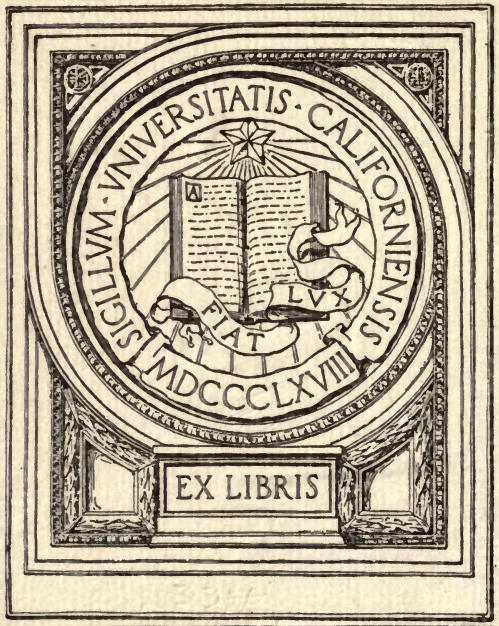
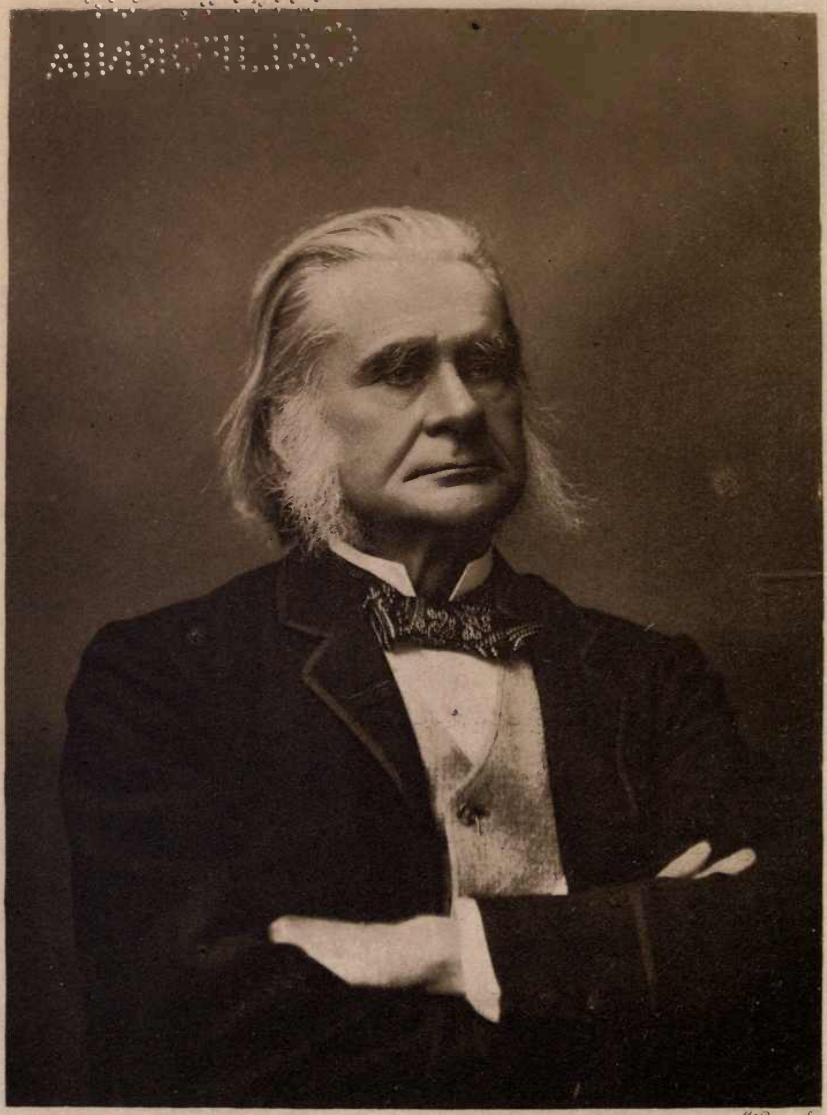


Huxley Memorial Lectures



M.E. Queen Sc

*T. H. Huxley.*

*From a photograph by Mayall, 1893.*

# Huxley Memorial Lectures

to the

University of Birmingham

With an Introduction by

Sir Oliver Lodge, D.Sc., F.R.S.



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# Contents

# INTRODUCTION.

A few years ago a Governor of the University of Birmingham, admiring the genius of Huxley, and wishing to do something to perpetuate the memory of his association with Birmingham, gave an endowment for the perpetual provision of a Lecture to be given annually, to the assembled University and its friends, under the title of " The Huxley Lecture." No conditions were attached, and no subject was prescribed, save that it should be on some theme which might have interested Huxley—a scope sufficiently wide for anything.

It seemed appropriate that the first one or two lectures should deal with some aspect of Huxley himself, and his friend Sir Michael Foster was asked to give the first lecture on the more personal side. No claim was made on the lecturers as to publication, nor was the discourse even written in every case. Those that were written often appeared subsequently in some serial publication and thus became more widely accessible.

Recently it has been thought desirable to collect such of these lectures as were available and publish them together; and thanks are due to the owners of the copyright for the permission freely given for this local re-publication.

The connection of Huxley with Birmingham may not be generally known. But in the year 1874 he came down to give an address on the occasion of the presentation of a statue of Joseph Priestley to the town of Birmingham—the town in which that scientific pioneer and political philosopher had been ill-used, his property destroyed, and himself expelled, at the time of the Birmingham "Church and King" Riots in 1791. The address which Huxley delivered on that occasion is the first of the collected Essays re-published by Messrs. Macmillan in the Eversley Series. The volume containing this particular address is called "Science and Education," it appeared in 1893 and has been many times reprinted.

Huxley came to Birmingham also to lay the foundation stone of Mason College, which was the predecessor and parent of the University; and when that College was opened—which it was in 1880, under the early title "Sir Josiah Mason's Science College"—Huxley came again and delivered the Inaugural Address; an Address which is published in the volume already mentioned, under the title "Science and Culture."

The complete list of the Huxley Lectures so far given is as follows :—

| | Date. | Lecturer. | Title. |
|---|---|---|---|
| 1 | 16th March, 1904 | Sir Michael Foster .. | "The Work and Influence of Thomas Henry Huxley." (Published in *The National Review*, Vol. 43, 1904.) |
| 2 | 23rd March, 1905 | Prof. E. B. Poulton .. | "Thomas Henry Huxley and the Theory of Natural Selection." (Published [not in full] in *The Scientific American* Supplement, Vol. 59, April, 1905.) |
| 3 | 27th Nov., 1907 | Prof. Sir J. J. Thomson | "The Influence of Recent Discoveries in Electricity on our Conceptions of Matter and Ether." |
| 4 | 25th Nov., 1908 | Prof. Sir Ronald Ross | "Malaria." |
| 5 | 1st Dec., 1909 | Prof. William Bateson | "Mendelian Heredity." |
| 6 | 23rd Nov., 1910 | Prof. Percy Gardner.. | "Rationalism and Science in relation to Social Movements." |
| 7 | 29th May, 1911 | Prof Henri Bergson .. | "Life and Consciousness." (Published in *The Hibbert Journal* October, 1911.) |
| 8 | 30th Oct., 1912 | Prof. John Joly .. | "Pleochroic Haloes.' (Published in *Bedrock*, Jan., 1913). |
| 9 | 8th Dec., 1913 | Sir Arthur Evans .. | "The Ages of Minos." |

And of these, Numbers 1, 2, 6, 7, and 8 are here reproduced; the others, for various reasons, are not available.

Before leaving the subject of Huxley—a man for whom I personally had a profound admiration—let me take the opportunity of emphasising the unfairness, as well as the illiterateness, of claiming him as a materialistic philosopher, or as an advocate of philosophic Materialism, merely because he set his face in the direction of a

rational interpretation of nature, and combated many intellectual errors with which the theology of that day had, through careless thinking and uncritical exegesis, been sorely tainted. The mistake is made—though that is no excuse—because he emphasised, as Newton did, the duty of scientific men to study and emphasise every extension of the province of what we call "Matter" and "Force"; and because he urged that "the growth of science, not merely of physical science, but of all science, means the demonstration of order and natural causation among phenomena which had not previously been brought under those conceptions."

Doubtless the claim that Huxley was a supporter of philosophic Materialism, as against Idealism, is only made by half educated people; but such persons are numerous; and hence for the present it is desirable to take every opportunity of pointing out that the contention is untrue, and was always resented by Huxley himself. The following quotation from his 1886 essay "Science and Morals," now included in the volume called "Evolution and Ethics," will suffice to show how he regarded such a rhetorical accusation.

[*Evolution and Ethics.* p. 129-130.]

> "I understand the main tenet of Materialism to be that there is nothing in the universe but matter and force; and that all the phenomena of nature are explicable by deduction from the properties assignable to

these two primitive factors. That great champion of Materialism whom Mr. Lilly appears to consider to be an authority in physical science, Dr. Büchner, embodies this article of faith on his title-page. *Kraft und Stoff*—force and matter—are paraded as the Alpha and Omega of existence. This I apprehend is the fundamental article of the faith materialistic; and whosoever does not hold it is condemned by the more zealous of the persuasion (as I have some reason to know) to the Inferno appointed for fools or hypocrites. But all this I heartily disbelieve; and at the risk of being charged with wearisome repetition of an old story, I will briefly give my reasons for persisting in my infidelity. In the first place, as I have already hinted, it seems to me pretty plain that there is a third thing in the universe, to wit, consciousness, which, in the hardness of my heart or head, I cannot see to be matter, or force, or any conceivable modification of either, however intimately the manifestations of the phenomena of consciousness may be connected with the phenomena known as matter and force. In the second place, the arguments used by Descartes and Berkeley to show that our certain knowledge does not extend beyond our states of consciousness, appear to me to be as irrefragable now as they did when I first became acquainted with

them some half-century ago. All the materialistic writers I know of who have tried to bite that file have simply broken their teeth. But if this is true, our one certainty is the existence of the mental world, and that of *Kraft und Stoff* falls into the rank of, at best, a highly probably hypothesis."

With this short introduction I leave the Huxley Lecturers to speak for themselves.

OLIVER LODGE.

*March*, 1914.

# HUXLEY *

*By Sir Michael Foster.*

Casting round for a theme which might fitly be the subject of this first Huxley Lecture which the University of Birmingham, doing me great honour, has asked me to deliver, I bethought me of the wish of the generous founder of the Lectures that, if possible, this first lecture should be entrusted to some one who knew Huxley, not by his writings and public utterances only, but in a closer way, through being numbered within the happy circle of his inner friends. That wish seemed to me an invitation to devote this first lecture to the man himself and his work; and, not without fear and trembling, I have ventured to guide myself by such an invitation. I will not attempt to dwell on any details of his life; these can be, ought to be, and probably are, known to you all. I must content myself with some thoughts about his ways, his views, and his aims. As I go along I can only touch lightly, and in a passing way, on some of the many and varied problems which are started by the consideration of his manifoldly active life; these, or at least many of them, will doubtless be fully dealt with

* Being the first "Huxley" lecture of the University of Birmingham, delivered on March 16th, 1914.

by the able men who will succeed me in the coming years. Following in his steps, I shall, even at the risk of giving offence, try to speak plainly and straightforwardly when I come to touch on themes with which he dealt, about which we all feel so deeply.

Every one in this world, at least every one of whom others need take count, has a dominant note. If I ask myself, what was Huxley's dominant note? I find myself answering without hesitation—a love of knowledge, an ever-present never-satisfied desire to know. There are many ways of knowing; of these two stand out as distinctive ways, offering a contrast the one to the other. One way of knowing lies in gathering up, in sweeping into the mind, all the grains of information which happen to be lying around. This is, as it were, the greediness of multifarious knowledge,—conspicuous in the child, but also common in the adult; it is that yearning to know everything that is going on which is the mainspring of daily talk and makes the fortunes of the Press. Such a greed of knowledge Huxley possessed; such a way of knowing he followed to a remarkable degree; nothing touched him, nothing even came near to him but what he strove to lay hold of it. And he found such profit to himself in this kind of knowledge that he laid it down as an axiom of education that every one, so far as possible, should be led towards knowing something of everything.

Another way of knowing is, when a thing is to be known, to know it fully and exactly; to be aware where the known begins, and where it ends; to be sure and clear what the terms, the symbols used in the knowledge, really mean; to have the component parts of each bit of knowledge so arranged that it may fitly serve as the instrument of clear and exact thinking. This is the kind of knowledge in which Huxley, above most men, found his heart's content. We know from his life that his love of machinery led him at one time to wish to be an engineer. What fascinated him in a machine was its completeness and perfection, the fitting together of all its parts to a common end, the feature that, if well and truly made, it could at any time without harm be taken to pieces and put together again. He demanded that, so far as possible, each piece of knowledge of which he had to make use should have the completeness, the perfection, the clean fit of a machine. With such exact and sharply defined knowledge alone could he feel that he was thinking clearly.

Some minds there are which find a charm in indistinctness; impressionists in matters of knowledge, truth seems to them to have the greater charm when its features are softened by a surrounding mist of doubt and uncertainty; placed before them in sharp, clear outlines, it offends them as being hard and crude. It was not so with Huxley. He felt as fully as any one the beauty born of dimness which rounds off with softness

the features of the far-off horizon where the known makes clouds out of the unknown; but to him that beauty belonged to that far-off horizon alone; in things within the focus of intellectual vision beauty lay in clear and well-defined images; whatever came before him with its outlines blurred by imperfect comprehension, loose expression, and vague presentation, was to him something ugly. It was this combination of wide and varied knowledge with a love of exact and rigorous thinking which gave to him, so it seems to me, his worth and influence as a man of science. Circumstances led him to find a sphere for his scientific activity in that branch of science which, under the name of Comparative Anatomy, or Animal Morphology, deals with the multifarious forms of the living beings which we call animals. His early wish had been to become an engineer, busying himself with machines; turned away from this by fate, he had wished to give himself to the somewhat allied science of physiology, which deals with animals as machines. But this also was not to be; he was driven to devote himself to a branch of science which was not his first love, and for which he was in some respects less fitted. Any lack of fitness, however, which there might have been was soon lost sight of amid the many and great products of his labours.

In each science progress appears as a series of steps, each step being marked by the appearance

of some work of prominent worth, the intervals between each such work being filled up with the products of a number of intermediate less significant labours contributing to the progress, but in a less effective manner. The work whose appearance thus marks a step, whether it be what is called a discovery, or whether it be the setting forth of a new view or theory, is often spoken of as a classic work; it is remembered, and referred to afterwards again and again, while the less significant labours are forgotten. For many years Huxley continued to produce in Comparative Anatomy, including Palæontology, for to this also by sheer force of circumstances he was led to direct his attention, works which are enrolled in the list of scientific classics. The earlier of these, those on jelly fish, molluscs, and other oceanic animal forms, were done as almost apprentice work, done while he was as yet a mere youngster, serving as a surgical subaltern on board the *Rattlesnake* in an exploring expedition to the Australian seas. These and the rest are to be found in the four large volumes of scientific memoirs which his publishers, Messrs. Macmillan, brought out as their contribution to the memory of his name. Of the many memoirs contained in those volumes a large number are now and always will be spoken of as classic memoirs. To the man of science those volumes alone are adequate proof of how much Huxley did to push forward the science among the followers of which fate had led him to enrol himself.

All real scientific work has this distinctive mark: it is reproductive and fertile, it gives birth to other scientific work following upon itself, and that in two ways. It is reproductive in the way of the parentage of fact; each new discovery of real worth becomes the starting-point of new inquiries, leading in turn to new discoveries. It is also reproductive in the way of the parentage of spirit and of method; and this parentage is, perhaps, the more fertile of the two. The new discovery, the new fact made known, the new view put forward and commanding assent, is, often at least, the outcome of a new way of looking at things; and that new way of looking at things spreads among those who are working at the same subject. Again and again the appearance of a memoir or a book has acted like a magnet, turning men's minds from looking in one direction and making them look in another. Huxley's work in Comparative Anatomy—or perhaps I ought to use a wider phrase, and say in Biology—was of the reproductive kind, and reproductive especially by way of parentage of method.

When he sailed away from England on board the *Rattlesnake* much, if not nearly all, the work which was being done, and for many years past had been done, in England at least, in the way of enlarging our knowledge of animal forms, consisted, on the one hand, in the careful but dull accumulation of facts, unillumined by any thought as to what was the real meaning of the facts so

industriously gathered together; and, on the other hand, in the putting forward of nebulous and fantastic theories as to that meaning, theories not springing out of the consideration of the facts themselves, but coming from elsewhere, the offspring of foreign ideas, thrust into the facts from the outside. Huxley's mind, with its clear and exact way of thinking, with its tendency to look upon a machine as a model of excellence, rebelled at the very outset against these vague and mystic theories, the hybrid products, it seemed to him, of careful observation and loose thinking. He strove to replace them by ideas more justly deserving to be spoken of as scientific. He saw how in the sister physical sciences progress consisted in the marshalling of facts under laws the knowledge of which came through observation and experiment, and which indeed were but the expression of elaborated observation; and he set himself to the task of making the same fruitful method dominant in biology. The very first papers which he sent home to England from the far-off Southern Seas not only added largely to new knowledge, but served as striking lessons in the new way of attacking biological problems; these were in turn followed by others, all exemplifying the value of the new method; and though the older men were in two minds about them, disliking the new ideas but admiring the ability with which they were put forward, the younger men received them gladly and at once. Under Hux-

ley's lead a new school of biological inquiry came into being. Thus from the very beginning of his career, by mere force of his efforts to get for himself a clear view of the things with which he had to deal, to gain a firm ground from which he could push forward into the unknown, Huxley, without thought of others, became a teacher of inquirers.

But he could not do without thinking of others. To his strong desire to know fully, and to think clearly for himself, there was added a no less strong desire that others also should know fully and should think clearly. Not content, as he well might have been, with being a teacher by example, he, very soon after his return to England, became a teacher by precept. While some of us of the biological craft are painfully aware of how much science would have gained had the stream of energy which later on spread over such wide fields been kept in its earlier and narrower channel, we must admit that the world at large would thereby have been greatly a loser. Huxley became a teacher by precept, set himself to the task of bettering the way in which men should be taught. He began, naturally began, with the teaching of what I may call the professional few, with the training of those who enter upon the study of science, knowing that a knowledge of science must be, in one way or another, an important factor in their future life; but he very soon passed on to the wider task of teaching the general many. In both these kinds of teaching

he held fast to the conception which had guided him in his own intellectual development, and which he formulated in the saying that the goal of teaching, that to which the face should be turned, though it might not be reached, should be to make the learner know something of everything and everything of something. The one stimulated intellectual appetite and awakened the innate capacities and tendencies of the mind, while at the same time it secured a broad basis on which to build. The other furnished the only means of developing that power of clear and exact thinking which was the main end of teaching, since every teaching which failed to secure this was in vain, and was potent in the measure that it did secure it. This view of the need of an effort to secure at one and the same time breadth and exactitude he carried into his teaching of science. This is seen clearly in the mode of teaching biology which he advocated.

The science of biology is split up into several parts. There are beings whose characters lead us to call them animals and others which we call plants, and the differences between the two are many and great. A living being, again, be it plant or animal, on the one hand, presents phenomena of form which have to be studied in a particular way, and so furnish the subject-matter of the science of anatomy or morphology. On the other hand, it presents phenomena of action, of function, which have to be studied in

another way, and which furnish the subject-matter of the science of physiology. Further, every living being may be studied from the point of view of how it came to be, how it is related to other beings, and what part it plays in the general economy of nature. Biology is thus split up into several branches, several more or less independent sciences, and the man who looks forward to advancing knowledge in any one of them finds, and finds increasingly as knowledge advances, that he must narrow his efforts to one of them, or even to a part, perhaps a small part, of that. And the temptation is natural and strong for the learner to turn to the narrowing early, even perhaps at the beginning, pursuing his narrow path from the outset in ignorance of what is going on around him. Yet these several sciences, these several branches of biology, are not really and wholly independent: they touch each other, here and there, again and again. Hence Huxley—and all of us, I venture to think, will agree that he was right—maintained that, necessary as it may be for the student to narrow his outlook when he is well on his way, he will work all the more fruitfully, gaining results of all the higher value if, before passing through the straight gate to his ultimate narrow path, he gets to know what other paths there are, what are their features, and whither they lead. Hence he introduced a teaching of biology, in which as many as possible of all kinds of biological problems, and not one kind

only, should be presented to the student. In that way he looked to get a breadth which could not otherwise be gained. Exactitude he trusted to secure at the same time that he was striving for breadth by the method of teaching. Selecting a few themes, and a few only, from the several branches of biology, and these so far as possible of an elementary, fundamental character, he strove to make the student grasp each of these as fully and as exactly as was within his power. And he taught through the eyes as well as through the ears. The younger generation to-day can perhaps hardly realise to what an extent, thirty or forty years ago, in science teaching, especially in biological teaching, oral exposition and the reading of books still supplied the dominant means of learning. Biological laboratories were then only beginning to be. Huxley was from the first insistent that a firm grasp, an exact grip, of the phenomena and laws of nature could only be gained by him who had been led to see the phenomena for himself, and to work out through observations and experiments conducted by himself the problems presented. Arguments, discussions, apt illustrations, lucid exposition, all these were needed to make good the lesson; but they were as so much beating the air, unless they dealt with things which had been really seen and actually handled.

It was not in the teaching of biological science alone that he urged this marriage of breadth with

exactitude; he advocated it as the proper mode of training for every kind of career. Begin with a broad basis, with a basis as broad as the mental power of the student can compass, but even in laying down the basis hold fast to exactitude. Breadth without the clearness and firmness which comes from direct sight and exact thought merely breeds mental flabbiness, a treacherous basis to build on. Some minds cannot spread themselves over a large field without losing touch with the exact and the real; don't attempt to stretch such minds too much; in the case of these be content with a basis of smaller area. Having laid a foundation as broad as the mind of the learner will allow, a foundation of simple elementary truths, build on this the teaching of higher, more difficult matters. As you ascend you will find that, in order to secure that full comprehension, that exact and clear thought which you aim to secure, the limits of mental power will compel you continually to narrow the range. Be not disheartened at this. Knowing that you have the broad basis below, do not fear to narrow the range as you raise tier on tier so long as the demands of exactitude call for it. As you ascend do not spoil the compactness of your product by attempting to put wide, loose wrappings round the solid core. Be content that the product of your teaching should be a cone, such as may be used as an intellectual missile, penetrating because its point is narrow, effective because its base is broad.

Such, in broad outlines, seem to me to have been Huxley's views as to the right teaching of the professional few. But in this matter of teaching his heart went out, beyond the limited circles of professions, to the great "general many." He put his hand to the work of rightly teaching these also.

Nothing, perhaps, in his whole career is more striking than his coming out in 1870 from the tent of the Professor to take his part in the popular battles of the London School Board. Never, perhaps, was he busier than he was at this time; his hands were full with scientific research and scientific teaching; they were full with scientific administration. Yet he knew that he had something to say about the teaching of the people; he refused to keep for the sect of science that which he felt was meant for mankind, and came forward to take his part in what he believed to be a task of great moment. He did not shrink from entering upon that which is, perhaps in many ways, most foreign to a scientific career, a popular contest; for, though few could appraise more truly than he the value of the thought of the few who know, none were more ready than he to accept the judgment of the many who feel. And the electors returned to him the confidence which he had placed in them.

He carried into the School Board the same views as to right teaching which had guided him in the academic lecture-room and in the labora-

tory, though the difference in the subject matter and the occasion made a difference in the form in which these were put forward. In the academic lecture-room the professional student is taught in part only; he comes to it already fashioned in part. In the school the child has to be taught wholly and from the beginning; his whole nature is placed in the teacher's hands. Yet the right method of teaching is in both cases at bottom the same. Throughout Huxley's system of professional teaching, which I have attempted to describe, the effort to combine breadth of view with clearness and exactitude of insight, there ran the fundamental idea that the real goal of professional teaching is not to fill the head with stores of knowledge, however accurate, however well adapted for professional use, but to lay the foundations of, and to develop as far as possible, all those qualities which go to make up the effective scientific professional character. And the goal of school teaching which Huxley put before him was the development of the whole nature, the building up of a fit character in the schoolboy or schoolgirl. If in professional teaching it was needful to keep this goal steadily in view, it was, in his eyes, a thousand times more needful to keep it in view at the school in the few, but pregnant, years during which the lad or lass comes under the moulding hands of the teacher. In the school, above all other places, everything should be made subservient to this great end.

The striving for this goal may be seen in all Huxley's School Board work. As I shall shortly have occasion to insist, he refused to split up human nature into this and that part—physical, intellectual, moral—to be treated apart in different ways. To him human nature was one and indivisible, to be treated in all its parts according to the same fundamental method. Hence his advocacy of physical training, not as a mere appendage to, but as an essential part of, school work. In the narrower training of the grown-up, or nearly grown-up, biological student he laid no little stress on physical training, the training of the eye, the ear, and the hand; for, the clearer the sight, the sharper the hearing, and the readier the touch, the greater the firmness with which the student can lay hold of the phenomena of nature, the more surely he can gain the basis needed for exactitude of thought and judgment. In the broader training of the growing child, physical training seemed to him to be one of the first of needs, not for the sake only of what some call the body, but for the sake of the whole child.

The same desire to reach character guided him in his selection of subjects to be taught and of methods of school teaching. It seemed to him that the primary object of all teaching of the young must be to awaken the mind, to rouse the attention, to excite the desire to know more. And though he knew that a good teacher has the power to accomplish this, whatever be the subject which

he handles, while a bad teacher may fail to do this with any subject, he sought for a basis of early education in the subjects likely of themselves, without taxing the teacher, to interest the scholars and stimulate them to mental effort. These he found in common things, in things with which the children came into touch, things of which they heard, things which they might use in daily life. He gave what is sometimes called useful knowledge a large share in school life, not simply because it was useful, though this he did not despise, but because it offered the best opportunities for awakening the young mind and at the same time could be so taught as to provide the desired discipline and training of the mind thus awakened.

It was this earnest wish of his to make the school the means of moulding the whole character, and not of developing this or that part of it at the expense of the rest, that led him to take a step which has been much criticised, and, if I may venture to say so, much misunderstood—to advocate the use of the Bible as part of the common school-lessons in the School Board schools. Of nothing was he more sure than this, that that schoolmaster fell short of his high calling who failed to guide his pupils to know the right from the wrong, and to follow the former in everything, not only in reading, writing, and arithmetic, in history, geography, and the other kinds of knowledge which he and they handled, but also and no less so in the treatment of the body and

in the conduct of life. The character which the school had to build up could, in his view, be nothing more than a broken fragment, a fragment whose broken edges were dangerous if, in attempting to build it up, the moral phenomena and the moral laws of the universe were wholly left out of sight.

But in seeking for a teaching which should thus build up the whole character he was met by a great difficulty. He himself had long been convinced that the conduct of life might be guided by a morality and inspired by a religion having no part whatever in the theological doctrines of any Church, whether Roman, Anglican, or any other. His own life had been guided by that morality and inspired by that religion. He believed that those who thought with him on this matter were increasing in numbers everywhere and would in the end become dominant. At the same time he recognised that in the face of the prevailing influence of the several forms of the Christian Church, and in the presence of powerful traditions, inwrought into the very national life, to teach such a morality and such religion in the common school called for teachers possessing convictions which were rare and powers which were still rarer. On the other hand, he recognised in the Bible, ingrained into the lives and dear to the hearts of so many, a most potent instrument for inculcating the moral lessons which he desired to see inculcated and for inspiring the moral

aspirations which he desired to see inspired. With its beautiful lauguage and its old associations, it seemed to him a means of awakening the moral sense and pointing out the duty of man, such as he could not find elsewhere, such at least as he could not wisely put on one side.

He was well aware that in it the great moral lessons which he sought to enforce were closely wrapped up in other things, were, indeed, conveyed by means of teachings, many of which he was convinced were erroneous, some of which he held to be mischievous. But he thought that this difficulty was largely met by the decision that the Bible was to be taught in the school in such a way as to be free from dogma. And, weighing one thing against the other, he accepted Biblical teaching as what in the language of the world is called a practical compromise. He was the more inclined to this step because he believed and hoped that it was the beginning of other things. He took it for granted that this Biblical teaching would be placed in the hands of laymen, and moulded by the thoughts of laymen. Laymen would, he conceived, be more and more drawn to his own way of thinking, and out of the teaching which he had helped to institute would be evolved another simpler ethical teaching free from all theological conceptions. He failed to realise that to make the Bible the chosen and sole means of enforcing moral lessons strengthened the ties binding the teaching of moral duties to the accept-

ance of ideas which he regarded as erroneous, or even mischievous. He failed to realise how strongly they who believe the whole Bible to be the word of God, and hold its teachings to be the only guide of life, would resent bits of it being used to enforce moral laws of human invention, while the rest of it was ignored or disparaged.

What he had hoped to be a compromise of peace became, even in his time, and since his death has still more become, like so many other practical compromises, a mother of strife. He did not, even in his last days, repent the compromise; since through it, it seemed to him, "twenty years of reasonably good primary education had been secured." But he did not regard it as final. He was forced to admit that the teaching of the duties of life according to natural or, as it is sometimes called, secular knowledge, that which he believed to be the true teaching must stand by itself alone and not attempt to make use of any other kind of teaching. It was clear to him that, so soon as it could be brought about, the State must limit itself to teaching the things which belong to natural knowledge and these only, leaving other bodies to teach other things in their own way, offering to all equal opportunities, but meddling with none and directly favouring none. He avowed his conviction that "the principle of strict secularity in State education is sound and must eventually prevail."

His zeal for education did not stop, however, at

children, or at young men and women; early in life he began to put his shoulder to the wheel in the great task of educating the people, of teaching the great public of all sorts and conditions, high and low, rich and poor, the main truths which in his opinion ought to guide them in the conduct of life; and as the years went on the call to fulfil this task seemed to him more and more urgent. He passed from the chair of the professor to the pulpit of the preacher, and in the later years of his life gave himself up almost wholly to the issue of writings which he himself acknowledged to be of the kind which men call sermons. Any attempt to describe Huxley's influence on his fellows and his place in the world which did not give ample room for the consideration of this side of his life and this direction of his labours would be a wholly vain one.

Following out his favourite analogy of a machine, he recognised in man, on the one hand, a moving power, or rather moving powers, and, on the other hand, directive agencies by which the movements set going by the power, in other words, the acts of man, are shaped so as to accomplish this and that end. Early in life he had come to the conclusion that these directive agencies were to be found in knowledge, in natural knowledge, and in this alone. He was convinced that the true conduct of life was that which was in accordance with the laws of nature, and that a knowledge of those laws could alone supply a

judgment, the more trustworthy the fuller the knowledge, whether this or that act was in accord with those laws or not, and so whether it was right or wrong. And when he spoke of " right " and " wrong," he meant every kind of right, and every kind of wrong.

His studies in biology had made it clear to him that man must be looked upon as a whole; that in respect to none of his acts, whatever be their kind, can man's nature be divided into two halves, in such a way that the one half is to be considered as wholly unlike the other half, to be viewed from a wholly different point of view and to be treated in a wholly different way. Without attempting to say what body was or what mind was, he insisted that the two were so wed together that no one in dealing with them could put them apart and treat each as if it stood alone. He found it freely admitted that the conduct of man's stomach, however much it had been in earlier times, and indeed still was, governed by the impulses of appetite, and by the results of rough experience embodied in custom and authority, was being more and more subjected to rules based on a still imperfect but rapidly growing knowledge of physiological laws. He noted that whenever any question arose as to what the stomach should be allowed, or be made to do, the final appeal was to physiology, and to this alone, the health and happiness of the stomach being sought for in obedience to physiological laws, and

in this alone. And what was true for part of man he claimed to be true for the whole of man. Man's whole nature, and not simply this or that part of it, was subject to natural laws; and the welfare of the whole, no less than of each part, was to be sought in obedience to these laws. As the path to so-called physical health lay in the strenuous search after physiological laws, and in obeying them when found, so the path to moral and social health lay in a like search after ethical and social laws and in a like obedience to them when found. He met with no one who contended that because at the present day our knowledge of physiological laws is fragmentary and halting it is to be set aside as of no avail for the conduct of life in its physical aspects; on the contrary, he met everywhere with urgent demands for vigorous research, prompted by the sure conviction that a fuller knowledge would bring to us the means of securing a more wholesome physical life. And he argued that the fact of our knowledge of ethical and social laws being still more fragmentary and halting than our knowledge of physiological laws—so fragmentary and so halting, indeed, that the ethical and social knowledge of to-day might be compared with the physiological knowledge of centuries ago—was no valid argument for refusing to accept that knowledge as the ultimate guide in the conduct of life. On the contrary, it seemed to him that this constituted the very reason why the most strenuous efforts

should be made to advance that knowledge as rapidly as may be.

Natural knowledge was, he maintained, the one and the same guide, the only sure guide in the quest after both physical and moral welfare. The address "On Improving Natural Knowledge," which was delivered nearly half a century ago, in 1866, and which comes first in the first volume of his collected *Addresses and Essays*, and is the key to all which follow, sets forth in telling words his conviction that what began as a search into things physical has become a search into things spiritual, and that the value of natural knowledge lies not so much in the mastery which it has given over the forces which determine the welfare of the body (valuable as that mastery may be) as in the mastery which it promises over the forces which determine the welfare of man as a whole. Natural knowledge was, he said, "a real mother of mankind, bringing them up with kindness, and, if need be, with sternness in the way they should go, and instructing them in all things needed for their welfare."

The improvement of natural knowledge, whatever direction it has taken and however low the aims of those who may have commenced it, has not only conferred practical benefits on men, but in so doing has effected a revolution in their conceptions of the universe and of themselves, and has profoundly altered their modes of thinking and their views of right and wrong. I say that natural knowledge, seeking to satisfy natural wants, has found the ideas which can alone still spiritual cravings. I say that natural knowledge, in desiring to ascertain the laws of comfort, has been driven to discover those of conduct, and to lay the foundation of a new morality.

Natural knowledge, moreover, gave man, in his opinion, not only directive agencies, but also moving powers for the conduct of life. It not only laid bare the laws according to which man must walk, but also, rightly grasped, raised up visions which awakened or which strengthened the emotions and affections needed to bear man up in his efforts so to walk, following right and shunning wrong. Love of good, hatred of evil, feelings of awe and reverence, such as must ever arise when man tries to pierce below the surface of things, yearnings for and strivings towards a goal of ideal perfection, nearness to which is the true measure of real happiness—these seemed to him the heart of every true religion whatever might be its doctrinal wrappings. Of all these he believed natural knowledge to be, and in the struggles of his own life had found it to be, a true, potent, and yet simple nurse.

He knew that in this view of the work and power of natural knowledge he was looking ahead ; he was aware how little had as yet been achieved in the improvement of natural knowledge, how much had yet to be done before that which it promised could be accomplished. But the way to effective truth had been entered upon, time and labour only were needed for the rest. Filled as he was with this dominant conviction of the higher power of natural knowledge and of the crying need for the advance of that knowledge, it is no wonder that he felt, and felt

strongly, that every hindrance of man's own making to that advance was a hindrance to man's social and moral progress, and told against man's highest welfare. It was this feeling which brought him into conflict with what I may here venture to speak of collectively as the Church. And no true conception of Huxley's life can be gained unless his attitude in this respect be clearly understood.

He distinguished in the work of the Church between the moving power and the directive agencies. The moving power may be found in the words, love and fear of God, hope and dread of the life to come. The dominant emotion indicated by the words love and fear of God seemed to him, when carefully examined, to be in essence identical with the dominant emotion which he recognised as the moving power making for man's welfare, which had been the moving power of his own life, which had been his religion, and which he spoke of as love of good and of truth and fear of evil and of lies. Whether the good and the true were presented in a personal form, or not so presented, seemed to him to make no real difference in the nature of the emotion itself; and if, on the one hand, it might seem that the emotion was intensified when sustained by a personal conception, on the other hand it might be regarded as more durable and constant when it stood alone and was not in any way contingent on intellectual conceptions. Moreover, so it seemed

to him at least, as man's knowledge grew more and more, there would come a growing potency of that other accompanying emotion of awe and reverence which springs from the increasing recognition of the mystery of the unknown for ever lying beyond the farthermost margin of the expanding known.

Towards the other moving power of the Church, the hope and dread of the life to come, his attitude was very different. These words signified, not as did the words love of God, a native emotion shaped, not created, by intellectual conceptions, but an adventitious emotion whose very birth was due to conceptions in which natural knowledge was more or less involved. To him natural knowledge brought no proof, and could bring no proof, of a life hereafter; this could neither affirm nor deny that man lived after death. He fully recognised the great part played in the conduct of life by the hope of reward and the dread of punishment; but in the conduct of life according to natural knowledge both the hope and the dread must have natural knowledge as their base; the sequence of the reward or of the punishment upon the deed must be within the reach of proof, otherwise neither the one nor the other could be of avail. The hope and the dread which did not rest on proof seemed to him a broken reed not to be trusted.

Deep, however, as was his conviction that the hope of future reward and the fear of future

punishment having no assured basis of certain knowledge, could not be used as the main motive power in the conduct of life without in the end doing harm, strongly as he felt that to go further and put these forward as the necessary and indispensable instruments in the moral government of the world was, as he said in a letter to Charles Kingsley, "a mischievous lie," this was not the mainspring of that continued active opposition to the Church which is displayed in so many especially of his later writings. That opposition was engendered not so much by the kind of moving power put forward by the Church as by the directive agencies through which the Church strove to make that moving power effective for the conduct of life.

He, as I have said, had early come to the conviction that since the conduct of life, of moral as well as physical life, must be guided by obedience to the laws of nature and by this alone, the welfare of mankind hung upon the continued progress of natural knowledge, through which man learnt the laws which he must obey and saw his way before him. But it seemed to him that the Church in every one of its particular forms, in framing rules for the conduct of life, now to a greater, now to a lesser degree, had made in the past, was making in the present, and would make in the future, use of an appeal to a something which, under the name of authority, inspiration, revelation, was not only no part of natural know-

ledge, but gave rise to teachings which might be, and often were, in direct contradiction to the teachings of natural knowledge. He further found that when such contradiction came to hand the Church demanded that natural knowledge should give way. This was the origin of the active opposition of which I am speaking. Quite early in his career, while his name was as yet but little known outside the narrow circle of men of science, he was brought face to face with this attitude of the Church by the way in which so many voices of the Church received the views put forward by Charles Darwin in his *Origin of Species*. The reception which that book met with entered like iron into Huxley's soul; he never forgot it. Stirred up by it, he was swept away from the quiet retirement of scientific inquiry, the results of which could not reach the larger world until after many days and then mainly through the mouths of divers interpreters; he was carried forth into the market-place to speak directly to the people and become before them the untiring, fearless champion of the claims of natural knowledge. It shaped the whole of the rest of his life. Henceforward he to a large extent deserted scientific research and forsook the joys which it might bring to himself, in order that he might secure for others that full freedom of inquiry which is the necessary condition for the advance of natural knowledge. Here was a book which, with a quietness born of the consciousness of

strength, made known the conclusions to which the author, working wholly within the bounds of natural knowledge, had been led while he during long years patiently gathered observations and as patiently meditated during long years on what those observations meant. Every line in the book dealt with natural knowledge and with natural knowledge alone; the whole of it appealed to natural knowledge as the only judge of the validity of its conclusions. By the light of natural knowledge Huxley himself tried the book, and, though aware of what was missing in this part or that, accepted the main contention as proved, and in accepting it threw aside views to which at an earlier period he had been led. Others, trying the book also by the light of natural knowledge, found it in their opinion wanting. With these Huxley could not agree; but, though their arguments seemed to him lacking in force, he could not otherwise find fault with their attitude.

With those voices of the Church of which I have spoken, it was different. These, so it seemed to Huxley, rejected the conclusions of the book, not because they were not according to natural knowledge, but because they were, or appeared to be, in contradiction to what was, or what appeared to be, the teaching of the Church. This, he thought, was the real reason of the opposition which so many of the Church offered to Charles Darwin's views; such opponents might

arm themselves with arguments drawn from natural knowledge, but the real fight which they were fighting was, in his opinion, one against the validity of natural knowledge itself when in conflict with the authority of the Church.

To this conflict Huxley girded himself with all his might on the side of natural knowledge. To understand his attitude it must be remembered how strong, as I have already said, was his conviction that natural knowledge and natural knowledge alone is to be trusted as the ultimate guide of man in the conduct of life. The efficacy of the guidance must be measured by the fulness of the knowledge; and Huxley's knowledge was great enough to make him see how imperfect was natural knowledge in its present stage when called upon to rule the conduct of even physical life, and how infinitely more imperfect when appealed to as a guide of the conduct of moral, social life. The welfare of mankind was, in his eyes, indissolubly bound up with the advance, the steady, nay, the rapid advance of natural knowledge. Any hindrance to that advance was, to his mind, a wrong to mankind. What hindrance could be more hurtful than the contention that natural knowledge was not master of its own domain, but must bow its head and keep silence when even in its own field it came into conflict with the master of another land? The call to strive for the doing away of that hindrance rang loud in Huxley's ears.

It was in his view of some importance, it was of perhaps of great importance, that Charles Darwin's conclusions should be generally accepted as solid contributions to natural knowledge, in order to increase their fruitfulness for the further advance of that knowledge; and we to-day can recognise how fruitful they have proved. Still more important was it in his opinion that these conclusions should be judged as to their validity by an appeal to natural knowledge, and to that alone, and not by an appeal to another tribunal. The reception of Charles Darwin's book was to him only an instance, was only one of many signs, of an abiding antagonism. The same thing had happened again and again in the past, it must be looked for again and again in the future; the fight will always be going on. His attitude was not changed on hearing other voices of the Church declare that the origin of species, including that of the human species, by selection, was not destructive to the teaching of the Church, but, on the contrary, was in accordance with it, and indeed had in a way been anticipated by it. He was glad that one cause of quarrel was out of the way; but he felt that even with these voices the potential cause of quarrel still held its ground. They now approved of Darwin's views; but would they approve of the next great result gained by some student of natural knowledge in even the near future should this seem to them to conflict with

the teaching of the Church? If they found that it did conflict, would not they also then join in denouncing it? He had no doubt but what they would. He was convinced that the antagonism was a fundamental one. It was one moreover which he seemed to meet with everywhere.

> I had set out [says he] on a journey with no other purpose than that of exploring a certain province of natural knowledge; I strayed no hair's breadth from the course which it was my right and my duty to pursue; and yet I found that, whatever route I took, before long I came to a tall and formidable-looking fence. . . . The only alternatives were either to give up my journey—which I was not minded to do—or to break the fence down and go through it.*

And especially during the latter years of his life he set himself vigorously to the task of breaking down fences.

The Church, he said to himself, whenever it sees fit, opposes natural knowledge; in the service of my sovereign lord, natural knowledge, it is my duty to oppose the Church. I am not going out of my way in doing this; it lies straight before me in my path. He went on the way which he had set before him, well knowing that in so doing he gave great offence. To many a quiet Christian heart he brought much pain, handling, as he did, themes which to them were indissolubly joined to their inmost feelings of reverence, with the free manner of a fighter who flashes in his sword wherever he sees an opening to do his

* *Collected Essays*, V., Pref. p. vii.

opponent harm. To those who blame him for this the reply may be given that the greater the reverence resting on what he was convinced was a false foundation, the more pressing seemed to him the duty to show the falseness of the foundation in the clearest, most direct way, such as could be understood by all. Moreover, the manner in which he used his weapons in this matter was in no wise different from his usual manner on other occasions. He was by temperament "ever a fighter"; in his combats within the realms of natural knowledge, and these were not a few, he hit quick and he hit hard, for such was his way of fighting.

Many of his friends, who, like him, put their trust in natural knowledge, reproached him with spending his strength in warfare of such a kind. The surest way to make natural knowledge prevail, they said, is to extend its boundaries; as it advances other things must give way before it. Was it not a misdirection of energy that he who in past years had shown such power and done so much to drive farther and farther off the line which parts the known from the unknown, should spend time and labour in controversies which in themselves brought no clear advancement of natural knowledge, and in conducting which he could make little use of that wealth of natural knowledge which he already possessed, and had, with tireless labour, to seek the arguments which he used in unaccustomed antiquarian and linguistic studies?

He thought otherwise. He was convinced, and increasingly convinced as years went on, that natural knowledge could not go on to that fuller development which was needed to make it accepted as the true guide in the whole conduct of life, so long as men in general still believed that as regards parts of that conduct the only true guide was to be found in the teachings of the Church and in these alone. He had no doubt whatever that for the adequate progress of natural knowledge some one must be bold enough to stand up against the Church whenever it said to natural knowledge, "thus far but no farther," bold enough to show the world that the Church's claim to dictate to natural knowledge broke down when it was tried without fear and without prejudice. Seeing none other bold enough, he took the task upon himself. Whether he was right or wrong, the world must judge.

He is gone; but the conflict, in which so much of his life was spent, still remains with us. Among the followers of natural knowledge, both the workers and they who only know its ways, there are and always will be they who hold that natural knowledge is not merely a hewer of wood and a drawer of water, a provider of physical health and material benefits, but beyond that the only sure guide to moral health and spiritual well-being, who hold that man can only safely direct his steps by frank obedience to the known laws of nature, the more safely the better and the more

fully these laws are known. Such are well aware that the always increasing, but ever limited known is wrapped round on all sides with a boundless unknown. Peering from time to time into that dark unknown they may people its depths with fancies; but they leave those fancies there when they turn back to their daily task in the clear light of the known. Yet the feelings of wonder and awe with which that vast unknown must always fill them will abide with them, chastening and humbling them, ennobling their daily task and fitting them the better to perform it. Borne up by such feelings Huxley lived and worked.

MICHAEL FOSTER.

# *HUXLEY AND NATURAL SELECTION

*By Prof. E. B. Poulton, F.R.S.*

On March 23, Prof. E. B. Poulton, F.R.S., delivered the Huxley Lecture at Birmingham. He said the attitude of Huxley toward natural selection was remarkable and unusual. Although no one fought so nobly, and against such odds in its favour, although no one had ever fought the battle of science with such success, Huxley was never a convinced believer in the theory he defended from unfair attack. At least one cause of that want of confidence he (the lecturer) believed to be due to the fact that his researches, determined by the bent of nature, were anatomical and palæontological rather than the study of the living organism in relation to its environment, and especially its living environment. The origin and growth of the theory and the circumstances under which it was made public had often been told. Darwin, convinced of evolution by reflection upon his observations in South America during the voyage of the "Beagle" (1831-36), began in July, 1837, systematically to collect facts bearing upon the modification of species and its causes. In October of the following year he read Malthus "On Population," and the idea of natural selection at once dawned on his mind.

**Revised from the "Scientific American" Supplement*, Vol. 59, p. 24515-16, April 1905.
In full in "Essays on Evolution," Oxford, 1858, pp. 193-219.

In June, 1842, he wrote a brief account of the theory, and two years later an essay; but he could not be induced to publish until, on June 18, 1858, almost exactly twenty years after the conception first came to him, he received a manuscript essay written by A. R. Wallace in the Moluccas "On the Tendency of Varieties to Depart Indefinitely from the Original Type." Darwin placed himself in the hands of his friends Lyell and Hooker, who asked for an abstract of his own work, and presented it, with Wallace's essay, to the Linnean Society on July 1, 1858. Now that we knew the circumstances under which Wallace wrote his essay, the coincidence was far more striking. He also was convinced of evolution, and had written a powerful paper in support of it. But he knew of no motive cause until, in February, 1858, lying ill of fever in Ternate, he began to think of Malthus's book, and the idea of natural selection instantly flashed across his mind. He did not wait twenty years. In two hours he had thought out almost the whole of the theory, in three evenings he had finished it, and sent it to Darwin. Thus on July 1, 1858, when Darwin was nearly fifty and Huxley just over thirty-three, the great theory was before the world, and the most striking thing about Huxley in relation to it was the fact that he knew nothing about it. Almost exactly a year after the appearance of the paper, on June 25, 1859, he wrote to Lyell in favour of the transmutation of species, but against the idea of

transition between species. The letter showed that he had no notion of natural selection, but only of changes wrought by external conditions, changes sudden and sharply marked off, like those which follow the replacement of one chemical element by another in a compound—to use his own metaphor. "The Origin of Species" was published in November, 1859, and an advance copy was sent by Darwin to Huxley. In his chapter on the reception of "The Origin of Species" ("Life and Letters of Charles Darwin," Vol. II) Huxley said: "My reflections when I first made myself master of the central idea of the 'Origin' was how extremely stupid not to have thought of that"—further evidence that he had known nothing of the details of the Linnean Society paper, where the central idea was admirably, although, of course, briefly, explained by its discoverers.

Huxley's want of knowledge of natural selection in the interval between July 1, 1858, and the end of November, 1859, suggested several interesting reflections. Great and original workers rarely had the time for wide reading in their subject away from the lines of their special investigations. They were also held back by the feeling that the attempt to be encyclopædic was itself destructive of originality; and yet there was nothing so inspiring to a young worker as the fact that his attempts had interested a great and original leader in his own subject. The position looked

like a dilemma, but the escape was easy. The conditions of science were daily becoming more favourable at our Universities, where the older worker had a parental interest in the younger and would by no means quench the smoking flax by unintended neglect. Science was also rich in societies where old and young could meet, and where through personal contact, far better than by endless hours of reading, the deepest inspiration and the highest encouragement could be given and received.

If, however, the antagonism between the excessive cultivation of the memory and the development of originality was seen in the lives of older men, whose capacity for the highest work was proved and certain, surely conclusions of value were to be learned from those whose duty it was to watch over the developing mind of the young. A little knowledge was said to be a dangerous thing; but as regarded the awakening and growth of the most indispensable part of our intellectual equipment —the imagination—it might be more truly said that a great deal of knowledge was a dangerous thing. With the very best intentions, but with the very worst results, the idea had taken root in this country that the imagination must not be allowed free play until some arbitrary amount of knowledge had been imbibed, and the result was that too often all original faculty was waterlogged and drowned in a sea of facts.

Huxley's independent views on evolution were what we should expect from a great student of animal structure rather than of animal life, who was at the same time a profound and cautious thinker. Huxley told us that before the appearance of the "Origin" he took his stand upon two grounds—first, that up to that time the evidence in favour of transmutation was wholly insufficient; and, secondly, that no suggestion respecting the causes of the transmutation which had been made was in any way adequate to explain the phenomena. And yet all along there was alive in him a sort of pious conviction that evolution would turn out true, and the kind of evolution he imagined was, so far as we were able to judge, a conception which would arise in the mind of one who compared animal structures with the eye and brain of the artist or engineer rather than of the naturalist. At the age of twenty-six he wrote to W. S. Macleay: "I am every day becoming more and more certain that you were on the right track thirty years ago in your views of the order and symmetry to be traced in the true natural system." Macleay's ideas of the grouping of the animal kingdom were about as regular and symmetrical as the figures seen in a kaleidoscope. And a conception of sharply separated mathematically grouped forms would naturally lead to the idea of evolution by sharp and abrupt steps, whereby a new form would appear by sudden transformation of the old, just as a chemical com-

pound changed when one element in it was replaced by another.

The evidence at our disposal led to the belief that such was the state of Huxley's mind when, in November, 1859, he read the "Origin." He there met with far more convincing proofs of evolution than he had ever encountered before, and he accepted them at once, unreservedly, permanently. He furthermore encountered what was to him the entirely new idea of natural selection, and he recognised that it disposed of his earlier objection that no motive cause in any way adequate had been suggested. But to the end of his life he never went beyond that. He never committed himself to a full belief in natural selection, and even contemplated the possibility of its ultimate disappearance. The difficulty which he felt early and late, and about which he had a prolonged discussion with Darwin, was the fact that the breeds created by the artificial selection of man were mutually fertile, while the species created *ex hypothesi* by natural selection were mutually sterile. Without going into the controversy, it might be said that, according to Darwin, Huxley's objection merely meant that the results of an experiment prolonged for an immense period were not in every respect the same as those attained when it endured for a time comparatively brief. Students of living nature felt a confidence in natural selection which was not shared by this great leader. Just as it required the naturalist to discover the principle itself, so

the experience which brought belief in it was that mainly of the naturalist, and the strongest confidence in the abiding truth of a theory was gained by those whose imagination had been inspired by it. Every verified prediction made by the light of natural selection placed the theory upon a more secure foundation. That foundation had been growing more secure for nearly half a century; but, as Prof. Poulton showed in conclusion, that increasing confidence was not so much due to the facts which were the province of the anatomist as those which formed the every-day experience of the naturalist, of the man who studied animal form and change and instinct, not in relation to the single individual or the single species, but in relation to the whole environment, and especially the living environment. That kind of study did not appeal to Huxley's nature, and therefore the confidence in natural selection, of which the lecturer had spoken, was not for him; but those who felt it should never forget how much they owed to Huxley for the leading part he took in the great battles which had to be fought before evolution and natural selection were accorded a fair hearing; and his success went far beyond even those issues. Whatever stirring and subversive ideas the future might be preparing for us, we might be sure that they would never suffer from the treatment accorded to the "Origin of Species," and far more than to any other single man the world owed that immense gain to Thomas Henry Huxley.

# RATIONALISM AND SCIENCE IN RELATION TO SOCIAL MOVEMENTS.

*By Prof. Percy Gardner.*

Whether your Council have made a mistake in the selection of the present Huxley lecturer it will be for my audience to judge. But up to a certain point I think they were certainly right. They decided that when a lecture was founded to commemorate a man so many sided as Thomas Huxley, justice could not be done to him if only a succession of biologists were nominated to the lectureship. I am older than most of my auditors, and vividly remember the part which Huxley played in the national life. He was not merely an authority on biologic questions, a first-rate lecturer on science and a prominent champion of Darwinism, but also a man through whose clear and powerful brain all the great questions of our time circulated, finding there an alembic whence they often issued altered and clarified. He was not only a man of science but also a man of letters, a philosopher, even in a degree a theologian. He once said of Mr. Arthur Balfour that he had science in his blood; we may say of Huxley that he had literature in his blood. If

we accept Matthew Arnold's view that the pursuit of letters consists in the acquainting oneself with the best which has been thought and said in the world, Huxley was literary; if we accept the same writer's definition of religion that it is morality heightened, kindled, lit up by feeling, Huxley was religious. And it was the combination in him of science with literature and religion which made him so great a force in the England of the Victorian age.

I never had the honour of personal contact with Huxley, but I heard him speak more than once, and his writings have deeply interested me since I was a child. I owe him a debt, which I may best pay by trying to combine as he did the fanaticism of veracity which marks the man of science with the broad outlook on human life which belongs to the man of letters. But the last quarter of a century has been a time of rapid, of constantly accelerated, intellectual movement, and Huxley, who was himself ever on the crest of the advancing wave, would condemn me if I did not try to penetrate further than he did into some of the tendencies of thought which are ever ebbing and flowing, and are now more clearly to be discerned than they were twenty years ago.

## I.

I have taken as my subject Rationalism and Science, in relation to social movements, and I must begin by trying to explain in what sense I

use these words. We are used to the word *rationalism* in religious discussions, and there we attach to it, as does Lecky in his History of Rationalism, a somewhat negative meaning. We think it implies the denial of old-fashioned orthodoxy, and greater reliance on reason and common sense. I do not propose to use the word in this somewhat narrow acceptation. Again, the word *science* is in this country applied almost exclusively to the knowledge of the phenomena of the material world, physics, chemistry, biology. But this is an abusive use of the term. For science can be nothing but orderly knowledge, and orderly knowledge is just as possible in such studies as philology and archæology and history as in those dealing with the physical world. In all the great academies of Europe it is fully recognised that science has two great branches, one of which deals with the visible world, the other with man, his faculties and his history.

The question which I propose to discuss is the parts belonging respectively to rationalism and to science in modern civilisation and progress. And I beg to be allowed to mean by rationalism the adoption of certain fixed principles from which the course of our action may be deduced or argued out; and by science I would mean the regular and methodic knowledge of man, in the past and the present; the investigation not of ethical principles but of consequences, of events, and of the results of action. But I must explain.

Human progress in general, the passage of mankind from a lower to a higher level, consists, as I earnestly believe, and as I have tried to shew elsewhere, in the gradual embodiment in society of certain impulses and tendencies arising in the obscure regions of sub-conscious life, and gradually making their way into all the forms of human activity, thought, feeling, action, art, institutions and social organization. These creative and life-giving impulses I should prefer to call divine ideas; but if anyone regards this phrase as too theological and question-begging, I will not at this moment insist upon it. We need not stay to examine the origin of these ideas; we have enough to do in tracing their manifestation in the field of consciousness. However they originate, they come bubbling up from unknown depths like the springs of rivers among the hills, and pass on to make the fields of life fertile. To each generation and to every nation it is given, or at least the opportunity is given, to manifest some particular ideas in higher or completer form. The Jews owe their place in the history of the world to their enthusiasm for the idea of the divine guidance and government of mankind, the Romans to their sense of civic law and order. The Greeks, more susceptible to ideas than any race that ever lived, have left us imperishable embodiments of the ideas of rationality, of human beauty, of measure and method in all things. The best achievement of the Teutonic races was their

development of the ideas of loyalty and chivalry. These races, and indeed all great races, have added some adornment to the temple of humanity, and made the life of each succeeding generation a thing of higher and nobler possibilities. No doubt they have all had defects to balance the excellences, the Jews narrowness and fanaticism, the Romans hardness and cruelty, the Greeks frivolity and want of moral purpose, the Teutons the vices of an aristocracy. But to every man whose eyes are not jaundiced by cynicism, these great national inspirations, in spite of all drawbacks, will appear as the rich legacies of the past, making life in the present worth living.

Savages and barbarians below a certain stage of development have attained a definite organization, what may be termed an equilibrium. They often go on from century to century without any great change. It is the rise of ideas which breaks the crust of fixed custom. The innovators are commonly regarded as destructive and mischievous, so that the path of progress is strewn with the bones of martyrs. It is through the self-devotion of the few that the many climb painfully to a higher level.

The ideas as they rise from the unseen depths of consciousness usually first make themselves known in action. They affect will and emotion, which are nearer akin to the unconscious, before they seek justification in thought. But sooner or later the rational part of man must be satisfied

as well as his emotional part. He has to give some sort of reason for the hope that is in him.

History shews us very clearly how this demand for a reason is at first met among all peoples and nations. It is met by a direct claim that the line of advance is shewn by revelation, that some person or society is inspired by the gods to lead the people in the right way. We are familiar with this kind of appeal from our acquaintance with the Old Testament. Nowhere is it so clearly and emphatically set forth as in the Jewish Scriptures, and quite especially in the writings of the earliest of the great prophets, Amos and Hosea. It is the word of the Lord which they make known to the people; and they tell their contemporaries in burning sentences that it is their life and peace to hear that word and to do it. But our religious horizon has greatly widened of late years, and we now know that among all peoples such a claim has been put forth by prophets. Israel is the prophet among the nations; but all nations have received from time to time like prophetic commands. The king of Assyria did not march to subdue the nations save at the command of Asshur. Numa received the laws of Rome from the goddess Egeria. Pharaoh of Egypt was an impersonation of the Sun-god Ra. Pythagoras was an inspired prophet, and his society arose on a theocratic basis. Nor was this claim at all confined to the men of the childhood of the world. Socrates was

launched on his career by the voice of the Apollo of Delphi. And through all the Middle Ages, the great Reformers and the Founders of Monastic Societies were fully convinced that they had a special mandate from above, which they dared not disobey. I need mention but three of the most conspicuous names, St. Francis, Luther, Wesley, all of whom were consciously the vehicles of a divine command.

This answer to the demands of the human intellect, the direct appeal to a divine inspiration, cannot be called a form of rationalism. What we know as rationalism is rather the very opposite. Rationalism arises as the belief in direct inspiration grows weaker. It is a reply to scepticism. When a prophet is asked by what authority he commands, he answers by a manifestation of spiritual force. But this reply does not satisfy the doubters of a sceptical age.

I am speaking, it must be remembered, of great ethical movements, proposals that we should modify our way of conduct, in regard to some of the great and important matters of life. A movement in such and such a direction, we suppose, is springing up in the consciousness of men. It will scarcely in our days be accepted on the authority of a prophet claiming a direct mandate from heaven. It meets with enthusiastic approbation and with determined opposition. We have as best we may to reason out its goodness or badness in discussion. This may be done either in

the way of rational ethics or of science. The ethical way is to make appeal to some principle generally accepted in the society, rights generally recognized, beliefs which are not seriously questioned. It has to be shewn that the proposed change is in accord with or contrary to these, so that consistency would compel us in the one case to accept, in the other to reject it. The way of science is to shew the results which follow the adoption of the disputed principle, results either good or bad, either attracting us towards it, or warning us to avoid it, as we avoid disease and death.

But abstract talk like this tends to make the ears dull, so that the speaker does not take his audience with him. Rather let us take a concrete case, in order that we may see the two methods of which I am speaking not as mere possibilities but as actually working principles. We will take up a controversy now practically extinguished, but raging with great force in the last century, the controversy which ended in the abolition of negro slavery in the British Colonies and in America.

Here the ultimate spring was no doubt an impulse springing up in the consciences of thousands—a conviction of the sinfulness of slavery. When the matter had to be argued on the platform and in the legislatures, the impulse had to be put on terms with men's ordinary ways of thinking and action. The advocates of emanci-

pation sometimes appealed to the general belief in certain rights of man, the principle that a being having human form and human faculties had also certain inherent rights, or the thesis that God had made all men of one blood. This may be regarded as the rationalist side of their appeal: but they also had resort to arguments of another kind, which were more closely akin to the demonstrations of science. They tried to shew that slavery had in the past worked with pernicious effect on the societies which had adopted it, and was in the countries which upheld it even in our own time working great harm on the character alike of the slave-holder and the slave. Sometimes they would take a lower line, and try to shew that in production slave labour was actually less efficient than free labour, and so dearer.

The controversy in regard to slavery may be said to be now closed. And we are disposed to think that the arguments were all on one side. But a century ago, there were good and wise men who took another view; and they also appealed alike to accepted principles and to history and experience, especially the latter.

Thus the abolitional movement found means for capturing the three great parts of human nature, will, emotion and intellect. The inner impulse bent the wills of men, especially carrying away in a strong enthusiasm the wills of the leaders of the movement, Wilberforce, Clarkson and the rest. The ethical appeal told especially

on the contagious enthusiasms of the platform; and in these days of popular government, arguments suited to the orator are necessary in all matters involving legislation. The appeal of science acted on more thoughtful people, comparatively few in number, but having influence out of proportion to that fewness, in virtue of their intelligence, and the quiet steadiness of their convictions. The final result was a great effort of national will, but it was helped on, and even made possible, because emotion and intellect worked on the same side.

But now we come to other forces which are mainly beyond human control, the constitution of man and the human environment. Let us suppose that there were two states existing side by side; and that in one of these negro slavery was abolished, while in the other it was retained. The two would necessarily compete, and one would be found more efficient, more successful than the other. Evidently here the abolitional idea would have to undergo a fresh test, that of working. And apart from violent interference of one state with the other, which is of course what happened in the United States, the final triumph of the one polity or the other must be determined by fact and by event. If the idea of abolition was in harmony with the facts of human nature, it would triumph. But if the impulse from which it arose was a baseless sentiment, if the natural rights of man were a delusion, and if the men of science

misjudged the results of slavery, then the slave-state would in the course of time crush out the state which abolished slavery, and survive.

There is then an ultimate test to which all human endeavours, all plans and all institutions must submit, the test of working, of fruits, of survival. It is a hard test, proceeding without fear or favour, and ruthlessly trampling out whatever will not endure it. This is of course no new doctrine; and from the beginning of literature it has been expressed in a hundred ways. The Hebrew Psalmist wrote 'Such as be blessed of the Lord shall inherit the earth, and they that be cursed of him shall be cut off.' 'What is contrary to nature cannot succeed' is the burden of philosophy in all ages, and especially of the greatest of all practical philosophies, the Stoic. And when in the last century Darwin emphasized the principle of the survival of the fittest, it was but this old wisdom made new.

The law of the survival of the fit and the destruction of the unfit works in the whole field of biology. And it works in human society. But it does not work among men with the same force and regularity with which it works among plants and animals. For the free will of man, however it be explained, is an existing reality: and man has the power of modifying his surroundings, even in some cases of dominating them. When two states compete in the markets of the world, that in which the labour is most effi-

cient will tend to drive out the other. But the state of less efficient labour may be stronger as a military force, and throw the sword into the scale, or it may be wiser politically and make treaties which shall give it an advantage in the markets. Or it may by higher internal organization diminish the friction which wastes power, and so make up for inferior powers of production. And within a state persons or classes of persons who would in the natural course of things be starved on account of their inefficiency may be kept alive through feelings of humanity. And education regulated by the state may be shaped for the particular purpose of promoting the efficiency which leads to survival.

In speaking of the conditions and environment of life it must not be supposed that I speak as a materialist, and am thinking only of the natural frame in which our lives are set. I believe fully that we also live in a spiritual environment, that our lives are parts of a greater and universal life, that we belong to a great commonwealth of spirit. And further I believe that in this spiritual world there may be traced something akin to human will and purpose, but on a higher scale. The ultimate fact for us is not the material world, but the spiritual power which dwells in it and has created it. But this spiritual world also has its laws, not fixed and rigid like the course of the stars, but yet overpowering and dominant.

Our environment may best be regarded as a

stream of tendency which bears us all along. If we are passive we move on steadily. If we resist, we may swim against the stream, but it is difficult and a constant drain of energy. If we swim with the stream we move fast. It is by swimming against the stream, very often, that character and personality are made. But our lives are short; and in the long run the stream has its way with communities if not with individuals. Our efficiency, and especially our efficiency in societies, depends greatly on going rather with than against the current.

It was necessary thus to map out the ground, in order to lead up to the things on which I really want to insist. The corollaries which follow the truths which I have outlined are not regarded as truisms. And it seems to me of great importance that they should be brought forward on occasions like the present, when a broad outlook on the great problems of life is specially in place. Progress, I have maintained, consists in the absorption into the frame of society of practical impulses or ideas. These ideas must be justified by appeals to accepted principles and to experience. And it is of the utmost importance that the ideas themselves should be in harmony with the laws of human nature, and that their working in the world should be seen as it really is. In all these respects in our days great difficulties arise from the character of our civilization and the existing habits of thought.

It is clear that the intellectual presentation of the ideas requires three classes of workers. We need a class of prophets who shall be susceptible to the ideas as they slowly emerge from the ground of the unconscious. We need philosophers and men of letters to connect them with the principles generally accepted by society. And we need men of science and observation, to trace the results of their working in history and in the human world around.

After all the great task is to persuade the people. In our days, whether for good or for evil, whether we like it or not, democracy has become more and more the ruling power. Even a Cæsar cannot move in any direction against the grain of his people's will. Nor can an aristocracy retain the direction of affairs, unless it can persuade the many that it rules for the general good. The counting of heads to save, as Bentham said, the trouble of breaking them, is the final test in all practical matters. This being a fixed point, let us consider how the working of ideas, which is to the community what the circulation of the blood is to an individual body, finds course or hindrance among us.

We need not greatly concern ourselves about the prophets. They are, so to speak, the supernatural element. Their advent cannot be procured or foretold any more than can the weather of a week hence. There will always be prophets, some true and some false, claiming to be heard:

the great need of mankind is to discern between those who lead to what is good, and those who seduce to what is evil. The really practical questions have to do with the tests by which ideas are to be tried.

In such testing it seems to me that, ever since Darwin and his school came upon the stage, the appeal to fact, to experience, to results has been steadily gaining in efficacy, at the expense of what may be called the rationalist appeal to a priori principles and beliefs. The reason is not far to seek. The constantly growing restlessness of mankind, the changes in our surroundings both social and economic, the drain of those who lived in the country towards the great cities with their life of fevered activity, have made it hard for any accepted principles to hold their place. The tendency is to call in question all the beliefs whereby in times past men have directed their actions. And on the other hand, science, which is of course only organized and formulated observation and experience, has been maturing with a rapidity compared with which its previous progress was but slow even in the most active and intellectual ages of the world's history, the ages of Aristotle and of Leibnitz. Into every branch of knowledge we are introducing method; the progress of discovery is advancing into fields never yet occupied; the test of results is the one test which is always accepted.

I am not concerned to justify this progressive

supersession of rationalism by science. In many ways it is to be deplored. The restlessness of modern society is in itself a serious evil; and one looks with anxiety to see whether the great root principles which have been worked into the fabric of modern society will not be called in question. Even such institutions as monogamy and the possession of private property do not pass without inquiry. All this, one hopes, is transitional, the result of too rapid changes physical and social. But whether one deplores, or whether one defends, the change in the centre of gravity, that such a change is taking place is past question. A recent speaker in the House of Commons spoke of the doctrine of the rights of man as 'dead as Rousseau': and one could scarcely contradict him.

And looking in all directions for a remedy, one can find it only in a broader, more human, more profound, study of human phenomena, and the growth of a science treating of man and his faculties as well developed and as detailed as is the study of the visible universe. No such science can give us ideals; there can be no mere observational determination of right and wrong, good and evil; but still, fuller knowledge may serve to protect us against some of the aberrations and absurdities which threaten society.

I have been reading the recently published letters of a man for whom I have always had the deepest respect, John Stuart Mill. Those letters

are full of the intellectual honesty and moral courage in which Mill perhaps surpassed all his contemporaries. But they are instructive in another way. Mill's career immediately preceded the great trend in the direction of the scientific treatment of human problems which we owe mainly to the influence of Darwin and Spencer. His letters remarkably illustrate the distinction which I have drawn between the rationalist and the scientific way of considering problems of conduct and sociology. The rationalist is self-confident, fully trusting in argument, ready to assert his principles in season and out of season. The man of science is, or ought to be, modest, laborious, most anxious to omit no phenomena, having a deep respect for every view which has actually worked among men. A letter of Mill's in regard to the religious observance of Sunday is very typical.* One would expect the great advocate of Utilitarian Ethics, before condemning this institution, to consider what part it had played in the history of England and Scotland, and what practical results might follow from its destruction. But the rationalist in Mill is far too strong for any such investigation. To attribute any sacredness to the day, he writes, 'is as mere a superstition as any of the analogous prejudices which existed in times antecedent to Christianity.' The preservation of the Sunday

* Letters, I, 100.

as a day of devotion is, according to the writer, mere cant. 'The devotion which is not felt equally at all times does not deserve the name.' And so he proceeds. It is strange that it did not occur to him to consider why in such a case the observance of Sunday had so long persisted in Great Britain. In some of Mill's letters one finds a painful consummation to which such rationalism as his may easily lead. He expresses a deliberate opinion that in the government of the world the spiritual power of evil is stronger than the power of good. That, I think, is a conclusion which will often be reached by a rationalist who first determines by the light of his own sentiments what a moral government of the world ought to be, and then condemns that which actually exists because it does not conform to such preconceived notions. The spirit of science is utterly different. Starting from the facts of the world and of human nature, the scientist will try so far as he can to understand them, and where he fails will be apt to lay the blame on his own faculties. At all events, taking them as they stand, he will try how human conduct may best be harmonized with these fixed surroundings. It is only by accepting the laws of nature that practical science progresses; and it is only by accepting the fixed tendencies of man and society that we can hope to improve mankind ethically and socially.

## II.

The moral is sufficiently obvious. It is of the utmost necessity for the well-being and progress of society that the sciences which have man for their subject-matter should be earnestly pursued; that they should be organized at our Universities, that research in them should be made one of the great ends of all higher education, that we should set aside every weight and hindrance which may prevent us from running this course with all the energy which we possess.

Theoretically, perhaps, almost any thoughtful person would concede this principle. Yet when we come to look at education as it is, we see that the practical means to this end are by no means so generally conceded. We in England are in this matter behind the nations of the Continent, especially France and Germany. With us education is still regarded as necessarily either literary or scientific. By a *literary* education we mean an acquaintance with certain languages and the books written in them, a training whereby a man acquires a good and correct style in writing, and a knowledge of the way in which nature and the great problems of life have been regarded, more especially by the Greeks and Romans. In its own way this training is admirable; I should be one of the last to speak slightingly of it. For four hundred years it has served to maintain a high standard of literature and culture. It takes

the minds of the educated out of their narrow surroundings into the broad spaces of Greek thought. It keeps before us the imperishable models of ancient beauty, the poems of Homer and Virgil, the dramas of Euripides, the dialogues of Plato, the lives of Plutarch, the statues of Phidias and Praxiteles. If we were to forget or to neglect these precious legacies of the past, we should fall many degrees in civilization. Nor less is the claim upon us of modern literature and art in all their phases. But yet this culture leaves lacunae.

By a *scientific* education men usually mean a training in what is in this country regarded as in a special degree science, the natural knowledge which begins with mathematics and ends with biology, the study of the visible world, of nature animate and inanimate. This training also is in its way admirable; it would be in me an impertinence to attempt to write its panegyric. But has it no tendency to drift into specialism, a narrowing of the mind to a single small field of study and observation? and is it free from the danger of disposing those who too exclusively pursue it towards materialism, and blindness to the higher and more human side of life? The space left between literary education on one side and scientific education on the other, is in England very imperfectly occupied. Human science is among us the Cinderella, whose sisters are made much of, while she has to take what they do not care for.

And the fairy godmother does not arrive, but in her place there come many spirits of delusion; so that the ground which should be occupied by ordered knowledge is seized upon by all sorts of charlatans, and becomes a hunting place for all kinds of untrained intelligences.

I would earnestly plead for a better recognition, a more complete organization, a better endowment for the studies of which man is the subject matter.

They fall naturally into three groups. *Firstly* we have the historic group, a series of sciences philological, archæological, and the like, the purpose of which is to make the life of men in the past live again in the present in all detail and vividness. Nothing in that life is irrelevant, no detail which can possibly be reached by research is unimportant. Every touch of the brush helps a great picture, and in the same way the discovery of a few small documents illuminating some phase of past history may be in its working quite revolutionary. A ray of light falling on a spot hitherto obscure may shew a diamond.

The study of history has no doubt in most places changed its character and methods, and become more fully alive. But generally speaking there is still too much in it of a merely literary character; the enjoyment of the writings of historians, however good in itself, cannot take the place of an intense realization of the meaning of

the past to all of us, and an insatiable desire to learn to the utmost what really took place.

Very often we hear a shameless avowal of contempt for 'mere history.' 'Let bygones be bygones,' men say; 'we have to do with the present.' But the very problems which these men have to solve in the present, have been attempted a thousand times before in the course of history. Are we to throw away all the results of human effort and learn only by the education of failure what is good for us? Would a biologist confine his attention to the study of existing species of plants and animals? or would a chemist set aside as unworthy of study the results of the experiments of his predecessors? So short is human life, and so feeble the intelligence of man, that unless he profits by the experience of past generations, he will be falling back, not advancing in knowledge. The truth is that the historian who discovers the real line of human progress in the past, even in some quite subordinate part of the field, does at least as much for the well-being of mankind as the man who discovers a new gas, or invents a new mode of more rapid intercourse between peoples.

Speaking in the light of my own studies I may say that there are two periods of ancient history which are of extreme interest to us moderns, not only as picturesque in themselves, but as shewing us the true working and results of many of the social tendencies now prevailing. These periods

are the age of the spread of Greek culture after Alexander, and the early age of Christianity in the Græco-Roman world. These times are full of modernity. The problems with which they teem are our problems, and nothing is more certain than that factors which then worked will work in the same direction now. Great shifts of population to new regions, the drift of the dwellers in the country districts towards the towns, the decay of religious belief, vast wealth of a few and galling poverty of many, distaste for military service, increase of divorce, a falling birth-rate, these and many other modern tendencies were familiar two thousand years ago. And men of those times, men quite as wise as any of us, tried to devise cures for these things, introduced some remedies which were palliations for the diseases of society, and some remedies which only increased the evils they were intended to prevent. All these things stand written in the history of the past. Are we so wise or so self-confident as to disdain to learn the lessons which history teaches? Must we learn only as do plants and animals, from the hard lessons of suffering?

In this matter Germany has something to teach. A French writer, M. P. Huvelin, writes as follows:—

'It is an enviable privilege of the Germans that they realize without effort and by nature the relations between practical aims and disinterested study. With them, new social and academic

needs give life not only to practical work, but to scientific research. Examples abound. Does Germany desire to acquire possessions beyond the sea? At once there arises a literature on colonial geography, methods of colonization, colonial legislation. Does she wish to augment her fleet? Her writers investigate history to see if there exists a necessary connexion between a powerful fleet and a prosperous commerce.' And so forth. The picture may be, as regards Germany, rather highly coloured; but it represents what would happen in an ideal Germany, or in any country which realizes the relations between knowledge and action.

But it may be said that all the facts of ancient history have been known by our ancestors for generations, and have been taken into account by our statesmen and publicists. Nothing could be less true than such an assertion. We are only beginning, by the help of exploration, excavation, renewed study of historians, to understand what really took place in the ancient world. The conventional notions on the subject which we inherit from our fathers are as unlike the reality as the engravings of the Tower of Babel which we find in old illustrated Bibles are unlike the palaces which actually existed at Babylon.* For example we have begun in recent years to realize how great a part in ancient history was played by

* No recently published work shews this more clearly than Professor E. Meyer's *Kleine Schriften.*

supply and demand of commodities, by desire of fresh markets, by poverty and unemployment. It is the course of events in our own days which has thrown an entirely fresh light on ancient history. And if we only take the trouble to pay attention, ancient history can in return throw a flood of light on our own present and on the future which awaits us. And what is true of ancient history is quite as true of more recent history.

*Secondly*, we have the psychological group of studies, which investigate the active and the thinking powers of man, the conscious powers, and that great realm of the unconscious which now takes so great a place in our horizon. It is astounding what great revolutions are wrought alike in our conceptions of history and our practical activities in the world by the introduction of truer views of the nature of human feelings, habits and thoughts. Every practical man has to deal with the minds of his fellows, and the analogy of all other studies proves that he will work far more effectually when he has an accurate and methodical notion of what those minds are, than he can when he merely knows them by rule of thumb. Practical statesmen are often disposed to think lightly of the methodical study of man, yet could not any psychologist point to Acts of Parliament and decrees of Emperors the failure of which, from their want of conformity to human nature, could quite well have been foreseen?

I must not venture to speak of a special side of psychology which has been lately brought into prominence, and in regard to which words from Birmingham are greatly valued, the study of the sub-conscious side of man. Hence has come indeed a great revelation. And I venture to say that as regards human progress and human happiness this great accession to our knowledge is far heavier in the balances than such discoveries as those of radium or of wireless telegraphy which only touch human life on the outside.

Perhaps it is the new psychology of religion which has, or is destined to have, the greatest effect on our practical and ethical life. In recent years there has been an immense deal of research and of writing in regard to such matters as the relations between reason and faith, or the connexion between fact and doctrine, or the phenomena of religious experience, which must needs have a profound influence on the faith of the Christian Church. It is now realized that religion does not lie in the reception of certain facts as historic, but in an attitude of the spirit; and that attitude is the result of an immense historical process. Like all great discoveries this change sometimes dazzles the explorer. We have perversions, as when some of the reactionary parties, more especially the Jesuits, think they can justify on psychologic grounds all the superstitions of the Middle Ages. But without going this length we may see that too great reliance on

reason greatly misled the Reformers of the sixteenth century, making them develop rigid schemes of theology almost regardless of the fact that religious truth is relative, and belongs not like mathematics to an abstract scheme of thought, but to the ethical and practical side of man. In a sense even the basest superstition has some justification, for it could not have arisen but for its satisfaction of some human need. But a society is debased if it retains too long beliefs suited to a barbarous age, but later tending to dwarf the intelligence and fetter the freedom of mankind.

Nowhere better than in Huxley's essay upon Descartes is expressed the growing conviction of investigators that all knowledge has a base in psychology, that every fact has a subjective element, that nothing can be seen but in a human mirror. The relativity of knowledge to the knowing mind is the truth which has altered the basis of all such branches of study as have to do with man's thought and feeling, æsthetics, religion, even economics; has destroyed their abstract and rationalist character, and drawn them into the ways of scientific method.

*Thirdly*, there is the group of studies included in sociology. In England in past days we made the mistake of setting apart one class of social phenomena, the facts of the production and distribution of wealth, and supposing that the Political Economy which is concerned with these can

be dealt with apart from all other phenomena of society. This is in the long run impossible. We may of course have Political Economists as specialists, just as we have Physicians who make a speciality of the lungs or the throat or the eye. But after all the health of a body depends upon all the parts working together, and the well-being of a nation depends not only upon its wealth but upon its efficiency in all fields of human activity. When one considers what must finally be included in sociology, all the studies which have to do with man in society, from eugenics and political economy on one wing to ethics and religion on the other, one feels that our society has reached a point like the summit of Pisgah, whence the promised land may be seen in all its beauty and fertility, a land, however, which has to be reached through much toil and many wars. The land is not yet even thoroughly surveyed; we have no good map of it, and we are dependent on the reports of solitary workers who have made their way into one or another of its many regions, and brought back weighty loads of fruit.

Let me take a concrete example. Lately I had the pleasure to take a modest part in an important conference held in London on the subject of town-planning. In the last ten years it has dawned upon the people of Europe and America that the planning of towns has hitherto been quite at the mercy of accident, that private owners, looking only to their own interests, have suc-

ceeded in making our cities very far from what they should be, without unity of plan, without consideration for the general convenience, quite unfit to serve many of the purposes of civilization. And there have sprung up in England, France, Germany and America, not merely a few, but hundreds of societies pledged as far as may be to remedy these evils, to make our cities more orderly in arrangement, more healthy, more cleanly, free from the thousand nuisances which make our lives dull and ugly, free from palls of smoke and the blatant vulgarity of pushing advertisements. Here indeed is a movement which stirs the pulses of men! Here are ideals which can only be attained by method and thought, that is to say by science. But the science by which they are to be reached is not mere constructive skill, nor the art of gardening, of paving or of building. It is essentially human science, and has a place in all three of the sections which I have mentioned. We want to know with accuracy what purposes men work with, what are the laws of health, what contributes to beauty and what overwhelms us with ugliness. We want also to study social conditions, the tenure of land, the divisions of employment in a locality, the needs of future generations, in order that we may learn to subordinate the interests of individuals to the general good, and to make our societies really healthy and progressive. Unless the laws of man and of society are first considered, our

plans will be struggles towards an unknown end. They will be like planning a shell for a marine creature of unknown size and habits, like building a house without knowing what sort of a family is to live in it.

The organizers of that Conference arranged that their proceedings should begin with papers on town-planning in the past, by the Greeks, the Romans and the Europeans of the Renaissance. These predecessors of ours had to face, not precisely our problems, but problems similar to ours. Cities like Rhodes and Antioch, Alexandria and Pergamon were laid out by architects whose technical skill was almost equal to that of their modern successors, and to whom the utmost freedom was given to make a city, with its walls and market place, its temples, gymnasia and streets, on the most scientific principles. It would be absurd that when a federal capital has to be built for Australia or India, or a great city like Chicago to be spread out on a plain, the lessons of the past should not be used to the utmost, and hints taken from all available records. Surely here is an example which justifies my contention that for wise action in the present, and for far-seeing plans for the future it is above all things necessary that our knowledge of man and of his history should be as exact, as detailed and as vivid as possible.

## III.

When we consider how rapid has been the progress in recent times of physical and biological sciences, and realize how slow in comparison has been the progress in the knowledge of man, we may almost despair. We can scarcely say that, in many important respects, we know more of the nature of human well-being than was known by Aristotle. Yet in some countries, more especially in Germany and America, at least the magnitude of the task and the infinite importance of reaching sound and trustworthy results are beginning to be recognised.

As the nineteenth century was the great age of discovery in the sciences of nature, so, I venture to prophesy, the twentieth century will be the great age of discovery in human science. Compared with our mastery of the forces of nature, our mastery of ourselves and our destiny is in an infantile stage. We see how utterly defective are the arrangements of society around us. We see how our medicine is capable of grappling with definite diseases, but has no ideal of human health, how our skill produces an infinite mass of wealth, and then distributes it in a way that is simply appalling. We see how marriage remains at the mercy of the worst regulated impulses of our nature, without any thought of the future of the race. We see how charitable feelings towards our fellow men, instead of being a raising

force in the world, tend constantly, through sheer want of method and wisdom, to degrade a great part of the people, and to promote the shiftlessness of the idle, and the multiplication of the unfit. These things brood in the hearts of all who try to look with unblinded eyes on modern society. And there comes among us a constant stream of would-be reformers, who see the evil and have a nostrum of their own to cure the ills of the world. As in the Middle Ages men sought a philosopher's stone, the touch of which would turn all substances to gold, so these social alchemists recommend some hastily adopted salve as sovereign for all the ills of society. When their remedy takes the form of the foundation of some socialist society, at all events it is an experiment from the failure of which mankind may learn much. But if such experiments are to be first tried on whole nations, it is terrible to think what misery and destruction will be caused.

The only true course is for practical experiments to follow in the wake of systematic knowledge. Systematic knowledge cannot give us ideals; they must arise within, and cannot be gained by study of fact and condition. But unless the ideals are pursued with a knowledge of history and of human nature the result can only be disappointment and disaster.

It seems to me that in our days everyone who desires extensive changes in the frame of society calls himself a socialist. As a result the most

discordant views and purposes are covered by that convenient term. The Marxian school of socialists on the Continent have as their avowed object the improvement of the economic condition of the manual workers, the securing for them of a greater share in the world's produce by means of a kind of social war. In England this is regarded as the main function of the trades unions; and with us the term socialism covers a much wider variety of views, from the desire of simpler and less ostentatious living to dislike of all existing institutions. And everyone who chooses to call himself a socialist thinks that he may dogmatize as to what socialism really is. One theorist will tell us that it implies the expropriation of all the owners of material resources. Another will say that it is not compatible with the present organization of the family. A third will regard it as bound up with secularity, and incompatible with the Christian religion. And so forth. But I would venture to submit, that socialistic theories and experiments have been going on in the civilized world from the very beginning of history. Plato opened an æra of speculation on the subject in his immortal Republic; and in the days of Plato there existed a community, that of the Spartans, in which socialist ideas had more full course in practical life than they have had in any commonwealth since. So the study of history must claim its right before we can venture to say that we know much about socialism. And

the study of man as an individual and of man in society claims its rights; for if we assume human nature to be other than it is, our whole construction is built of unsound materials, and will topple into ruins as fast as we build. Men are the bricks of which any community must be built, and we must know what strain those bricks will stand, and whether they can resist wind and rain. I take it that the only true basis of socialism lies in the idea that the good of individuals must be subordinated to the good of the community. Here we are all agreed. But we come at once to the question what is the good of the community, and how is it to be promoted?

If socialism implies a belief in the perfect equality of the sexes, then the Maker of the world certainly is not a socialist, for He has given the two sexes different faculties, and imposed on them different tasks. If socialism wishes to abolish the family, it must discover motives sufficient to induce men and women, apart from the old family motives, to observe the rules of morality and to greatly desire to have descendants. If socialism wishes to make the state the universal employer it must find out how to secure energy and honesty in those who direct, and docility and industry among those who labour, apart from the hard discipline of the struggle for existence which at present keeps society going, whether better or worse. It is possible that as we have superseded sailing vessels by steamships,

and horse traction by motor traction, so we may be able some day to discover an organization of society which will be more economic of force and productive of better results than the organizations of the past. But the only safe road to the goal is the same road which has been followed in our improvements in communication. First we had the man of science in his laboratory making experiments, weighing results, eliminating friction, examining materials. Then we had modest experiments on a small scale, at first experiments with mere playthings; and these experiments gradually grew in scale because they succeeded, until, in branch after branch of transport, the new methods competed with the old, and fairly beat them out of the field. When motors were first heard of we did not proceed to slaughter all our horses, and when aviation is beginning to succeed we do not break up our railways. Yet that is the way in which some of the speculative schools of socialism would go to work on the organization of society. Newton, the greatest of our men of science, claimed to excel his contemporaries only in patience or persistency. And it is this active patience, patience in research, patience in conforming to the conditions of the world, patience in enduring what cannot be altered, and in gradually changing what can be altered, which must be the essential feature of all reform, unless we would fling away all the rich results of the

striving and sufferings of our ancestors, and run the risk of relapse into a state of barbarism.

I think we may in this matter see clearly the contrast between the rationalist and the scientific tendencies in the remoulding of society. In the French Revolution, for example, the guiding principle was a regard for certain assumed human rights. In order to secure those rights everything was thrown into the melting pot. No doubt the world learned a great deal of wisdom from the reckless experiments of those stormy days. But to what did they lead? To Napoleon, and a militarism which deluged Europe with blood, and brought upon France a depression from which she has not yet recovered. The custom of science when it sees things going amiss, is not to leap like Curtius into the opening gulf, but to interrogate history and experience, to see when such evils before existed, and how they were met, where such evils are in our day not to be found, and the reason why. This method requires patience both passive and active, passive patience to bear the evils until we have fair prospect of a remedy, and active patience or persistence to bring together all the facts, to examine theory after theory and make experiment after experiment on a small scale, until we find a way which is certainly a thoroughfare. A science which is at home amid the facts of geology and of past history will strongly believe in the possibilities of progress; but it will also be very anxious not

hastily to throw away anything which has in it the germs of future amelioration.

Here, it seems to me, lies the greatest task of our Universities in the immediate future. Besides keeping up the standard of literary culture on the one hand, and studying physical science largely with a view to practical results on the other, we want to found great schools of human science, schools not starting with any settled theories, but working hard to map out the field, to find the true line of progress in past history, to discern of what human nature is capable, and of what it is incapable. We need both research, and as a corrective to research the foundation of classes of workers who may test the practical validity of the theories formulated by researchers. And we need these schools especially in England. For we are told by all our best advisers that England is falling behind other countries in method and in practical efficiency. In past days, from the time of Locke to that of Darwin, great scientific movements have commonly started in England. There is no reason why we should not at least equal other nations in exploring the vast field of the orderly knowledge of mankind.

It may be said that this task will naturally fall rather to the older Universities, where Humanities flourish, while the newer foundations necessarily devote themselves to studies of more immediate practical application. There is no doubt force in this suggestion. But the older Universi-

ties are dominated, in a degree which is hardly realized by those who have not taught there, by traditional ways of thought. They do not greatly encourage research; and the energies of their ablest men are mostly absorbed in teaching on well-established lines. The newer Universities have at least greater freedom, and greater power of self-adaptation to new needs. I remember reading the first address of your Chancellor to this University; and it seemed to me that although he was no professed savant, yet he had a broader and a saner notion of the functions of a University than was usually current in the older academic bodies. You are the brain of a great working community; and such a community needs to think not only of business success, but of all sides of human life and action.

I know that you have in Birmingham had your attention called before to the overwhelming importance of human science. Some of my distinguished predecessors, Sir Francis Galton and Mr. Karl Pearson have spoken here with the greatest ability and the highest authority on the question of heredity, and other subjects which are on the border-line between biology and the humanities. Doubtless these and similar studies are pursued here in some degree by teachers. It is difficult to over-express our obligations to those who carry on researches which have such direct bearing on the future of mankind. In such matters as these I am only a learner. But I have

given serious attention to two branches of the group of historic studies, those concerned with Ancient Greece and the Origins of Christianity. Even in purely historic studies such as these we greatly need a new spirit and better methods. Above all we need to feel that the whole history of the human race is one; and that everything that has ever happened in the human field may be a light to the present. While investigators, hemmed in by the narrow space of human life, can but master the phenomena of some few phases of history or some aspects of society, all are really working together for a common end.

I have tried to shew that whereas great impulses and ideas come from the unseen, the manner of their working in the world falls within the field of conscious thought and endeavour. And intellect is turning more and more from the attempt to reconcile them with accepted principles, after the manner of the leaders of the French Revolution and the framers of the American constitution, towards the consideration of their results in experience. In our days democracy has arrived, and has come to stay. We have to educate our masters, and in the first place to instruct them as to what really has happened, and does happen in the world. And it seems to me that the average citizen, the man who now governs the world, will soon be more ready to listen to the proved results of experience than to any sort of a priori appeal. To go no

further than to the last general election, it was very notable how on most platforms the appeal was to results and consequences. The average man is being more and more completely trained to the notion that there is a fixed order in the world, and that events do not happen at random. He is now ready in matters of physical science to take the word of those who have been trained, those who really know. He does not perhaps yet recognize so completely that the events of history and of human society may also be matters of definite knowledge, and considering how unripe is most of the fruit of the knowledge of mankind which is offered him, we can scarcely wonder that he does not altogether relish it. That only shews how much remains to be done in this field. We are used to hearing men set forth the patent evils of society, and then at once leap to the propounding of some remedy warranted to set everything right. It is the same procedure with which we are familiar in the advertisements of quack medicines. 'Do you feel languid, out of spirits; have you internal pains? Then try our pill or our ointment.' In the same way those who see the evils of modern society jump at some remedy, some form of socialism it may be, or eugenics, or female suffrage; and set it up as a general remedy. The intermediate stage of studying in what particular way each evil may be met they overlook. What has to be insisted upon is that between the perception of an evil and the pro-

pounding of a remedy there is need for infinite care and investigation, a process which must not be slurred over or abridged, and which involves the keenest exercise of the wisest among us for generations. Here is the opportunity of our Universities.

In human science it is far more important than even in the science of the material world to avoid superficiality and extreme specialism. As man is an unit, all the studies which bear upon him and explain him must be kept together and their results harmonized. Not good but evil would result, if the recognition of human science were to take the form either of teaching superficial rules from books about psychology or pedagogy, or of encouraging a minute subdivision of the field into small plots in which jealous specialists should sit keeping watch against any infringement of their domain, and fully convinced, each of them, that he alone possesses the key of knowledge which should guide conduct. As I have observed, man is an unit, and whether as an individual or in an assembly he must pursue one course and repudiate other courses. The grounds of action have to be taken from a number of different studies; the line of action is necessarily a compromise, and influenced by a great variety of motives. Hence the narrow specialist who thinks the particular results at which he has arrived ought at once to dictate conduct, is as fatal a leader as are the rationalist charlatans of

whom I have spoken. Great collators of results and systematizers of knowledge are a prime necessity of the situation. And they will need the highest faculties which human nature can grow.

I should not of course commit the absurdity of suggesting that all attempts at improving social conditions should be suspended until we have a more precise knowledge of what their results are likely to be. Practical experiments must go on, and they must needs do something to increase the bounds of our knowledge, whether they are successful or not. But I would venture to urge the great need of more complete organization and better endowment for human studies.

If the question be asked how these studies may be organized, the answer seems to be that as they develop they will organize themselves, and each branch of the tree will find its due place. In human science as in natural science one cannot cultivate any part of the field without increasing the productiveness of the whole. A man who gives most of his life to the discovery of a new chemical element, and a man who gives most of his life to the examination of the marks on the backs of crabs or to the respiratory organs of frogs are equally the children of science, and workers in the cause of light. In the same way men will equally be of service to historic science whether they study the antiquities of Greece, or the insti-

tutions of the Middle Ages, the faculties of man or the working of economic laws. All knowledge is really one; and all men of science are what Comte called them, in a sense the priests of humanity.

But to come for a moment to a more practical point of view, I may venture to affirm, from the experience of half a life time in University teaching, that for the due cultivation of any branch of science in a University two things are necessary. First institutes, workships with a settled place for working, with apparatus of all sorts and specialist libraries. For such purposes an ordinary library is insufficient; the books must be within reach, and one must be able to turn them over and criticize them in the presence of fellow-workers. The second thing that is necessary is research studentships, that the workers may at least be able to live while they devote themselves for the good of the community. Whether any such institutes exist at Birmingham I know not; but I am sure that sufficient provision of this kind is not made in any of our English Universities. For work in anthropology, archaeology, statistics, psychology, workshops are as necessary as they are for chemistry or anatomy.

It may be regarded as a paradox if one affirms that studies which deal with the remote past or with obscure barbarous tribes in Africa or Australia have much to do with practical ethics

and sociology. In the pursuit of physical science men have passed this stage of objection. No one would find it difficult to understand that technical chemical researches may have a bearing on the selection of the food we eat, or that biological studies like those of Darwin may have great value in the field of human action and morals. Why then should we doubt that special and minute studies in history and psychology may be a guide to conduct in the present? In all branches of science one pursues the truth for its own sake; but one reaches a result of practical advantage, a far richer result probably than one could ever have attained by limiting one's investigation to what appeared to be fruitful subjects.

The sum of the matter is this. Three appeals are possible in justification of lines of action. The first, that to authority, is passing out of favour. The second, that to fixed principles, must always be of value to all who try to think consistently: but in the haste and confusion of modern life it does not convince people as it used. The third, that to fact and experience, falls in very much with the tendencies of the times; and therefore it is the bounden duty of those who have leisure and intelligence to organize it, to endow it, to give it a great place in our Universities. If it be taken up in a rash and hasty mood, it may lead the human race into infinite trouble. But if taken up in the true spirit of science, modest, slow to affirmation, given to testing again

and again every result, it may furnish the spirit of progress with data of inestimable value, and give us in time a complete chart of the ocean of human life over which we all have to guide our course.

# LIFE AND CONSCIOUSNESS.*

*By Prof. Henri Bergson.*

Generally speaking, when a lecture is dedicated, as this is, to a thinker or scientist whose name it bears, the lecturer has to make an effort, at times an effort of some difficulty, to maintain himself, by the choice of his subject, in the sphere of interests of this thinker or scientist. But, for a lecture associated with the great name of Huxley, no such effort is necessary. Rather, indeed, we may ask what scientific question, what philosophic problem, is there which did not interest that luminous intellect—one of the broadest and most comprehensive that nineteenth-century England produced, fertile in great intellects as it was?

It has seemed to me, however, that the question of consciousness in general—of its relations with nature and life—corresponds fairly well with one of the main lines of Huxley's thought, with one of his chief pre-occupations. And as I personally know none more important nor more crucial in the whole range of philosophy, that is the subject I have chosen.

* The "Huxley Lecture," delivered at the University of Birmingham, May 29, 1911, with some additions.

But, before attacking the problem itself, there is one point to which I wish to call your attention —namely, the meagre light thrown on this problem by the "systems" of philosophy properly so-called. What are we? What are we doing here? Whence do we come and whither do we go? These, it seems, are the essential and vital questions, the questions of supreme interest, which first present themselves to the philosopher and which are, or should be, the very cause of philosophy's existence. But not at all. If we consider the enormous work done in philosophy from antiquity down to the present time, we find that attention has been engrossed with a host of special problems in psychology, in morals, in logic, as well as a crowd of very general metaphysical speculations on the more or less hypothetic principles of things; and then again we find a welter of critical reflections on the manner and method of knowledge, and finally a multitude of works of history and discussion which give us the opinions of thinkers on the opinions of others; but we perceive that those problems which interest us as *human beings* above all else, and which are for us *the* vital problems, have very seldom been squarely faced. I mean that the solution given has been thrown out in passing, as a consequence of certain very general and highly abstract conceptions of Being, of Thought, of Extensity, of Substance, etc. It seems as if philosophy thought it would be slighting the

claims of these problems, failing in respect to them, to study them in the same way as an ordinary question of biology or history, which cannot be resolved save in an approximate, imperfect and provisional manner. No; it seems that for the answer to these great problems some great system is necessary in which solemnly and immutably it may take its place, as a geometrical theorem takes its final place in a book of Euclid. The disadvantage of this way of proceeding is that we thus put in the second place problems which should be in the first; but, besides that, we render the solution of these problems dependent on general systems of philosophy, with which they stand and fall. And then the solution shares in the strictness and rigidity of the system to which it is attached; it must be taken or left, just as it is, and admits of no gradual development or perfecting.

Either I am much deceived or the future belongs to a philosophy which will give back to these problems their rightful place—the first!—which will face them in themselves and for themselves, directly; which, no longer returning to these questions an answer deduced from systematic principles (a self-styled "final" solution, to be replaced in its turn by other solutions which will claim equal finality), will be gradually perfectible, open to corrections, to retouchings and unlimited amplifications; a philosophy that will no longer pretend to have reached a solution of

mathematical certainty (which mathematical certainty, in such a case, must always be deceptive), but will be content (like a good number of sciences at the present time) with a sufficiently high degree of probability, with a probability capable of being pushed farther and farther till it becomes so great that it may end by becoming practically equivalent to certainty. In short, I am of opinion that there is no absolutely certain principle from which the answer to these questions can be deduced in a mathematical way. Nor does there exist a privileged fact, or a collection of privileged facts, from which the answer can be inferred, as, for example, occurs in a problem in physics or chemistry. But it seems to me that in a great number of different fields there is a great number of collections of facts, each of which, considered apart, gives us a direction in which the answer to the problem may be sought—a direction only. But it is a great thing to have even a direction, and still more to have several directions, for at the precise point where these directions converge might be found the solution we are seeking. What we possess meanwhile are *lines of facts*, none of which goes far enough, none of which goes right up to the point which interests us and at which we want to place ourselves; but these lines may be more and more prolonged, and they, moreover, already sufficiently indicate to us, by the ideal prolongation

that is open to us, the region in which the answer to the problem will be found.

Now, it is some of these lines that I desire to follow with you to-day. Each of them, taken apart, will give, I repeat, nothing but a probability; but all together, by converging on the same point, may give us an accumulation of probabilities which will gradually approximate scientific certainty.

Here is the first line I wish to follow, the first aspect of the question that I wish to point out to you. What we call "the mind" is, before all, something conscious—it is consciousness. But what do we mean by consciousness? You rightly guess that I am not going to define this simple thing which eludes all definition, and which everyone can experience. But, without exactly giving a definition which would be much less clear than the thing defined, we may at least indicate its most obvious and most striking character. Consciousness signifies, above all, memory. The memory may not be very extensive; it may embrace only a very small section of the past, nothing indeed but the immediate past; but, in order that there may be consciousness at all, something of this past must be retained, be it nothing but the moment just gone by. A consciousness which retained nothing of the past would be a consciousness that died and was reborn every instant—it would be no longer consciousness. Such is just the condition of

matter; or, at least, such is just the way we represent matter when we wish to oppose it to consciousness. Leibnitz defined matter—that is to say, what is not consciousness—by calling it a momentary mind, an instantaneous consciousness. And, in fact, an instantaneous consciousness is just what we call unconsciousness. All consciousness, then, is memory; all consciousness is a preservation and accumulation of the past in the present.

But, on the other hand, all consciousness is an anticipation of the future. Analyse your mental state when you hear someone speaking: you are intent on what is being said, but also on what is coming; and even the present only interests you in so far as it will profit the immediate future. We are essentially drawn and, as it were, inclined towards the future, because we are creatures of action, and every action is like a leap into the future—into the next moment.

So that to remember the immediate past and to anticipate the immediate future is the most striking function of consciousness. Indeed, what we call the present instant is something that hardly exists except in theory, for it has already ceased to exist when it attracts our attention. Try to catch the present instant, it has already gone, it is already far away. Practically, what we call our present is something that has a certain length or breadth of duration, and is composed of two halves, one being our immediate past, the other

our immediate future. What we feel ourselves to be at any given moment is what we were just before and what we are just about to be: we recline on our past and incline towards our future, and that reclining and inclining seem to be the very essence of our consciousness. So that consciousness is, above all, a hyphen, a tie between past and future. Now what is the use of such a tie, and what is consciousness called upon to do?

To reply to this question, we must first ask what are, in the whole of Nature, the creatures which, to all appearances, are conscious beings. To tell the truth, in order to be absolutely sure that a being is conscious like ourselves, we ought to penetrate it, to be it. Here, again, if we seek for mathematical certainty, we shall obtain nothing, for you cannot even be mathematically sure that I, who am speaking to you at this moment, possess a consciousness. I might be a well-constructed automaton—going, coming, speaking—without internal consciousness, and the very words by which I declare at this moment that I am a conscious being might be words pronounced without consciousness. However, though this is mathematically possible, and consequently the existence of my consciousness cannot be for you a matter of mathematical certainty, I think that it is sufficiently probable for you. The truth is, that whenever you assume consciousness in a being other than yourself, you infer this consciousness from certain outward analogies that you find

between this being and yourself. So let us follow up this reasoning by analogy, and ask ourselves up to what point it is probable that consciousness may be imputed to nature, and at what point it probably stops short.

One reply sometimes made to the question is this: In ourselves, consciousness is bound up in one way or another with a brain; we may therefore assume the presence of consciousness in all those living beings in whom a brain is found, and in those alone. But a moment's reflection will show us the fallacy of this reasoning. For in applying elsewhere this mode of argument, we might as well say: digestion in us is bound up with a stomach, therefore we ought to attribute the faculty of digestion to the living beings who possess stomachs, and to those alone. Now this would be absolutely wrong, for living beings who have no stomachs and even no organs, which consist of a simple protoplasmic mass, are still able to digest. Only, in proportion as the organism becomes more perfect, a division of labour is brought about: special organs are destined to diverse functions instead of the whole mass doing all, and the digestive faculty becomes localised in a stomach and in other organs which accomplish it *better*, whilst the rest of the organism renounces the faculty, having got rid of this care by putting it on to a special organ. But the function was previously performed in the undifferentiated organism: it was performed all over it, though

with less precision. Now, without doubt, in ourselves consciousness is bound up with a brain in some way, but as we descend in the animal scale we see the brain become more and more simplified (as also does the whole nervous system), and then the nervous centres separate from each other, until finally the nervous elements are merged in the mass of undifferentiated living tissue. Now, is it not probable that if, at the top of the organic scale, clear and distinct consciousness is bound up with a brain and a highly differentiated nervous system, consciousness accompanies this system the whole length of the descent, and that ultimately, when the nervous substance is merged in the rest of living matter, consciousness itself is diffused in the whole of this mass: diffused, confused, weakened, but not reduced to nothing? So that, in the end, consciousness might exist in Nature wherever there is living matter. At least, it is not impossible. But is it actually the case? I believe it would be going too far, and here is a fresh line of considerations which will, I think, lead us to limit this conclusion to a certain degree.

We have just said that in the conscious being that we know best—namely, man—consciousness appears in some way to be bound up with a brain. Since in this case it is through a brain that the consciousness works, and since the work is thus performed with the greatest precision, let us glance at the brain, and ask ourselves what are its most obvious functions. The brain, as you

know, forms part of a whole called the cerebro-spinal nervous system, which, in addition to the brain itself, comprises the spinal cord, the nerves, etc. In the spinal cord are set up mechanisms which permit the various parts of our body to perform complicated and well co-ordinated movements. These mechanisms may be set in action without the intervention of the brain, under the direct influence of an external stimulus; in such a case, the bodily reaction follows immediately on the stimulation. But there are cases in which the external stimulus, instead of obtaining at once, through the spinal cord, an appropriate bodily reaction, goes up to the brain, in order to come down again thence to the spinal cord, and only then obtains from the cord the complex physical movement. Why did it go to the brain? And what has it gained by this roundabout proceeding? A glance thrown on the general structure of the brain will answer these questions. The brain is in communication with those mechanisms of the spinal cord that we have just referred to, and can send to any one of them the order to work. Imagine a stimulation coming to the brain from without, by the eye, ear or touch. The brain is like a switch having the faculty of putting the current thus received in communication with one or other of the motor mechanisms of the spine, chosen at will. So that in sum, and broadly speaking, the spinal cord is a storehouse of ready-made complex actions, and the brain is

the organ permitting choice, in any circumstances, of that particular complex action which is appropriate. The brain is the organ of choice.

Now, according as we descend in the animal scale, we see that the functions of the brain and those of the spinal cord become less differentiated, as if a part at least of the faculty of choosing, which in us is attached to the brain, had descended to the spinal cord. In this latter, then, we see that the mechanical attachments are fewer, and probably also constructed with less precision. Finally, it seems indeed as if the two functions, the one an absolutely precise automatism, the other an absolute faculty of choice, become mingled, and blend with each other so thoroughly that when we arrive at organisms in which there are only a few heaps of nerve-cells scattered here and there, and even more so when we come to organisms where there are no longer differentiated nerve-cells, we are faced by a living substance such that external stimulus provokes from it a reaction both undecided, though not altogether chosen (there comes in the element of choice), and ill-defined although aiming at a certain precision (there comes in the element of automatism). Such is probably the condition of an amœba—of one of those tiny lumps of protoplasmic jelly you can see with the microscope in a drop of water. When anything that can be turned into food floats by, the amœba throws out in various directions protoplasmic filaments

which draw the substance towards it. These pseudopodia are temporary organs, ill-defined (there comes in the element of mechanism), but everything seems to happen as if there were at least a rudiment of intention on the part of the little organism, a certain choice of appropriate movements.

It appears, therefore, as if from the top to the bottom of the animal scale there is present (although the lower we go, the more vaguely it is seen) the faculty of choice, and more particularly the choice of action, of combined movements, in response to stimulation arising from without. This is what we find in pursuing our second line of facts. Now, observe that the point we come out at is pretty close to that to which the first line led us. We said, you will remember, that the function of consciousness seemed primarily to retain the past and to anticipate the future. That is quite natural if its function is to preside over actions which are *chosen*. For choice implies that one thinks of what is to be,—of the immediate future,—with a view to creating this future to some extent; and that cannot be done save by profiting from past experience—by retaining the past in order to project it within the future.

But all this gives no answer as yet to the question we put: Does consciousness cover the whole domain of life? and if it does not extend everywhere, where does it stop?

We have not yet the answer to this question, it is true; but we are getting near it. For if consciousness implies choice, and choice amongst various possible actions, consciousness will not be found presumably in organisms that do not possess the power of free action—the power, consequently, to choose between several actions. In very truth, I believe no living organism is absolutely without the faculty of performing actions and moving spontaneously; for we see that even in the vegetable world, where the organism is for the most part fixed to the ground, the faculty of motion is asleep rather than absent altogether. Sometimes it wakes up, just when it is likely to be useful. Therefore, in principle, this faculty of spontaneous motion probably exists in every living thing; but, in actual fact, many organisms have given it up,—as, for example, the numerous animals living as parasites on other organisms, and thus able to get their food on the spot, and again, almost the entire vegetable kingdom. It seems probable, therefore, and this is my last word on the point, that consciousness is in principle present in all living matter, but that it is dormant or atrophied wherever such matter renounces spontaneous activity, and on the contrary that it becomes more intense, more complex, more complete, just where living matter trends most in the direction of activity and movement. Observe that this is a point we can experience in ourselves. Precisely as our actions cease to be spontaneous

and become automatic, consciousness is withdrawn from them; when we learn a new physical exercise, for example, and have to decide on each of our motions and choose that which is appropriate, we have distinct consciousness of each. As we get used to the exercise and it becomes automatic, consciousness fades away. Again, when is our consciousness most acute, most intensely alive? Is it not, above all, at those times of internal crisis when we are hesitating between several possible actions, several lines of conduct that are equally possible? Consciousness in each of us, then, seems to express the amount of choice, or, if you will, of creation, at our disposal for movements and activity. Analogy authorises us to infer that it is the same in the whole of the organised world.

Let us consider living matter, then, under its simplest form, as it may have been in the beginning: a simple mass of protoplasmic jelly like that of an amœba. This mass can change its shape at will—it is therefore vaguely conscious. Now, in order to develop and evolve, two courses are open to it. Either it may follow the path leading towards movement, action—action growing more and more complex, more and more deliberate and free as time goes on: this means adventure and risk, but means also a consciousness more and more wide awake and luminous. Or, on the contrary, giving up the faculty of movement and choice that it possesses, even

though of course in very feeble degree, it may decide to fix itself just where it finds suitable conditions of life which will do away with the necessity of going to seek the materials it requires: that means an assured and tranquil life, a humdrum sort of existence, but it involves the drowsiness which dogs our inactivity, the slumber of consciousness.* The former direction corresponds in the main to the line of animal development (I say in the main, because many species of animals give up their mobility, and thus probably also their consciousness); the latter, in the main, is proper to vegetables; again I say "in the main," since the faculty of moving, and probably therefore also of consciousness, may occasionally reawaken in vegetable life.

Now, if we consider from this standpoint the entrance of life in the world, this entrance will appear to us like the introduction, into the world, of something that encroaches upon inert matter. In the non-living unorganised world, if this were left alone, necessity would sit enthroned. In determinate conditions inert matter reacts in a determinate way; in the inanimate world nothing is unforeseeable, and if our science were sufficiently advanced we should be able to foretell what will happen there, precisely as we can foretell the eclipses of the sun and moon. In short, inert matter is subject to mathematical necessity.

* See on this subject: Cope, *The Origin of the Fittest*, 1887, p. 76.

But, with the coming of life, we see the appearance of indetermination. A living being, no matter how simple, is a reservoir of indetermination and unforeseeability, a reservoir of possible actions or, in a word, of *choice*. And in it, too, we find that faculty of imagining future eventualities (or, speaking more generally, of anticipating the future), and at the same time of storing up the past for that purpose, which is the faculty of consciousness.

If this be so, consciousness and matter would appear to be antagonistic forces, which, nevertheless, come to a mutual understanding and manage somehow to get on together. They are antagonistic in this, that matter is theoretically the realm of fatality, while consciousness is essentially that of liberty; and yet life, which is nothing but consciousness using matter for its purposes, succeeds in reconciling them. Life, therefore, must be something which avails itself of a certain elasticity in matter—slight in amount as this probably is—and turns it to the profit of liberty by stealing into whatever infinitesimal fraction of indetermination that inert matter may present. Now I believe that this twofold conclusion is precisely what we shall come to after following certain other lines of facts, and that in following these lines we may, moreover, catch a glimpse at once of *how* consciousness finds matter an obstacle, and *how*, notwithstanding, it succeeds in making use of it. I will begin with the last point.

If we ask ourselves *how* a conscious animal succeeds in obtaining from matter—that is to say, from its body—the execution of movements on which it has decided, we find that its method consists in making use of special substances which might be called " explosives." These substances are the foodstuffs, more particularly those called ternary, the essential elements of which are carbon, oxygen and hydrogen. In these foodstuffs is stored up a considerable amount of potential energy, ready to burst out suddenly, like the energy stored up in gunpowder. This energy has been slowly, gradually, borrowed from the sun by plants; and the animal which feeds on a plant, or on another animal that has fed on a plant, or on an animal that has fed on another animal that has fed on a plant, etc., thus passes into his own body an explosive made by life through a storage of solar energy: when this animal performs voluntary movements, it does so by simply producing the infinitesimal spark which sets off the explosive—by, as it were, just brushing the trigger of a pistol and thus setting free a considerable force in the direction chosen at will. Now if, in the beginning, the first living beings swayed between animal and vegetable conditions, sharing at once in both one and the other, it is because life at its origin had to perform the double work of making the explosive and turning it to account. In proportion as plants and animals differentiated, life split up into two king-

doms, of which one, the less concerned with movement, was more concerned with making the explosive, whilst the other confined itself to making use of it. Nevertheless, the essence of life seems to be to secure that matter, by a process necessarily very slow and difficult, should store up energy ready for life afterwards to expend this energy suddenly in free movements. Now, what precisely would a free cause do—a cause incapable of forcing the necessity of matter, or only able to force it to an infinitesimal extent, and which, nevertheless, were desirous of producing movements of increasingly greater power? It would act in precisely this way. It would arrange so as merely to have to press, as it were, the trigger of a pistol in which there would be no friction, or to furnish an infinitesimal spark, profiting by an energy that it would have gradually accumulated by turning every movement to account.

But we arrive at the same conclusion if we regard the living and conscious being along a different line of facts—not on the side of "choice," but on that of "memory." By what sign do we recognise in current experience a "man of action,"—I mean a man able to impress his mark on the events, large or small, amongst which he evolves? Surely by the fact that he can take in, at a single glance, a great number of things, especially a great number of previous happenings. He seizes all these in a single perception

which instructs him for the action he prepares. The more successive events he seizes in this single glance, the better he succeeds in dominating them. Now, if we consider consciousness confronted with matter, we find that it is characterised by just this fact, that in an interval which for it is infinitely short, and which constitutes one of our "instants," it seizes under an indivisible form millions and billions of events that succeed each other in inert matter. Yes, that indivisible sensation of light which I have at this moment, if I open my eyes for a single instant, is the condensation of an immensely long history unrolling itself in the world of matter: there are, in that single instant, billions of successive vibrations—that is to say, a series of events such that, if I wished to count them even with the utmost rapidity, it would require thousands and thousands of years for the enumeration. It is this immense history that I seize all at once under the pictorial form of a very brief sensation of light. And we could say just the same of all our other sensations. Sensation, which is the point at which consciousness touches matter, is, then, the condensation, in the duration peculiar to this consciousness, of a history which in itself,—in the world of matter,—is something infinitely diluted, and which occupies enormous periods of what might be called the duration of things. So, looked at from the side of sensation, consciousness gives us the same impression as it did just

now from the side of movement. Consciousness behaves just like a power entering matter in order to draw the highest possible advantage from the elasticity it finds therein, to take possession of matter from the side of movement as well as from that of sensation: from the side of movement, by an explosive action setting free, in a flash, energy drawn from matter through years and years, and directing this energy in a chosen way; from the side of sensation, by an effort of concentration which seizes as a whole, in one moment, billions of events happening in things, and thus allows us to control them.

Thus all the lines of facts we follow seem to converge on the same point, a point at which we seem to see the following image arise: on the one hand, matter subject to necessity, a kind of immense machine, without memory, or at least having only just sufficient memory to bridge the interval between one instant and the next, each of the states of the material world being capable, or almost so, of mathematical deduction from the preceding state, and consequently adding nothing thereto; on the other hand, consciousness—that is to say, on the contrary, a force essentially free and essentially memory, a force whose very character is to pile up the past on the past, like a rolling snowball, and at every instant of duration to organise with this past something new which is a real creation. That these two forms of existence, matter and consciousness, have indeed a

common origin, seems to me probable. I believe that the first is a reversal of the second, that while consciousness is action that continually creates and multiplies, matter is action which continually unmakes itself and wears out; and I believe also that neither the matter constituting a world nor the consciousness which utilises this matter can be explained by themselves, and that there is a common source of both this matter and this consciousness. But I cannot now enter deeply into this question. Let it suffice to say that I see in the whole evolution of life on our planet an effort of this essentially creative force to arrive, by traversing matter, at something which is only realised in man, and which, moreover, even in man, is realised only imperfectly.

There is no need to recall here all the facts which, since Lamarck in France and Darwin in England, have been adduced to confirm the idea of an evolution of species, that is to say, of the generation of some species from others, commencing by forms probably of infinite simplicity. I think that on this head it is impossible to dispute the results accepted to-day by practically all biologists. And it is impossible not to admire the enormous amount of effort expended during the last fifty years to show the part played in the evolution of living beings by the necessity these labour under to adapt themselves to their environment. But this necessity of adaptation explains, to my thinking, the arrests of life at

such or such determinate forms much more than the movement through which life becomes more complex and raises itself towards greater and greater efficiency. A very simple rudimentary being is as well adapted as a man to its environment, since it succeeds in living in it: why, then, if adaptation explains everything, has life gone on complicating itself, and, moreover, complicating itself more and more delicately and *dangerously?* Molluscs such as the Lingulæ, existing at the present time, existed also in the remotest ages of the palæozoic era. Why did life go any further? Why, if there is not behind life an impulse, an immense impulse to climb higher and higher, to run greater and greater risks in order to arrive at greater and greater efficiency?

I think it is hard to survey the whole of the evolution of life without the impression that this impulse is a reality. The error is to believe that this impulse has projected living matter in a single direction, that species are classified along a single scale, that everything has gone on smoothly and without let or hindrance. It is, on the contrary, obvious that the force I speak of has found resistances in the matter it had to make use of; that it has been obliged to split up—I mean to share along lines of different evolution the different tendencies it carried; that on each of these lines there is a crowd of failures, of deviations, of reversions; that many of these lines of evolution have not been able to go on very far; that

two alone seem to have led to a certain success, partial only on one, but relatively complete on the other. These two lines are those of the Arthropods and the Vertebrates. At the end of the first we find instinct in its most marvellous forms; at the end of the second, the human intellect. It seems then, indeed, as if the force I speak of were a force that contained in itself, at least potentially, and interfused, the two forms of consciousness that we call instinct and intelligence.

Things seem to happen as if an immense current of consciousness (a consciousness which includes a multitude of potentialities all crowding on and hindering each other) had traversed matter in order to entice it to organisation and make of this matter, which is necessity itself, an instrument of liberty. But it has scarcely escaped being itself ensnared. Matter, which is essentially automatism and necessity, enfolds the consciousness which seeks to entice it, converts it to its own automatism, and lulls it into its own unconsciousness. On certain lines of evolution, as, for example, in the vegetable kingdom, this automatism and unconsciousness have become the rule, and the liberty of the evolutive force cannot show itself except in the creation of forms which are, indeed, veritable works of art. These unforeseeable forms, once created, repeat themselves automatically, and the individual has no power of choice. On other lines, consciousness

succeeds in disentangling itself sufficiently for the individual to have a certain latitude of choice, a certain feeling, but the necessities of life are there, and make of this power of choice a simple auxiliary of material existence. Thus, along the whole course of the evolution of life, liberty is dogged by automatism, and in the long run is stifled by it. With man alone the chain has been broken. I cannot here enter into detail as to the causes which have permitted life, by a sudden leap from animal to man, to break the chain. I confine myself to saying that the human brain, although, seen from without, it differs little from that of a highly developed animal, yet possesses this remarkable feature—that it can oppose to every contracted habit another habit, to every kind of automatism another automatism, so that in man liberty succeeds in freeing itself by setting necessity to fight against necessity.

I doubt that the evolution of life will ever be explained by a mere combination of mechanical forces. Obviously there is a vital impulse : what I was just calling an impulse towards a higher and higher efficiency, something which ever seeks to transcend itself, to extract from itself *more* than there is—in a word, to create. Now, a force which draws from itself more than it contains, which gives more than it has, is precisely what is called a *spiritual* force : in fact, I do not see how otherwise spirit is to be defined. But, on the other hand, we are wrong when we fail to take

into account, in the explanation of the organic world, the obstacles of every kind which this force encounters. The spectacle of the evolution of life from its very beginning down to man suggests to us the image of a current of consciousness which flows down into matter as into a tunnel, which endeavours to advance, which makes efforts on every side, thus digging galleries most of which are stopped by a rock that is too hard, but which, in one direction at least, prove possible to follow to the end and break out into the light once more. This direction is the line of evolution resulting in man. Now, what has been gained by forcing this tunnel, and why did life start on the undertaking? Here, again, new lines of facts might lead us to a plausible conclusion, one that may become more and more probable. But I have so little time, and it would be necessary to enter into such great detail on the mechanism of psychical facts—above all, on the physio-psychological relation—that I can now only formulate briefly my conclusions. When, setting one against the other, we examine consciousness and matter in their mutual reactions, we have the impression that matter plays at first, in relation to consciousness, the part of an instrument that cuts it up in order to bring about a greater precision. A thought only becomes precise when it is divided into words, that is, if it can be so divided; an orator does not quite know what he is going to say, and what he means to say, until he has taken

a sheet of paper and set forth clearly in separate phrases, placed side by side, what in his mind was given in a state of mutual interpenetration. Thus first does matter separate that which was blended, and distinguish what was confused. But moreover, and above all, matter is what provokes effort and renders it possible. The thought which is only thought, the work of art which is only in the conceptual state, the poem which is only a dream, costs as yet no effort: what requires an effort is the material realisation of the poem in words, of the artistic conception in a statue or a picture. This effort is painful, it may be very painful; and yet, whilst making it, we feel that it is as precious as, and perhaps more precious than, the work it results in, because, thanks to it, we have drawn from ourselves not only all that was there, but more than was there: we have raised ourselves above ourselves.

Now, this effort would not have been put forth without matter, which, by the unique nature of the resistance it opposes and the unique nature of the docility to which it can be brought, plays at one and the same time the rôle of obstacle and stimulus, causes us to feel our force and also to succeed in intensifying it.

Philosophers who have speculated on the significance of life and the destiny of man have not sufficiently remarked that Nature has taken pains to give us notice every time this destiny is accomplished; she has set up a sign which

apprises us every time our activity is in full expansion; this sign is joy. I say joy; I do not say pleasure. Pleasure, in point of fact, is no more than an instrument contrived by Nature to obtain from the individual the preservation and the propagation of life; it gives us no information concerning the direction in which life is flung forward. True joy, on the contrary, is always an emphatic signal of the *triumph* of life. Now, if we follow this new line of facts, we find that wherever joy is, creation has been, and that the richer the creation the deeper the joy. The mother looking upon her child is joyous because she has the consciousness of having created it, physically and morally. A man who succeeds in his enterprise—for example, a captain of industry whose business is prospering—is he joyous solely on account of the money he is winning and the notoriety he has acquired? Doubtless these elements count for much in the satisfaction he feels; but they bring him pleasures rather than joy, and whatever true joy he tastes belongs essentially to the consciousness he has of having established an enterprise which marches on, of having created something that goes ahead. Consider exceptional joys like those of the great artist who has produced a masterpiece, of the scientific man who has made a discovery or invention. We sometimes say they have worked for glory and derive their greatest satisfaction from the applause of mankind. Profound mistake!

We care for praise in the exact measure in which we feel not sure of having succeeded; it is because we want to be reassured as to our own value and as to the value of what we have done that we seek praise and prize glory. But he who is certain, absolutely certain, that he has brought a living work to the birth, cares no more for praise and feels himself beyond glory, because there is no greater joy than that of feeling oneself a creator. If, then, in every province, the triumph of life is expressed by creation, ought we not to think that the ultimate reason of human life is a creation which, in distinction from that of the artist or man of science, can be pursued at every moment and by all men alike; I mean the creation of self by self, the continual enrichment of personality by elements which it does not draw from outside, but causes to spring forth from itself?

May we not therefore suppose that the passage of consciousness through matter is destined to bring to precision,—in the form of distinct personalities,—tendencies or potentialities which at first were mingled, and also to permit these personalities to test their force whilst at the same time increasing it by an effort of self-creation? On the other hand, when we see that consciousness, whilst being at once creation and choice, is also memory, that one of its essential functions is to accumulate and preserve the past, that very probably (I lack time to attempt the demonstration of this point) the brain is an instrument of

forgetfulness as much as one of remembrance, and that in pure consciousness nothing of the past is lost, the whole life of a conscious personality being an indivisible continuity, are we not led to suppose that the effort continues *beyond*, and that in this passage of consciousness through matter (the passage which at the tunnel's exit gives distinct personalities) consciousness is tempered like steel, and tests itself by clearly constituting personalities and preparing them, by the very effort which each of them is called upon to make, for a higher form of existence? If we admit that with man consciousness has finally left the tunnel, that everywhere else consciousness has remained imprisoned, that every other species corresponds to the arrest of something which in man succeeded in overcoming resistance and in expanding almost freely, thus displaying itself in true personalities capable of remembering all and willing all and controlling their past and their future, we shall have no repugnance in admitting that in man, though perhaps in man alone, consciousness pursues its path beyond this earthly life.

This is as much as to say that, in my opinion, the aspirations of our moral nature are not in the least contradicted by positive science. On this, as on many other points, I quite agree with the opinion expressed by Sir Oliver Lodge in many of his works, and especially in his admirable book on *Life and Matter*. How could there be disharmony between our intuitions and our science,

how especially could our science make us renounce our intuitions, if these intuitions are something like instinct—an instinct conscious, refined, spiritualised—and if instinct is still nearer life than intellect and science? Intuition and intellect do not oppose each other, save where intuition refuses to become more precise by coming into touch with facts scientifically studied, and where intellect, instead of confining itself to science proper (that is, to what can be inferred from facts or proved by reasoning), combines with this an unconscious and inconsistent metaphysic which in vain lays claim to scientific pretensions. The future seems to belong to a philosophy which will take into account the whole of what is given: I shall have attained the object I proposed if I have succeeded in indicating to you, however vaguely, the direction in which such a philosophy would lead us.

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PARIS.

# PLEOCHROIC HALOES.*

*By Prof. John Joly, F.R.S.*

It is now well established that a helium atom is expelled from certain of the radioactive elements at the moment of transformation. The helium atom or alpha ray leaves the transforming atom with a velocity which varies in the different radioactive elements, but which is always very great, attaining as much as $2 \times 10^9$ cms. per second; a velocity which, if unchecked, would carry the atom round the earth in less than two seconds. The alpha ray carries a positive charge of double the ionic amount.

When an alpha ray is discharged from the transforming element into a gaseous medium its velocity is rapidly checked and its energy absorbed. A certain amount of energy is thus transferred from the transforming atom to the gas. We recognise this energy in the gas by the altered properties of the latter; chiefly by the fact that it becomes a conductor of electricity. The mechanism by which this change is effected is in part known. The atoms of the gas, which appear to be freely penetrated by the alpha ray, are so

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far dismembered as to yield charged electrons or ions; the atoms remaining charged with an equal and opposite charge. Such a medium of free electric charges becomes a conductor of electricity by convection when an electromotive force is applied. The gas also acquires other properties in virtue of its ionisation. Under certain conditions it may acquire chemical activity and new combinations may be formed or existing ones broken up. When its initial velocity is expended the helium atom gives up its properties as an alpha ray and thenceforth remains possessed of the ordinary varying velocity of thermal agitation. Bragg and Kleeman and others have investigated the career of the alpha ray when its path or range lies in a gas at ordinary or obtainable conditions of pressure and temperature. We will review some of the facts ascertained.

The range or distance traversed in a gas at ordinary pressures is a few centimetres. The following table, compiled by Geiger, gives the range in air at the temperature of 15° C.:—

| | cms. |
|---|---|
| Uranium 1 ... .. ... ... | 2.50 |
| Uranium 2 ... .. ... ... | 2.90 |
| Ionium ... ... ... ... ... | 3.00 |
| Radium ... ... ... ... ... | 3.30 |
| Ra Emanation ... ... ... ... | 4.16 |
| Radium A ... ... ... ... | 4.75 |
| Radium C ... ... ... ... | 6.94 |
| Radium F ... ... ... ... | 3.77 |

| | cms. |
|---|---|
| Thorium ... ... ... ... ... | 2.72 |
| Radiothorium ... ... ... ... | 3.87 |
| Thorium X ... ... ... ... | 4.30 |
| Th Emanation ... ... ... ... | 5.00 |
| Thorium A ... ... .. ... | 5.70 |
| Thorium $C_1$ ... ... ... ... | 4.80 |
| Thorium $C_2$ ... ... ... ... | 8.60 |

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| | cms. |
|---|---|
| Radioactinium ... ... ... ... | 4.60 |
| Actinium X ... ... ... ... | 4.40 |
| Act Emanation ... ... ... ... | 5.70 |
| Actinium A ... ... ... ... | 6.50 |
| Actinium C ... ... ... ... | 5.40 |

It will be seen that the ray of greatest range is that proceeding from thorium $C_2$, which reaches a distance of 8·6 cms. In the uranium family the fastest ray is that of radium C. It attains 6·94. cms. There is thus an appreciable difference between the ultimate distances traversed by the most energetic rays of the two families. The shortest ranges are those of uranium 1 and 2.

The ionisation effected by these rays is by no means uniform along the path of the ray. By examining the conductivity of the gas at different points along the path of the ray, the ionisation at these points may be determined. At the limits of the range the ionisation ceases. In this manner the range is, in fact, determined. The dotted curve (Fig. 1) depicts the recent investigation of the ionisation effected by a sheaf of parallel rays of radium C in air, as determined by Geiger.

The range is laid out horizontally in centimetres. The numbers of ions are laid out vertically. The remarkable nature of the results will be at once apparent. We should have expected that the ray at the beginning of its path, when its velocity and kinetic energy were greatest, would have been more effective than towards the end of its range when its energy had almost run out. But the curve shows that it is just the other way. The lagging ray, about to resign its ionising properties, becomes a much more efficient ioniser than it was at first. The maximum efficiency is, however, in the case of a bundle of parallel rays, not quite at the end of the range, but about half a centimetre from it. The increase to the maximum is rapid, the fall from the maximum to nothing is much more rapid.

It can be shown that the ionisation effected anywhere along the path of the ray is inversely proportional to the velocity of the ray at that point. But this evidently does not apply to the last 5 or 10 mms. of the range where the rate of ionisation and of the speed of the ray change most rapidly. To what are the changing properties of the rays near the end of their path to be ascribed? It is only recently that this matter has been elucidated.

When the alpha ray has sufficiently slowed down, its power of passing right through atoms, without appreciably experiencing any effects from them, diminishes. The opposing atoms begin to

exert an influence on the path of the ray, deflecting it a little. The heavier atoms will deflect it most. This effect has been very successfully investigated by Geiger. It is known as "scattering." The angle of scattering increases rapidly with the decrease of velocity. Now the effect of the scattering will be to cause some of the rays to complete their ranges or, more accurately, to leave their direct line of advance a little sooner than others. In the beautiful experiments of C. T. R. Wilson we are enabled to obtain ocular demonstration of the scattering. The photograph (Fig. 2), which I owe to the kindness of Mr. Wilson, shows the deflection of the ray towards the end of its path. In this case the path of the ray has been rendered visible by the condensation of water particles under the influence of the ionisation; the atmosphere in which the ray travels being in a state of supersaturation with water vapour at the instant of the passage of the ray. It is evident that if we were observing the ionisation along a sheaf of parallel rays, all starting with equal velocity, the effect of the bending of some of the rays near the end of their range must be to cause a decrease in the aggregate ionisation near the very end of the ultimate range. For, in fact, some of the rays complete their work of ionising at points in the gas before the end is reached. This is the cause, or at least an important contributory cause, of the decline in the ionisation near the end of the range, when the

effects of a bundle of rays are being observed. The explanation does not suggest that the ionising power of any one ray is actually diminished before it finally ceases to be an alpha ray.

The full line in Fig. 1 gives the ionisation curve which it may be expected would be struck out by a single alpha ray. In it the ionisation goes on increasing till it abruptly ceases altogether, with the entire loss of the initial kinetic energy of the particle.

A highly remarkable fact was found out by Bragg. The effect of the atom traversed by the ray to check the velocity of the ray is independent of the physical and chemical condition of the atom. He measured the "stopping power" of a medium by the distance the ray can penetrate into it compared with the distance to which it can penetrate in air. The less the ratio the greater the stopping power. The stopping power of a substance is proportional to the square root of its atomic weight. The stopping power of an atom is not altered if it is in chemical union with another atom. The atomic weight is the one quality of importance. The physical state, whether the element is in the solid, liquid or gaseous state, is unimportant. And when we deal with molecules the stopping power is simply proportional to the sum of the square roots of the atomic weights of the atoms entering into the molecule. This is the "additive law," and it obviously enables us to calculate what the range

in any substance of known chemical composition and density will be, compared with its range in air.

This is of special importance in connection with phenomena we have presently to consider. It means that, knowing the chemical composition and density of any medium whatsoever, solid, liquid or gaseous, we can calculate accurately the distance to which any particular alpha ray will penetrate. Nor have the temperature and pressure to which the medium is subjected any influence save in so far as they may affect the proximity of one atom to another. The retardation of the alpha ray in the atom is not affected.

This valuable additive law cannot, however, in strictness be applied to the amount of ionisation attending the ray. The form of the molecule, or more generally its volume, may have an influence upon this. Bragg draws the conclusion, from this fact as well as from the notable increase of ionisation with loss of speed, that the ionisation is dependent upon the time the ray spends in the molecule. The energy of the ray is, indeed, found to be less efficient in producing ionisation in the smaller atoms.

Before leaving our review of the general laws governing the passage of alpha rays through matter, a point of interest must be referred to. We have hitherto spoken in general terms of the fact that ionisation attends the passage of the ray. We have said nothing as to the nature of

the ionisation so produced. But in point of fact the ionisation due to an alpha ray is *sui generis*. A glance at one of Wilson's photographs (Fig. 2) illustrates this. The white streak of water particles marks the path of the ray. The ions produced are evidently closely crowded along the track of the ray. They have been called into existence in a very minute instant of time. Now we know that ions of opposite sign if left to themselves recombine. The rate of recombination depends upon the product of the number of each sign present in unit volume. Here the numbers are very great and the volume very small. The ionic density is therefore high, and recombination very rapidly removes the ions after they are formed. We see here a peculiarity of the ionisation effected by alpha rays. It is linear in distribution and very local. Much of the ionisation in gases is again undone by recombination before diffusion leads to the separation of the ions. This "initial recombination" is greatest towards the end of the path of the ray where the ionisation is a maximum. Here it may be so effective that the form of the curve is completely lost unless a very large electromotive force is used to separate the ions when the ionisation is being investigated.

We have now reviewed recent work at sufficient length to understand something of the nature of the most important advance ever made in our knowledge of the atom. Let us glance briefly at what we have learned. The radioactive

atom in sinking to a lower atomic weight casts out with enormous velocity an atom of helium. It thus loses a definite portion of its mass and of its energy. Helium which is chemically one of the most inert of the elements, is, when possessed of such great kinetic energy, able to penetrate and ionise the atoms which it meets in its path. It spends its energy in the act of ionising them, coming to rest, when it moves in air, in a few centimetres. Its particular initial velocity depends upon which of the radioactive elements has given rise to it. The length of its path is therefore different according to the radioactive element from which it proceeds. The retardation which it experiences in its path depends entirely upon the atomic weight of the atoms which it traverses. As it advances in its path its effectiveness in ionising the atom rapidly increases and attains a very marked maximum. In a gas the ions produced being much crowded together recombine rapidly; so rapidly that the actual ionisation may be quite concealed unless a sufficiently strong electric force is applied to separate them. Such is a brief summary of the climax of radioactive discovery:—the birth, life and death of the alpha ray. Its advent into Science has altered fundamentally our conception of matter. It is fraught with momentous bearings upon Geological Science. How the work of the alpha ray is sometimes recorded visibly in the rocks and what we may learn from that record I propose now to bring before you.

In certain minerals, notably the brown variety of mica known as biotite, the microscope reveals minute circular marks occurring here and there, quite irregularly. The most usual appearance is that of a circular area darker in colour than the surrounding mineral. The radii of these little disc-shaped marks when well defined are found to be remarkably uniform, in some cases four-hundredths of a millimetre and in others three-hundredths, about. These are the measurements in biotite. In other minerals the measurements are not quite the same as in biotite. Such minute objects are quite invisible to the naked eye. In some rocks they are very abundant, indeed they may be crowded together in such numbers as to darken the colour of the mineral containing them. They have long been a mystery to petrologists.

Close examination shows that there is always a small speck of a foreign body at the centre of the circle, and it is often possible to identify the nature of this central substance, small though it be. Most generally it is found to be the mineral zircon. Now this mineral was shown by Strutt to contain radium in quantities much exceeding those found in ordinary rock substances. Some other mineral may occasionally form the nucleus, but we never find any which is not known to be specially likely to contain a radioactive substance. Another circumstance we notice. The smaller this central nucleus the more perfect in form is the darkened circular area surrounding it. When

the circle is very perfect and the central mineral clearly defined at its centre we find by measurement that the radius of the darkened area is generally 0·033 mm. It may sometimes be 0·040 mm. These are always the measurements in biotite. In other minerals the radii are a little different.

We see in the photograph (Fig. 3), much magnified, a halo contained in biotite. We are looking at a region in a rock section, the rock being ground down to such a thickness that light freely passes through it. The biotite is in the centre of the field. Quartz and felspar surround it. The rock is a granite. The biotite is not all one crystal. Two crystals, mutually inclined, are cut across. The halo extends across both crystals, but owing to the fact that polarised light is used in taking the photograph it appears darker in one crystal than in the other. We see the zircon which composes the nucleus. The fine lineated appearance of the biotite is due to the cleavage of that mineral, which is cut across in the section.

The question arises whether the darkened area surrounding the zircon may not be due to the influence of the radioactive substances contained in the zircon. The extraordinary uniformity of the radial measurements of perfectly formed haloes (to use the name by which they have long been known) suggests that they may be the result of alpha radiation. For in that case, as we have seen, we can at once account for the definite

radius as simply representing the range of the ray in biotite. The furthest-reaching ray will define the radius of the halo. In the case of the uranium family this will be radium C, and in the case of thorium it will be thorium $C_2$. Now here we possess a means of at once confirming or rejecting the view that the halo is a radioactive phenomenon and occasioned by alpha radiation; for we can calculate what the range of these rays will be in biotite, availing ourselves of Bragg's additive law, already referred to. When we make this calculation we find that radium C just penetrates 0·033 mm. and thorium $C_2$ 0·040 mm. The proof is complete that we are dealing with the effects of alpha rays. Observe now that not only is the coincidence of measurement and calculation a proof of the view that alpha radiation has occasioned the halo, but it is a very complete verification of the important fact stated by Bragg, that the stopping power depends solely on the atomic weight of the atoms traversed by the ray.

We have seen that our examination of the rocks reveals only the two sorts of halo: the radium halo and the thorium halo. This is not without teaching. For why not find an actinium halo? Now Rutherford long ago suggested that this element and its derivatives were probably an offspring of the uranium family; a side branch, as it were, in the formation of which relatively few transforming atoms took part. On Rutherford's theory then, actinium should always accom-

pany uranium and radium, but in very subordinate amount. The absence of actinium haloes clearly supports this view. For if actinium was an independent element we would be sure to find actinium haloes. The difference in radius should be noticeable. If, on the other hand, actinium was always associated with uranium and radium, then its effects would be submerged in those of the much more potent effects of the uranium series of elements.

It will have occurred to you already that if the radioactive origin of the halo is assured, the shape of a halo is not really circular, but spherical. This is so. There is no such thing as a disc-shaped halo. The halo is a spherical volume containing the radioactive nucleus at its centre. The true radius of the halo may, therefore, only be measured on sections passing through the nucleus.

In order to understand the mode of formation of a halo we may profitably study on a diagram the events which go on within the halo-sphere. Such a diagram is seen in Fig. 4. It shows to relatively correct scale the limiting range of all the alpha-ray producing members of the uranium and thorium families. We know that each member of a family will exist in equilibrium amount within the nucleus possessing the parent element. Each alpha ray leaving the nucleus will just attain its range and then cease to affect the mica. Within the halo-sphere, there must be, therefore,

the accumulated effects of the influences of all the rays. Each has its own sphere of influence, and the spheres are all concentric.

The radii in biotite of the several spheres are given in the following table :—

URANIUM FAMILY.

| | mm. |
|---|---|
| Radium C ... ... ... ... | 0.0330 |
| Radium A ... ... ... ... | 0.0224 |
| Ra Emanation... ... ... ... | 0.0196 |
| Radium F ... ... ... ... | 0.0177 |
| Radium ... ... ... ... ... | 0.0156 |
| Ionium ... ... ... ... ... | 0.0141 |
| Uranium 1 ... ... ... ... | 0.0137 |
| Uranium 2 ... ... ... ... | 0.0118 |

THORIUM FAMILY.

| | mm. |
|---|---|
| Thorium $C_2$ ... ... ... ... | 0.040 |
| Thorium A ... ... ... ... | 0.026 |
| Th Emanation ... ... ... ... | 0.023 |
| Thorium $C_1$ ... ... ... ... | 0.022 |
| Thorium X ... ... ... ... | 0.020 |
| Radiothorium ... ... ... ... | 0.019 |
| Thorium ... ... .. ... ... | 0.013 |

In the photograph (Fig. 5) we see a uranium and a thorium halo in the same crystal of mica. The mica is contained in a rock-section and is cut across the clevage. The effects of thorium $C_2$ are clearly shown as a lighter border surrounding the accumulated inner darkening due to the other thorium rays (upper halo). The uranium halo (to the right) similarly shows the effect of radium C, but less distinctly.

Haloes which are uniformly dark all over as described above are, in point of fact, "over-exposed"; to borrow a familiar photographic term. Haloes are found which show much very beautiful internal detail. Too vigorous action obscures this detail just as detail is lost in an over-exposed photograph. We may again have "under-exposed" haloes in which the action of the several rays is incomplete or in which the action of certain of the rays has left little if any trace. Beginning at the most under-exposed haloes we find circular dark marks having the radius 0·012 or 0·013 mm. These haloes are due to uranium although their inner darkening is doubtless aided by the passage of rays which were too few to extend the darkening beyond the vigorous effects of the two uranium rays. Then we find haloes carried out to the radii 0·016, 0·018 and 0·019 mm. The last sometimes show very beautiful outer rings having radial dimensions such as would be produced by radium A and radium C. Finally we may have haloes in which interior detail is lost so far out as the radius due to emanation or radium A, while outside this floats the ring due to radium C. Certain variations of these effects may occur, marking, apparently, different stages of exposure. Figs. 6 and 7 illustrate some of these stages; the latter photograph being greatly enlarged to show clearly the halo-sphere of radium A.

In most of the cases referred to above the structure evidently shows the existence of con-

centric spherical *shells* of darkened biotite. This is a very interesting fact. For it proves that in the mineral the alpha ray gives rise to the same increased ionisation towards the end of its range as Bragg determined in the case of gases. And we must conclude that the halo in every case grows in this manner. A spherical shell of darkened biotite is first produced and the inner colouration is only effected as the more feeble ionisation along the track of the ray in course of ages gives rise to sufficient alteration of the mineral. This more feeble ionisation is, near the nucleus, enhanced in its effects by the fact that there all the rays combine to increase the ionisation and, moreover, the several tracks are there crowded by the convergency to the centre. Hence the most elementary haloes seldom show definite rings due to uranium, etc., but appear as embryonic disc-like markings. The photographs on the screen illustrate many of the phases of halo development. Rutherford succeeded in making a halo artificially by compressing into a capillary glass tube a quantity of the emanation of radium. As the emanation decayed the various derived products came into existence and all the several alpha rays penetrated the glass; darkening the walls of the capillary out to the limit of the range of radium C in glass. Fig. 8 is a magnified view of the tube. The dark central part is the capillary. The tubular halo surrounds it. This experiment has, however, been anticipated by

some scores of millions of years, for here is the same effect in a biotite crystal (Fig. 9). Along what are apparently tubular passages or cracks in the mica, a solution, rich in radioactive substances, has moved; probably during the final consolidation of the granite in which the mica occurs. A continuous and very regular halo has developed along these conduits. A string of halo-spheres may lie along such passages. We must infer that solutions or gases able to establish the radioactive nuclei moved along these conduits, and we are entitled to ask if all the haloes in this biotite are not, in this sense, of secondary origin. There is, I may add, much to support such a conclusion.

It must not be thought that the under-exposed halo is a recent creation. By no means. All are old, appallingly old; and in the same rock all are, probably, of the same, or nearly the same, age. The under-exposure is simply due to a lesser quantity of the radioactive elements in the nucleus. They are under-exposed, in short, not because of lesser duration of exposure, but because of insufficient action; as when in taking a photograph the stop is not open enough for the time of the exposure.

The halo has, so far, told us that the additive law is obeyed in solid media and that the increased ionisation attending the slowing down of the ray obtaining in gases also obtains in solids; for, otherwise, the halo would not commence its

development as a spherical shell or envelope. But here we learn that there is probably a certain difference in the course of events attending the immediate passage of the ray in the gas and in the solid. In the former initial recombination may obscure the intense ionisation near the end of the range. We can only detect the true end effects by artificially separating the ions by a strong electric force. If this recombination happened in the mineral we should not have the concentric spheres so well defined as we see them to be. What, then, hinders the initial recombination in the solid? The answer probably is that the newly formed ion is instantly used up in a fresh chemical combination. Nor is it free to change its place as in the gas. There is simply a new equilibrium brought about by its sudden production. In this manner the conditions in the complex molecule of biotite, tourmaline, etc., may be quite as effective in preventing initial recombination as the most effective electric force we could apply. The final result is that we find the Bragg curve reproduced most accurately in the delicate shading of the rings making up the perfectly exposed halo.

That the shading of the rings reproduces the form of the Bragg curve, projected, as it were, upon the line of advance of the ray and reproduced in depth of shading, shows that in yet another particular the alpha ray behaves much the same in the solid as in the gas. A careful

examination of the outer edge of the circles always reveals a steep but not abrupt cessation of the action of the ray. Now Geiger has investigated and proved the existence of scattering of the alpha ray by solids. We may, therefore, suppose with much probability that there is the same scattering within the mineral near the end of the range. The heavy iron atom of the biotite is, doubtless, chiefly responsible for this in biotite haloes. I may observe that this shading of the outer bounding surface of the sphere of action is found however minute the central nucleus. In the case of a nucleus of considerable size another effect comes in which tends to produce an enhanced shading. This will result if rays proceed from different depths in the nucleus. If the nucleus was of the same density and atomic weight as the surrounding mica, there would be little effect. But its density and molecular weight are generally greater, hence the retardation is greater, and rays proceeding from deep in the nucleus experience more retardation than those which proceed from points near to the surface. The distances reached by the rays in the mica will vary accordingly, and so there will be a gradual cessation of the effects of the rays.

The result of our study of the halo may be summed up in the statement that in nearly every particular we have the phenomena which have been measured and observed in the gas reproduced on a minute scale in the halo. Initial re-

combination seems, however, to be absent or diminished in effectiveness; probably because of the new stability instantly assumed by the ionised atoms.

One of the most interesting points about the halo remains to be referred to. The halo is always uniformly darkened all round its circumference and is perfectly spherical. Sections, whether taken in the plane of cleavage of the mica or across it, show the same exactly circular form, and the same radius. Of course, if there was any appreciable increase of range along or across the cleavage the form of the halo on the section across the cleavage should be elliptical. The fact that there is no measurable ellipticity is, I think, one which would not on first consideration be expected.

For what are the conditions attending the passage of the ray in a medium such as mica? According to crystallographic conceptions we have here an orderly arrangement of molecules, the units composing the crystal being alike in mass, geometrically spaced, and polarised as regards the attractions they exert one upon another. Mica, more especially, has the cleavage phenomenon developed to a degree which transcends its development in any other known substance. We can cleave it and again cleave it till its flakes float in the air, and we may yet go on cleaving it by special means till the flakes no longer reflect visible light. And not less remarkable is the

uniplanar nature of its cleavage. There is little cleavage in any plane but the one, although it is easy to show that the molecules in the plane of the flake are in orderly arrangement and are more easily parted in some directions than in others. In such a medium beyond all others we must look with surprise upon the perfect sphere struck out by the alpha rays, because it seems certain that the cleavage is due to lesser attraction, and, probably, further spacing of the molecules, in a direction perpendicular to the cleavage.

It may turn out that the spacing of the molecules will influence but little the average number per unit distance encountered by rays moving in divergent paths. If this is so we seem left to conclude that in spite of its unequal and polarised attractions there is equal retardation and equal ionisation in the molecule in whatever direction it is approached. Or, again, if the encounters indeed differ in number, then some compensating effect must exist whereby a direction of lesser linear density involves greater stopping power in the molecule encountered, and *vice versâ*.

The nature of the change produced by the alpha rays is unknown. But the formation of the halo is not, at least in its earlier stages, attended by destruction of the crystallographic and optical properties of the medium. The optical properties are unaltered in nature but increased in intensity. This applies till the halo has become so darkened that light is no longer transmitted

under the conditions of thickness obtaining in rock sections. It is well known that there is in biotite a maximum absorption of a plane polarised light ray when the plane of vibration coincides with the plane of cleavage. A section across the cleavage then shows a maximum amount of absorption. A halo seen on this section simply produces this effect in a more intense degree. This is well shown in Fig. 3 *(ante)* on a portion of the halo-sphere. The descriptive name "Pleochroic Halo" has originated from this fact. We must conclude that the effect of the ionisation due to the alpha ray has not been to alter fundamentally the conditions which give rise to the optical properties of the medium. The increased absorption is probably associated with some change in the chemical state of the iron present. Haloes are, I believe, not found in minerals from which this element is absent. One thing is quite certain. The colouration is not due to an accumulation of helium atoms, *i.e.*, of spent alpha rays. The evidence for this is conclusive. If helium was responsible we should have haloes produced in all sorts of colourless minerals. Now we sometimes see zircons in felspars and in quartz, etc., but in no such case is a halo produced. And halo-spheres formed within and sufficiently close to the edge of a crystal of mica are abruptly truncated by neighbouring areas of felspar or quartz, although we know that the rays must pass freely across the boundary. Again it

is easy to show that even in the oldest haloes the quantity of helium involved is so small that one might say the halo-sphere was a tolerably good vacuum as regards helium. There is, finally, no reason to suppose that the imprisoned helium would exhibit such a colouration, or, indeed, any at all.

I have already referred to the great age of the halo. Haloes are not found in the younger igneous rocks. It is probable that a halo less than a million years old has never been seen. This, *primâ facie*, indicates an extremely slow rate of formation. And our calculations quite support the conclusions that the growth of a halo, if this has been uniform, proceeds at a rate of almost unimaginable slowness.

Let us calculate the number of alpha rays which may have gone to form a halo in the Devonian granite of Leinster.

It is common to find haloes developed perfectly in this granite, and having a nucleus of zircon less than $5 \times 10^{-4}$ cms. in diameter. The volume of zircon is $65 \times 10^{-12}$ c,cs. and the mass $3 \times 10^{-10}$ grm.; and if there was in this zircon $10^{-8}$ grm. radium per gram (a quantity about five times the greatest amount measured by Strutt), the mass of radium involved is $3 \times 10^{-18}$ grm. From this and from the fact ascertained by Rutherford that the number of alpha rays expelled by a gram of radium in one second is $3{\cdot}4 \times 10^{10}$, we find that *three* rays are shot from the nucleus in a year. If

now, geological time since the Devonian is 50 millions of years, then 150 millions of rays built up the halo. If geological time since the Devonian is 400 millions of years, then 1200 millions of alpha rays are concerned in its genesis. The number of ions involved, of course, greatly exceeds these numbers. A single alpha ray fired from radium C will produce $2{\cdot}37 \times 10^5$ ions in air.

But haloes may be found quite clearly defined and fairly dark out to the range of the emanation ray and derived from much less quantities of radioactive materials. Thus a zircon nucleus with a diameter of but $3{\cdot}4 \times 10^{-4}$ cms. formed a halo strongly darkened within, and showing radium A and radium C as clear smoky rings. Such a nucleus, on the assumption made above as to its radium content, expels one ray in a year. But, again, haloes are observed with less blackened pupils and with faint ring due to radium C, formed round nuclei of rather less than $2 \times 10^{-4}$ cms. diameter. Such nuclei would expel one ray in five years. And even lesser nuclei will generate in these old rocks haloes with their earlier characteristic features clearly developed. In the case of the most minute nuclei, if my assumption as to the uranium content is correct, an alpha ray is expelled, probably, no oftener than once in a century; and possibly at still longer intervals.

The equilibrium amount of radium contained

in some nuclei may amount to only a few atoms. Even in the case of the larger nuclei and more perfectly developed haloes the quantity of radium involved is many millions of times less than the least amount we can recognise by any other means. But the delicacy of the observation is not adequately set forth in this statement. We can not only tell the nature of the radioactive family with which we are dealing; but we can recognise the presence of some of its constituent members. I may say that it is not probable the zircons are richer in radium than I have assumed. My assumption involves about 3 per cent. of uranium. I know of no analyses ascribing so great an amount of uranium to zircon. The variety cyrtolite has been found to contain half this amount, about. But even if we doubled our estimate of radium content, the remarkable nature of our conclusions is hardly lessened.

It may appear strange that the ever-interesting question of the Earth's age should find elucidation from the study of haloes. Nevertheless the subjects are closely connected. The circumstances are as follows. Geologists have estimated the age of the Earth since denudation began, by measurements of the integral effects of denudation. These methods agree in showing an age of about $10^8$ years. On the other hand, measurements have been made of the accumulation in minerals of radioactive *débris*—the helium and lead—and results obtained which, although

they do not agree very well among themselves, are concordant in assigning a very much greater age to the rocks. If the radioactive estimate is correct, then we are now living in a time when the denudative forces of the Earth are about eight or nine times as active as they have been on the average over the past. Such a state of things is absolutely unaccountable. And all the more unaccountable because from all we know we would expect a somewhat *lesser* rate of solvent denudation as the world gets older and the land gets more and more loaded with the washed-out materials of the rocks.

Both the methods referred to of finding the age assume the principle of uniformity. The geologist contends for uniformity throughout the past physical history of the Earth. The physicist claims the like for the change-rates of the radioactive elements. Now the study of the rocks enables us to infer something as to the past history of our Globe. Nothing is, on the other hand, known respecting the origin of uranium or thorium—the parent radioactive bodies. And while not questioning the law and regularity which undoubtedly prevail in the periods of the members of the radioactive families, it appears to me that it is allowable to ask if the change rate of uranium has been always what we now believe it to be. This comes to much the same thing as supposing that atoms possessing a faster change rate once were associated with it which were

capable of yielding both helium and lead to the rocks. Such atoms might have been collateral in origin with uranium from some antecedent element. Like helium, lead may be a derivative from more than one sequence of radioactive changes. In the present state of our knowledge the possibilities are many. The change rate is known to be connected with the range of the alpha ray expelled by the transforming element; and the conformity of the halo with our existing knowledge of the ranges is reason for assuming that, whatever the origin of the more active associate of uranium, this passed through similar elemental changes in the progress of its disintegration. There may, however, have been differences in the ranges which the halo would not reveal. It is remarkable that uranium at the present time is apparently responsible for two alpha rays of very different ranges. If these proceed from different elements, one should be faster in its change rate than the other. Some guidance may yet be forthcoming from the study of the more obscure problems of radioactivity.

Now it is not improbable that the halo may contribute directly to this discussion. We can evidently attack the biotite with a known number of alpha rays and determine how many are required to produce a certain intensity of darkening, corresponding to that of a halo with a nucleus of measureable dimensions. On certain assumptions, which are correct within defined limits, we

can calculate, as I have done above, the number of rays concerned in forming the halo. In doing so we assume some value for the age of the halo. Let us take the maximum radioactive value. A halo originating in Devonian times may attain a certain central blackening from the effects of, say, $10^8$ rays. But now suppose we find that we cannot produce the same degree of blackening with this number of rays applied in the laboratory. What are we to conclude? I think there is only the one conclusion open to us: that some other source of alpha rays, or a faster rate of supply, existed in the past. And this conclusion would explain the absence of haloes from the younger rocks; which, in view of the vast range of effects possible in the development of haloes, is, otherwise, not easy to account for. It is apparent that the experiment on the biotite has a direct bearing on the validity of the radioactive method of estimating the age of the rocks. It is now being carried out by Professor Rutherford under reliable conditions.

Finally, there is one very certain and valuable fact to be learned from the halo. The halo has established the extreme rarity of radioactivity as an atomic phenomenon. One and all of the speculations as to the slow breakdown of the commoner elements may be dismissed. The halo shows that the mica of the rocks is radioactively sensitive. The fundamental criterion of radioactive change is the expulsion of the alpha

ray. The molecular system of the mica and of many other minerals is unstable in presence of these rays, just as a photographic plate is unstable in presence of light. Moreover, the mineral integrates the radioactive effects in the same way as a photographic salt integrates the effects of light. In both cases the feeblest activities become ultimately apparent to our inspection. We have seen that one ray in each year since the Devonian period will build the fully formed halo: unlike any other appearance in the rocks. And we have been able to allocate all the haloes so far investigated to one or the other of the known radioactive families. We are evidently justified in the belief that had other elements been radioactive we must either find characteristic haloes produced by them, or else find a complete darkening of the mica. The feeblest alpha rays emitted by the relatively enormous quantities of the prevailing elements, acting over the whole duration of geological time—and it must be remembered that the haloes we have been studying are comparatively young—must have registered their effects on the sensitive minerals. And thus we are safe in concluding that the common elements, and, indeed, many which would be called rare, are possessed of a degree of stability which has preserved them unchanged since the beginning of geological time. Each unaffected flake of mica is, thus, unassailable proof of a fact which but for the halo would, probably, have been for ever beyond our cognisance.

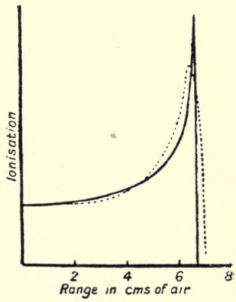


Fig. 1.

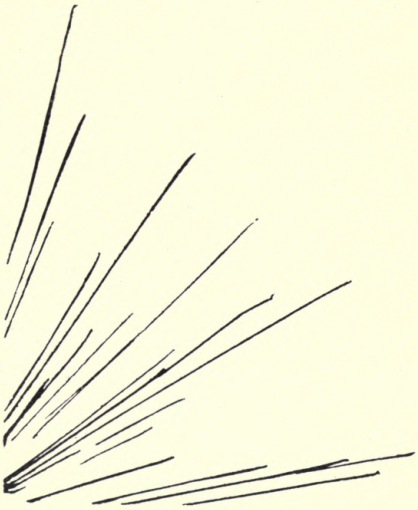

Fig. 2.

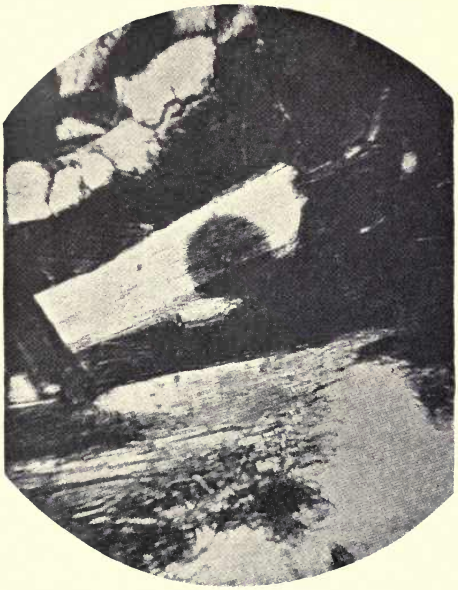

Fig. 3.

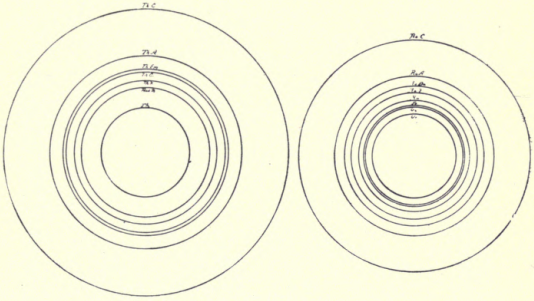

Fig. 4.

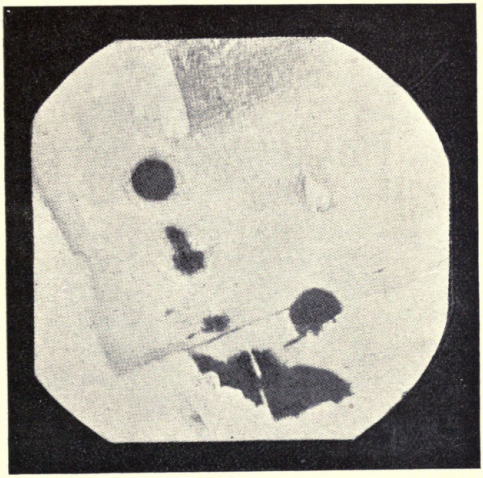

Fig. 5.

Fig. 6.

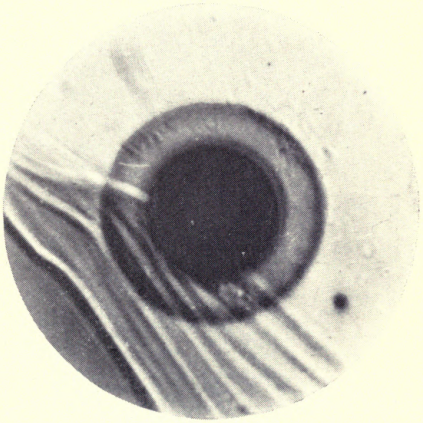

Fig. 7.

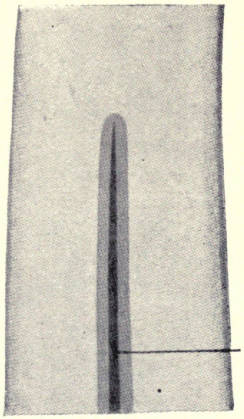

Fig. 8.

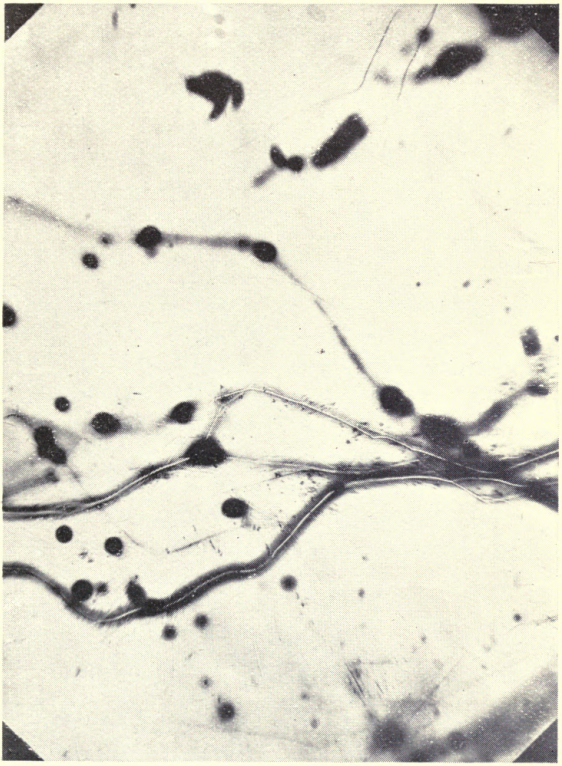

Fig. 9.

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