Dialectics of Nature

BY FREDERICK ENGELS

PREFACE

MARXISM has a two-fold bearing on science. In the first place Marxists study science among other human activities. They show how the scientific activities of any society depend on its changing needs, and so in the long run on its productive methods, and how science changes the productive methods, and therefore the whole society. This analysis is needed for any scientific approach to history, and even non-Marxists are now accepting parts of it. But secondly Marx and Engels were not content to analyse the changes in society. In dialectics they saw the science of the general laws of change, not only in society and in human thought, but in the external world which is mirrored by human thought. That is to say it can be applied to problems of "pure" science as well as to the social relations of science.

Scientists are becoming familiar with the application of Marxist ideas to the place of science in society. Some accept it in whole or in part, others fight against it vigorously, and say that they are pursuing pure knowledge for its own sake. But many of them are unaware that Marxism has any bearing on scientific problems considered out of their relation to society, for example to the problems of tautomerism in chemistry or individuality in biology. And certain Marxists are inclined to regard the study of such scientific and philosophical problems as unimportant. Yet they have before them the example of Lenin. In 1908 the Russian Revolution had failed. It was necessary to build up the revolutionary movement afresh. Lenin saw that this could only be done on a sound theoretical basis. So he wrote *Materialism and Empirio-criticism*. This involved a study, not only of philosophers such as Mach and Pearson, whom he criticised, but of physicists such as Hertz, J. J. Thomson, and Becquerel, whose discoveries could be interpreted from a materialistic or an idealistic point of view. However, Lenin did not attempt to cover the whole of science. He was mainly concerned with the revolution in physics which was then in progress, and had little to say on astronomy, geology, chemistry, or biology.

But thirty years before Lenin, Engels had tried to discuss the whole of science from a Marxist standpoint. He had always been a student of science. Since 1861 he had been in close touch with the chemist Schorlemmer at Manchester, and had discussed scientific problems with him and Marx for many years. In 1871 he came to London, and started reading scientific books and journals on a large scale. He intended to write a great book to show "that in nature the same dialectical laws of movement are carried out in the confusion of its countless changes, as also govern the apparent contingency of events in history." If this book had been written, it would have been of immense importance for the development of science.

But apart from political work, other intellectual tasks lay before Engels. Dühring had to be answered, and perhaps *Anti-Dühring*, which covers the whole field of human knowledge, is a greater book than *Dialectics of Nature* would have been had Engels completed it. After Marx's death in 1883 he had the gigantic task of editing and completing *Capital*, besides which he wrote *Feuerbach* and *The Origin of the Family*. So *Dialectics of Nature* was never finished. The manuscript consists of four bundles, all in Engels' handwriting, save for a number of quotations from Greek philosophers in that of Marx. Part of the manuscript is ready for publication, though, as we shall see, it would almost certainly have been revised. Much of it merely consists of rough notes, which Engels hoped to work up later. They are often hard to read, and full of abbreviations, *e.g.* Mag. for magnet and magnetism. There are occasional scribbles and sketches in the margin. Finally, although the bulk of the manuscript is in German, Engels thought equally well in English and French, and occasionally produced a hybrid sentence, such as "Wenn Coulomb von particles of electricity spricht, which repel each other inversely as the square of the distance, so nimmt Thomson das ruhig hin als bewiesen." Or "In der heutigen Gesellschaft, dans le méchanisme civilisé, herrscht duplicité d'action, contrariété de l'interêt individuel avec le collectif; es ist une queue universelle des individus contre les masses." The translation has been a very difficult task, and the order of the different parts is somewhat uncertain.

Most of the manuscript seems to have been written between 1872 and 1882, that is to say it refers to the science of sixty years ago. Hence it is often hard to follow if one does not know the history of the scientific practice and theory of that time. The idea of what is now called the conservation of energy was beginning to permeate physics, chemistry, and biology. But it was still very incompletely realised, and still more incompletely applied. Words such as "force," "motion," and "*vis viva*" were used where we should now speak of energy. The essays on "Basic forms of motion," "The measure of motion—work," and "Heat" are largely concerned with the controversies which arose from incomplete or faulty theories about energy. They are interesting as showing how ideas on this subject developed, and how Engels tackled the controversies of his day. However many of these controversies are now settled. The expression *vis viva* is no longer used for double the kinetic energy, and "force" has acquired a definite meaning in physics. Engels would not have published them in their present form, if only because, in the later essay on tidal friction, he uses a more modern terminology. Their interest lies not so much in their detailed criticism of theories, many of which have ceased to be of importance, but in showing how Engels grappled with intellectual problems. The essay on electricity "dates" even more. As a criticism of Wiedemann's inconsistencies it is interesting, and it ends with a plea for a closer investigation of the connection between chemical and electrical action, which, as Engels said, "will lead to important results in both spheres of investigation." This prophecy has, of course, been amply fulfilled. Arrhenius' ionic theory has transformed chemistry, and Thomson's electron theory has revolutionised physics. Here again, the manuscript would certainly have been revised before publication. In a letter to Marx on November 23rd, 1882, he points out that Siemens, in his presidential address to the British Association, has defined a new unit, that of electric power, the Watt, which is proportional to the resistance multiplied by the square of the current whereas the electromotive force is proportional to the resistance multiplied by the current. He compares these with the expressions for momentum and energy, discussed in the essay on "The measure of motion—work," and points out that in each case we have simple proportionality (momentum as velocity and electromotive force as current) when we are not dealing with transformation of one form of energy into another. But when the energy is transformed into heat or work the correct value is found by squaring the velocity or current. "So it is a general law of motion which I was the first to formulate." We can now see why this is so. The momentum and the electromotive force, having directions, are reversed when the speed and current are reversed. But the energy remains unaltered. So the speed or the current must come into the formula as the square (or some even power) since $(-x)^2 = x^2$.

In the essay on "Tidal friction," Engels made a serious mistake, or more accurately a mistake which would have been serious had he published it. But I very much doubt whether he would have done so. In the manuscript notes for Anti-Dühring,[1] he supported the view, quite commonly held in the nineteenth century, that we find truths such as mathematical axioms self-evident because our ancestors have been convinced of their validity, while they would not appear self-evident to a Bushman or Australian black. Now this view is almost certainly incorrect, and Engels presumably saw the fallacy, and did not have it printed. I have little doubt that either he or one of his scientific friends such as Schorlemmer would have detected the mistake in the essay on "Tidal friction." But even as a mistake it is interesting, because it is one of the mistakes which lead to a correct result (namely that the day would shorten even if there were no oceans) by incorrect reasoning. Such mistakes have been extremely fruitful in the history of science.

Elsewhere there are statements which are certainly untrue, for example in the sections on stars and Protozoa. But here Engels cannot be blamed for following some of the best astronomers and zoologists of his day. The technical improvement of the telescope and microscope has of course led to great increases in our knowledge here in the last sixty years.

On the other hand, Engels' remarks on the differential calculus, though inapplicable to that branch of mathematics as now taught, were correct in his own day,

[1] See p. 314.

and for some time after. He points out that it actually developed by contradiction, and is none the worse for that. To-day "rigorous" proofs are given of many of the theorems to which he refers, and some mathematicians claim to have eliminated the contradictions. Actually they have only pushed the contradictions into the background, where they remain in the field of mathematical logic. Not only has every effort to deduce all mathematics from a set of axioms, and rules for applying them, failed, but Gödel has proved that they must fail. So the fact that the calculus can be taught without involving the particular contradictions mentioned by Engels in no way impugns the validity of his dialectical argument.

When all such criticisms have been made, it is astonishing how Engels anticipated the progress of science in the sixty years which have elapsed since he wrote. He certainly did not like the atomic theory of electricity, which held sway from 1900 to 1930, and until it turned out that the electron behaved not only like a particle but like a system of moving waves he might well have been thought to have "backed the wrong horse." His insistence that life is the characteristic mode of behaviour of proteins appeared to be very one-sided to most biochemists, since every cell contains many other complicated organic substances besides proteins. Only in the last four years has it turned out that certain pure proteins do exhibit one of the most essential features of living things, reproducing themselves in a variety of environments.

While we can everywhere study Engels' method of thinking with advantage, I believe that the sections of the book which deal with biology are the most immediately valuable to scientists to-day. This may of course be because as a biologist I can detect subtleties of Engels' thought which I have missed in the physical sections. It may be because biology has undergone less spectacular changes than physics in the last two generations.

In order to help readers to follow the development of science since Engels' time, I have added some notes. A few readers may object to my pointing out that Engels was occasionally wrong. Engels would not have objected. He was well aware that he was not infallible, and that the Labour Movement wants no popes or inspired scriptures. *The Condition of the Working Class in England in* 1844, of which an English translation had been published in America in 1885, was first published in England in 1892. In his preface written after forty-eight years he says:

"I have taken great care not to strike out of the text the many prophecies, amongst others that of an imminent social revolution in England, which my youthful ardour induced me to venture upon. The wonder is, not that a good many of them proved wrong, but that so many of them have proved right."

I think that readers of *Dialectics of Nature* will come to a similar conclusion.

I have not yet mentioned the sections on the history of science. These are among the most brilliant passages in the whole book, but they represent a line of thought which was followed by Marx and Engels in many of their books and which has since been developed by others, so most readers will find them less novel. Finally, there is the delightful essay on "Scientific research into the spirit world." There is a tendency among materialists to neglect the problems here dealt with. It is worth while noticing that Engels did not do so. On the contrary he produced a number of phenomena which were regarded as "occult" and mysterious in his day, and arrived at the same conclusions as most scientific investigators in this field have reached, provided that, like Engels, they brought to their work robust common sense, and also a sense of humour.

It was a great misfortune, not only for Marxism, but for all branches of natural science, that Bernstein, into whose hands the manuscript came when Engels died in 1895, did not publish it. In 1924 he submitted it (or part of it) to Einstein, who, though he did not think it of great interest from the standpoint of modern physics, was on the whole in favour of publication. If, as seems likely, Einstein only saw the essay on electricity, his hesitation can easily be understood, since this deals almost wholly with questions which now seem remote. The manuscript was first edited by Riazanov, and printed in 1927. However, Adoratski's edition of 1935 is more satisfactory, as several passages which made nonsense in the earlier edition have now been deciphered.

Had Engels' method of thinking been more familiar, the transformations of our ideas on physics which have occurred during the last thirty years would have been smoother. Had his remarks on Darwinism been generally known, I for one would have been saved a certain amount of muddled thinking. I therefore welcome wholeheartedly the publication of an English translation of *Dialectics of Nature*, and hope that future generations of scientists will find that it helps them to elasticity of thought.

But it must not be thought that *Dialectics of Nature* is only of interest to scientists. Any educated person, and, above all, anyone who is a student of philosophy, will find much to interest him or her throughout the book, though particularly in Chapters I, II, VII, IX, and X. One reason why Engels was such a great writer is that he was probably the most widely educated man of his day. Not only had he a profound knowledge of economics and history, but he knew enough to discuss the meaning of an obscure Latin phrase concerning

Roman marriage law, or the processes taking place when a piece of impure zinc was dipped into sulphuric acid. And he contrived to accumulate this immense knowledge, not by leading a life of cloistered learning, but while playing an active part in politics, running a business, and even fox-hunting!

He needed this knowledge because dialectical materialism, the philosophy which, along with Marx, he founded, is not merely a philosophy of history, but a philosophy which illuminates all events whatever, from the falling of a stone to a poet's imaginings. And it lays particular emphasis on the inter-connection of all processes, and the artificial character of the distinctions which men have drawn, not merely between vertebrates and invertebrates or liquids and gases, but between the different fields of human knowledge such as economics, history, and natural science.

Chapter II contains an *outline* of this philosophy in its relation to natural science. A very careful and condensed summary of it is given in Chapter IV of the *History of the C.P.S.U.(B)*, but the main sources for its study are Engels' *Feuerbach* and *Anti-Dühring*, Lenin's *Materialism and Empirio-criticism*, and a number of passages in the works of Marx. Just because it is a living philosophy with innumerable concrete applications its full power and importance can only be gradually understood, when we see it applied to history, science, or whatever field of study interests us most. For this reason a reader whose concern lies primarily in the political or economic field will come back to his main interest a better dialectical materialist, and therefore a clearer-sighted politician or economist, after studying how Engels applied Dialectics to Nature.

At the present moment, clear thinking is vitally necessary if we are to understand the extremely complicated situation in which the whole human race, and our own nation in particular, is placed, and to see the way out of it to a better world. A study of Engels will warn us against some of the facile solutions which are put forward to-day, and help us to play an intelligent and courageous part in the great events of our own time.

J. B. S. HALDANE.

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INTRODUCTION

I

MODERN natural science, which alone has achieved an all-round systematic and scientific development, as contrasted with the brilliant natural-philosophical intuitions of antiquity and the extremely important but sporadic discoveries of the Arabs, which for the most part vanished without results—this modern natural science dates, like all more recent history, from that mighty epoch which we Germans term the Reformation, from the national misfortune that overtook us at that time, and which the French term the Renaissance and the Italians the Cinquecento, although it is not fully expressed by any of these names. It is the epoch which had its rise in the last half of the fifteenth century. Royalty, with the support of the burghers of the towns, broke the power of the feudal nobility and established the great monarchies, based essentially on nationality, within which the modern European nations and modern bourgeois society came to development. And while the burghers and nobles were still fighting one another, the peasant war in Germany pointed prophetically to future class struggles, not only by bringing on to the stage the peasants in revolt—that was no longer anything new—but behind them the beginnings of the modern proletariat, with the red flag in their hands and the demand for common ownership of goods on their lips. In the manuscripts saved from the fall of Byzantium, in the antique statues dug out of the ruins of Rome, a new world was revealed to the astonished West, that of ancient Greece; the ghosts of the Middle Ages vanished before its shining forms; Italy rose to an undreamt-of flowering of art, which seemed like a reflection of classical antiquity and was never attained again. In Italy, France, and Germany a new literature arose, the first modern literature; shortly afterwards came the classical epochs of English and Spanish literature. The bounds of the old *orbis terrarum* were pierced. Only now for the first time was the world really discovered and the basis laid for subsequent world trade and the transition from handicraft to manufacture, which in its turn formed the starting-point for modern large scale industry. The dictatorship of the Church over men's minds was shattered; it was directly cast off by the majority of the Germanic peoples, who adopted Protestantism, while among the Latins a cheerful spirit of free thought, taken over from the Arabs and nourished by the newly-discovered Greek philosophy, took root more and more and prepared the way for the materialism of the eighteenth century.

It was the greatest progressive revolution that mankind has so far experienced, a time which called for giants and produced giants—giants in power of thought, passion, and character, in universality and learning. The men who founded the modern rule of the bourgeoisie had anything but bourgeois limitations. On the contrary, the adventurous character of the time inspired them to a greater or less degree. There was hardly any man of importance then living who had not travelled extensively, who did not command four or five languages, who did not shine in a number of fields. Leonardo da Vinci was not only a great painter but also a great mathematician, mechanician, and engineer, to whom the most diverse branches of physics are indebted for important discoveries. Albrecht Dürer was painter, engraver, sculptor, and architect, and in addition invented a system of fortification embodying many of the ideas that much later were again taken up by Montalembert and the modern German science of fortification. Machiavelli was statesman, historian, poet, and at the same time the first notable military author of modern times. Luther not only cleaned the Augean stable [1] of the Church but also that of the German language; he created modern German prose and composed the text and melody of that triumphal hymn which became the Marseillaise of the sixteenth century.[2] The heroes of that time had not yet come under the servitude of the division of labour, the restricting effects of which, with its production of onesidedness, we so often notice in their successors. But what is especially characteristic of them is that they almost all pursue their lives and activities in the midst of the contemporary movements, in the practical struggle; they take sides and join in the fight, one by speaking and writing, another with the sword, many with both. Hence the fullness and force of character that makes them complete men. Men of the study are the exception—either persons of second or third rank or cautious philistines who do not want to burn their fingers.

At that time natural science also developed in the midst of the general revolution and was itself thoroughly revolutionary; it had to win in struggle its right of existence. Side by side with the great Italians from whom modern philosophy dates, it provided its martyrs for the stake and the prisons of the Inquisition. And it is characteristic that Protestants outdid Catholics in persecuting the free investigation of nature. Calvin had Servetus burnt at the stake when the latter was on the point of discovering the circulation of the blood,

[1] Augean stable: one of the mythical labours of the Greek hero Heracles (Hercules) was the removal of dung from this stable.

[2] *Ein fester Burg ist unser Gott.* ("A safe stronghold our God is still"): This hymn has recently been sung on a large scale by protestant congregations in Germany which have not accepted Hitler's theology.

and indeed he kept him roasting alive during two hours; for the Inquisition at least it sufficed to have Giordano Bruno simply burnt alive.

The revolutionary act by which natural science declared its independence and, as it were, repeated Luther's burning of the Papal Bull was the publication of the immortal work by which Copernicus, though timidly and, so to speak, only from his deathbed, threw down the gauntlet to ecclesiastical authority in the affairs of nature. The emancipation of natural science from theology dates from this act, although the fighting out of the particular antagonistic claims has dragged out up to our day and in many minds is still far from completion. Thenceforward, however, the development of the sciences proceeded with giant strides, and, it might be said, gained in force in proportion to the square of the distance (in time) from its point of departure. It was as if the world were to be shown that henceforth the reciprocal law of motion would be as valid for the highest product of organic matter, the human mind, as for inorganic substance.

The main work in the first period of natural science that now opened lay in mastering the material immediately at hand. In most fields a start had to be made from the very beginning. Antiquity had bequeathed Euclid and the Ptolemaic solar system; the Arabs had left behind the decimal notation, the beginnings of algebra, the modern numerals, and alchemy; the Christian Middle Ages nothing at all. Of necessity, in this situation the most fundamental natural science, the mechanics of terrestrial and heavenly bodies, occupied first place, and alongside of it, as handmaiden to it, the discovery and perfecting of mathematical methods. Great work was achieved here. At the end of the period characterised by Newton and Linnæus we find these branches of science brought to a certain perfection. The basic features of the most essential mathematical methods were established; analytical geometry by Descartes especially, logarithms by Napier, and the differential and integral calculus by Leibniz and perhaps Newton.[1] The same holds good of the mechanics of rigid bodies, the main laws of which were made clear once for all. Finally in the astronomy of the solar system Kepler discovered the laws of planetary movement and Newton formulated them from the point of view of the general laws of motion of matter. The other branches of natural science were far removed even from this preliminary perfection. Only towards the end of the period did the mechanics of fluid and gaseous bodies receive further treatment. Physics proper had still not gone beyond its first beginnings, with the exception of optics, the exceptional progress of which was due to the practical needs of astronomy. By the phlogistic theory, chemistry for the first time emancipated itself from alchemy. Geology had not yet gone beyond the embryonic stage of mineralogy; hence palæontology could not yet exist at all. Finally, in the field of biology the essential preoccupation was still with the collection and first sifting of the immense material, not only botanical and zoological but also anatomical and even physiological. There could as yet be hardly any talk of the comparison of the various forms of life, of the investigation of their geographical distribution and their climatic, etc., living conditions. Here only botany and zoology arrived at an approximate completion owing to Linnæus.

[1] There can be little doubt that Newton and Leibniz invented the calculus independently. Here and elsewhere Engels is perhaps overcritical of Newton. It must be remembered that Newton's essentially mechanical outlook on nature had been so brilliantly successful for over a century that it had been accepted as a dogma, and was therefore retarding the progress of science. Now that we can see where Newton went wrong, we can perhaps appreciate his greatness better than was possible when it was absolutely essential to criticise him.