BIOLOGY AND MARXISM

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BY

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FOREWORD

To be entrusted with the task of introducing this translation to English readers, the first work in that language [1] on biology and Marxism, must be regarded as no small honour. There are other English men of science who would perhaps have carried it out much better than I can hope to do. Sir Peter Chalmers Mitchell gives us the example of a biologist of the last century, the contemporary of figures now almost legendary, such as Ray Lankester and Michael Foster, who after a lifetime devoted to the scientific care of the London Zoological Gardens ending in the achievement of the great park of Whipsnade, concluded in his Spanish retirement that communism represents the next stage of civilisation at which man must aim, and proclaimed this to be so in the courageous last chapter of his Autobiography.[2] Professor J. B. S. Haldane, equally at home in all departments of biology, shows us the meaning of the unity of theory and practice; while Professor J. D. Bernal, whose discourses, as yet very insufficiently printed, have illumined many a fascinated audience, could elucidate, none better, the dialectic flow of physical and biological evolution. But the invitation came to me doubtless for two reasons, first, because I have from the beginning of my scientific work made a study of theoretical biology, and secondly, because I have the privilege of the personal acquaintance of Professor Marcel Prenant.

[1] Certain chapters, however, in R. L. Worrall's "The Outlook of Science" (Bale, London, 1933), are not without value.

[2] "Fullness of Days" (London, 1937).

It was in 1925 that I arrived one day in early summer for a period of work at the Marine Biological Station at Roscoff in Brittany, and there I found Prenant as sub-director, the son of a most distinguished father, Auguste Prenant the histologist. Throughout a very enjoyable period of work we collected animals, made experiments, and discussed biological topics together, in the most academic isolation, almost unconscious of any links between our problems and those of social and economic life. What first awakened Prenant to the connection between biology, philosophy, and politics (for every sociological change has a political aspect) I do not know, but for many of us in England it was the experience of the General Strike in the following year that forced upon our attention the relations of men with men and with the Nature which should be their fruitful source of good, but which in this still barbarous age is too often the source of strife between the possessing and the dispossessed. If we look through the whole of evolutionary history, as Prenant, for instance, does in the book now before us, we cannot but see a progressive rise in level of organisation, exceedingly slow but also very certain. Why should it have stopped with us? In the past there were definite points of change, definite triumphs: the first attainment of a stable internal medium, the first vertebral column, the first plough. May we not expect future advances of technique: perhaps the first stratosphere flight or the final conquest of cancer? Similarly in the past small groups of tribes combined to form peoples and peoples were welded into empires. May we not expect the abolition of national sovereignties and the coming of the classless world-republic? But anyone who reasons thus is driven to think of man on the grand scale, not just the small circle of those who share the habits and prejudices of his own upbringing; and as the vast majority of men are working men, earning their daily bread under the shadow of an economic system which has other ends than their happiness, he is driven first to study and then to aid as best he can the great working-class movement of the world.

In England the working-class movement has traditionally been averse from all theory, and some of its leaders have even boasted that they had no philosophy. Yet by a curious paradox it was a London scholar and a Manchester business man (though German, it is true, by origin) who laid the foundations of the philosophy, the economic system, and the theory of history by means of which the working class becomes conscious of its mission—the abolition of all classes and the replacement of the exploitation of men by the administration of things. Marx and Engels, as the most cursory glance through their writings and their letters to each other will show, had a sort of universal genius which enabled them to understand very well what was going on in the sciences of their time, and to this biology was no exception. Hence in the present book Prenant is able to give some quotations of great historical interest. But his main thesis is, of course, that the Marxist philosophy of dialectical materialism, being a sort of quintessence of the scientific method itself, is able to help the biologist both by pointing the way towards the kind of hypotheses which it will be most profitable for him to form and by indicating which questions are meaningless and which are answerable. Terms such as the "negation of negation" and the "inter-penetration of opposites" are often derided by those who have reasons of their own for doing so, but the technical terminology of any philosophy always appears a particularly uncouth jargon to those who have given it no study. Prenant has let the facts speak for themselves, knowing that nothing is more dialectical than Nature. He has emphasised from time to time the value of dialectical thought in the concrete problems of biology. But I might add two examples which show particularly clearly the value of the concept of dialectical level.

As a matter of personal experience, the years after the war were occupied with a study of the origin and historical development of the classical controversy between vitalists and mechanists. Since my sort of biology was biochemistry, this difficulty was unavoidable. Could the phenomena of life be explained by known physico-chemical laws or by laws congruent with them to be later discovered ? Together with a group of colleagues under the leadership of Dr. J. H. Woodger, we came to the conclusion that life phenomena constituted a separate level from the inorganic world on account, and only on account, of its exceedingly complex degree of organisation. The mechanists had been entirely right in opposing hypotheses of vital forces, entelechies, etc. The vitalists had done good service in persistently drawing attention to the phenomena of organisation. Just as the liquid crystal state has laws which do not operate for other forms of matter, such as liquids or true crystals, so the laws of the living cell, though eventually perfectly comprehensible, simply do not operate elsewhere. We then found that this was precisely the position of dialectical materialists : life constituted a new dialectical level, not inscrutable, but not to be forced into the framework of laws operative at the lower levels.

The second example has more practical bearing on human life. The forcing of a higher dialectical level into the framework of laws operative at lower levels is the cardinal heresy of fascist theory. I use the word " heresy " advisedly, for Athanasius, who believed that the universe was governed by a committee, could have been no more firmly convinced that the Arian heresy of monotheistic dictatorship was dangerous to man. The fascist philosophers, whatever their assurances may be, recognise at bottom no categories other than those of biology. National imperialist ambition is to be founded on theories of racial superiority, and that these are utterly erroneous is not here the issue : the point is that they are, or wish to be, purely biological.[1] The principle of leadership from above is founded on a pessimistic valuation of human psychological capacity.[2] The totalitarian principle depends on the analogy between society and a metazoan organism or between society and a hive of colonial hymenoptera.[3] Totalitarian war is justified on the ground of an assumed struggle for existence between the national states of to-day, regarded as ultimate biological organisms, as if a centrally controlled world population were not yet a possibility.[4] Aerial warfare on civilian populations is claimed as a eugenic measure since the crowded dwellings of the "lower" classes suffer most severely.[5] An eminent (and presumably responsible) biologist in a democratic country can propose the wholesale sterilisation of the unemployed as "unfit," on the basis of a flimsy analogy with wild populations of lower mammals.[6] English sympathisers with Fascism, such as Sir Arnold Wilson at a recent conference of Modern Churchmen, praise the fascist states precisely because they and they alone are striving to build human society upon a sound

[1] Cf. Paul Brohmer, "Mensch-Natur-Staat ; Grundlinien einer nationalsozialistischen Biologie" (Frankfurt a/M., 1935).

[2] L. Klages, "Grundlagen d. Charakterkunde" (Leipzig, 1928) and A. Rosenberg, "Der Mythus d. 20ten Jahrhunderts" (Münich, 1934), also "Blut u. Ehre" (Münich, 1934).

[3] Cf. E. B. Ashton, "The Fascist, his State and Mind" (London, 1937).

[4] General Ludendorff, "The Nation at War" (Hutchinson, London, 1936).

[5] Major Erich Suchsland, *Archiv. f. Rassen u. Gesellschaftsbiologie*, 1936.

[6] Prof. E. W. MacBride, *Nature*, 1935, **137**, 44.

biological basis.[1] This is not merely nonsense, it is nonsense dangerous for civilisation. Man did not arise from the animals by building himself upon a sound biological basis. He had that already. Man's society must be built upon a sound sociological basis. Obviously there must be a fundamental place for biological and also for chemical and physical considerations, but man differs from the animals in the possession of highly developed consciousness and the utilisation of tools for the production of the means of life. He in his societies therefore constitutes a higher dialectical level, not to be forced into the framework of lower levels. Thus fascist philosophy runs counter to the entire trend of evolution, and if we may judge from the past it will perish like everything else which resists this trend. But the suffering involved in the process may well be incalculable.

All this and many other things besides will be found in Prenant's book. As might be expected, there are various minor points on which I do not find myself in complete agreement with him and others which I should not have put in quite the same way. Dialectical materialism is so sharp an instrument that although there can be no question about its value as a general system, the detailed application of it must always be a delicate and difficult matter, in which dogmatism must at all costs be avoided. Specific interpretations, if made with undue confidence, may be dangerous. For example, most biologists believe, at any rate, that during the recent discussions on genetics in the U.S.S.R. classical gene theory has suffered some criticism which was not well based. The further discussions and experiments which are still going on, and for which, as for all other branches of science, the U.S.S.R. offers more

[1] Sir Arnold Wilson, *Modern Churchman*, 1937, **27**, 339.

material support than any other human community, will assuredly in due course put matters straight.

As for Prenant's book, it has received widespread approbation and Soviet biologists have recommended that it be translated into Russian. It is certain that the book will be valuable to many an English-speaking student as a pocket companion to the technical material which he has to master, and to older biologists as a stimulating aid in the consideration of their problems, both special and general.

J. N.

Tamaris, 25/9/37.

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NOTE

References in the text are given to the following editions (title in English if translated):

K. MARX

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INTRODUCTION

I

In the world of 1938 the teaching of Karl Marx is an ideological force of profound significance. By its accurate forecast of the decay of capitalism and its every day more brilliant successes in the U.S.S.R., it is forced upon our attention, whether we are attracted to it or not. It can be intensely hated, violently attacked, cleverly bowdlerised . . . it cannot, however, be ignored. The rapidity of its penetration among the working classes and intellectuals has altered out of recognition the pre-war position, when it was possible among a group of socialist students in London or Paris to find not one who had read " Capital."

Its advances have been mainly in the field of economics. For many thinkers, even among those who most sincerely admire the practical successes of communism, dialectical materialism [1] remains a bogy, something separable from its implications, social or scientific. It is associated with intellectual tyranny and accused of destroying the true objectivity of knowledge.

This is not the place, however, to consider whether science can ever attain complete objectivity or whether each historical period does not necessarily impose on it the limitations of its technique and social structure, whether indeed the Independence of the Spirit is not a mere façade cloaking the domination of historical factors.

The object of this book is to show by taking biology

[1] For the definition of dialectical materialism, see Chapters 1 and 5.

as an example that, far from placing tyrannical restrictions on science, dialectical materialism is of the nature of science itself, the experimental method continued without a break, but now not afraid to face its own implications. It is a striking fact that so many of our best empirical biologists find themselves thinking dialectically when they are aiming at a synthesis, but do so only in flashes and fail to keep it up.

"It is possible," said Engels, "to reach this standpoint (the dialectical view of Nature) because the accumulating facts of natural science compel us to do so; but we reach it more easily if we approach the dialectical character of these facts equipped with a consciousness of the laws of dialectical thought."[1]

II

In the first part of the book an attempt will be made to take from modern biology the essential facts on which Marxism in part reposes. Has science shaken or strengthened this basis since the time of Marx and Engels? Are we to-day more or less certain than then of the evolution of living species, that fragment of the dialectic of the world? Are we more or less certain of the recent animal origin of man, the foundation-stone of materialism? What do we know of the beginnings of human society? What, finally, is the relation of man to the world of living things?

This first part with its four chapters is clearly incomplete. Dialectical materialism acquires a comprehensive philosophical meaning only when it draws into its synthesis the totality of knowledge. In the domain of human relations, the social events which we are witnessing prove it more correct every day. Let us hope that some qualified expert will undertake the task of giving us a dialectical introduction to the recent

[1] "Anti-Dühring," p. 19.

prodigious developments in the physical sciences, bringing up to date Chapter V of " Materialism and Empirio-Criticism " and justifying the words of Lenin :[1] " Modern physics has deviated towards idealism principally because physicists ignored the dialectical way of thought." [2] Here, however, we must confine ourselves to the world of living matter.

In the second part the principal problems of biology will be examined from the materialist point of view. It is not only a question of showing that Marxist interpretations fit the facts of modern science : this could be claimed also by any kind of enlightened organicism. It would, however, fail in one essential respect, namely, that it would be incapable of providing sound and fruitful working hypotheses likely to lead to fresh advances in biology. But a review of recent biological problems will also show that an understanding of materialist and dialectical thought would have hastened their solution, and can still do so.

If the empirical biologist rejects vitalism it is precisely because it seems to him unhelpful and barren, even sterilising. His antipathy to it is an implicit illustration of Marx's celebrated Theses on Feuerbach :

> " The question of knowing whether human thought can attain objective truth is not a theoretical but a practical question. It is in practical activity that man can test and demonstrate the truth, that is to say the reality, the power, the accuracy of his thought." [3]

III

I owe some kind of apology to any biologists who may happen to take up this book. It is not, however,

[1] " Materialism and Empirio-Criticism," pp. 211 ff.

[2] See on this, P. Langevin, " Corpuscules et Atomes " (Hermann, Paris, 1933).

[3] " German Ideology," p. 533.

primarily designed for them. They will find in it no new experimental results, no reviews of the literature. Lack of space has made it necessary to restrict its scope to that of a concise exposition of the most important facts and to leave the rest to the numerous technical works, to which it may serve as an introduction. This is not meant to imply that each question does not need studying in detail by the materialist method.[1] Particularly it does not mean that laboratory experiments and, better still, those experiments furnished by the social use of applied science, are not the living sources from which Marxist science flows, and which, as Engels said, must unceasingly modify the formulæ of materialism. But the most urgent need felt and expressed recently by many biologists is some attempt at ordering the mass of material unearthed by empirical science.[2]

Since 1932 I and my students in the Workers' University of Paris have discussed biology every week. With them I have learned much ; at least as much as I have taught them. If one thing has impressed me greatly it is the ease and accuracy with which a good Marxist can handle a scientific question which is quite new to him, putting forward the right objection, stating the problem with precision, placing it in its proper context. From such friendly discussions this book has enormously profited. In return I hope it will prove of some use to the students of Workers' Universities and to all those who, like them, are interested in the study of Marxism.

I have still to make my apologies to the Marxists for the gaps which are certainly to be found in this exposition. In particular difficulties of language have prevented me from making use of Soviet work on the

[1] I have tried to do this for one sort of biological problem in my "Adaptation, Écologie, et Biocœnotique" (Hermann, Paris, 1933).
[2] Woodger, Tzanck, and many others have appreciated this.

relations of biology to Marxism. Time will know how to repair these defects; but it seemed to me that in so far as this book was likely to prove of use, it should appear without delay.

IV

Finally, there is one fundamental objection which has been made to me by many critics. The affirmation, they say, that "there exists an external world on which all thought depends, whereas the contrary is not true" is a mere assumption. The context shows, I hope, that there is nothing fatalistic about this statement; for Marxism has great confidence in the co-ordinated conscious activity of mankind. The statement allows varying degrees of autonomy to mental activity, small or large according to circumstances, and very large in the case of man. What it refuses is the recognition of an origin of mental activity foreign to matter or a development of it independent of matter. The statement is, in fact, monist. Its acceptance or its rejection is not a purely theoretical question, an abstract metaphysical point, as my critics seem to think. It is a question of practice, and the experimental proof of such a monism must be expected to take specific and concrete forms in all departments of human activity.

For me personally, the author of a book on biology such as this, the question takes the following form: Does the book apply a synthetic conception of any value to the realm of living organisms, ranging from the simplest protista to the highest mammals and man? Does it indicate a sure method capable of elucidating various difficult problems in theoretical biology and of suggesting new and fruitful researches? In a word, is it good or bad? If it is bad, we might have to conclude that Marxism was not applicable to biology and had no value as an interpretation of the world. Or, more probably, that its application to biology had here been badly made.

Some biologists, it is true, have told me that the book is good, that it throws new light in various directions. Others have said that someone would have had to have written a book of this kind sooner or later. To them I would say, why did you not write it yourselves ? Why was it not written by the most learned zoologist or the most brilliant experimentalist of our time ? Why was it left to one who just happened to be the earliest in France to study biological problems in the light of dialectical theory ? And how was it that he himself did not perceive the applications of this theory and their place in a general biological view-point till the day when he began to appreciate the Marxist unity of theory and practice ?

The answer is that your method and the whole of your scientific language is encumbered by the debris of outworn metaphysical systems which the advance of science has long since relegated to their due place in the history of thought. The obstacles of your work you surmount, more or less painfully and with difficulty, because in your own special fields you are obliged by the facts to do so ; and in these fields you all behave as " materialists in spite of yourselves." [1] But when you arrive at the marches and debatable lands of your sciences, you invoke all kinds of subtle forces not amenable to investigation, or at the least you are unwilling to deny their existence. You imagine that such forces and notions are indispensable for a wide, synthetic philosophy of biology. Or perhaps you renounce all possibility of such a philosophy. And agnosticism, which might have been described in the rising period of the bourgeoisie as a " shame-faced materialism," has

[1] Lenin's " Shame-faced Materialists " : " Materialism and Empirio-Criticism," p. 251.

become to-day, in the period of its decline, a "shamefaced idealism."

The proof of the pudding is in the eating. Materialist monism is not to be justified by metaphysical arguments, but by the whole of human activity, by the sum-total of individual and collective experience. And biologists who wish to be consistent cannot reject it if they accept the sketch, albeit imperfect, which I have here made of a materialist biology.

If the book is good, it is because it is a Marxist book and not in spite of it. If it is bad, that is not because it is Marxist, but because it is not Marxist enough. Biologists, putting aside all political prejudices of whatever colour, must judge to what extent this new view-point, however inadequately applied, will be a progressive force in biological thought, and the seed of many new researches.

MARCEL PRENANT.

Paris.

PART ONE

THE BIOLOGICAL BASIS OF MARXISM

CHAPTER ONE

EVOLUTION AND DIALECTICS

"The conception was prevalent among the French of the eighteenth century, as well as with Hegel, of Nature as a whole, moving in narrow circles and remaining immutable, with its eternal celestial bodies, as Newton taught, and unalterable species of organic beings as Linnæus taught. In opposition to this conception modern materialism embraces the more recent advances of natural science according to which Nature also has its history in time."—Engels.[1]

(i) THE DEVELOPMENT OF THE WORLD

Marxist philosophy is revolutionary partly because it is dialectical, because it accepts Hegel's principle that the fundamental law of the universe is change. Nothing is final. Whether in the sphere of lifeless matter, of living beings, human society, or mental activity, everything contains within itself the causes that will one day bring about its destruction. And the capitalist system of society is no exception to this rule.

> "Amid the welter of innumerable changes taking place in Nature," says Engels, "the same dialectical laws of motion are in operation as those which in history govern the apparent fortuitousness of events, the same laws as those which similarly form the thread running through the history of the development of human thought, and gradually rise to consciousness in the mind of man."[2]

[1] "Anti-Dühring," p. 31. [2] *Ibid.*, p. 16.

Their dialectical conception of the world was based by Marx and Engels primarily on the scientific study of History, but also on certain advances in the natural sciences which were then fairly recent. First there was Kant's view that the solar system is the result of the condensation of a nebula, a theory later developed mathematically by Laplace and confirmed by the use of the spectroscope in astronomy. This theory, according to Engels, "for the first time began to shake the conception that nature had no history in time."[1] Secondly, there were the great geological discoveries, according to which "in the course of millions of centuries ever new strata are formed and in turn are for the most part destroyed, serving anew for the formation of new strata";[2] the geographical face of the earth having thus incessantly changed throughout millions of centuries. But, above all, there was the theory of the evolution of living species, forgotten since the time of Lamarck, but warmly hailed by Marx and Engels when it received in their time a new form and a new impulse at the hands of Darwin. That its Darwinian form was not final, and even contained, according to Marx's expression, many "crudities" Engels was convinced.

> "The theory of evolution itself is, however, still in a very early stage, and it cannot therefore be doubted that further research will modify in important respects our present conceptions, including strictly Darwinian ones, of the course of the evolution of species."[3]

But the form was not the essential.

What was the essential was that life, like the earth, the solar system, and the entire universe, had a distinct history which was more than a mere eternal cyclic

[1] "Anti-Dühring," p. 68. [2] *Ibid.*, p. 155. [3] *Ibid.*, p. 87.

repetition and showed a really creative process of development. The importance of Darwinism lay in the new and particularly rude blow it struck at the idea of the fixity and immutability of the world. More recent discoveries have in no way weakened the evolutionary doctrine, have rather strengthened it; and this is the first point to establish in considering the relations of biology and Marxism.

(ii) EVOLUTION AS IT OCCURS TO-DAY

The transformation of one living species into another is no longer a mere hypothesis which has to be proved, a theory to be established; it has become an undeniable fact for every educated person, whatever his philosophical views. Even Vialleton's recent book,[1] written against evolution and saturated with religious prejudices, cannot deny that related species can arise as the result of the modification of a common type, according to certain natural laws. Darwin already knew some cases, but since his time there has been a great multiplication of examples of new living forms which have appeared before our very eyes. In his book on variation Guyénot [2] devotes more than seventy pages to a brief enumeration and description of them. Many of these new forms, called mutations, differ very little from the old species which gave rise to them. But what is most important is that the new characters are transmitted by heredity from the outset, according to precise rules.[3]

Thus in the space of twenty years a species of small fly, *Drosophila*, has yielded to Morgan and his co-workers more than four hundred different mutations,

[1] L. Vialleton, "L'Origine des êtres vivants et l'illusion transformiste" (Plon, Paris, 1929).
[2] E. Guyénot, "La Variation" (Doin, Paris, 1924).
[3] See Chapter 10.

differing in the shape of the wings, the disposition of their nervures, the form and colour of the eyes, the form and arrangement of body hairs, shape of head, thorax, abdomen, legs, general colour of the body, and even such physiological characters as fertility and vitality. The well-known Snapdragon (*Antirrhinum*) has given the botanist Baur many hundreds of mutations, which differ from the ordinary type in the form or colour of the flowers, the shape and colour of the leaves, a dwarf stature, etc.

These characters are hereditary, but it is possible to object that they are too small for the mutations to be regarded as distinct species. However, we know of cases where the new characters, equally hereditary, are much more obvious. In 1763 in a bed of strawberry plants there appeared a mutant whose leaves had only one foliole, instead of three like normal strawberries. In 1855 the *Robinia*, or *Acacia* (locust tree), gave a similar mutant whose leaves possessed only one leaflet instead of several. These new forms have perpetuated themselves ever since. There is no doubt that had botanists discovered them and had no idea of their origin, they would have taken them for distinct species. More striking still, Bouvier showed thirty years ago that certain fresh-water shrimps of warm countries can yield in one generation descendants differing so widely that zoologists have no hesitation in classing them not only as separate species but as distinct genera. However these observations may be interpreted in point of detail, it is impossible to escape the conclusion that a mutation can produce an entirely new species.

This last example answers another objection. The majority of known mutations have indeed been observed in the laboratory or under experimental conditions, among domesticated animals or cultivated plants. It can well be asked if they take place equally under natural conditions without human interference. Bouvier's observations prove that they do. Moreover, this is not an isolated case, as many of the mutations of *Drosophila* occur in the wild state as well as in the laboratory; and the same thing has been observed in still other cases.

It is not known for certain if there exist other modes of transformation of species apart from mutations. But there can be no doubt that mutations play a much more frequent part in the modification of species and the establishment of new ones than is often believed. For the moment this statement must be sufficient, leaving until Chapter 11 the question of what additional conditions are required for the establishment of a stable species.

(iii) ARE MUTATIONS LIMITED?

It is not, then, against this point that the opponents of evolution measure their criticisms. What they deny is that a series of mutations, however extended, can have produced *all* of our living species from one or a small group of original species. Vialleton, for example, considers it necessary to invoke divine creation for a large number of types, which he terms "formal types," each of which has been able subsequently to develop to a limited degree into several different species.

In what way does one of Vialleton's formal types differ from a species? An example will explain it. The wing of a bat contains in a different form all the bones and muscles characteristic of the foreleg of a four-footed mammal, and those alone. There are four greatly elongated fingers which support the membrane of the wing, while the thumb is short, free, and bears a claw. The usual pectoral muscle, here of very great power, gives the wing its motive force. What can be said of all parts of the wing can be repeated for the entire organisation of the bat, which is, as anatomists put it, homologous to that of a four-footed mammal.

This much Vialleton is obliged to admit. What he rejects is the conclusion drawn by evolutionists that bats have actually arisen from four-footed mammals as a result of certain modifications of their anatomy. He objects that the mode of action of a wing is quite different from that of a foreleg, that the joints of a leg prohibit movements properly belonging to a wing, and that consequently no leg could ever have undergone modifications which transformed it into a wing.

This argument recalls that of the philosophers who denied the existence of motion because it was impossible for a body to pass from rest into motion. It is nothing more than a sophism, or to put it another way, an example of that "metaphysical" way of thinking stigmatised by Engels, who opposed to it the dialectical method.

> "To the metaphysician, things and their mental images, ideas, are isolated, to be considered one after another, apart from each other, rigid fixed objects of investigation, given once for all. He thinks in absolutely irreconcilable antitheses. His 'communication is Yea, Yea, Nay, Nay for whatsoever is more than these cometh of evil.' For him a thing either exists or it does not exist: it is equally impossible for a thing to be itself and at the same time something else."[1]

Vialleton's metaphysical logic has led him even to a contempt for well-known facts. As far as bats are concerned, he cannot be refuted by showing flying quadrupeds; the mechanical conditions for flight are unfortunately too exacting. But Vialleton would deny, for the same reasons, that a fin could act as a leg, although we know of fish, such as the periophthalmi,

[1] "Anti-Dühring," p. 28. It must be noted that Marx and Engels use the term "metaphysical" simply in the sense of "not dialectical."

whose fins have undergone but very slight anatomical changes, and yet are used as legs on damp ground. He would also deny that a leg could be used as a fin, having apparently forgotten that dogs and horses swim with their legs, and that the same legs serve the frog on land as in the water, the same fins the seal.

> "The metaphysical outlook . . . always reaches a limit beyond which it becomes one-sided, limited, abstract, and loses its way in insoluble contradictions. And this is so because in considering individual things it loses sight of their connections; in contemplating their existence it forgets their coming into being and passing away; in looking at them at rest it leaves their motion out of account, because it cannot see the wood for the trees." [1]

The modification of a species is only possible, then, according to Vialleton, if the new characters have no practical functional value—if, for example, they are merely a matter of colour or ornamentation. The members of the feline family (cats, lions, tigers, etc.) can have appeared by the modification of a single original type; but the original families, felines, bears, dogs, squirrels, civets, hyenas, cannot have ancestors in common, and must be regarded as so many formal types.[2] On this basis, taking the number of present species as approaching a million, corresponding formal types must number tens of thousands; if extinct species are included, however, they must have been created by the million.

This conclusion, the feebleness of which is made obvious in this way, represents what is to-day the most reactionary position with regard to evolution. The only object in mentioning it is to put the lay reader on his guard against it.

[1] "Anti-Dühring," p. 28.
[2] Vialleton, *loc. cit.*, p. 201.

But even among the best of our present-day biologists there can be seen a tendency towards scientific defeatism which is much more serious. Men like Caullery and Guyénot [1] have come to the conclusion that mutations such as we know them, however numerous we suppose them to have been, cannot explain the whole evolution of life. Mutations, they say, never go beyond modifying existing organs or, more strictly speaking, making them disappear; we know no cases where anything new is created. Also it is quite impossible for mutations to have given rise, for example, to the limbs so characteristic of the majority of vertebrates, or the wings of insects, or to have produced a functioning eye, or the innumerable inter-connecting fibres of a brain. They could only begin to alter these organs in their ready-made state.

This objection bears some similarity to that of Vialleton. Like his it leads to the conclusion that variability by mutations is limited to certain types of organisation, such as that of the vertebrate with four limbs, the winged insect, etc., the origin of these types remaining unknown.

But unlike that of Vialleton, this objection rests on a scientific foundation. First there is no suggestion here that the origin of these types of organisation is supernatural and unfathomable. And second, because the amount of variability allowed is greatly extended, the number of types which remain for the time being an enigma for biologists is reduced from a matter of some millions to a few score or hundreds. This problem can only be satisfactorily dealt with in Chapter 11, after the discussion of apparently quite other questions, but some observations can be made at this stage. First, is there such a difference between the modification and the formation of an organ? Is not this mainly an

[1] Also A. H. Clark, "Zoogenesis" (London, 1930).

argument over words which becomes much less important when we think dialectically about the realities which words represent ? When, for example, an organ is modified by a mutation, does this not mean that certain of its parts have disappeared while others have appeared which did not exist previously ? And has not the mutation therefore, created something, whatever we say ?

But that is not all. When we speak of an organ being modified or created we naturally think of it in its adult and final stage, that in which it performs its full function. But study of the development of the forms of living beings shows us that this adult state has to all appearances nothing in common with that in which it first appeared, in particular, the egg. In fact, the " creation " of an organ can very well result from a " modification " in an egg. Here again dialectical thought, which tries to understand the object in its development, can perhaps enable us to avoid a verbal conflict between conceptions which are themselves too rigid.

In short, without underestimating the importance of the objection we are discussing, we must not take it too literally. It is evidence of a gap in our knowledge much more than of a difficulty of principle.

(iv) PALÆONTOLOGICAL PROOFS OF EVOLUTION

We have seen on page 4 that a whole number of new forms have appeared during the time that naturalists have investigated them ; that is to say, during the last two or three centuries at most. But it is clear that the much greater modifications demanded by the generalised theory of evolution go far beyond this short period, indeed far beyond the whole historical period. It is, therefore, useless to contend, as some have done, that animals have scarcely changed since the time of ancient Egypt. But nor is it any longer necessary to express evolution, as its popularisers have too often done, in such phrases as " men are descended from monkeys." The great majority of living species are descended, indeed, not from other living species but from species which have disappeared, and these must be interposed before it is possible to trace any descent whatever.

Extinct species are known by fossils which are discovered in the strata of the earth. They are composed of remains (usually of shells, teeth, bones) which have been buried in mud, sand, or earth, have been petrified where they lay, and have been preserved through the ages by the consolidation of the deposits into rocks.

We are thus acquainted with fossils the oldest of which in the opinion of geologists date back millions of centuries. Physicists by quite different processes estimate their age at more than a thousand million years.[1] The two evaluations agree quite well, though neither of them can be worked out very precisely, and they give no more than an order of magnitude, which is roughly the same in each case.

Since this epoch, the most ancient in which life can be traced, the study of fossils shows that the fauna and flora have been replaced many times. Not only innumerable species but very important groups have appeared and disappeared. These changes, linked with those which have at the same time altered the configuration of the globe, have enabled us to subdivide geological history, from the time of the first known fossils to the present day, into four great eras of very unequal duration.

The earliest of these, the Primary, lasted by far the longest. During millions of centuries two enormous chains of mountains were successively formed, and some of the most ancient groups, like the Trilobites, appeared

[1] See Vernadsky's " Les Problèmes de la Radiogeologie " (Hermann, Paris, 1934).

and then completely disappeared. It was about this time that the first fish arose, very different from ours; and towards the end of the period the first amphibians and reptiles and the first higher plants, analogous to ferns.

The Secondary era which followed lasted only tens of millions of years. During this time the land was dominated by innumerable grotesque and gigantic reptiles. Some of these flew like bats (*Pterosaurus*), others swam like whales in the sea (*Icthyosaurus*); but the ocean was principally inhabited by ammonites, molluscs somewhat resembling the octopus, the earliest species of which had already appeared in the Primary period. Towards the end of the Secondary, however, the ammonites and huge reptiles totally disappeared, until nothing remained of this latter once dominant group but a few reduced forms similar to our lizards, snakes, tortoises, and crocodiles. On the other hand, it was the Secondary era which presented us with the first mammals, birds, and flowering plants.

The Tertiary period, shorter still, lasted only a few millions of years.[1] It was during this period that the so-called "alpine" chains of mountains, including the Alps and the Pyrenees, were built up, and little by little there was established a world geography resembling that of the present day. In the Tertiary seas, moreover, the species of animals, though distinct from ours, were not utterly different. On the land the mammals already predominated, with a luxuriousness and abundance of forms indeed far above that of to-day.

Finally came the Quaternary period, in which we are still living. Its length has not been above a few hundred thousand years; nevertheless this space has sufficed for the appearance and extinction of important animal

[1] Ten million at most, according to Vernadsky (*loc. cit.*). It is again only a question of order of magnitude.

species. Strictly speaking, the Quaternary is merely a prolongation of the Tertiary, but the distinction is made because it is the Quaternary which has seen, if not perhaps the first appearance, at least the expansion of man.

The foregoing rather schematic history takes account only of the most important groups ; but from it we can draw several important conclusions with regard to the evolution of life.

First, the various groups come into existence, reach their zenith, and then die away. It is so, for instance, with the ammonites which appear towards the middle of the Primary, attain an enormous development in the whole Secondary, but utterly fail to survive it. Reptiles, appearing at the close of the Primary, have a similar history, particularly when considered in their separate groups ; out of the whole, however, only a few impoverished forms have survived to our own day, and the same thing applies to countless other groups.

Species have a still more restricted span. Each one appears, flourishes, and declines in a time which on the average is not above a few hundred thousand years. Consequently since the beginning of the primary there has been time for at least several hundred generations of species.

Finally, the groups do not follow each other at random. As a general rule, *those whose organisation is most complex arrive latest.* The only plants known at the close of the Primary are inferior types resembling seaweeds ; then come more complex forms similar to our ferns ; towards the boundary of the Primary and Secondary come the first conifers ; finally, at the close of the Secondary the higher flowering plants. This order is exactly what a biologist would expect from anatomical theory alone. The same applies to the vertebrates ; first come the fish, towards the middle of the Primary ; they are followed by amphibians and reptiles, and then mammals and birds arise in the Secondary.

The incontestability of this increasing complexity in so many groups lends strong support to the theory of evolution. In order to explain it on his views, Vialleton is forced to declare that the creation of species was governed by a complete plan conceived at the outset by the creator, who proceeded in order from simple to complex. Evolution has indeed occurred, but under supernatural guidance. Here, however, we say good-bye to scientific explanations.

How does it come about that this increasing complexity does not exhibit itself in all groups? How is it that the earliest living beings we know, those of the dawn of the Primary, are far from being extremely simple things, but comprise such complex creatures as crustaceans and molluscs? This difficulty seems at times to disturb even the most experienced biologists. But the reply is not hard to find. Geologists have long known that the strata of the early Primary are far from the earliest which may have been fossil-bearing. Since then, however, the preceding strata have suffered the modifications summarised in the word "metamorphism." Buried at great depths in the crust of the earth, subjected to intense heat and enormous pressures, acted upon by various gases, they have undergone crystallisation and become what are now granites, gneiss, mica schists, etc., in which all fossils have perished. Even in these strata, nevertheless, we can sometimes detect faint traces of life which have to a certain extent survived the general destruction.

It is impossible to estimate even approximately the length of the period of time which preceded the Primary, which may be thought of as the prehistory of the earth. In the strata which correspond to it geologists have, by patiently piecing together the data, recognised the traces of six great mountain chains. When it is remembered that no more than three have existed since the Primary began, it becomes probable that the part of that prehistory of which we have some record has lasted not more than twice as long as all subsequent ages put together. Physicists have computed the age of the oldest metamorphic rocks as something like two thousand million years. But even then nothing goes to show that these were the earliest, and everything points to the contrary.

For the last hundred years each new geological discovery has tended to lengthen enormously our estimate of the time in which evolution has been able to act. There is thus no reason to be surprised that the fauna of the early Primary was so rich and varied. It is now no longer necessary to suppose, as some biologists have done, that the rate of evolution has slackened ; of the four great branches of plants and eight of animals distinguished by biologists, only three have appeared in the period of time we know well, that is to say, in the last thousand million years. It is such vital points as this which can give a well-balanced appreciation of the antiquity of life and of the relative shallowness of human penetration into it.

As has been said above, we know nothing of the first living beings that inhabited the globe. Not only were they certainly very small and soft, and therefore not readily fossilised, but also the rocks which may have contained their relics have doubtless completely disappeared.

In a schematic way the descent of biological groups can be represented by a kind of genealogical tree with more or less regular branchings. To what degree do fossils enable us to follow the detail of this tree ? In particular, is it possible to pass from one species to another by differences small enough to be bridged by mutations ?

In certain cases this is possible. It is possible with the molluscs, whose evolution can be followed step by step from the first to the last strata containing them. It is possible in the Tertiary beds for the ancestors of horses, elephants, and other mammals.

For the several million years from early Tertiary to our own times, it is possible to establish, from the structure of the feet, skull, jaws, teeth, the stature, and other particulars, a series of a dozen stages which link primitive mammals to our modern highly specialised horses. In this series the feet, for example, first have five toes, then four, then three, of which the lateral ones become steadily smaller before disappearing; while the foot comes to stand more and more on the extremity of the middle toe. Out from this series, which continues into our own time, there fork all manner of lateral branches whose corresponding species have disappeared long ago.

It is often urged against the reconstruction of such series that there is nothing to prove that they represent actual lines of descent. It is certainly impossible to return several million years into the past in order to be present at the origin of some species in the series. But the problem can be stated in another way. The theory of evolution demands a host of intermediate forms spaced out between primitive mammals and our modern horses. The fact that these forms are to be found regularly distributed in time is surely a verification of the theory.

Obviously all genealogical series have not been worked out to the same perfection of detail. Many of them show gaps. It would be surprising if they did not. Of the great mass of animals and plants existing at a given time very few reach the fossil state. The greater number disappear without trace. It is only necessary to think of the multitude of shells which are broken and destroyed on the sea-shore; all the skeletons which crumble above ground; and, above all, of the soft animals like worms and jellyfishes, which are completely destroyed except under very exceptional circumstances. Added to this is the fact that the places from which the fossils can be recovered are not very extensive (quarries, mines, cuttings, cliffs), and it is, indeed, only by chance that they are encountered. There is therefore nothing strange in the fact that our knowledge suffers from huge gaps.

It is useful to obtain a clear idea of these gaps, as they are frequently discussed without much preciseness. The evolutionist maintains that they are considerable, but his opponents do their best to minimise them.

One of the arguments of the latter is that at the beginning of the Primary the fauna and flora was just as rich as it is at present. We have seen that they are probably correct on this point. But we have also seen that since this time the species have probably been replaced several hundred times over. If there are nearly a million species living to-day several hundred million ought to be discoverable in the fossil state. In actual fact the number of fossil species we actually know is scarcely two hundred thousand—about one in a thousand.

It can be objected, of course, that in this calculation the soft animals are included though they leave scarcely any fossils and that the proportion would have been very different if we had considered molluscs or vertebrates by themselves. But let us take fish, for example. The group was already very widespread by the middle of the Primary, and it can be estimated that one or two hundred million years ago it was as rich in species as it is to-day. According to our calculation, therefore, there should then have existed about 500,000 species of fish, all of which should be found to-day in the fossil state. However, 15,000 at the outside are known—that is, one in thirty.

There are, therefore, enormous gaps in our knowledge. Our information is gathered from odd places, thanks to happy chances. This is particularly true in the case of those fossil species which are known by one specimen only. The first fossil birds of the Secondary era, of the genus *Archeopteryx*, strange creatures provided with teeth, recalling reptiles in almost all points of their anatomy, are known by only three specimens. The first bird to be found after them is later by several million years and is known by only a single example. Who would suggest, however, that no birds existed throughout this long interval ?

It is, indeed, to be wondered at that in spite of these great gaps, it has been found possible to reconstruct some almost complete genealogical series and to outline a great number of others. All scientific criticism of evolutionary palæontology can be condensed into two simple truths—that a genealogy incompletely known presents gaps, and that these gaps naturally set a limit to a genealogical series whose reconstruction is attempted. At the moment these are the only arguments which can oppose the triumph of evolution.

CHAPTER TWO

EVOLUTION AND MATERIALISM

"Man confronts Nature as one of her own forces." [1]

(i) THE POSITION OF MAN

Marxist philosophy is materialist. By this is simply meant that it declares the existence of the world outside ourselves to be beyond question. All psychical activity depends upon it, while the reverse is not true. Human understanding gradually makes itself master of this outside reality not by contemplating it but by acting upon it, individually and above all socially. The activity is possible because man himself forms a part of Nature and is a product of it. In this sense the animal origin of man is an indispensable part of the materialist theory of knowledge.

Lamarck had hesitated before this essential result of the theory of evolution. Darwin had the courage to assert that man is a product of biological evolution. After furious polemics, this view gained universal assent in scientific circles, and even among theologians it is now scarcely ever questioned.

But some biologists of religious tendencies, though they admit in general that man is physically an animal, insist that he has been endowed with a special soul. Moreover, other biologists hesitate before the psychological and social implications involved by the animal origin of man or fail to see them clearly. Hence a host of problems which must be examined one by one.

[1] "Capital," I, p. 169.

(ii) COMPARISON OF MAN WITH PRESENT-DAY ANTHROPOID APES

There is no doubt that among living animals the most similar to man are the great tail-less apes called anthropoids, the gorilla and chimpanzee in Africa, the orang in Malaysia, and various species of gibbons in Indo-Malaya. Between these and man there are, of course, differences which must be taken into account.

It is sometimes stated as a distinctive character of man that he has two hands, it being supposed that an ape has four. It is true that the big toe of an ape can come face to face with the others, and that the foot is capable of grasping like a hand; but it is not on this account less clearly a foot, quite comparable with the foot of man in the anatomy of the bones and muscles, and very different from a hand; it possesses, for example, the two large bones, astragalus and calcaneum, which exist in the ankle but not in the wrist. As for the opposability of the big toe, it is important functionally but much less anatomically, and there are men and races of men which possess this power also to a more or less marked degree.

The other supposedly essential physical character is two-footedness. True, gorillas, orangs, and chimpanzees cannot stand completely erect like man, but lean lightly on the backs of their hands; true also, they are supported on the outer edges and not on the whole of the foot. Gibbons, however, walk very erect on the flat of their feet, arms swinging, and their aspect is very human. Even the very lowly genus of apes, or rather lemurs, the Indris, display perfect two-footedness, and run with their arms lifted above their heads.

Neither two-footedness nor two-handedness have the decisive importance which some would like to attribute to them. This is not to say that man has no anatomical peculiarities—more powerful leg muscles; broader pelvis; vertebral column with a more complex curvature, permitting the trunk to be more erect; face less elongated; head better balanced on the spinal column, and consequent slight differences in the conformation of the skull and the upper vertebræ.

Compared with the anthropoids man has the greatest cranial cavity, and the heaviest brain by a long way in proportion to the weight of the body. This fact, extremely important as one of the factors that explain his psychological faculties, is perhaps connected with the diminished power of his masticatory muscles, which exert less pressure on the skull during the course of their development. And this diminished power itself is perhaps related to the extended use of the hands throwing less work on the jaws.

The lower jaw of the anthropoids differs from that of man, by the absence of a chin and other characters. They have the same number of teeth as man, and these appear in the same order, both in the case of milk teeth and those which replace them. The teeth are very similar, but specialists can distinguish them without difficulty, and everybody knows that the teeth of anthropoid apes are more or less protruding like fangs. None of these differences are very great. They would appear still smaller if the comparison were made with young apes, where, for example, the face is less protruding. The resemblances are confirmed by physiological similarities. The flow of menstrual blood is a phenomenon peculiar to women and female anthropoid apes, to the exclusion of other apes. Certain serum reactions which only succeed between the blood of two individuals of the same species or of two related species are positive in the case of man and anthropoid apes.[1]

[1] If, for example, the serum of a chimpanzee is injected into a rabbit the blood of the rabbit gives a coagulation with the serum of the chimpanzee, other anthropoid apes, and man, but not with other monkeys or other animals.

On the whole, leaving social and psychological differences for the moment on one side, a fairly accurate statement of the biological situation is given by considering man on the one hand, gibbons on the other, and finally the group of gorillas, orangs, and chimpanzees as constituting three collateral families of anthropoids.

(iii) PALÆONTOLOGICAL FACTS REGARDING THE ORIGIN OF MAN

In the language of evolutionists this means that man is related to living anthropoids, but there can be no question of his being descended from them. The formula "men are descended from monkeys" is a serious over-simplification. Their common ancestors are to be sought in the geological past. The first known anthropoids have been found among the Tertiary beds, and therefore date back about two or three million years. Certain of them closely resemble gibbons; but there are also anthropoids of a little more recent date, which have received the names *Sivapithecus* and *Neopithecus*, whose characters in some respects approach those of man, notably in the structure of their molars. In South Africa in 1925 there was even discovered a young anthropoid (*Australopithecus*) whose skull is remarkable for the size of the brain, the position of the nose in relation to the eye-sockets, and other similarities to man. Unfortunately, we are unable to give the geological date of these remains. In the Quaternary a number of more human fossils are known. The earliest is *Pithecanthropus*, found in Java in 1890, in the most recent beds of the lower Quaternary. Of this species there has been found a thigh-bone of human type indicating perfect two-footedness; teeth resembling those of the orang and man; and finally the top of the skull, which is intermediate in form between that of a gibbon and that of a man, both in form and in its traces of cerebral convolutions.

Since 1927 there have been discovered near Pekin about twenty-five skulls belonging to a creature very closely related to *Pithecanthropus*, but a little more recent (beginning of middle Quaternary)—*Sinanthropus*. Taken as a whole the skull is strictly human, with some simian details; but the chinless lower jaw is like that of a chimpanzee; the teeth, on the other hand, are very similar to those of man, the canine scarcely protruding and the back molar very reduced.

In 1912 there was discovered at Piltdown in England some remains of an anthropoid which was called *Eoanthropus*. The skull is comparable to that of modern man, but the lower jaw and teeth resemble those of a chimpanzee. A second similar find, at Piltdown in 1917, made it clear that these remains were those of a single species. The disharmony between the skull and the face is not more extreme than is observed in *Sinanthropus*. *Eoanthropus* seems to have lived also in Saxony, where two teeth have been found.

Like *Eoanthropus*, the Heidelberg man, discovered in 1908, lived in the middle Quaternary. Only a lower jaw-bone is known, and this is strictly simian, but carries human teeth. Here again the canine is no greater than the other teeth.

Next comes the Neanderthal man, the best known of the extinct human species, towards the end of the middle Quaternary. Since 1856 over forty more or less complete skeletons have been found, ranging from the South of England to Palestine, from the Caucasus to Spain, and even into South Africa. The South African specimens, which are the most recent, must have been contemporary with modern man, while those of Ehringsdorf, the earliest, were almost contemporary with the Heidelberg man.

The Neanderthal men were small in stature, scarcely exceeding five feet. The shape of bones in the thigh and leg shows that they walked with knees bent; the big toe was opposable and the foot probably touched the ground with the outer edge. The highly developed face and the conformation of the skull and upper vertebræ show that the neck was curved forward. The teeth are of a very human type, but the lower jaw displays many simian characteristics. The skull, flattened and provided with enormous cushions of bone above the eye-sockets, has developed a relatively large cranial cavity and very much more marked cerebral convolutions than are found among anthropoids, though these are greatly inferior to those of modern man. Specimens vary a good deal from one bed to another, in the proportions of the skull, the prominence of the bony projections, the details of dental structure, etc.

Several races of *Homo neanderthalensis* must have existed and, especially when young, the most oriental of these could have differed but slightly from some living or extinct races of modern man, for example, the Australian. The present species of man, *Homo sapiens*, is first found in the beginning of the upper Quaternary, though it does not follow from this that it did not exist somewhat earlier. From that epoch the species was subdivided into a number of races which, in France for example, lived side by side. To take only a few examples, the Grimaldi cave men were much akin to the South African bushmen of to-day, and in a more general way to the negroids; the Cro-Magnon, scarcely later, are related to present-day races which are called Caucasian, and more especially to the Basques; those of Chancelade were yellow men very close to the Eskimos. Since then, on the whole, human types have varied but little.

Apart from those of the Neanderthal man and, of course, those of modern man, none of these fossils were known in Darwin's time. The progress of discovery has therefore admirably confirmed his view of the animal origin of man, and this pillar of Marxism is more solid than ever. The series of transitional forms still presents notable gaps, the most serious of which separates *Sivapithecus* or *Australopithecus* from *Pithecanthropus*. But these gaps, which are quite similar to those of all other genealogical series, are every year reduced by the march of fresh discovery.

Here the series of transitions presents a straight-line descent no more than anywhere else. There is no gradual perfection in a single direction, as if a supreme intelligence had decided to make a man out of a monkey. In a number of characters *Pithecanthropus*, *Sinanthropus*, *Eoanthropus*, and the Heidelberg man foreshadow Neanderthal man and the modern species. In drawing this genealogical tree we must give it a bushy character with many branches which reach their full stature at no great height while one of them is continued up to our own time. In this respect human evolution is in no peculiar category.

Another important point—if, as the anti-evolutionists would have it, man is to be defined by his psychological qualities, these have been possessed by several species, even several genera of man, for the Neanderthal man, the Heidelberg man, the *Eoanthropus*, and *Sinanthropus* have all been discovered with traces of fire and implements clearly indicating psychological capacities.

In short, man originated comparatively recently. *Pithecanthropus* cannot be older than a maximum of 200,000 years. Even counting back to *Sivapithecus* we have only one or two million years, a very short time compared with the millions of centuries for which the world has existed. From these scientific results Plekhanov, then Lenin, drew an argument against certain extreme idealist philosophers who believed that the only reality was thought. Human thought indeed appeared only as a product of a very advanced stage of world evolution. But on this subject it is sufficient to refer to Lenin's words,[1] relying on—

> "The instinctive conviction, unconscious, uncrystallised, possessed by the great majority of scientists, of the existence and objective reality of the external world which is reflected by our mind."

[1] "Materialism and Empirio-Criticism," p. 300.

CHAPTER THREE

THE ORIGINS OF HUMAN SOCIETY

" It is possible to distinguish man from the animals by consciousness, religion, or what you will. They themselves begin to distinguish themselves from the animals when they begin to produce their means of existence."—Marx.[1]

(i) ANIMAL SOCIETIES

It can be said to-day that what Marx called " Robinson Crusoe " theories, according to which isolated men consciously assemble so as to reap the benefit of co-operation, have fallen out of vogue. There is no doubt from the standpoint of science that society preceded man, in the form of a society of anthropoids possessing, like human society, a certain level of technical ability. There are many types of animal society, but all have one trait in common—the animals which compose them experience a mutual attraction to one another ; whereas solitary animals avoid one another, or are at least indifferent. In this respect closely related species often behave in quite opposite ways. Indeed, sometimes in a single species the individual is at some periods of his life social, at others solitary ; for example, swallows, which become social for their migration but disperse in separate couples for the nesting season. This attraction or repulsion has a quite material basis, operating through the senses, and no doubt differs only in degree from the attraction exercised for some insects by a bright light. Animal society, whether temporary or permanent, exhibits great variation in point of development and complexity. In the simplest case, that of

[1] " German Ideology," p. 237.

many insects, birds, bats, etc., the uniting of the individuals in a group scarcely modifies their behaviour as individuals ; each individual in a flock of sparrows hops about seeking food on its own account, although through many vicissitudes the flock remains united. The stability of the group is the means of distinguishing a society of a low order from mere crowds of animals brought together fortuitously, as the result of some outside influence, dispersing as soon as that influence ceases—as, for example, moths round a lamp.

The second stage is that when the individuals of a group act in a co-ordinated way, without, however, working upon common tasks or being subjected to a chief or even a guide. This is the case with many migratory birds like swallows or quails. In such groups the synchronisation of movements is often astonishing, as, for example, in the enormous swarms of locusts which take wing or settle in one movement, or in the case of those sea-gulls which seek food on the shores in an orderly way, changing their direction all together and taking wing simultaneously.

Societies in the true sense of the word are groupings of animals which display distinct organisation, whether they carry out work collectively or are subjected to leaders. Such groups have a very stable existence and fuse with other groups of the same species only with difficulty, or even not at all, so that a stray individual is very rarely incorporated into another group.

Collective work is carried out by societies of beavers, for example. These animals build their huts close together beside a watercourse, but, above all, construct by their united labours just below their " village " a dam which raises the water to a suitable level, so that it submerges the entrances to their huts. There is collective work again among the birds known as weaver-birds, which build their very compact nests close together, some species building a thatched roof overhead and various common passageways.

When cut off from society a weaver-bird or beaver is still able to subsist, and the rare beavers of the Camargue in the South of France have lost the art of building and live in the solitary state. The same no longer applies in the case of insect communities; ants, bees, even bumble-bees and wasps have lost the ability to live for long apart from their societies.

A great number of highly coloured descriptions have been written comparing these insect societies to societies of men. Such accounts have done great harm to objective study. Assisted by the jargon of bee-keepers, people have spoken in general terms of queens and workers, kings and soldiers among termites, slaves among ants; they have discovered the supposed equivalents of agriculture, stock raising, war, and even such human failings as drunkenness; the term "communism" has been used. From a consideration of these societies they have even sought to deduce a moral for humanity, according to whether they admire the apparent reign of order or whether they are revolted by the weight of social tyranny apparently pressing on the individual.

All this is beside the point. The constructional works of these societies (hives, ant-hills, termite colonies) appear wonderful because of their great size, but taken in detail they are neither more nor less remarkable than those of some solitary insects. Social activity in these species is no more surprising than the instincts of many non-social insects, and it is of the same order. The so-called queens are only fertile females without any peculiar authority. The terms "worker" and "soldier" have no real value, for in many cases the workers fight and the soldiers do not. All that can be picked out from an objective standpoint are sexual individuals, male and female, and on the other hand asexual individuals, which among termites can be sometimes male, sometimes female, with atrophied sexual organs, and which in other species are always sterile females; these sexless individuals are more or less different from the sexual, and can frequently be still further subdivided into more or less well defined categories, differing in form. Thus comes about the formation of castes [1] within one species, each caste possessing the special instincts which arise from its peculiar functions or succession of functions in society; a worker bee, for example, begins by feeding the larvæ, then at the end of some days assists in the building of wax honeycombs, and finally becomes the familiar honey-gatherer. This history, however, is not radically different from that of a non-social bee.

This sharing out and differentiation of activity in a hive or ant-hill sometimes receives the title of "division of labour." But the term can only be accepted on condition that no analogy is implied with human division of labour. An animal caste whose members are characterised by special morphology bears no relation to a class which is defined by the possession or lack of possession of the means of production. Even when a worker bee undertakes his social activities in succession, the change of function does not alter his social position. The entire process is purely instinctive.

On account of its foundation on instinct, insect society is many times more rigid than human society. It may appear to function as a more perfectly regulated unity, but its individuals are so much more dependent on the perfect working of the whole that sometimes they are even unable to nourish themselves without assistance. The social machinery may be more perfect than in human

[1] That is to say, castes in the biological sense of the word and no in the social sense usually given to it when applied to human society.

society, in a hive, for example, but to hold up such a community as an example for humanity is as childish as to make the machine an ideal for an individual man. Again, to speak of social tyranny in a society whose individuals are devoid of consciousness is quite without meaning.

In insect society, however well organised it may appear and however high the degree of perfection attained by the social labour, there is no evidence of the existence of rulers. In mammalian societies, however, there are signs of internal subordination. These societies frequently contain only females and the young, the males living apart and only mingling with the herd at the time of reproduction; or they may contain among their number a handful of adult males; or, again, one male may make himself master and expel all the others. In some cases the tribe is composed of distinct families, polygamous or otherwise; elsewhere, as among elephants and a number of apes, the sexes are not segregated at all. There is no case, however, in which the tribe can be supposed to have originated in the family, the social instincts in the sexual, these instincts normally compromising as best they can, in very different ways in different species, and often even remaining to a certain degree antagonistic.

Communities of mammals are usually without industry and carry out no collective labour. But the social nature of their activity makes itself very apparent in case of danger. On the approach of wolves, for example, it is possible to see the wild stallions form themselves into a ring around the mares and foals; in similar circumstances the older bulls and cows collect the calves into the centre of the herd and stand guard around them.

From such communities, particularly hordes of apes, human society must have been derived. Among some apes such as *Cynocephalus* social behaviour appears to have reached a stage of exceptionally high consciousness. When the herd is feeding certain of its members are stationed a little distance off in every direction as sentinels to give warning of the approach of enemies. Several of these animals will combine together to lift a large stone for the sake of the insects under it. They fight together against preying animals and protect the weaker individuals of the tribe. Moreover, they are able to throw stones and can make themselves dangerous even to man.

(ii) ORIGINS OF HUMAN LABOUR

Marx many times returned to the idea that the distinguishing characteristic of man is his technical ability :

> " The use and fabrication of instruments of labour, though we find their first beginnings among certain other species of animals, is specifically characteristic of the human labour process, and for that reason Benjamin Franklin defined man as ' a tool-making animal.' " [1]

And again :

> " The precondition for all human history is naturally the existence of living human individuals. The first historic act of these individuals by which they distinguish themselves from other animals is not, however, that they begin to think but that they begin to produce their means of existence. We must therefore first address ourselves to the physical organisation of these individuals and the relations thereby imposed upon them with the rest of Nature. This relation not only governs the organisation of man in his primitive natural state, expressing itself sharply in differences of race, but controls the whole course of his development, or his stagnation, up to the present day." [2]

[1] " Capital," I, p. 172.
[2] " German Ideology," p. 237.

These two quotations contain in a nutshell the essence of historical materialism ; that history is, above all, the evolution of human technical ability acting upon Nature ; all other history, including the history of thought, arises from this one source, directly or indirectly ; but thought in its turn reacts back on history, through the new influence which it brings to bear on the progress of technique.

The key to the understanding of the origin of human society is, therefore, that it arises from animal society when tools are first used and a technique first acquired. As this contention is the very root of historical materialism and is intimately bound up with biological theory, it will be necessary to examine it in more detail.

The prehistoric beginnings of man's use of tools are lost in the mists of the past. Stone tools, of very crude but evidently intentional workmanship, characterise the type of industry known as pre-Chellean, which appears towards the end of the lower Quaternary. But previous to this, from the middle of the Tertiary, the much-discussed split flints called eoliths are found. For the most part their cleavage could have been caused by purely natural forces—sudden shocks or changes of temperature. Some, however, may have been shaped intentionally ; those, for example, shaped like eagle's beaks, from the late Tertiary. But human remains have never yet been found associated with them.

Such are the difficulties which surround the origin of tools. The first were undoubtedly pieces of wood and stone, such as are now collected by certain apes, picked up at random and impossible, therefore, to recognise. The accidental fracture of a flint would perhaps provide a shape more convenient to the hand, and imitation of this shape created by accident would lead to intentional cutting.

After that we can trace the principal stages of technique, but it would be a great mistake to expect a line of uniform development obeying a standard formula—the Palæolithic cut-stone culture, with its successive stages of pre-Chellean, Chellean, Acheulian, Mousterian, Magdalenian; followed by the Mesolithic transition culture; and then by the Neolithic culture of polished stone with the working of copper, bronze, and finally iron, extending right down to the dawn of historic times.

> "Apart from whatever may be the degree of development of social production, the productivity of labour always remains closely linked to natural conditions, which can always be referred, either to the nature of man himself, or to racial factors, or to the special natural conditions in which he lives."—Marx.[1]

From these conditions there often comes about with different geographical positions an unequal rate of technical progress. At the beginning of historic times Egypt was far ahead of Gaul; and to-day certain Australian tribes remain at the Neolithic stage. The different stone cultures, moreover, were connected not merely with different races, but with different species, of man. Different countries also offered immensely different natural conditions. And during the Quaternary, with its enormous climatic changes, there must have been great differences in climate.

In the lower and middle Quaternary, indeed, that is, the post-Pliocene and Pleistocene, traces of intensely cold periods can be recognised. These ice ages were characterised by an enormous extension of the glaciers, those of the north extending at times over the whole of the Baltic countries and as far as the south of England, those of the Alps reaching the foot of the mountains and almost completely covering them. Neighbouring countries were naturally subjected to a climate similar

[1] "Capital," I, p. 556.

to that of our sub-arctic regions, and possessed a corresponding flora and fauna. The periods of maximum glaciation were separated by warm periods during which the ice retreated and the flora and fauna were again modified. Ever since the last ice age the post-glacial epoch has displayed marked changes of temperature on a smaller scale, and corresponding slight variations in the extent of the regions covered with ice.

The first glacial period took place in the middle of the post-Pliocene, following the warm period which was the prolongation of the Tertiary. This period does not interest us here, as it is anterior to all traces of tools, as indeed also of human remains. It is from the last glacial epoch but one that *Pithecanthropus* dates, that is to say, from the end of the post-Pliocene. It lived in the warm, damp climate of Java.

From the same period pre-Chellean flints have been found in India, unaccompanied by human remains; but flints of the same age from South Africa are already of superior workmanship and of the Chellean type.

Sinanthropus also was contemporary with the glaciation last but one, but, living in the neighbourhood of Pekin, could scarcely have been affected by it.

Over the vast expanses of China and North Mongolia tools of about the same stage, such as quartzite scraping knives, have been found, both as isolated specimens and in large numbers in the places where they were made. Hearths of the same date have also been discovered.

Eoanthropus, *Homo heidelbergensis*, and the Ehringsdorf man, that is to say, the first Neanderthal men, lived in the last warm interglacial period, when the hippopotamus, horse, and deer roamed wild in Europe. The tools of this time are all of the Chellean and Acheulian types. This type, known in South Africa since the penultimate interglacial period, is not found in Australia until the last, when it was also distributed over the greater part of Africa and Asia, where human remains are still unknown. The very simple culture of roughly cut flints, or of sharpened bone as at Piltdown, corresponded to needs that were very immediate.

An identity of needs in three different, though comparable regions, led three different species of man to evolve practically the same type of implements.

Neanderthal man was in the main contemporary with the last ice age when the cold climate fauna included the mammoth, reindeer, and bison. This explains why his remains are usually found in the caves which served him for shelter, while those of his predecessors are more sparsely distributed in open places. He understood the art of fire and had brought hunting to a very high pitch of perfection, making use of spears, lances, and javelins: weapons made quite frequently from pieces of bone, but more often of flint cut according to the Mousterian pattern very different from the Chellean or Acheulian. The latter were cut according to the grain of natural flints and sharpened on both faces, but the Mousterian flints, smaller and sharper, were begun as large pieces and were later retouched on one face only. From grooves and scratches left in the bones we know that the flint knives were used to skin and cut up the products of the chase. Mousterian tools exactly correspond to Neanderthal man, being distributed throughout precisely the same region, Central and Southern Europe, the Mediterranean countries, and Africa.

Subsequent stages of technique correspond to races of *Homo sapiens* and have all occurred since the last glaciation. As the level of technical development improved tools were developed for more specialised uses, and it is from this time that distinct local differences begin to emerge. In France, for example, a number of different techniques were clearly differentiated, following each other in the order Aurignacian, Solutrean, Magdalenian, and Mesolithic. But inequalities of climate made themselves felt. In the south, Aurignacian culture was far more highly developed and gave rise to what is often called the Capsian.

Aurignacian culture corresponded to a warm period which gradually grew colder again during the Solutrean, and much colder towards the Magdalenian, which occurred in one of the post-glacial cold periods. But even in warm periods the cave-dwellings of the Mousterian were not necessarily abandoned. Very often the presence of relics of all periods in one case indicates a continuous occupation throughout the entire upper Palæolithic.

During the whole of this era man was essentially a hunter. Aurignacian man hunted the horse ; Solutrean the reindeer ; finally Magdalenian man the mammoth. From its great abundance and essential role in the life of man, the reindeer has sometimes given its name to the entire epoch—the Reindeer Period.

From the Aurignacian onwards man possessed the art of making much more perfect flint knife-blades, and invented needles, graving tools, scratch-knives, javelins. The Solutrean was remarkable for the high degree of perfection attained in the making of flint implements. The Magdalenian, however, was a period of regression ; bone was coming into use and replacing flint as the principal material. Aurignacian man was familiar with rods, pins, nails with split heads ; the Solutreans, however, invented needles with eyes, for sewing skins, and could work ivory. Reindeer-horn was used in the Magdalenian for barbed fish-spears, javelin points and handles, and for a number of other instruments, while stone was used for receptacles such as mortars and lamps. The Mesolithic period in our country, though much less cold than the Magdalenian, was very wet.

Reindeer were replaced by deer, reindeer horn by hartshorn. It was then that, in the new culture arising out of the Magdalenian and Capsian, the first indications of polished stone appear.

But polished stone is not the distinguishing feature of Neolithic industry. For ordinary purposes stone was still cut in the old way, and some anthropologists maintain that only objects of religious significance were polished.

The Neolithic is a period of tremendous advance. Herding, agriculture, and navigation, if not first discovered, were then brought into wide use. It is claimed that signs of the domestication of the dog and even of the horse are to be found as far back as the Mousterian, but the first of any certainty are in Mesolithic Scandinavia. It was during the Neolithic that the pig, goat, sheep, and cow were domesticated in Egypt and in Switzerland. The domestication of the horse came more slowly. The much greater security of herding as it replaced hunting made possible for the first time the growth of large human communities.

But in quite a number of regions agriculture also was developed. Flint picks, reaping hooks, and ploughshares have been found in Egypt. The researches of Vavilov and his collaborators in the U.S.S.R. have shown that, apart from Egypt and the Mediterranean, there were six other centres where agriculture was evolved in response to similar requirements but using very different tools and plants—India, China, Abyssinia, Mexico, Peru, Asia Minor. The same investigation shows that in these regions the number of wild species capable of cultivation is extraordinarily high, and it is the presence of these which made the invention of agriculture possible.

If stock-breeding favoured the aggregation of men into larger communities, agriculture carried the process much further and, moreover, imposed on them a settled mode of life. Agricultural man had to abandon his small caves, inconveniently situated, and build his own dwellings near the fields. Villages arose in the valleys or on piles at the edge of lakes.

During the Neolithic tools became more and more numerous and varied. Stone, either cut or polished, continued to play a great part as fresh technical details were gradually invented—axe-hammers, double hammers, the joining of handles by means of perforation, and sometimes even by sheathing. The use of bows and arrows, known in Spain from the upper Palæolithic, was greatly extended ; and spoons, dishes, flails, combs, and other instruments made of bone, horn, or wood were used. Certain important inventions are especially noteworthy. Pottery, of which we have previously only one fragment from the Solutrean, came into general use, being made by hand, baked in the open air, and frequently decorated. Flax and hemp were the textile plants, and remains have been found of fabrics, cords, and fishing nets. Towards the end of the Neolithic the discovery of copper, bronze, and then iron, led to the degeneration and practical disappearance of the art of making stone implements.

Navigation is probably older than this period. From the upper Palæolithic human remains are found in America, although there is absolutely no trace of anthropoid life on that continent. These men must therefore have arrived from the old world. But it is only in the Neolithic that we find the establishment of a regular commercial traffic along the coasts and up and down the rivers.

Previous to this a species of traffic, at times over fairly large distances, had grown up. A shell which could have come only from the Red Sea has been found in an Aurignacian station in the Pyrenees. During the

Palæolithic there must have existed in certain places genuine workshops of stone implements, on the evidence of the great abundance of chippings found at certain places. These workshops, however, could have had no more than a local importance. Later, during the Neolithic, industry and commerce became widespread.

At Grand-Pressigny in Touraine there was a workshop whose axes were of a pattern easily recognised. Their wide distribution in the whole of the lower Loire region, extending even to the Breton coast, suggests water transport, and there are indications of certain well-defined ports. The amber of the Baltic and Friesland was transported to the Mediterranean by way of the Elbe valley. All the great river-routes, like the Rhine, Rhône, Danube, Vistula, Dniester, carried canoes across the continent, while there grew up a coastal navigation traversing the straits of Gibraltar.

Many Neolithic populations, of course, continued to live at the level of poor hunters, fishers, or even of coastal tribes living mainly on shell-fish. But for the greater part, agriculture, the domestication of animals, commerce, and industry provided fresh resources, far above those of the Magdalenian. Populations grew very much denser and concentrated at certain places. Human remains of this period are abundant, while those of previous ages are precious rarities. The new high level of technical production was the herald announcing the dawn of historic times.

Since the pre-Chellean period the motive-power of human progress has been need—need satisfied but perpetually renewed. "The first need satisfied, the satisfaction itself and the instrument that brought it about, themselves led to new needs." [1]

[1] "German Ideology," p. 245.

(iii) ORIGINS OF HUMAN SOCIAL FORMS

In what has gone before we have made as little allusion as possible to the question of the migrations of human populations. This is because the question is scarcely to the point. Engels [1] admitted pre-historic migrations, but there is a tendency among Soviet ethnologists to deny them. It seems, however, that this denial can be too strict and absolute. Migrations of animal species are well known; those of humanity at the dawn of history also; it is moreover necessary to invoke migration to explain the population of America or the repopulation of the North when the glacial ice finally retreated. Indeed, certain pre-historic migrations appear to have been demonstrated.

But Soviet ethnology is undoubtedly right in protesting against the abuse of the migration theory by some anthropologists. These see the remains of different kinds of implement in one cave and are incapable of conceiving that there could have been technical evolution on the spot. By supposing that the change was brought about by migration they cast its origin into the unknown. This superficial mode of explanation leads to a denial of all invention, all permanent development in human society. Pushed to its illogical conclusion it would seek the steam-engine and the capitalist system in some inconspicuous corner of the Chellean world. It is therefore quite understandable that Soviet ethnologists have fought shy of it and have perhaps reacted against it in too rigorous a way. In any case, nothing prevents us from neglecting the effect of migration in a general outline of social evolution.

Engels' adaptation of the work of Lewis Morgan provided a system which is in its broad outlines accepted by Soviet scientists, though modified greatly in matters

[1] "Origin of the Family, Private Property, and the State," p. 31.

of detail by recent discoveries. In the first hypothetical stage man is envisaged as scarcely arisen from animality, living on fruits, berries, roots, and small animals, practically unprovided with tools of any sort, and living in small unorganised groups like many anthropoid apes.

The first upward step was the invention of fire, so remote that *Sinanthropus* possessed it, and there is no pre-historical site where careful examination for traces of charcoal has failed to reveal it. Fire permitted the roasting of berries and cooking the flesh of animals and fish as soon as the first arms permitted their capture, and led to the extension of human populations along the courses of rivers. We find certain Australian and Polynesian peoples still at this stage, and it was doubtless that of Palæolithic man up to the Mousterian at least. In such a state of society the only division of labour is the spontaneous differentiation which regulates the work of the sexes. There is no question of class founded solely on economic privilege. On the other hand there may exist subdivision into clans.

Society maintained this form beyond the higher stage of technique characterised by the bow and arrow, thanks to which hunting became the basic and normal branch of activity. Many tribes at the present time are in the stage which was that of the Mesolithic, partly of the reindeer age. There are, in fact, in the whole period from the Mousterian to the Mesolithic already signs of social organisation : instruments and pigments used in tattooing, from the Aurignacian onwards ; the cult of the dead as far back as the Mousterian with its ceremonial burial of certain corpses and the stripping of the flesh from certain bodies ; and the painting of the skeleton before burial in the upper Palæolithic. On leaving the Aurignacian and, above all, in the Magdalenian æsthetic tastes appear. Ornaments like necklaces, bracelets, head-dresses, made of shells or strung teeth, were worn. But, above all, there were sculptures in ivory, reindeer horn, or stone; clay models, engravings, and mural paintings on the walls of caves. In all such works of art the representation of the human form is extremely weak, but that of animals and fish is of an extraordinarily high artistic standard. These pictures are generally thought to have been of magical significance. In any case his artistic tendencies and religious practices show that upper Palæolithic man had risen above the level of producing purely and simply his immediate means of existence.

The economic revolution accomplished during the course of the Neolithic by the domestication of animals and the development of agriculture, industry, and commerce was correlated with the first appearance of social division of labour. Slavery became economically useful. At the beginning of historic times society split into the first classes, masters and slaves. But this involved the breaking up of the older clan society and the substitution of ancient class society for it.

The disappearance of the highly developed artistic culture of Magdalenian society is perhaps connected with this immense social upheaval. The lack of pictures of animals in this period is possibly due to the fact that magic had lost its significance as far as they were concerned.

> "All mythology overcomes, dominates and fashions the forces of Nature in imagination and by imagination. It disappears as soon as these forces are really dominated."—Marx.[1]

By this time, in fact, hunting and fishing had lost their importance. Neolithic society was now relatively powerful and no longer feared wild animals. As for

[1] "Selections," p. 131.

domestic animals they offered scarcely any basis for magic. On the other hand the cult of the dead continued, and the great Megalithic monuments[1] once thought to be part of a religion of sun-worship are now considered part of a cult of the reincarnation of souls. In the cult of the dead, moreover, the newly arisen class-distinctions were introduced, the dolmenic sepulchres being reserved for the chosen few.

Such is the summary sketch which we can make of pre-history, with the primitive communism of the savage horde developing through clan society to its inevitable disintegration on the appearance of classes. In part it is still hypothetical. We are perhaps no longer absolutely certain that the stages gone through were everywhere alike. But what is essential is that from the beginning to the present day human society has evolved under the permanent and fundamental influence of its material relationship with Nature. This is the basic principle of historical materialism.

[1] Such as Stonehenge.

CHAPTER FOUR

PRESENT-DAY RELATIONS BETWEEN MAN AND OTHER LIVING THINGS

"By acting on the external world and changing it, man at the same time changes his own nature."—Marx.[1]

We have just seen a picture of society becoming human society, freeing itself bit by bit from animalism by the perfection of its technique. To-day this process is not yet complete, but it is well advanced. In 1938 men still carry vestiges of their animal past, and yet they have won a master's place in Nature. The influence which they exert on the world is now very powerful and to a certain extent they accomplish their ends consciously. They have, therefore, a certain degree of liberty; not the liberty of arbitrary action, but that of acting in accordance with natural laws. They must, indeed, abandon themselves to chance, that is, they must submit to blind necessity; but in so far as natural laws are understood, man and society are free.

Such is the Marxist thesis, again summarised by the statement that the history of nature and the history of man are inseparable—"As long as men exist the history of Nature and the history of men mutually determine each other." [2]

To understand modern men and their society we must look at them in their natural framework and take the measure of their technical acquisitions and the modifications they impose on the world. We must find out what are the obstacles to further progress, to further

[1] "Capital," I, p. 169.
[2] "German Ideology," section i.

modifications of the world in accordance with human design. We can only sketch this scheme in its broader outlines, confining ourselves to the relations between man and the world of living things.

Since the historical period began and throughout the length of the Quaternary, many species of plants and animals have been exterminated, for the greater part by indiscriminate hunting and clearing or by the introduction, intentional or unintentional, of destructive animals. This process is accentuated in proportion as technique grows more perfect, and reaches its extreme during the last few centuries of oceanic navigation and capitalist commercial traffic.

The aspect of living Nature has been completely altered. In our own country at the dawn of historic times impenetrable forests covered almost the entire soil. Their rare vestiges are to-day almost always under human control. Cleared of trees, forest has become prairie, arable, or town land. Heaths and scrublands have sprung up on ancient clearings, and not many of our woods are now the direct descendants of the ancient forests.

In hot countries deforestation was a native practice, but it has been developed and systematised by colonisation. The virgin forest of yesterday is traversed by roads and strewn with plantations. Nowhere has the flora and fauna altered so radically as in those countries which are of recent discovery. In New Zealand, for example, more than a thousand species have been imported from other countries, intentionally or by accident, in a century, and indigenous species have given way before them. As a result of human intercourse the population of the globe is tending towards an ever-increasing degree of uniformity.

For modern man the biological struggle for existence has practically disappeared. The great wild beasts have been all but eliminated from highly developed countries, or at most survive as harmless curiosities. In tropical countries they frequently exist only on sufferance or under protection. Little by little venomous animals are becoming excluded from inhabited places.

Agriculture and stock-breeding can for the most part make the food-supply of humanity secure. Abundant harvests have been brought about by intensive cultivation of the soil, rational use of manures, creation of domestic varieties more suitable to human requirements. Countries previously uninhabitable have been made fertile by clearing and irrigation. The effects of droughts and other climatic extremes, even those of the seasons, are nullified by long-distance transport. During times of plenty our food industry builds up reserve stores of commodities previously perishable.

Physiology and hygiene, anatomy and surgery, have made enormous progress. Very few diseases remain incurable ; some are prevented by vaccination or inoculation, and in the countries of highest technique epidemics are rare and comparatively mild. Antiseptics, anæsthetics, radium, X-rays, and still other physical and chemical discoveries have given us powerful weapons against disease. Even the most harmful of living creatures have been made our servants ; in recent years we have combated certain cases of syphilitic insanity by inoculation with malaria, and have cleansed infected wounds by placing in them the larvæ of flies reared under aseptic conditions.

To these briefly outlined advances there correspond others of equal importance which have given us the mastery of the physical world. The man of 1938 lives in an environment profoundly transformed and unconsciously submits to its influence from his earliest childhood. Quite apart from education we have in this a fundamental reason for the profound differences between his mentality and that of primitive man.

Other modifications of Nature are brought about unconsciously and thus testify only to the material power of human technique. Seeds, for example, are accidentally transported for short distances attached to the coats of animals or for long distances by steamships and railways ; the difference is merely one of degree.

Acts such as the felling of a tree or the killing of a dangerous animal imply some consciousness of purpose, but whether their ultimate result is deforestation or the extermination of the animal species is a matter of chance since each result arises from the satisfaction of identical immediate needs. The result can be disastrous, as in the extreme deforestation of mountains.

In order that human influence may rise above this level there must be a more thorough knowledge of biological laws, and this knowledge, moreover, must find expression in social undertakings, more or less extended and co-ordinated collective works of irrigation, reforestation, sanitation, organisation of research and medical services, organised destruction of dangerous animals, snakes, insects, and noxious plants, protection of forests, birds, beasts, and fish, repopulation of waters, etc.

Great progress could still be made by the development of biology, but it is clear that its social application has up to the present lagged sadly behind scientific knowledge. If colonies are still indiscriminately deforested, if the spread of alcoholism contributes to the extermination of whole populations, if there are still people living in hovels without light or air, if pregnant women work right up to the time of their confinement, it is not because we are unaware that such things are evil, it is because private interests impose them on us. If millions of men are suffering hunger at this very moment, it is not on account of a shortage of foodstuffs, as in past ages when famines were common, it is because in the present system poverty arises from over-production. If, in sum, in the society of to-day the scientific results acquired have not given us their expected practical fruits, it is because the structure of society prevents it. It is because more or less respectable private interests clash among themselves in a chaotic way ; it is because man still carries with him a part of the legacy of his animal ancestry. But this is *not* the effect of some primal inescapable malediction.

> " With man," says Engels, " we enter the period of historic time. Animals also have a history ; that of their origin and development towards their present state. But this history is imposed upon them from without, and such part as they themselves do play in it is without conscious direction, without knowledge, without will. On the other hand the higher man rises above the animals, the more he creates his own history through his conscious activity, the more restricted becomes the operation of masterless forces, the more closely do historical results correspond to the ends in view. But if we apply this principle to human history, even for those peoples at present most highly developed, we find a colossal disproportion between the aims in view and the actual results achieved. The unforeseen effects predominate ; the uncontrolled forces are much more powerful than those set in motion according to a plan. Yet it cannot be otherwise when the essential historical activity of man, that which has raised him from animality to humanity, the material support of all his other activities, *i.e.* the production of the means of his existence, which to-day has become socialised, is entirely given over to the mercy of unforeseen effects, seldom reaching its desired end, and resulting as often as not in its diametrical opposite. In the most advanced industrial countries we have subdued natural forces. We have brought them into the service of mankind. We have multiplied production a thousandfold, so that to-day a child can do more

than a hundred adults could have done at one time. And what is the result ? Increasing misery of the bulk of the people and every ten years a terrific crash. Darwin did not know what a bitter satire he wrote against humanity, and especially against his own countrymen, when he showed the free competition and struggle for existence which economists were celebrating as the highest pinnacle of human achievement to be no other than the normal state of the animal kingdom. Only the conscious organisation of social activity with planned production and distribution can give man his social freedom and liberate him from the remnants of his animality, just as production itself gave him his biological freedom. From day to day historical evolution makes such organisation more and more indispensable, but at the same time more possible. From the achievement of this organisation will date a new era of history, when man, and with him all branches of his activity (natural science in particular), will take on such a brilliance that all that has gone before will be thrown into deep shadow." [1]

This prediction is coming true before our very eyes as the absurdity of the present capitalist system grows ever more obvious. But in the U.S.S.R. man is master not only over Nature but also over his own social forces. There the backward tundra peoples are being enabled to leap from their clan form of society straight to socialism without passing through the stages of feudalism and capitalism. If this audacious experiment has already in part succeeded, apparently contrary to natural laws, it is because Marxist science, resting on accurate anthropological researches, has to a sufficient degree become master of those laws.

With greater reason Marxism dares and knows how to dominate all known physical and biological laws so as to use them to increase human happiness. At the very time when in capitalist countries there is talk of

[1] "Dialectics of Nature," p. 494.

renouncing technical and scientific progress, since it leads only to misery,[1] in the U.S.S.R. science is richly endowed [2] because of the essential part which it plays in the building of socialism.

In our country, for example, new cultivated plants are only sought out and studied thanks to the limited resources of private persons. In the U.S.S.R., on the other hand, the Government has sent numerous expeditions, directed by Vavilov,[3] all over the world in order to discover varieties and species of cultivable plants. After a number of years more than 100,000 had been collected, that is to say, more than man had ever known before. This collection, studied by the Institute of Plant Breeding, is still being added to, and is admired by specialists throughout the world. The Institute has up to the present retained as interesting for various reasons nearly 500 new kinds of wheat, 250 of barley, 15 of oats and buck-wheat, 45 of hemp, and numerous leguminous plants. Valuable hybrids have also been obtained, such as the cotton plants of Vysotsky, which combine rapid maturation with great resistance to cold and yield large returns of fibre of excellent quality. It was found that certain exotic varieties could not be acclimatised in the U.S.S.R. because their seed period was too long. But Lysenko has succeeded in shortening it by subjecting the seed before sowing to appropriate temperatures. Mitchourin can produce numerous races of fruit trees able to stand the winter season of the central regions of the U.S.S.R., such as the vine which has begun to be cultivated in the neighbourhood of Moscow. There has begun also not only the improve-

[1] Cf. Sir J. Stamp, "The Science of Social Adjustment" (Macmillan, London, 1937).

[2] Approximate figures for the proportion of national income going to science are: Great Britain, 0·05 per cent.; U.S.S.R., >1·0 per cent.

[3] Cf. the contribution of Vavilov to "Science at the Cross-Roads" (Kniga, London, 1932).

ment of the yield and quality of the crops but also their extension into desert and glacial regions previously reputed unsuitable for anything—the winter rye, *Camelina*, and barley have been pushed northwards into the neighbourhood of the Arctic circle; wheat and summer rye up to latitude 65° N.

These successes provide the basis for the economic and social advancement of the peoples of the far north, and have permitted the establishment of an industrial centre at Khibinogorsk in the Kola peninsula.

In stock-breeding, veterinary science, surgery, medicine, hygiene, results have also been achieved which by their effectiveness illustrate the power of social consciousness which directs researches towards the profit of the community. When the immediate needs of building socialism are less pressing, classless society with all its power will be able to apply the same methods to new problems.

> "The reign of liberty," says Marx, "begins where work dictated by necessity and external utility comes to an end. By the very nature of things it is beyond the sphere of material production in the strict sense. Just as the savage must wrestle with Nature in order to satisfy his needs, in order to maintain his life and to reproduce it, so also must civilised man, and this is true of all forms of society and of all possible modes of production. As he develops, the realm of natural necessity expands because his wants increase; but at the same time the forces of production increase, by which these wants are satisfied. Freedom in this realm consists only in the fact that social man, the community of producers, consciously regulates material interchange with Nature and brings it under collective control instead of being ruled by it as by some blind power. Men accomplish this task with the minimum effort under the conditions most adequate to their human nature and most worthy of it. But a realm of necessity always remains. It is only beyond

this realm that there begins the development of human power which is its own end, the true realm of liberty, liberty however which can flourish only upon that realm of necessity as its basis. The shortening of the part of the day given over to work is its fundamental condition." [1]

[1] "Capital," III, p. 954.

END OF PART ONE

PART TWO

BIOLOGICAL PROBLEMS AND THE MARXIST METHOD

CHAPTER FIVE

SOME IMPORTANT POINTS IN MATERIALIST DIALECTIC

"The basic materialist spirit of physics, as of the whole of modern science, will overcome all sorts of crisis, provided the necessary change from metaphysical to dialectical materialism takes place."—Lenin.[1]

(i) MATERIALISM AND BIOLOGY

At the end of last century and at the beginning of this, biology experienced a great wave of materialism more or less frankly professed by such men as Jacques Loeb, Haeckel, le Dantec, Ray Lankester, and Delage, to speak only of those who are dead. At this time it was fashionable to interpret life in terms of pure physics and chemistry. Such explanations were frequently attractive, but often over-simplified and crude. A great number of them failed to survive subsequent criticism, the experimental tests of biologists, and the theoretical criticisms of philosophers. Vitalists and animists of all kinds, theologians, Bergsonians, etc., noisily proclaimed their victory ; materialism appeared to be discredited and the majority of biologists contented themselves with a narrow empiricism.

It is not here our business to inquire how far the materialist current of the years around 1900 was associated with French "anticlericalism" or English

[1] "Materialism and Empirio-Criticism," p. 262.

" rationalism " and represented the struggle which was still being waged by the capitalist class against the last remnants of feudalism. On this view the vitalistic reaction which followed would represent the religious peace desired by the capitalist middle class after it had gained its object, and also the anxiety it was beginning to feel at the first signs of the decay of its system. Similarly the empirical school might correspond to Cuvier's " school of facts," [1] but a hundred years later and in an equally revolutionary period when the class in power again had reason to dread the subversive conclusions of synthetic science.

Remaining within the biological field it will be possible to show that the undeniable scientific fault of the materialism of thirty years ago was its " vulgar," mechanical character, as opposed to that of a " modern," " consistent " materialism, to use the expressions of Engels.[2] Its failure was in not being sufficiently firmly materialist, in not being Marxist.

(ii) MATTER AND MOVEMENT

The root of Marxist materialism is nothing other than the affirmation, contrary to the opinions of idealist philosophers, of the real existence of a world of which man forms a part and the various elements of which react one upon another. The word " matter " has no more significance than this, and we are bound to no specific conception, atomic or otherwise.

> " The one property of matter," says Lenin, " the assertion of which defines philosophical materialism, is that of being an objective reality existing apart from our consciousness." [3]

[1] Cf. M. Prenant's contribution to " À la Lumière du Marxisme," 1936, I, p. 123 (Paris).

[2] By " vulgar materialism " Engels meant mechanical materialism as popularly misconceived.

[3] " Materialism and Empirio-Criticism," p. 220.

Such a definition would necessarily be very vague but for the fact that scientific knowledge and human practice provide it with a concrete content which is subject to variation with the development of knowledge itself.

> " The form of materialism must inevitably vary," says Engels, " with every epoch-making discovery in the natural sciences." [1]

And again :

> " An all-embracing system of Nature and history giving final conclusions is in contradiction with the essential laws of dialectical thought, which, far from excluding, on the contrary includes the idea that the systematic knowledge of the external universe can make giant strides from generation to generation." [2]

Thus in the material content supplied by experience there is one general fact which is well established : matter is in a continual state of change. It is in fact in a state of perpetual motion.

> " Motion is the mode of existence of matter. Never anywhere has there been matter without motion, nor can there be. . . . Matter without motion is just as inconceivable as motion without matter." [3]

The term " motion " must however be given a very extended significance :

> " Among scientists, the word ' motion ' is always assumed to mean mechanical motion, that is, change of place. This habit has its origin in the eighteenth century, before the days when chemistry was a science, and is a great hindrance to the clear understanding of processes. Motion, as applied to matter, is simply change. From the same misapprehension arises the craze for reducing everything to mechanical motion,

[1] " Feuerbach," p. 36.
[2] " Anti-Dühring," p. 31.
[3] " Anti-Dühring," p. 71.

effacing the specific character of other forms of motion. This is not to say that each one of the higher forms of motion is not always firmly and necessarily linked to a true mechanical motion (external or molecular). Thus the higher forms of motion produce others at the same time: chemical action is not possible without thermal and electric effects; organic life is not possible without mechanical, molecular, chemical, thermal, electric, etc., changes. But the occurrence of these accessory forms in each case does not destroy the individuality of the principal form. Certainly we shall one day 'reduce' thought to molecular and chemical motion in the brain; but shall we thereby destroy the essence of thought?" [1]

This insistence on the universality of change is what is essentially dialectical in Marxist materialism:

"But dialectical materialism insists on the approximate, relative character of every scientific proposition concerning the structure of matter and its properties: on the absence of absolute boundaries in Nature; on the transformation of matter in motion from one state into another, which from an ordinary view-point seem evidently irreconcilable." [2]

In 1877 Engels quoted several very different examples of the universal dialectic—Laplace's nebular theory, the evolution of the surface of the globe and of living species, the liquefaction of gases, the transformation of energy, and many others. To-day we are able to add to these the development of radio-active elements, the transmutations of the chemical elements, and perhaps, at the outer edge of modern physics, the transformation of matter into energy and of energy into matter.[3] All distinctions of category disappear one after another and the general formula of "consistent materialism"

[1] "Dialectics of Nature," p. 617.
[2] "Materialism and Empirio-Criticism," p. 221.
[3] Cf. Langevin, *loc. cit.*, and Lord Rutherford's last publication, "Modern Alchemy" (Cambridge, 1937).

becomes ever more simple. As Engels said, "Natural science has now arrived at a point where it can no longer escape the dialectical synthesis."[1] What exists is matter in motion.

(iii) THE LOGIC OF CONTRADICTION

> "Now," says Engels in the same passage, "it is precisely these polar antagonisms regarded as irreconcilable and insoluble, these forcibly fixed lines of demarcation between classes, which have given modern scientific theory its restricted and metaphysical character. The recognition that these antagonisms and distinctions are in fact to be found in Nature, but only with relative validity, and on the other hand that their imagined rigidity and absoluteness have been introduced into Nature only by our minds—this recognition is the kernel of the dialectical conception of Nature."[2]

From this passage it can be seen quite clearly that dialectics does not set out forcibly to suppress all lines of demarcation, the entire object of science and reasoning, at one blow. It merely insists that these lines of demarcation, these concepts, are invariably relative and transitory things and that the rules of logic are only applicable to them with great caution.

> "The combinations which we speak of as objects," says Plekhanov, "are permanently in a state of more or less rapid change. In proportion as such combinations remain the same combinations we can judge them according to the formula 'Yes is yes, and No is no.' But in proportion as they change to a degree in which they cease to exist as formerly we must appeal to the logic of contradiction, we must say, 'Yes and no. They exist and they do not exist., Just as inertia is a special case of movement, so

[1] "Anti-Dühring," p. 19.
[2] *Ibid.*

thought in conformity with the rules of formal logic, in conformity with the ‘ fundamental laws of thought,’ is a special case of dialectical thought.” [1]

It would not embarrass a physicist to find cases where dialectical thought was indispensable. He would admittedly find it no more surprising to hear of cases where logical thought sufficed. What does this mean but that he has to deal from time to time with objects which are only relatively unstable? But in the biological field this is no longer so, for life is to a great extent instability itself.

> “ In spite of some appearances,” writes a modern biologist,[2] “ it can be said that there can be no stable state compatible with life, and that the idea of development, including the various conceptions of change, of variation, or of evolution, is inseparable from the idea of organisation or of a living being.”

Here he agrees with Engels, who returns to the idea several times :

> “ Every organic being is at each moment both the same and not the same ; at each moment it is assimilating matter drawn from without and excreting other matter ; every moment the cells of its body are dying and new ones are being formed ; in fact, within a larger or shorter period the matter of its body is completely renewed and is replaced by other atoms of matter, so that every organic thing is at all times itself and yet something other than itself.” [3]
>
> “ Life is also a contradiction, which is present in things and processes themselves, and which continually asserts and solves itself ; and as soon as the contradiction ceases, life also ceases and death occurs.” [4]

[1] “ Fundamental Problems of Marxism,” p. 115.
[2] E. Fauré-Frémiet, “ La Cinétique du développement ” (Paris, 1925).
[3] “ Anti-Dühring,” p. 29.
[4] *Ibid.*, p. 138.

This admirable definition is very general in its terms. By itself, as Engels remarks, it cannot give that detailed knowledge of life which can only come from experimental studies. But it makes perfectly clear the insufficiency of purely logical thought in biology ; by its nature this form of thought always leaves out of account the very thing which is the essence of life—motion.

Hence we can agree with Bergson in his justifiable criticisms of the mechanist interpretations of life. But after reaching this point Bergson was not able to construct anything useful. He invented the *élan vital* : an easy way out, but a mere phrase and utterly sterile. It is for the Marxist method to clear the way for scientific analysis of this " vital urge."

(iv) CAUSE AND EFFECT

Conceptions of cause and effect require handling with extreme caution. Not that Marxist materialism puts causality into doubt, or could subscribe to the attempts of modern vitalists to establish indeterminism.[1]

> " Cause and effect," says Engels,[2] " are conceptions which have a validity only in their application to a particular case as such ; but when we consider the particular case in its general connection with the world as a whole, they merge and dissolve in the conception of universal action and interaction in which causes and effects are constantly changing places, and what is now or here an effect becomes then or there a cause, and *vice versa*."

Lenin makes himself very clear in speaking of the " universal and complex character of the interrelations

[1] Cf. Lenin : " Whoever reads his philosophical works with attention must clearly see that Engels does not admit a shadow of doubt about the objective existence of law, order, causality, and necessity in Nature." (" Materialism and Empirio-Criticism," p. 125.)

[2] " Anti-Dühring," p. 29.

of the world, a character which causality expresses only in a unilateral, partial, and incomplete fashion."

It is therefore not a matter of denying the principle of causality, but of extending and generalising it in the best way.[1]

For the physicist, the chemist, even the physiologist working under the controlled conditions of laboratory experiment, it is quite reasonable to attribute effects to causes. This is indispensable for scientific progress, permissible because here a certain degree of isolation is obtainable. But the man of action knows that in the outside world things are not so simple : he must expect great complexity. It is this which renders technical applications so difficult to carry out successfully. Both in the realm of human relations and in biology the great complexity of the operating forces makes quite clear how insufficient are the notions of cause and effect.

Here lies the main difference between physiology and biology : in the physiological field, as in physics and chemistry, experiment is able to isolate cause from effect. But when the subject-matter approaches the complexity of organic nature, this becomes no longer possible. Thus, consequently, in making use of experimental results it is very necessary to view with suspicion the traditional logical mode of thought. Through lack of acquaintance with dialectics mechanist biologists have in a great variety of problems reached one-sided solutions, frequently more metaphysical than scientific, and deserving only too well the criticism to which they have been exposed.

(v) THE NATURE OF LIVING MATTER

The chief duty of dialectical thought is that of never losing sight of the complex interrelations between the

[1] Cf. the contribution of G. Friedmann to "À la Lumière du Marxisme," 1936, I, p. 262 (Paris).

living being and its environment. From the common-sense point of view the living thing very often seems almost independent of what surrounds it, or at least possessed of a high degree of autonomy. Mechanist biology has to its credit an energetic reaction against the popular view, which has now practically disappeared from most biological problems, though traces still remain in the most complicated, those of variation and consciousness.

Thus there has gradually developed the concept of the " organism-environment complex," a highly dialectical idea due to le Dantec, made known widely by Rabaud, but unfortunately lost by most subsequent mechanists. It was quite natural that the mechanists should lay great stress on environment, on external factors of physics, chemistry, and mechanics, all of which are quite readily dealt with by those whose business it is to isolate causes from effects. They tried to explain the whole of the phenomena of life in terms of these factors, as we shall see, especially when we study the question of living forms. What they also forgot was that if the environment reacted on the organism, the organism in its turn reacted on the environment.

The mistake they made was therefore just as serious as the opposite error. Too frequently it led the mechanist to treat a living thing as so much inert matter, the passive plaything of physico-chemical forces. They neglected its special peculiarity of being alive, and moreover forgot that they were dealing with particular living things, each with a character of its own and not with something indeterminate.

One of them, le Dantec, however, remarked that the term " life " is in a certain sense too general, and that instead of saying that the dog lives or the fish lives, it would be better to say the dog dogs, the fish fishes. But he and the other mechanists have too often forgotten this principle, and have clung to their generalised solutions which are clearly unsatisfactory in the majority of cases.

Against this abstract materialism, Marxism opposes a concrete materialism founded more closely on facts, and taking into account the particular circumstances. In his great work of synthesis, " Capital," Marx worked out the basic economic laws of capitalism, but this did not prevent him from studying the system in minute detail, and observing even the most insignificant and local of working-class demands. Without losing sight of the unity of all matter, Marxist biology still insists that the phenomena of life have their own characteristics, which must not be *forced* to conform to known physico-chemical formulæ.[1] Each living thing has a material structure which is peculiar to it and which operates alongside the environmental factors to produce the concrete results of life.

(vi) QUANTITY AND QUALITY: CHANCE

But if Marxist materialism maintains this concrete character, always keeping in mind the special peculiarities of each object, how is it possible for it to rise above a narrow empiricism ? How, for example, can it at one and the same time assert the special nature of the phenomena of life and nevertheless grasp the underlying unity of the living and the non-living ?

Again the answer lies in its dialectical mode of thought. Just as it sees no unbridgeable gulf between cause and effect, it sees no complete antithesis between the concepts of quantity and quality. This idea, taken from Hegel, was frequently used by Marx ; for example, in the passage in " Capital " in which he describes the transformation of the possessor of money into a capitalist :

[1] Cf. B. Zawadowsky's contribution to " Science at the Cross-Roads " (Kniga, London, 1932).

> "Here," he says, "as in the natural sciences, is illustrated the correctness of the law discovered by Hegel in his 'Logic,' that at a certain stage purely quantitative changes become transformed into differences of quality." [1]

A whole chapter of "Anti-Dühring" is devoted to this question.

After reading the examples given by Engels, it is not difficult to think of others, both from one's personal experience and from the natural sciences.

In a very simple and classical case we can see that the "transformation of quantity into quality" is linked with the intervention of chance; but at the same time chance does not mean the absence of determinism, as certain vitalists would have us believe, but corresponds to a summation of a number of distinct causalities which are too complex to be analysed by our present methods of scientific investigation. In a gas the molecules moving in all directions collide with each other and with the vessel. If they were very few in number it would theoretically be possible to study the movements of each individual and to trace their causes. With large numbers, however, such knowledge is impossible; but on the other hand it then becomes possible to apply the laws of chance and probability; a phenomenon of a new quality is created—gas pressure, obeying its own well-known laws, for example, that of Boyle.

We shall see that in a number of biological problems it has recently become necessary to consider the importance of chance, and to adopt the statistical methods of calculation which it demands. This has been done quite apart from preconceived philosophies, simply owing to the necessity of recapturing the continuity of phenomena at a higher level of complexity when the

[1] "Capital," I, p. 319.

experimental study of causes was no longer capable of dealing with it.

Mechanist biologists have sometimes displayed a profound distrust of probability and statistics.[1] Hypnotised by their struggle against the vitalists, they feared that by giving right of entry to chance they would be opening the way for indeterminism and miracle. Dialectical materialists know, however, that every phenomenon has two faces: [2] it can be considered as a totality, its peculiar laws sought out, as if it were a simple element isolated by its quality; on the other hand, on account of the unity of matter it is possible to reduce it to an edifice of more elementary phenomena; but this edifice is so complex that it is necessary to supplement detailed analysis by introducing chance and statistical regularity. The more experimental science progresses, the more phenomena will be isolated and the greater part will causal laws appear to play; but there will subsist an unanalysed remainder where knowledge can be nothing but statistical. This residue, nevertheless, will illustrate the richness and regularity of reality.

No more than quantity and quality do chance and causality stand opposed in rigid antithesis.

> "Chance," wrote Engels, "is only one pole of an interrelation whose other pole is called necessity. In Nature, where chance seems to reign, we have long ago demonstrated for each separate domain the underlying necessity and the internal laws which determine the course of chance." [3]

If this has not been understood by the mechanists it is because they have allowed themselves to fall into the same error as their vitalist opponents.

[1] This tendency was much more marked in France than in England. Rabaud and Houssay exemplify it; Galton, Pearson, and Lotka do not.

[2] See Colman's *Statistical and Dynamic Regularity* in "Science at the Cross-Roads" (Kniga, London, 1932).

[3] "Origin of the Family, Private Property and the State," p. 213.

(vii) BREAKS AND CRISES

Another mistake of the mechanists was their unwillingness to admit sudden changes in the biological field, through a suspicion that this might leave a loophole for indeterminism. This repugnance on their part was made particularly clear by their very cool reception of the discovery of mutations until it was forced upon them by the weight of experimental evidence.

Sudden changes in no way surprise the dialectical materialist, as Plekhanov [1] has shown by giving numerous very varied examples among which figure metamorphoses and mutations.

We know that " Quantitative changes accumulating little by little finally become qualitative changes. These transitions take place in leaps and cannot occur otherwise."

This necessity is best explained in a quotation from Hegel given by Plekhanov : [2]

> " The ordinary notion of the appearance or disappearance of anything is the notion of a gradual appearance and disappearance. Nevertheless there are transformations of being which are not only changes from one quantity to another, but also changes from the quantitative to the qualitative ; such a transformation is an interruption of ' gradual becoming ' and gives rise to a kind of being qualitatively different from the preceding. Every time that there is an interruption of ' gradual becoming ' there occurs a jump in the course of evolution after which the place of one phenomenon has been occupied by another. Underlying the theory of gradualness is the idea that that which makes its appearance already exists effectively, and only remains imperceptible because it is so very small. In like manner when we speak of the gradual disappearance of a phenomenon

[1] " Fundamental Problems of Marxism," pp. 97 ff.

[2] *Loc. cit.*, p. 104.

> we represent to ourselves that this disappearance is an accomplished fact, and that the phenomenon which takes the place of the extant one already exists, but that neither the one nor the other is as yet perceptible. . . . In this way however we are really suppressing all appearance and disappearance. . . . To explain the appearance or the disappearance of a given phenomenon by the gradualness of the transformation is absurdly tautological, for it implies that we consider as having already appeared or disappeared that which is actually in course of appearing or disappearing." [1]

The evolution of matter always takes place in leaps. But what takes away anything of the miraculous from these changes is the fact that they are prepared for. Before the passage quoted, Plekhanov insists that every leap, every revolution, is preceded by a preparation, a crisis, whose frequently rather mysterious nature is due only to the fact that we are unable to follow it. Here again the difference between sudden change and gradual change does not take the form of an absolute antithesis. Each change, sudden in its totality, is gradual if considered in the elements which make it up; gradual if its totality is regarded as a statistical sum of sharp changes. Whether a change is regarded as sudden or gradual is in essence relative to the actual state of our knowledge and possibilities of action.

(viii) THE HISTORICAL CHARACTER OF PHENOMENA

In this criticism of mechanical materialism one cardinal point remains to be emphasised: that it fails to understand the historical nature of phenomena. Admitting neither theoretical nor practical limits to its determinism, it must therefore claim to be able to deduce from the present state of the world the whole of the future and the whole of the past: all that is required

[1] Hegel, " Wissenschaft d. Logik," I, p. 313 (Nuremberg, 1812 edn.).

for this task is an intelligence sufficiently vast working on the present data completed to an infinite degree.

These are two metaphysical suppositions which cannot be admitted in Marxism. For such a work of deduction, Marxism knows only human intelligence as it is, resting on the relations of human society with Nature. It does not doubt that these relations will be extended and that the resulting development of the human spirit will be unlimited, if no catastrophe supervenes to annihilate it; for Marxist "divinity" lies in the future of man, not in the past.

But man is not a pure contemplative spirit who can be satisfied by such theoretical perspectives. He is a material being, with an urge to action, who, in order to attain his ends, must regulate his conduct according to what he has gathered of the world, practically and experimentally. Now what he has gathered is only a sample and cannot suffice for a complete explanation. The unanalysed remainder, at the very least, gives to the evolution of matter a historic character.

This is striking in biology. If all species are different, if no two individuals are identical and each cell has its own peculiar character, this results from their having separate historical developments, about which in general we know very little, but which cannot be left out of account.

> "The more physiology develops," writes Engels,[1] "the more important become these incessant infinitesimal modifications, and therefore the more physiology demands a study of the difference which lies inside identity, and the more out of date becomes the old formal and abstract view of identity, according to which an organic being was treated as being simply constant and always identical with itself. In spite of this, the mode of thinking by categories, which is founded upon it, still survives."

[1] "Dialectics of Nature," p. 608.

To take historical evolution into account means first, to cast aside abstract and general solutions, such as are proposed by the mechanists, and to make a thorough study of concrete cases. But these concrete cases must themselves be studied as far as possible in their own history and evolution, and not in their present state alone.

Contrary to what mechanists have often believed, causes situated only in the present, at least as usually understood in biology, cannot explain all the present phenomena of life. Appeal must be made to past causes, to the degree in which they remain engraved in the structure of the modern living being.

(ix) THE LIMITATIONS OF MECHANICAL MATERIALISM

It may possibly appear that this chapter has criticised mechanical materialism too exclusively, and allowed the various forms of vitalism in biology to escape almost scot-free. These have, however, been mentioned on p. xix and will be dealt with further, on page 187 in particular.

If criticism has taken this form it is not due to any underestimation of the good intentions of mechanism as the direct successor of eighteenth-century materialism, nor indeed of the services it has rendered to science. " Marx and Engels," wrote Lenin, " always condemned the vulgar antidialectical materialism, but they condemned it from the standpoint of a higher, more advanced dialectical materialism, and not at all from the view-point of Hume or Berkeley." [1] The same is the case here, and finally we can repeat point by point criticisms made by Engels at the end of the second chapter of his " Ludwig Feuerbach." These apply to the French materialists of the eighteenth century, and particularly to their followers Buchner,

[1] " Materialism and Empirio-Criticism," p. 201.

Vogt, and Moleschott. Their thought, he said, had failed to rise above three fundamental limitations.

The first was " mechanist " in the sense that " they applied the mechanical scale pure and simple to the chemical and the organic in Nature," and failed to appreciate that the motion of matter may also take other specific forms, equally real.

The second was their metaphysical and anti-dialectical outlook, which made them ignore or neglect historical processes and underestimate the complexity of interactions ; thus they failed to òbserve the often sudden and qualitative character of material evolution.

The third limitation of mechanical materialism was its complete abandonment of the social sciences to idealism, through failure to understand historical materialism.[1] Hence, as we shall see in Chapter 12, the impossibility of giving a satisfactory solution to the problem of consciousness by the unity of thought and being.[2]

These limitations have been overcome by Marxist materialism, and consequently it will remain irrefutable as long as its content is determined by scientific and practical experience.

Without such humility in face of experience Marxist materialism will be untrue to itself.

[1] This is also the principal reproach made by Marx against Feuerbach in the " German Ideology."

[2] The attempts made in this direction by the mechanists Huxley, Maudsley, le Dantec, consisted of considering thought as an epiphenomenon. They failed. But it is a long way from them to the Marxist conception according to which thought is an original and active superstructure.

CHAPTER SIX

THE PROBLEM OF COMPETITION AND THE LAWS OF POPULATION

(i) THE POWER OF GROWTH OF LIVING MATTER

For a clear conception of the Darwinian " struggle for existence " the average exposition, even from the pens of many Darwinians, is insufficient.

> " Nothing is easier," as Darwin foresaw, " than to admit in words the truth of the universal struggle for life, or more difficult—at least I have found it so—than constantly to bear this conclusion in mind." [1]

The enormous capacity for multiplication and expansion of living matter must never be lost sight of, but frequently it is scarcely mentioned in biological textbooks or in the teaching of natural science.

Certain bacteria have so great a power of self-multiplication that they can double their volume and mass every twenty minutes. At this rate of increase an initial bacterium would yield 8 at the end of an hour, 64 at the end of two, and so on. At the end of thirty-six hours the number of its descendants would have to be written by a 1 followed by 30 digits, and despite the infinitesimal size of each individual the aggregate would more than cover the entire surface of the globe in a continuous layer. At this rate of reproduction, if it were continued, their volume at the end of two or three days would exceed that of all the oceans put together.

Certain protozoa, which though much larger are still

[1] " Origin of Species," p. 46 (Murray, London, 1902).

microscopic, can double their volume five times a day. At this rate of increase one individual could produce in a month descendants expressed by a number of 45 digits, and their volume would be about a million times greater than the sun.

Flies lay about 200 eggs at a time, and under favourable climatic conditions the young become adult and can lay in their turn at the end of 15 days. As it requires two flies to produce a set of eggs, the number of couples from an initial couple would be 100 at the end of fifteen days, 10,000 at the end of a month, 100 millions at the end of two months, and so on. In nine months, that is between one winter and the next, we should have a number of 37 digits, and the total volume corresponding to it would be several million times greater than that of the earth.

Analogous calculations could be made for all kinds of animals and plants. Every year innumerable acorns are shed by oak-trees. Fish like the cod and the turbot, or invertebrates like the sea-urchin, produce many million eggs in a single lay, and these are not exceptional cases. Even for birds whose average clutch is only five or six eggs, Wallace has calculated that in fifteen years one couple could produce ten million descendants. For the elephant, which does not attain maturity until the age of sixteen and is not very fertile even then, Darwin showed that at the end of five centuries an initial couple could give fifteen million individuals.

Mental calculations of this kind give an impressive conception of the potentialities of living matter. But in Nature the facts are very different. Bacterial reproduction soon comes to a stop for lack of a sufficiency of the right kind of nutriment. In the normal course of events examination of a forest always yields about the same number of trees. The abundance of cod and turbot does not vary much from year to year. A couple of summers does not suffice for the alarming increase in flies which we have calculated. Each species appears to have a limit. Apart from the exceptions to which we shall return, it is so well limited that the general equilibrium of living things persists with very little alteration.

This can only mean that of all the possible descendants of a single individual or a couple, a great number fail to achieve maturity or perish prior to reproduction. Out of 200 eggs we are forced to admit that on the average only two individuals reach sexual maturity: 99 per cent., therefore, perish beforehand. If the laying is two million eggs, here again on the average two only attain maturity. In other cases the proportion is smaller still: sometimes one in a thousand million.

Cuénot recommends these minute yields to the teleologists for their admiration.[1]

> "Is there anything more surprising than the migrations and the metamorphoses of the worm parasitic on the sheep's liver, so complex that it is with difficulty that one individual among five thousand millions can pass through the net of successive difficulties?"

One can more justly say, is there anything more contrary to the conception of teleology than a web of difficulties which allows only one individual in five thousand millions to pass through?

(ii) LAWS OF POPULATION

The low yield of living matter and the enormous average wastage to which it is liable are due to two series of causes, varying in relative importance but always distinguishable.

First there are factors traceable directly to the physical environment, often irregular and accidental;

[1] Cuénot, "l'Adaptation" (Doin, Paris, 1925), p. 6.

a period of drought or extreme humidity, a sudden increase of temperature, a rigorous winter, may take a heavy toll. If such factors are local they can be compensated on a large scale. In a pond which is drying up, for example, the eggs of the toad perish completely, and this local catastrophe lowers the average, but in a neighbouring pond the eggs may develop in an unusually high proportion, counteracting the first depression and raising the average. But the factors are not always irregular. Flies suffer terrific mortality on the onset of winter cold, while in summer their generations suffer much smaller losses : hence an annual cycle.

The other factors causing wastage have nothing accidental about them. They arise from the fact that environment is never unlimited or inexhaustible. The descendants of an individual or couple, in the process of multiplying, naturally begin very soon to obstruct each other, to compete for space, nourishment, light, etc., and furthermore the continuous production of toxic waste-products gradually poisons the environment.

After its first rapid growth the population increases more and more slowly, and eventually fails to exceed a certain limit. This limit depends entirely on the resources of the environment and not at all on the number of individuals which were introduced into it at the outset. The limitation of number in this case is to a great extent an automatic effect. It is a result of the multiplication itself and is an excellent example of what Hegel called a phenomenon which " negates " itself, that is to say, spontaneously limits itself. On the other hand, the limitation is also related to the reciprocal interactions between the various individuals, the precise causes varying according to the particular case, but the general fact remaining that such interactions do come into play as the population grows.

These interactions can operate sometimes at quite considerable distances. The corn weevil is a small insect, one individual living in a single grain of corn. Limitation, however, makes itself felt as soon as there is one individual per 400 grains. For another minute insect, weighing 2 milligrams and living in flour, it appears when the quantity of flour available falls to 16 grammes per individual. For the fly *Drosophila*, limitation begins to appear when there are two flies in the space of a quarter of a litre. In this case it is due to the extreme sensitivity of the insect to disturbance, and the effect of a thicker population is to deny the females the quietness necessary for nourishment and laying and so to diminish fertility. For the yeast which causes alcoholic fermentation, limitation seems to be chiefly due to the strongly poisonous effect of the alcohol generated by the fermentation itself.

The business of the biologist is to discover what is the cause of limitation in each particular case, but the general fact remains that limitation of some kind is inevitable. This is as true of experiments in laboratories as it is of natural environments of vast size. Liebig's pronouncement that the food resources of plants are always subject to limitation is now classical. Marx attached great significance to it and returned several times to the idea in "Capital." [1] But the same applies to the ocean. The rapid growth of microscopic algæ (diatoms) is sufficient to deprive its surface layers almost completely of nutritive salts, such as phosphates, silicates, and nitrates. Similarly life has a powerful influence even on the composition of the atmosphere.

Thus limitation results to a great extent from competition between individuals of the same species or of neighbouring species whose needs are more or less similar. In addition to this there is the action of carnivorous animals which nourish themselves on others'

[1] *E.g.* "Capital," I, p. 343.

destruction and of parasites which kill their hosts or sterilise them. The problem is very complex. If carnivores, herbivores, or parasites increase vigorously, other animals or plants which serve as prey or hosts will become less plentiful and will no longer suffice as food sources. This is another example of the dialectical law that the increase of any species, whatever its nature, itself brings about its own limitation.

These phenomena are so regular that mathematicians have been able to study them theoretically and arrive at conclusions which are well borne out by the facts, either of laboratory experiments or of external Nature.[1] When a number of species are found living together in one environment and some provide nourishment for others, the number of individuals of each species fluctuates around certain values, at which an approximate equilibrium is attained.

It is in fact perfectly possible to assume in the case of such natural populations as the plants and animals in a forest or the creatures living on a marine rock that a stable equilibrium lasts through a number of years or as long as the external conditions remain roughly the same. Though the individuals die and are replaced, the species remain the same and are represented in closely constant proportions. By very accurate statistical studies biologists (botanists in particular) have repeatedly shown that this constancy is no illusion, and to such populations they have given the name "associations." The term is perhaps imperfect through its unfortunate reminiscence of human society, which is something totally different, but the essential thing is

[1] I am not of the opinion expressed by Colman in his article in "Science at the Cross-Roads" (Kniga, London, 1932), that mathematical studies in biology are too theoretical and have no concrete value. Mathematical formulation of the theory of evolution has been achieved in recent years through the work of Volterra, Fisher, J. B. S. Haldane, Lotka, Kostitzin, and Gause; this leads to precise questions which may be answered experimentally.

the existence of groupings rendered stable by the interplay of the reactions between individuals.

On the other hand, cases are known where there are marked fluctuations around the average equilibrium. In the mussel shoals around our coasts there are star-fish which prey on the mussels ; when these increase most rapidly the mussels approach very closely to total extinction ; but the star-fish in their turn die in large numbers, this time of starvation ; and after the mussels have regained their abundance the cycle begins anew.

In another rather more complex case the population of a marine rock includes mussels and barnacles, which are fixed animals, and a genus of molluscs (*Purpura*) which normally feed upon the barnacles. But the too rapid development of the mussels causes the barnacles almost to disappear ; the molluscs then die of hunger in large numbers. Certain of them, however, begin to eat the mussels, and this new nourishment proves so valuable that they increase rapidly, destroy the mussels, and give the barnacles an opportunity to develop again. Here the first part of the cycle is due to the direct competition between the mussels and the barnacles, and the second part of the fluctuation cycle to the intervention of the molluscs.

Laboratory experiments, among which one should quote those of the Soviet biologist Gause, the American Pearl, and in France those of Teissier, have been carried out in simple cases in a more precise way, on species as different as *Drosophila*, protozoa, and various yeasts. They have shown the extreme interest of the mathematical laws of population, in all cases where two species are in competition for the same environmental factor. When Gause reared two species of protozoa, one of which devoured the other, he found the laws were verified provided the vessel possessed irregularities which could serve as refuges ; if not, the destruction of the weaker species was so complete that the other perished entirely through lack of nourishment.[1] From this fact and others Gause rightly concluded that such apparently insignificant details of environment can exert a powerful influence on the laws of population. The existence of these laws is not to be doubted.

Engels had already been of this opinion and had understood their importance :

> " For that matter, the organisms of Nature also have their laws of population, which have been left almost entirely uninvestigated, although their formulation would be of decisive importance for the theory of the evolution of species." [2]

(iii) CHANGES OF EQUILIBRIA IN POPULATIONS

In a population in equilibrium it is possible, as we have just seen, for a part to be suppressed and yet the whole to recover its original composition without much delay. We may, for example, cut down a forest, but as soon as we abandon our cleared ground, the forest will reconquer its territory, through intermediate stages, probably taking the best part of a century.

This is, of course, provided that the physical environment has not materially changed and that no new species is introduced. Such a species might well mean that the new population was totally different from the original forest. If, for example, deforestation of mountainous districts has allowed the streams to wash away the scanty soil, the forest will never reinstate itself. Or if species of pine are introduced into Corsican scrubs they increase very rapidly and profoundly affect the physiognomy of the scrub land.

Even in a population which is intact the introduction

[1] Another case is the competition between two species of mosquito larvæ for chloride in the water in which they live (Wigglesworth).
[2] " Anti-Dühring," p. 81.

of a new species can lead to profound changes if this species develops too plentifully. In 1872 nine small carnivores of the mongoose family were sent from India to Jamaica in the hope that they would destroy the rats of the sugar plantations. Their descendants, however, spread over the whole island. After devouring the rats they set about the poultry, eggs, small domestic animals, birds, reptiles, frogs, crabs, and were responsible for the complete disappearance of several species. Insects which were normally kept within bounds by the birds and reptiles which feed on them flourished so abundantly that vegetable life itself began to suffer.

But the gradual attenuation of their food resources began finally to tell on the numbers of the invaders, and a new equilibrium came about, very different from the old one.

Very slight changes in the conditions of the environment can also produce changes in the population. It has been shown in laboratory experiments made on two competing species of *Drosophila* that a variation of temperature of a few degrees produces a quite appreciable alteration in equilibrium, although the two species taken separately would live quite well at either temperature.

The fluctuation of the climate or the development of some great geographical change in the land-surface can have far-reaching repercussions on the fauna and flora. But the changes caused by life itself are more interesting.

The fact that an association lives on a certain soil, from which it draws food and which it makes the repository of its waste products, means that it can modify it in a dialectical way and make it unsuitable for its own further existence and suitable for its successor. The first plants to grow on a wall, for example, are lichens, which need nothing beyond rainwater. But gradual accumulations of dust and debris on and around them result in a soil sufficient for mosses to live. These in their turn prepare the way for larger plants, and the roots of these loosen the wall and make it possible for even larger plants to exist there. Botanists now study these spontaneous changes of population and give them the name of "successions."

In sum, therefore, populations possess a degree of stability which makes their study possible. But this stability does not exclude their being modified, in one way or another, according to their composition and the nature of their environment. Through these innumerable interactions life persists in spite of its low yield, on account of its prodigious fertility.

> "Nowhere on the globe," says Vernadsky, "is there a chemical force more immutable and consequently more powerful in its ultimate consequences than the totality of living organisms." [1]

[1] W. Vernadsky, "La Biosphère," p. 27 (Alcan, Paris, 1929). The term "immutable" must evidently not be applied in this quotation except to the totality of living beings.

CHAPTER SEVEN

THE PROBLEM OF ADAPTATION

(i) ADAPTATION AND PURPOSE

In the last chapter the fact that life continues to survive was explained on a materialist and concrete basis. But attempts to explain it on the basis of "adaptation" use an abstract term which, without precise definition, can be dangerous.

Adaptation, it has been said, is a "terrifying question." It is certainly a question which alarms the imagination when loosely stated. The living being seems such a frail creature against the forces of a hostile world, and in its survival there is something almost miraculous. Consequently it is easy to take another short step and to regard this "miracle" as planned and life created with survival permanently in view. Too many scientists and philosophers have taken this step.

But in real Nature the survival of any given individual is in fact a very exceptional phenomenon. However well adapted to survive species may appear at present, we know that they are condemned to extinction after a period which will not exceed a few thousand centuries. The instantaneous glance that man has been able to give to the world too often leads him to assume in it a stability which does not exist. The fact is simply that individuals and species approximately adapted survive as long as circumstances allow them to do so, and that their ultimate disappearance is approximately compensated by the colossal fertility of living matter, which throws into the arena new individuals and new species. The stability of the living world exists only from the view-point of the whole. This is the conclusion reached by Vernadsky, and even vitalist biologists state it, though in uncertain terms. "The fact that life has begun and persisted," says Cuénot,[1] "clearly indicates some kind of harmony or co-ordination between it and cosmic conditions." [2]

Any uncertainty here is due to life being considered as a stable entity and not as a complex of incessantly changing material beings. Thus it might be easy to postulate a volitional harmony, perhaps the expression of some divine purpose or teleology.[3] But material details soon dispose of the confusion.

[1] Cuénot, "l'Adaptation," p. 388.

[2] The classical statement of this "universal teleology," from which all theistic or idealistic implications were carefully excluded, occurs in the brilliant book of the American biologist, L. J. Henderson: "The Fitness of the Environment" (Macmillan, New York, 1913). In this he urged that "fitness" is a reciprocal concept; living organisms are no better fitted for their environment than their environment is for them. For example, water possesses a greater number of unique or very unusual properties, *e.g.* thermal, solvent, dielectric, surface-tension, etc., etc., suitable for living organisms as we know them. So does carbon dioxide. Yet these substances, and all the others of which living organisms consist, existed in vast quantities prior to the appearance of life. Life, exactly as we know it, was thus implicit in cosmic evolution. This is strong support for the Marxist conception of the unity of cosmic, biological, and sociological evolution.

[3] We must be clear regarding the meaning of the word "teleology." When in what follows it is not qualified in any way, it must be taken in the sense of intelligent or providential purpose. Vague instinctive purpose, of the type of Bergson's *élan vital*, will be called "Bergsonian teleology." The unconscious teleology which Goblet postulates will not be discussed, because it is a mere word, and dialectical materialism must penetrate beyond such ambiguities into the domain of the concrete and the real. Henderson's "universal teleology" has, of course, nothing to do with the limited purposivenesses assumed for individual living organisms; it means only the preparation of the inorganic stage for the drama of life as a whole, and it is subsumed in the dialectics of natural evolution as a whole. Henderson himself regarded his conclusions as the death blow to vitalism. "Science," he said, "has finally put the old teleology to death. Its disembodied spirit, freed from vitalism and all material ties, immortal, alone lives on, and from such a ghost science has nothing to fear. The man of science is not even obliged to have an opinion concerning its reality." But "the philosopher will never cease to perceive the wonder of a universe which

(ii) ADAPTATION AND EVOLUTION

If life exists as an equilibrium of populations such as we have described, is there room for such a purpose? The idea is very old, as old as the belief in the goodness of providence. Bernardin de Saint Pierre pushed it to the extreme: it was his opinion that the fruit-laden branch bends towards the earth so that men can gather its fruit more easily; and the melon has sides so as to be more readily partaken of by a family. It is not merely the anthropocentrism of such teleology that makes it ridiculous. Too many naturalists have held and still hold conceptions hardly less puerile on the relations that exist between living beings.

This is above all true when they deal with animal societies, or with symbiosis, the grouping together of different species with mutual benefit. The scientific materialist method of dealing with animal societies has already been explained. Symbiosis is approached similarly. When we say, for example, that each partner in the union of an alga and a fungus, known as a lichen, is assisted in its nutrition and development by the presence of the other, this does not imply that their association is a matter of intention. It means simply that this union achieves the natural conditions in which both best thrive. Under suitable artificial conditions, indeed, the fungus, and still more the alga, can be separated and live perfectly well without the other.

The optimistic enthusiasm of naturalists has led them into describing a whole host of supposed symbioses which subsequent closer study has proved indifferent or even harmful to one of the partners. There are all possible intermediate stages between symbiosis and the

moves onward from chaos to very perfect harmonies, and quite apart from any possible mechanistic explanation of its origin and fulfilment, to feel it a worthy subject of reflection." The work of Marx and Engels was apparently unknown to Henderson.

more or less favourable result of two living beings living in simple proximity.

The facts of symbiosis, which are in any case merely details of the smallest possible order in relation to the whole universe of life, do not contain the slightest ground for the justification of teleology.

It is sometimes imagined, however, that the balance of forms in the world as a whole provides teleology with some plausibility. Such a teleology would require the carnivora for limiting the herbivora, the herbivora to limit the growth of plants, and parasites to hold back the multiplication of their hosts. This is no more and no less than the whole struggle for existence. But does it make it any more comprehensible ? Even if the equilibrium is considered from the point of view of mere chemical turnover, the low yield is very striking ; the enormous proportion of inert matter used up, and by comparison, the trifling amount that is assimilated. According to estimates a marine animal transforms into its own substance little more than a tenth of the materials which it consumes. If, as is frequent, this operation is repeated several times, the last carnivore will use no more than a thousandth of the original vegetable matter.

If the hypothesis of a teleology is to be judged from the point of view of the whole living world, it must not be forgotten that science and philosophy are the work of man in his relations with Nature, and that the existence of man presupposes certain natural conditions, material and indispensable. It presupposes a length of evolution sufficient to produce the complex creature that he is ; and a certain degree of stability both in physical conditions and in life as a whole. The environment must be such that man is able not only to appear as an animal species, but also to reach a technical and intellectual level sufficient for philosophy to arise. If things went too badly in the world of life we should not be here to state it. It is no use reversing the terms of the problem, like Joseph Prudhomme, who wondered at the divine providence which had sent a river flowing through the middle of every town.

Is it otherwise if we examine living beings separately ? The same number of hardy illusions still persist, even now not fully renounced by scientists, many of whom can still believe that the structure and physiology of an animal or plant are exactly adapted and adjusted to the requirements of their existence.

The classical statement of this doctrine is of course that of Galen, who in his book " On the Uses of the Parts " maintained in the second century A.D. that all the organs of man and animals were perfectly and purposively adapted to their use. It was on such a basis that Cuvier founded a method for reconstructing the form of fossil animals. He believed that certain morphological characters were always associated with a particular mode of life. From these he deduced other details of form yet unknown. The more fanciful writers, like Bernardin de Saint-Pierre, assigned some useful function to every detail of form, and indeed arrived at some odd conclusions : [1] " Nature has blackened the end of the tail in the Siberian Ermine, so that these little animals, otherwise completely white, following one another in the snow and leaving scarcely a trace can avoid getting lost, and can recognise each other in the luminous reflections of the long Northern night."

Even among the older evolutionists, Lamarck and Darwin, and especially among Darwinians, traces of this exaggerated optimism can be found.

It is now a long time since Cuvier's hypothesis that adaptation was precise has been discarded. It is now recognised that a living creature can possess organs which are useless, indifferent, or even harmful. Man,

[1] " Études de la Nature," X, p. 319.

who above all other creatures is supposed to be particularly perfect, has had a voluminous work devoted to his imperfections by Metchnikoff.[1] A passage from Cuénot in which he shows that the adaptation of living beings is far less perfect than that of the average industrial machine gives a very clear impression of the position : [2]

> "In an organism," he says, "which as a whole is specifically adapted to its environment, because it lives and reproduces there, by no means all its details are of direct use. Besides the necessary organs whose function and suitability are not in question, there are certainly some whose use has now departed, vestigial organs, residues from previous evolution. There are apparatuses whose complexity and dimensions are out of proportion to their supposed usefulness. . . . I have tried to show that besides indifferent mechanisms, which could be altered without inconvenience, there are superfluous organs, scarcely useful, perhaps even almost harmful. Without knowing it we are ourselves imbued with ready-made conceptions of the usefulness of all parts of an organism, so that we have some difficulty in admitting that the spleen, the uropygian gland, the air-sac, complex organs with nerves, vessels, and a physiology of their own, are useless, or almost so ; but the fact that removal leads to no perceptible inconvenience proves it."

This, with regard to detailed adaptations, is the position of a scientist who later in the very same passage declares himself a teleologist. But biologists of a mechanist tendency have adopted a rather different standpoint. Rabaud, for example, denies altogether that living forms are adapted to their functions : instead he insists on a rigorous adaptation of a physico-chemical kind, lying in the exchanges of materials between the living being and its environment.

[1] Metchnikoff, "Études sur la Nature Humaine."
[2] "l'Adaptation," p. 81.

This, however, is at the same time going too far and not going far enough. From the physico-chemical point of view the relation between the organism and its environment is very far from perfect. There is an American shad which under natural conditions lays its eggs in fresh water at 12° C. and in the light; while its optimum conditions, determined in the laboratory, are salt water with a salinity of 7·5 per 1,000, a temperature of 17° C., and darkness.

This discordance is responsible for high mortality among the eggs, but that does not prevent the species from surviving. Similarly there is a marine mollusc, the whelk, which seldom survives being stranded, but this does not prevent it from being abundant in the bay of Fundy in Canada, where the tides are the strongest in the world and where at each tide it loses large numbers of individuals. Innumerable other examples could easily be given.

On the other hand Rabaud concedes too little to the adaptation of forms. That an animal can swim without highly specialised fins is certain. But can an animal fly without wings? Why this difference, if not because the mechanical conditions of flying are more restricted than those of swimming? In the same way the eggs of the shad cited above would be incapable of living in highly salt water or at a temperature of 40° C. That is to say that environment imposes on form, structure, and the various capacities of the living being a limit outside which life is altogether impossible. If the being satisfies the conditions, life is possible for it. Within these limits the fact of its existence and survival depends on the nature and intensity of competition, that is to say that it depends essentially on the animals and plants which surround it. We are led back to the dynamic equilibrium of the living world as a whole.

Thus the more or less precise adaptation of an organ either in form or in physico-chemical constitution, has no decisive effect. It can exercise a faintly favourable effect on the individual. But the same individual may possess other organs much less precisely adapted and even harmful. It is the totality of complex conditions with which the verdict of life or death must rest.

Here again there is no room for teleology. The life of the individual and even that of the species is never anything but precarious, transient, and uncertain. Survival has, however, a certain degree of probability ; and the degrees of more or less perfect adaptation in the various organs also have their probabilities. In this sense Cuénot speaks of " statistical adaptations " :

> " Limbs formed into fins," he says, " are so common among aquatic animals that their presence in a fossil allows us to assume that it lived in water. This is merely a probability, though a very high one, since there can be aquatic animals without obvious fins where these are replaced by other organs, and there can be terrestrial animals which have conformations closely analogous to fins." [1]

And he adds :

> " When we speak of statistical adaptation this does not mean only that in a given environment A, the great majority of the species exhibit a special character *a* which is considered suitable to that environment ; it also means especially that in environment A there is a number of species with character *a* which is relatively great in comparison to the number which could exist in environment B, C, and so on. For example, along the coasts or on islands there are many insects and birds which lack wings or possess aborted wings or wings which have lost their function, but this is true only in comparison with the continent, as flightless species do not form the majority on the coast."

[1] " l'Adaptation," p. 18.

The existence of statistical adaptation explains the fact that physiologists seeking the usefulness of each organ usually find it, though not invariably ; thus the supposition that an organ has a function is not without probability.[1]

Recourse to chance in this matter does not imply suspension of causation. It means that in the tangle of complex causes and interactions a great number of causes are unknown : the immediate causes—since we are far from a correct analysis of the mechanical, physical, and chemical factors which go to make up environment ; the historical causes especially, since they are bound up with evolution itself. When we state, for example, that a fish and a whale which are both capable of rapid movement in the sea possess closely similar forms, we naturally associate this similarity with the mechanical properties of water. But to explain the huge difference between these forms, the different orientation of the tails, for example, we can only point to the different courses of evolution which the two species have followed, that is to say, to historical causes.

Certainly the historical causes are expressed at the moment in the composition and structure of the fish and the whale. We shall return to this point later. The differences of composition and structure in the two species, however, are still unknown ; we are as yet unable to influence them by experiment, and while this is so we are entirely dependent on data of a historical kind, which must be taken into account in any attempt to understand adaptation.

[1] This subject is discussed in the chapter, *The Chance that a Phenomenon has a Significance* in J. Barcroft's book "Features in the Architecture of Physiological Function" (Cambridge, 1934) ; and by M. Stephenson in her contribution to "Perspectives in Biochemistry" (Cambridge, 1937).

CHAPTER EIGHT

THE PROBLEM OF LIVING MATTER

(i) BIOCHEMISTRY

As we have seen, the basic biological fact which explains the continued existence of life on the earth is the immense power of self-expansion possessed by protoplasm. But protoplasm does not grow out of nothing. It must arise from inanimate nature, by transforming the materials it assimilates into products of similar structure to itself. The first stage is carried out by plants.

Assimilation may seem a very mysterious process. But outside the biological field there are closely parallel processes which are purely chemical, as many biologists have pointed out. Not infrequently a molecule of a substance A enters into reactions with substances B, C, D, and the final product is two molecules of A. This is the formula for assimilation, but such a phenomenon does not necessarily imply that A is living, because here the reaction will not take place unless the appropriate reagents B, C, and D are introduced in a definite order by human technique, whereas in the case of living matter this is, of course, unnecessary.

The remarkable feature of living matter is that it possesses a high degree of stability throughout all the changes of structure which it undergoes, and therefore remains recognisable, a fact which is incomprehensible or at least paradoxical on the basis of " metaphysical " logical thought. But dialectical thought finds no difficulty in the notion of living matter being, like everything else, at once " the same and not the same," and aims rather at defining the concrete conditions of this existence.

For a long time it was believed that living matter was composed of peculiar chemical substances quite different from those of lifeless matter. From this epoch dates the distinction between "organic" and "inorganic" chemistry, a distinction which is still preserved but with a completely altered meaning. About a century ago Wöhler first showed that urea, a chemical compound present in urine, could be reproduced in the laboratory by synthetic methods from mineral substances, and since then chemists have succeeded in synthesising nearly all natural organic compounds: sugars, fats, essential oils, and even the nitrogenous bodies called amino-acids and polypeptides. Even with substances like proteins, which still defy synthesis, there is no doubt that great progress is being made towards it. Moreover, the ingenuity of man has surpassed Nature and succeeded in building up hundreds of thousands of artificial compounds, still called organic on account of their relationship to the old organic substances, but which have never existed before either in the world of the living or the dead.

But does this immense progress give us any hope of synthesising protoplasm in the near future? Sixty years ago materialist scientists would have replied in the affirmative. It was their opinion that the synthesis of protein would be the creation of life. Their approach was, of course, mechanistic and metaphysical. Modern experimental science is more dialectical. Life is more than a mere mass of protein. It is a highly complex system where proteins play decidedly the most essential part, but where other substances are hardly less indispensable—fats, lipoids, sterols, sugars, acids, water, etc. The interactions of all these substances among themselves and with the environmental medium gives that complex form of the motion of matter which we characterise as life.

If we were to combine proteins and all these other substances in as complex a way as we are capable of, we should yet not produce living matter. The chemical reactions in this jelly-like mixture would be unorganised and would quickly come to a standstill. We should not have reproduced that structure or organisation which is just as peculiar to life as its chemical composition.

(ii) VISIBLE STRUCTURE: THE CELL

All living matter has a structure. At no time is it shapeless and of indefinite proportions. It exists normally in the form of cells each kind of which possesses a definite dimension and aspect. The cells may live separately in an external medium or they may be grouped together into complex organisms, as we shall later describe. The human body, for example, is an aggregate of several billion cells.

Each cell has a distinct individuality and internal structure (Fig. 1). It possesses in general a nucleus surrounded by cytoplasm. And both the nucleus and the cytoplasm have a structure. In the nucleus small bodies known as nucleoli are often enclosed. The cytoplasm frequently contains numerous grains or small rods called mitochondria; small spherical liquid inclusions called vacuoles; droplets of fat, grains of starch, etc., varying with the type of cell. All these parts of the cell do not possess the same structure or chemical composition. The nucleoli differ in constitution from the nucleus; the mitochondria and vacuoles from the cytoplasm. That certain cells, such as those of bacteria, are more simple and contain no nucleus does not alter the fact that living matter always possesses structure of some sort, down to the lowest bacteria.

For a long time it was fashionable to speculate on the

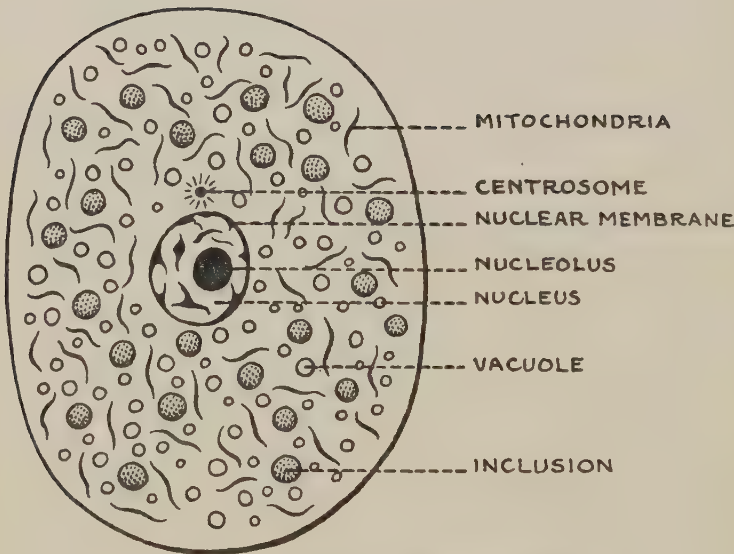

FIG. 1.—DIAGRAM OF CELL STRUCTURE.

position of the actual seat of life. Some biologists favoured the nucleus, others the mitochondria, while others preferred a small body near the nucleus called the centrosome. According to the supporters of the nucleus, the phenomena of cell life were explained if the nucleus played the part of an active and autonomous directive body, the remainder of the protoplasm being no more than an unleavened mass passive to this control. The partisans of the centrosome pushed an analogous view-point to a similar extreme ; the displacements of this were eagerly followed under the microscope throughout the phases of cell life and seemed to indicate a leading function. So great was the general confidence in the idea, encouraged by an undeveloped state of technique, that the key to the mysteries of life lay in the internal structure of the cell, that innumerable new details were continually described, many of which have since been found to be inaccurate and the result of artificial conditions.

In this work mechanists and vitalists worked in much the same way. For vitalism the centrosome became a sort of cellular soul. For mechanism, according to genuine but nevertheless crude analogies, it became a focus of electric forces or a nest of filaments. From one or the other standpoint both failed to consider the relations of the centrosome with the rest of the cell, and neglected to study the constitution of the whole.

The first glimmering of a dialectical conception of cell life came from those who, thirty years ago, attributed the essential vital phenomena to the formless cytoplasm which bathes all the specialised bodies of the cell ; they regarded this constituent of the cell as being most essential, on the view that what was least coagulated in form must be the most alive. Thus they possessed the germ of the idea that life is essentially change.

Since then much progress has been made. There are few modern scientists who do not regard cell life as a totality of incessant material interchanges among the various structural elements of the living substance through the medium of the amorphous cytoplasm, as between the cell as a whole and its surroundings. It is impossible to say that this or that element is alive or not. Certain components, such as the nucleus and a certain minimum of cytoplasm, seem particularly indispensable. But the life of the cell is a resultant made up of the activities of practically all the constituents present.

Life, therefore, is fundamentally bound up with structure. Without structure there can be no internal interchanges, and no expression of them in interchanges with the environment. Without structure no reaction can be arrested before it has used up all the material available in the cell, or at least before reaching stable equilibrium such as would result if the reaction took place in a chemist's test-tube. Without structure it would be impossible for living matter to maintain its stability throughout its infinitely complex interchanges.

(iii) INVISIBLE STRUCTURE; THE COLLOIDAL STATE

Structure certainly does not cease at the limits of microscopic observation, at the order of a ten-thousandth of a millimetre. The greater part of the substances in living matter are what is known to chemists as "colloidal"—a state also known in inanimate nature. The colloidal state has the possibility of extremely complex structures whose dimensions lie between those of the largest chemical molecules and those of the smallest microscopic structures. We can obtain shadow pictures of the largest of these structures by means of the ultra-microscope, but the smallest are not directly visible and are proved to exist by indirect means.

Thus the colloidal state permits living matter to be neither a simple mixture of chemical substances nor to be confined to the rigid structure of a chemical molecule. Between these two extremes it achieves something of a synthesis : it allows local physical or chemical variations to occur without violent repercussions upon the cell as a whole. There is achieved in the cell, in fact, the complex interactions which make life possible.

But this is not all. Colloids, whether living or non-living, possess another property also found occasionally in non-colloidal inorganic matter to a more limited degree. The reactions taking place at one time depend on the previous reactions which the substance has taken part in. These have a historical character. For example, the solution of a quantity of common salt, a non-colloidal substance, in water, brought afterwards to a definite temperature and to very precise physical conditions, varies very little whether the original solution was made with hot or cold water, with a large amount of salt and then diluted or with the required amounts of each. The result is the same final solution in any case. But with colloids the final result depends very largely on the conditions through which it passes during the course of preparation, since it is these conditions which partly determine its structure.

This conception is sometimes expressed by speaking of the " memory " of colloids. The term is dangerous, because it might conceivably be imagined that colloids possessed a memory analogous to ours. But it is correct as well as suggestive to see in this imprint of the past expressed in the structure of colloidal living matter what is undoubtedly the material basis both of psychological memory and of heredity.

As the perpetual interchange takes place between the cell and its environment, and between different parts of the same cell, the internal structure is modified also. Regions of the cytoplasm become more or less mobile or viscous; vacuoles grow or diminish in size; the nucleus alters its form or position; reserve materials accumulate or are consumed; or the surface of the cell suffers deformation.

(iv) CRISES IN STRUCTURAL CHANGE

Structural modifications are normally slow, but from time to time take place so suddenly as to be veritable revolutions. As an example we can give a brief description of cell division, one of the most frequent and important of these sudden changes (Fig. 2).

In a cell in the resting stage the first sign of the impending revolution is the division of the centrosome into two. Each of these daughter centrosomes becomes the centre of a zone of more viscous protoplasm with a radiating structure. They then appear to repel each other towards the two poles of the cell. During this period the material of the nucleus alters in structure and distributes itself into a number of usually elongated bodies known as chromosomes. The number of chromosomes is constant for a given species. These become immersed directly in the cytoplasm by the disappearance of the nuclear membrane which divides the nucleus from the cytoplasm. At first they take up a position equidistant from the two centrosomes, then each chromosome splits lengthwise and the halves gradually move one towards each centrosome, so that ultimately each centrosome has a half from each chromosome. The halves then lose their individuality and fuse to form a daughter nucleus, which soon takes on the resting structure. The total result is that the old cell is divided into two daughter cells each with a precisely analogous structure. This division, however, takes place by means of a complete revolution, and not, except

FIG. 2.—DIAGRAM OF THE DIVISION OF THE NUCLEUS AND THE CELL.

1 to 3: Formation of chromosomes in the nucleus and doubling of the centrosome.

4 to 7: The chromosomes split and move towards the poles.

8 and 9: Reconstruction of the nuclei and the separation of two daughter cells.

in very simple cells, by simple fission, the drawing out of equal quantities of nucleus and cytoplasm.

Such a change-over depends for one thing on the internal conditions of the cell. It tends to occur at intervals wherever the growth of the cell leads it to approach a certain limiting size, probably when the surface of the cell and the nucleus where the interchanges of materials take place become too small in relation to the total volume of living matter. In this sense there occurs something of a cell crisis.

In addition it depends, like all crises, on external circumstances. In multicellular organisms various disturbances of the equilibrium can open the way for cell divisions. For several years some biologists have thought it possible to detect an influence exerted by cells in course of division on their neighbours which leads them to divide also. And undoubtedly there are experimental ways of arresting or restarting cell division already in progress.

(v) LIFE AS ORGANISATION

No scientist doubts the fundamental identity of physical and chemical phenomena in living and in lifeless matter. Vitalists themselves recognise this, but reserve a place for an overriding teleology which in some way regulates and guides the totality of the phenomena and gives the living being or the cell its essential unity.[1] Sertillanges, for example, tells us that :

> " The success of the experimental method applied to living things proves, in so far as the method can, that life possesses physico-chemical forces as the exclusive instruments of its action." [2]

[1] The best-known English representative of this view-point was J. S. Haldane in his " Mechanism, Life, and Personality " (Murray, London, 1913) and the *locus classicus* is H. Driesch, " Science and Philosophy of the Organism " (Black, London, 1929).

[2] Quoted by R. Collin : " Physique et Metaphysique de la Vie," p. 91 (Paris). This book is entirely permeated by the same point of view.

Taken up by modern vitalists this position is strong enough in that it permits them to avoid all contact with experiment. Any proof that a phenomenon of cell life can be influenced by physico-chemical factors, or even reproduced experimentally by these means, simply evokes the reply that this is not surprising, but that the whole living organism with its assumed purposiveness can never be grasped by such methods. We are challenged to synthesise a living organism.

The synthesis of life from inanimate matter is an old dream of biologists.[1] In Engels' time [2] it was conceived as a matter of chemistry pure and simple. But to-day the matter seems much more complicated. It is true that some still cherish the belief that one day somebody will discover some unsuspected physical or chemical phenomenon which will deprive life of all its secrets at one fell blow.

But this attitude is mechanistic, mistaken, and very dangerous. It states an insoluble problem in terms of the vitalist conceptions themselves. For there can be no single secret of life. There exist perhaps as many kinds of living matter as there are species, or as there are varieties of cells in one species, or even more. It is very unlikely that all these " secrets " will be one day revealed by the discovery of some quasi-miraculous phenomenon.

It is not unlikely that each form of living matter is characterised by the chemical constitution of the substances, in particular the proteins, of which it is made up. These substances are so complicated that the number of different but nevertheless closely comparable combinations is enormous, and indeed greatly exceeds the number of all known living species.

[1] It goes back at least to Paracelsus and his " homunculus " in the sixteenth century.

[2] For the attitude of Engels to this question, see pp. 196 ff.

That each form of living matter is characterised by different proportions of the chemical constituents of its highly complex structure is practically certain, and on this question a greater volume of experimental data is available.

Finally, that it is characterised by the particular structure or organisation of the complex is again practically certain. A particular form of living matter can only be characterised in this very complex way. It is the result of an evolution lasting at least millions of centuries. And yet the scientist is asked to succeed in reproducing it in the laboratory in a few minutes.

What has been achieved up to now, and is certain to be developed further, is the influencing of the fundamental phenomena of life, not merely so as to modify their action but so as to improve them from the point of view of life itself. This opens up to man the whole realm of "biological engineering." For example, certain protozoa cannot under natural conditions reproduce themselves indefinitely by cell division. At the end of two or three hundred generations the rhythm of the divisions grows slacker and ultimately the individuals degenerate and perish if they cannot in time carry out the rather complex process of conjugation in pairs. Before reaching this stage they pass through a crisis of degeneration due to the development of their life itself. Now to-day it is possible if not completely to avoid the crisis at least to mitigate it by cultivating them on artificial media, like meat extract, or by adding to the medium small quantities of certain chemical compounds, such as alcohol or strychnine. If we wish to admit that a purpose presides over the life of these organisms, it cannot be denied that, here as elsewhere, human purpose surpasses natural purpose.

CHAPTER NINE

THE PROBLEM OF FORM

(i) FORM AND DYNAMIC EQUILIBRIUM

One of the most striking characteristics of the living organism is that its form, apart from temporary deformations associated with movement, is practically stable throughout the more or less extended period of its life.

For this chapter we shall leave on one side the very simple case of a unicellular organism in contact on every side with the surrounding medium. Despite their simplicity of principle such beings can display very varied forms, but in this case we are still dealing with cellular form to be explained, as we have seen, on the basis of the internal structure of living matter.

But the problem of living forms concerns animals and plants whose bodies are made up of aggregates of cells varying in number from a few dozen to some billions. Such an agglomeration has a distinct structure, the cells being formed into tissues and the tissues in their turn into specialised organs. This hierarchy, from which results the general form, may appear to be the result of teleology. Can it be explained from the materialist view-point ?

One thing which it is important to note is that stability of the whole form and of that of the various organs does not generally imply that of their cellular elements. The cells of almost all tissues are being constantly renewed, a factor which is often left out of account. Every moment cells are dying and others are taking their place. Common observations give many examples of this process. The bark of a tree, the skin of a man, constantly peel off at the surface and are constantly renewed from below. Red blood corpuscles are constantly destroyed in the spleen, while new ones are produced in the marrow of the bones ; even the bone-tissue, hard as it is, is often destroyed in certain places while it is being built up at others. This is part of a general dialectic from which scarcely any escape but certain very small animals with a very small and invariable number of cells and, at the other end of the scale, the nerve-cells of higher animals.

In attempting to explain living forms, therefore, it is necessary to adopt a dynamic point of view. In a living being which outwardly changes very little, the losses and renewals are almost exactly counter-balanced in tissue and organ. This is possible, as we shall see, because the influence exercised on each tissue and organ by the other tissues and organs of the body remains practically the same.

(ii) MATERIAL INTERACTIONS WITHIN THE ORGANISM

The various organs and cells of a living being are, in fact, far from independent. They are linked by interactions and correlations on which their form and function depend, and which are capable of acting over considerable distances.

One kind of co-ordination is effected by means of the nervous system, whose function is too well known to require description here. It is worth remark in passing, however, that the nervous system can often influence the form of the body, because nervous action contributes towards the regulation of nutrition and the " tone " of certain parts.

A second type of co-ordination is achieved by means of what physiologists call internal secretions, or hormones. These products are released into the blood-stream by certain organs and can exert a most important influence on other parts of the body. Digestion takes place as a result of a hormone (secretin) secreted by the intestine under the influence of the stomach contents. This hormone automatically stimulates the secretion of the pancreas, which is responsible for digestion. The sugar content of the blood is governed by the liver under the influence of another hormone secreted by the pancreas (insulin). Again, it is hormone action which, through an elaborate interplay of material chemical reactions, ensures the regular cyclic functioning of the genital organs in women or the females of mammals (œstrin).

But hormones have also an influence on form in accelerating or, on the other hand, holding up the development of certain organs. Everybody is acquainted with the alterations of form which result from castration in man as well as in the bull or the sheep; these changes are due to the suppression of a hormone emitted by the testicle. In women the genital hormones at the same time promote the development of breasts and prevent that of the beard. The crest of a cock, its spurs, the difference between its plumage and that of the hen, are again dependent on genital hormones. But the development of the genital apparatus itself depends on hormones issuing from a gland attached to the brain, the anterior pituitary, while the thyroid and posterior pituitary send out hormones which act on the growth and form of the body. These hormones have in many cases a known chemical constitution, and some have been synthesised in the laboratory.

In attributing phenomena to hormones physiologists rightly demand very rigorous tests. It is necessary, for example, that the experimental removal of the organ which produces the hormone leads to the very disturbances in the organism which are compensated experimentally by the injection of extracts of this organ. But this does not imply that all reactions of a chemical order between cells and organs are now understood. It seems more likely, indeed, that these classical cases are only the extremes and that such reactions are in fact general phenomena. This can be verified by the method of explanation, the artificial culture of tissues.

For a long time it has been known that an organ or tissue can in certain cases survive after it has been separated from the animal to which it belonged. Thus white blood corpuscles continue to move about for several hours; the heart of a tortoise can beat for several days. But this is only a limited survival without any growth of the separated tissue.

Twenty-five years ago Ross Harrison discovered a means of achieving a true culture of tissues with unlimited survival and growth, that is to say, with multiplication of cells. Certain of the original cultures of another pioneer, Carrel, have been conserved to this day. They were taken from the embryos of chickens which, even if they had not been killed, would in any case by to-day have died of old age. The cultivated tissue, therefore, has survived much longer than the animal itself could have done, and man has again achieved results far beyond the possibilities of natural conditions.

The growth of a culture is such that at times its volume can double itself in two days; at this rate, in theory, it could rapidly attain astronomical dimensions. In practice the growth of a cultivated tissue cannot take place in this way owing to the lack of appropriate media of sufficiently vast dimensions, and it suffers the same restrictions in its multiplication as protozoa and bacteria. The artificial separation of a tissue from its normal relations in the organism which experiment achieves, however, is favourable to its growth : in other words, this is normally limited by the subordination of the tissue to the organism.

If the culture is made under the best possible conditions, that is to say, on coagulated blood plasma to which embryo extract has been added, and with frequent transplantations, the multiplication of the cells is very rapid. Under these conditions the cells lose more or less the special characteristics which mark them as belonging to this or that organ. The first observers to notice this fact believed that in culture the cells were de-differentiated, that is to say that they became ordinary cells which preserved no traces of their history as liver-cells, bone-cells, or skin-cells, etc. We now know that this is not the case ; under such circumstances liver cells may entirely lose their characteristic appearance and become unrecognisable as such, but their past still lives within them, so strongly, indeed, that under changed conditions, if the culture is badly nourished, they again adopt the aspect and function of liver cells and of no others. Similarly, bone cells when deprived of nourishment in a culture regain the appearance and function of bone-cells, and so on.

From all this it follows that for any tissue the organism exerts a limiting influence on nutrition, multiplication, and the degree to which the differentiated activity is expressed. The organism limits the potentialities of the tissues which make it up.

In a pure culture, that is, a culture of only one kind of cell, multiplication is not unlimited ; at first rapid, it gradually slackens and ultimately ceases as the resources of the medium approach exhaustion. It obeys exactly the same mathematical laws as the growth of population of organisms of the same kind, and to a certain degree a tissue culture can be regarded as a cellular population.

A tissue culture cannot, however, be equated to a population of unicellular organisms such as protozoa in a liquid medium. The abstract growth laws are in each case the same. But this protozoan population has generally neither structure nor form: the individuals move about in a quite irregular fashion; the most that the external medium can achieve is to govern their distribution according to certain statistical laws.

A tissue culture, on the other hand, has a definite form, usually circular or discoidal. This difference is not fundamental: it is connected primarily with the physical state of the medium. Tissues are cultivated on more or less solid media, and certain unicellular organisms such as bacteria when cultivated on such media also give aggregations or colonies of such constant form that experienced biologists can thereby recognise their species. A tissue culture is, in short, a colony of cells obtained on a solid medium.

That the circular form of these cultures is not pure chance has been shown by Ephrussi. The removal of a portion of a culture results in modification of the growth, which becomes more active in the neighbourhood of the wound and gradually restores the discoidal shape. This phenomenon recalls in a simpler form that of regeneration, or the reconstitution of removed organs observed among a great number of living organisms.

Ephrussi has been able to analyse experimentally the complex reasons for the return to the discoidal form, which represents a sort of stable equilibrium.

To begin with, the wound causes a general interruption of the normal relations between the colony and the resources of the medium; its growth therefore increases in the same way as that of a population which has suffered decimation without any change in environment; this acceleration takes place most in the neighbourhood of the wound because it is there that the equilibrium is most disturbed. But, apart from this, there is little doubt that the wounded cells liberate substances which stimulate cellular multiplication. This is naturally local rather than general. Thus we have another example of a phenomenon which itself gives birth to the causes of its own destruction, that is to say a dialectic phenomenon.

Such phenomena are undoubtedly very common. In all tissue cultures, particularly towards the centre, cellular mortality is very high. There is reason to believe that the death of these cells liberates substances which stimulate the growth of the culture, and one arrives at the paradoxical conclusion that the cultures whose growth is most active are those whose cells have the shortest life and are the most fragile. As a result of studies of cancerous tissues there is even a tendency to believe that cancer may involve such very fragile cells, whose rate of multiplication is so rapid that in some way they are freed from the correlations which the organism imposes on normal tissues and invade these without any limit other than the death of the organism.

The form and size of a pure tissue culture are due to interactions between the cells which compose it. But a tissue-culture can comprise two or more different tissues. In this case interaction between tissues takes place.

Interaction first shows itself by a modification of the rate of growth of each component, generally a slowing down, at times a speeding-up as in a cancerous tissue in contact with a normal one. The presence of the other tissue, moreover, makes it far easier for each to retain its original characteristics, activity, and disposition. Thus glandular tissues cultivated in the pure state, though normally arranged in tubes, lose this arrangement and develop as simple layers. But if they are cultivated in the presence of connective tissue they again tend to form regular tubes.[1]

It has even been found possible to cultivate portions of the primordial bone tissue which have been taken from very young chick or rat embryos. As these samples are complex and contain several different kinds of tissue, they do not lose their differentiation and develop as a whole almost normally; but if they are cut into pieces their development becomes almost anarchic. In short, the entire architecture of a sample is the determining factor in its course of development; that is to say, the factors which limit its growth reside primarily in itself.

But this is not exclusively true. In feeding tissue cultures with blood taken from animals of different ages, it has been possible to show that the blood contains substances which can modify the rate of growth of the cultures; some accelerate, others retard it. As animals grow old the substances which inhibit growth predominate more and more markedly. These substances are released into the blood by certain tissues, giving rise to a mode of interaction which much resembles that of hormones.

Thus in an organism, however complex, the maintenance of its structure and form is well known to take place by a multiplicity of interactions, between the cells of each tissue, between adjacent tissues, between organs even when widely separated, through the agency of hormones or of the nervous system. From these interactions results a limitation of growth in each tissue and a total equilibrium which is never seriously disturbed

[1] The German experimental embryologist Holtfreter extended the principle of tissue-culture to parts of developing frog embryos, which are very convenient for the purpose as they carry within their cells the necessary food in the form of yolk. He was thus able to show that the normal shape of an organ such as the nerve-cord depends enormously upon what other tissues it has with it in its isolation.

except in abnormal cases such as those of cancer. This explanation, however, takes for granted the existence of already differentiated cells and tissues. We have yet to trace this differentiation to its source.

(iii) PREFORMATION OR EPIGENESIS ?

In the majority of cases a multicellular organism arises from an initial cell called the egg by a process of development which can always be described by the following scheme: the egg divides into a number of cells of varying sizes; after a certain time the cells thus formed begin to differentiate, that is to say, to group themselves more and more definitely into tissues and organs, the rudiments of which thus become more and more clear. The animal thus passes through a series of forms which lead to that of the adult. We shall deal first with the simplest case where this series is most continuous and regular.

The naturalists of the eighteenth century believed that in the eggs there existed in little the successive forms which growth would later make apparent. This was the doctrine of preformation. Subsequently the progress of microscopic observation rendered this view untenable; it became clear that the egg was in appearance simple but that it passed by stages into new and more complex forms. Preformation was opposed by epigenesis.

In spite of the unquestionable truth of these observations the fact remains that an egg does not produce an individual of no matter what species: apart from exceptions caused by mutations, it always gives an individual of its own species. In this sense, therefore, the individual is preformed, but it is clear that the word "preformation" has not here the same sense as it had in the eighteenth century.

Vitalist biologists get out of this difficulty quite easily. "The egg in the course of its development," says one of them, following Aristotle, " proceeds to the conquest of a specific form which only comes about later. This form is determined from the moment of fertilisation, but it exists in the egg in a state of reduction since the mechanism of development is epigenesis, not preformation. We therefore say that the future form is potentially present in the egg, or again that the ' idea ' of the future form, that is to say, the end or aim to be attained, is in the egg." [1] This is only some two thousand years out of date.

Another, more crudely, speaks of a series of ideal moulds which the living thing fills successively in the course of its development. This is a doctrine of material epigenesis but ideal preformation.

The mechanist biologists of fifty years ago strove to imagine the material forces which could govern these changes of form during the process of development. Not unnaturally they looked to the external environment because this seemed the simplest thing to do. Sometimes they gave explanations like this: at a certain stage the embryo is spherical because nothing prevents it being so; a little while afterwards it ceases to be so because, the number of cells increasing, the complexity of the form allows them to find room for a smaller volume of embryo. Such explanations, though they began mechanistically, quickly led to flirtations with teleology. But they had a graver fault than that. They did not take into account the details of the species considered, details which are not modified by external factors whatever they may be: if we act by some process on the egg of a frog we can obtain a monster, but it will always be a monstrous frog, and not any other species. In fact, such explanations were not even

[1] R. Collin, *loc. cit.*, p. 21. In this quotation the words " preformation " and " epigenesis " are evidently taken in the eighteenth-century sense.

mechanistic—they were geometrical; far from taking into account the complexity and the detail of concrete living matter, they dealt in purely abstract systems.

Modern biology, ever more experimental, has been led to ever more deeply materialist conclusions. The egg of a species is a material whole with a structure; its various parts at a given moment have actual compositions and special structures. Hence each of the parts has its own law of development, and it is the reciprocal limitation of these, more or less marked according to the particular case, from which the form of the living being at a particular moment arises. Such is the idea of a whole which arises from researches in what is called, perhaps a little inappropriately, "developmental mechanics." It is, if you will, the idea of a material preformation quite different from the preformation of the eighteenth century, tempered with a certain degree of epigenesis, very different from the simple-minded epigenesis of the mechanists. Between the preformationist thesis and the epigenetic antithesis modern science has found the dialectical synthesis.

(iv) MATERIAL INTERACTIONS DURING DEVELOPMENT

In interpreting development the fundamental conception is that of an egg of a given species having a heterogeneous material structure, endowed with a certain symmetry, and always characteristic. This was recognised for the first time and most clearly in the Ascidians, a group of marine invertebrates. Here different parts of the egg are differently coloured, and it is possible therefore to follow the history of their development until a stage is reached when the various organs of the embryo become easily distinguishable. The material structure of the egg was thus found to be symmetrical about a plane, so that despite its apparently spherical form it already possesses right and left halves corresponding to the right and left halves of the animal which will develop from it. Moreover, each coloured area of the egg is responsible for a particular organ or a group of cells. One produces the digestive tube, another the nervous system, a third the muscles of the tail, and so on.

These facts were corroborated in a more precise way by experimental evidence. In the earlier stages of development the successive divisions of the egg into 2, 4, 6, 8, 16 cells lead to the isolation of various areas (Fig. 3). But if certain of these cells are artificially removed or killed by pricking with a very fine needle, subsequent development, instead of giving a complete animal, gives an animal lacking the very organs corresponding to the suppressed cells. If, for example, after the first division of the egg the two cells thus formed right and left of the plane of symmetry are separated, each of these fails to develop into a complete embryo, but becomes a half-embryo, a right half or a left half, closed up on itself but possessing only the organs of the right or left side. If after the second division of the egg one of the four cells is killed an incomplete embryo results. A quarter of the organs are missing, those of right or left, front or behind according to the cell killed.

A considerable number of such experiments has now been made. Whatever form they have taken they have all gone to show that in the Ascidian each of the areas of the egg has its own law of development and that if one of them is missing the embryo is defective in a perfectly definite way. The total development of the embryo appears capable of analysis into a number of partial developments. This is true even among Ascidians whose eggs are not coloured, for the pigments are in no way responsible for the peculiarities of development; their importance is purely that of indicators which facilitate observation and description.

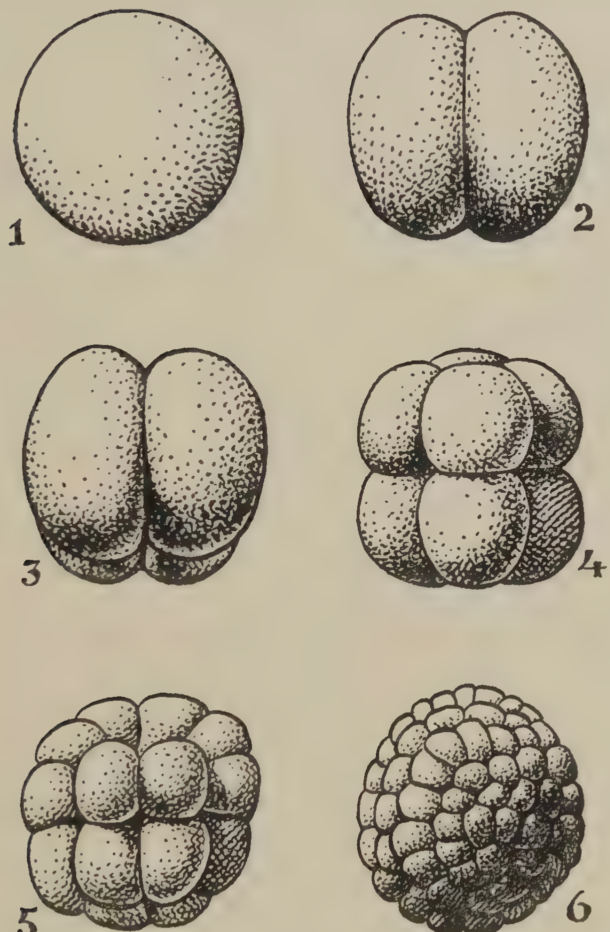

FIG. 3.—SIX STAGES IN THE EARLY DEVELOPMENT OF THE EGG.

1. Undivided. 2. With 2 cells. 3. With 4 cells.
4. With 8 cells. 5 and 6. More advanced stages.

Eggs with heterogeneous constitution and a development like those of Ascidians occur in other groups of animals : insects for example. They are called " mosaic eggs," a term which fits their structure well. The various areas of the egg with specific laws of development are called " germinal localisations."

The first experiment on the mechanics of development were made by Chabry in 1887 on the eggs of Ascidians. Shortly afterwards the vitalist biologist Driesch arrived at diametrically opposite conclusions. He declared that if during the course of development of a sea-urchin egg a single cell was isolated, that cell would always give a complete animal no matter what its position before removal. Naturally the smaller the size of the cell in question, *i.e.* the later the stage of development at the time of removal, the smaller was the size of the embryo produced, but the essential fact was that it possessed all the normal organs. The operation was of course impossible with cells which were too small, less than a fiftieth of the volume of the egg.

Driesch concluded that development bore no relation to the material structure of the cell removed, and could therefore be explained only on the basis of an immaterial regulative principle, a teleological force which led it to become identical in every case. Extending this theory, he even tried to show by experiments contradicting those of Chabry that this conclusion applied also to Ascidians.

Subsequent inquiry has proved Driesch both right and wrong. There is now no doubt that his experiments contained mistakes and that the sea-urchin egg, like those of the Ascidians, possesses germinal localisations. But nevertheless it has also been shown that in the sea-urchin egg, as in many others, the germinal localisations are neither so precise nor so stable as in that of the Ascidians. To a fairly large extent these localisations can regenerate themselves, either in the course of normal development or under experimental conditions. It frequently happens that this regeneration can be complete so that the cell artificially removed approaches in little the structure of the whole egg ; in these circumstances its development leads to a complete embryo, as Driesch correctly observed. Such a reconstitution is naturally easier with a large cell which contains a better selection of the types of materials possessed by a normal egg, that is, with a cell taken at an earlier stage of the egg's development. In many cases the cell is too small and badly situated with regard to the whole, so that it cannot contain more than a part of these materials ; here regeneration is incapable of reproducing the entire structure of the egg, and development only leads to a more or less partial embryo.

Eggs of this second type are called " regulation eggs." *In the course of normal development each cell produces fewer organs than it is capable of when isolated.* This is again another way of saying that although the various parts of an egg have each, in virtue of their particular composition, their own law of development, and fairly wide potentialities, the complex interactions set up between them result in the limitation of each by all. The development of the whole egg is not the mere sum of the development of the various parts : it achieves a higher unity.

Further, there is no absolute opposition between mosaic eggs and regulation eggs. An examination of the various groups of living beings reveals that Nature presents all intermediate stages between eggs of the mosaic kind and those with high regulative capacity. But even in the latter the power of regulation diminishes little by little during the course of development, as if the germinal localisations gradually became more fixed and rigid. And various more recent researches have proved the existence of feeble regulation even in typical mosaic eggs. The difference between them thus seems more a matter of quantity than of quality, a matter of the greater or less rapidity and preciseness with which localisations are fixed.

All the areas of a regulation egg do not possess the same importance for the course of development. There are some whose influence on surrounding areas is very weak, while others exert a fundamental influence on the formation of organs of great importance. Such privileged areas are called organisation centres. For example, in the egg of a newt or frog there is one area without which the primordial nervous system, the main embryonic axis, never appears. But this area takes no part in the nervous system itself; it is an organisation centre, or "organiser."

The very delicate experiment, first made by the German embryologist Spemann, of removing an organiser and regrafting it in another place in another embryo leads to the formation of the primordial neural tube in an abnormal position. If, for example, at the beginning of the development of the egg of a newt a second organiser is grafted into it, there arises a monster with two nervous systems, instead of one; in fact, a Siamese twin. Many other analogous experiments show very clearly the preponderant role of organisers.

In this connection the following question is much under discussion at present. Is the organiser a homogeneous thing possessing peculiar directive powers, or is it something complex arising from the interaction of its various parts, and its reactions with the rest of the egg? Experiment is still indecisive on this point, but from the materialist point of view it does not seem possible to doubt the answer that will be given. The first answer, in fact, would give the localised organiser the same abstract teleology which Driesch bestowed on the egg : it is a vitalist solution. The second, however, puts the question in terms of dialectical materialism.

Experimental reality, however, seems to be even more directly materialist than one would have dared to imagine. Recently the English biologists Needham, Waddington, and others have succeeded in replacing the action of a living organiser by certain chemical compounds, first by the ethereal extract of eggs, including the organiser-region, and then even by synthetic substances. Organiser action, therefore, at least in part, is analogous to the secretion of hormones, of which we have already spoken.[1] Researches on these "form-producing hormones," which are still going on, provide definite proof that the interactions which take place in a developing egg are of a material and chemical nature.

(V) MATERIAL INTERACTIONS DURING REGENERATION

If an earthworm is cut in two or the tail of a lizard amputated or the leg of a newt cut off, the animal is often capable of replacing the parts thus lost. This process is called regeneration, and has received many teleological interpretations, since it often restores the living thing to its normal form. But many animals, for example man and the higher vertebrates, have practically no power of regeneration. Moreover, it is not unusual for regeneration to give rise to an entirely new form which may even be fatal to the organism. Worms can arise with two opposite heads or with two tails and no head. Adaptation is again merely a probability and by no means certain.

Experimental studies have shown, first, that regeneration is possible only when the wounded animal possesses cellular material sufficiently undifferentiated to be able to multiply rapidly. Moreover, this multiplication

[1] See p. 103.

must be set in action by wounding, as in the case of tissue cultures.

A second basic fact of regeneration is that this cellular material must not proliferate excessively or irregularly, but must show an orderly growth. The regularity is imposed by the structure of the tissues surrounding the wound. If, for example, the eye of a crayfish is amputated but the ganglion at its base is left unharmed the result is the regeneration of an eye. But if the ganglion is destroyed the result is an antenna. In the same way a worm must be divided below a certain point if a tail is to develop; if not a second head will grow in place of a tail. In sum, the remaining tissues act upon the regenerating part in a similar way as the organisation centre does upon the primordial tissues whose development it stimulates and controls.

This is not the only analogy with the phenomena of development. The production of a complete embryo from a fragment of a regulation egg is very comparable with regeneration. Regeneration in the adult is not fundamentally different from regulation in embryonic development. Regeneration, indeed, is a residue of regulation which has survived to an age when the material structure has been fixed much more rigidly and the potentialities of the various parts have suffered a progressive reduction. The last remnants of a teleological explanation of regeneration are thus destroyed.

(vi) CRISES WITHIN ORGANISMS

The foregoing will have made it clear that the development of a living thing must at every instant be regarded as the interplay of complex material reactions between parts with their own composition and laws of development. This interplay, however, though doubtless harmonious, is not always in unison, and as a consequence the organism suffers periods of crisis followed by genuine revolutions.

Crises and revolutions abound in the world of life. The metamorphoses of insects, amphibia, and many other animals belonging to a variety of groups can be quoted. In addition, there are the moultings of skin of insects, crustacea, and others. But close examination reveals many other examples, even up to the higher vertebrates.

The growth of a higher animal considered as a whole seems to display perfect continuity from birth to death ; at first it is rapid, but slows up as time goes on—following, indeed, the same general course as the growth of a tissue culture or a simple population without external restraint. But examined more closely, organ by organ, as has been done by Teissier and Needham with rats and chickens, the life of the animal shows distinct stages, inside which the various growth curves of the organs and the variations of chemical composition are very regular. These curves, moreover, differ among themselves in the various stages, so that the chemical composition, structure, and form of the organism change during each stage in a slow and continuous way. The successive stages are separated by critical periods of quite brief duration, when the laws of development change very sharply. These facts translate themselves in the growth curves as discontinuities. From the physiological point of view they correspond to more or less profound changes in the reciprocal equilibrium of the constituents of the organism. It is probable, judging by the phenomena displayed by the growth of various glands with internal secretions, and by what we know of the interactions of these glands, that these critical points frequently correspond to important modifications in the interplay of hormone correlations.

In the rat, for example, a first critical stage is reached when the animal attains the weight of about 15 grams. The rate of growth changes at the same time for the heart, the thyroid gland, the skeleton, the muscles, the ovary, the thymus, the testis, the pituitary and suprarenal glands, but above all for the eye and the brain : it is the precise moment when the nerve-cells cease to grow in number and when the chemical composition of the adult nervous tissue becomes constant. The second critical phase is reached at the time of puberty, that is to say, when the animal attains the weight of about 80 grams. It is especially marked for the genital organs, the thymus, and the suprarenals of the females. These two critical points, which stand at either end of adolescence, correspond to genuine metamorphoses, much less marked externally, however, than those of insects. In the chick embryo two analogous critical points have been revealed, corresponding respectively to 9 and 15 days of incubation.

The terms " crisis " and " critical point " are common currency among biologists for all such cases. Everyday language speaks of the " crisis of puberty." Biologists use the word " crisis " similarly when an organism passes from the independent to the parasitic mode of life or when a parasite changes its host. In all such cases the organism encounters special difficulties in its development, resulting in a relatively high rate of mortality for the species. We must, however, examine the notion of crisis more carefully.

Let us take as an example the metamorphosis of a butterfly. Externally it is characterised by the immobilisation of the caterpillar which becomes a chrysalis, and from this there issues at a later stage something of totally different aspect, namely, a butterfly. In the chrysalis there occurs a destruction of older tissues and the building of new organs such as wings out of tissues which existed in the caterpillar but which develop at this moment only, or are considerably modified. Here we have all the essentials of a revolution. But this revolution is preceded by a period of crisis in which the course of development is particularly sensitive to outside influences. It is impossible to produce metamorphosis in a very young caterpillar, whatever means are employed. But after a certain stage it becomes easy to produce this result—by depriving it of food, for example ; it has entered a stage of crisis ; and later, when the crisis is more advanced, it becomes impossible to prevent metamorphosis.

Teissier gives us another example. Among certain crabs the males differ greatly from the females, particularly in possessing much longer claws. Throughout the earlier stages of development and up to a carapace length of 7 mm., however, the growth of the two sexes is identical. For the females it is continued according to the same law. But the sexes part company when the males enter a phase of crisis, in which they remain until the carapace length is 18 mm. The growth varies from one individual to another in this phase, because of the sharp discontinuity which takes place in the growth of each one of them. After the discontinuity the growth of the claws becomes more rapid, and the increased rate is shared by the other typically male organs. But retarded individuals which have not effected this revolution before the end of the critical period maintain the type of growth characteristic of females, and, probably never attaining sexual maturity, are lost for the reproduction of the species.

Finally, cannot natural death itself be regarded as the outcome of the crisis of senility ? The first indications of this crisis are, indeed, felt well in advance of old age, even from the beginning of development, when the potentialities of the egg suffer their first restrictions.

This crisis contains the whole length of life, but is aggravated towards old age. But it can have two different results according to whether the living thing reproduces itself or not. If it does not it perishes completely ; if it does it lives in its descendants, and death can then be likened to a metamorphosis in which one part of the organism is annihilated while the other acquires fresh vigour. With animals which reproduce long before death the parallel seems strained, but with the very numerous creatures in which death actually liberates the young or the reproductive cells it is quite natural.

In living things, therefore, the conception of development is inseparable from that of crises, great or small, general or particular, due to the fact that the interrelations which make up the organism's outward semblance are not always in unison. Here again life does not escape the laws of materialist dialectic.

CHAPTER TEN

THE PROBLEM OF HEREDITY

(i) THE IMPORTANCE OF THE CYTOPLASM

In the majority of cases the problem of heredity can be stated as follows : given two parents, how is it that the descendants resemble sometimes one of them and sometimes both ? Hereditary resemblance is a matter not only of form but also of structure, chemical constitution, physiological and even psychological activity. Here, however, we are principally concerned with form because of the greater ease with which morphological characters can be dealt with experimentally.

In the last chapter we saw that, setting aside the comparatively slight influence of environment, the form of a living being depends on the material structure of the egg which gives rise to it. The question of heredity, therefore, reduces itself to that of seeking the material bodies in the egg which are constant from generation to generation and play an important part in the determination of form. At first it will be necessary to study these bodies in isolation, but at the end of the chapter it will be possible to study the results of their interaction.

It must not be forgotten that the developing egg is usually one that has been fertilised, that is to say, the result of the union of the unfertilised egg with a spermatozoon derived from the male. In any one animal species the structure and dimensions of the egg and the spermatozoon are usually very different. The egg is generally a large spherical cell incapable of movement and very rich in protoplasm and reserve materials, while the spermatozoon is usually a very small cell, capable of independent movement, consisting essentially of a nucleus and a very thin surrounding layer of protoplasm. The difference between the two cells lies above all in the amount of protoplasm, for though the spermatozoon's nucleus also is often smaller than the egg nucleus, it contains the same number of chromosomes, and without a doubt the same amount of useful material, though in a more condensed form.

It is a matter of common knowledge that paternal characters are transmitted just as readily as maternal ones, and this seems to place the material basis of heredity rather in the nucleus than in the cytoplasm. We shall see later that this is true for hereditary characters of relatively small importance, such as the differences between individuals of the same species. But the characters which concern the general form of the body and which form the basis for the separation of the great zoological and botanical groups depend on the material structure of the cytoplasm.

This conclusion follows from the last chapter, since the germinal localisations whose development determines the general form are essentially cytoplasmic. But it is further borne out by the direct experiments of cross-fertilisation.

In exceptional cases it is possible to secure the fertilisation of the egg of one species by the male cell of a species that is very distant, the sea-urchin's egg by the spermatozoon of the crinoid or feather-star *Comatula*,[1] or by that of a worm, for example. Development comes to an end more or less quickly because the embryos are so poorly viable, but it is sufficient to

[1] The feather-star and the sea-urchin are two echinoderms, but belong among echinoderms as far apart as fish and mammals do among vertebrates.

allow recognition of the group to which the hybrid belongs. The hybrid always belongs to that of the maternal parent. Up to this stage the spermatozoon appears to exert no influence.

Still more decisive results have been obtained by fertilising a sea-urchin's egg in which the nucleus has been destroyed, by a *Comatula* spermatozoon. Development soon comes to a standstill, but goes far enough to leave no doubt that the hybrid is of the sea-urchin type.

These facts show that the most fundamental hereditary characters depend essentially on the protoplasm and its germinal localisations. The heredity which is based upon the nuclear material is better understood, and for this reason ordinarily receives exaggerated attention. We must not, however, forget that it plays a role which is relatively secondary.

(ii) THE IMPORTANCE OF THE NUCLEUS

It will be remembered that at each cell division the material of the nucleus is condensed into chromosomes, each animal species possessing a definite number, and that each chromosome splits longitudinally so that of the newly formed cells each possesses one-half of the original nuclear material divided as nearly as possible equally between them, both quantitatively and qualitatively. From division to division, therefore, each cell of the living organism has practically the same nuclear composition as the fertilised egg from which it arises.

Reproductive cells, however, eggs and spermatozoa, are generally an exception. The two cell divisions which immediately precede their formation are of a special kind; in one of these the chromosomes do not split longitudinally, but group themselves as far as possible in pairs.[1] Afterwards the pairs dissociate and

[1] There is sometimes an unpaired chromosome which remains isolated. But we can leave this exception out of account in a general statement.

one member of each pair moves into each daughter cell. Pairing, however, does not take place at random; at least, this is to be concluded from particular cases where the chromosomes are not very numerous and are of unequal sizes. In the fly *Drosophila*, there are eight in the egg and the body cells, and these separate into four well-defined pairs, two pairs of large chromosomes, one of small, and one of intermediate size. After the two special divisions, each egg or spermatozoon possesses four chromosomes only, two large, one small, and one of intermediate size.

When fertilisation takes place the spermatozoon chromosomes join those of the egg, and so restore the normal number of the species, so that there are again two of each kind of chromosome in the cell. In *Drosophila*, for example, the fertilised egg again contains eight chromosomes, formed of four pairs, four large, two small, and two chromosomes of intermediate size. This number remains constant throughout the entire course of development until a new series of reproductive cells comes to be formed.

The essentials to remember are that the unfertilised egg and the spermatozoon contain equal numbers of chromosomes, and each of the chromosomes of one corresponds to another similar chromosome in the other; when fertilisation takes place the two reduced numbers are added together, so that the fertilised egg and all the body cells which arise from it have the same number of chromosome pairs.

Let us suppose now that the two members of a pair of chromosomes are not identical, say in the case of the two middle-sized chromosomes of *Drosophila*. When the pair separates in the formation of spermatozoa each constituent will be in a separate and different spermatozoon. Similar eggs fertilised by these spermatozoa will possess chromosomes of the same value, but not identical. If this chromosome is assumed to influence development, the difference which it makes in the constitution of the fertilised eggs will result in slightly different characters in the living beings which arise from them. An analogous argument applies to the egg. The two preceding hypotheses not only give a good explanation of how small characters are transmitted by parents to children, but, as we shall see, they agree to the smallest detail with the laws of heredity. A very simple account of these laws, derived from the work of the Czech biologist Mendel, and hence called Mendelian, will give an approximate notion of what they imply.

White mice crossed with white mice never produce anything but white mice; so we say that the white mice are a pure race as regards colour. Grey mice are also sometimes of pure race, but by no means always so. If a white and a grey, both of pure race, are crossed (Fig. 4) the descendants of the first generation will all be grey. If they are sufficiently numerous to be bred further, the next generation sees the reappearance of white mice of pure race. But the grey mice which are also produced in this second generation are of two kinds: a number of them are of pure race, while the remainder behave exactly as their grey parents of the first generation. These, although grey to all appearances, must therefore carry the white factor in a state of inactivity, that is to say in a "recessive" state relative to the grey, which is "dominant." Numerically the dominant greys make up about half the second generation, while the pure whites and pure greys make up a quarter each (Fig. 4). These results are statistical, and the larger the number of animals in the experiment the more exact they become.

The chromosome theory offers a clear explanation of these facts. Suppose the white character is "carried" by a pair of chromosomes in the pure white and the

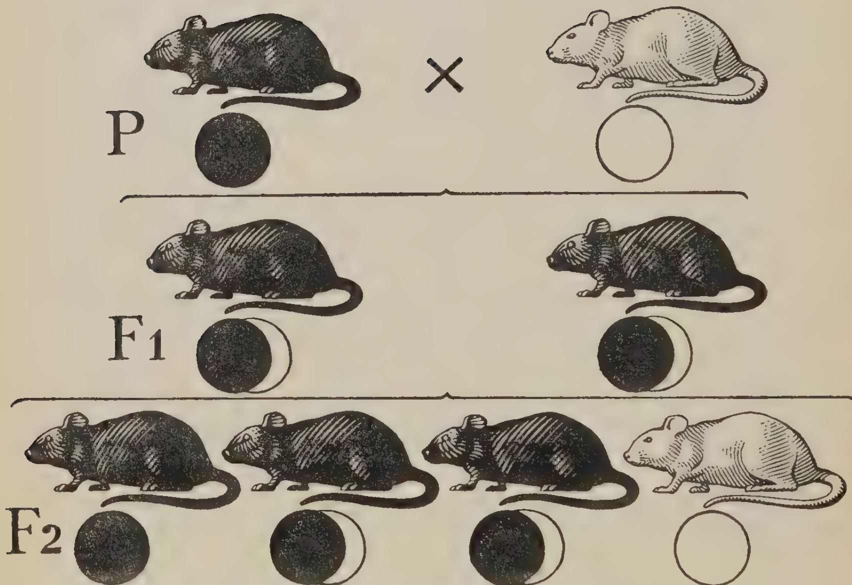

FIG. 4.—DIAGRAM OF THE RESULTS OF CROSSING WHITE AND GREY MICE.

P, Parents. F_1, First generation. F_2, Second generation.

The circles placed under the mice indicate their genetic constitution, pure white, pure grey, or grey dominant and white recessive.

[*After Cuénot.*]

grey by a corresponding pair in the pure grey. In each reproductive cell of a white mouse there will be a chromosome carrying a factor for whiteness, and in each of a grey there will be a corresponding factor for greyness. The children of the first generation have therefore in the same chromosome pair a chromosome carrying a white factor and another carrying a grey. Hence by virtue of its dominance only the grey makes an appearance externally, and the white is latent. In their reproductive cells the chromosomes bearing white and grey characters are again separated, so that half of these cells carry a grey and half a white factor. When the grey mice of the first generation are bred again the following four combinations take place in equal proportions :

"White" egg × "White" spermatozoon
"Grey" egg × "White" spermatozoon
"White" egg × "Grey" spermatozoon
"Grey" egg × "Grey" spermatozoon

The first combination gives eggs with two white factors leading to the production of whites of pure race. The last gives two grey factors to one cell and produces pure greys. Either of the two intermediate combinations should give the same result, mixed eggs giving mice similar to those of the first generation. Such, indeed, are the results of experimental crossing. The chromosome theory, moreover, explains all possible crosses made in subsequent generations, or between individuals of different generations ; the result in each case can be predicted with fair accuracy given the starting point of the chromosomic constitutions of the parents and reasoning as above.

One of the Mendelian laws can, therefore, be stated as follows : " If two pure races differing by one character are crossed, the descendants of the first generation are all alike, the second generation yield pure races in equal numbers, each amounting to a quarter of the whole, while the remaining half resemble their parents."

When two lines differ by two characters, these may be situated on chromosomes of different pairs. In this case there is no reason why the characters should be transmitted together, and consequently the result of crossing two such lines can only be predicted when each pair of complementary characters is considered separately and the results combined in all possible ways. If, for example, a mouse of pure race, grey and normal, is crossed with one white and "waltzing,"[1] the descendants of the first generation are all grey and normal. Further breeding shows, however, that they also bear the factors for white and "waltzing" in a recessive state. The next generation will reproduce mice that are white and "waltzing" and in addition produce new combinations, grey "waltzing," and white normal. Taking into account the recessive characters which reappear in the third generation there are here really nine combinations, appearing in numerical proportions which can be predicted on the assumption that the two characters belong to different chromosomes, and that these are distributed quite independently when reproduction takes place.

The two characters can, on the other hand, be carried on a single chromosome. In this case, for a first approximation at any rate, they are indissolubly linked, however unconnected and ill-assorted they may seem at first sight. Thus in crossing the fruit-fly *Drosophila*, where one parent is of grey body and vestigial wings and the other with black body and long wings, we do not find the expected four types in the second generation resulting from the four possible combinations of

[1] "Waltzing" mice are mice which display a hereditary peculiarity in their movements, connected with a malformation of the inner ear.

the two sorts of character, but two only, which reproduce those of the parents. This is because the characters grey vestigial and black long are linked.

It is clear that in a species like a mouse, with numerous chromosomes and few hereditary characters thoroughly worked out, there is a high probability that different characters will be independent. It was in such cases that Mendel deduced the independent transmission of characters as a fundamental law of heredity. But in a species like *Drosophila* with only four chromosome pairs (Fig. 5), two characters have every chance of being linked. In fact, of the 463 distinct characters which have been studied in *Drosophila* the hereditary transmission falls into four groups, and the most remarkable thing is that of the four groups one is small (three characters) and probably corresponds to the small chromosome, two others are numerous (120 and 140 characters respectively) and probably correspond to the large chromosomes, while the fourth, with 200 characters, probably corresponds to the middle-sized chromosome.

In two other species of *Drosophila* with three and five chromosomes respectively the characters fall into three and five groups. The phenomena of linkage, therefore, provide yet another proof that the characters of Mendelian inheritance are associated with the chromosome-matter.

(iii) GENOTYPE AND PHENOTYPE

Researches into Mendelian heredity in *Drosophila* have been carried out especially by Morgan and his school in America, and form a huge and monumental whole. But they have revealed a degree of complexity which was unsuspected by Mendel.

First they have shown how frequent is the phenomenon which Morgan interprets as the result of an exchange of parts between two chromosomes of a single

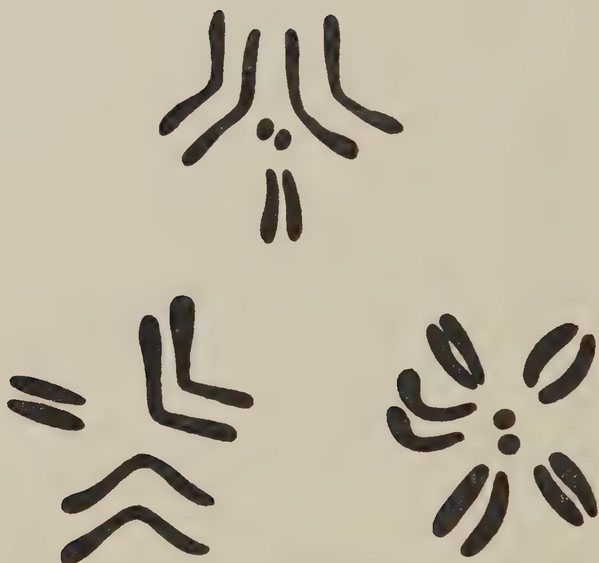

Fig. 5.—Chromosomes of Three Different Species of *Drosophila*.

Above—The four very unequal pairs of the common species.
Below—The three and five pairs of two other species.

[*After Morgan.*]

pair, at the time when they lie close together. The result is an anomalous distribution of the linked characters carried by a pair of chromosomes. Another remarkable fact which goes still further to confirm the chromosome theory is that this phenomenon is much more frequent in the largest group of characters and in the middle group than in the smallest. The transverse rupture of a chromosome is more likely the greater its length. In a given group the nature and frequency of such phenomena has even allowed Morgan to determine the approximate position of the genes on the chromosomes. Genes are the hypothetical particles which correspond to the various characters. It is easy to imagine that the breaking of a chromosome between any two of these particles becomes more likely the further apart they are. Innumerable experiments followed by precise statistical studies of the descendants have made it possible to draw maps of the chromosomes and to show the position and distribution of the genes.

We must, however, be careful to distinguish between the genes and the external characters to which they correspond. For one thing, a single gene may condition several characters at once ; though these may be very distinct in the anatomy of the adult, they may never be dissociated in the hereditary transmission of characters. Thus, in *Drosophila*, there is a gene which reduces the number of facets of the eye, modifies the size of the head, the length of the thorax, the length and breadth of the wings, the structure and amount of body hair, and yet other characters which in our description of the anatomy would be treated separately.

Conversely it may be that several genes transmitted separately condition a single character in a complex way. This character will only appear when the requisite genes all chance to occur in the one individual. In the mouse the colour of the coat, which our description defines with one word, is influenced by seven genes acting at once, and according to the combinations of these genes can be grey, white, or grey with black belly, black, yellow, or patchy, all these colours being more or less weakened or modified by a shortage of the various pigments.

Finally, though the sum-total of genes in an individual, or, as it is called, its genotype, is completely fixed, it is nevertheless true that its external appearance can vary, at times considerably, due to environment. But these changes are not hereditary. Thus there is a race of *Drosophila* with an abnormal abdomen. In moist environments this character is quite stable, but in a dry environment it gives place to the normal form. The internal conditions which permit of the anomaly are still hereditary, for they become operative again as soon as the descendants of these flies of normal appearance are returned to a moist environment. In the same way among the primroses there is a race whose flowers are always white and another whose flowers, though red at ordinary temperatures, are white if the plant is grown at 30° C. This complex character is hereditary. Even in cases where environment has less effect, it can succeed in creating some variation of external appearance, even when the genotype is constant. From the genotype we must therefore distinguish the phenotype, the appearance of an individual, the sum-total of external characteristics. It is conditioned by the genotype, but also by the environment. But only the genotype is hereditary.

(iv) THE DIALECTICAL CONCEPTION OF HEREDITY

We have given above a highly summarised account of the main principles of the chromosome theory of Mendelian inheritance, such as emerge in particular from the admirable researches of Morgan and his collaborators. As a result of these inquiries there can now be little doubt about the role played by the chromosome substance in the determination of heredity. Although from the chemical point of view the problem is still almost inaccessible, there is little doubt that the different chromosomes of the same cell possess slightly different compositions and that in the same chromosome the composition varies from point to point.

But many geneticists and theorists have made the mistake of attaching to these results an absolute value and a " metaphysical " significance. Through lack of dialectical insight they have too frequently regarded the chromosome system as entirely independent of its surroundings, the genes quite unconnected particles which happen to fall into juxtaposition, and the characters isolated by genetic analysis as immutable as the genes to which they correspond.

Such exaggerated views for a long time damaged the chromosome theory by rendering it suspect of vitalism. The elimination of such extremes makes possible the attainment of reasonable conceptions, such as the following.

The chromosomes which put in an appearance during the division stages arise from the nuclear material, and cannot be regarded as independent of their surroundings, since the nucleus in the resting stage at least is in constant material contact and interchange with the cytoplasm. They can both influence the cytoplasm and be influenced by it.

The genes are probably centres of slightly differing chemical composition which as a whole form the structure of the chromosomes. The fact that these substances can without enfeeblement of their power of reactivity be transmitted to all the cells during the course of development is explained by the assumption that they are capable of producing replicas of themselves during the course of life and of multiplying from division to division, capacities shared by all the essential constituents of living protoplasm as a result of assimilation.

Again, the living being clearly cannot be regarded as a mere aggregate of characters each carried by a gene. This grotesque " metaphysical " conception contradicts known facts. As we have seen, some of the most essential features of development are determined by the cytoplasm of the egg by way of the germinal localisations. They appear just as distinctly even when the only chromosomes present in the egg are imported from a very distant species, which can scarcely be expected to possess genes with appropriate characters, as in the case of *Comatula* chromosomes in the sea-urchin's egg. The function of the chromosomes and their genes appears, therefore, to be to produce continuous slight modifications in the course of development, perhaps after the laying down of the germinal localisations. If we associate particular genes with particular characters it is because these characters only have received experimental study. Their isolation is, however, artificial and due to the method of scientific research. There, as elsewhere, human technique confronted by the wholeness of phenomena has selected a small number of definite laws which we must guard against considering absolute.

The hereditary resemblance between children and parents is due, then, to the fact that the fertilised egg has a well-defined material structure, with cytoplasmic localisations orienting development in the way normal to the species right from the outset, and paternal and maternal chromosomes modifying this development and causing the appearance of paternal or maternal characters according to certain laws. The aspect of the individual which arises from the egg is not even then finally decided; to an extent usually small it varies with the nature of the environment. The form is the result of the sum of these material conditions, some of which belong to the internal structure of the egg, while others are imposed from without; the form can be separated from neither type of cause, but it is the preponderance of internal conditioning which accounts for heredity.[1]

[1] Nothing is more illuminating in this connection than our present knowledge of the determination of sex. First there is the chromosome constitution. One of the sexes is generally characterised by a particular chromosome called the heterochromosome or chromosome X. But the environment also exerts its influence, for in an increasing number of cases we are becoming able to modify the sex of an animal by experimental means, and in some cases we can observe modifications of sex with age. There are also cases of bisexual individuals presenting to a variable extent both male and female characters, and these again can be produced experimentally. Finally, the study of mutations which yield abnormal chromosome numbers has shown that changes of sex and intersexuality become increasingly easy to produce as the relation borne by the mass of the X chromosomes to that of the remainder becomes distant from that characteristic of one or the other sex.

CHAPTER ELEVEN

THE PROBLEM OF EVOLUTION

(i) EVOLUTION OR HEREDITY?

EVOLUTION is undoubtedly a fact. But heredity is also a fact, and apparently its antithesis. In so far as characters are hereditary they seem to be permanent, and in so far as they alter they are not hereditary. The metaphysical mode of thought is incapable of resolving this difficulty, hence the willingness to speak of a "crisis in evolution theory" when the only crisis is in metaphysical thought due to lack of dialectical understanding.

In the last chapter we gave considerable attention, and rightly so, to genetical studies of Mendelian heredity and its chromosome mechanism. From these studies it follows that since any genotype that is once fixed corresponds to a pure race whose characters are hereditarily transmitted, the evolution of species can only occur in a discontinuous fashion, by sudden changes involving at least one gene in the genotype.

The more extreme geneticists further believe that modifications, additions, or losses of genes or even of chromosomes, resulting in alterations of the genotype, are perfectly spontaneous and are independent not only of environment but of the body as a whole. Thus the changes would take place only in the germ-cells, and these would have no relation in this respect with the rest of the body. Consequently if a variation is produced in an individual as a result of its environment it can have no repercussions on the germ-cells and cannot possibly affect the offspring. The environment, according to this conception, can only produce some degree of change in the phenotype, and cannot touch the germ-cells or genotype. If species or races are approximately adapted, this is in the first instance by pure chance, later by selection. This theory is considered ultra-Darwinian.

For the extreme geneticists the chromosome changes which give rise to mutations are quite spontaneous. Hence it matters little whether they are explained mechanistically or vitalistically. Essentially they belong to a living organism, which possessed them from the origin of life, either in some vital principle or possibly in some purely internal chain of causes. Such a theory leads back to a thinly disguised hypothesis of special creation ; mutations change only the appearance of things, but not their real essence.

Few biologists have dared to push this thesis to its logical conclusion. Rosa, however, has done so, for he does not hesitate to declare that among the first living beings, all of similar appearance and formed as they were of simple masses of protoplasm, each modern species had its own predestined ancestor. Through trying to reconcile the incontestable facts of evolution with too rigid and " metaphysical " an interpretation of heredity, Rosa reaches an obvious absurdity, which even eminent biologists have discussed with some solemnity.

At the other extreme of metaphysical thought stands the Lamarckian thesis, in a variety of modernised forms ; it maintains that the living organism is constantly and completely adapted to its environment in every way. In accordance with the science of his times, Lamarck conceived this adaptation in a simple and direct way, as relating to the climate, general mode of life, and the quest for food.

> "The bird," he says, "whose needs drive it to seek in the water the prey on which it lives, separates the toes of its feet in striking the water and moving on its surface. The skin which unites the toes at the base, as a result of these repeated separations, acquires the habit of extending. Thus in time are formed the large membranes which to-day unite the toes of ducks, geese, etc." [1]

Or again :

> "The giraffe lives in places where the ground is almost invariably parched and without grass. Obliged to browse upon trees it is continually forced to stretch upwards. This habit maintained over long periods of time by every individual of the race has resulted in the fore-limbs becoming longer than the hind ones, and the neck so elongated that a giraffe can raise his head to a height of eighteen feet without taking his hind limbs off the ground."

And more generally :

> "In any animal which has not outlived its possibilities of development the more frequent use of any organ little by little strengthens it, develops it, increases its size, giving it powers proportional to the duration of this use ; while the continued disuse of such an organ leads insensibly to its enfeeblement, deterioration, and a progressive diminution of its size, tending finally to its disappearance." [2]

Lamarckism in this primitive form is defended by nobody, but with the progress of science it has acquired new aspects in which its fundamental conception, that of a rigorous adaptation of the organism to the environment, recurs. A mechanist Lamarckian like Houssay would regard the shape of fish as perfectly modelled to accord best with the hydrodynamic laws of their motion

[1] "Philosophie Zoologique," Vol. I, pp. 248, 255 (Dentu, Paris, 1809).

[2] *Loc. cit.*, p. 233.

in water. Modern Lamarckians may readily renounce adaptation of form, but insert in its place a strict adaptation in the sphere of physico-chemical exchanges. All, one way or another, regard the living thing as in strict equilibrium with its actual surroundings, which is to say that they regard it as determined by the surroundings, irrespective of any historical influences. Consequently each individual is different from his neighbour and the categories of species, or race, in which they are usually grouped are entirely artificial. Such, indeed, are the views of certain extreme Lamarckians, for whom the conception of heredity gives way completely before that of evolution and environmental determination.

But nevertheless Lamarckism cannot do without heredity. The problem, in fact, is not to know whether a living organism can be modified under the influence of environment or even if it frequently is modified in an adaptive way. Certainly however much influence is ascribed to hereditary characters the effects of environment always remain ; studying genetic heredity we were obliged to draw a line between the genotype and the phenotype which is the only concrete reality, and which expresses at once the genotype and the environment. It is only necessary to think of the development of muscles under the influence of exercise and conversely their atrophy if they are not used to be convinced of the effects of use or disuse on an organ.

But it is one thing to assert the influence of environment on a living organism, and even to allow that modifications due to this cause have repercussions even as far as the germ cells, so that the progeny may be modified in their turn ; and another to agree with the Lamarckians that the descendants present exactly the same modifications as the parents. The inheritance of acquired characters is, however, the second fundamental thesis of Lamarckism.

It agrees very badly with the first. If, in any way whatever, the living being is strictly determined by environment, there can be no purpose in assigning any value to historical causes, such as the modifications induced in parents by their environment and passed on to their offspring. For example, certain plants of the plains when cultivated at higher altitudes become more hairy and squat, a change which might be regarded as an adaptation to a mountain climate, and which is certainly an acquired character; but if their descendants are moved back to the plain they recover the old glabrous form, which is a new acquired character exactly negativing the value of the first.

Secondly, although Lamarckism often seems a rational and basically determinist doctrine, the inheritance of acquired characters can scarcely be conceived without a miracle. What material cause, indeed, can be invoked to explain how a local modification in a parent as a result of environment, acting only very indirectly on the germ cells, can produce in the protoplasm of the nucleus exactly the change which will give rise to exactly the same local modifications in the children?

Above all, the inheritance of acquired characters has never been proved experimentally in any decisive fashion. A large number of attempts have been made. The results are in all cases more than doubtful, sometimes because the results of one worker have not been reproducible by others or have given negative results only, sometimes because lack of sufficiently strict control has allowed causes of error to slip in. Geneticists make the particular objection to these experiments that they have not been made on well-ascertained pure races, and consequently that the inheritance of acquired characters claimed is really quite another thing—the inheritance of certain specialised genotypes selected by environment, when the genotypes most frequent in the old environment prove incapable of surviving in the new.

In short, though the influence of environment on the living being is an undisputed fact, the inheritance of the characters acquired through environment is not proved, and would, moreover, be a phenomenon most difficult to provide with a rational explanation.

(ii) EVOLUTION AND HEREDITY: THE DIALECTICAL SYNTHESIS

To transfer the terms used in the development of the individual, it could be said that the genetic theory is preformationist, the Lamarckian epigenesist. Here again we can expect modern experiment to supply a dialectical synthesis from these antitheses. Before this can be done, however, we must return to concrete facts and inquire a little more closely into the nature of mutations.

Take a pure race of *Drosophila*, for example, one of whose characters is red eye-colour. As long as this pure race is bred by itself, the descendants will all possess red eyes. But it happens from time to time that among several hundred eggs there is one which gives rise to a fly with white eyes, and that from the outset this new character is inherited in accordance with Mendelian laws. It appears that this egg has suffered a change in one of the genes of the genotype. It has suffered a mutation.

In any one lot of eggs the number which give rise to mutant individuals is always small. Moreover, nothing is known of the reasons why a mutation should occur in one egg rather than in another. This is what is expressed by saying that mutations occur by chance. But chance does not, as we have seen, signify pure spontaneity and complete absence of causation; it simply means that the causation is complex and therefore unknown, or so far defies analysis. This point is made very clearly by a biologist as acute as Guyénot.[1]

Another point often made, which arises from the preceding, is that the production of mutations is independent of environment. If there were strict dependence, it is argued, there would be no more reason for a mutation to occur in one egg than another, or in one generation than another. This is quite true, but by a chain of reasoning which Engels would have called " metaphysical " the false conclusion is reached that the mutation is completely independent of environment.

Long ago Darwin and de Vries believed they had observed an unusually high proportion of mutations [2] among domesticated animals or plants cultivated on rich soil. This vague indication of environmental influence has been rendered more precise by subsequent researches, as a result of which it has been found possible to increase the number of mutants very appreciably, or even considerably, in certain cases by 150 times. These researches have been carried out with a number of species, among which are *Drosophila* and barley, and with various physical and chemical factors, the most effective of which have been X-rays, as Muller discovered, and to a lesser extent temperature, ultra-violet rays, and radium emanations. Without joining those biologists who claim that the whole of evolution is due to the natural radio-activity of the earth in the various habitats, we can at least see grounds in these experiments for the conception of an effective influence of environment in the production of mutations.

All attempts to produce a desired given mutation have, however, failed. Moreover, a single physical factor seems to increase the proportion of all kinds of

[1] " La Variation," p. 339.
[2] Darwin did not use the word " mutation " but " sport."

mutations equally. The conception of chance re-enters the problem. Environmental factors clearly affect the stability of the chromosome system, provoking the losses, ruptures, modifications, etc., which, as can be observed in a variety of cases, accompany mutations and are probably their immediate material cause. The complexity of the structure of living matter is so great, however, that these external influences do not decide the mutations ; they simply throw the cell into a state of crisis in which these changes have a certain chance of taking place. When it is remembered that artificially produced mutations are identical with those which occur in Nature, it can be asked whether these other species are not those which have approached this same state of crisis by the process of natural evolution, fortuitous circumstances then modifying this or that chromosome in this or that cell.

(iii) MUTATIONS IN EVOLUTION

The only form of inherited variation whose reality is beyond question is the mutation. Can it explain the evolution of species ?

At the outset it is clear that mutations are not merely abnormal phenomena produced nowhere outside laboratories and domestication. They are perfectly normal natural phenomena, as is borne out by the fact that the great majority of artificial *Drosophila* mutations occur naturally also. There must exist many millions of these flies in the world ; when it is appreciated that the species yields one mutant for every 10,000 to 100,000 eggs, it can be seen that mutations are anything but rare. They take place every minute of the day. What is rare is their survival and multiplication without human interference. The mutants of *Drosophila* are in Nature but short-lived, mainly because their chances of being better equipped to survive than the parent species, which has already proved its adaptation, are fairly slender.[1]

Sometimes, however, a mutation appears which is able to establish itself so well as to threaten the parent species and even to replace it. A British butterfly of the genus *Biston* was completely replaced by a black mutation. In this case the new species must have had some advantage over the parent species in physiological characters not immediately obvious.

Many species, in the Linnæan sense, are complex aggregates of a number of pure lines which must have arisen from each other as a result of mutation. The pure races may be intermingled with the products of their hybridisation, but can always be isolated by suitable experiment. They are often given the title "micro-species" or "Jordanian" species, and a Linnæan species is therefore like a bundle of Jordanian species whose minute differences are none the less heritable.

These mutations can occasionally, moreover, be very important in promoting the passing over of one Linnæan species into another. This we saw on pages 3 ff. This is frequently the case when the chromosome modification is considerable, involving a change in their number or even a modification of the form of one of them. This has been verified with several examples.

Plants seem particularly prone to mutations where the chromosome number is reduced to a half, or doubled, or otherwise modified in such a way that it remains a multiple of the original number. In *Datura*, races with the normal number of 24 have given races with 12, 36, and 48 chromosomes. Now comparison of closely related species reveals that they frequently differ in precisely this way; thus the various species of *Chrysanthemum* have respectively 18, 36, 54, 72, and 90

[1] As R. A. Fisher has said, "Evolution has proceeded in the teeth of a storm of adverse mutations."

chromosomes, that is to say, all multiples of 18. Roses have 14, 21, 28, 35, 42, 49, and 56 chromosomes, all multiples of 7; species of wheat occur with 14, 28, and 42 chromosomes, multiples of 14.

In other cases instead of all the chromosomes being duplicated this has occurred to some of them only, the total number being increased by a few units only. This occurs, for example, in certain mutations of *Datura*. And finally, very frequently one or several chromosomes are modified simply by loss or exchange of matter, and from these changes mutations result, but of a less profound nature.

Mutations seem linked to the chromosome apparatus all along the line. We have so far mainly dealt with their occurrence in the germ-cells because such cases are most marked and have been longest known. But it is now known that "somatic mutations" in non-genital cells can take place. There is, indeed, no reason why modification of the chromosome mechanism should be confined to the germ cells. Somatic mutations are known in animals, but are more interesting in plants, where the germ cells are differentiated later and therefore stand a greater chance of being so affected that these mutations are inherited. Examples are to be found in shoot-mutations, where a shoot and the branch into which it develops display new and heritable characters; they have been described in maize, snapdragon, lemon, orange, wheat, and many other species. Among species of *Chrysanthemum* alone more than 400 shoot-mutations are known.

A mutation, therefore, is nothing miraculous or exceptional, exclusively affecting the reproductive cells. As far as is known it is a material phenomenon affecting the chromosomes of any cell, and causing modifications of more or less importance in the descendants. Although rare relative to that small number of individuals which we are able to study, it is of very frequent occurrence, considering the whole number of individuals of one species in the world.

Some mutations are real monsters and are not viable. Others are of poor vitality and soon disappear, except in certain exceptional habitats where they are able to succeed because the environment is favourable to them. Others are robust enough by themselves but are less so than the type species, and consequently fail to supplant it in a struggle for closely similar vital necessities. Or, again, the question of the survival of the mutation or its elimination by the type may depend on conditions of environment which can favour one or the other race at different times ; thus under certain conditions we shall find the mutation alone, and under others the type alone. Finally it may be that the mutation possesses such positive advantages over the type that it pursues it steadily and inexorably to extinction.

For a new species or even microspecies to be set up it is therefore not enough merely that one should appear in Nature. The mutation must in addition undergo the test of physical environment and competition, and must emerge with flying colours. This is a very rare phenomenon, and it is this very rarity which saves living Nature from a state of perpetual confusion and disorderly change. In the same way as cells and living individuals are produced every day in enormous numbers new mutations occur incessantly and on a large scale, but they also have to submit to this colossal wastage, and disappear by the million. Those, however, which enjoy some advantage, in their own make-up or by the fortuitous circumstances of the place where they are born, subsist and form new species.

Evolution, therefore, occurs at least in part through the agency of mutations. But is this the only way ? To that question we cannot yet give a definite reply.

There are some racial characters which appear to vary continuously ; for example, the dimensions of organs or colouring. For long it was believed that these cannot be explained by mutations. But there is an increasing tendency to refer these also to mutations, where several genes are involved at one time. This applies, for example, to skin-colour in man. Quite recently, indeed, a mathematical argument has even been worked out showing that any other explanation would run counter to known facts, since there would then be no reason why skin colour, for example, should show any constancy at all.

It is another thing to inquire whether mutations which affect only comparatively minor characters are capable of explaining the whole of past evolution, especially if they could produce such startling innovations as the first vertebrate. We here encounter among biologists an anxiety similar to that already mentioned on page 8. We must ask ourselves first if there could ever have existed an animal of which it could be said sharply that it was the first vertebrate, and that its predecessor was not one. As we have seen, the shortage of palæontological evidence must not lead us astray. There is a theoretical possibility, dialectically almost a necessity, that the cytoplasm changes. We know that the main structural outlines of the living organism are conditioned by the cytoplasm of the egg, with its germinal localisations. But there is also the fact insisted upon by Wintrebert, that germinal localisations are not given once and for all, and that their installation in the egg is a process in which many influences can affect. One such influence is probably that of the nucleus and the chromosome material which it contains. A large number of experiments lead to the conclusion that the cytoplasm is physico-chemically more stable than the nucleus, and that it is affected far less readily by influences originating in the environment. There is thus a likelihood that after a chromosome mutation the cytoplasm and the germinal localisations are not *ipso facto* in equilibrium with the new nuclear material. Perhaps many such mutations must occur before the disequilibrium leads to a change in the cytoplasm great enough to alter the germinal localisations and by this means the general bodily form.

This is a hypothesis only, and one which will be hard to test for a long time to come. Changes of this kind must certainly be far less frequent than simple mutations. However, it has two merits. It is of the dialectical type which applies to the whole realm of known human experience; and it makes the sudden developments which it implies not miracles but revolutions following long preparation through crises.

(iv) THE ORIGIN OF LIVING BEINGS

While we are in the domain of hypotheses we may say a few words about the origin of life. Palæontology, as we have seen, throws no light and can perhaps never throw light on this subject. Hopes of artificial spontaneous generation have been repeatedly disappointed, and there is little chance of a chemist being successful in producing even so simple an organism as one of the bacteria.

This being the case, hypotheses on the origin of life are generally of two types.

One is that of the eternity of life. It is as old as the universe and has had no beginning. Long before the earth was habitable life existed on other celestial bodies, and from them through interstellar space came the infinitesimal germs which sowed it on the earth.

The other hypothesis regards the spontaneous generation of life from lifeless matter as impossible to-day, but not as having been always impossible. The history of the world must contain somewhere a privileged epoch whose peculiar physico-chemical conditions permitted the first living beings to appear, very simple but capable of evolving as they have done.

Positive arguments are lacking for either. Their acceptance or rejection is therefore largely a matter of taste. The first leads to the duality of living and non-living; its weakness lies in the physical conditions of interstellar space, intense cold and radiation in particular, which seem scarcely suitable for the preservation of life during a journey which would necessarily be very long. And the second hypothesis involves something of a miracle.

There seems to be a third possibility indicated by recent work on the non-filtrable viruses, bacteriophages in particular. These organisms are much more minute than the smallest known bacteria, are invisible even with the ultramicroscope and approach in size the dimensions of the larger protein molecules. They can all, however, be handled by bacteriological technique and can be recognised by their properties. The non-filtrable viruses, harmful just as are certain bacteria, are the cause of contagious diseases such as smallpox. Bacteriophages destroy cultures of microbes and can be transmitted from one to another. Bacteriophages are, indeed, such unknown quantities that it has not yet been possible to come to any decision as to whether they are living or not. If, however, spontaneous generation were to produce in Nature beings similar to the bacteriophage, but harmless and comparable in properties to common bacteria, we should know absolutely nothing of them. The difficulty would then be not to be present at the generation of life, but to detect it. What would be exceptional for life would be not to appear, but to maintain itself in a world already occupied by beings of earlier origin, in the same way as what is exceptional for a mutation is not to appear but to survive and evolve further. Thus all present and past living organisms would not be compelled to trace back their ancestry to some single initial being, a kind of protozoan Adam, but might have had a large number of separate progenitors favoured by chance amid an infinity of frustrated competitors.

(v) PROGRESS AND SELECTION

But we must leave pure hypothesis and return to something more verifiable. The basic fact of organic evolution is that living matter changes like everything else. It changes not as an expression of an internal law of evolution independent of all outside, but as a result of reactions taking place between it and the environment. Moreover, it is not in a state of equilibrium with environment, for all the forms of living matter which we know have their own composition and structure which they retain when they grow and when the organisms of which they form part undergo multiplication. This relative autonomy and fixity is the basis of heredity.

From the imperfect equilibrium between living matter and environment result crises which are resolved in sudden changes of structure called mutations. We may assume the existence of the rare phenomenon of cytoplasmic mutation. Chromosome mutations are, however, not in doubt and are extremely common.

Chromosome mutations are produced not in all directions, but in various directions for each species. There exists, therefore, no single direction for the whole of evolution, and mutations give no explanation of the general progress of the organisation of living things, which can be traced through geological history, gradual but beyond question, since vertebrates appeared late and birds and mammals later still.[1]

[1] We are not discussing here the facts of " orthogenesis," that is to say of progressive development of an organ in a series without apparent relation to environmental conditions.

This gradual perfecting of organisation is the work of selection, that is to say of a new influence arising in the environment which causes the disappearance of the more unfavourable mutations. Selection has no precision of action and the importance of its effects must not be exaggerated. For species of large size which usually have few representatives it is possible to show mathematically that selection plays a small and chance an extensive part in deciding their survival or extinction.[1] Nevertheless, taken in the aggregate, the effects of selection are such as to direct evolution towards an average progressive improvement, giving certain living forms a greater and greater independence of the environment, that is to say greater and greater chances of survival.[2]

Thus, says Guyénot, by a succession of chances comes about this organic world which we are so much tempted to regard as the result of a great design.

[1] See P. L'Héritier : "Génétique et Evolution" (Hermann, Paris, 1934).
[2] Cf. J. S. Huxley's presidential address to the British Association, *Annual Reports, Brit. Assoc.*, 1936, pp. 96 ff.

CHAPTER TWELVE

THE PROBLEM OF CONSCIOUSNESS

(i) MATERIALISM AND ANIMISM

However firmly we may be convinced that living matter had its origin in lifeless matter, and that man arose by evolution, there still remain difficulties regarding the nature of thought and consciousness. We know from experience that man feels and thinks, and that his awareness influences and to some extent guides his action. But in inanimate Nature nothing similar is to be found. There seems to be a basic distinction, which all varieties of vitalists have placed in high relief in their refutations of old-fashioned materialism.

On this subject the old materialists took up two opposite positions. Some adopted the view of Darwin, Romanes, Buchner, and Vogt, and endeavoured in every way to minimise the differences which separate man and the animals, endowing even the lowest forms of life with thought, will, sensation, even human feelings. Darwin made no bones about quoting proof of mutual affection between snails; Romanes could suppose that what drew the moth irresistibly to its own destruction in the flame was nothing other than curiosity.

An attitude of such generalised anthropomorphism merely resulted in an obliteration of the division between the living and non-living world.

An opposite, more mechanistic, view was favoured by more recent materialists. The old Cartesian theory of the animal-machine was revived with new scientific content. All animal activity was as far as possible reduced to simple physico-chemical reactions, this naturally involving the principle of rigid determinism. This assumption has been far more fertile from the point of view of science and continues to inspire valuable experimental work. In generalising the results of their work, however, they hesitated before our conviction, possibly over-emphasised but undoubtedly sound, that we can foresee and guide in a certain measure the course of events. Consequently they were put to the necessity of breaking the connection between animals and man or of maintaining, against all evidence, that man is also a machine.

Whether in dealing with the origin of life or with that of man, the old materialism failed to resolve the antinomy of freedom and necessity, and as a result of this failure vitalism was able to assert the irreducibility of the human soul, or more generally the existence of a vital principle. We know, however, how Marxism makes this resolution. Following Spinoza and Hegel, it declares that liberty consists in the understanding of necessity. "Necessity is only blind in so far it is not understood." Understanding comes from the disentangling of phenomena, the knowledge of natural laws and their technical application. The measure of liberty which men possess is due to the development of technique in the framework of society. And although it is still imperfect in many ways, this liberty clearly distinguishes man from the animals, though by no means signifying a radical and irreducible difference.

The difficulties which arise in discussing this problem would all be avoided if a sufficiently resolute dialectical attitude were adopted, if we could avoid rigidity of concepts and could confine ourselves to strictly experimental and scientific ideas, resisting the temptation to speak freely of ideas, sensations, will, reason, etc., among animals. All this is outside the scope of experiment, and cannot be explained by analogy with our own consciousness.

(ii) THE NOTION OF THE REFLEX

Many of the actions of animals are reflexes or associations of reflexes. When a sensory organ is stimulated it starts the transmission of a change, probably physico-chemical, which passes along a chain of nerve-cells and terminates, for example, in a muscle. The muscle then contracts and makes the movement which is the characteristic response, the obligatory effect of the stimulus.

For example, the hind-leg of a frog from which the brain has been removed in order to suppress all "voluntary" action is pricked with a needle. A sudden contraction of the irritated limb takes place. The reflex leaves the sense organs, passes along the sensory nerve-cells of the leg, reaches the spinal cord, and returns along the motor nerve-cells to the muscles of the leg; during this process at least two nerve-cells come into play.

The operation of the nervous system is not essential to reflexes. The same feature of simple and obligatory reaction occurs in certain cases where the nervous system is lacking, among higher animals when they are so young that it has not begun to function, or in experiments where it has been destroyed. Transmission of stimuli and their translation into actions can take place in other ways, for example, directly through the muscles. Similarly in plants and unicellular animals, where no nervous system exists, reflex action can still be observed, as in the case of sensitive plants whose leaves respond to stimuli administered at a distance. According to the teaching of physiology, in none of these cases are the boundaries of simple mechanism overstepped; to a given cause always corresponds a given effect.

Reflexes, however, do not exist only for the physiologist in his laboratory experiments. They are to be found in Nature. An animal which is moving in a perfectly regular way may suddenly halt or change its direction under the influence of light or temperature or a change in the chemical composition of the medium; in such a case the phenomenon called differential sensibility is nothing other than a reflex. Again, an animal such as a crab or an insect retreats into the ground or slips itself into a narrow cavity; in many cases it has been shown that such movements are nothing but a series of reflexes, set in motion by the stimuli of temperature, contact, etc.

(iii) THE NOTION OF THE TROPISM

Certain stimuli, such as light, heat, gravity, and various chemical substances, can produce reflexes of two different kinds. Acting uniformly on the living organism they simply release movements by reflex action or, on the other hand, increase or arrest them. This mode of action has been termed "kinesis." But if their action is essentially directional, the reflexes always acting in such a way as to orient the organism in accordance with this direction, we call the result a "tropism."

The two halves of an elongated animal such as a worm or an insect, right and left, are usually symmetrical and equal both in the matter of sense-organs and muscles and as far as we know in chemical composition. Subjected to uniform illumination its motion becomes quite irregular, and the only effect of the light is to accelerate its motion by kinesis. But if a suitable species is illuminated more brightly from one side than from the other, the unilateral illumination will by reflex action increase the tension and contraction of the muscles of that side. The result is that the animal will turn towards the light and progress towards it. It will give the appearance of seeking the light, though this impression is false since we are dealing merely with a succession of reflexes without leaving the realm of mechanism. We shall consider here in particular "phototropism," so called since the agent is light, but other stimuli give similar effects.

Such a case bears more resemblance to the growth of plants than appears at first sight. A vertical stem uniformly illuminated grows less quickly than a similar shoot in the dark, illustrating kinesis. But if one side is lighted more brightly than the other, growth on that side will be slower, and consequently there will come about in a purely mechanical way a curvature giving the impression that the shoot is seeking the light. This is again a case of phototropism.[1]

The results obtained with gravity, heat, nearness to water, chemical substances, we call respectively geotropism, thermotropism, hydrotropism, and chemotropism. For each kind of stimulus the tropism can be either positive or negative; it can lead either to approach towards or retreat from the site of the stimulus. But the common feature of all tropism is the automatic directional movement made under the influence of a directional stimulus. Now if the organism is naturally or artificially asymmetrical (for example if one side has been rendered blind in an experiment with phototropism) it no longer moves in a straight line, but tends to make deviations more or less quickly corrected, or even carries out trial movements.

A tropism, in the strict sense of the word, is still a phenomenon of a mechanical order. It is essentially a

[1] In this particular case we know now that the effect is produced by the unequal distribution of a growth-promoting hormone, auxin, the chemical nature of which is also known (see Thimann & Went, "Phytohormones," New York, 1937). Hormones are doubtless involved in animal tropisms.

specific series of reflexes excluding choice. If a phototropic animal receives light from two sources of equal intensity it does not move towards one of them, as a man who can choose might do, but pursues a course exactly intermediate. By a series of very fine experiments, subjecting young rats which had not yet acquired sight to the action of gravity on an inclined plane, Crozier has shown that tropisms can be measured as precisely as any physical phenomena.

Tropisms no more than reflexes are the artificial products of laboratory experiment. Nature is full of clear examples, as when insects are attracted by a flame and fly into it or birds dash themselves against the windows of a lighthouse. Frequently several tropisms can act simultaneously or in succession ; a tropism may be complicated by the operation of other reflexes, differential sensibility, or kinesis. The actions of the animal may then seem capricious or voluntary, but in reality they are easily explicable on grounds of pure mechanism.

(iv) THE NOTION OF INSTINCT

Instinct, however, must be considered to be a different matter. The classical definition is that of an adapted action which is carried out without having been learned, by all the individuals of a species, without any knowledge of the end which the action serves or the relation between this end and the action which promotes it. Usually it is opposed to an act of intelligence, which is learned by the individual, implies knowledge of the end, and moreover is a matter for the individual and not necessarily uniform throughout the species.

Though accepted by Darwin and many Darwinians, the idea of instinct was inspired by special-creationism, even to a theological degree, for it was easy to assume, as the preacher Bossuet put it, that animals had been provided with instinct by God, " in order to make them play their parts worthily and to drive them towards their appointed ends." It corresponded to the idea of a plan of life to which the actions of the animal must conform; in this sense it has been possible to associate it with the idea already discussed in Chapter 11, of the predestination of the development of the living organism. With this in the back of their minds and an admiring imagination, many naturalists tended to exaggerate the " marvels of instinct "; particularly Fabre, who spent years studying the habits of numerous insects, but whose results have now been recognised as partly wrong and always scientifically inferior to those of other observers such as Perez and Ferton.

In many cases where the precision of instinct verges on the amazing, more careful observations reveal that the so-called instinctive action is neither so innate nor so well-adapted as was claimed. For example, pæans have been sung in praise of nest-building among birds, which results perhaps to some extent from innate tendencies; but building is only quickly and effectively carried out if one of the partners has previously constructed a nest, has seen one constructed, or has been reared in the normal nest of the species in its youth. If not, the result is chaotic, badly constructed, uninhabitable, and very painfully achieved at that. Song and flight must also to a large measure be learned by birds, and young ostriches when they are first hatched from an incubator have so little instinct to seek their food that in order to teach them the actions the breeder must strike the ground in front of them with a stick.

The great precision with which wasps return to their nest, a precision greatly affected by the slightest displacement of it, is only acquired after a few days of flight. The young wasp acquires the capacity to return by leaving the nest backwards and making circular flights of ever-increasing radius around it. During these preliminary flights the habit of return is not so fixed that a minor displacement will not prevent its being rapidly found again ; this is acquired later.

Behaviour said to be instinctive is known which takes place only once in the lifetime of the individual, and in some cases it can be neither learned nor imitated by other individuals. Such conduct is usually less complex and displays a high percentage of failures. It results directly from the relations between the organism, with its material constitution, and the surrounding environment. If both are normal, the conduct is normal. If one is aberrant, conduct is aberrant, and then frequently fatal.

The larvæ of wasps a little before metamorphosis stop up the cells in which they have grown with a plug of silky material, and this work generally appears to be carried out with remarkable regularity. But closer examination reveals that the proportion of failures can vary, according to circumstances, between 3 and 75 per cent., the failures mainly depending on the health of the larvæ and their conditions of nourishment, the cells being built in a very regular way. But on the other hand, if the form of the cells is artificially modified and the larvæ are in good condition, the forms of these plugs will be accordingly modified, in a way determined by the new conditions. Here instinct, if instinct it is, has none of the wonderful ability attributed to it by Fabre of " knowing everything in the unchanging path mapped out for it " and " knowing nothing outside that path."

The experimental criticism to which the idea of instinct has been subjected has led certain biologists to revive the phrase of Condillac, " Instinct is nothing." Without going so far as this we can at least agree that the word " instinct," like the word " adaptation," is ill-defined and dangerous for those who are not sure of thinking in a materialist way. For a better definition we must consider the correlations of instinct with tropisms and other reflexes on the one hand and on the other hand with intelligence.

(v) BEHAVIOUR AND MECHANISM

Can instincts or behaviour generally be reduced to a series of tropisms or a mechanical linkage or grouping of reflexes ? There are biologists who adopt this view with all its implications, and do not hesitate to extend it to include the whole of human behaviour.

No doubt external physical conditions, such as light and temperature, do to a certain degree affect man's thoughts ; but their influence is vague and restricted, relating only to the most animal part of his mental activity.

On the other hand, it is certain that many fundamental instincts of animal life can be reduced to tropisms or reflexes. Thus the power of the mature female butterfly to attract the male even from a great distance is due to a chemotropism associated with her odoriferous glands. If these glands are removed the females lose their power of attraction but the detached glands retain it. Here we have all the characteristics of a tropism as defined on page 157. Fruit-flies (*Drosophila*) are attracted to fermenting fruit by a positive chemotropism for acetic acid ; ordinarily useful, this serves them in bad stead when it drives them into the acetic acid which kills them. Similarly blow-flies (*Lucilia*) are chemotropically attracted by decaying meat, where they lay their eggs. This chemotropism is normally useful, but proves disastrous when it leads them to lay on decaying plants or on fat impregnated with meat-juice, where their larvæ perish.

In short, existing tropisms account very well for a number of important instincts, but it must be remembered that an instinct, like any adaptation, is always relative and statistical. On the other hand, tropisms are capable of thwarting instincts, a fact which establishes that they are fundamentally distinct; thus the swarming of bees can be prevented by inserting at the apex of the hive a glass window, to which the insects are attracted by phototropism and so prevented from leaving.

But does it follow that all instinct, indeed the whole of behaviour, is a simple chain of reflexes and tropisms, and is purely the result of known physical and chemical factors? Even biologists with pronounced mechanist leanings like Loeb or Bohn do not think so, and admit that past history can affect present action by modifying reflexes and tropisms. Past phenomena leave their imprint in the living matter, and this is associated, in the new reaction, with the stimulus from the environment. Thus we speak of associative memory. There quite clearly is a phenomenon of a historical order, which can be understood in a materialist way, but not in a mechanist way as long as the physico-chemical detail of living matter remains a closed book to us.

The existence of associative memory is not in doubt. A newly hatched butterfly possesses a reflex of the antennæ; if once the operation of this reflex leads to the antennæ coming into contact with a warm object, it will be inhibited or even reversed. From a large number of more complex experiments we can quote only one, due to Yerkes. An earthworm is made to pass along a T-shaped tube of which the right arm leads to earth and the left to emery-paper and an electric discharge. After some dozen attempts the worm acquires the habit of using the right-hand arm every time, and this habit becomes more or less stable. It is therefore possible to say not only that the worm possesses memory, but that this memory associates the recollection of the left-hand passage, the emery-paper, and the electric discharge, phenomena which occur in succession. There is more than memory. In the actions which follow there is anticipation. This is a fact which escapes mechanism, a fact which is plainly psychological.

(vi) INSTINCT AND INTELLIGENCE

Vitalists have frequently tried to make instinct and intelligence a fundamental antithesis. Our examination of the concept of instinct has shown, however, that they confuse two distinct kinds of effect, the absolutely indispensable automatisms common to all the individuals of a species, since they result from the interaction of closely similar individuals with an almost identical environment, and secondary automatisms resembling habits whose origin can easily be followed. As our knowledge of instinct grows deeper, based increasingly on the study of young animals, we are led to give increasing prominence to habit and less to innate automatisms.

It is in this sense that the physiologist Verlaine, who has contributed much to our knowledge of this subject, has been able to question the innateness of tropisms and reflexes in general, thus paving the way for a great stride in modern materialist psychology. Hitherto tropisms and reflexes have been regarded as the bricks and mortar of mechanist psychology, and their existence and importance has been challenged only from the side of the vitalists. Verlaine does not, however, deny their extreme interest in so far as they are justifiable concepts. But, as he very dialectically observes, tropisms and reflexes are not given once and for all without gradations, both are variable, and have an origin, if only in the evolution of the organism; they can be understood only by experimental study of its development.[1]

The similarity of the problem of instincts and that of form had already struck certain vitalists. Buitendijk, for example, was ready to attribute the achievement of specific form to instinct. Verlaine reversed the problem in a materialist way and " restored to its feet that which had stood on its head." Just as in the development of a living organism, the egg begins with wide potentialities which are gradually restricted as material structure and form is achieved, so psychological potentialities are at first indeterminate, but gradually narrow down, becoming more restricted and definite as the internal constitution of the organism develops and its experience of contact with environment increases. And just as the morphological potentialities of some animals are rapidly " crystallised " while others retain considerable powers of regulation throughout development, so psychological activity tends to automatism at a quicker or slower rate ; all gradations exist between instinct and intelligence. It is always possible by suitable education to set up automatisms in so-called intelligent animals, and to make the so-called instinctive animals perform acts which are universally regarded as intelligent ; thus Verlaine has apparently succeeded in inducing in bees a precise recognition of the triangle and even of an equilateral triangle, which is very remote from their normal instincts.

Thus the essential distinction of quality by which " metaphysicians " separate instinct and intelligence falls to the ground. This distinction can now be

[1] There is no contradiction between experiments of this kind and those of Crozier referred to on p. 159, for the conditions are very different. In Verlaine's experiments every effort is made to give the behaviour of the animal a practical usefulness, whereas in Crozier's usefulness is reduced to a minimum. Crozier's point of view is more physiological and artificial. Verlaine's biological and natural.

regarded as relative only. No longer can we speak of two kinds of activity, instinct and intelligence, arising from two fundamentally different principles. Psychological phenomena from their simplest to their most complex forms are explained on one principle only, called by Verlaine "generalisation." [1]

(vii) PSYCHOLOGICAL PHENOMENA AND ACTION

In Nature an animal never finds itself in exactly the same situation twice; the circumstances have always altered in some respect, if only because the animal reaches the situation in a different way. This fact has frequently been brought forward by vitalists against those who uphold rigid reflexes, even in a complex combination; each animal would require an infinity of reflexes in order to be prepared to respond appropriately to an infinite number of possible situations. This difficulty disappears on the view that reflexes are relative and progressively built up.

The experiments of Verlaine and his school on bees and on the dog-faced ape (*Macacus*) have shown that the actual nature of the memory retained by an animal of an object with which it has once entered into relations is impossible to determine. It is neither its luminosity, nor its colour, form, orientation, position in space, nor indeed the sum of all these, for any other totally different object presented under similar conditions will immediately cause the animal to repeat the same behaviour.

For this very vague knowledge to become definite in later experiments the object must possess a practical value, good or bad; or rather (since these terms imply human understanding) positive or negative, positive if

[1] This word was used by Bergson in "Matter and Memory" in a similar sense, but it seems to have been abandoned in "Creative Evolution." That is to say, instinct and intelligence are there completely opposed.

it promotes the repetition of the same behaviour, negative if it inhibits it. As in the case of Yerkes's work, memory, anticipation, and action are always closely linked.

Both apes and bees can, as we have seen, be led to recognise geometrical form, but only when this is constantly associated with a reward of some kind. Once any geometrical form comes to be accepted as indicating a reward, the animal can immediately classify the different forms which it is given to choose from, as for example triangular or non-triangular if triangle is positive (that is, always associated with an inducement) and other forms negative (that is, without inducement). After a period of apprenticeship the triangular forms are selected at once. The triangle can then be divided into equilateral and non-equilateral, by making equilateral always positive and the others negative. By carrying the same process further, they can be taught to classify the equilateral triangles according to colour or size, and alternately, by continual narrowing down of the contrast, to select a particular concrete equilateral triangle. Again they can be made to choose between two identical equilateral triangles one of whose orientation is always constant, the other variable. Finally, they can recognise the position of the triangles if the reward is always associated with the one whose position is fixed.

We can hardly go much further in the pursuit of a concrete object, and yet to some extent the perception of the animal still remains general, since the retinal images of the chosen triangle are never perfectly identical from one time to another.

This series of experiments, and other similar ones involving the recognition of colours and patterns or impressions of smell and touch, confirm that in animals, as seems likely in young children, general and relative impressions precede particular and concrete ones, and that psychical processes do not follow the reverse order, as would appear from the experience of adults capable of abstraction.

In such a series as is described above the repetition of identical trials results in a more or less marked automatism in the animal, which can persist even after conditions have changed. If, for example, an animal is well trained to move towards an equilateral triangle on the left and a non-triangular figure is substituted, the animal may move towards this new figure none the less. The readiness with which such automatisms are lost and leave room for a new apprenticeship on the basis of fresh associations denotes intelligent activity in the animal, while the stability of the automatisms denotes instinctive action.

One final conclusion is very important. Ideas never reach the stage of precision unless they involve a material activity connected with needs. Apart from a few possible rare exceptions, animal life gives us no examples of pure knowledge separate from concrete life and the requirements of action.

(viii) PSYCHOLOGICAL PHENOMENA AND THE STRUCTURE OF THE ORGANISM

The old "popular" materialists, such as Vogt, Buchner, and Moleschott, were guilty of an error of extreme over-simplification when they held that the brain secretes thought in the same way as the liver secretes bile.

First, it is impossible for the brain to secrete thought since thought is not in the nature of a material secretion. Second, the brain cannot be regarded as the only organ involved in the production of thought, or in that of any psychological phenomena, for these appear as the result of the whole organic structure and the sum-total of its relations with the environment. To identify it with any special material structure to the exclusion of all others, even though that be as important as the brain, is to distort the facts and make them incomprehensible.

The first signs of psychological phenomena, according to such workers as Jennings, already make themselves felt in protozoa, that is to say, in unicellular animals possessing neither a brain nor even any centralised nervous system. They consist simply of masses of irritable protoplasm. The existence of "nervous" fibrils in some of them certainly confers an improved contractile power, but seems to make little difference between them and the others, either in point of "psychology" or behaviour.

In the majority of lower multicellular animals the nervous system is but weakly differentiated or centralised. Relations with the world outside are comparatively simple, most frequently through the medium of movements of small complexity and a few very general senses. These animals are sensitive to vague luminosity, equilibrium and contact, and possess a chemical sense, which may be called that of taste or smell according to the conditions. Psychological phenomena are still very slightly developed, these animals especially being the playthings of reflexes and tropisms.

This is no longer true in the three main evolutionary branches, the vertebrates, the insects and neighbouring groups, and the cephalopod molluscs. Here we are dealing with active and mobile animals, frequently endowed with very accurate senses, sight which allows a more or less distinct perception of forms, movements, and colours, and often a sense of hearing. The nervous system is much more concentrated, the relations between the nerve cells consequently more highly developed and numerous, giving the possibility of more numerous and varied interactions.

These animals are certainly able to attain more precise " conceptions " regarding their environment. We may limit ourselves to a comparison of insects and vertebrates. These groups are classically supposed to reach the peak of psychological phenomena, taking the form of instinct in insects, intelligence in the vertebrates ; this is certainly true, though we must guard against too violently opposing one group to the other. Here again it is impossible not to relate the difference to the physical constitution. Not only are the eyes, auditory organs, and nervous systems constructed on completely different lines, but the bodies of insects, enclosed in a rigid armour movable only by means of joints, lend themselves to the fixation of automatisms far more readily than the supple bodies of vertebrates.

Another peculiarity, perhaps again a condition of high psychological level, occurs in both groups but especially in vertebrates, the stability of the internal environment.[1] In contrast to the state of affairs in the lower animals, the chemical composition of the blood, the lymph, etc., generally shows obvious independence of the surroundings ; among birds and mammals even the temperature must be approximately constant. All this, together with the great longevity of the nerve cells, must permit the establishment of associative memory of much greater stability.

To consider only mammals, the lower are still essentially olfactory animals whose sight is still imperfect and plays a very secondary role to smell. A mouse, for example, can only with difficulty see movements and never shapes on account of an enormous long-sightedness. With few exceptions apart from birds, only apes and carnivora move about in a definite way comparable to that of man and are able to form a clear

[1] See J. Barcroft's " Features in the Architecture of Physiological Function " (Cambridge, 1934).

idea of spatial relations; only the ape possesses the forward position of the eyes which makes possible true stereoscopic vision taking account of relief.

But apes possess further essential physical characters. Their free and prehensile limbs give them an exceptionally precise action on the external world. In the anthropoid apes more or less perfect two-footedness and the power of turning the hand to face either upwards or downwards allows the arm to develop into an organ of a unique kind, an organ which can create a tool.

It should be noted also that the mode of life of carnivorous animals certainly provides them with more varied experience than comes the way of herbivorous animals. Those like the apes, whose food is extremely varied, thereby acquire still more varied experience and fewer automatisms. This explains the often noted fact that the intelligence of apes is of a peculiar quality. A carnivorous animal is capable of intelligent action, but only following a series of attempts which seem to him of equal value, and which gradually approximate to the appropriate action. In the course of such a series of trials an ape, however, generally changes his behaviour very sharply; he seems to have understood, to have formed an idea. For this reason simian intelligence was most capable of expanding into intelligence of the human type.

(ix) HUMAN INTELLIGENCE AND TECHNIQUE

We do not think with the brain, or at least, as we have seen, not with the brain alone. Thought requires the whole body, the whole activity, and even the whole of social activity. Man, whose relations with the world have been characterised since his origin by tools of his own making, thinks with his tools. In man alone the material improvements of technique and the changes of environment they have brought about, without any intentional education, give the child of 1938 a psychological character quite different from that of a child of 1904, and how much more so from that of an Aurignacian child.

Certain branches of technique, establishing as they do connections between individuals and even between generations, play an especially prominent part in the psychology of social man, and particularly of modern man, enabling one to profit from the experience of others. Among these, for example, are mimicry, language, writing, printing, mathematical symbols, wireless, etc.

The first of these techniques are not lacking in certain animals. But neither the mimicry nor the cries of birds can attain the power and variety of human speech, or even of human mimicry. Must we therefore regard articulate speech as a special gift ? The larynx of an ape, even of the orang, which is most similar to that of man, is prevented by its anatomical structure from producing a modulation of sound comparable to that of man. But parrots and jays, capable of articulating sound, possess a true language no more than other birds. And for the rest we know from the recent evolution of language that new words are created when they become necessary. It can be supposed that man, possessing the organs necessary for articulation, articulated and spoke little by little, in so far as he had something to say, that is, according to the development of his technical action upon Nature. But at the same time speech, however primitive, clearly assisted the development of social technique.

That language has allowed the formation of clear ideas and precise concepts is a commonplace idea. That these concepts and the art of writing were necessary for the invention of mathematical symbols is equally certain. That mathematical symbols, or at least clear concepts, were necessary for the greater number of modern scientific technical discoveries is indubitable. Here we have one of the most complex of the dialectical cycles, beginning in technique and ending in technique, which have secured the progress of civilisation. If the man of to-day, armed only with logical thought, turns towards the origin of humanity and life, he can no longer understand it. He stands and wonders at his possession of two feet, two hands, language, and reason.

But if he has attained scientific dialectical thought, according to Engels the most highly human because it evaluates concepts themselves, he then realises that he is no more than one element of a vast becoming which, starting from the amœba or even less, will leave animality finally behind on the achievement of classless society, and will then progress little by little towards a power unlimited.

END OF PART TWO

CONCLUSIONS

CHAPTER THIRTEEN

THE BIOLOGICAL AND THE SOCIAL SCIENCES

(i) IS SOCIOLOGY MORE THAN HUMAN BIOLOGY ?

THERE is no lack of theorists who have attempted to transfer biological conceptions without modification into the social sciences, or, on the other hand, to introduce sociological conceptions into biology. Ever since Menenius Agrippa, with his fable of the stomach and the limbs, the organism as a whole has very frequently been compared to a society of organs and cells dividing the work among them, and moral conclusions have been deduced. Other authors who have studied the most specialised insect societies, admiring the reign of order which exists there, have described them in anthropomorphic terminology and have recommended them as a model for human society. Forel, Wheeler, Bouvier have done this in varying degrees, and more recently all the fascist philosophies of the state base themselves on a purely biological sociology, as witness Escherich (the rector of Münich University), Spann, Klages, Rosenberg, Brohmer,[1] and many others.

All such applications of biological theory to sociology are condemned by Marxism, including the so-called " social-energetics " and other nonsense. All depend on simple analogy and fail to take into account the differences which actually exist between these realms,

[1] See, for example, P. Brohmer's " Mensch-Natur-Staat ; Grundlinien einer nationalsozialistischen Biologie " (Frankfurt a/M., 1935).

since human society is something other than the animal kingdom, and still more something other than the domain of physics.[1] This will be seen clearly in the two following examples.

(ii) BIOLOGY AND RACIALISM

Race-theorists have always sought biological sanction. Nazi expositions, for example, usually begin with a review of the biological theories of pure races and Mendelian heredity. This is followed, as an application, by the statement that in man the " Nordic " race, that is to say, above all the German race, is superior to all others and must be kept free from all hereditary contamination.

The racialists forget from the outset that even in natural animal populations it is very rarely that individuals of pure race are to be found. The pure races discussed by biologists are usually obtained from mixed populations by a lengthy process of breeding and selection. Human populations are still more mixed from the racial point of view. Those situated outside the great currents of migration and trade, remaining for the most part at a low technical level, show least admixture ; but the so-called civilised peoples show it to a very high degree—and these are the very peoples whose racial superiority is to be made sacrosanct. The most orthodox race-theory in Germany is obliged to

[1] If the theoreticians of fascism try to force the phenomena of human social life into the narrower framework of purely biological categories, it is perhaps hardly surprising that someone should have made the attempt to force them into categories of physico-chemical type. And, according to L. J. Henderson's curious book " Pareto's General Sociology ; a Physiologist's Interpretation " (Harvard University Press, 1935), that is what Vilfredo Pareto did. His " General Sociology " (London, 1935, Eng. tr.), which discusses sociological equilibrium states, cannot be appreciated without comparison with the laws of mutual dependence in chemical systems enunciated by Willard Gibbs. Thus it is not strange to find Pareto regarded as among the theoretical founders of fascism. See further on this subject an article in *Cambridge Review*, 1936, p. 414.

admit that the country contains seven races intermingled and that pure " Nordic " types are very rare. In a quite recent anthropological treatise of racialist tendency Aichel is obliged to abandon completely the conception of a " Nordic " race, and to replace it by that of a German people, which is biologically meaningless.[1]

Race-theorists also forget that in no race is even purely physical superiority independent of the factors of environment. This is true of *Drosophila*, as we have seen. It is true of man also, but here conditions may also include ideological factors. For example, statistics show that the natural fertility of the Japanese, though very high in their own country, falls considerably on emigration; on the other hand, the fertility of the French in Canada is much higher than that of the same people in France.

The great difficulty, however, is that of defining superiority in a human race. The " Nordic " race, for example, is held to be superior sometimes for its physical qualities such as stature and form of head, sometimes for its psychological qualities such as self-sacrifice and courage. And the race-theorists are then obliged to declare that a " Nordic " soul may be lodged in a non-" Nordic " body, or *vice versa*. This amounts to admitting that underneath its pseudo-scientific trappings the race theory has absolutely no foundation in fact.

Apart from conscious deception, due to the fascist desire to generate nationalist mysticism, the mistake lies precisely in confining the study of man to purely biological factors. It is probably true that there are a number of more or less intermingled races of man capable of being studied accurately by anthropology.

[1] The very existence of races in man may be disputed, if the word is used in a strictly biological sense, for the so-called racial characters do not seem to be transmitted according to Mendelian laws.

Between them exist physical and corresponding physiological differences and even slightly differing psychological tendencies. But we can definitely affirm that physiological and expecially psychological differences, those, that is to say, on which human superiority rests, are not primarily matters of race. They are far more closely related to the social mode of life, to the technical level of society, and to class position; in the final analysis they depend on a specific synthesis of all the conditions historically imposed, whether physiological or social.

As for the technical, political, and intellectual backwardness of certain peoples, it is much less due to racial differences than to circumstances of historical development. During the Aurignacian and Magdalenian periods, it will be remembered, industry and art were definitely the same for the three races then inhabiting Europe. Two of these are strictly related to present "backward" races, Bushmen and Eskimos. And the ease with which at the end of the nineteenth century backward Japan, which had remained at the feudal stage, caught up the economic and scientific level of the most advanced scientific countries, must not be forgotten. So successful were they that Nazi race-theorists now hint that the Japanese may also be of "Nordic" race.

Scientific fact condemns not only open racialism, but the more hypocritical form of it which is used to justify colonial oppression. It explains, however, the success which has met the efforts of the Soviet Government for the economic and cultural emancipation of the backward nationalities. The revolutionising of the economic condition of northern Siberia by the introduction of modern technical methods without the accompaniment of capitalist exploitation has laid the material foundations for the intellectual development of these peoples of the extreme north, and has made possible the foundation of an already flourishing University.

(iii) THE STRUGGLE FOR EXISTENCE AND THE CLASS STRUGGLE

Darwin did not conceal the fact that in part he derived the ideas of the struggle for existence and selection from the economist Malthus.[1] In spite of their admiration for Darwin's work, expressed in several letters,[2] Marx and Engels made a number of reservations, one of which bore precisely on this question of "A law claimed to be general, which in reality applies to capitalist economy at the most."

> "Darwin, whom I am re-reading," wrote Marx in a letter to Engels, dated 18 June, 1862, "amuses me when he says that he extends the Malthusian theory to animals and plants, as if Malthus's pleasantry had not been to apply the theory, including geometrical progression, not to animals and plants, but to men as opposed to animals and plants. It is strange to see how Darwin discovers among animals and plants his own English society, with its division of labour, its competition, its opening of new markets, its 'inventions,' and its Malthusian 'struggle for existence.' This is Hobbes's 'war of each against all,' and recalls Hegel's remark in his 'Phenomenology,' that bourgeois society is a 'spiritual animal kingdom,' while for Darwin the animal kingdom figures as bourgeois society."

Coming from the eighteenth-century naturalist Buffon by way of the economist Malthus, the Darwinian theory

[1] "In October, 1838, that is, fifteen months after I had begun my systematic inquiry, I happened to read for amusement Malthus on population, and being well prepared to appreciate the struggle for existence which everywhere goes on, from long continuous observation of the habits of animals and plants, it at once struck me that under these circumstances favourable variations would tend to be preserved, and unfavourable ones to be destroyed. Here, then, I had at least got a theory by which to work."—Darwin: "Autobiography."

[2] *E.g.* "Selected Correspondence," pp. 125, 198.

of natural selection was no sooner born than it was re-applied to human society on all sides. Theorists hailed the struggle for existence as a justification of capitalist competition, since the struggle according to Darwin led to selection and was thus a factor making for progress. Among them Spencer,[1] however, restricted this individualism by declaring that it should be overruled by the common good. Reformist and Utopian socialists pointed out that the struggle for existence, if it was really to select the best fitted, supposed individuals starting at scratch no matter what their social origin; they therefore demanded a fair start. Nietzsche, the extreme individualist, insisted, on the contrary, that human initiative should continue the selective work of Nature, and from this point of view we can derive the racialist form of modern eugenics with its pseudo-scientific appearance. Sentimental anarchists, on the other hand, wished to mask the more brutal characteristics of the struggle for existence, and Kropotkin tried to prove that alongside it there existed mutual assistance as much in the world of Nature as in that of society. The general state of mind was reflected in the polemics which Darwinism initiated in scientific circles: Virchow fought it as related to socialism; Haeckel, its most enthusiastic propagandist, gave an assurance that, on the contrary, Darwinism and Socialism agreed "like fire and water"; and it has been observed that in France, and particularly in England, Darwinism aroused fewer passions than in Germany, since in these two countries the bourgeois revolution had already taken place.

The very multiplicity of these views was a sign of their confusion. We may disregard the fact that natural selection does not fully possess the progressive

[1] For an account of Spencer's position, see J. Needham's Herbert Spencer Lecture (Oxford, 1937).

value which Darwin attributed to it. We may disregard the fact that mutual assistance or symbiosis is a relatively rare phenomenon. There still remains one general and decisive criticism which dismisses the preceding theorists one and all. Marx ironically expresses it, applied to a particular case, in a letter (29 June, 1870) written to Kugelmann :[1]

> " Mr. Lange, you see, has made a great discovery. The whole of history can be subsumed under a single great natural law. This natural law is the *phrase* (in this application Darwin's expression becomes nothing but a phrase) ' the struggle for life,' and the content of the phrase is the Malthusian law of population or rather over-population. So instead of analysing the struggle for life as represented historically in different definite forms of society, all that has to be done is to translate every concrete struggle into the phrase ' struggle for life,' and this phrase itself into the Malthusian population fantasy. We must admit that this is a very impressive method—for swaggering sham-scientific bombastic ignorance and intellectual laziness."

This condemnation, echoed by Lenin in a more incisive way, is of value for the whole of sociological literature and for all propositions about biological morals. It is not reasonable to force an entry for vital phenomena into the realm of physical law. Nor is it reasonable to transfer biological laws bodily to human society, for society possesses characteristics peculiar to it : technique, class differentiation, human purpose, and human freedom.

Whatever the social regime, the struggle for life is a vastly different thing in human society from the struggles of the biological world, because tools in the most general sense, that is instruments of production and arms, now play a decisive part. The relative speed

[1] " Selected Correspondence," p. 201.

with which the means of production reach perfection implies that natural resources can never be as restricted as those of an animal species. Consequently the Malthusian theory does not apply.[1] In addition to this, ever since the first day when the social and economic system allowed the appropriation of these means of production by a single class, that is to say, ever since the disruption of the old clan society, the struggle for existence could no longer be a means of physical or mental development, but merely helped to perpetuate the domination of the class possessing the means of production over that which did not. The struggle for life under its primitive animal aspect, therefore, largely disappeared. It bears no resemblance whatever to competition under the capitalist system, which is peculiar to that system. Throughout all social forms what replaces the struggle for existence is the struggle of oppressed classes against possessing classes.[2]

[1] Marx and Engels were deeply interested in the application of biochemistry to agriculture, since they realised that it destroyed the Malthusian arguments about the inevitable excess of population over food-supply. "The advance of science," Engels wrote in 1843, "is as limitless and at least as rapid as that of population." In 1866 Marx wrote to Engels that he had been "wading through the new agricultural chemistry in Germany, especially Liebig and Schönbein, who are more important than all the economists put together." ("Selected Correspondence," pp. 33, 204.) J. von Liebig's great book "Die Chemie in ihre Anwendung auf Agricultur" was published in 1840 and laid the foundations of agricultural chemistry.

[2] This replacement is, of course, not absolute. Natural selection continues to operate within human communities, since it is likely that differential susceptibility to infectious and other diseases is inherited among individuals according to Mendelian laws. It is at least equally certain that susceptibility to disease is also a function of social class, as the tuberculosis figures in different English boroughs demonstrate. It must always be remembered that the "struggle for existence" involves two things, the struggle to get food and the struggle to produce offspring. In the declining phase of capitalism a remarkable paradox has arisen in that although social success means success in the former struggle, it does not in the latter. The "lowest" strata of society have the largest families. This state of affairs is only depressing to those who cherish the belief (as it has been expressed) that the public-school tie covers all the best genes: a belief which has no scientific foundation.

On this subject Engels says : [1]

> " The whole Darwinian theory of the struggle for life is simply the transference from Society to Nature of Hobbes's teaching of the war of each against all, the bourgeois economic theory of competition, and the Malthusian doctrine of population. That such a masterpiece is correct without reservations is still very doubtful, especially as regards the Malthusian theory ; but once it has become accepted nothing is easier than to take these theories from natural history and carry them back again into society. It is a little too naïve to believe that this proves them to be the natural and eternal laws of society.
>
> " For the sake of argument let us provisionally accept the expression ' struggle for life.' The animal succeeds at most in accumulating ; man produces ; in the widest sense he creates means of existence which would not have existed but for him. Whence the impossibility of carrying over biological laws bag and baggage from animals into human society. The fact of production means that the supposed struggle for existence is no longer concerned solely with the means of existence as such, but more with the means of enjoyment and development. From the moment when we have means of development produced in society, categories drawn from the animal kingdom altogether cease to apply."

Later in the same passage Engels again shows that in a period of revolutionary crisis the struggle between classes plays the same progressive part as belongs in nature to the struggle for life. In the economic crisis which we are now experiencing it is this struggle which will enable us to transfer the direction of social production and distribution to the mass of producers from the outworn incapable capitalist class. And Engels concludes :

[1] " Dialectics of Nature," p. 641.

> "The interpretation of history as a series of class struggles has a far richer and deeper content than its reduction to a mere series of scarcely distinguishable phrases about the struggle for life."

All this does not, of course, signify in any way that Marxists make an ideal of the class struggle. They see in it nothing but an incontrovertible fact, a distant legacy from Darwinian competition. From this last remnant of animality mankind will be delivered only by the abolition of classes, now made economically possible by the superabundance of production. This is the task of the socialist revolution.

CHAPTER FOURTEEN

THE BIOLOGICAL SCIENCES AND OUR VIEW OF THE NATURE OF THE WORLD

"Nature is the test of dialectics. Modern natural science has furnished extremely rich and daily increasing materials for this test, and has thus proved that in the last analysis Nature's process is dialectical and not metaphysical. But the scientists who have learned to think dialectically are still few and far between, and hence the conflict between the discoveries made and the old traditional mode of thought is the explanation of the boundless confusion which now reigns in theoretical natural science and reduces both teachers and students, writers and readers to despair." [1]—Engels.

(i) EMPIRICISM AND THE DIALECTIC

In all the problems we have considered, whether in connection with population and adaptation, living matter and the problem of form, heredity and evolution, even comparative psychology, we have recognised two extreme points of view whose characteristics are always the same. One of these refers all the phenomena of life to properties which are intrinsic to it, and when sufficiently thorough-going invokes some vital principle, entelechy, teleological force, or whatever it may be called. The other conception invokes the action of environment with its mechanical, physical, and chemical forces, and strives to reduce to phenomena of the same order the whole of life, not excluding thought.

Modern empirical biology professes independence of either view. It endeavours to stand on experiment alone, although this is, strictly speaking, an impossibility. If it departs from this position it attempts only timid partial syntheses, using ill-defined terminology

[1] "Anti-Dühring," p. 29.

and concepts whose limits of application have never been decided. The utilisation of such terminology and concepts by logical thought leads to strange results, and so biology oscillates from one extreme to the other, from mechanism to vitalism, with a bias sometimes in favour of one, sometimes in favour of the other. This almost justifies Engels's biting criticism :[1]

> " Scientists imagine that they can free themselves from philosophy by ignoring or disdaining it. But as they are unable to move a step without thought, and thought demands logical definitions, the only result is that they take these definitions uncritically either from the current ideas of so-called educated people, dominated by hang-overs from philosophical systems long since decayed, or from their random and uncritical reading of all kinds of philosophical works. In fact, they prove themselves prisoners of philosophy, but unfortunately on most occasions of philosophy of the worst sort. Thus while they are most violent in their contempt for philosophy they become the slaves of the most vulgarised relics of the worst philosophical systems."

Throughout these vicissitudes, however, empirical biology painfully approaches a more and more coherently dialectical outlook. All its decisive advances involve the shedding of rigid concepts and diametrical oppositions under the pressure of experimental fact. They involve a more accurate definition of the terms used, or, what amounts to the same thing, finding the appropriate synthesis between thesis and antithesis.

Under such circumstances would it not be better to recognise that the dialectical laws which are being progressively forced upon the attention of biologists exist in Nature itself ? Would it not be preferable to deduce from these a method which would cease to consider the contradictions in the results of experiment as

[1] " Dialectics of Nature," p. 624.

calamities and excuses for discouragement and the renunciation of science ? Such a method would foresee contradictions as inevitable, but would postulate as a matter of principle that they could always be resolved once the rigidity of concepts was abandoned.

Rigidity of concepts or, in other words, verbalism, can lead to a variety of forms of vitalism which Lenin described as " barren excrescences of human knowledge." Among biologists the naïve thoughtless forms are more prevalent than is usually supposed. Delage has ridiculed them in a passage well worth quoting :

> " The second irritating result is a dangerous tendency to bow down before words, of which even well-trained and distinguished minds are guilty. It is becoming the fashion to-day to consider heredity, atavism, variation, adaptation, etc., as so many directive forces of evolution, whereas they are really nothing but categories, groups of facts each with its individual mechanical reason. Out of them arises, all unsuspected, a kind of biological pantheon whose divinities dispute over the future of the organism in the same way as the Olympian deities disputed over the fate of Greeks and Trojans. And it is fondly imagined that something has been explained when it is announced : ' This is atavism, that is due to variation, and the other is a result of heredity '." [1]

(ii) CRITIQUE OF TELEOLOGICAL VITALISM

But there exist also more refined vitalist philosophies which, having been dislodged by experimental science from a whole series of successive positions, now find refuge in a teleology which appears unassailable. Bergson has written with some pride on this subject :

> " The doctrine of final causes will never be definitely refuted. If it is deprived of one form it will adopt

[1] Y. Delage, " l'Heredité et les Grands Problèmes de la Biologie " (Schleicher, Paris, 1903).

another. Its essentially psychological principle is highly flexible. It is capable of such development, its advance is so wide, that something of it is accepted the moment pure mechanism is turned down." [1]

This defiance proves nothing but its author's ignorance, since he had already been refuted by dialectical materialism, which discards mechanism and yet insists on the priority of matter over all purpose.

In any case, Bergsonian teleology is not a tendency towards an end. It is better expressed by a sort of impulse or vital force which, as it were, spreads out in a sheaf as evolution goes on. There results a dialectic of life which in its outward appearance simulates Marxist dialectic, in the sense that both involve the creation of new facts and new beings. But there is this fundamental difference. One is concrete, leading on to experiment and action ; while the other, a metaphorical philosophy, merely gives an easy way out, general and unverifiable, bearing no relation to scientific research and even discouraging it. We can apply to it, by way of criticism, the following comment of Engels on Hegelian teleology :

> " Internal teleology in the organism is represented by Hegel as a force. Not so fast. The force must put the isolated living being more or less into harmony with its conception. Hence we see how internal teleology is itself an ideological conception." [2]

The only interest of Bergsonism for biology would be its critique of mechanism, had this not been made long before by Marx and Engels. As for the supposedly constructive part, it is valueless. Bergsonism is found to be but the hollow mould of dialectical materialism.

Bergson postulated a teleology peculiar to life. But the Neo-Thomists have a somewhat different point of

[1] H. Bergson, "l'Evolution Creatrice," p. 43 (Alcan, Paris, 1911).
[2] " Dialectics of Nature," p. 655.

view. One of them, Dalbiez,[1] has emphasised the fact that teleology is not peculiar to life and that it can only be correctly defined in very general philosophical terms, such as " the preordination of potentiality to actuality." Let us translate this into concrete terms. There is preordination of potentiality to actuality in an animal population, for the enormous number of descendants to which a pair of animals could give rise do not in fact reach maturity. Or again a given fragment of a sea-urchin's egg can potentially produce a complete embryo, which is not in fact achieved. But it is perfectly clear that though this distinction between the potentiality and the actuality may be quite justified in the abstract, it ceases to be justified as soon as the pair of animals or the egg are considered in material relations with the environment, since it is this relation which is responsible for limitation, and creates a unity of a higher order, population, or embryo. In any of the questions outlined in Chapters 6 to 12 it can be seen that the idea of teleology, that is to say of a preordaining of potentiality to actuality, arises from an abstraction which cannot be made without breaking real relations. The Neo-Thomists carry with them, as a heritage from Aristotle, radical and scholastic oppositions such as those of form and content, potentiality and actuality. These concepts are then utilised in a purely logical fashion, and thus in the gap between their concepts they manage to squeeze in teleology. But in concrete fact, as Engels says, " the whole of organic Nature proves without exception that form and content are identical or inseparable." The same dialectic which tries to avoid neglecting interrelations with environment makes of the distinction between potentiality and actuality an experimental phenomenon of a purely material order.

[1] "Transformisme et Philosophie" (Vrin, Paris, 1927).

Neo-Thomist teleology is a logical abstraction. Bergsonian teleology, though more dialectical, is a poor compromise with reality. It may succeed in effecting an apparent reconciliation with reality, but remains sterile and incapable of acting upon it. Moreover, it quite mistakenly limits dialectics to biology. Both have an easy victory when attacking pure mechanism, but are powerless in the face of Marxist materialism, which recognises both the apparent teleology and the incessantly creative aspect of organic evolution, supplying a method capable of accounting for them. Never losing sight of the fact that human knowledge is the creation of living, material men, the materialist is not surprised that in this small corner of the universe which man inhabits matter possesses a relatively high degree of stability, suggestive of a statistical teleology; if this were not the case nobody would know anything about it.

(iii) CRITIQUE OF AGNOSTICISM

In biology to-day clear-minded and conscious teleologists are as rare as thorough-going mechanists. The great majority of biologists are empiricists and agnostics, unwilling to make any hypothesis outside experiment. Whether they succeed in their object of remaining strict specialists is questionable. It is very difficult to avoid risking something beyond experiment, as the case of Cuvier goes to show. This apostle of the "school of facts" committed many an error of interpretation. But one thing is certain, those biologists who, while still guided by experimental results, yet rise above them to a wider synthesis are led to an unconscious dialectical materialism. This fact is the more striking the wider the synthesis attempted, and it is not always easy to understand why these scientists hesitate to call themselves materialists.

Engels has well depicted this deprecated materialism of the empirical scientist :

> " As soon as our agnostic has made these formal mental reservations he talks and acts like the rank materialist that at bottom he is. He admits the possibility of vitalism in the abstract, but will have none of it in the concrete. Thus as far as he is a scientific man, as far as he *knows* anything, he is a materialist ; outside his science in spheres about which he knows nothing he translates his ignorance into Greek and calls it agnosticism." [1]

(iv) OUTLINE OF THE MATERIALIST VIEW-POINT

Man, the child of living Nature, finds himself face to face with her.

> " In front of him," says Lenin,[2] " there extends a network of natural phenomena. Instinctive man, the savage, does not distinguish himself from Nature. Conscious and active man makes this distinction. The categories denote the stages of this detachment, that is to say, of the recognition of the world ; they are the knots in the network which help him to recognise it and make himself master of it."

Thus man parcels out the great general system of natural phenomena, and it is this parcelling, artificial but indispensable, which accounts for the notion of causality. This, says Lenin again,[3] is only a very small part of the great objective universal interdependence.

What determines the special points first recognised in the network, and hence the categories and the objects which are defined in the world, is the need of man struggling with Nature. For man is not a pure contemplative spirit. He has animal bodily needs and acts

[1] Preface to " Socialism, Utopian and Scientific," p. xviii (Allen & Unwin, London, 1892). The original text reads " spiritualism " for " vitalism."

[2] " Kritik d. Hegelschen Wissenschaft d. Logik," p. 10.

[3] *Loc. cit.*, p. 80.

in order to satisfy them. This is whence knowledge first arises; however refined it may become, science receives its motive force from necessity and can be checked again only against action and practice.

Certain brief expressions used by Engels in "Anti-Dühring" might lead to a belief in too mechanical an interpretation of human knowledge. Concepts, he says occasionally, are "the copies of objects in the minds." But the real opinions of Marx and of Engels himself are to be found in the passages where they criticise Kant's "Thing in Itself" by definition unknowable, where they show that in reality the "thing in itself" is unceasingly transformed into the "thing for itself," the object of which man takes possession and which enters into his cognition on that account.

"Truth," Lenin explains,[1] "is a process. From the subjective idea man attains objective truth by way of practice and technique."

And he adds: [2]

> "Understanding is the continuous approach of thought towards the object. The reproduction of Nature in human thought is neither dead nor abstract; neither without movement nor without contradictions, but included in the continual process of motion, of contradictions engendered and resolved."

This active theory of knowledge implies that man is an integral part of Nature, in particular of living Nature, within which he acts. It is in this sense that modern biology (more especially Darwinism in spite of all its weaknesses) has contributed a major argument in support of the Marxist conception of the world.

[1] *Loc. cit.*, p. 121. [2] *Loc. cit.*, p. 115.

APPENDICES

I. CITATIONS FROM MARXIST WORKS, RELATING TO BIOLOGICAL PROBLEMS

(i) INTRODUCTORY NOTE

In applying the Marxist method to biology there are two dangers to be avoided. One is that of excessive quotation from Marxist classics, which would give a false impression of dogmatism. For this reason such quotations are all but absent in the preceding seven chapters; appeal is made to experiment alone. But there is also the danger of giving the impression that the attribution of opinions on biological matters to Marx and Engels is purely arbitrary. Too many people who call themselves Marxists reiterate that Marx was really never more than an economist and that Marxism is concerned only with the social as opposed to the biological sciences. Further quotations, therefore, become necessary, including some from Plekhanov and Lenin. The essential is, of course, always the method, and not the verbal doctrine which cannot foresee the new data which it is continually anxious to assimilate.

(ii) COMPETITION AND ADAPTATION

Marx and Engels, as we know, gave an enthusiastic welcome to Darwin's "Origin of Species." For them it contained not only fundamental arguments in support of the dialectical conception of the world, but also, in the "struggle for existence," a materialist explanation of organic evolution. They were not on that account fanatical supporters of Darwin. Both speak of the

" crudities " in his work. They saw perfectly well from the start that the term " struggle for life " is defective on account of teleological implications.

> " The *name* ' the struggle for existence,' can, for that matter, be willingly handed over to Professor Dühring's exceedingly moral indignation. That the *fact* exists also among plants can be demonstrated to him by every meadow, every cornfield, every wood." [1]

They realised, moreover, that Darwin's Malthusian premises were unsound ; but that did not stop them from grasping the essentials of his theory far more clearly than many either of his supporters or his opponents did afterwards.

> " However great the blunder made by Darwin in accepting so naïvely and without reflection the Malthusian theory, nevertheless anyone can see at the first glance that no Malthusian spectacles are required in order to perceive the struggle for existence in Nature, the contradiction between the countless host of germs which nature so lavishly produces and the small number of those which reach maturity." [2]

Engels also criticised Darwin's failure to differentiate the two series of causes of loss : accidental causes and the automatic limitation of the number of individuals.[3]

> " Darwin's mistake is to have mixed in natural selection or the survival of the fittest, two entirely different things :
>
> " (*a*) Selection under pressure of over-population, where perhaps the strongest survive, but where these may also be the weakest in many other respects.
>
> " (*b*) Selection based upon greater adaptive plasticity in the face of new circumstances, where the survivors are the best adapted to those circumstances

[1] " Anti-Dühring," p. 82.
[2] *Ibid.*, p. 81.
[3] " Dialectics of Nature," p. 660.

but where adaptation can mean equally progress or regression (for example, parasitism is always a regression).

" The fundamental point is that all progress in organic evolution is at the same time regression, since it fixes upon one line of development to the exclusion of further development along many other lines. But this is a fundamental law."

Engels pronounced in favour of adaptation as a fact of experience, but denied to it all conscious purpose.[1]

" If, therefore, tree-frogs and leaf-eating insects are green in colour, desert animals sandy-yellow, and animals of the polar regions mainly snow-white, they have certainly not adopted these colours intentionally or in conformity with any ideas ; on the contrary, the colours can only be explained on the basis of physical forces and chemical action. And yet it cannot be denied that these animals because of their colours are fittingly adapted to the environment in which they live, in such a way that they are far less visible to their enemies. In just the same way the organs with which certain plants seize and devour insects alighting on them are adapted to this action and even purposefully adapted. But if Professor Dühring insists that this adaptation must be effected through ideas, he says in other words that the purposive activity must also be brought about through ideas, it must be conscious and intentional. And this brings us, as is usually the case in his philosophy of reality, to a purposive creator, to God."

He also reproached the Darwinists for exaggerating the idea of struggle for life : [2]

" Until Darwin, it was precisely those who are now his disciples who insisted upon the harmonious working of organic nature ; they showed how the vegetable kingdom produces for the use of animals food, oxygen, ammonia, and carbonic acid gas. The moment

[1] " Anti-Dühring," p. 84.
[2] " Dialectics of Nature," p. 641.

Darwin's ideas were accepted the same people discerned everywhere nothing but struggle. Both conceptions are justified within strict limits, but they are both equally one-sided and restricted. The interaction of inanimate bodies involves both harmony and collision ; that of living beings includes common action conscious and unconscious, as also conscious and unconscious struggle. In Nature already it is impossible to write on the flag the one-sided word 'strife.' But to try to sum up the rich variety of development and historical change in the meagre and one-sided phrase 'struggle for life' is merely childish, and means less than nothing."

Thus the founders of Marxism clearly outlined several of the basic ideas developed in Chapters 6 and 7.

(iii) THE CHEMISTRY OF LIVING MATTER

Engels repeatedly insisted on the dialectical nature of life. The clearest example is the quotation on page 58. Simple exchange of substances was for him an insufficient criterion of life :

"That organic exchange of matter is the most general and most characteristic phenomenon of life has been said times without number during the last thirty years by physiological chemists and chemical physiologists. . . . But to define life as an organic exchange of matter is to define life as—life . . . This explanation carries us no further." [1]

Engels avoided the mistake of mechanist biologists who take physical or chemical diagrams for causal explanations :

"Exchange of matter as such takes place even without life. There is a whole series of processes in chemistry which with an adequate supply of raw material constantly reproduce their own conditions, a definite body being the carrier of the process. . . ."

[1] "Anti-Dühring," p. 93.

[there follows an account of an industrial catalysis, the lead-chamber process of sulphuric acid manufacture]. " Exchange of matter also takes place in the passage of fluids through dead organic and even inorganic membranes, as in Traube's artificial cells. Here, too, it is clear that we cannot get any further by means of exchanges of matter; for the special exchange of matter which is to explain life itself needs in turn to be explained through life. We must therefore try some other way." [1]

The peculiarity of living beings is therefore to be at one and the same time both themselves and not themselves. Engels develops the idea as follows:

" But what are these universal phenomena of life which are present in all living organisms? Above all an albuminous body absorbs other appropriate substances from its environment and assimilates them, while other older parts of the body are consumed and excreted. Other, non-living, bodies also change, and are consumed, or enter into combinations in the course of natural processes; but in doing this they cease to be what they were. A rock worn away by atmospheric action is no longer a rock; metal which oxidises rusts away. But what with non-living bodies is a cause of destruction, with albumen is the fundamental condition of existence. From the moment when this uninterrupted metamorphosis of its constituents, this constant alternation of nutrition and excretion, no longer takes place in an albuminous body, from that moment the albuminous body itself comes to an end and decomposes, that is, dies. Life, the mode of existence of albuminous substance, therefore consists primarily in the fact that at each moment it is itself and at the same time something else; and this does not take place as the result of a process to which it is subjected from without as is the way in which this can occur in the case of inanimate bodies. On the contrary, life, the exchange of matter which

[1] Anti-Dühring, p. 94.

takes place through nutrition and excretion, is a self-completing process which is inherent in and native to its medium, albumen, without which it cannot exist." [1]

The above passage would be irreproachable both from the scientific and the dialectical materialist point of view if it did not endow proteins with "innate" properties. Engels several times mentions this innateness of life in albumen :

"Life is the mode of existence of albuminous substances." [2]

"And hence it follows that if chemistry ever succeeds in producing albumen artificially, this albumen must show the phenomena of life, however weak they may be." [3]

This position is clearly mechanist, and in explaining life as an innate property of protein Engels was straying from the dialectical path. Moreover, in this passage he seems to have been bound by submission to the state of science in his time, for he added a qualification :

"It is certainly open to question whether chemistry will at the same time also discover the right food for this albumen." [4]

Modern biology, with its complex conception of protoplasm, is more dialectical than Engels was able to foresee. Although the proteins are assuredly essential to life, it is probable that many other very complicated molecules, such as those of the lipins and sterols, are so too. But in a number of passages in "Dialectics of Nature" he returned to the idea that protein molecules are not simple, static, isolated structures, but undergo continual change as long as life lasts. Modern chemistry has led to similar conclusions on a wider scale ; chemical

[1] "Anti-Dühring," p. 95.
[2] *Ibid.*, p. 94.
[3] *Ibid.*, p. 96.
[4] *Ibid.*, p. 96.

molecules are no longer regarded as immutable and invariable.[1]

(iv) FORM

There are few quotations to add on this subject, but the important part played by material interactions clearly arises from profoundly dialectical principles. With regard to the relation of form to function and differentiation, the following passage must receive special notice :

> " The whole of organic Nature proves without exception that form and content are identical or inseparable. Morphological and physical, form and function, are mutually determined. The differentiation of form (in the cell) conditions the differentiation of substance in muscle, skin, bone, epithelium, etc., and the differentiation of substance reacts back again and conditions new form." [2]

The interpretation of metamorphoses as sudden leaps following a period of crisis was indicated by Engels and developed at greater length by Plekhanov.[3]

[1] The above text is that of the French edition (1936). It may be that Engels, in his definition of life as the mode of existence of proteins, was nearer the truth than is there suggested. Although most living forms contain many complex organic substances in addition to the proteins, modern biochemistry seems to be coming to the conclusion that the proteins, with their almost unimaginable complexity and variety of molecular architecture, represent the substances characteristic *par excellence* of life phenomena, and most indispensable for life. The proteins certainly stand on a level of organisation very much higher than any other organic compounds. If this is so Engels showed remarkable vision in his conclusion of 1872, to which he may have been assisted by his friend Schorlemmer, the eminent Manchester chemist. Recent work on the chemical nature of certain non-filterable viruses of plant diseases indicates that protein in a fairly highly purified state may show some of the properties of life. The significance of this has been brought out by J. B. S. Haldane (*Science and Society*, 1937, **1**, p. 473) and by N. W. Pirie (contribution to " Perspectives in Biochemistry," Cambridge, 1937). The Soviet biologists B. Barkhach and A. Krinitsky make the same point in their criticism of the present book (*Commune*, 1937, **4**, 696).

[2] " Dialectics of Nature," p. 623.

[3] " Fundamental Problems of Marxism," pp. 97 ff.

(v) HEREDITY AND EVOLUTION

As regards heredity and evolution Engels was naturally limited by the stage which science had reached in his time. But he saw perfectly well that this was bound to be surpassed :

> " The theory of evolution is, however, still in a very early stage, and it therefore cannot be doubted that further research will modify in very important respects our present conceptions, including strictly Darwinian ones, of the course of the evolution of species." [1]

He clearly noted one important hiatus in Darwinism :

> " Darwin, when considering natural selection, leaves out of account the *causes* which have produced the variations in separate individuals, and deals in the first place with the way in which such individual variations gradually become the characteristics of a race, variety, or species. To Darwin it was of less immediate importance to discover these causes—which up to the present are in part absolutely unknown, and in part can only be stated in quite general terms—than to establish a rational form according to which their effects are preserved and acquire permanent significance. It is true that in doing this Darwin attributed to his discovery too wide a field of action, made it the sole agent in the alteration of species and neglected the causes of the repeated individual variations, concentrating rather on the form in which these variations become general ; but this is a mistake which he shares in common with most other people who make any real advance." [2]

Obviously Engels could know nothing of mutations. But their actual discovery and the work of de Vries was warmly hailed by Plekhanov, so warmly indeed than Riazanov thought the welcome exaggerated.[3]

[1] " Anti-Dühring," p. 87.
[2] *Ibid.*, p. 82.
[3] " Fundamental Problems of Marxism," p. 138

As regards the origin of life, Engels deprecated the notion that it had existed from eternity, dispersing its minute germs through interstellar space.[1] On the other hand he showed some sympathy for the conception of the repeated origin of life :

> " The statement that Darwin traced all existing organisms back to one original creature is, to put it politely, a product of Professor Dühring's ' own free creation and imagination.' Darwin expressly says on the last page but one of his ' Origin of Species ' (sixth edition) that he regards ' all beings, not as special creations, but as the lineal descendants of *some few beings*.' "[2]

(vi) CONSCIOUSNESS

The relation between liberty and necessity in human evolution was clearly expressed by Engels :

> " Freedom does not consist in the dream of independence of natural laws, but in the knowledge of these laws, and in the possibility this gives of systematically making them work towards definite ends. This holds good in relation both to the laws of external Nature and to those which govern the bodily and mental life of men themselves—two classes of laws which we can separate from each other at most only in thought and not in reality. Freedom of the will, therefore, means nothing but the capacity to make decisions with real knowledge of the subject. Therefore the *freer* a man's judgment is in relation to a definite question, with so much the greater *necessity* is the content of his judgment determined ; while the uncertainty founded upon ignorance which seems to make an arbitrary choice among many different and conflicting decisions, shows by this precisely that it is not free, that it is controlled by the very object it should itself control. Freedom, therefore, consists in

[1] " Dialectics of Nature," p. 629.
[2] " Anti-Dühring," p. 84.

the control over ourselves and over external Nature which is founded on knowledge of natural necessity ; it is therefore necessarily a product of historical development. The first men who separated themselves from the animal kingdom were in all essentials as unfree as the animals themselves, but each step forward in civilisation was a step towards freedom. On the threshold of human history stands the discovery that mechanical motion can be transformed into heat, the production of fire by friction ; at the close of the development so far gone through stands the discovery that heat can be transformed into mechanical motion : the steam-engine. And in spite of the gigantic and liberating revolution in the social world which the steam-engine is carrying through—and which is not yet half completed—it is beyond question that the generation of fire by friction was of even greater effectiveness for the liberation of mankind. For the generation of fire by friction gave man for the first time control over one of the forces of Nature, and thereby separated him for ever from the animal kingdom." [1]

On the separation of man from the animals and its consequence, the psychological differences between man and animal, the following passage from Marx is interesting :

"A spider carries on operations which resemble those of a weaver and many a human architect is put to shame by the skill with which a bee constructs her cell. But what distinguishes the worst architect from the best of bees is this, that the architect raises his structure in his head before he erects it in wax. At the end of every labour process we get a result that already existed in the imagination of the labourer at the beginning. He not only effects a change of form in the material in which he works, but he also realises a purpose of his own which gives the law to

[1] "Anti-Dühring," p. 130.

his *modus operandi* and to which he has to subordinate his will." [1]

This does not mean that between man and animal there is an irreducible difference. This would be contrary to dialectical materialism as a whole. Engels has expressed the point very clearly : [2]

> " All modes of the understanding, induction, deduction, abstraction, analysis, synthesis, and experiment, man has in common with the higher animals. The difference is only a matter of degree. The essentials of the methods are similar and lead to similar results, as long as the question remains on an elementary level. But dialectical thinking is possible only to man."

In the relation of psychological attributes to the structure of the body, Engels did not make the mistake of assigning exclusive importance to the nervous system. " Sensation is not necessarily associated with nerves," [3] he concluded, after stating, in error, no doubt, but in accordance with the science of his time that :

> " Not only all primitive animals, but also all the plant-animals, or at any rate the great majority of them, show no trace of a nervous apparatus." [4]

And he uses this argument :

> " Are the sensitive plants which at the slightest touch fold their leaves or close their flowers, are the insect-eating plants, devoid of the slightest trace of sensation and do they even lack any apparatus for it ? " [5]

At a very different position in the scale of psychological development man's thought is linked with all his activity, as Engels shows :

[1] " Capital," I, p. 169.
[2] " Dialectics of Nature," p. 637.
[3] " Anti-Dühring," p. 93.
[4] *Ibid.*
[5] *Ibid.*

> "The specialisation of the hand signifies the tool; the tool signifies the peculiarly human activity of modifying Nature, production. There are animals in the strict sense of the word which possess tools, but merely as members of their bodies: ants, bees, beavers. There are animals which produce; but the effect of their activity upon surrounding Nature is negligible compared with that of man. Man alone has succeeded in setting his seal on Nature, not only by overthrowing the vegetable and animal kingdom, but by changing the aspect, the climate, of his habitat, changing the plants and animals themselves, so that the fruits of his labours will only pass away with the age and decay of the planet. All this has been done first and foremost by means of his *hand*. The steam-engine itself which up to the present time is his most powerful weapon in the transformation of Nature comes back in the last analysis to the hand, since it is a tool. But alongside the hand has developed the head. First came the consciousness of the conditions of certain practically useful effects. Then followed knowledge of the natural laws on which they depend. With his rapidly increasing acquaintance with natural laws, additional forces for the attack on Nature came into being. The hand alone would never have turned out the steam-engine if the brain had not developed with, and alongside, and, in part, through it." [1]

Hence the error of "vulgar" materialism, which Lenin condemned, explaining that the way to regard materialism

> 'consists not in the derivation of sensation from the movement of matter or in the identification of sensation with the movement of matter, but in the recognition that sensation is one of the properties of matter in motion. On this particular question Engels held Diderot's views. Engels opposed the 'vulgar' materialists, Vogt, Buchner, and Moleschott, because they

[1] "Dialectics of Nature," p. 493.

assumed that thought is secreted by the brain as bile by the liver, holding that in this matter they were confused." [1]

It is from Lenin, again, that we must quote a passage to emphasise the priority of matter to thought, that cardinal proposition which is the very foundation of materialism :

> " Materialism, in full agreement with the natural sciences, takes matter as the *prius*, regarding consciousness, reason, and sensation as derivative, because in their clearest form they are connected only with the higher forms of organic matter. It becomes possible, therefore, to assume the existence of a property similar to sensation in the foundation-stones of the structure of matter itself." [2]

[1] " Materialism and Empirio-Criticism," p. 28.
[2] *Ibid.*, p. 26.

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III. GLOSSARY OF TECHNICAL TERMS

ACHEULIAN.—Period of prehistory in the lower (*i.e.* more ancient) Palæolithic between the Chellean and the Mousterian (from the place, St. Acheul).

AMMONITES.—An extinct group of molluscs related to our octopus and cuttle-fish, appearing towards the end of the Primary and extinct before the close of the Secondary.

ANTHROPOID.—Term applied to the man-like apes, those which are most nearly related to man.

APTEROUS.—Wingless ; said of species which have lost their wings.

Archæopteryx.—The most ancient known bird, still very similar to the reptiles, dating from the Secondary era.

ASTRAGALUS.—A bone of the ankle.

AURIGNACIAN.—A period of prehistory in the upper Palæolithic.

Australopithecus.—A fossil species of monkey from the Tertiary, related to man.

BACTERIA.—A group of one-celled microscopic organisms, found in soils, water, decaying organic matter, etc., and sometimes parasitic on the higher animals and plants, then frequently causing disease. Popularly termed microbes.

BACTERIOPHAGES.—Recently discovered organisms, invisible even to the microscope, betraying their existence by their power of destroying bacteria. See VIRUSES.

BIOCŒNOSIS.—The living together of organisms so as to form a stable grouping (often synonymous with " association ").

BIOSOCIOLOGY.—The study of biocœnosis.

CALCANEUM.—The bone of the ankle which supports the heel.

CAPSIAN.—That period of prehistory which in some countries is the equivalent of the reindeer age and Mesolithic.

CELL.—A unit of living matter, usually microscopic, composed of a nucleus surrounded by cytoplasm ; living matter is generally organised in cells.

CENTROSOME.—A small granule contained in the cell, which seems to play an important part in cell-division.

Chellean.—One of the earliest periods of prehistory, between the pre-Chellean and the Acheulian (from the place, Chelles).

Chromosomes.—Bodies into which the nucleus resolves itself during the process of cell-division.

Colloidal.—A state of matter in which the particles are generally of greater size and more complex structure and organisation than those of matter in the crystalloidal state. Colloidal matter consequently possesses markedly different properties. Living matter is composed of colloids.

Comatula.—The feather-star; a genus of echinoderms.

Cynocephalus.—The dog-faced baboon; a genus of ape inhabiting the desert regions of Africa and Arabia.

Dedifferentiation.—The loss of specialised characteristics: applied, for example, to a cell which recovers its earlier, more generalised form.

Determination.—The settling of the destinies of the parts of an embryo.

Differentiation.—Increase in complexity, organisation, and specialisation; as in embryonic development.

Echinoderms.—The group of marine animals which includes our sea-urchins and star-fish.

Entelechy.—Name given by Aristotle to a supposed intrinsic purposefulness of living organisms.

Enzymes.—Colloidal catalysts present in living matter responsible for the many and varied chemical reactions proceeding in it.

Eoanthropus.—The Piltdown man; an extinct genus very similar to man.

Eoliths.—Roughly splintered stones which may possibly be the work of human beings.

Epigenesis.—The conception of development in which the adult being is not determined in all its ultimate details in the egg; the opposite of preformation.

Era.—Term used to designate the great epochs of geological history—Primary, Secondary, Tertiary, and Quaternary.

Evolution.—The theory that the various living species have been transformed, giving rise to new ones according to natural laws.

Finalism.—The view that a non-material principle acts upon events with an end in view.

Genes.—Hypothetical bodies which according to genetic theory enter into the constitution of the chromosomes and are the basis of hereditary characters.

GENOTYPE.—The sum total of genes in an individual.

GLACIATION.—Ice-age. A period marked by enormous extension of glaciers ; there have been several since the appearance of man.

GLANDS.—Organs which secrete various substances. Glands of internal secretion send their products into the blood-stream, those of external secretion outside the organism or into the intestines.

GNEISS.—Crystalline rock resulting from the metamorphism of clay.

GRANITE.—Crystalline rock analogous to gneiss, but resulting from metamorphism under greater pressure.

GROWTH.—Increase in size and weight, as in the development of the individual, before and after hatching or birth.

HEREDITY.—The transmission of characters from parents to children.

Homo sapiens.—The Latin name given to the present human species to distinguish it from others.

HORMONES.—Chemical substances secreted into the blood by the glands of internal secretion, and thus distributed throughout the organism.

HYBRID.—A living being arising from the crossing of two different species.

ICHTHYOSAURUS.—A great marine reptile of the Secondary era.

INDRI.—A genus of lemur found in Madagascar.

INTERACTION.—Reciprocal action of phenomena in which it is not possible to state with certainty which is cause and which is effect.

INTERGLACIAL.—The warm periods separating glacial periods.

INVERTEBRATES.—Animals without a backbone.

JORDANIAN.—Micro-species differing only in characters of detail, which the botanist Jordan was the first to recognise within the major species.

LAMARCKISM.—Lamarck's doctrine that evolution takes place gradually through a process of adaptation to environment.

LARVA.—Form intermediate between the embryo and the adult.

LEMURS.—A group of mammals resembling apes but more primitive.

LOCALISATION.—By cytoplasmic localisations we understand the regions of distinct composition and structure which characterise the various parts of a cell. Germinal localisations, in particular, are localisations of the egg-cell.

MAGDALENIAN.—The last period of the upper Palæolithic, between the Solutrean and the Mesolithic.

MECHANISM.—Non-dialectical materialism which aims to explain all phenomena, all forms of motion, in terms of those believed to be simpler, and especially in terms of mechanical movement.

MEGALITHS.—The huge monuments, dolmens, menhirs, cromlechs, such as Stonehenge, made of huge pieces of rock, at a late stage in prehistory.

MENDEL.—The botanist who in 1863 discovered important laws of heredity which bear his name.

MESOLITHIC.—The prehistoric age separating the Palæolithic from the Neolithic.

METAMORPHISM.—The sum of physical and chemical phenomena which, operating in the deeper beds of the earth's crust, transform such rocks as clay into crystalline materials like mica schists, gneiss, and granite.

METAMORPHOSIS.—The process by which the adult form originates from the larval form, *e.g.* the butterfly from the caterpillar or the frog from the tadpole.

MICA SCHIST.—A crystalline rock produced by the metamorphosis of clay, but less altered than gneiss.

MITOCHONDRIA.—Granular or elongated bodies forming an essential part of the cytoplasm with a chemical composition slightly different from that of the rest of the cytoplasm.

MORPHOLOGY.—The science of living forms.

MOUSTERIAN.—A prehistoric age in the lower Palæolithic, following the Acheulian and preceding the Aurignacian (from the place, le Moustier).

MUTANT.—The individual which arises as the result of a mutation.

MUTATION.—A sudden change of biological characters which is inheritable.

NEOLITHIC.—The " New Stone Age," the last period of prehistory leading to the beginning of historic times.

NUCLEAR MEMBRANE.—Membrane separating the nucleus from the cytoplasm.

NUCLEOLUS.—A well-defined, usually rounded body contained in the nucleus of the cell.

ORGANISER.—One of the regions of the egg which has a preponderating influence on the development of those around it, and on the egg as a whole.

ORTHOGENESIS.—Evolution which appears to proceed in the same direction for a considerable time.

PALÆOLITHIC.—The "Old Stone Age," at the beginning of prehistory, before man learnt to polish stone.

PANCREAS.—Digestive gland, attached to the intestine, functioning at the same time as a gland of internal secretion.

PARASITISM.—The living of one organism within or upon another (its host), at the expense of the latter.

PERIOPHTHALMUS.—Genus of tropical coastal fish, capable of moving on land by crawling on fins.

PHENOTYPE.—The sum of the actually existing characters of an individual; the phenotype is distinguished from the genotype in that it results from the conditions of the environment as well as from the genotype.

PINEAL GLAND.—A small organ found on the upper surface of the brain.

Pithecanthropus.—A fossil ape from the early Quaternary, intermediate between man and the apes proper.

PITUITARY GLAND.—A gland of internal secretion situated below the brain.

PLEISTOCENE.—The middle period of the Quaternary.

POLYPEPTIDES.—Chemical bodies whose constitution is similar to that of the proteins but less complex.

POST-GLACIAL.—The period of the Quaternary following the last glaciation and extending to our own days.

POST-PLIOCENE.—The earliest period of the Quaternary.

PRE-CHELLEAN.—The earliest period of prehistory, before the Chellean.

PREFORMATION.—Hypothesis according to which the living being is already determined and formed in the egg and has only to grow.

PRIMARY.—The first great era in the geological history of the world.

PROTISTA.—The third kingdom of living organisms, usually microscopic and one-celled; they include the Protozoa, which are related to animals; the Protophyta, which are related to plants, and the Bacteria, much smaller and related to neither.

PROTOPLASM.—Living matter.

PTEROSAURS.—Flying reptiles of the Secondary, resembling huge bats.

QUARTZITE.—Very hard siliceous rock.

QUATERNARY.—The most recent of the great geological eras, in which man made his appearance and in which we still live.

RADIOGEOLOGY.—The application of the technique of radioactivity to geological problems.

Reflex.—A nervous phenomenon which according to the classic notion was involuntary, so that a given movement necessarily followed a given stimulus.

Reindeer Age.—The entire upper Palæolithic age is included under this term (Aurignacian, Solutrean, Magdalenian).

Secondary.—The second great geological era, between the Primary and the Tertiary.

Sinanthropus.—A fossil ape related to *Pithecanthropus* recently discovered in China.

Sivapithecus.—A genus of Tertiary apes, now extinct.

Solutrean.—Period of the upper Palæolithic between the Aurignacian and the Magdalenian.

Species.—It is hard to give a definition of species; *in principle*, each species includes all living beings whose resemblance to one another is of the same order as the resemblance of each to its parents.

Symbiosis.—Union of two living beings of different species in which each appears to reap advantage.

Teleology.—The view that evidences of design or purpose exist in nature.

Tertiary.—Geological era between the Secondary and the Quaternary.

Thymus.—Organ situated at the base of the neck in mammals, and much more developed in the young than in the adult.

Thyroid.—Gland of internal secretion situated in the neck.

Trilobites.—A group of fossils of the Primary era, related to crustaceans.

Tropism.—A combination of reflexes having the effect of orientating the living being in relation to the stimulus.

Urea.—The chemical substance contained in urine which was the first organic compound to be synthesised.

Vacuole.—A part of the cytoplasm, probably more rich in water than the rest, which plays an important part in the life of the cell.

Vertebrates.—Animals with a backbone.

Viruses.—Exceedingly small filter-passing organisms, invisible under the microscope, some of which cause diseases in man, animals, and plants. As in the case of the Bacteriophages, it is not yet certain whether they should be called living or not.

Vitalism.—The doctrine according to which life is the product of a vital force independent of matter.

INDEX

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