to justify their position.

Following a very tentative suggestion by Eddington,‡ it has been asserted by many writers§ that the apparent clash between evolution and entropy is illusory. Just as a part of the energy of hot steam may be converted into highly ordered work at the expense of the remainder so, during the course of evolution, animals may in the last resort have obtained their organisation at the expense of the sun's energy which has been degraded on the earth's surface.

Though ingenious, this analogy will not bear examination. As we have already seen, the steam engine creates no order which was not there before ; it merely makes use of molecules which happen to be moving in a certain direction. The analogy certainly shows that reproduction in biology is not inconsistent with physical principles, but it does nothing whatsoever to show how *new* types of organisation could come into existence in the first place.

The second analogy which has been invoked is that of the crystal. Here, at all events, it is urged that remarkable new structures can come into being of their own accord as atoms or molecules organise themselves into a crystal lattice. Some writers go further than this and assert that we may see a series of rises of organisation in nature : electrons and protons produce atoms, atoms produce molecules, while molecules produce crystals, or reach a still higher level in the living organism.

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* H. F. Blum, *American Naturalist*, 1935, 69, 354.

† D'Arcy W. Thompson, *On Growth and Form*, C.U.P., 1942, p. 1093.

‡ A. S. Eddington, cf. Pres. Add. to Mathematical Assoc. 1931. *Nature* 1931, 127, 448. *New Pathways of Science*, 1935, p. 56.

§ For example, E. Schrödinger, *Science and the Human Temperament*, 1935, p. 39.

According to the doctrine of " emergence," new qualities turn up when complex structures are made from simple ones, and the coming of life is, therefore, merely the last stage in a series of transitions which are to be found throughout nature.

The doctrine of emergence has been singularly unsuccessful, in so far as it relates to the production of new organisation. Thus, crystal structures are determined by the properties of atoms, and in no sense do they represent the " emergence of novelty."

Modern research has shown that the absence of chemical equilibrium affords a criterion of novelty. Certain chemical and physical changes are, under suitable conditions, found to be reversible, while others are irreversible. Thus if hydriodic acid is heated, an equilibrium between this gas and its decomposition products, hydrogen and iodine, is rapidly attained, after which no further change occurs : on the other hand, if sugar is heated it undergoes complete decomposition, and no reversible equilibrium is established. In the first case, hydrogen and iodine can be built up to form hydriodic acid, but in the second water, carbon, etc., do not give sugar. The difference between the two cases is simply that hydrogen and iodine can only combine in one way, so that no true rise in organisation occurs when hydriodic acid is formed. On the other hand, there is no limit to the number of ways in which carbon and water can combine, so that a particular molecular structure, such as a sugar molecule, must be considered as an organised whole. It cannot be said to " exist " already in the atoms out of which it is made.

The production of atoms out of positive and negative charges, of molecules from atoms and of crystals from molecules are all cases of the first-mentioned type. In each case the constituents, on being placed together, can produce one or at best a very few combinations under particular physical conditions. If several possibilities arise all are formed ; mixtures of many elements are, for instance, produced in the stars.

In all such cases parts themselves possess properties which determine the shape of the whole. Thus, as we have already seen, the shape of the whole is already present in the parts in the same sense that a cause may be said to contain the effects which it produces.

In the case of complex organisations, however, this is no longer the case. The individual words or letters of a page of print do not in any sense contain their final arrangement, nor is it conceivable that the intricate complexities of living organisms can be

necessary consequences of the amino-acid or carbohydrate molecules out of which they are constructed. If the evidence of "inconceivability" is doubted, we have the direct evidence afforded by organic chemistry that such compounds show no tendency to organise.

Biologists have sometimes compared biological organisms with atoms which, after they have lost electrons, soon regain them and so remake their original structures.

But as Kapp* has pointed out, no scientist to-day doubts the fact that the laws which govern the building of atoms, of molecules and of crystals are the same laws which govern all other phenomena in inanimate nature. This being so, it is hard to see why the biologist should seek analogies with atoms, molecules and crystals rather than, say, with the events which take place when a boulder disturbs the end moraine of a glacier. To do so is, in the last resort, to replace a fundamental distinction between dead and living matter by another equally fundamental distinction between processes of atom, molecule and crystal building and the rest of physics.

The analogy of the crystal may be carried one stage further. In rare instances crystal "seeds" come into existence as a result of the random motions of molecules, and when this occurs they can often grow and reproduce themselves. Is it not possible that in the same way genes may occasionally become more complex, and then likewise perpetuate themselves? But here again the study of the crystal reveals the difficulties such an hypothesis must meet. The difficulty associated with the building of a nucleus increases enormously with small rises in the complexity of a molecule, as every laboratory worker in organic chemistry is only too well aware. The fact that some very complex organic substances, such as proteins or certain viruses, crystallise relatively easily is not to the point, for investigation has shown that in such cases the organisation of the crystal by no means fully represents the complexity of the molecule, identical crystals being formed despite considerable changes in chemical constitution.†

* *loc. cit.*, p. 164.

† Thus Stanley (*Science*, 1936, **83**, 626) made derivatives of the crystaline tobacco mosaic virus by treating it with various reagents (formaldehyde, nitrous acid, ultra-violet light, etc.). The products differed greatly in their biological effects, but all gave mixed crystals with one another and with the original virus. The same phenomenon is very frequently found in connection with complex natural products. In such cases it is clear that the crystal form is substantially unmodified by changes in a part of a large molecule and so cannot enshrine all the organisation of the molecule.

Julian Huxley* attempts to avoid the difficulty by invoking natural selection. "Natural selection," he writes, "achieves its results by giving probability to combinations which would otherwise be in the highest degree improbable. This important principle clearly removes all force from the 'argument from improbability' used by many anti-Darwinians, such as Bergson." But molecular combinations are not made more probable if, when once they have been formed, they are enshrined in a species. The analogy of the crystal nucleus shows us the extreme limits of spontaneous ordering in nature, and it is an analogy which is unfavourable to the mechanistic evolutionist.

The fact is that the formation of molecular structures as highly organised as those in living matter is inconceivably improbable, and no suggestion has yet been made which will alleviate the difficulty.†

According to yet another suggestion,‡ the "order" of the entropy law and the "order" of biological morphology do not refer to the same thing—in fact, as the one diminishes, so the other increases, for while entropy rises, crystal patterns often come into existence.

But again this statement proves physically unsound on examination. As we have seen, the formation of a crystal pattern is most emphatically *not* the production of new order, but merely makes visible an order already possessed by atoms and molecules. While organisation is being lost it is not surprising if, during the process, that which still remains becomes more readily visible.

Thus the more carefully the matter is considered, the clearer does it become that the theory of the evolution of highly organised organisms from simple ones violates a fundamental principle of science.

At this point, however, having totally failed to reconcile mechanistic evolution with scientific principles, the biologist may urge that, at all events, an attempt to catch him on the horns of a dilemma is both unscientific and unfair. He is certain that evolution has occurred, for the highly organised mammals in existence to-day were certainly not in existence in remote geological time; but that is no reason why he should be forced to explain *how* it happened. The "how" may safely be left to future research; meanwhile, the facts must be accepted.

* J. S. Huxley, *Nature*, 1936, **138**, 573.
† R. E. D. Clark, Jour. Trans. Vict. Inst. 1936, **68**, 172.
‡ J. Needham, *Time: The Refreshing River*, C.U.P., 1943.

Though plausible enough, this evasion cannot stand. The theory of a rising level or organisation in evolution is so directly contrary to the presuppositions of all scientific thinking that it cannot be left to future discoverers to effect a reconciliation by "filling in details." If it is true that biology forces us to accept this interpretation of evolution—and all biologists are not convinced that this is so—then if no explanation is forthcoming, let it be admitted candidly that evolution has occurred in the face of all the laws of nature: let it be admitted that theologians are right in insisting that if the process took place at all it was God-guided and was, in fact, equivalent to a whole series of creative acts.

After all, the biologist has no grounds for adopting an attitude wholly dissimilar to that adopted by scientists in other fields. The mechanistic biologist is at pains to show that the laws of physics and chemistry are applicable to biology: he has, therefore, no right to postulate a law of increasing complexity in defiance of those sciences.

Nor is it relevant to reply that an overwhelming mass of evidence supports the theory of evolution, for in no other science has overwhelming evidence been permitted to jeopardise the very mental processes by which we seek to understand nature.

There are literally scores of instances in which direct experimental observations *apparently* violate the fundamental laws of science, but the laws are not called in question. Even in modern atomic physics the basic principles of science have in general remained untouched, save that in some cases the theory of probability has undermined the immediate usefulness of the principle of causality. In practically every instance, scientific explanation has had its greatest triumphs in its ability to explain away apparent exceptions.

Thus, when a stone falls to the ground it *apparently* gains energy, but no one uses this as evidence against the law of the conservation of energy; instead, the stone is said to have possessed the energy before in a *potential* form. Recently cinephotographs of the sun's corona showed streams of matter constantly falling towards the sun, but no sign that they ever rose upwards to feed the "invisible hose." Thus direct observation seemed to support the view that matter could arise from nothing, but the conclusion reached by astronomers was that the matter rose upwards in an *invisible* form. This point of view has since explained several related phenomena.

When a piece of red-hot iron is allowed to cool it suddenly gets hotter (*recalescence*) at a certain stage in the process, but no physicist urges that therefore the law of entropy is violated. Repeated accurate measurements showed that the surface tension of mercury in a vacuum was raised by admission of air, though it was easy to prove from the entropy law that it ought to have been lowered. Physical chemists do not doubt the entropy law: they hold that the measurements were vitiated by the presence of dirt! * When radium was discovered it was found to maintain itself at a higher temperature than the surrounding air, and it was suggested in some quarters that an exception to the law of entropy had at last been discovered.† Rutherford saw the falsity of such reasoning immediately and, by assuming the truth of the entropy law, he was able to create and develop the science of the atom. At one time it was urged that since animals made energy with a greater efficiency than that predicted by Carnot's theorem for a reversible steam engine, the animal body violated the law of entropy. Clear-thinking physiologists saw that the evidence only proved that the mechanism of muscle contraction was not that of the reversible steam engine.

In face of these and many other examples, it would be reckless indeed to see in evolution a self-ordering principle of nature which runs contrary to the entropy law. If in other sciences observable events which seem to contradict this law are never taken at their face value, it is difficult indeed to see why a biological theory about non-observable events of past history should be given an altogether different status. Moreover, it is difficult to avoid the conclusion that previous attempts to make use of biological concepts in defiance of ordinary scientific thinking have been disastrous in the history of biology itself. One is reminded in particular of the fierce opposition of Haeckel and his contemporaries towards His and Wilhalm Roux who, at the end of last century, were trying to apply science to embryology and to build the new science of "developmental mechanics." His‡ tells us that the scientists of his day thought they had "better things to do in embryology than to discuss tensions of germinal layers and similar questions, since all

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* R. S. Burdon, *Surface Tension and the Spreading of Liquids* 1940, chap. 3.

† J. Needham and W. Pagel. (Ed.). *Background to Modern Science*, 1938, p. 58.

‡ W. His, *Proc. Roy. Soc. Edin.*, 1888, **15**, 294.

embryological explanations must of necessity be of a phylogenetic nature." He continues: "This opposition to the application of the fundamental principles of science to embryological questions would scarcely be intelligible had it not a dogmatic background . . ." The same words can surely be applied to the doctrine of constructive evolution and for precisely the same reason.

It seems reasonable to conclude, therefore, that if in past ages complex organisms ever did evolve from simpler ones, the process took place contrary to the laws of nature, and must have involved what may rightly be termed the miraculous. For this reason the doctrine of evolution can never legitimately form a part of naturalistic philosophical or sociological thought, nor can it ever be rightly used to support such dogmas as the inevitability of progress.

Discussion.

The Chairman (Mr. Douglas Dewar) said:—Dr. Clark's paper is, I think, one of the most important that have been read to this Institute of recent years. It deals with a subject which, in view of its extensive implications, has attracted remarkably little attention. The word entropy was, I believe, coined in 1865, *i.e.*, 6 years after the publication of Charles Darwin's "Origin of Species." At the time of the appearance of this volume, physicists generally do not seem to have held the belief that our universe is running down like a wound-up clock; had they done so, presumably they would have looked askance at Darwin's theory, according to which one or more particles of matter not only suddenly ceased to disintegrate, but reversed the process, and began to integrate, having in some mysterious manner acquired the power of capturing heat and other forms of energy, which they utilised to grow increasingly complex. It is curious that, even when the law of entropy was enunciated, the theory of evolution did not fall into disrepute. Because, as Dr. Clark well puts it, "The fact is that the formation of molecular structures as highly organised as those in living matter is inconceivably improbable," and "the theory of the evolution of highly organised organisms from simple ones violates a fundamental principle of science."

These considerations, however, do not prove that the above astounding phenomena did not take place, but they call for the

production of very strong evidence that they did occur. Such evidence is not forthcoming. It is true that the geological record shows that for a long period there were no living organisms on the earth. Even so, the fact that the earth is now filled with them in no way helps the theory that blind forces of nature brought them into existence. It is true that Darwin said nothing about the origin of life. He was an adept at avoiding difficulties. The closing passage of his " The Origin of Species " runs : " There is a grandeur in this view of life, with its several powers, having been originally breathed by the Creator into a few forms or into one ; and that, whilst this planet has gone cycling on according to the fixed law of gravity, from so simple a beginning endless forms most beautiful and most wonderful have been, and are being evolved."

This leaving the matter of the origin of life, so to speak, in the air did not appeal to many of Darwin's followers, such as Haeckel, Weismann and others.

Professor Oscar Schmidt wrote (" The Doctrine of Descent," p. 162) : " In this concession, Darwin has certainly been untrue to himself ; and it satisfies neither those who believe in the continuous work of creation by a personal God, nor the partisans of natural evolution. It is directly incompatible with the doctrine of descent, or, as Zöllner says : ' The hypothesis of an act of creation (for the beginning of life) would not be a logical but a merely arbitrary limitation of the causal series, against which our intellect rebels by reason of its inherent craving for causality.' Whoever does not share this craving is beyond help, and he cannot be convinced. To hold the beginning of life as an arbitrary act of creation is to break with the whole theory of cognition."

The notion that blind forces of nature converted non-living matter into living organisms arose at a time when the great complexity of the simplest organisms was not appreciated. Now that this is realised, Sir Gowland Hopkins may well be right in thinking that " most biologists, having agreed that life's advent was at once the most improbable and significant event in the history of the universe, are content for the present to leave the matter there."

Leaving out the question of origin, the evidence for the theory that all existing plants and animals are descended from simple one celled organisms is, to say the most for it, very meagre. It amounts to little more than that the earliest known fossiliferous

rocks contain no fossils of many of the highly-organised animals and plants now existing. Biologists to-day mostly assert that this fact renders it certain that these animals and plants had not come into existence when the rocks which lack their fossils were laid down. This may be the case, but it is not necessarily so. It may merely indicate that none of these organisms at that time dwelt in any of the many areas in which the rocks known to us were laid down. Two very important facts have been overlooked by men of science. First, that nearly all the marine rocks known to us contain matter derived from the land, showing that they were laid down at no great distance from the shore : thus the fossils they hold represent denizens of the shallow seas, and they tell little, if anything, of the creatures confined to the open ocean. Secondly, rocks exposed to the atmosphere are subject to continual erosion and in time become weathered out of existence, unless they become submerged beneath the sea and there protected from sub-aerial denudation. This submersion is likely to happen only to rocks laid down near the sea, or at low elevations. Therefore the fossils of the ancient land rocks that have been preserved are those of the inhabitants of the lowlands. Such rocks tell us little of the plants and animals of the uplands. Thus it is possible that the late appearence in the rocks known to us of the fossils of any group of animals is due to the fact that their early habitat was the open ocean or the highlands. The rocks thus certainly do not afford *proof* that the animals now living are descended from any of those of which fossils have been found in very ancient rocks.

But the fossils do tell us that a great many kinds of animals and plants have become extinct. If all the animals and plants now existing came into existence at the same time as those that are extinct, the present floras and faunas are meagre compared with those of the early ages of the earth, and this would mean that the organic world, like the inorganic, is subject to the law of entropy. At present this can be regarded only as a possibility—but it is one which should not be ignored. Evolution may be a myth. In this connection let me here repeat the dictum of Vavilov : " the ocean of knowledge is practically untouched by biologists."

In conclusion, I ask you to pass a hearty vote of thanks to Dr. Clark for his most valuable paper ; I am sure you will all agree with

me in expressing the fervent hope that he will favour this Institute with many more papers.

Dr. F. T. FARMER said: I think the Institute should be proud to have so fine a thesis as Dr. Clark has just presented. I have been greatly impressed by its scientific value, the large weight of experimental data of all kinds which is brought to bear on the subject, and the clear logical way in which Dr. Clark has put the ideas forward. I should like to add my warmest thanks to Dr. Clark.

One point of general character strikes me. The problem is one of life. And unfortunately, when all is said and done we haven't the slightest idea what life is—what it is that differentiates a certain complicated collection of atoms from a living cell. And it is this which has been the overwhelming barrier against which biologists have striven, as well as being the cloak which has covered their rather careless attitude to physical laws. Dr. Clark has shown how they have disregarded the second law of thermodynamics despite a large weight of evidence for its general validity; yet I think we don't always appreciate the line of thought which has led up to this.

Suppose, for instance, we see two identical ants walking along on a slope. One turns to the right up the slope and converts heat into work. The other turns to the left down the slope and converts work into heat. Why this divergence? There is no parallel in ordinary material systems, and biologists may, with some right, question the law of direction of energy change. Again, we look at two cells under a microscope. They seem exactly similar in every detail. Yet as we observe one will assimilate material from its surroundings and grow and divide; the other will just disintegrate—the one is alive, the other is dead. Again there is no parallel in the world of ordinary matter. Step by step it has been shown that physical and chemical laws govern more and more of the mechanisms of the body, such as digestion, etc., as Dr. Clark has pointed out, and he has given good reason to believe that wherever the processes of life can be unravelled, they conform to the entropy law. But let us be cautious in our statements regarding the general application of the law. Can we be *sure* that the element of *soul* and *mind* in a living cell, which in large scale living beings is alone capable of defying the entropy law, is not in

some mysterious way responsible for the ordering of matter that exists in it ?

One point further. The second law states that the entropy of a system cannot decrease. In practice it is always found to increase—there is always that little bit of friction or disturbance which makes a process thermodynamically irreversible. In biology it is the same. Dr. Clark has pointed out how even the molecular structure of living organisms tends to degenerate to a more stable form, resulting eventually in death. But there is one exception. The germ cells, which pass on the characteristics of a species from one generation to another, do not show any such decay or only the minutest amount even over hundreds of generations. The astounding thing to my mind is not that characteristics are changed by mutations from time to time, but that these changes are so infinitely small in relation to the whole complex organisation which the cells contain and pass on from one generation to another. Why do they not degenerate like the rest ? How do they stand up to the disordering influences that bear on all the rest of the body ? It seems that one thing may be concluded : that where life exists order *may* be preserved practically without loss ; as soon as life ceases the complex structures immediately lose their ordered state and degenerate at once to more typical and probable states.

Written Communications.

Lt.-Col. L. M. Davies wrote : This is an excellent paper, most interesting and timely. In dealing with evolution theory from the standpoint of his own special knowledge of chemistry, etc., Dr. Clark offers a discussion of peculiar value to those who approach the same subject from other angles. Not being a chemist, I will offer no detailed comment on what he says ; but I can underline his reference to evolution as being " a biological theory about non-observable facts of past history "—a fundamental truth which should never be forgotten when discussing the subject—and express peculiar interest in the fact that he protests against biologists " adopting an attitude wholly dissimilar to that adopted by scientists in other fields."

It is perhaps significant that, without any knowledge of Dr. Clark's paper, Mr. Dewar and I have been similarly insisting that

the truth of evolution cannot be empirically established, since it concerns ancient history; and, after discussing the subject as zoologist and palaeontologist respectively, we have expressed the very opinion which Dr. Clark voices, namely, that evolutionary biologists adopt methods which are not scientific, and are never seen in other departments of research ("Science and the B.B.C.," by Dewar and Davies, *Nineteenth Century*, April, 1943, pp. 167–173).

It is of course only a coincidence that Dr. Clark's paper and ours should appear almost simultaneously; but those who regard evolution as proved might do well to study both Dr. Clark's arguments and ours, compare their totally different natures with their identical conclusions, and judge whether such convergence of testimony from different angles does not indicate the truth of the common finding, that the doctrine of organic evolution is not demonstrably true, and is not even founded upon scientific argumentation.

The Rev. Principal H. S. CURR wrote: While disclaiming all knowledge of science except in its most elementary forms, I may venture to make one or two observations on Dr. Clark's paper which is characterised by that lucidity and thoroughness which he has accustomed the Victoria Institute to expect from him. The perusal of the paper has been a source of abounding pleasure and profit.

The general argument seems to be an expansion and development of the truth expressed in the old saying that water cannot rise higher than its own level. In the same strain one recalls the Latin adage, *Ex nihilo nihil fit.* The consequences are but the unfolding of the causes. To my thinking, the principle needs a wider examination than it receives in the paper. The case of a corn of wheat falling into the ground and dying is a case in point. It bears much fruit, thirtyfold, sixtyfold, and a hundredfold. Dr. Clark is much better qualified than I am to do justice to these incredible returns, representing percentages which are simply staggering in their magnitude. Yet their origin, source, and sufficient cause is a single grain. Would it not be well to speak cautiously of possibilities and potentialities in view of such facts? A similar conclusion is reached when we contemplate the emergence of human genius. How is Plato, to whom the paper refers, to be explained by reference to his heredity or environment, even if these expressions be interpreted in the widest possible sense? The same may be said with even greater force of

Shakespeare or Bunyan. For myself, I am well satisfied with the doctrine that the hand of God may be traced in all these things. The applications of the doctrine of entropy to the unsearchable resources of the Creator offers food for edifying reflection.

I am separated at present from my library so that I am unable to state exactly Lord Kelvin's argument for the comparatively recent appearance of our planet on the grounds that such a theory was demanded by the second law of thermodynamics. If my recollections be correct, this line of reasoning has been used to invalidate the doctrine of evolution since it demands an immeasurable period for the production of the globe on which we live.

Dr. Clark has recalled attention to a profound truth in his reference to recalescence, the scientific designation for the fact that, when a piece of red-hot iron is cooling, it suddenly turns hotter at a certain stage, only to resume the former process within a short interval. That surely applies with even greater force to the moral and spiritual spheres. Thus one is tempted to wonder if the present war be not an instance of moral recalescence. In the personal and national affairs of all civilised nations, appeals to arms have long since been reduced to vanishing point. Duelling is now very uncommon indeed. One would fain hope in the interests of world welfare and happiness that there is a similar trend in international affairs, bending towards saner and surer modes of settling disputes, and that the present war is an instance of recalescence in the history of international relations.

Sir AMBROSE FLEMING wrote: This paper, in my opinion, is one of the most valuable and instructive that the Victoria Institute has received of late years. It opens up a new line of thought; and one wishes it could be republished in some journal where it would certainly be read by all naturalists, especially those who believe in and advocate the theory of evolution. As Dr. Clark suggests, it is desirable to extend the meaning of the word "entropy" and make it synonymous with a tendency to "disorder" generally. In all our experience of natural phenomena we find a general tendency to disorder, but in no case a tendency for that disorder to cure itself and produce order or to overcome disorder in one field spontaneously by disorder in another. So firmly is this fixed in our experience that even the most unscientific minds would greet with ridicule any contradiction of it. The pebbles on a sea beach are of all colours,

shapes and sizes; and that disorder tends to increase with time. If we were to find on any occasion these stones arranged in an orderly pattern, no one, capable of serious thought, would admit that this order was the result of the action, say, of the waves. They would at once say, "Who did this?" and not "What did this?" And there is a wide distinction between *who* and *what*.

The only agency which can overcome this "entropic" tendency in the phenomena of the universe is "intelligence." The little word "who" implies a personal intelligent agent which has the power of conception of order and power to create it and appreciate it. The tendency or effort of much biological thought and literature is to seek for originative causes which are non-intelligent but automatic, and, when applied to the universe as a whole, this denies the existence or necessity for a self-conscious and intelligent First Cause to which the appellation "God" is given. The convenient word "evolution" has been coined in past time to meet the requirement of language for a term which can convey the conception of an originative cause without any implication of intelligence in it. But when sufficiently considered, it will be seen, as Dr. Clark says, "It would be reckless indeed to see in evolution a self-ordering principle in Nature which runs contrary to the entropy law." Nothing can overcome the law of entropy but the order making power of intelligence, and to attempt to interpret the phenomena of Nature, whilst denying the necessity for intelligence in its origin and progress, is as impossible as it is to understand it properly if we deny the reality of energy, force or action in its manifestations.

This paper by Dr. Clark is then a most timely and useful contribution to the *Transactions* of the Victoria Institute because its philosophical character make it very acceptable to a Society the second title of which is the Philosophical Society of Great Britain.

Professor A. PIERSON KELLEY wrote: Dr. Robert E. D. Clark's paper on "Evolution and Entropy" is a valuable paper that, without attacking evolution, removes the foundation from under that hypothesis.

Dr. Clark very well says: "The mechanistic biologist is at pains to show that the laws of physics and chemistry are applicable to biology; he has, therefore, no right to postulate a law of increasing complexity in defiance of those sciences."

I am glad that Dr. Clark calls attention to the abandonment, by Goldschmidt, among others, of belief in transformism by mutation. Several years ago Leonard Darwin called upon an infinitude of small mutations as the *dernier resort* of Darwinism ; and, as we all know, Darwinian evolution is the very cornerstone of the present Russian system of thought. Now, if mutations " of the ordinary kind " are proved non-existent, the effect on Darwinian evolution is self-apparent.

Weighing evolution as a philosophy, as Dr. Clark does in this paper, and as Hahn did long ago, is of the greatest value to those who are candid enough to value truth.