Science in the Making

SCIENCE IN THE MAKING

by

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London
FABER & FABER LIMITED
24 Russell Square

FIRST PUBLISHED IN JUNE MCMXXXV
BY FABER AND FABER LIMITED
24 RUSSELL SQUARE LONDON W.C.I
PRINTED IN GREAT BRITAIN BY
LATIMER TREND AND CO PLYMOUTH

To
C.W.

Contents

Preface

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The groundwork of these slight commentaries on current science is a series of B.B.C. talks. They have been rearranged, expanded, connected. Still they were in origin topical and popular, the reflections of one lay man on his weekly readings in science made in the casual ear of any other lay man or woman who happened to be by themselves and inclined for this sort of chat between six-thirty and six-forty-five on some thirty Monday evenings in 1934. They are published not because of any news-value they may have retained—in science news goes stale quicker than in drama, art or letters; though here and there a reader may find an amusing fact—but because they are a kind of diary, the reactions of an ordinary citizen who has been watching one (and he thinks the most important) stream of influence which is flowing into the channel of our social life.

Science is changing our lives, transforming our circumstances, revolutionizing our conditions. That, we generally, if a little casually, allow. But, more, it is (whether we resist or accept the fact—we usually do neither, but try [a very English reaction] not to think about it) changing our thought.

Earlier ages could or had to accept much, and could or had to choose little. We find the condition reversed. The things we have to accept become fewer, and those we have to choose among become more. That is not a wholly pleasing reversal of fortune. We care as little for responsibility as we do for compulsion. That however seems the only choice which we are given. We must either control or be controlled. As science unfolds we are discovering a new and even more onerous sense in Burke's political maxim: 'The price of freedom is eternal vigilance.'

Sometimes, I think we comfort ourselves that somehow science will blow over. There will come a time when the lamp which some people are irresponsibly rubbing will give out. The last pantechnicon will roll away, and amid the piles of bales and packing cases we—humanity—shall be able to start really moving in, settling down and sizing up.

This wish I believe is as strong as it is unexpressed, and as unfounded as it is dangerous.

The first excuse for publishing this 'wartime diary' is to disturb that non-interventionist spirit. If we don't start taking stock of this dumping we shall be deluged by new powers, new conflicting processes; yes, and new outlooks, until beside our vision that of a squinting cat would be lucid and straight. We shall not be enriched: we shall be embarrassed, confined, confounded. These entries show how quickly and ever more quickly the volume of scientific powers pours in on us. It is evident science is not showing any signs of stopping—quite the reverse: our responsibilities are

only just beginning. More and more of those happenings which even our parents classed as providential or unlucky, are now under our control, and, further, no one can say where the limits of that control may finally be ruled. All we know is that our powers are added to at an ever increasing speed; I think these weekly entries establish that.

There is, however, another reason for reissuing them: they may answer the lazy mind's objection to being roused—they may do something toward checking the irresponsible indifference which believes science is only a secondary and temporary accident, something that will pass and permit older and more irresponsible ways of living to be resumed.

But if these entries do that, they must also attempt to disturb another complacency. Many people hope that science will somehow pass or come to a halt; far more are certain that those anyhow who make can shape, and that the men who find out will also control. The expert and the specialist have undoubtedly made science as it is to-day, but they are, because of their higher and higher specialization, less and less concerned with what science as a whole is becoming, and even less aware of what science as a whole is doing.

We know these primary producers acutely resent a layman's trespass on their territories, and have every right to dictate under what conditions they choose to germinate and incubate their brilliant ideas. But though we ought to respect their nesting rights, and see that their hatcheries are undisturbed, we also have

to realize that these magic beings are as indifferent to what happens to their fabulous lay as the goose that laid the golden eggs was ignorant of sterling. Certain it is that no Master Scientists, or Board of Masters, is watching over science, or even suggesting how it should be developed or applied. This is quite natural. The specialist is a specialist and therefore his job is to specialize, and not to generalize.

Yet obviously someone has to generalize, and to apply. The unpleasant conclusion is that that part of the task is ours. The scientist, that is the specialist, is not going to do our work for us. He could not even if he would. If you have developed an eye like a microscope, you are useful for crime detection, but you are disqualified as a traffic director.

We lay folk must then get a general view of science, for science is daily increasing both in power—and therefore giving us new capacities of choice and burdens of responsibility—and also—because it is not grown by one directive mind, or board of minds, but by a rapidly increasing number of unco-ordinated specialists—in irresponsibility, and therefore our responsibility becomes daily more inescapable and urgent.

Lay folk feel, and must feel, a certain impertinence in venturing to take a general interest in science, and no doubt it would be better if there were a number of scientists, expert and specialized in every specialization, who were also far-sighted statesmen and devoted social servants. Such supermen do not however exist.

Increasingly and of necessity the brilliant scientist

in one subject is a layman in another. The task of being a master in his own subject exhausts his capacities. He cannot keep himself abreast in the continually ramifying specializations and finally he often becomes completely uninformed about other entire sciences. Because of the immense and increasing load of his own special knowledge he has to know less of other sciences than a layman may know who sees science as a single front, and watches for the social effects it produces. An expert anthropologist without shame may own he has forgotten whether he has ever heard of Bode's Law. An authoritative anatomist may never have seen a reference to the Law of Reversed Effort. An advanced botanist might not be able to tell you whether Oken's principle was right or wrong. A master chemist could quite possibly be puzzled by finding words such as Mousterian, and Neanderthal, being used as apparent interchangeables.

It is this general knowledge however that the layman may hope to have and must hope to have if science and society are to continue developing harmoniously. As it is the task of the specialist to master every detail of his subject, so it is the duty of the layman to know in broad outline the front of science, how that front as a whole is moving and what sectors are at the moment most likely to undermine and transform the practical ways of mankind.

These commentaries are very slight, but their aim has been to give some impression of that extended front and of those sectors which are nodal points, where living issues are met and are undergoing rapid

change through new knowledge and new insight, as well as new power.

This book is issued not to inform but to rouse interest. Anyone who cares can keep such a diary for himself, the information is to hand in expert periodicals, and after a very short time the collector, like any other naturalist, learns to pick up the trail he is watching and to piece together the clues, until not a day ever passes but he has some development to note, some advance to write up. And anyone who cares, being interested, not merely for himself, but for the development and advance of his community and civilization, must keep such a diary.

Would we have voted to subsidize sugar beet, at an annual average cost to the taxpayer of four millions, if we had known, as any such diarist did know, in broad outline, the history of scientific research into sugar production? Certainly not. Yet sugar is only one staple science is upsetting. The citizen to-day cannot be a scientific specialist, but he can and must be a scientific generalist—one who sees scientific advance as a whole.

It is then to such lay folk as myself that these notes and queries are addressed. Between this Preface and the notes themselves there is included an introduction. This is inserted for such readers as may be particularly interested not only in the effects science is having on society, but on the developments that seem discernable in science itself. These developments are probably more important, more indicative of significant change than the immediate reactions between

science and society. They are not however of such direct appeal, and those who are actively concerned with what science will do to them and theirs, here and now, may perhaps be advised to turn at once to the diary.

Introduction

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For better or for worse science has made the modern world, the world we live in and have to manage.

Our science is our essential characteristic, the formative feature which marks off us and our age from all other peoples and ages. Mankind has always had Art, Religion and Law. Many ages have excelled ours in the beauty of their creations, the loftiness and exultation of their faiths, the majesty, consistency and stability of their laws. None have approached our science. Its applications have remade the apparatus of our lives, its speculations have dissolved the assumptions we inherited from earlier cultures.

True other ages had the beginnings of science. Hero of Alexandria invented in the dawn of the Christian era the first crude model of the steam turbine. Callinicus of Damascus, in what we call the Dark Ages, discovered a gunpowder. Long before this the Assyrians had made experiments in chemistry, tempering and alloying metals, fusing glazes, firing glass and pottery. But all the scientific achievements of the ancient world—indeed till that century

of invention, the seventeenth century—compared with our achievements to-day, are only to be likened to the crude pottery of the Neolithic, compared with the ceramic mastery of the great ages of porcelain and faience. Yet though science is the peculiar and dominating characteristic of our age, we are far from recognizing the fact. That is perhaps the strangest fact about our state. Stranger even than this peculiar thought and action which we call science, is our attitude toward it. Though it is an activity of our minds which is rapidly remaking our circumstances, giving us powers which any other age would have thought it merely fanciful to desire, we are oddly unaware of it. Popular science is often reprobated by scientific specialists. If they knew the populace they rebuke, they would find that their fears were groundless. Being cloistered experts they know as little of the world they frown upon—for too avid an appetite for their preserves—as does the ecclesiastic of that same world which he denounces because it has too little taste for what he offers. People are not interested in science. This may be reassuring to the scientific specialist, but the social student may be surprised and need not necessarily be relieved. First then we must ask why are people uninterested in the greatest force of their age, a force whose consequences they are well able to appreciate? Is not this called a material age, and does not science add incessantly to our material equipment? And, secondly, is it a good thing that they should be so indifferent?

The answer the ordinary man will generally give is

that science is too stiff. He finds it hard to decode the messages of the specialists, of the men who take more and more interest in less and less. He finds it even harder when he has decoded this fragmentary script to fit it into a full-scale, life-size story of discovery and understanding. Specialization has undoubtedly broken up the broad sweeping beam of that early science, which was rightly called Natural Philosophy, into a number of intense spotlights, each picking out its own pencil of a path in a general darkness. Some historians of science may challenge that description. They would maintain that, though science has specialized high lights, yet the vast illumination of a natural philosophy has been maintained and advanced. Science has not only answered many particular questions and unravelled many knots, it has also made a single explanation of experience and woven into one consistent tapestry the threads it has spun from the vast web in which man finds himself. It is, however, just that point about which the ordinary man feels most doubtful and possibly it is here that we find in him an even stronger disinclination for science than that roused by its cryptic expression. He accepts with indifference, relief or even delight, the various applications to which science has given rise. He does not wish to enquire further into the nature of this activity and method, for he realizes not only with his consciousness that the language is difficult, but with his subconscious that the meaning is daunting.

In short, the ordinary man is actively if subconsciously averse to science, for he feels dimly that,

though it has made his age more powerful than any other, it would, if it were let have its way and became recognized as the interpreter as well as the caterer of the age, make the age as meaningless as it is powerful.

Like all good and easy men, the man of to-day wants to eat his cake and have it; he wants the applications, the material comforts that scientific theory makes possible, and at the same time he does not want to recognize that theory for fear it would disturb his mental comfort and dissolve his values. He will not think out his difficulty; he fears that if he did he might have to choose one or the other, his new means or his old hopes; so he thinks that by disregarding science, by leaving it wholly to the specialists, by taking its applications offhandedly and giving his main interest to the art, philosophy, religion and conventions he has inherited, he can strike a happy mean and make the best of both worlds. The specialist is also pleased with this deliberate inattention. Increasingly engrossed in the complete confirmation of certain severely restricted hypotheses, nothing could be more displeasing to him than clumsy life-size interference which questions of 'real meaning' must import. Let anyone, philosopher, politician or fellow worker, suggest that his work may have a relation to any practical and decisive issue, and his resentment is as natural and unrestrained as that of the solitary patience player to whom a busybody dares propose a conclusion to his game—or perhaps a juster simile, that of the child absorbed with its bricks told by nurse that it is time to tidy up.

Whatever the historian of science may think, the true scientific worker, the specialist, has in the vast majority of cases abandoned the hope of a natural philosophy embracing in scientific terms the whole of experience and has concentrated on particular interpretations of deliberately insulated problems.

There seems therefore adequate reason why science as a whole should not awake interest. The ordinary man would find it difficult in any case to understand, and his heart has reasons for not wishing to understand it. On the other hand the actual scientists themselves are nearly all specialists, little interested in science as a whole, and, it appears, even less in the scientific attitude to life in general. How seldom these men are natural philosophers, carrying their critical and detached judgment from their laboratories into their lives, can be seen by their controversies and their conventions. Their sharp divisions from fellow specialists and their blind adhesions with their fellow subjects show no apparent difference of character from the repulsions and attractions which direct and dominate us lay-folk.

Also not only are they themselves by nature and interest unsuited to popularize science, but they prefer that there should be no general interest in it. As far as they are aware of the outer world and its life-size scale of interests, they are actively anxious that no one should interfere with their work. They realize, if dimly, that their interests would be considered by the vast majority as either frivolous or mischievous and they hope that one of the uses of a highly technical

language may be to discourage popular prying. Is it not enough that every now and then they strike the rock and the people are watered: must these lower clumsy creatures be eavesdropping as to what they mutter to the rock?

Yet is it a good or even a possible thing that we should remain uninterested and ignorant of science? It is not a good thing for quite practical reasons. In the first place we are faced with the indifference of specialists to the consequences of their work, an indifference which though inevitable is very dangerous. Among them are both the most powerful and the most irresponsible of men. It is a little absurd that we should have taken such care to curb the arbitrary power of despots and yet leave specialists free to tumble into the world forces beside which the insane violence of an Ivan, or the savage brutality of a Genghis are only the tantrums of an ill-conditioned child.

It has lately been suggested that specialized chemists should agree not to make fresh torture poisons which a frightened people might use in war. It was countered that such restraint—a demand no sane man who views his actions on a life-size scale would consider anything but reasonable—would be impossible for an expert. An even graver danger, though more diffused, is the dislocation of industry and livelihood which is caused by inventions which, bursting upon the economic world, suddenly render obsolete plant worth millions and put out of work the thousands this plant employed.

It is clear then that the specialist is not going to

instruct us lay people about science, and it is equally clear that we ordinary people have to obtain such instruction. That is a practical issue which our economic and political life no longer permits us to shirk, nor can we neglect any longer the other complementary question. We have to ask not only what science is doing but what it is meaning. Here too we see the actual scientific worker claims privilege of specialization, averring that the general meaning of what he discovers is no more his concern than the particular application to which we choose to put it: We are then left to face the task not merely of directing the applications of science to the good of civilization, but also the other task, more difficult and more serious, of discovering what science as a whole means. The facts which the special sciences have established: how do they combine with one another, how do they combine with our other informations and experiences? When we have added together what the specialists tell us they have established, and put these finds alongside our inherited principles, with what sort of picture or map of the world and ourselves are we presented, and how with this map (enlarged or restricted) are we going to set our course?

Briefly, if science means cosmic nonsense, if physics is the tortoise on which all the other sciences stand, and if physics establishes that the universe is an immense senseless machine, then we must face up to the fact. We and we alone are left conscious and directive in a blind cosmos, we alone have vision and reason. We must therefore act on that knowledge. But when

we have withdrawn our attention from the Universe —because it is fundamentally meaningless, it has no message for us and we have no control over it—we have to concentrate on ourselves. Here then biology becomes, owing to the abdication or disposal of physics, the primary science. Life alone concerns us who alone are alive in a desert of matter, which leads nowhere and which we are helpless to shape. Biology however throws doubts on this division between ourselves and the universe. We are conscious, alive; but liveness biology traces down to such dim movements that no one can say where chemistry ends and biology begins, and as to consciousness it too seems to dawn as imperceptibly, beginning as the faintest of dreams and growing without break to the full intensity of self-conscious individual awareness. This raises the question: if we are an integral part of the universe, a rare but natural product, and the universe is blind, how can we see? If it is bound, how can we be free? That question arising, the focus of our attention (shifted and narrowed already from the universe) has to be shifted and narrowed still further, from biology and all life, to our minds and the manner in which they apprehend and understand. As biology doubted whether our living bodies were as separate from the dead universe as we assumed, so psychology in its turn doubts whether our enquiring minds are really as detached from the living body and its matrix the 'dead universe', as we took for granted.

The question then we lay folk have to ask is a double one: does science decide we can form adequate

pictures of ourselves and the universe, and if so are those pictures able to be combined into one single picture, a Natural Philosophy—'natural' because the bits are all there to hand, anyone can pick up the pieces for themselves, anyone can see for himself the facts, that do not need special faculties to find them, but are all here and now; 'philosophy' because these facts, when they are all put together, none left out and none discarded, give a general consistent pattern? Do they make a single meaning? I do not think that question has been answered as yet. At the same time I am certain that no question is more important. It is for our age the Sphinx's challenge; either we must answer it or perish, for if we cannot make a consistent meaning of what we find, if we cannot decide whether Life has purpose or direction, if we fail to conclude whether 'the universe is friendly'[1] or hostile or indifferent, then we are done. We know too much—practically we are too dependent on this knowledge for our comfort, our 'security' and our power—to retreat voluntarily.

If we cannot find out what the world now means in this bigger focus science has given us, we shall go on using the new powers for the old aims and we shall smash civilization. The only thing which can make man safe against himself, armed as he now is with superhuman power, is to discover superhuman purpose. He will never willingly relinquish the power: then he must find the purpose. This crisis is

[1] F. W. H. Myers: 'If there is one question I might ask the Sphinx it would be—Is the Universe friendly?'

I think also realized by such scientists as are both specialists and also philosophers, men of double focus who can leave their microscope or their telescope, and still carrying in their mind's eye what they have seen, look out on the world as its citizens, and wonder where their special knowledge may be worked in and made to serve.

There was a time when such were inclined to think they had a revelation—if a very Protestant one. Glory to man in the highest, for man is the master of things, had sung Swinburne, and perhaps this exultation over an elder and sometimes needlessly obscurantist and harsh authority brought a flush even to the scientific pale cast of thought. Might not man be marvellously free, using, unrestrained by superstition, powers which would raise him above accident and circumstance? Surely, and should he not go further and with the antiseptic ray of science sterilize the universe of those spores of superstition still lurking in it? Was not truth, the whole truth, his alone? Did not he at last see life steadily and whole, and so was he not able and bound to promulgate the final meaning of things? 'Natural philosophy', was not that a philosophy in which religion was dissipated (product of disproved anthropomorphism); art relegated from vision to fantasy—an amiable play of imagination and within bounds permissible—and values disposed of as hypertrophied instincts—sometimes socially useful. The progress of science itself has undermined this assurance. The philosophic scientist is now aware how unscientific it is for the scientist to assume that

he, and he alone, has full objective apprehension of the universe, that he now at last sees things as they are and all others were deluded. His instruments tell him of scores of octaves of radiation to which his senses cannot respond. His psychology informs him of the highly selective, distorted and fragmentary nature of those impressions which he calls data. He learns that the aperture of the mind can be shifted as can the aperture of a telescope and when that is done other data may be apprehended.

The vision of the artist, the intuition of the saint, cannot be dismissed, without examination, as obviously illusory.

Science, then, the analytic method which does not question its data, and does not doubt they will give the clue to the structure of the universe and the meaning of life, is now extending still further its enquiry. It realizes that it needs the co-operation of other observers who attempt with equal honesty, patience and descriptiveness to set down their findings. In short, science is again of necessity about to attempt a new cosmology which may be the sanction of a new ethic, a new description of nature with a new deduction of how, in the face of such facts, it is natural and reasonable to live.

This effort is a supreme one. To attempt it in the present age of specialization we all, specialists and ordinary men chiefly concerned with full-scale living, must combine. Science is neither a destroyer of sense and meaning, nor a specialized irresponsible activity unaffecting and unaffected by life and the responsi-

bility of responsible living; nor yet again in itself, and by itself, a complete interpretation of reality. It is the peculiar contribution of our age to the meaning of life and the understanding of the universe. Because of that we must all work at it to bring this vast contribution as a single unit, an essential and hitherto neglected part of philosophy, to join up in a whole with those other apprehensions which we have inherited and still employ.

Science, and the intuitive method (expressed most commonly in art and religion), the analytic and the integral approaches, these may now hope to combine to make at last a fully valid natural philosophy. Before that is possible we must however link the sciences into their single unit. To do that, liaison officers between the sciences and then further between the analytic and the integral methods, are necessary. Such men do not at present exist. In consequence journalists who have realized the importance of science and the necessity of this advance of the subject as a whole, have had to attempt the task. Such tentative efforts have proved two things: first that there is a popular demand for such liaison work, and secondly that this work can only be undertaken adequately by specially equipped persons. The faults of this book may well be its most useful contribution, because they will establish the need for those liaison experts who will both co-ordinate science in itself and also combine that co-ordinated science with those other apprehensions of reality which will make a fully valid Philosophy of Life.

Part I

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The Front of Physics

Chapter I

The Full Range

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(a) How our dividing-up ends size; but size turns into energy

Last year was certainly a great physics year, and if all science depends on physics, we have good reason for starting our review with a bird's-eye-view of the main advances on the physics front. Early in the spring there appeared the following bulletin—it ran: 'Professor F. Joliot and Madame Irene Curie Joliot have succeeded in their Paris laboratory in inducing artificial radioactivity by obtaining positrons from bombardment of boron with alpha particles.' I know that does not sound very startling or even very illuminating; and yet, in spite of all the other sensations there were in the news—the scandals in France, the alarms in Spain, the excitement in Germany—that scrap of news was worth all of them. When all the political scares and excursions of to-day have become as difficult to recall as the track of last week's thunderstorm or snow-squall, that bit of news will be remembered. Say in 1960, when people looking back ask each other: 'Did anything really important take place early in 1934?' I think it is most likely the answer will be just that line—'Positrons were obtained by bombarding boron with

alpha particles.' For the truth is that what is hidden under those decently obscure words is nothing less than our old, and none too reputable friend, transmutation. Even that word is long enough to put some people off. So let us be brutally frank. Let us call a spade a spade and call transmutation alchemy. For that is what it is. It is turning one element into another. It is doing what sober science long thought could only be a childish dream. And it is not merely making a fairy-tale come true—with all the awkward consequences that arise when that sort of thing happens—it is also doing what even the old alchemists never dreamt transmutation could do. It is actually making new elements, elements which we have never found in nature. Human beings have now found out how to create completely new substances. It is true that like fairy gold they do not stay long enough and are not in sufficient amounts for us to make use of them at present. But they are here long enough for us to discover something quite unexpected about them. They are new radioactive substances. That is, these are new elements which can send out atomic energy just as does radium. As it were they effervesce with that fabulous energy which we now know is locked up inside every atom, and which if we could tap it would give us so much power that we should not care whether we could turn all the lead of the world into gold or into platinum. And not only should we have supplies of power, light and heat so that we should never again have to think of scarcity, but beside all that, these

radiations give us a power over disease which is perhaps the most precious and the most unexpected of all these strange gifts.

There is sufficient reason for starting this diary with a physics entry, for really no other branch of science can matter so much to all of us, and this news from the physics front is really tremendously exciting—things are happening there far faster during these months than anyone dared hope. Since the above bulletin was issued fresh confirmations and reports of further advances have been pouring in to this very moment from here and from America.

Still, just because these discoveries are so fundamental, just because what is being found lies so deep down out of our ordinary sight, it needs some explaining before we can realize what is up. This story, which is the story of the most exciting hunt men have ever gone on, is so hard to follow because the bulletins come out in such scraps, and these scraps, as is plain from this one, sound so obscure. So perhaps it would not be out of place to give here a very sketchy synopsis of the story of the super treasure hunt down to to-day, down to those latest obscure stop-press messages.

As far as we are concerned it all began of course with the discovery of radioactivity when most of us were children. Most of us remember the excitement in 1898. Two French scientists—M. and Mme. Curie—found radium. It is their daughter and her husband who are to-day in the news. The scientific world realized what the parents had done. This find,

confirming work done with uranium, meant that alchemy was no longer theoretically impossible. One element was actually turning into another under human eyes. Radium was transforming itself into lead. And as theories interest scientists quite as much as practical results, the scientific world was duly impressed. But we, on the other hand, are more interested in whether a find can be used than in what it may mean. When then we were told that for all practical purposes Alchemy and the release of atomic energy were just as far off as ever they had been, we began to lose interest. It seemed after all there was nothing in all this for us but only for researchers—men who can be interested in what really makes no difference. We tried to hope that one day science would learn how to do the extraordinary trick which Nature had been discovered to be up to, but we were not encouraged. It was true that every atom had inside it these fabulous gifts, but we were told that it was locked up with such strength that our puny blows would never loosen it. It was true you could knock it about a bit, but you only dented it; you never split it; and unless you could cleave right into its minute core you could not make it transmute.

Still, a good many of us remained hanging about, keeping an eye on the news, as people remain after the fire engine has gone away, still hoping there might be a fire after all. Well, we have not waited in vain. The fire is there, and considering what a fire it is and the difficulties of getting at it, the search has not taken so long. To cut a very complicated story

short, in 1919 Lord Rutherford at Cambridge did actually bring about the first chemical transmutation. But of course he could only do so in quantities so small that though it mattered immensely to science, as a proof, it mattered not at all to us, who only want a profit. The experiments were expensive and there was nothing to show for them except that the theory, that matter was really electrical force, was correct. All that had been done was that man had succeeded in making Nature, under exact and defined laboratory conditions, do what for some twenty years we had known that she did somehow. When aluminium was played upon (bombarded is the scientific phrase, but I think it raises in our minds altogether too big a picture of those experiments which were really at that stage very delicate), when aluminium was played upon by atoms of the gas helium there were unmistakable signs that just here and there more energy was coming out than was being put in. But the symptoms were so slight that we should only have thought that a great deal of energy was being shot away just to get a few minute scintillations. Still the scientists knew what they were after and were properly encouraged.

So—as short-story writers say—another thirteen years of constant work went by and then came another break-through. You probably remember in 1932, again in Lord Rutherford's laboratory, a resounding blow was struck on the lock of the atomic treasure chest.

And now at last we can begin to speak of bombard-

ment. For in these experiments large electric charges of hundreds of thousands of volts were hurled at the cores of the atoms. The success was again scientifically most gratifying, tiny sparks glittered out on the target. The gunners were making hits. Still, it remained their victory, not ours. It is true you did get direct hits on atoms and blew them up, and considering their size you were rewarded. You saw the flash of energy as they exploded. But the rub is in those words 'considering their size'. You were lucky if you hit one atom in thousands of millions. The rest remained dark, obscure, unyielding. You could not rouse them *en masse*. Far and away the greater part of the target refused to light up. What then is remarkable about the latest news? Quite simply it is this—the target which up till now the utmost efforts have only made spark, has for a few moments smouldered. What has actually been made happen is this: in all other former experiments in atom bombardment the moment you stopped bombarding the target went dead. In this year's experiments when the bombardment is stopped the target continues to be disturbed. The radioactivity you have struck up actually continues for a few moments going on its own. I think this discovery is only to be compared with man's other super-discovery after which he ceased to be an animal and became a man—the discovery of fire. Just look how uncannily similar the steps in the two discoveries have been. The cave man chipping his flints saw the first chance-made sparks. In 1898 men first catch sight of radioactivity. Next

the cave man discovers he can make sparks for fun whenever he likes, but they die as soon as they flash. That stage is paralleled by the radioactive work till to-day. Then comes the turning point in man's mastery of fire when he sees the first fizzle, he sees the sparks continuing to run about in the dry grass after he has stopped striking. The news of our now being able to make radioactivity catch on shows that we have now reached the same point. We can make radioactive material.

What is the use? Well, just think what is the present need for radium in cancer treatment alone. There is not a first-rate general hospital throughout the world that is not begging for more. Do you know that to meet this world-wide need of the two thousand million people in the world, some two hundred million of whom may die of cancer if they live until they reach the cancer age, and cancer is still uncured, the whole available supply of radium is under two pounds in weight. If we can actually create fresh radioactive substances which would act as radium acts, could any gift be a greater blessing to humanity? It is true that the elements which have been made radioactive do not at present remain active for long. The aluminium which was first lit up in this way went on only for four minutes, while the boron first fizzled for a quarter of an hour, but already, in America, it has now been made to keep going for an hour. And even longer spells are now on record for artificial radioactives. So not only are we making a beginning but that beginning is going ahead very fast.

Another need which may be met by this power to make materials become radioactive is the need for helium. Dr. Eckener, the great Zeppelin master-pilot, was here this year (1934). He showed that we can have a world-wide airship service to-day, but an essential safety-first need is an inexhaustible supply of this gas helium, which is both so light and also non-inflammable. At present we depend for our supplies of it chiefly on natural sources coming out of the earth in quite a few places. But all radioactive substances give off helium. So if we can carry out the laboratory experiments on a large scale, while we make stuff to save life we could collect from it as a by-product the gas whereby airship communication linking the world, is brought a great stride nearer. We must look out or otherwise these things will be here before we have time to see they are used for the best. Art is long, life is short, but science is now so fast that we have to plan for a very different world from that we were born into. Indeed, physics is now such an active science that we cannot say what new use and power may not at any moment be put in our hands; here are some examples of particular finds which may lead to further great discoveries. The simplest of these but not the least surprising is this strange stuff, heavy water. Quite apart from all its other odd properties—it has many—this fact, that there can be waters of different weights, came as a great surprise. To talk of heavy water to our grandparents would have seemed as absurd as talking of a ton of coal weighing a great deal. Still, there is this stuff now for us to see—heavy

water being turned out by the gallon. And it is full of peculiarities which obviously mark it off from the ordinary water which we thought was the only possible water. It freezes and boils at different temperatures from ordinary water, and there is something even stranger, something even sinister about it. Though all the difference about it is that it is water a little heavier than common water, it acts almost like a poison. If seeds are put into it, instead of sprouting freely as they do in common water, they grow badly. Even yeast cells are not at all happy if given a wetting with this fluid. This shows how much more delicately balanced life is than we have thought. All life needs water as much as it needs air. Yet alter the water by an atom and what is literally the water of life becomes deadly. Still, to deepen the mystery, now comes the news that some bacteria thrive in heavy water; less poisonous forms of Life, however, cannot stand it. In America where the water was first made they have not only damped down seeds with it: they have given a drink of it to a mouse. The mouse behaved as though it were drunk. It is doubtful, however, whether heavy water would ever have become a rival to whisky, even if prohibition had not been repealed, for it is very expensive to make and is evidently found nowhere in ordinary water. It was thought that if anywhere it ought to be found in the Dead Sea, because there the water which is poured into this huge stagnant pool never escapes, but is kept from overflowing simply by evaporation. Careful tests have now been carried out and it is certain that the whole

of the water in the Dead Sea is not a scruple heavier than an equal volume of any other water. Heavy water is however found in minute quantities in certain places. Those places are liquid batteries—electric cells which have been replenished again and again with fresh water. The water which gets left behind is found to contain traces of this strange water. And this, roughly speaking, is the method of getting it—to electrify water over and over again and then separate out the drop or two of really heavy water. Naturally this is expensive and slow, but the great Imperial Chemical works here and big electric works in Norway have decided to produce the stuff and as they work on so large a scale all the heavy water scientists want will probably soon be able to be got. Indeed, still newer methods of making heavy water may make it quite as common as we need. The British Association in 1934 was told by Professor and Doctor Farkas of Cambridge that they had found a way of producing it at one twentieth of the cost of the earlier method.

But why do scientists want it; is it any use? Yes, first we want to try it out medically. As we have seen, it can act as a new sort of drug. In America they tried it out at once on cancer. Each cell of our body has so much water in it that it was worth seeing whether cancer cells could be checked, like seeds are checked, by this new water. The results certainly do not seem promising. But other experiments with heavy water may throw light on life, old age and decay. It has been suggested by some researchers that though the

mouse, which was made drunk with heavy water, seemed to get the fluid out of its body and so recover its normal friskiness, old age itself may be the effect of too much heavy water. There seems to be some reason for supposing that all our lives we are like liquid electric batteries in this respect: we are taking in water and keeping back just a trace in our body's cells of this heavy water. Plants seem to do the same thing. So old age would be a sort of self-drugging, even teetotalers are drinking themselves to death, even the purest water in the end proves a poison, and our years literally become burdensome because our bodies are being loaded up with heavy water; though, in the end, an animal or vegetable body would contain so little it would not be worth extracting. Still more lately a scientist, with the stoical courage of his tribe, himself drank some heavy water. It seems to have done him no harm.

These biological experiments certainly do not promise us very much at present. If heavy water could give us no further information than it has given us up to date in medical matters, it would not be more than a scientific curiosity. But it is quite obvious that it is going to be of immediate value as an instrument, a key to open the door to new knowledge. There seems no doubt it is a tool which can be used at once to help us in the present rapid advance in physics. The chief task before physics is to break into the nucleus of the atom. It is easy enough to drive away the electrons that buzz around the nucleus, like flies round a plum, but unless you hit the plum itself

and knock it out, back the flies come a moment after. In a word, transmutation—making gold, if you wish, out of other metals, and the release of atomic energy —these revolutions—greater than any political or economic revolution—depend on hitting the nucleus. When you want to hit and smash an object which is extremely small and extremely hard, you need two things—a very high explosive power to drive your projectile and a projectile which shall be extremely hard and heavy for its size. Those immense electric currents and discharges which we can now use safely in the laboratory—more than a million volts is now used in America and more will be in use soon—they give us the explosive. It looks as though heavy water will yield a peculiarly heavy and hard projectile. Already this year (1934) this bombardment reached such a pitch that atoms were exploded so that they gave off three million volts, a million more than the strongest radiation ever given off from radium or any natural radioactive stuff. But how does heavy water help here? Its secret appears to be that it is made up of the two atoms of oxygen which go to making up ordinary water, but instead of being content with an ordinary atom of hydrogen, this queer water manages to hold on to an atom of hydrogen, weighing twice as much as a normal hydrogen atom—a sort of philopoena. This double weight atom gives the projectile you want. Here to your hand is a sort of loaded bludgeon with which to beat on other atoms. And out of this heavy water we may draw further sling-stones with which to pelt the nucleus we are determined to

break open. For this heavy water we have got hold of is a trickle which is leading physicists to follow it up to other springs of still other sorts of heavy water. Already triple-weight hydrogen has been extracted. One need not blame scientists for missing it up till now, for one of these triple-weight hydrogen atoms only turns up once in a billion times when you are sorting through the common hydrogen atoms. That is the rarity of these freaks, so the Department of Physics at Princeton, U.S.A., has calculated. In fact it seems that there may be no less than nine heavy waters altogether to be found. Merely to christen them all is going to strain the fancy of most physicists. Perhaps if there are going to be nine, the simplest thing would be to name the whole litter after the nine muses. There, ready for use, are nine memorable names with the additional aptness that the nine muses were supposed to circle round a well of peculiar water. Well, whatever names their godparents decide to give them, we lay people may hope that the godparents will agree. It is hard enough to remember all the new entities which keep on turning up in physics, electrons, protons, neutrons, positrons, neutrinos—all the more hard because these new objects are invisible and we cannot refresh our memories by looking at the things themselves. At the very beginning of this study of the invisible some terribly misleading names were given. Look at the two sorts of electricity. When they were found, one was called positive and the other negative. But, ever since, it has been the negative electricity which has proved to be

the most active and prominent and positive electricity seems more and more difficult to define. As you know, the electron, the active constituent of all matter, is made of negative electricity. Now Professor Dirac has worked out, and Prince de Broglie has confirmed, that the positron, or the electron made of positive electricity, is not a thing but a hole, a gap into which the active electron falls and disappears. If then to this fact, that the names themselves do not describe the objects at all well, you add the further confusion that different countries call the same object by different names, the confusion seems getting really dangerous. Dean Inge once remarked that science was running the risk of coming to a standstill for the very same reason which is said to have brought to an end another far earlier international effort, the building of the Tower of Babel, because the various specialized workers themselves will cease to be able to understand each other's technical language. Certainly the news that the physicists themselves cannot agree as to the names of the new things they find does suggest a confusion of tongues. What is in a name? All too much. If on the road I say 'Left', and to you 'Left' means 'Right', there will be a smash. Yet this muddle is not anyone's fault—though I do think the scientists might have debated a little more carefully about the names they gave their finds. No doubt they would, could they have foreseen what was going to happen. But they thought they would always be dealing with obvious things and not with such invisible and metaphysical things as holes in space, etc. Perhaps the best thing we can do is to try

to realize three things that have happened to physics, the study of what people thought was going to be definite, clear objects. The first thing of course is that no picture can any longer be made out of our present knowledge of the nature of matter. If we go on making pictures they are only made by picking out some facts and leaving out others—because the latter make nonsense of the picture. All we really have are marks made by something invisible as it passes by. It is as though you had never seen a bird but found in the snow marks of its feet as it hopped. Beside those marks every now and then you find the brushings made by its feathers as it swoops up into the air. But as you cannot imagine an animal which can walk on the air you have to dismiss these queer prints of the feathers and make a picture of a wingless animal. That of course fails to explain why the footprints cease at one place and suddenly begin somewhere else. The second thing we have to realize is that the experts themselves cannot define this something of which no picture can be made. They own that even if we give up trying to picture it and confine ourselves to making out how it moves, even then, if we put down all its movements, the chart of its tracks is full of difficulties. And the third thing is even more unsettling: you obviously cannot study anything unless you can throw light on it. But to throw light on the ultimate particles of matter is to upset them, to change them. What are they doing when we are not watching them? We can only know they are there when they are disturbed and so send out a vibration. When

they are quiet they show no sign. One cannot help then asking: are they really there when we can't see them? That brings us back to the common-sense position of the eighteenth century Irish bishop. He said: 'Unless you can perceive a thing, you can't say it exists.' That then, in a word, is the present state of physics, of the study of matter—it has exploded matter. What is left in its place? All we know for certain is that we receive certain impressions which we used to take for granted meant that we were surrounded by a solid dead world. Physics now shows that we made that assumption because we didn't realize how poor is our power of taking in what is around us. What is the next step? Well, obviously we ourselves come back into the picture. When I find my glasses are failing to let me know what I'm up against, I take them off and have a look at them. So it seems clear that the next great step in understanding the outer world must and will be made by understanding better just how it is that we do understand. The supermicroscope that Mr. Barnard uses sees more than any ordinary microscope, but you have to be trained to use it. The ordinary person would see nothing with it. And so with our minds, studying matter with all this new and wonderful knowledge. We have got so far that only very highly trained minds can think fruitfully on the problems that now confront us. Science, especially physical science, used to be simple organized common sense. That stage is over and we shall have to learn how to develop a very uncommon sense if we are to advance. I think we shall; but mean-

while we shall have to wait till psychology, the science of the mind, catches up physics, the study of the outer world.

And still comes fresh news: yet more finds and new names. As if it wasn't enough for us to have to remember that every atom now contains electrons, protons, neutrons, probably neutrinos and possibly even further constituents, we are adding to the atoms themselves. There was a time when we thought every atom was made of only two things, electrons and protons, and that all the atoms of the universe could be tidied up into the ninety-two elements. But now comes the news from Rome that we are adding to the atoms. We are learning not merely how to transmute, how to turn one element into another—mercury into gold would be an instance of that—but much more wonderful, how to make new elements, stuffs which are not found, as far as we know, anywhere in the universe. We are getting a new, fresh sort of matter. We seem to have created a new element, one beyond any so far known—element ninety-three. What could be done with it? Well, as you'd expect, it is radioactive and so it will probably open the way to new sources of radiant energy such as radium gives us. And considering how short we are of radium, simply for the cancer cases—as was mentioned above—anything which would add to our sources of radioactive stuff is far more valuable than gold or diamonds.[1]

[1] It is worth adding a postscript here, as Professor Cockcroft, who with Dr. Walton made the transmutations at Cambridge

But the new stuff is also, as we might expect, very unstable—that is, it is very hard to keep, it vanishes away, breaks down into common stuff—in thirteen minutes half of it has so degenerated. That is pretty certainly why we do not find it in Nature. These super-atoms—for that is what it is, an atom with ninety-three electrons buzzing round a nucleus in which is crowded hundreds of electrons and protons—find it very difficult to hold together—they collapse just as record card-castles collapse. And yet this super unstable atom is the heaviest thing we have ever found—heavier than anything in the universe. That alone shows what an odd world we are moving into. Here's a stuff more massive than any material we have ever come up against and yet it fizzes away more quickly than soda water. That is perhaps the most vivid illustration we have ever had of how matter and force are really one—as we might say the heaviest material is the least stable, the least material. And here again crops up the need for a name. What is this utterly new thing to be called, this new matter which we have called out of the abyss of sightless energy? It is perhaps naturally suggested it should be called Mussolinium. I wonder whether the Duce would be well advised to accept that honour? Again, what's in a name?—a great deal for a dictator. Give a dictator a bad name—well, it is much the same as giving a dog a bad name. 'Names that awake command must be auspicious.' To tie the Duce's name to

in 1932, has reported (April 1935) that sodium made radioactive may perhaps serve as a radium substitute.

an element which though immensely massive, and active, is essentially unstable and which is half spent in thirteen, unlucky, minutes—well, that seems altogether too risky a compliment. Anyhow, the actual thing we are left with is the atom, the atom being sifted out into more and more units which are less and less observable, and at the same time the atoms themselves being built up into more and more elements. At one end we are learning as it were to boil down matter into ever fresh forms of energy, and at the other to build up energy into fresh forms of matter. Where is it going to stop? One thing seems clear: we are learning letter by letter the spell which holds together the hard, safe, commonplace universe around us. No one can say how soon we shall be able to recite 'Open Sesame' and the rock will open. That, I am sure, matters more than all the politics of to-day—but the politics of to-day, do they show we are fit for this new vision and power. Of that I am not sure. Are you? We find ourselves back at that question again. Can our knowledge of ourselves, psychology, catch up in time with our physics, our new knowledge and new power over the outer world?

(b) How our reaching-out now spans space; but space turns out to be full

In the first chapter we were seeing how far science has gone in analysing the universe around us, in breaking up matter and finding what it is funda-

mentally under all its appearances and forms. We have seen what science has made out the very grain and substance of things to be, and how it has done this. But that is only half the picture. We have taken a drop of the ocean of being and analysed that. Now we have to take a map and see if we can get any idea of the size and depth of the whole ocean itself. The first step is from the microscope to the telescope, and for most of us that is a step we take with alacrity. The microscope is useful and may be wonderful. The telescope is seldom useful but it is always wonder-stirring. Somehow the stars always fascinate us. Yet even here, hasn't the progress of science spoilt our pleasure? I don't mean because science has upset astrology, for after all astrology considered the stars as useful rather than beautiful. Modern astronomy has spoilt our interest in the stars for another reason. As it has gone further and further afield into the great desert of the heavens and still found nothing but unending blackness through which drives a blizzard of stars, we ordinary people have got left behind. Those vast distances once stirred us, they roused our imagination. Now they have grown really too much, and like all excesses, instead of stimulating us they numb and stun our minds. One hundred and forty million light years—that, you know, is about as far as the present telescopes can see. But long before that our interest and attention has snapped like a piece of elastic stretched too far. A distance so great that light, which travels at more than 186,000 miles a second, could only get there in 140 million years—frankly it

is too much for us. So when the news came that the new 200-inch lens—nearly seventeen feet across—twice the size of the present largest telescope lens in the world, had been cast, I think even the few of us who were interested were more interested at the size of the glass, the record breaking effort to make such a monstrous reflector—than in what it would show. It is pretty impressive to think of a lens made of twenty tons of molten glass which has to be poured into a mould seventeen feet across. And it also gives one some sense of the size of this work when we learn that though science is associated in our minds with speed, and Americans generally want to hustle things and usually do, in this case that can't be done. This huge mass of glass will have to be given ten months to cool. Day by day the heat at which it is kept must be let ebb away degree by degree. Special heaters will prevent it cooling too fast. It has to be let harden very gently or it will get stresses and strains in it. And then when it is cool, another two years will be spent in grinding it, on getting this huge surface to exactly the right curve.

But when we ask 'What will it show?' then our interest gets a severe shock and chill. We are told that it will photograph star-clusters 1200 million light years away; 140 million was bad enough, 1200 million is quite hopeless. This telescope isn't to increase our vision and enlarge our imagination. It is simply the end-piece of a calculating machine. It is an instrument for which, as an astronomer said to me the other day, the photographic plate does all the seeing and the

work can be done just as well by an astronomer working with the plates and records in a cellar. He added: 'Astronomy deals more and more with objects which we really never see. The largest telescope can't show the disc of any star, only the gleam of light which it gives off, and as for those furthest-away objects, the star-clusters, in many cases we don't see even points of light, only a faint blur.'

So astronomy, like so many of the sciences, seems to be shaking off our amateur interest—our interest which is excited by seeing new things and which is chilled by abstractions. And yet I don't believe that need happen—at least in astronomy. I know the specialist must want to know more and more of less and less. He wants to make his soundings deeper and deeper into the uncharted abyss of space. Yet there are plenty of workers still exploring the rock-pools and the bays of the heavens; there is much still to be discovered there, and they are full of fascinating objects. It is true we don't hear so much about these astronomical close-ups. But that is partly our own fault. Up till now we've been so interested in super-distances and record-breaking depths that when the press reports astronomical news it goes on giving us those figures. Figures, just figures are, I'm sure, no longer of interest, but sights are and will always be. And the new telescopes do promise us astounding sights, real visions. We take for granted that everything is known about our next-door neighbours, the sun and the planets, the only heavenly bodies we can really see. That is quite untrue. We forget how

much is going on in those places and needing to be explored. Saturn isn't merely a striped globe whose shadow 'sleeps on his luminous ring'. As we learnt last year, when it suddenly produced a huge white spot, some immense activity is going on there—if only we could see. Jupiter too, the belts that gird his ruddy bulk, they are always changing. What is brewing there? No one knows. Something like a huge bubble has just bulged up north of that equator. Or to come closer, not merely closer in mileage but closer to our main interest, the problem of life and its destiny: no one who has looked at the melting snowcaps of Mars or studied the charts of its coloured patches which seem to change tint with the seasons, no one can doubt that here is a mystery not only fascinating in itself but which very likely, if we could study it closely, would throw light on the fate which awaits our world and all it doth inherit. Yet, until we get better telescopes, there, this world, ahead of us on the road of life, will hang just tantalizingly beyond what our eyes can be sure of. For even Mars is some ninety-four million miles away. You have to use a good deal of imagination besides eye strain to realize that that buzzing, blurring little disc is really another world.

There is however a world so close to us, astronomically speaking so up against us, that we usually take for granted that we know all about it, and there is nothing further to learn. True, it is a small world, little over two thousand miles in diameter, but what it lacks in size it makes up in nearness—most of the time it is only some 230,000 miles away. 'Ah, but the

moon is quite dead and changeless,' you say. Now that is just the question which the new large telescopes are reopening—and could any question be more exciting? I wonder whether you have ever seen the moon through a really large telescope? I know after I'd had my first glimpse I felt I should like to give up a whole lifetime studying that astounding landscape. First of all one is so surprised at its beauty. It's dazzling. That's not a conventional phrase. It is literally ablaze with light. For a moment you think you are looking at a vast incandescent gas-mantle, for some spots are as bright as freshly fallen snow under full sunlight. Then you experience the dizzy feeling, not of looking up but of hanging over looking down at an enormous countryside. Next you notice that the edges are jagged with shadows. You watch, and you realize it is sunset coming on. Those black jags are the shadows of peaks, some twenty thousand feet in height and more, thrown far across the plains as the moon turns away from the sun. To watch dawn and night stealing over those vast ranges and plains on which no foot has ever trod is a strangely moving sight, as though one were a ghost visiting this world when it too has died. 'Still, it is only black and white.' No, that again is one of those casual errors we make because we take for granted we know all about such a commonplace object as the moon. Here are some of the colours which observers with quite small telescopes have been able to notice. Two of those vast plains, which used to be called seas, Mare Imbrium and Frigoris, they are yellow-green; another,

called Humorum—about the area of England—is dusky green. Another big enclosure, Palus Somnii, is a rich golden-brown, and there are here and there areas of steel grey, pale blue and patches of chocolate, besides those snow-white dazzling spots. And not only has the moon landscape plenty of colour when you study it. It has something more arresting: it has change. In quite a number of those strange crater-floors, those sunken countrysides scores of miles across, shut in by peaks tens of thousands of feet high, the floors themselves often many thousands of feet below the outside ground level, most puzzling changes do take place. Watch, for instance, the floor of Plato, which is one of the largest; when the sun has been pouring on the steel grey plain for some time the whole surface darkens. Another such sunken plain starts the day by being chocolate, but it also changes colour as the sun's heat increases. While when you try and peer down into some of those great wells, for some reason you never seem able to see the floor quite clearly. Why? Is there a mist which forms and billows down there? Certain it is that right out on the open plains some quite well marked ravines and canyons have the oddest way of being as clear as day at one observation, and then, when the moon is again in exactly the same position, and everything else is quite clear, you can't find that one fissure. Where has it gone? Is it under a fog? You see, after all, the moon is not so bare and plain. It has mysteries still for us to explore. Perhaps it is not yet quite dead. Perhaps it is still faintly stirring. You may have heard of that par-

ticular mystery crater, Eratosthenes. That is the one about which at present there are the greatest suspicions. Something is going on down there, and the astronomers who have observed it with the best telescopes are least inclined to say what it can be. In fact, Dr. Pickering, who has made it his special study, has called it, half seriously, the Gardens of Eratosthenes. Something grows there, crouched under the shadow of those immense protective walls. It may be a chemical growth. It may be a growth of something more complicated, more organic than a chemical. We are not nearly so certain as we were of the conditions under which life can't exist. We now know that some fungus spores can survive and breed after they have been frozen in liquid helium—a cold close to the cold of outer space. Perhaps then a fungus could grow in certain fissures of the moon. An American biologist has claimed that he has found living Cocci—very live germs considering the diseases some of this family can give us—still surviving inside a meteorite. All manner of bacteria have been netted by aeroplanes flying several miles high. Certainly we are coming to realize that life isn't a rare freak, weakly waiting to be snuffed out. On the contrary it is something which is intensely dynamic, always fighting against deadness, always striving to snatch a fresh foothold in the unceasing struggle against Chaos and Old Night. Well, the moon may throw an unexpected light on this mystery. But to be certain we must see more. Life is always as small as it is intense. Even the largest forms of life known, the giant Sequoia Redwood trees, are

only some three hundred feet high. With the largest telescopes we have at present we can see on the moon an object some six hundred feet big. You could pick out a building somewhat bigger than St. Paul's, if you knew exactly where to look for it. But such an object would be quite a large thicket. With the two-hundred-inch telescope we may see, perhaps, four times as much; in fact, you could see a clump of trees or an outbreak of toadstool growths if they could cover say the pavement round the Eros fountain in Piccadilly Circus. The problem of course is to find such minute patches. Remember you have to search a desert several thousands of miles across and camouflaged with all sorts of mountains and valleys and canyons. Still no one can doubt that with all the new telescopes—the two-hundred-inch glass lens is only one invention—there are multiple lenses, cone-shaped lenses, aluminium mirrors, all being experimented with, and all of which will give us better visibility—with all these new eyes there is a new world of wonder opening up for us just over our heads. Granted we find that companion world of ours more dead than the Sahara. Still, who of us, vexed and weary with the dust and mud of this world's conflicts, may not get refreshment by leaving behind for an hour these sublunary confusions of life and cruising in complete calm over that quiet and majestic landscape? The Stoics said: 'If you would endure life nobly, contemplate the nightly heavens.' Well, we can hope to act as none before us could act on that fine advice. I think visiting the moon may prove one of the finest tran-

quillizers. So after all, astronomy, like the contemplation of all beauty, can have uses.

That, then, is one reason why astronomy interests us. It raises us above ourselves—it is so odd that we minute creatures, tied on to our insignificant ball and whirled helplessly through uncharted space, should be able to look out through those deeps and understand how the vast universe is moving, and map its gigantic coasts and deeps. But we can also find out much of the strange vast surroundings in which we have woken up, by studying the things the universe literally throws at us. Look at meteorites. About everything else in the sky we may have our doubts. After all, we know we can only see, or at the utmost, as we shall see, hear the stars, and we know that sight and hearing can be easily taken in. Seeing is believing, but only feeling is knowing. But about meteorites we can have no doubt. We can see them come in from outer space and we can feel them, we can pick them up and study them. Here, Nature does not say simply 'Look' or 'Listen', but 'Here—catch'. And there in our hands, when we have let the catch cool, we have a bit of stuff from outside the world altogether. Already careful chemical study of these meteorites has told us a great deal. We have found that some of them are stone, and others made mainly of nickel iron—the one that has just been sent us from Rhodesia, where it was seen to fall a little while ago, is a mixture of stone and this iron. That alone is very interesting, for we know that our earth is made up of a rind or crust of stone, and a core of what from its weight seems to be a mass of

nickel iron. So it has been thought that perhaps these fragments are fragments of wreckage from another one of the sun's family of satellites, perhaps even the fragments of a burst planet which was like our earth.[1] Now lately the proofs of this have got distinctly stronger. First a meteorite of stone was found fallen in New Mexico. That stone was analysed with great care to find what minerals were in it, and traces of gold were found to be mixed up in it. This is the first time that our familiar precious metal has been found in a meteorite, and it gives one more proof that some object in space must have been made of the same stuff as our earth and have cooled as our earth has cooled and so the gold condensed out in the rocks. Of course it needed very careful chemical tests to find that precious metal, but there is no doubt about it. An ordinary smelting and refining company, which has to test ores taken from the earth and see what metals are in them, also made the assay of this meteorite—that is, it tested the stone as you test for ordinary earth-gold and it confirmed the test first made in a special laboratory—here was real gold sent in from outer space. And at the same time comes further news of other delicate scientific tests being carried out on meteorites so as to learn still more about them. After chemistry has told us what metals and chemicals are present in them, we can go further and can find out how old the meteorite is. We can discover how long ago it was that it solidified into what it is now—hard

[1] This view has lately been given further support by Prof. Lindblad, Director of the Stockholm Observatory.

stone. That is done by what has sometimes been called the Radium Clock. The heaviest element, uranium, which is present in minute amounts in rocks, seems always to be turning itself very slowly into lighter elements. And what is more, nothing that can happen to the rock seems to upset the uranium. It goes on running down at the same pace, whatever happens. As it does so it lets out into the rock minute traces of the gas helium. Now chemistry, or rather physics, can tell the exact amount of helium gas in a fragment of stone. So the age of the earth—the time when the world caked hard and got its rind of rock—has been calculated. It comes out at some 1725 million years. Naturally this way of dating could be used for learning more about meteorites—and it has already. No less than the pieces of two hundred different meteorites from different parts of the world have been tested in this way. And the interesting thing is that they all give the same date. These stones which have come in from outer space seem all the same age, and that age—of course we are only speaking roughly—is the same age as the Radium Clock gives to the earth itself. Here again is another proof that somewhere in space there was a world probably like ours—tiny bits of the wreckage of which are constantly being thrown up from the ocean of space on to our shores. What was that world like? Had it come to have life? Well, there is the claim made by a chemist that he did find microscopic germs in the heart of a meteorite, germs which though small do belong to a family which is well known, almost too well known, for its activities here

on earth. He said these germs were cocci, and some of these are the germs which give us boils and many other diseases. I don't think anyone else has as yet found any germs in meteorites, so we must wait and see. But it is clear that if Nature goes on flinging us fragments of that ill-starred satellite, science will go on learning how to find out more about it. But would not the heat of the friction of coming down through the air kill any germs bedded in the stone? Don't we see these stones burning like torches across the sky? That is true, but careful study now seems to have shown that part of the time that we see this light, the meteorite itself may not be burning, but because the upper air is being pressed away in front of it so fast, it is this we see blazing, and not the stone itself. A moment later, as it makes the final plunge to earth, the stone itself burns, but that may be for only a few moments, and it does not seem quite certain that the heat must reach germs bedded well inside, in time to bake them.

So much for sky news sent in to us by meteorite. Now we must strike out further afield and see what more news there may be not actually to hand but through the telescope; and there is a good deal about our own solar system and our companion planets. They must always come first in our interest about anything in the skies, for when we look at them the question must come up: could there be life on them also? Well, now we have further news that bears on that question. Jupiter and Saturn, our world's giant brothers, have a gas round them: that has been proved.

But the gas seems to be methane and ammonia, two gases which are poisonous. So 'No life yet' seems to be the verdict for those huge worlds. But at the other end, from Venus, the planet between us and the sun, comes different news. Venus, it has long been known, is wrapped in thick folds of pure white mist. That is the reason why it shines so brightly. Now this white fog, it has been found, is thick with the gas carbon dioxide. Of course carbon dioxide by itself poisons us. Still, we can't live without it, and we know that all plants and animals, everything which breathes, gives it out. So our finding so much of it in the air of Venus makes us ask, can life be starting again under that white veil of fog on the sister planet? This discovery makes that look rather more likely. This planet, because of its position next closer the sun, could be the next place where life could start its story. There is of course one great difficulty, that is, does Venus revolve on its axis as it goes round the sun? Does it have a night and day, or is it so close to the sun that, like the moon in regard to the earth, it can only keep one face always to the sun? If it does that, then one side must be boiling, and the other freezing, and that is a poor look-out for life. Owing to the fact that we can only watch these dazzling clouds of white mist it is very difficult to decide whether it is spinning round or is fixed. But it may seem even more impossible to say what is the gas which makes up these white mists, for we can never take a sample and test it in a laboratory. It was that fact, that we can only look at the stars but never touch, that made the great philosopher Kant say,

when he was thinking about the things which man could never know, that one of those things must be the stuff of which the stars are made. Of course, quite soon the spectroscope solved that problem, for the light of a burning star when it is thrown through a spectrum or prism shows certain distinctive bands and lines. Chemistry has long known what bands of colour and lines chemicals give when you burn them. So when you see the same colours and lines in a star's spectrum you know such chemicals are burning in the star. Of course this detective method doesn't exactly apply to planets, because they give out no light themselves—they only reflect the sun's. Still, work done lately has shown just how much sunlight is absorbed when you pass it through carbon dioxide, and it is now possible with the super-telescopes to watch how the sunlight is being absorbed in the mists of Venus. So it has been found not only that carbon dioxide is present in the Venus clouds but how much of it is there. It happens to be some ten thousand times more than the earth has. It must be like the hottest greenhouse we can imagine down there, because this gas holds heat; in fact, it holds heat so well that some people have thought that the coming and going of the Ice Ages in our earth's history is due to how much or how little carbon dioxide is in our atmosphere. So you see it is becoming little by little more possible that just as Mars is ahead of us, and is dried up, as we shall be millions of years hence, Venus is on its side going through a stage of its history similar to that we went through perhaps at the very dawn of life. What

a lot we might learn about our past if we could only see through those clouds and watch what is going on at ground level. Perhaps some day we shall. Perhaps we shall get radiations which will pierce mist. We know already that the red rays can cut through a great deal of fog and that infra-red cinema films can be used in what seems to us complete dark.

That naturally brings us to news items of the latest progress in making those instruments with which we probe space and, as it were, move our eyes millions of miles closer to objects which seemed placed for ever out of their reach. The chief news is again about the great two-hundred-inch mirror which is to be the centre of the world's greatest telescope. The first attempt to make this huge thing was a failure. You may remember that when they were casting it, pouring in that cataract of melted glass, the heat became so great that some of the cores—the supporting parts of the cast—became loose, and a couple floated up through the fiery syrup. It was hoped that they had been fished out in time to have done no permanent damage. Unfortunately, they have. The vast mirror is spoilt. But the Americans, with their wonderful energy, without waiting to know whether the damage could be put right or was too bad for that, as soon as they knew there was a risk that the mirror had been spoilt, set to work at once to make another, regardless of the immense expense. The second was a successful cast and is now well on its way to safety, stability and cool hardness.

So the spoiling of the first, though it put back the

date when this, the world's greatest, eye will open, was only a check. The mirror should be ready only a few months behind schedule. The latest news is that it has now been given its coat of aluminium, which is a far better reflector than silver. And not only are we making telescope eyes larger. We are learning how to make them more sensitive. The new photographic plates are being made to record fainter and deeper radiations such as the dark red stars give out. The use of these new sensitive plates has lately made astronomers change their view of what the Milky Way, our own Galaxy Island Universe, can be like. It is now thought that though the bright part—the part we see easily—is like a great wheel or disc, the real shape is like a great globe, if you take in all the faint and deep-coloured stars which only show up on these new sensitive plates. It begins to look, then, as though our new telescopes are showing that there is less and less empty space and the universe is really dense with all kinds of unsuspected objects and forces, if we can only train ourselves to see.

Chapter II

The Closer-up Space

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(a) Near space and its fullness

So much for the largest outline, the broadest sketch-map of Nature. We glance at the far files of 'the army of unalterable law', though we may be a little less certain as to what exactly is that law than was Meredith. We bring our telescope-eye a little closer and we see our companion worlds—the satellites—wheeling on our flanks and the vapours rolling round their mysterious forms. Still, it is an effort to imagine that outer space is anything more than an awful emptiness, an awful freezing terror of vacuity, or more simply for us practical folk who will never go there, an awful bore. But let us draw in our eye-tipped horns and, in our taking stock of our situation, focus nearer home. We shall find that perhaps, after all, that vacuity owes more to our lack of sense or senses than to its own emptiness. But when we leave the moon, can we stop anywhere till we are back on earth? Must not our interest make a nonstop run from that the last station, and end up on *terra firma*? Surely there are no halts or frontiers in between. That, it now seems, is not true.

(b) The vault of heaven

One of the most surprising discoveries of our age is the discovery of the vault of heaven. That phrase, we thought, was a mere poetic survival from the time when people could not grasp that there was really nothing above us. But now we are finding there really is a vault. Of course we have known for what seems to us many years now (but it is really only a few)—that there are up above our heads at least two ceilings or vaults which are of very practical use to us now—the Heaviside layer along the echoing vault of which wireless words must run, and the Appleton layer, on which echo the 'short waves'. But such vaults seem to us just as intangible and immaterial as the wireless waves which glide along them. I think, then, it makes the vault of heaven gain immensely in solidity when we learn that the sound-waves, loud noises, can and do run along that vault just as they bound along a vault of stone. Of course you need an immense shout really to make the sky echo. But it can be done. Up in the chill and silence of the Arctic night lately, a series of huge crackers were set off, 13,500 pounds of explosives were fired. And it was found, as had been suspected, that the sound-waves ran up against the vault of the heavens, and then bounded back to earth. That is the explanation of the fact which has been known for some time, that great crashes can generally be heard within a circle of some 150-200 miles across, then there is a belt of silence; and then, outside that again, the sound is heard, the

sound-waves coming back to earth echoing off the vault of sky. But the fact which really brings home to me this strange discovery that there is a vault above our heads—though it is as transparent as glass—is not so much that we can throw things against it and they bounce back, but that it can shelter us from a torrent that comes pelting on us from outside. It is so strong and sound that it throws back waves which, if they got through, would sweep away all life from the surface of the earth. For that is the discovery which has made us take the vault of heaven as a serious fact and not a flight of fancy—cosmic radiation. There is a lot more news of this which is, after all, perhaps the greatest mystery of our lives, and which indeed would be the end of our lives, if it were not for that invisible unsuspected 'blue targe', as Browning called the blue sky. For under that we are safe from an attack beside which the bullets of a machine-gun are comparatively harmless. They may miss you or you may shield yourself from bullets, but not from rays. The cosmic rays are certainly some of them particles driven with the unparalleled charge of ten thousand million volts. We are finding that this radiation, these tremendous invisible currents shot across space, even with the vault of sky to shelter us, pierce far further than we thought. A little while ago we imagined that if we went some fifty feet under water, we were clear of them, but now it has been found that you must go no less than 880 feet down before you can be sure you have left them behind. It is clearer and clearer we must go up to the front and

study this attack where it breaks on our upper defences. Down here we are like inland men who hear the roaring of the sea, and sometimes taste a tang in the air, but have never been on the beach and seen the breakers and what they break upon. What an upset in our ideas this alone is. We used to think of this stormy world down here and the unruffled heavens above. Now we see down here we are as quiet as eels bedded in mud, while it is up there that hurricanes of force rush and beat. We do know already that the fury of that attack is such that it could only be generated by an explosion which is so great as literally to blow everything, blow the atom itself, to pieces. Certainly, instead of our being put to live down on the stormy, stressful earth, however much we upset things, it is beginning to look as though the quietest spot possible had after all been found for us, where, as it were, we could grow undisturbed under glass. That makes the exploration of that transparent roof all the more interesting—we want to find out two things: what is the full force of that storm that beats on it, and what is the vault's own structure and strength. It is obviously very difficult for us to get near it. We can, we have seen, bound radio waves and even sound waves against it, but no human being could live near it. For in the first place, going near it is like going on to a pier during a typhoon—enough of the waves bursting on it could lash at you and knock you out—and in the second place, to change round the simile and make it more exact, you could not go near the door of a furnace which had already

itself become white-hot from the heat it was holding back. It looks as though the upper vault of the sky is ionized, electrified by the terrific bombardment of the cosmic radiation that is always crashing upon it. So even if a balloon could take human observers right through the great cold of the stratosphere, and they could screen themselves from the increasing radiation which would be reaching them, they would still have to face the immense risk that the balloon would burst in the heat. How hot the uppermost atmosphere may be no one can yet be quite sure, but scientific opinion is pretty certain it is uncomfortably hot. At sixty-two miles up it has reached 80 degrees Fahrenheit. We can, however, make robot raids into the lower limits of the upper atmosphere. Sounding balloons have now gone up on their own as much as twenty miles high. And when they get as high as that, the atmosphere has already become so thin that, though it goes on for a hundred miles beyond that, yet you are already the best of the way through the ceiling, or across the beach, and out where the cosmic waves are dashing on the shore. But of course it would be of little use sending them up if they could not tell us what they found there. That was first done by sending up with them ingeniously slender instruments. When the balloon reached the height at which it burst, these instruments came down in specially constructed parachutes with crashproof undercarriages, and later came down even more quietly by being hung on a second balloon too small to bear their weight, and too small to burst, but just large

enough to break their fall. This however was not good enough. For one thing, the balloons were too often lost. So an Indian, Professor Benade, invented an ingeniously simple device which went up with the balloon and all the while sent out radio signals telling how high it was, how cold, and even how much the cosmic radiation was increasing. It does not matter much then if you do not get back your balloon. It has told its story before it burst, and you have the record without needing to recover the instrument. Now that we have this method of making the unmanned sounding balloon talk to us all the while it is climbing, we have a real chance of getting records from the outermost rim, the furthest shore-line of the atmosphere. Rockets are now being prepared which will carry such talking instruments, and the rockets will of course be able to go on unchecked by any limit at which a balloon must burst. There is no mechanical obstacle in the way of their rushing right out into open space, into the full rage and swell of the cosmic tempest, and carrying out their instruments, which will send back, every second, signals to tell of how that incredible storm rises to its full height of unrestrained energy. It looks then as if quite soon we shall have our eyes fully opened to one of the strangest and least suspected forces in the universe. And this recording and mapping of these invisible torrents and tides, these intangible frontiers and coasts, is making clear not only the forces that beat against these unsuspected natural defences, they are making clear to us the exact structure of these defences. We are learn-

ing that though the outer side of this our protective vault must be swept, scooped and torn like a sea wall that faces the Atlantic, yet the underside, the soffit of the world's vastest arch, is smooth as glass, smooth as a still lake. We can say that the surfaces on which the radio waves run are liquid mirrors, so sensitive that a roll of thunder makes them 'dusk and shiver'. The underside of heaven's vault can be thought of as a vast lake of sacred calm across which our restless whisperings run and which are blurred by the lightning. Yet here again we come across one of those queer contradictions of common sense and practical experience, contradictions and upsets of our ways of thinking which are always meeting us as soon as we step a few miles out of the narrow layer in which we are fitted to live. It is not merely that it is the lightning and not the thunder which shakes and blurs that mirror vault above our heads. There is a queerer fact than the tremendous ruffles and ripples that run across its smoothness. The whole vault as we know it is continually heaving and falling, pulsing and spiring like a great heart or a great breath, and perhaps the oddest thing about this huge tide is that it is in the quiet of the night that it is most restless, and in the busy day it is most quiet. Careful experiments made over many months to see how the time varies in sending a signal from Paris to Algiers, showed that it amounted to as much as 10 per cent. The signal goes there and back in one-hundredth of a second. During the day the signal darts there and back without variation, but during the night it is continually chop-

ping and changing; the vault is never steady at night.

And all this work on our common ceiling, the vault of heaven, we must remind ourselves, is practical. The vault of heaven has come back into our thoughts and calculations as a practical thing. More, it is as firm and practical a thing as the road surface under our feet. The newly discovered vault of heaven is the new world's highway.

It is quite certain that one of the best hopes of peace is through radio, through the fact that up there no frontiers can be drawn, speech can pass freely round the world, making men realize that they are all gathered together under a common heaven. And this exploration of the great dome will also open still another frontierless roadway. For the study now being made of the upper atmosphere is being undertaken not merely for radio—in order that men may speak and, with television, see each other—but in order that the globe may actually be linked together through stratosphere flight which will make the whole world to be in daily touch.

Still, as one turns away from looking toward that invisible vault, one realizes that neither radio, still less stratosphere planes will make men one, if they wish to be hostile, and the thought recurs, is not really the most wonderful thing about the dome of heaven not what we can do with it but what it does for us? Here we are, frail animalculae, delicately set, as we have known, between deadly heat below and deadly cold above—reared in this film of an atmosphere. And now we learn that that film also protects us so we

can be warmed and lit, and yet be screened from forces so tremendous that our faint little senses have not even had any suspicion that they were there. We have not been able to discover that we were even threatened by such a danger, so unfamiliar is it to us. It really looks more and more as if there were something in what has been called the fitness of the environment—as if we had been fitted for a particular purpose into a particular place. Anyhow, surely is it not ridiculous that we should bluster and threaten one another as though our force really counted and the universe stood aside to watch us battle, when all the while, just above our heads, we have to be sheltered from cosmic forces which, if they were let get through only for a few seconds, would wipe out all our race, all life? It is often said, only a common peril will make men united, but one may hope perhaps, instead, as knowledge grows, unity may also grow from a sense of a common protection from peril, and a common gratitude.

Chapter III

'The Great Globe Itself'

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(a) Our tidal earth

Now at last, in studying the map of the Universe which Science gives us to-day, we reach our Earth.

First we saw what science by the highest magnification found matter to be made of. Next, we saw how with the opposite kind of highest magnification —with the super-telescopes—science makes out all the matter there to be arranged in great dumps of star-clusters throughout the universe. Then we saw that science was finding the universe to be more complicated than that simple picture of empty space sparsely filled with dumps, or one ought to say sprinkled with pinches of star-dust. The last chapter closed with our discovery that space was filled with tremendous forces, and that they beat on a roof or series of vaults about 100 miles above our heads.

That brings us to earth with a sense that the world is not nearly as commonplace as we thought, and Science has certainly not banished romance and wonder from life. Still, we sometimes think, however strange outer space may be, the solid earth can hold no surprise for us. Let us then see what science is now

telling us about the 'Great Globe Itself', and whether it is so dull and stable as we have thought. First of all, what is the news about Seismology—the wish to know how this half-cooled globe is shrinking, and cracking, and ticking like a cooling cinder as it shrinks. This subject bores many people because they feel you can hardly expect men who are so much less than specks of dust on the earth's surface to be able to do much about such a gigantic process. But there is another side to seismology. We are learning how to do something about earthquakes. It is true that we can do nothing to prevent them, but we are learning how to foresee them. That knowledge will be of incalculable value. For, though earthquakes kill at a stroke probably more people than are ever killed in any other way, half the peril is due to the fact that they can catch us unawares. For example, if only the great Messina earthquake could have been foreseen even half-an-hour ahead, most of the two hundred thousand people who perished in a few minutes might have been saved. It came as a thief in the night, and the heavy stone buildings fell on tens of thousands of sleepers and killed them at a blow.

Of course, till quite lately men thought that nothing could be done. Nature hit without warning. Now we are discovering that notion to be quite untrue. Indeed, we may doubt whether Nature ever hits without a warning—if only we could attend to it. Certainly she gives plenty of notice about earthquakes, and certainly we should learn to attend, for most weeks there is quite a large earthquake somewhere in the world.

Take the last terrible earthquake, the one in North India. We are finding out that there was plenty of notice given that trouble was brewing underfoot there. This was no inexplicable outrage—a bolt from the blue. The mischief had been storing up much longer than Guy Fawkes was storing up his powder-barrels to blow up Parliament. In fact, an earthquake is only the end of a long chain of events. It is the final settlement and settling-down. There seems reason to suppose that in the last seventy years all the country-side in which that terrible Behar earthquake broke out, had been steadily rising. It is true it had only been rising at the rate of some six feet a century, but when a rise like that goes on, it is very serious. And in that part of the world you have to keep a peculiarly sharp lookout. For the Himalayas are the highest mountains in the world because they are quite young as mountains go—much younger than the Alps and mere infants beside some of the Welsh and Irish hills. In fact, the Himalayas are still growing, growing quite appreciably, and no one can say how tall they will be when they are fully grown-up. This is probably the reason for part of the earthquake trouble thereabouts. The plains at their feet are being drawn up also, just as the sheets rise in a slope when you raise your knees in bed. You may think it would be impossible to measure a rise of the countryside which only amounts to less than three-quarters of an inch in a year. Such increases, can, however, be measured by modern surveying instruments, and though there is some doubt as to whether the instruments of a

quarter of a century ago have left us results equally accurate, yet it seems on the whole that this significant rise of the foothill plain has taken place. Nature's warning can be read and it is undoubtedly to be read as a warning. Two years ago this rise was read as a draw-up in a certain direction. And where the main line of this drawing strain went east-north-east toward the Himalayas, there it was that, on January 15th, 1934, suddenly the tension broke, the solid earth rippled and flowed like treacle, and of course all buildings on such ground came to grief. But what is the use of telling people: 'In a couple of years or so you may probably get a bad quake'? Mankind, which will go and live on the sides of active volcanoes, and will go back to its earthquake zone the moment the earth has finished shuddering, will pay as much attention to such advice as was paid to the boy who always shouted 'Wolf'. If you are to make any impression and to save lives, you must be able to name the day when the earthquake is coming and the earth must fulfil your prophecy. Is there any hope we shall ever be able to do that? Can seismology ever reach such a standard of efficiency? Yes, it may. For here again it has been proved that the earth does give warnings, if only we can read them. Japan is certainly the most densely inhabited earthquake zone in the world, and, as we know, the Japanese are of all people least inclined to sit down and wait to be attacked. If science can teach them anything about earthquakes, they may be trusted to learn it. And certainly they have already found out a great deal. For instance,

they have found that not only long before an earthquake is the ground undergoing a great strain—very often, as we've seen with the Indian earthquake, rising for a generation and more before the convulsive readjustments. They have found also that shortly before many of the actual convulsions the ground tilts. Then generally within a few hours the strain breaks down and the earth rocks, spreading devastation. The tilting seems a sort of final twist before the vast subterranean vaults collapse or the foundations slide. There are instruments now in use which can measure that tip, though, of course, it is quite invisible to our eyes, and when that tip goes beyond a certain point, then the wise man will go and stand in open country where nothing can fall on him. But even then the earthquake-forecaster can't be sure the earthquake is coming then and there. It is a serious thing to tell a whole town to come out of their houses, the fishermen to leave the shore, the quarrymen the quarry, and then no earthquake turns up; and worse, if just when the people have gone back to their work, should the delayed violence suddenly break loose. Is there any other way of reading Nature's intentions and finding out what she has in store? We evidently need a detector more sensitive than any mere measuring instrument which can show how many inches the earth has already moved. Electricity of course at once occurs to our minds. Couldn't an electric detector be found which would serve as a reliable alarm-clock? Certainly there is no reason why some such electrical recorder should not be found. It is pretty certain

that an earthquake is attended by electrical symptoms. For a long time there had been popular reports that flashes of queer light are seen during really bad quakes, and since the serious earthquakes of the last few years have been carefully observed by naturalists on the spot, there seems evidence that such peculiar flashes are an earthquake feature—though how precisely they are caused and what they mean no one can yet say. They do, however, suggest that some considerable electrical disturbance is involved in the general confusion. Yet so far no electrical instrument has been devised which would, as a barometer records an oncoming air-storm, show that an earthstorm was brewing. Nevertheless an electrical recorder has been found. Anyone who notes new finds in science will have his attention drawn to our constantly growing knowledge of the unsuspected sensitiveness of living organisms—the plant or the animal. Probably the evidence of that Mitogenetic radiation—the radiation given off by living cells when they divide and so multiply—the evidence for this mysterious living current is accumulating. But everyone is agreed that it is amazingly difficult to record. No instrument can measure it. The only thing which records it is a living cell, if exposed to it. Yeast cells, and, now it has been found, the eggs of the famous fruit-fly Drosophila, do seem to give evidence of the radiation by responding by greatly increased growth. Even our own senses, which we are always calling so blunt and blind when compared with the sensitiveness of our instruments, those five sense of ours take in far more

than we ever imagine. Experiments with hypnosis have proved that. Nine times out of ten, when we don't notice a thing, it is not our senses but our attention—the poor way we focus our senses—that is at fault. And some animals are amazingly and peculiarly sensitive to electricity, more sensitive, it would seem, than any instrument we have at present. That, at least, seems the only explanation of the latest earthquake detector, the cat-fish. Certainly, when you visit this very unattractive fish in the Zoo, there does not seem any reason why it should have been preserved, or any hint of the strange and valuable gift which lies behind its dull appearance. To call the cat-fish plain would be a compliment. It is a large, lead-coloured, wormy object with a number of smaller wormy soft warts about its face. It is an insult to a cat to give it such a fish as its god-child. I'm sure if we had been able to get at all the world's cat-fish, we should have exterminated them and not felt that we had lost anything. But we should have. For the cat-fish can tell you when an earthquake is coming on. Maybe other animals can. Before one of the last Californian earthquakes, one observer noticed that some birds of a particular species suddenly left the tree they were roosting in—it was nearly dawn—and rocketed into the air half-an-hour before the shock. When the the shock itself was on, they did not seem to pay any attention. It was something intangible, that had gone before, which startled them. However, no one has ever managed to keep birds under observation and to notice from their behaviour whether an earth-

quake is on the way. That would be true augury. But this, though it sounds almost unbelievable, is exactly what has been done with the unlovely and unlively catfish. The Japanese have made the discovery. As they are always searching for an earthquake herald, they have found one in this queer fish. The procedure in consulting this latest oracle is as follows. The catfish is kept in a tank. Once every six hours the observer taps on the table which carries the tank. If all is clear you will notice nothing odd about the fish's behaviour. On the other hand, if when you tap the fish suddenly plunges through the water, then look out. Within six hours you may count on an earthquake. It has now been proved that four times out of five the catfish is a perfectly sound forecaster. The Meteorological Office would be pleased if it could have as high a percentage of hits—80 per cent—and when you think what the hit is, how much more important it is to know whether an earthquake is on the way, more important than any weather bulletin short of a tornado warning, one can see how catfish may rise in value in earthquake zones. How does the fish do it? It is pretty clear that it is abnormally sensitive to some electrical condition. For, if you insulate the tank, the fish can't respond, though the crack of doom was about to break. It has to be in electrical contact with the earth.

So we may hope one day to get an electrical instrument which will record what the fish feels, and perhaps it will write a record for us, like a barograph writes a record of the atmospheric pressure and shows

how it is changing. Looking at that, we should be able to see at a glance whether an earthquake was brewing and about to break in the next six hours. Certainly the catfish, invaluable as he is at present, in our present stage of earthquake ignorance, could be improved upon. For instance, he cannot, it would seem, distinguish whether the earthquake is only a local tremor of the slightest sort, say, like that tiny tremor which shook one village near Deal in Kent on the 23rd April, 1934, and is now forgotten, or an oncoming convulsion which may wreck a whole countryside and deluge half a dozen coast towns. The minutest strain directly under his tail disturbs him just as much as the messengers of a destruction the lair of which is a hundred miles away. But the fish has undoubtedly pointed the way. And once more our race may be grateful to another odd animal ally. We shall be reviewing a few of these involuntary friends in a later chapter. We shall see how, for instance, the ferret may yet save us from the pestilence of influenza. The catfish may show us how we can escape the fury of an even more terrible and blinder power, the seizure of the earth itself. In one of the Southern United States there is a public monument to an animal. It is to the boll weevil, which nearly destroyed the cotton plantations, then the staple crop of those Southern States. The boll weevil's depredations drove the Southern agriculturists to develop other crops, and so in the end they found themselves grateful to the pest which drove them out of the rut. If the boll weevil has its monument, surely

the catfish also deserves a stone of remembrance?

The subject of earthquakes, the study of our globe as a globe, leads us however far beyond the mere practical question of just avoiding being shaken out of our lives.

The shudders of the earth, science views not merely as dangerous but as vastly interesting. Why does the earth shudder? Because it is a cooling cinder. But why should it shudder and vibrate just as it does? That raises a very interesting question and starts us off on the next great study, as we come in from the stars and with our glasses sweep the front of science which ends up with ourselves.

That question and study is the Tides. Science has a great deal of knowledge both useful and wonderful to give us on these rhythms and swings. We are beginning to realize that the whole universe is really pulsing with an incessant energy. Even the obvious tides are very mysterious things, though we think they are quite simple. We smile when we read of the Romans' dismay when they came out of the Mediterranean, where they had had no tides that mattered, and found themselves up against these strange floods and ebbs. They were astounded to find their ships stranded, where an hour or two before was ample water. We know that tides are caused mainly by the moon, with the sun as a good second. And yet even the ocean tides are very difficult to account for fully, even now. Many people don't realize that though round these coasts we have two tides a day, there are many places in the world which only have one. All

sorts of complications have to be taken into consideration if you are to be able to calculate even a sea tide. The sort of coast or channel on which the tide comes: if it is funnel-shaped, you may get those rushing walls of water called bores. So little is known about them that though we have several round our coasts, there is going on now a special study of the one on the Trent, to find out exactly how it works. And the sea floor itself may be altered by the weight of water mounting on it, and so throw out simple calculations. It has been proved that the floor of the Straits of Dover actually sinks a measurable number of inches with the weight of a full tide coming up over it, and the same delicate measurements and calculations have shown this taking place on ocean coasts. And that discovery about sea tides brings us to another discovery—the tides of the earth itself. We see the earth isn't the rigid ball we thought, round which the great tidal wave of waters rushes, vainly following the flying moon. It is not merely as springy as turf, so that the weight of full tide-water makes it bend. It also has its tide. The springy earth bulges out—of course very slightly, but measurably—pulled toward the moon. There is a vast ripple running round the globe through earth and rock. It is this fact which has made it so difficult, almost impossible, to say with absolute precision where the moon will be found at any moment. The Nautical Almanack, that monument of accurate information, cannot always be trusted completely just here, because the observations by which the moon's path is calculated cannot them-

selves be taken from an absolutely fixed point. All the observatories rise and fall just a little under the pull of the moon, and so what they say about the moon's exact position cannot be perfectly accurate. So much for the simple tides, the only tides which we used to think mattered. We are however finding out that there are a lot more tides flowing round us, which, though much more difficult to notice, are certainly as important as any of the tides of the sea. Indeed, I think we can say that our outlook on the whole universe is becoming tidal. In trying to understand the world around us, we seem to have reached a stage similar to that the Romans reached when they left the tideless, landlocked Mediterranean and launched out on the huge tidal oceans. We are giving up the notion, with which everyone starts, that the natural state of everything is a state of rest—that movement is simply the effort to settle down. Instead we are beginning to realize that that is a pure assumption. The natural state of everything may be a state of action, of flux and flow. I think the first thing that helped us to realize that was the weather. Meteorology showed that though the weather seems hopelessly confused (at least our temperate weather), that was only because we had to deal with very confused cross-tides. In the tropics the weather is as regular as a sea tide. It is growing increasingly certain that our weather is linked up with that regular cycle and tide the sunspot cycle, and that that in its turn is linked up with the tidal pull which all the planets, right out to Neptune and Uranus—exert on the sun. Of course that makes

calculation and, even more, forecasting enormously difficult. You know the spot-cycle itself is not an exact number of years, and there are sun-spot maxima, which may be called spring tides, and others so much less in size that they may be called neap tides. But what is of chief interest to us lay folk in this branch of tide-research is that these tides are magnetic tides. The sun-spots, because they are magnetic disturbances, all radio listeners know, can upset our reception hopelessly. It is pretty certain also that they rule our weather and, further, it is quite possible that they can affect directly our health. You know about the earth's magnetic field, how the earth is a huge magnet. The sun's electrical discharges rush to the poles, and there is a constant wash of tidal energy pouring from one of the poles to the other. These facts may help us link up several odd observations. The barometer, quite apart from obvious weather changes, records a daily tide of atmospheric pressure gently rising and falling. Some vast tide is passing over our heads. It is perhaps worth comparing this with the fact that the clinical thermometer also often records a tide in our bodies. Anyone who has done careful nursing knows that there is always a slight rise in temperature about six in the evening. Can these two tides be linked? Perhaps so. That our bodies are sensitive to the earth's magnetic field and its tidal movement there is distinct evidence. If a patient is undergoing special radiation treatment, some clinical reports have shown that the effects will not be satisfactory if the patient is faced north and south, that is, in the path of the earth's

magnetic current, but must be placed east and west. This fact may account for some people finding that they sleep better if they lie east—west, not north—south. I remember Lord Knutsford saying he had discovered this for himself, though he couldn't imagine why. Certainly in the radiation cases I've just mentioned it wasn't a matter of the patient just thinking he would or would not be benefited. He didn't know which way he was being faced, or why. But let's go further, and take the case of electrical tides which aren't affecting people but inanimate objects. Here, I think, we have lately had some of the strangest evidence of the hitherto unsuspected tides that are always flowing round us and through things. Did it ever occur to you that dead things could have tides in them, tides which if you wish to tackle the object and turn it to your will, it would be wise for you to know about? It seems almost absurd; and yet proof is now growing that such a hard and definite thing as steel actually has its pulsations and, one might almost say, its tides. That seems to me almost more difficult to believe than that the solid earth rises into a sort of rippling blister as it swells out pulled by the moon. And yet, of course, when we remember how impressionable steel really is—how it can be magnetized so that it is sensitive to the earth's magnetic current, and further, as we shall see later, the way magnetism can impregnate steel tape with voices and music —well, we see that steel is not nearly as strong and silent as we'd thought. And this work confirms that suspicion. Of course, now we have been told that all

matter is really electrical energy, we are used to the idea that everything must be vibrating and pulsing in waves and tides. But for most of us, all that is simply scientific fancy. We know light is really vibrations, and beyond the vibrations of light are the faster and faster vibrations of X-rays up to the cosmic rays. And below light we know that heat is simply a vibration and the wireless wave is another of those slower vibrations. But 'slow' is only one of those scientific courtesy words. It doesn't really mean slow in any common-sense meaning of the word. It only means slower in comparison with vibrations of light, etc. So we've thought that these pulses and tides didn't actually mean anything of the sort. For all practical purposes you were dealing not with tides but with steady intense jets and streams of force, and we assumed that all research—like the research into the cosmic rays—would be into higher and higher frequencies, intenser and intenser speeds, until everything is found to flash away in astronomical figures too vast to do more than stun our imaginations. But that just shows how, like slow-witted cats, we will watch only one hole. Research has now broken out at the other end of the line. After all, we might have expected that. If up the scale everything gets faster and faster, down the scale we ought to find slower and slower pulses, true tides. Yet how hard it is to recognize a thing you don't expect, even when it turns up under your nose, this research into what I may perhaps call steel tides illustrates very well. For a long while, as the United States Naval Research Labora-

tory reports, it has been found that as steel ages it fluctuates in its hardness. That on the face of it looks as though some tide were flowing in the metal. However, it seemed absurd to own that steel could have a tide, and, so, much time was spent in trying to find out by very careful work why the testing machine would fluctuate so strangely in the results it gave. That is like a man dipping a sounding line into a tidal well, and on finding different lengths of it to be damp or dry at different hours, trying to discover how the line managed to stretch and shrink of itself. Now, however, this latest of the tides or pulses has been recognized as a fluctuation which can be gauged by testing regularly the varying hardness of the metal, and research is going ahead fast. And it is peculiarly interesting to learn that the most usual frequency which has been discovered in cold metals is one of six hours, a pulse like our own ocean tide.

Of course these frequences aren't like sea tides, always flowing. Rather they are like the radio waves sent out by stations when they signal, or like the vibrations which you set going when you strike a big bell. If you magnetize or twist the metal, it sends out this immensely slow vibration. And of course this tidal vibration isn't in the air, any more than a radio wave is in the air. Like the radio wave, it also is an electric magnetic pulse. This knowledge isn't merely curious. It will be of use. It will help us to work and temper metals far better than we have been able to, and that means better tools, lighter—because stronger —cars and aeroplanes, wider bridges, faster trains. It

gives us the power of being able to temper metals simply by passing them through a magnetic field. That is a pretty practical demonstration that after all the hardest metal is only at heart a pulse of energy—an argument that might have convinced even Dr. Johnson that matter was more mysterious than he thought. Everything we know of, when we once get to know it, seems subject to this principle of tide and flux. Hasn't Einstein said that even the entire expanding universe isn't really exploding, but itself only taking part in this vast law of tides, flooding now, but in due course ebbing again? Still, that idea is a bit big for our minds. When I want to realize the pulse in everything, I find it more practically impressive to think of steel hardening and softening as the invisible magnetic tides are sent running through it. By using these pulsing forces we can shape the most stubborn forms of matter to our will. What better proof could we have that he who understands the tide behind all things may control everything? It gives a new sense that Shakespeare never suspected to his well-worn words: 'There is a tide in the affairs of men which, taken at the flood, leads on to fortune.'

(b) Listening-in to the tide in all things

The universe, then, is a throbbing, pulsing condition of things, from our pulsing hearts to the star-clusters rushing out and then probably back again. That upsets our old-fashioned picture of our small flash of life in the fabulous stillness of All the Rest.

It makes us ask, is Nature as still and silent as we thought? Frankly, has Nature got a voice? People used always to think so, but then it seemed that science had stilled that voice. That was a shock. Pascal, the great religious mathematician of three hundred years ago, said, in a phrase which went on echoing in people's minds: 'The eternal silences terrify me.' It was a dreadful thought that everything was as dumb as a ghost. Even our braver, less clever Addison, looking out on the universe, had to own in his famous hymn, 'What though in solemn silence all move round this dark terrestrial ball? What though no real voice or sound is heard the vast creation round?' But is the world really so silent? Has Nature really got no voice? Of course Nature makes plenty of noise—hurricanes, thunderstorms, eruptions, yes, and earthquakes—these can all be deafening. But all this has been taken as nothing but blind hubbub, 'full of sound and fury, signifying nothing'. Nature never spoke. She only showed things. You could learn nothing by listening but only by looking. There was nothing to be learnt from natural sounds. They were only the noise made by shifting the scenery. But this, it is now seen, was going too far. True, Nature doesn't speak any more than she draws or paints. But there is no doubt we have underrated and neglected what her sounds may tell us. Men got into their heads that sounds didn't matter, and could tell you practically nothing. Sight was the only real guide. Seeing was believing, and the only ground for belief. So the world has come to be thought far more dumb than

it really is, because we didn't attend to sounds as we did to sights. Now, however, that neglect of our ears is beginning to be corrected. Perhaps broadcasting has something to do with it. Certainly we are, myriads of us, getting used to listening again, when before broadcasting we were using our ears less and less, except to tell us where to look. But whatever the reason of the re-employment of our ears, there can be no doubt that in science hearing has lately come back as a valued contributor to new knowledge and discovery. We are beginning to notice that Nature can tell us many things if we listen, because she has far more voices than we suspected. Let us start with what used to be called the silent wastes. First came the singing sands. Travellers had occasionally reported that they had heard a strange musical sound coming from desert dunes. It was dismissed as a typical traveller's tale. Now, however, the latest explorers from the hitherto unknown desert of Arabia report that such musical sands are a fact, and that the sound has drawn attention to an arrangement of the sand-grains which the eye would have overlooked. And even later we have learnt that as the desert has its singing sands, so the snowfields of the Arctic have their singing snows. But up in the Arctic there is an even stranger sound—the whisper of the Aurora. Again that voice has also been denied. People have said that these great curtains and fringes of coloured lights are waved and drawn without a sound. The sound heard is only the breath of the onlooker in that intense cold falling in ice-particles on the ground at his feet. Still,

on the whole, it seems that the Aurora may have a voice of its own. The latest evidence seems to show that a real whisper is coming down from the sky. Our ears may be able to pick up the sound made by the playing of this by far the greatest coloured fountain in the world—for that is what the Aurora is, a gigantic spray of electric sun-energy pouring in at the Pole and lighting up the air. And these freezing whispers may tell us something more about those mysterious Northern Lights which, the more we know about them, the more intriguing they become.

But we are not merely 'catching sound' of new, strange noises. We are beginning to use sound to tell us of things about which sight can tell us nothing. In the last few years our knowledge of the deeps and heights of this world has come through the ear and not the eye. Plumbing the depths of the sea used to be a clumsy, slow and slipshod method when done by the eye, checking out the plumb-line. Now it is done by sending down a sound-wave which strikes the sea floor and echoes back against the ship's keel. So not only can you keep sounding the ocean floor, and so get a complete map of it—which you couldn't do with a slowly unwound line—but new deeps have been found. Through this listening-in it is now known that the deepest place in the ocean is nine miles down, not seven as we used to think. When you think that the deepest mine in the world is only about a mile and a half deep, the discovery of this abyss makes one wonder what things must be like down there where our sounding-echo runs quickly there and back, but no

beam of sight can pierce. The same echo idea is now being worked out for aeroplanes, so that as they come to land they can tell their height-distance whether in fog or night. A shrill note which cuts through the plane's roar makes an echo from the ground, and this echo works a dial. So, though flying blind, the pilot can sound his way safely to earth.

And as in the deeps, so in the heights, the ear, through echo-sounding, leads us where the eye fails. As most wireless listeners know, there is now going on an exploration of the upper atmosphere by wireless echoes sent bounding against those strange ceilings—the latest news reports that this sounding has discovered two more of these ceilings or spheres of the highest atmosphere. So there are now four in all. To the one 62 miles up and the other, 155 miles, have, it is thought, been added one 375 miles high and another as much as 725. Yet the eye looks through these layers, although they can carry broadcast waves round the world. Farther still this echo-sounding is pressing on, and echoes have now for some time been known which may be coming from invisible layers a couple of million miles out in space. We used to think that sight must always beat hearing, for in the end sight could leap out into space and the poor ear must be left hopelessly behind. To-day, however, we find the ear searching interstellar space and finding things there where the eye saw nothing. Still, we may think the ear can only go as far as its echo-throwing gear will carry. Sight will always hold its own in those vaster spaces whose absolute silence

frightened poor Pascal. But is that so? Is it certain that the vastest things in the universe, the things far behind our sun and its planets, have no sound, no voice? On the contrary, it seems as though one of the vastest objects we can know about, the thing on which we may say everything literally turns, this thing can only be known directly by sound, by hearing, and not by sight. That object is the Super-Sun. That is the vast central body which it is thought acts as hub or axle in the gigantic wheel of stars which we call The Milky Way. When at night you look up at The Milky Way you are looking at part of the rim of what is perhaps the greatest wheel in the universe, the great spin of stars in which our sun is only an orange dwarf, an insignificant little outsider whirled along in the press among some hundred thousand million others. That great spin has a centre and should at that centre have a great mass, a super-sun. For it is revolving round something and all those millions of stars ought to have some counterweight round which they drive. But if it is there, why don't we see it? We can see the glowing centres of other island universes: this Galaxy must be built on the same plan as they. Many astronomers think we cannot see it because this centre of excessive light is shrouded, perhaps mercifully, in clouds of black dust. For we are discovering how much of space is not clear but filled with fogs, beside which one of London's best pales to insignificance. It has even been suggested that this super-sun may be so vast and massive that even light cannot get out and away from it, for light is attracted by mass

and if there were enough mass light rays would stick to the body which produced them—one of the queerest thoughts. Whatever the reason, the fact remains that we don't see the super-sun. Then have we no direct evidence that it is there? Not by sight, it is true. Sight can only tell us that millions of stars, our own among them, are behaving as though they were planets going round a sun. But though our eye can show us nothing of this immense object, it now seems just possible that our ear is beginning to detect it. For more than two years now in the Bell Telephone Laboratories in the United States there has been in use a special set for listening-in to radiations that come in from outer space. One particular hiss has interested these listeners. First they thought it must be the sound of one of those many tides of invisible energy our own sun pelts down on us. Then a queer thing was found. This hiss wasn't coming from the sun. Every day it came from a point a little further ahead of the sun's position. At last, after a year's listening, it was clear that it had gained on the sun a whole circle of the sky, a whole rotation of the heavens. That means that the hiss comes probably from some spot out in the Milky Way. Further the spot whence the jet was shooting out seemed to be where our orbit, the tiny wheel of us sun-circling planets, cuts across the great wheel of the Milky Way. That, it is suggested, shows that the jet is shooting out from the Milky Way's centre, from where the super-sun should be. So here, again, the ear has gone ahead of the eye, and, whether it has got the first direct proof of the super-sun or not,

has certainly found something of a very odd nature which the eye had completely failed to spot. Here is some message coming in from the deeps of Nature, a message which the eye could never pick out, for which we have to listen-in. And beside this murmur or hiss there are other queer ticks, scratchings and whisperings which exploratory radio sets pick up, the sound of waves coming in from heaven only knows what fount or storm of energy.

Still we are stubborn about our eyes. We are a single-sense generation, and I expect some reader may be murmuring: 'It's all very well to try with flattery to soothe our dull old human ears. Still the fact remains that when we have to judge the volume even of sound, we have to turn it into a written graph if we are to gauge it exactly. Can our ear ever be an instrument of precision? If you want anything perfectly finished, mustn't you always trust the eye?' No. As it happens, there has just been reported a new way whereby you may tell straight away whether a surface is really smooth—smoother than the eye can see and where it becomes invisibly, intangibly rough, or, perhaps one should say, not quite so smooth as the rest. It is done by using a needle in the way a gramophone needle is used. You know the surprising way, as you put the needle down on an almost invisible notch on the record, you hear the gramophone give a loud 'pock'. Well, this needle machine for telling if metal surfaces are really smooth runs over the polished plate and if the polish is fine enough, your ear hears an intensely high note, for the needle is pass-

ing over nothing but very fine and regular furrows. But the moment these furrows get larger or irregular, yet long before your eye can see any roughness, the needle-point begins to bump up and down and so to give out a deeper note.

So perhaps I have said enough to show that we have unfairly neglected our ears and that we should bring them back more into use, not merely for the great pleasure of music but also as a useful instrument for giving us information which our eyes miss. To know this world we find ourselves in, we have to listen as well as look. Indeed, I begin to suspect that before we can really know much more about it we shall have to use all our senses far more—yes, and make them all far sharper than they are at present. Anyhow, I think it grows clear that Nature is not nearly as dumb as we have thought; on the contrary, that it is full of voices telling us things our eyes would overlook. Perhaps, then, we should repeat to ourselves the old warning: 'He that has ears to hear, let him hear.'

Part II

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The Front of Life

Chapter I

Life in General

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(a) When did mind appear?

Now in our sweep of the universe we must put down our telescopes, spectroscopes and radio sets, which plumb space, and literally face up to life. We have seen the universe we thought empty and dead is far more full and lively than we had assumed. Can it be that our assumptions about the deadness and stillness of matter have made us too inclined to think that living things are also much simpler and duller than they actually are? Anyhow the time has come to turn our attention on life in this rapid review of our present situation, and in thinking what news of all the news about life is really the most important, I believe it is news which tells us more, not about our bodies, but about our minds. What more have we lately learnt about the thing we know best and yet least—about mind, about our minds and the minds we watch working in all the other creatures? I think the most surprising thing has been how low down, how far away we can now begin to sight this thing that matters most to us and yet remains the most mysterious—mind. Let us start with the reptiles. I was taken round those gigantic fossil reptiles at

South Kensington Museum the other day. I was shown how these strange experiments from life's workshop, though some of them the size of a small submarine, had brains not larger than a horse-radish. That is odd. But it is even odder to find that the largest of these super-lizards had beside a skull-brain two other brains: one between his shoulders and another between his hips. What sort of mind could he have had? Dr. Matthews has said, in a little book he published on the nervous systems, that these lizards were so slow in the uptake that if you'd pricked them with a pin on the end of their long tails, you ought to have been able to get away safely before they realized what you had been up to. But now I'm not so sure. Perhaps this creature might, as Americans say, have shot from the hip, and knocked you out by using that more-on-the-spot brain, while head-quarters went on munching, no more aware that it was being troubled than the study knows that the back door is being answered. At least this fact that this reptile had three brains of a sort does make the problem of what its mind can have been, and how it made it up, very complicated. 'Ah, but it wasn't conscious at all,' say some people. 'It simply acted on reflexes'—that is, it twitched and snapped like a trap snaps when you touch the trigger. Well, we shall never know. These fascinating, if awkward, forms of life cleared off more than one hundred million years ago. But they did leave one or two distant relations lurking in little visited places, and we can study these. There are reptile dragons living to-day. Have they

minds or feelings? They certainly have very small and low brains. While I was in the Museum I was also taken to see one of these, the Komodo dragon which has just been preserved. For you probably saw the Zoo lately suffered this loss, the loss of one of its real dragons. What was its character? It had lived with us since 1927. It came from its Javanese jungle with a terrible reputation. It was indeed a dragon, armoured, weaponed, untamable. 'This animal', we were told, 'is very dangerous.' However, when it arrived it went to school under Miss Proctor, a naturalist who certainly deserved the much-abused name of genius. For she could get on with snakes and reptiles about as quickly as we get on with puppies and kittens. The Komodo dragon also warmed to her. And before she died she had made this unprecedented bridge between dragon and man. With his keeper the monster used to go for a constitutional every morning in the gardens. But, though quite friendly, he was too stupid to learn arbitrary rules. He could not be taught to keep off the grass. He failed to realize that the flower-beds were for show and not, as was obvious to him, a daintily served vegetable salad. It is little use trying to hold back with a string a creature weighing a couple of hundredweights, when it really wants to do a thing. Henceforward, then, he had to take his walks round the reptile house, while the snakes and crocodiles were having their beds made before the public reception begins. Well, he has followed his brilliant teacher out of this world. He died of a heart attack (one wouldn't expect that in a

cold-blooded animal), but not before he had shown that, though he was a reptile and might be very stupid, yet these limitations did not debar him from being a gentle and pleasant person with his human friends.

So, evidently, intelligence and amiability need not be tied too closely together—a comforting reflection for most of us. You can have sensibility even though you have little sense. Now I think that raises perhaps the most interesting question about life and all its manifestations. For we have always taken for granted that the less sharp you were, the more brutal you must be. So we have the popular picture of 'Nature Red in Tooth and Claw'; of 'Dragons of the Prime, which tear each other in their Slime'; and more up-to-date, but no more encouraging, the picture of Cave Man, always clubbing his neighbour and pommelling his family. And that so-called scientific picture has very practical results. Worse results, I think, than any cinema with its story of vamps and gangsters. Look at Bernhardi saying, in 1914, that the Darwinian 'struggle to survive' meant that Germany must have war. Look at Mussolini saying that war is to man what motherhood is to woman—a law of Nature and life. Such sweeping generalizations are based on what Mussolini honestly thinks biologists have discovered. I believe that is the science not of to-day but of yesterday. No animal is so set and slow and instinct-bound as a reptile, and between its race and ours is a profound repugnance. Even a restless little monkey, shown the other day a film of snakes,

ceased to fidget, sat literally spellbound for twenty minutes, until the sight was too much and it turned to where the screen was out of sight. Yet, we've seen, Miss Proctor could take snakes and the old dragon itself, and by sympathy, which goes so much deeper than sense, make them understand that they were among friends. And once they realized that, they themselves became friendly. And this triumph of what we may call the New Naturalism is not confined to reptiles. It is spreading up through the whole of our study and understanding of animals. Last year I met a scientist who was trained as a genetist but who had taken up the study of animals' minds, and had trained, among other forbidding beasts, even hyenas. His recipe was simple—if heroic. He said you must never be frightened of the animal. You must always be perfectly patient. It attacks because it does not understand, and thinks you must be hostile. But how are you to make it understand? Here we come to the hard and heroic part of the recipe. You can't speak to it through the mind. You must get in touch through the emotions. So your feelings really decide everything. If you feel fear—even though you show no sign—then it senses your fear, and your fear means to it that you are about to attack it—so (like most European statesmen) it feels it must attack in self-defence. You see, you have to have absolute sympathy for the animal before you can hope to tame it. But if you can do that—what Miss Proctor did and this man does—then no one knows the limit of the animal's response. Literally, fear paralyses and sympathy creates. Your

affectionate interest acts like a current of air on the dim, smouldering spark of the animal's character. The smoking flax breaks into a small flame. This isn't uplift. It is borne out by some of the most careful laboratory work lately done on monkeys. Dr. Klüver, in the United States, has demonstrated that even the most scatterbrained of all the monkeys, the South American monkeys, can be taught to use tools. This discovery marks a revolution in our exploration of the sub-human minds. It was thought that only an ape could do such a thing. Monkeys, it was certain, were far too low. But how it was done is even more important than the actual doing of it. Dr. Klüver discovered that the more care you took not to upset your monkey in the slightest possible way, the more the limitation of fear lifted, and the tiny brain grew to attempt things it could never have done either by itself in the wild or disturbed by a rigorous, impatient attention. Then there is the work of the Doctors Kellog on the chimpanzee, which these psychologists brought up with their own child. Here, again, under constant human affection it broke out of the rut of apedom and began to walk across the gap which we have assumed must always separate ape and man. Surely all this work converges on one point. It shows how even those small persons whom we call the beasts have in them capacities which can raise them far above the bestial, that they can respond in quite unsuspected ways to opportunity. And it shows also that that opportunity is sympathy. It shows that sympathy is a power far greater and far more exten-

sive than argument or any of the methods of conscious intelligence. For not only does it let us get into touch with creatures we can never hope to speak to—it is not merely a greater power of communication—it is a power of creation. The beast is not only roused, it is raised to capacities it otherwise would never touch. And doesn't this work throw a beam of light on to our outlook on the whole of life? We've been too defeatist, too certain that Nature had set everything hard. 'You can never change Instinct'; 'You can never change Human Nature': how often these phrases are used to excuse brutality, cowardice, hopelessness. All this latest work suggests, I believe, that they are untrue. If you can change a beast's nature, if even that is not set hard by instinct, it is criminal nonsense to say you can't change human nature. If (of course it is a big 'if') you have the courage really to understand—and by understanding one means also that intuitive understanding which is sympathy—then we have yet to find the beast which can resist that force.

But surely all evolution has been by the strongest and toughest pushing the weakest to the wall? The latest researches throw increasing doubt on that. Those giant dragons did not have to arm themselves—they literally sprouted bayonets. Yet they died out. And what was the animal which carried on, what beast gave rise to the animals of to-day and ourselves? That used to be a puzzle. Now we have found those ancestors of ours who beat the great armour-plated monsters in the struggle to survive. They are small

ratlike creatures, without thews or armour or even a sting! But surely man himself springs from a fierce, gorilla-like ape? That too grows doubtful. All the latest research tends to show that the gorilla is only a living fossil, on the way to extinction, certainly no ancestor of ours. Later, again, the beetle-browed cave man, the Neanderthal man—he's no ancestor. He and his breed died out completely. Who were our ancestors? We are beginning to be able to answer that question since Dr. Leakey started digging in East Africa. He has found deposits which experts agree must be about a million years old. In those deposits he has found some of the earliest stone tools. We have had those before, but we never had, with the tools, the bones of the men who made them. Now Dr. Leakey believes he has found them. Fresh discussion has arisen about this, but if it is true (and we must remember finds such as were made years ago at Galley Hill in Thames gravel, and at Clichy near Paris, make it likely) then these early stone-age men were men like ourselves, with light, small bones. Again, you see, it is the frail and sensitive that has won in the struggle.

(b) Who feels most fares furthest

It begins to look as though brutal strength were not much good. Nothing has failed like ruthless efficiency. That is the idea expressed by that new notion of evolution called Fœtalization: man, it now seems clear, is the baby-form which the ape outgrew, and the dog

is the baby-form the wolf also lost. That means that man and dog are man and dog because, somehow, they have managed to remain in the childlike stage which ape and wolf both lost. In fact, you can only advance if you keep supple, receptive, sensitive. Harden up, and you are beginning to fossilize. If you would solve life's problem, you must feel acutely. It is painful, but it is the only way. As in O. Henry's terrible story, the hand must have the nails cut to the quick if it is to feel how to pick the lock. Dare to feel: that in a phrase seems life's challenge and its secret. Yes, I know we've ended with a moral, but at least it's not one of the cold sort. Perhaps, even, it may help thaw out some of the icy suspicion which at present has the world in its grip. If sympathy works with beasts, mightn't it work with men?

(c) Is life an inventor?

That thought that all living creatures may be more pliable, teachable, yes, even kindly, than we assumed leads naturally to a further question. That may be put perhaps by saying: have we really best understood life as a whole by thinking of it as nothing but a rather simple machine? We are too inclined to think of life as a weak, unenterprising accident. We underrate the way it can take the initiative, the way it can contrive new instruments so as to keep on widening its hold on the world. Certainly some of the latest facts greatly increase our wonder and our admiration for life and for its power of invention and discovery.

We saw on the astronomy front the great efforts we are now making so as to fashion still greater lenses to see still deeper into the heavens. Perhaps there is nothing more remarkable about life than its power to make lenses. In this chapter I want to illustrate life's inventiveness principally by examples of Nature's work as an optician.

A lens must be hard, absolutely clear and very accurately shaped. The only way we know of getting such an instrument is through using sand and great heat. Life also has to make lenses. Indeed, if life had not first made the lens in the eye, then all our glass lenses would be of less use than a ladder to a limbless man. But the astounding thing is that life has to make its lenses without the use of heat, and more, that it has to make them out of protoplasm—a little pasty slime. Yet biology shows us that whenever eyes are wanted, there eyes appear. The gigantic Kraken, the largest of the squids, with arms sometimes forty feet long, lives deep down in the ocean dusk. It has an eye like a soup plate, a huge, lidless, unsleeping eye, an organ so unlike our eye that here again we can only say that life wanted to see down there as up here, and so life made the lens its creature needed. The snail has his mounted like periscopes. The insects have eyes with many facets and some with ultra-violet vision. Birds have perhaps the most remarkable of eyes, for they can use them at one moment like a microscope to pick up a minute insect, and next, with a twist of the neck and a sudden change of focus, they can turn their eye into a telescope and sweep the heavens for

that fluttering spot which means a hawk up aloft. Perhaps you know all this, and though it is a wonder, familiarity makes it seem commonplace. But here is a piece of news about life's inventiveness in eye-making which, because it is new, may stir our wonder. One of the great comforts of modern glasses is the bifocal lens, ground so that one part focuses the eye to see at one level and the other helps it to see as clearly at another, closer up. Surely such a device as this is beyond the power of life to frame. Here, with our mechanical inventiveness, we have gone one better than life could go? Not at all. Fishes are more primitive types of animals than nearly all the creatures which walk upon land. Yet it is a fish which has been found to have this extraordinarily up-to-date eye equipment. There is a Central-American species which has been found to have its eyes developed just like our bifocal spectacles, divided horizontally in two. It has to get its living just along the surface of the water, and so life has provided it with double vision. For an eye which is efficient in air is inefficient in water, and *vice versa*. Lately, human inventors have been trying to copy Nature in this particular also. A biologist is experimenting with special glasses for divers to wear. They will make possible immensely improved underwater seeing. One of these experimental spectacles will allow you to read the paper underwater should you wish to add that luxury to your bathing. I know it is common to hear people complaining about the human eye, and quoting scientists who have belittled it. We all know the story

of the scientist who said: 'If my optician had sent me such a lens for my microscope I'd have sent it back with a note telling him he didn't know his business.' Yet the human eye has power which no instrument has. It can adapt itself in a few seconds to an increase in light-volume of some three million times. And, as I've said, Nature has not given her prize eyes to us humans—probably because we really don't want them so much—but to some of her simpler creatures, birds, insects and even fish. But perhaps the most wonderful thing about life's inventiveness is not so much the finished lens—all these different sorts of seeing apparatus for different sorts of seeing—but the mysterious way life works as an optician. I remarked above that it is an astounding achievement to make a crystal-clear lens out of muddy paste, all the material which life has at its disposal; but the more we study the way the trick is done, the more we are surprised. Of course, it has always struck naturalists as a very odd fact that life has to form the eyes of nearly all its creatures long before birth, when they are still closely shut up in their egg. The eye has to be formed before there is anything which it can see. That looks like some sort of foresight. Some life force in the body, some power called—because we know so little about it—the Organizer, has this power to shape and build; yes, even to alter things if they have been upset, and so to preserve the original purpose and plan. And what is perhaps more important, to us who want to understand, is that this force seems very patient with us. If only we will observe the rule of being scrupu-

lously clean in all the experiments, life seems willing to work its wonders while we watch, as a really good conjuror will repeat his sleight-of-hand and ask you to notice exactly how he does it. And is there any sight more fascinating than to be let watch the force which has made us and is always sustaining and repairing us, actually at its superhuman work of skill? A film not long ago was issued from a Cambridge laboratory. It was to show how life builds up such a thing as a thigh bone. A minute fragment of a chicken's femur was taken and put in a solution in which it would grow. The film was speeded up, and there before one's eyes was the fragment first of all throwing off the tissues it did not want, as no muscles would be needed; it had only to become a thigh bone. And then, as though following the rhythm of a dance, one saw these bone-cells expand and shape themselves until out of this splinter there grew that graceful shaft—the thigh bone which Nature has evolved to be the slender pillar on which the body is carried. It was hard to realize no hand, no human intelligence was shaping this shaft, but that some invisible force centred on the fragment was making it re-create this elaborate design.

And there can be no doubt, life is prepared to teach us more and more of its craftsmanship, if we will observe the few rules it requires if it is to be able to work. We have persuaded this force to grow bones for us where we can watch them being modelled under our eyes, as it seems, out of nothing and by nothing. Now we are finding out the conditions

under which life would grow for us, not merely bones but whole bodies while we are let look on. This is sometimes called Ectogenesis—getting a body to grow as it were in the open, under observation. The first step toward this has now lately been done with such a large and complicated animal as the rabbit. The conditions which life requires, if it is to carry out for us this instructional lesson, have now been made possible, and life has done what we asked of it. Rabbits have actually started their lives in a test-tube. We can't carry them in glass the whole way yet. The first, and certainly one of the most difficult, of the steps has however now been taken, and then the new creatures were put back to a foster-mother. After which, in due time, they made their second appearance in the world, this time as normal babies, and proceeded to grow up as perfectly healthy rabbits. Now that life has consented to show us the first steps, there seems little doubt that it will be possible to persuade it to let us follow the whole of its creative technique. It is hard to imagine any teaching from which we shall learn more or which will increase more our sense of the wonder of life. Why have we not been able before this to persuade life to give us these invaluable demonstration lessons? For two principal reasons. First, there was the matter of absolute cleanliness. Till Pasteur's time no one realized that germs could get in practically anywhere. If everything is not completely sterilized, then the new growth becomes infected and dies. The other reason is that many forms of new growth can be damaged

not merely by germs but by heat, and even by light. Some plant cells can be killed outright by light, and we know that ultra-violet radiation is always rather too much for life unless it has grown a skin. This difficulty is really a greater one than guarding against germ-infection, for how are we to watch a process if the process will only take place in the dark? Still, the initial difficulties of watching life when it is performing its most delicate manipulations are rapidly being overcome. We need to know so much more, and the more we know the more questions arise. How does life handle its material; how does it shape and organize; what feelers or ties pull the whole together and give it its elaborate design? Why does this cell build itself up into that soft organ, and this other cell capture lime and make bone? Can it be that the living organism, when there is least of it and it is growing most swiftly and creatively, is much more than we can see or sense—that the germ as it makes its body is really the centre of a vital field of force, and it is the presence of that field which draws in and arranges and builds up material as a wind-eddy draws in and builds up the twisted pillar of flying sand? The great German biologist, Woltereck, has, after more than twenty years of research, come to the conclusion that we have to postulate some such field or vortex. Now that present-day research tells us of the electric field that surrounds each living cell, perhaps with these new super-delicate detector instruments, the Geiger Counter and the Wilson Cloud Chamber, which can record the passage of a single electron, we may be able

to detect these vital fields. If so, we shall be taking another big step towards understanding the conditions under which life works and how it carries out its elaborate designs. I feel pretty certain that that knowledge will not lessen our wonder at the skill and power of life. Indeed it looks as though it would show us what many workers have suspected, that life is no feeble accident, nor merely the latest flicker of force, but the most intense form of energy which the universe has ever produced.

That rapid review of the latest entries science has made on the absorbing subject of life and mind, brings us to ourselves. That is not provincial. We are the supreme creature and ours is the master mind. But are we not, in spite of all that, a sorry, ailing creature? Let us leave aside our sins, about which science preserves a discreet silence. What about our mental and physical efficiency? 'There is no health in us,' says the Anglican General Confession. Is that physically, scientifically true? What has science to tell us in its latest news about man's fitness? He is undoubtedly the present leader of all creatures, of all creation, the last achievement of evolution. It is then a first-rate scientific question to ask what is the latest news about this super-creature. Is he still holding his amazing lead in the race of life, or is he beginning to fall back, is he decadent? Is his life and all life only an endless struggle with decay, or is he, and life which backs him, getting away with it?

(d) Are we beating disease?

To answer that means, of course, facing up to a subject most people think too depressing to mention, disease. It is not really depressing, however, because we are making real progress toward understanding it. You may think that it will be quite impossible in that case to give any outline of this progress in the small space it can have in the whole outlook of our science progress. But just the way that knowledge is growing rather helps us to get a picture of this advance and to get the many details into focus. For in finding out about disease our knowledge has been growing, in the way that all scientific knowledge has lately been growing—it has been narrowing down, converging, instead of widening out and scattering. What I mean is that we are beginning to see all diseases as the different ways the body breaks down when it gets weak. You don't say, when a storm knocks about a set of houses, that there was one wind which was a slate-tearing wind and another a plaster-stripping or window-smashing wind. In other words, we are beginning to look upon disease and health as telling us not so much about how germs work but how the body resists or fails to resist their attack. In short, the point that now interests students of disease is this general but mysterious thing, resistance. Of course, in a way this has made the job of understanding disease more difficult. When we thought that germs were the only cause of every disease and our bodies just stood about like targets until they were hit, you

only had to catch your germ and then cook it, and then the patient lived happily ever after—or should have. This is still mainly true of some diseases, but in more and more of the common diseases it is not so much the germ but the way you are feeling when it comes along which decides whether you will get ill or not. The common cold, there is no doubt, is our chief pest. For it not only opens the way to many other diseases, but is itself a first-rate public enemy. And the common cold seems more and more to be a matter of weakened general resistance. Colds are caused by germs—those smallest of germs, the viruses. At the same time, it seems less and less necessary for you to have a cold if you can make your body refuse to give any quarters or quarter to those minute colonists. A couple of dozen volunteers, normal persons who were used to having their cold once every chilly quarter, were put to live close up—even to sharing his drinking glass—with the possessor of a really fine, growing cold. The volunteers were simply kept warm and fit and healthily comfortable; and none of them caught the cold, it could not get a grip on them. And in the United States they have just been making a countryside enquiry into what is often the most dangerous follower-up of the common cold, tuberculosis. And the verdict is the same here also. Though much can be done to fight T.B., when it once has hold the best armour against that fate, it has been found, is a regular job. The person who is well employed, nourished, unanxious and interested resists T.B. best. Again, you see, we are back at general

resistance. But when we have said that, have we got any further? What is general resistance? We all know the common sense advice, 'don't get wet feet', and there is some truth in that. Pasteur showed that with chickens which had attacks of lockjaw coming on, the ones which stood on dry ground had a good chance of getting over the attack; the ones who stood on damp had a very poor one. But some people don't seem to be a penny the worse for getting damp feet. Damp doesn't undermine their resistance. And that fact, for fact it is, that some people seem to be able to resist nearly any attack of disease, has of course led many people to say disease is largely, if not wholly, imagination—if you believe that you will get an attack, you will. And we shall see in a later section on our minds and how they can control our bodies, how it has been found that if you get low or frightened, then one of your ductless glands often fails to work hard enough, and then the cells in your blood, which are always eating up disease germs, do not get the stimulant which keeps them up to their job. So there is a direct connection between how you feel and how you are. How much our minds can control our bodies is a fascinating subject. We certainly don't know the limits of that. But that hope—that some day in the future we may keep ourselves well by knowing how to train our minds to the job—that hope has sometimes made people say things about disease in the past which now can be shown to be untrue. Certainly all that we have found out lately about general resistance has seemed to some people to show disease as

simply a man-made thing, a fault of civilization. It is always pleasant to blame civilization, because if civilization is the fault of everything, it is so easy to cure. You have only to let everything slide, and there you are, back at the Golden Age. Now, however, facts are coming to light which show that, whether we have made matters better or worse, we certainly did not start disease. Disease was here long before man. How do we know that? The diseased bones of animals which died out a hundred million years and more ago have been found. I think we all take some interest in the giant reptiles, the dinosaurs. As we have seen, it is hard to talk about life and not bring them in. Their odd shapes, the fact that they were real dragons—and dragons have always attracted man, and their huge size—these features always make us ready to hear the latest news about them. Well, one of the latest news items about them is that these tremendous animals suffered from disease. Of course, as we have hardly anything of them save their bones we can only tell what bone diseases they suffered from. But even then, the sick list up to date is an impressive one. Not only did they suffer from huge abscesses—no doubt wounds into which germs had got and bred—but it now seems proved that they suffered from arthritis. Imagine having acute rheumatism in a tail twenty feet long; imagine dragging about a body weighing ten tons and more, when all your joints were creaking and groaning. They also suffered from the even worse bone disease, osteomyeletis, and there even seems some evidence that

they may have had one of the worst forms of cancer, sarcoma. I was also shown a huge fossil reptile tooth drilled right through with an abscess. When the size of some of their teeth is considered, toothache in such a tusk is a terrifying thought. And we certainly can't say—as is often said about our own bodily ills—that these enormous creatures brought on their diseases by being too nervy or intelligent, or by indulging in wrong thoughts or brooding on their feelings. No animals should have been more splendidly healthy, if lack of brain makes for health of body. When you weigh, as the latest of these creatures which has come to light must have weighed, fifteen tons, and your brain weighs, as its brain must have weighed, one ounce, half the size of a kitten's and much less well organized, well, your problems, whatever they are, are not brain problems. No; it seems clear that whether brain may or may not cure all disease, it was not brain which brought it on. Perhaps all the diseases were there already, waiting for man to turn up and to tackle them, or to go under. Certainly in rocks which were formed as long ago as the Oligocene period, a period which it is calculated was some eleven million years ago, there has been found fossilized the dreaded glossina, the tsetse fly, which now causes the sleeping sickness which has devastated Africa. Whether the fly then had the germs of this plague in it or no, there was the insect all ready to act as the disease-carrier. You will see all about this problem of dinosaurs and disease in Dr. Swinton's delightful book, *The Dinosaur*, which has lately been published. The whole of

their story is an amazing chapter in the book of life, and it is clearly and charmingly told by the author, who is a great authority.

And disease hasn't ceased to attack animals living wild. The dinosaurs were not diseased because they were animals which were dying out and so were getting decadent, though toward the end of their long history they do show signs of getting very odd, over-developed and physically crusty. For we have examples of wild animals to-day which are very much alive, and yet who suffer from diseases which we have taken for granted belong to us because we are decadently civilized. The commonest disease of our teeth, caries, is of all diseases said to be due to civilization. But now it has been shown that chimpanzees and orang-utans, when living wild, with fresh air and fruit all around them, vegetarian, virtuously free of cooked foods, stimulants, tobacco, still very often have caries. And even gorillas suffer from tooth-disease, though their main trouble is abscess formation in those immense eye-teeth.

No, disease is showing up as a bigger problem than we've thought. But at the same time I think this picture is encouraging, not depressing—we may be going ahead into an age of health never attained before. I know many people think that is not much comfort. They are wretched, thinking of all the helpless suffering that has gone on because of disease, and so they want to make out that disease was somehow only our fault, and all our fault. But that is not a right solution of this problem, and so it is right to say some-

thing more about pain itself and our new knowledge of it, in the next section—for pain and disease are not the same thing. But this one I want to finish by pointing out that instead of our minds increasing disease and civilization being the cause of it, it is our minds which will help to get rid of it. Let me make quite clear what this means. Some diseases have evidently always been there. Other diseases are evidently due to our new ways of being able to upset ourselves, diseases which are not so much due to civilization as to our ignorant way of trying to be civilized, our hustle and nervous worry. Dr. Crile's book, *Diseases Peculiar to Civilization*, makes a good case for supposing that much diabetes, peptic ulceration, and even epilepsy of one sort, may be due to gland disturbances, especially disturbances of the suprarenals—those glands of fuss and combat. Such examples of these diseases can often be cured by learning not to upset our glands. And because we do now know that, we know something about curing the other diseases. For this new power of ours of upsetting our glands—to-day we use it ignorantly, like putting a match to a barrel of powder. To-morrow we shall use this explosive energy just as we have learnt by controlling petrol explosions, to run our engines. The power which damages to-day will energize to-morrow. That in a nutshell seems to be our new knowledge about health and disease. We civilized men and women have been given with our highly strung nervous system a new power of drawing on the body's energies. Because we are still so uncivilized, we misuse that power too often, though we

must also remember that a healthy savage set to face the rush of our life has often been found to break down very quickly. We are tougher than we know. The war proved that. It was the weedy looking Cockney who stuck it out best. The healthy, stolid farm lad broke up badly. But we shall learn how to draw on the body's energies—to blow on the flame to heighten it, not to blow it out. Then it seems we shall not only get rid of the diseases of civilization, but of the diseases which less vital animals suffered from in the past. For that seems the secret of this mysterious thing, general resistance: it is the profoundest form of vitality. And through the scientific discoveries of the last few years we have new forms of vitality within our reach. I can only give you the bare names of three: there are the vitamins—the latest news to hand here is that concentrated vitamin C, found chiefly in oranges and lemons, is probably the very best defence against pyorrhea, and may help to cure it when there. Then there are the secretions of the ductless glands themselves. You know the way a cretin lights up when given thyroid; so, when we know more about the other secretions of these glands, we may raise our vitality as much above the low standard most of us put up with as that is above a cretin's. And, last, there is perhaps the quickest of all these ways of blowing on the sparks of our vitality and making them flame, through super- and sub-light radiations. The latest news here is that with the super-light, the short-wave radiations, you can rouse the vitality of the blood and make it flow full of excited warrior cells to any weak

spot in the body however deep it may lie. You can make focus a beam of curative radiation on a spot the size of a pin's head, without disturbing any of the flesh through which the radiation is passing.

With such new methods of putting vitality into ourselves, it looks as though the answer to the question 'Is health natural?' may well be: 'It wasn't, but it will be.' But what of us, meanwhile? We who to-day are the prey of diseases and epidemics at which no doubt the future will smile: is there no good news for us here and now? What are the chances that we may have, if not real health in our time at least a mitigation of our sentences to periodic incapacities and snuffling miseries, collapses and declines? For example, if we can hope to tackle the common cold and tuberculosis, two extremes of our general weakness, can we hope to tackle (what is so often the great link between the great nuisance the cold and the great peril 'the white plague'—consumption) influenza? It is really one of our greatest pests and our most irritating mysteries. Most people have now seen tables of the ravages made by the world epidemic late in 1918. They know how it killed in as many months far more people than had been killed during the whole four years of war—how in South Africa alone it wiped out such numbers of the negro population that it completely altered the balance of the black and white races there.[1] But it is not so clearly realized that quite a commonplace, routine attack will often carry off fifty thousand people in a few weeks. If we were sud-

[1] See Dr. Cousins's *Census of South Africa.*

denly swept away like that by any other attack, we should make a fuss and insist that 'something must be done', but with 'flu we simply take it for granted. That uncharacteristic fatalism in this one matter is partly due to the fact that influenza is so mysterious. Just look at that name—lasting on among ourselves and our doctors when we have all learnt to rattle off long Greek or Latin titles for nearly all our other complaints, with the descriptions of their bacteria, toxins, symptoms, etc. 'Influenza'—The Influence—why, the name belongs to the age of the humours, the vapours—no, it goes back even further, to astrology, to the 'soft influence of the Pleiades' and the baleful influence of Saturn and the moon. Yet what could medicine do? Look at these epidemics, first like a cold in the head, then like earache, then like gastritis or appendicitis, and then like a nervous breakdown. No, really, the protean changes of this complaint are too much for respectable cataloguing. But can't the germ be caught? There, again, influenza kept up its mystery role. At last the viruses—virulent germs too small to be seen even with a high-power microscope—were suspected of being the cause of many-infections, and were proved to be in a number of cases. Could not influenza be caused by such a virus germ? It is here that a successful line has been struck on. And really this part of the story is in itself very odd. As you know, the dog-world also used to have its plague, also called, because we couldn't know or do anything about it, the Distemper, the Great Out-of-Sorts, and no dog-lover could count his friend his

own until the Man's Friend had had its distemper. Now virus research suggested that perhaps distemper was one of these viruses. A paper much concerned for dogs' health collected a sum of money. The research so helped forward proved that distemper is such a disease.

The next step was to grow the virus of the disease in some other animal, and when that animal recovered, make an anti-toxin from the blood, which now had resistance to the disease. The story turned out to have a good many more turnings in it than that. Still, the conclusion was that the researchers held on, and in the end were rewarded with a serum which made this world of infection safe for dogs, at least in this very important particular. Distemper had at last been tackled.

But the particular step in the discovery, which is of interest to us, is the point where the researchers had to find another animal to act as 'host' or 'bedder-out' of the virus. All germs are pernickety guests. That's fortunate for us, because, if a germ were not fastidious and would put up anywhere and with anyone, probably human history would have ended long before this year of grace. You'd think we were always catching germs. It isn't true. We keep ourselves to ourselves, and introductions are very rare. It takes thousands of years to make even the larger guests, or—to use a word which originally had no uglier sound than guests —the larger parasites to take up with us. That fact incidentally led to a very pretty piece of detective work. It has lately been noted that our skin-guests,

what the great entomologist, the late Dr. Shipley, called the 'minor horrors of war', which made so many people learn during those war-years the skin-game—those guests, it has been found, are only to be paralleled by the guests which the cave-haunting bats have about them. You see the odd link and the queer beam of light that this throws down into the dark of prehistory? We first lived out in the open, round water-holes, during the long genial age before the ice-age, and then we may suppose our coats were as clean as the coats of our cousins the great apes who, backward though they may be, are excessively cleanly bodies. Then down came the ice-age, creeping over what had been semi-tropical England and France. For some reason many of our lot wouldn't go south. We couldn't dig ourselves in, so we had to take to the caves. There we hung on. And perhaps the struggle made us what we are—with all our faults—something more than the best of apes. But we paid, and one of the queer little costs of making that stand was the queer company we picked up. And it was not only queer and highly irritating, but it could also be extremely dangerous. For we learnt, when the war again drove men who wouldn't give way into caves and holes in the ground, that trench fever and the deadly typhus are carried by that louse who first managed to scrape an acquaintance with us when we and the bats together sat out the long siege of the ice-age.

That shows how slow even the larger guests are to change their accustomed lodgings, and we certainly

owe a great deal to this lack of enterprise on the part of these lower creatures.

What a germ can do when it is really a 'good mixer' the Black Death showed us. It was so successful that in some eighteen months it killed close on half the people in Europe—a record which makes even the worst 'flu epidemic look like a fleabite.

But this particularity of most germs, the way they stick out for the diet they are used to, and refuse, even to the death, to accept fodder which looks to us just as good, that characteristic, convenient to us as potential germ-fodder, is highly inconvenient to the researcher. He wants to grow germs in order to study them; but who can be found to put up such difficult lodgers? As it happens, the distemper research found an unexpected helper in a rather disliked animal, the ferret. He would take distemper and keep it going, and if he could himself be kept going and get over it, he yielded the precious essence which could give immunity to the disease.

But what has this got to do with our influenza? It occurred to researchers who had been engaged on the successful distemper-hunt that if the distemper could be so tackled, it might be worth trying the same method on the influenza. So they took some really fine influenza sneezings and filtered away from them every bacteria. What was left they persuaded a ferret to sniff, and there, in a couple of days, was the ferret as snuffly and feverish and irritable as any human. I must say I don't envy the person who has as his pet charge a ferret with its never-too-nice temper made

even more cross-grained by a 'flu attack. But the really important thing is yet to mention. The ferret was as infectious as he was unwell. Just like ourselves, he had become not only a temperamental nuisance: he was also a health risk. His fellow ferrets had double cause to curse him. He started an epidemic. This, however, was just what the researchers wanted, and you will be glad to know that not only were the recovered ferrets immune but their blood will kill the 'flu virus. By those days in which they were initiated into one of the human indignities they have raised themselves to the rank of human benefactors. That alone is a strange reversal of ferret fortunes. For you probably know, we so dislike the ferret family that we nearly exterminated it in this country. In fact, the ferret only saved itself when we went for its wild and perhaps nobler cousin the polecat, by becoming a rather despicable ally and helping us at the none too pleasant job of making rabbits choose between being killed by him in their burrows or by us outside. The polecat is gone, and perhaps if we had done in the ferret at the same time we might have exterminated someone whose services were far more valuable than the price of all the rabbits in the world. For it is quite possible that no other available animal can take influenza from us and give us back at least the first essences which may lead to an influenza inoculation as effective as the distemper inoculation.

That is an important reflection, considering the careless way we wipe out species. Why, even malarial mosquitoes have been found, quite by accident, to

have an invaluable gift for man in their poison glands, and in the United States now there is a special express service to rush malarial mosquitoes, or their glands, north to the hospitals where the terrible disease paresis is being treated and can, in some cases, some authorities still think, best be treated by this strange drug.

But this balance of life, our debt to other living creatures, we must remind ourselves, doesn't end with the large animals of the outer world. We now know that we owe our health and life to the co-operation of whole tribes of millions of friendly bacteria and warrior cells which live and move about our bodies. We have already seen that health, like peace, isn't merely a passive state into which some enemy plunges like a pike into a stagnant pool. Health is an active state. We come back to that first fact: health is having a fine resistance. Much as anti-toxins, serums and vaccines can help us, they can do nothing if that fundamental thing, our resistance, is beaten. Our principal job in healthy living must therefore always be to keep up our resistance, to keep up to scratch those strange forces which garrison our bodies. We all know that people who are so afraid of disease that they won't go and see a sick friend are often the very people who, in spite of all their precautions, are always catching things.

But doesn't this conflict with all this research into injections? Isn't it just here that the bitter squabble goes on between those who would heal us by getting us to co-operate with our whole minds and bodies in

the cure, and those who say that our frame of mind has as little to do with our disease and its cure as a kitchen has to do with the ridding it of its cockroaches? I'm very glad, therefore, to be able to close this section on health-in-the making with news of a bit of research which, if it won't close that bitter gap, may be a very useful stone in building the bridge. It does show that both sides are right in what they know—and that they should stick to that. It has now been discovered that our warrior-cells in our blood, on which our lives depend, can't tackle germ-invaders unless the invaders are first doped. They are doped by a secretion which it seems can only be made by the coats of those ductless suprarenal glands which we all now know can be made active or passive according to whether we are in a tonic or a slack state of mind. So you see, that cheery, resilient mood, for example, that determination not to get scared of epidemics, has real health value. We can now see the actual way it works in our body and how it gives us resistance to disease. We see it's not nonsense or fancy—it is physiologically demonstrable why a cheery, unfrightened person can go and see an influenzal patient, come away not a penny the worse, and leave the patient better. Yes, health is a complicated business, but the more we know about it the more, I'm sure, we'll find that there is no real quarrel between mind and body. The mind is coloured by the body, but the chemistry of the body can be changed by the mind. After all, cheerfulness is a real tonic.

(e) How we are using our ductless glands

Thinking about this mysterious thing, general resistance, and looking for where it may lie, brings us naturally to the subject which has, of all biological subjects, interested us lay folk most: the ductless glands, and how they affect us.

In fact, the ductless glands, some people think, are the discovery of our age. Some experts have gone so far as to say we *are* simply our glands. When they pour one of their secretions into our blood, we become cold, energetic, ruthless. They pour in another, and we are gentle, compassionate and unenterprising. That, however, is going too far. Indeed, I think you will conclude that with this latest news the balance is now tipping the other way. We can use our glands. It is not they which wholly shape us. Still these discoveries, which have all been made in this generation, were and are so wonderful that it is easy to understand the over-enthusiasm they roused. For in the last century people had thought that these tiny nodules hidden up and down the body must be useless. The reaction from that ignorance has made some people say that nothing else matters beside the glands. The truth lies pretty certainly in between. After all, there is nothing very new about the *effects* they produce. We all know now that cretins are people suffering from deficiency of the thyroid gland, and people with staring pop-eyes, rapid pulse and restlessness are generally suffering from too much thyroid activity. But these diseases are very old ones. They have

nothing to do with civilization. Cretins are generally found high up in mountain valleys. We now know why: because they are cut off from the iodine which is present in sea air. And so with the rarer and even more obvious diseases, gigantism, acromegaly, horse-face. These have been traced to diseases in the pituitary gland, the gland that lies about an inch in from the root of our noses. But such diseases go back long before civilization—long before man. In fact, it has been suggested that those dinosaurs, especially triceratops, which, one hundred million years ago, grew those absurd Elizabethan looking frills of bone round their necks, may have done so because their pituitary glands had become upset—for bone growth is one of the pituitary specialities. Yet it is also perfectly true that when these magic drug-makers take to unbalanced work, they can transform us in a brief time so that we seem to have had a spell cast on us, so impossible do such changes appear by any natural means. I have mentioned people made into giants and dwarfs and their faces changed so as to look much more like horses' than men's. But the tiny glands which lie alongside the thyroid in our necks can do just as astounding things. If they are upset they can remove the lime from our bones at such a rate that they lose all their boniness and we literally collapse. And they can affect not merely our solid substance but our mental capacities. The Doctors Jaensch of Marburg discovered that many of the children there had the power called Eidetic imagery—that is, the power to see, long after they had looked at a thing,

the object so clearly that they could draw it as though its outlines were traced on the paper in front of them. Research showed that these children suffered in their diet from lime deficiency. This upset the minute parathyroid glands in their necks, and so they had this strange capacity. I think we should note here a possible explanation of the well-known connection between fasting and visions. We also need remind ourselves how for some time it has been known that hens which had been kept without the chemical manganese, a chemical which is certainly very like one of the secretions of the pituitary gland, lost all affection for their chicks, but when manganese was given freely in their diet they could hardly let the chicks out of their sight. Yes, certainly our glands affect our tempers and, as it were, underline our moods. Still, to say they make our characters, that is going too far. We are more than our glands, and the latest work supports, I think, a more balanced view. For example, that rind or cortex of the suprarenal glands, the glands that nestle on our kidneys. It is this part of this gland which, we shall see, makes a secretion which helps our blood cells to tackle infectious germs and may especially give resistance to such a deadly germ as that of infantile paralysis. We shall also see, when we are collecting further news about our bodies and minds, and how we feel and can be stopped feeling, that it is this cortex which also helps us to overcome shock such as surgical shock. Now comes the news that the exact chemical formula of this invaluable self-made drug has been found, and so we

may soon hope to make it synthetically. That is important; for sufferers from Addison's disease, as well as those who collapse after operation, must have it. And up to the present it has only been able to be obtained from animals, and one of the ways it has been so obtained in foreign countries is, I think, outrageous. But we also know that this invaluable self-made medicine is closely linked with the gland—the suprarenal gland—which, in its turn, responds by special activity to all our moods and feelings. You may remember that a couple of years ago a new operation was started in New York. It was to cut the nerve leading to these glands. It was found that business men, by continually making themselves excited, were straining the gland, and it in its turn, under their pressing demands for hustle, was pouring its secretions into their blood in such quantities that they were wearing out. But you see it was their hectic way of living, not the gland, which was to blame. And this evidence that it is our way of life which provokes our glands, is increasing. That suprarenal gland is of course the gland of the sudden spurt, the spring, the violent hit-back. And it has been found that animals which are fighting animals have these glands proportionately much larger than peaceful animals; and among those peaceful animals, I am glad to say, is man. If you choose to live like a beast of prey, well, nature will so equip you, but don't forget the choice was yours. 'Yes,' you may say, 'but that's all very well for the race—changes may take place during æons, and habit may gradually modify our

natures. But so far as we individuals are concerned, that's too slow. We can't change our nature in a moment. Our glands dictate to us here and now how we shall feel and how we shall behave.' I'm not so sure. Let's take for example a gland which isn't a gland which directly affects our emotions, which isn't a moody gland. The pancreas, as we know, controls among other things the use of sugar, the great energy-maker in the body. Well, it has been proved that the way you live can affect this important organ, which, if it goes wrong, lays you low with diabetes. The experiments were carried out with creatures as cool and uninclined to take a vivid and upsetting interest in the experiment as trout. Overfeeding and under-exercise did tend to bring on a diabetic condition and, what is more interesting and more hopeful, the trout which had already begun to become diseased did show distinct signs of recovery when they were put on a spare diet. You probably know that during the war, though tuberculosis increased terribly in Germany, diabetes shrank to almost the lowest figure ever recorded. That shows that each of us in our individual lives can do something about our glands. You may think, however, that the simple rule of simple living is not much of a discovery, and though it may add greatly to our physical health, it doesn't show how our moods, our tempers, our ways of feeling and thinking, are reflected in our health, through our glands, and how such moods may set up health or disease. As it happens, however, further researches into this very question—the problem of

diabetes, of how the body uses its sugar-energy—is throwing light on this constant connection of our minds and our bodies. It is showing us that mind and body, mood and organ, are always interacting. It certainly used to seem that such a definite disease as diabetes, caused by such a well-known organ as the pancreas, could not have much about it that was mysterious or mixed up with our emotions. Yet it is now becoming clear that the causes of diabetes may be linked up with our glands and with those glands which we know are linked up with and affected by our emotions. It has long been known that should a patient suffering from diabetes also suffer from the thyroid gland becoming too active, then the diabetes becomes worse. The problem was, how does the thyroid affect the pancreas, which is far away? It does not do so directly. It has been found now that the indirect way this change is worked is by the thyroid gland which is in the throat affecting by its decreased activity the pituitary gland which is in the head. But even then, the pituitary gland does not act directly on the pancreas. On the contrary, it sends a message to those very temperamental glands, the suprarenals in the middle of our backs, and it is they who finally send the message on to the pancreas. That is a nice illustration of the way these ductless glands actually work. No wonder Starling and Bayliss, the men who first realized this complicated interchanging system, called these, the body's self-made medicines, 'hormones', messengers, which go right through the gland's wall, rush into the blood and hurry all over

the body on their work of retoning and reforming the whole body. What the limit of their control over our bodies may be no one can yet say. At present there is a tendency to regard the pituitary as the master gland. But as we can now trace back some diseases, say to an overstrained pancreas which in turn was due to an over-active suprarenal, which again was due to an over-active, a too excitable thyroid, which finally was tracked to a restless pituitary, we must ask, and behind the pituitary—what? Certainly it lies in so central a part of the head that we can be sure that it has a close connection with the brain itself. But the unravelling of this greatest of mysteries—for here we are tracing the threshold between mind and body, between consciousness and matter—will prove very complicated. We don't know whether as yet we have the full list of all these magic makers, the ductless glands. There may be more of them lurking round, unrecognized, in corners of the body. They certainly have the most mysterious powers, not only of changing our bodies but of disguising themselves when they like. The Thymus, for instance—I haven't yet mentioned it—the gland of childhood. What does it do? It used to be thought it was mainly a sort of brake—a gland to prevent you growing up too quickly, for it seemed to keep that master-gland the pituitary from coming into action, and so long as the pituitary couldn't come into action, you couldn't grow up, your voice couldn't break, your beard grow or your body become adult. Then, as you grew up, the thymus vanished away; it turned into just ordinary

tissue. That by itself is a queer story. For if the glands do everything, who or what tells this holding-up gland to clear out and leave the way open to the others, the transforming glands? But latest research seems to show the story to be more complicated than that. The thymus gland, if one is to trust experiments lately done on rats, isn't a mere inhibitor. It has something to do with growth. Rats given an extra supply went ahead at an unnatural pace. But perhaps the oddest thing of all was that the rats which had these thymus injections seemed to pass on the effect to their children. Indeed the effect was so strongly inherited that it was the grandchildren which showed the most striking results.

There seems little doubt that when we understand these glands and their essences, we shall have a power over our bodies and our states of mind—our moods and energies—which no drug or diet can give. At the same time, I repeat, all this latest work seems to show that these glands, which can so affect our bodies and states of mind, are themselves constantly sensitive to our states of mind. The latest research is adding, I think, some considerable support to the saying: 'We are as we think.' Remember, most experimental work has been done on animals, where the question of the mind taking a hand and reacting on the gland, instead of the gland wholly dominating the mind, does not come in. Where there is a fully conscious mind present, then we know that the glands can be greatly affected by it. In short, the picture of ourselves which all this vital gland-research is building up is, I think,

not one in which we see a poor shadowy mind swayed like smoke by the body's home-made drugs. What this work begins to dissolve is that absolute division of mind and body. Instead, we see body and mind, not uneasy enemies but a close alliance, each only perfectly creative when understanding and helping the other. This research endorses Browning's saying: 'All good things are ours. Nor soul helps flesh more now than flesh helps soul.'

(f) The conquest of pain

Still, the problem of pain remains here and now. Has science any news for us here? In comparison with the vast stretches of the front of knowledge which science explores, pain is a very small point. As a matter of size, how ridiculous to include in the same focus an expanding nebula and an aching tooth. But as a matter of quality not quantity, of intensity for the looker-on, the tooth matters more while it aches than all the outer universe. This is a fact science has to recognize, and does recognize. A focus of pain can blaze up until all our interest in natural philosophy and the vast panorama of island universes and space are hidden and lost behind the flash and flare of a single tooth at full ache, a single threadlike nerve in full vibration. That the latest news is that we are conquering pain is therefore of great scientific importance, of great hope for our further advance in all scientific knowledge of the universe around us. The victory over pain is scientifically important not merely because it adds to

our physical and animal comfort and pleasure. It is so vital because, when we have pain out of the way, then we can never again be degraded by bodily suffering to the level of cringing, whimpering, frightened, self-absorbed animals. We can look at the universe calmly and patiently. Threats and risks of agony no longer can deflect our outlook or make us too fearful to enquire how and why things actually are. We are raised by overcoming pain, far nearer than has in the past been possible for most of us, to the position of a natural philosopher.

We cannot escape accidents, but we can hope to become quite fearless about them, because we can take the sting out of accidents even when they have caught us, that sting which we call pain. I think this line of science progress must interest all of us more than any other. For accidents can really only touch us through our nerves. If we can control our nerves, we can hold in check anything and everything the world or our bodies can do to us. And here in pain-control we have made astounding progress. One may be sceptical about medicines and hostile to some surgery, but about the progress in pain-checks—anæsthetics and analgesics—there can be no doubt, the progress has been wonderful, especially in the last few years. And it has been, I believe, pure gain. If we compare our civilization with any other, this one point I believe is wholly in our favour—no other generation of man has ever had such a control over pain as we of this generation have been given. The advance has been so rapid that most of us don

realize it. The first anæsthetics are not a century old. Naturally we don't like to think of unpleasant things, but I think we should sometimes grumble less about our hard times if we knew more about times past, especially in this cardinal matter of pain. Do you know that Darwin wouldn't become a doctor because he shrank from having to perform operations on fully conscious people? You had to be tough to do that, yet there was no escape. Then came gas—nitrous oxide, chloroform, ether. And then discovery seemed to rest on its oars. People took for granted—till they became patients—that all that was necessary had been done. Of course it hadn't. Chloroform can be very dangerous. It can act as a heart poison. Laughing gas, of course, could hold you away from pain only for a minute or so. Ether? Ether isn't as dangerous as chloroform, but I don't think there's any anæsthetic which most people hate more, and the old way of giving it, when you might stifle for two or three minutes before you went under, made it to many people a perfect nightmare. But with the twentieth century things began to move. Not only was there great progress in how to give comfortably the old anæsthetics. Completely new ones were put into use. First came Stovaine, the French anæsthetic, which didn't affect your breathing at all—the point where most of us are most touchy—that hatred of being stifled. For it was pricked into your spine, and there you were, able to read a paper, while below the puncture for the next few hours your body seemed no more to belong to you than uncoupled railway

carriages belong to the engine. This discovery led naturally to even neater methods. If you could put all the nerves below a certain level out of action, why not just put out those particular ones which run to the spot the doctors needed to work on? Knowledge of the pain-nerves had shown that the body is wired with its nerves very much as our houses are wired for electric light, etc. And just as the man who comes to see what's wrong, when the electric light fails, turns off the switch and maybe draws the fuse-plug before he touches the wire, so the doctor can turn off the pain-nerves running to any place before he starts working on it. I can't help feeling, though, that if, every time a doctor touched one of our live nerves, he, like the electric engineer, got the shock, and not we, then anæsthetics would have advanced even faster than they have. Anyhow, they have advanced, thank heaven, immensely, and there was plenty of room. For we human beings suffer not merely from direct pain but from that indirect pain, that nearly all animals are completely spared, fear. So we haven't solved this our problem of suffering when we have made the body painless. Very few people can read their morning paper unconcernedly while their body is quite out of pain but still obviously there and obviously being treated in a way which ought to be painful. They get alarmed, and the alarm is not only unpleasant for them; it does their body harm. Fear is probably physically more harmful than pain. Not only does it make all your muscles become tense so that you have to have more anæsthetic, but, beside that, it lowers your

resistance to infection. The doctor, then, quite as much as the patient, wants the patient to be as unaware as possible. Yet the patient shrinks from being put forcibly under. It looks as though our poor sensitive selves both wanted to eat our cake and have it—at the same time to be there, for fear something should go wrong, and yet not be there, for fear of being frightened. That seems really asking too much, and yet, as it happens, it is just that very natural, if very exacting, demand which science has succeeded in meeting. It has managed to be able to put us into a condition the best description of which is exactly this —that we are not quite all there. It is research into those interesting drugs, the barbiturics, which has given us this odd and highly convenient power. They were known as sedatives for a long while. It then occurred to chemists to try to increase their very slight anæsthetic power. Through this wonderful modern chemical method, whereby you get right down to the molecule of the chemical and can manipulate it until you can pick out those qualities you want, and knock out those you don't, the trick has been done. With several of these new synthetic drugs you can now, in consequence, be both conscious and also sublimely indifferent, able even to help if called on, but at the same time as unruffled and detached as nurse herself. So anæsthetic progress is being made all along the line. At one end we put out of pain more and more precisely smaller and smaller areas. The local anæsthetics have been rapidly improved. First the task was to make them stay put. They tended to

drift, and sometimes they went, say, from your tooth where they should have stayed, to your throat, where they were far from being wanted. Then one of the earliest, cocaine, had poison and habit-forming risks attached to it. Here again molecular chemistry is finding how to take Nature's gift and to separate away the dangerous factors. There is now a synthetic morphia called Dihydrodesoxy-morphine-D, which is no less than ten times more pain-preventing than natural morphia, and which may have other great advantages. It just possibly may be without the habit-forming power of common morphia. If it is, then we have here the greatest advance in pain prevention since the discovery of chloroform. And at the other end—the general anæsthetics, the condition of painlessness spread, as it were, from headquarters, that, too, has advanced, for instead of putting out a person's breathing and laying them out altogether, the diversion is made right at the very highest brain centres, so as only to affect the patient's power of self-concern and worry. He is still quite himself, apparently, except that he can't take himself any more seriously than does his physician; in short, he is made just sufficiently physically insensible so that he can be intelligently sensible about himself. Only one pain problem remains over to be solved. What about pain after the actual touching and disturbing of the nerves is over? This pain, while our nerves are recovering from being interfered with, is generally got over by giving us, after the anæsthetic has worn off, a little dope to tide us over. It would, however, obviously be much better

if the anæsthetic could last on, and not only look after us when we are being handled but when we are still aching from the handling. Well, here again rapid progress is being made. We ask, and research is hurrying to answer us. First of all there are now a number of ointments and dressings which not only help a wound to heal, but also help to make it painless, and the anæsthetics themselves are being extended to cover with their merciful shadow not only the time of wounding but the time of aching. Already one of those anæsthetics, which is injected into the spine, can give us complete comfort for six hours, and often for a whole day after the operation, and after a complete day's ease often the worst of the ache is over. In short, so fast are we advancing now in the conquest of our worst enemy, pain, that the day seems in sight when we shall find ourselves completely freed from this tyranny. I should not, however, be quite frank with you if I didn't tell you about some further research which is scientifically intensely interesting, and which I think we ought not to shrink from knowing. For it does at least show how much more complicated our nature is than we have thought. 'Is pain any use?' we often ask. And the usual reply is that it warns us, for example, to take our hand out of a flame. We are told of the rats, which quite unconcernedly and without any misgivings, will make a meal of their paws if their paws are numbed. We are told: 'There, you see why Nature gave you feeling.' We reply: 'But what use is violent internal pain?' For example, has calculus pain, one of the worst known, ever taught people how

to avoid that disease? Anæsthetic research is now giving us a completely new answer to that question: what is the purpose of pain? Some great pain may not be a warning but a stimulant. Great pain nearly always attends grave injury. Your body is undergoing a terrific strain. There is risk you may collapse. You may give out under the shock. It has been noticed that after major operations there is always a danger of pneumonia—sometimes there isn't even pneumonia; the patient simply gives out. He dies of what is called surgical shock. Now it has been discovered how to deal with that. In the Health section above I have mentioned that the body's power to hit back at its invaders depends largely on those invaders being doped by the body through a secretion called cortin, which is largely made by the rind of the suprarenal ductless glands. It has been found that when patients collapse with surgical shock, that in nearly every case it is this minute but essential part of their bodies which has failed. You see how pain can serve here. Whenever you are attacked by pain and are consciously spurred, then of all your glands it is those suprarenal glands which are most quickly excited and begin to stimulate you. The suprarenal glands are those which respond at once to your feelings. You can't cry or laugh, cheer or groan, without their getting to work. High spirits make them flood your blood with their intense tonics. But sudden anguish can do the same. For those glands are, above all, the glands of immediate resistance. Now see what may happen if your body is gravely injured and yet you know nothing

about it. If you remain quite indifferent while a major operation is carried on, there is naturally a risk that those glands, especially that vital part of them, the cortex, may not get into action. Your resistance has been lowered, perhaps foreign germs have got into you, and yet your nervous system, because you have been asleep, may have omitted to ring the alarm-bell and call out the special glandular reserve. That, then, is the new theory about profound pain. By agony you call on the body to manufacture a special drug in special quantities, so as to resist the grave physical danger which is probably causing such agony. I'm sure you have often wondered why people in great pain so often seem all the more determined to stick it out and hang on to their lives. I think we may have at least the chemical explanation here, in the discovery of this purpose in pain. And we can see also how the group of drugs manufactured by this brace of glands not only makes us want to stick it out, for this supra-renal gland is the same gland which, when it works, makes us desperately brave and utterly disregardful of wounds—so that when deeply wounded, still we don't bleed to death—but is a life-saver as well. That of course brings us back to the ductless glands, which we have already glanced at. Anæsthetic research is following up this line carefully and learning how to keep you painless and yet have your body capable of stimulating itself. For you see anæsthetics can now be so carefully adjusted that they are no longer a sort of blind oubliette into which you pitch people, and then, the crisis over, pull them out again. You can lower

them now, as it were, inch by inch. So we are beginning to be able to study states of mind almost as exactly as we can study states of body. Anæsthetics no longer only save the patient, they inform the doctor. One last piece of research news. That phrase, 'anæsthetics can dip people exactly as far as is needed into painlessness', raises another question. What if you have to put people very deep, and you want suddenly to call them back? That, till the other day, was not to be done. You had to wait till Nature sent them back again to the surface. Quite lately, though, a way of sudden recall has been found, and very properly called palinæsthesia, making you feel again. It is curiously simple. All you have to do is to give the patient an injection of weak hydrochloric acid and back he bobs to the surface, like a bubble stirred up from the floor of a pool. And these are only some of the latest anæsthetic triumphs. It is a record of success which will compare with any scientific advance. And I doubt whether any other advance of science concerns us more or has been more wholly for the good of us all, not merely because we are animals capable of great suffering, but because till suffering is out of the way few of us can be natural philosophers, the men who understand, and so advance science and all understanding.

Still, some people think pain is natural and so cannot really be extirpated. If, as we have seen, disease is in some sense natural, pre-human, must not pain and anguish be so also? That, however, is fortunately not an inevitable or sound deduction. Those dinosaurs,

with their cold-blooded bodies and their one- or two-ounce brains—fortunately we can think of them all as practically painless. All pain must go through a brain. Intense pain needs an intense brain—that is a merciful law. Anæsthetics have shown us that. When part of you can still breathe and keep your heart beating and your body running, you yourself can be mercifully out of the way. And, as was mentioned in the last section, on anæsthetics, they are being so rapidly improved that more and more of you can be free and out of the way while still pain is kept at arm's length. You can even be quite conscious in a way and yet be outside the range of pain because with some anæsthetics you can manage to lose pain before you lose consciousness. All this shows that pain is an advanced thing. Life has been more merciful to its more helpless creatures than we used to suppose. But about ourselves? Well, there we can do two things, and are doing them. In the first place, we are beginning to see how much pain we actually make for ourselves. I don't mean by that that we make ourselves ill by not knowing what we ought to eat or how we ought to live. That is true enough. But in this section we are dealing not with disease but with pain. And it grows clearer and clearer how much actual pain we inflict on ourselves by being ignorant of how to turn it off. Pain, bodily pain, we think is always caused by the body being injured and by the nerve keeping on sending up to the brain a thrill like an electric bell or a burglar alarm. As long as the bell-push is pressed the bell must ring. But pain often

turns out to be not nearly as simple as that. If that were all, all you would have to do would be to stop pressing on the wire and the pain current would stop also. But sometimes the wire itself—the nerve on its own—starts ringing the pain alarm. In that case modern surgery is now so good that it can find the actual nerve which is misbehaving, and inject alcohol into it, and so you drug just it and no other part of you—surely such a neat use of intoxication that not even a teetotaller could object. If even then the nerve won't be quiet, it can be cut so that it can't go on disturbing. Now that ought to be final. But so odd a thing is pain that even then the pain will sometimes go on. How on earth does it do that? It is rather a mystery, and the only explanation at present is that pain may give such a shock to our elaborate brains that, as it were, the pain goes on echoing in those labyrinths long after—weeks, yes, sometimes months—after the bodily blows have ceased. It is worth noting that only a very complicated brain could have that sort of pain. Well, it is obvious that when pain breaks all the rules in this way, we also must break away from the strict rules that every feeling must be wholly due to some change in the body. For here is pain behaving like the Cheshire Cat in Alice's adventures—we clear away the cat, and still the ghostly grin remains. Still, there is no need yet to give up the struggle and simply say: 'Well, it's all fancy,' or 'Science is stumped—you had better go away and cure yourself.' Pain, physical pain, is a vibration. That we can cling to, though how it can hop and stab and short-circuit and echo, that we

can't yet say. Now, that notion that everything is finally some sort of vibration or wave, that idea we have been made familiar with through modern physics—the section on tides illustrated how proof of that is growing rapidly. It is probably one of the most helpful ideas we can have about everything physical; and that of course includes our bodies. And I'm glad to say that, as far as our bodies and the way they suffer are concerned, it is not merely an idea. It has been acted on and has already given very surprising results. Our teeth, very few of us don't know, are abominably sensitive and capable of pain. It really does seem maddeningly unfortunate that first a set of nerves of intense painfulness should be shut up in a series of the hardest little cases in the whole body, that these cases should be liable to decay, and then only be able to be cut and repaired with a drill. I am sure the health of England would leap up if teeth suddenly became painless, for so many people who are shirking the dentist, and so poisoning themselves, would make appointments to-morrow. Well, a step has been taken by using vibration to conquer vibration, to flatten out or block the pain wave by sending down the jaw another wave. It has been known for a long time that your jaw conducts sound very well. That is why people, when they really want to hear with all their might, let their mouths fall open. You can test this for yourself. If, when you can no longer hear it, you put a tuning-fork on one of your teeth, once again you will hear the note. This way of bone-listening, which I mentioned some years ago at the

microphone, when it was still largely experimental, is now being used widely to help the deaf hear. But sound vibrations sent through the jawbone can also be used to counteract the painful jarring which the dentist's drill is sending down to the jaw and its nerves. A radio earphone has been clamped on to the big bone just behind the jaw, and the vibrations have been found in many cases to counteract successfully the drill's horrid jar. This of course is only a very simple beginning, but it points the way to fuller trials and discoveries. All pain, we have seen, must be, like all sensations, an electric current, and as we now command so many delicate and intense electric currents, it looks as though we should soon be able to jam any electric current that we don't want. Then all pain, which is using electric current for its misbehaviour, should be jammed out of existence. Will pain then vanish? I'm not sure. For, you see, in spite of all that we know about the way the current which will cause pain is carried, in the end pain—yes, bodily pain—isn't in the body; it is in the mind. And though it is the most terribly real thing in the world, yet it is a different sort of real thing from a pound of tea or a minute of time. We can all see the tea and hear the ticks which count out the time, but pain is a strangely lonely thing. No one knows for certain that anyone else has ever really had his or her sort of pain. And as pain, physical pain, is such a mental thing, and, as we've seen, it can go on when, as far as we can see, the body itself can't be setting it up, we have to own that sometimes the mind can cause physical pain.

Again, I'm not thinking of mental pain. I'm talking of pain coming from quite definite spots, pain which isn't fancy. How do we know? We know because some of these pains, when they have kept on for some time, actually change the body, so that we can see the marks, and may damage it fatally. It has long been known how the terrible pain angina tends on the whole to attack mainly those people who are continually under great nervous strain—such men, for example, as barristers and business men. The great Viennese school of medicine reports that peasants out on the countryside are practically never found with this disease. The man who lives under a constant series of nervous strains does bring on a painful state of strain which finally ends in a bodily breakdown. But a far commoner painful disease seems even more closely connected with worry. If you are constantly suffering from what is rightly called gnawing anxiety, you will pretty probably keep on getting indigestion. But that is not the end of the story. The indigestion can go on until the acids of the body become so sharp that they have actually eaten into the body, and there is the poor patient with all too clear physical proof of how states of mind can alter and break down a state of body. But this story can have a happy ending. What mind has done to body, mind can repair. A good example of how this can be done was given the other day. Nineteen patients all with their digestions so upset, with their stomachs so inflamed, that they had given up attempting to eat any ordinary food, were treated. They were given ordinary medical

treatment, and something else. Twenty-one other patients were only given the ordinary medical treatment. Of this latter lot—what one might call the 'control' group—only two-thirds of them could be said to be well on the way to recovery after a month's time, and, what is more, they all got ill again as soon as they went back to their ordinary food. But all the nineteen patients who had the something extra together with the routine medical treatment, all of them in six weeks could eat whatever they liked. For it was found that what was going on in them was that anxiety was literally gnawing at their vitals. The something extra in their treatment was, then, simply to get them gently but firmly to switch over their minds on to thoughts which were the opposite of worrying. When that could be done—nothing like as easy as it sounds—the tension relaxed, the acidity became uncorrosive, and kindly Nature, always ready to heal if only we will give her a chance, repaired the damaged tissue and gave the sufferer back his health. That is certainly a nice story, and a true one; but the question remains: 'Yes, we know this "Don't Worry" slogan, but how are we to stop ourselves?' It is true that is the serious question. As the great psychologist Carl Jung has said: 'To recognize that a disease or pain is caused by the mind is not to cure it, or to be able to cure it.' Indeed, it may be easier to cure faults and pains that have started in the body than those which have started in the mind. Why? The answer is not pleasant, but it grows increasingly clear, and we must face up to it: because

we may not really want to be cured. That is the final thing we have learnt about pain and the most mysterious thing about it. Part of us, the part which can control our bodies far better than the conscious part of us can, that part may not wish us to live as we intend to live. Pain, we know, is a warning, often a warning that something is wrong with the body, but now we are beginning to learn it can also often be a warning that something is wrong with our way of living. And just as when we refuse to attend to a pain-warning about something wrong in the body, the pain is followed by a breakdown, so the pain-warning about something wrong in our way of life can be followed by a bodily breakdown. Now that, as I've said, does give us a hopeful outlook on pain. For it looks as though here too pain is after all something which is meant to teach us. It looks as though, when we greedy, excitable creatures go rushing after all sorts of silly, feverish aims, something deep and quiet in us puts on the brake, tells us to listen, and if we won't listen lays us on our back. But not all people who are attacked by severe pain which, if it goes on, may well turn into grave disease, are fussing, hustling persons. Some are people who seem to have no interest in their lives save their precious complaints. True, there is this other class of persons, but there is a good reason also for the spur of pain being pressed against them as well. For here the profound force which is in them seems to be urging: 'Find a purpose in life, find an absorbing interest, or you shall find it in pain. At least you cannot fail to be

interested in *that*. But I will not have it that you should find this amazing life simply pointless and boring.' Certain it is that if these persons find a great interest in life, their pain goes. They are healed because they have obeyed life's spur. It looks, then, as though we had only to attend to our deepest nature, not only to get out of pain but also, what is really more valuable, what is worth all our pains, to learn how to live really well. We are like people only half awake burning themselves against their hot-water bottles because they want warmth but haven't sense enough to know why they are hurting themselves.

But, after that, what is the next step? When things reach this pass most people want to be cured. But if the cure is to be thorough, it will take time. It took time for the run of your feelings to damage your body. It will take time to repair that damage. We have got to change our habits, and then our habits will gradually change our body. But most people find it easier to have a tooth pulled or an appendix cut out than to change a habit, especially such ingrained ones as worry or irritability. We have got to relax our whole muscle-system. We find we can't. The more we try, the tenser we get. But get the knack, and wonderful recoveries can be made. Much actual pain can be stopped almost at once when you can get the patient really to relax. His pain is often due just to his state of tension, like a cramp, agonizing, self-inflicted, outside his conscious control to stop, but stopping when he can relax. This is the last item of pain-control news that I can give you—what is

called progressive relaxation. It is not a quack remedy or a short cut to health. Quite the opposite: it is slower than using drugs but it is more lasting also. The patient can be taught by his doctor, but he himself must do it—there's the rub. As Dr. Jacobsen, the American neurologist, a thorough researcher in this subject, points out, most people won't give the time, the time necessary to untie the tangle in which their fuss and hustle knots their body and nerves. They haven't time, they think, to learn real self-control. If once we could learn to live with that patient self-knowledge, far fewer of us would be patients. So it looks as though the age of painlessness will be when we have grown wise enough to live without that crude warning, and when that will be depends largely on ourselves.

Chapter II

Ourselves, More Particularly

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(a) How we take things in

Our diary now must enter up some further latest science bulletins about ourselves. We cannot leave that part of the science front yet. For if we do not grasp the scale of things at this point we shall get the rest of the front out of proportion. Study of ourselves is so important because we have to understand ourselves as part of the universe and also because if we fail to understand this peculiar part and how it works and takes in we cannot understand any of the rest. On the body-mind's clearness and freedom from the disturbances we call disease and pain depends obviously our power to make a valid picture of all the rest. Outwardly all science may depend on physics but inwardly it certainly depends on psycho-physics in the study of our body-mind and how it apprehends. Now we have discussed pain and disease the place is reached where we have to examine this instrument, ourselves, when it is normal, and try to find out how it takes in and what is its range and limit even when it is well and comfortable. For one of the most remarkable things about science is the way it is showing us how little we really see or hear things. We take for granted

that we notice things. But really we attend to very few of them. We generally overlook things unless we can see at once how we can use them. Look at your finger-prints. Nothing could show more vividly how we have failed to notice things, important things, literally under our hands. From the earliest times men have been trying to make unique seals, signets, signatures and sign manuals. Some of the very earliest records of civilization are the seals of kings who ruled before the Flood. And long before that, stone-age artists, fifteen thousand years ago and more, were signing their masterpieces on the cave walls with the prints of their hands dipped in paint and pressed against the rock-face. When men did that, before the dawn of civilization, they were close to making the most important discovery about their hands—that there really was no need to make seals or tallies, or to learn to write your signature so that no one could quite copy it. For Nature had and has marked each of our hands with signs that distinguish them from all other hands. Nearly every one must have studied his fingers, and yet it was only three generations ago that the oddness of these signs was first noted and used. So far as we know this find was first made in India by an Englishman who saw that the thumb and finger-prints of each person were always different and so could be used as signatures which could never be disowned. Then the discovery came to Europe. But still only as an ally of the law, just to tell who you were in case you should be wanted. Now however we are taking another step in this direction and the arrangement and shape of

these fine lines on our finger-pads are beginning to be used to tell not only who you are but what you are—what race you may belong to, what physical type, yes, even as to what sort of health you may have. So what has proved useful to the law may also prove equally useful to medicine.

And if we have been slow about seeing and noting the importance of things which we actually have at our finger-tips, we have been quite blind to numbers of things almost at the ends of our noses. The truth is we never really trouble to notice how we notice. We get a general impression and think we are acting on exact information. We muddle up our senses in the oddest way. Do you know that one sense can alter another sense without our knowing? If you smell the strong scent citronella, it has been proved that just during the whiff your eyes see more clearly. The shock down the smell nerves spurs the sight nerves. And here is another example from our way of picking our food —a thing about which most persons are pretty certain that they know what they are doing. Surely we choose our food because we think it will taste good? The proof of the pudding is in the eating. Maybe: but the choice is not nearly so simple. Here is one of the tests which proved this. A dozen grape-fruit were cut in halves. In one of each of these halves was put a cherry —the other was cherryless. People were left to choose. It was noted that all the cherried grape-fruit were chosen but the cherry itself was put aside before the grape-fruit was eaten. These people thought they were picking their food so as to please their palate but really

their eye was having a look in on its own without their knowing it. And if we don't know how we take things in, still less do we know how other people notice things—how the world strikes strangers. Of course we think we do but science is showing how mistaken we can be. Do other people really see the world as we see it? Pretty certainly not. For, first, other people attend to other things. They mind their business and if their business is hunting or fishing they notice things which we never notice. Up to a point we can learn to track and note just as well as they. But here's a queer thing that has been found. You not only attend to what you see. You see what you attend to. It has long been noted that some savage peoples have few if any words for blue and don't seem to notice all the blues we see, while they have names for and can notice shades of red we overlook.

(b) How other lives take things in

That gives us a hint of how different the world may seem to different people. We can hardly help thinking we see the same world. But doubts are beginning to arise. And if that is true about men what about animals? Before we go on to study the range and limit of our senses we must realize how much science has found out about the different way our fellow creatures take things in and so what a different place the world seems to be to them. We English are very fond of some animals and we think we understand them and how they look at things. That grows increasingly un-

likely. The dog or cat, which we are sure 'understands every word we say', we take for granted is aware of much the same world as we know. If we don't make that assumption then we go to the other extreme and think it is merely automatic. Mannikin or machine, those seem the only possible opinions we can have of our pets. It looks, however, as though animals do see, are aware of the world around them but in a different way from ours. Let's start with simple examples first. The other day some careful experiments with a cat showed that it had been blind for a considerable time but no one had noticed, because its sense of smell was so good that it seemed to need its eyes only about as much as we need our noses. A cold in the head is a nuisance if you want to smell a flower but you can enjoy yourself well enough without being able to smell. And so this cat evidently felt about sight. That gives us a glimpse into the topsy-turvy world in which dogs and cats, animals guided chiefly by smell, must live. Take a step further out, from cats to mice, to that queer mouse the flitter-mouse, the bat which has developed its ears at the expense of its eyes. It was always a problem how a bat could nosedive about in the dark and never bump into anything. It is not its eye that lets it. A really blind bat was let fly in a room across which piano wires were stretched. It never touched one of them. But all the time it sent out that highest of animal squeaks. It seems then that what the bat may be doing is echo-sounding all the time like the ships and aeroplanes I mentioned in my first talk. The echo of its squeak coming off objects may tell

those immense microphonic ears how to fly clear. Some other sorts of bats seem to fly clear because they have a strangely sensitive patch on the cheekbone of their faces and this tells them what is ahead. Still further away from us than the bats are the snakes. How do they take in? Can they hear? They have such ridiculously small ears. Lately naturalists have been watching the way the snake uses its tongue. That forked tongue constantly darting in and out used to be thought to be a sting. Of course as soon as people actually examined the snake's mouth they found that it was nothing of the sort. But why that constant darting? Very few animal movements are useless. Now a reason has been suggested. With its tongue the snake is taking soundings. Its tongue seems specially sensitive to vibrations. So the snake may be said to be hearing with its tongue, using this queer forked member as a sort of aerial to listen in. Still further away from us than the snakes are the fishes. Can we know how they look at the world? One of the oddest things about some fishes is the way they can change themselves so as to match their background. Do they see their background and decide that, say, against pale brown it would be a mistake to wear a blue skin? Certainly not. But then we went to the other extreme and took for granted that fishes change colour just as we blush or tan in the sun—not through the eye but through a shock to our nerves as a whole or through the direct effect of the sun on our skin. Now, however, it is found that the fish after all is taking everything in through its eye and gauging to a nicety how dark or

light a tint it should go. For if the fish's eye is covered up nothing happens. Move the fish where you will, however much it clashes with its background it cannot see that it is doing so and so will not change. Leave the lower part of the eye uncovered and only hood the upper part and the fish still is unable to see enough to start altering its complexion. It is just the upper part, turned to where all its light comes from, that tells the fish, how and when to alter its colour. Of course there can be no conscious choice with the fish, any more than there is conscious choice with us half an hour after a meal as to how to deal first with the meat and then with the pudding, or, when we suddenly look up from our book, how to change the focus of our eyes so as to recognize a friend coming up the road a hundred yards away. Indeed Dr. Mackenzie pointed out on this very subject at the British Association in 1934 that a fish simply cannot reflect on what it sees. For whatever it sees goes straight past its front brain (which anyhow is not a very elaborate organ) and strikes directly on the nerve centres which control its body. Still there is an eye, a very strange eye, taking in in some way something of the world. It is clear then we need to know a great deal more about the ways other creatures take things in. A beginning has been made. Photographs have been taken through insects' eyes and lately one has been taken of an insect as seen through a real bull's eye—the fly looks rather dim. But that's only a beginning. We want if possible to be able to tap all the senses which animals use. For we have found out that if we use ultra violet

and infra red photography we see rather a different world from that our ordinary eyesight shows us. So if we can use the lenses and other senses of animals we may see still further fringes of the world to which our senses do not answer. Of course the senses of animals have many limitations. They fail to notice much that we can take in. But we are coming to realize that it is far easier to gauge limits, to say what the animal can't see and sense, than notice what it can see and sense and we cannot. It is very hard to tell what additional and wider powers they may have and we lack. But we are finding out here also. We all realize that dogs and cats can smell in a way which makes our ordinary sense of smell hardly worthy of the name of a sense, and the dog can hear notes our coarse ear is deaf to and the bird see with a keenness which makes all of us in comparison purblind. And even the fishes can beat us on points. For example, as Andrade and Huxley point out in their excellent book *Simple Science*, the Cat-fish which I introduced to you some time ago as an earthquake detector also has the faculty of being able to taste to the very end of his whiskers while that other fish the rockling goes one better and not only tastes with these fleshly whiskers but with a couple of its fins as well—a useful taste-extension which would save us a good many digestive upsets if only our bodies were fitted with it. The house cricket has another peculiar 'extension' advantage, for it puts its ears out in its front legs. There would be no need for a night ban on hooting if when we put our feet under the blankets all noise was blanketted and shut out as well as the cold, and ear-

trumpets would become a drug on the market if we only needed to put out our hands towards a speaker to concentrate what he was saying and grasp it clearly.

It is clear a new world may come in view if we can use new instruments, and every animal is to some extent an instrument which is tuned in to a different wavelength from the wavelength we usually use. Certainly we must get out of the rut of thinking that the world we usually attend to through our ordinary senses is the only world that is there for us to see. All this new work on animals and their senses I believe is making us begin to be able to look upon every animal as a possible informer, a possible teacher about, and guide in that world of which we know we see so little. This is quite a new way of looking at the animal kingdom and I think a humane one. And not only does it make us view animals with a new interest, it gives us a new sense of their possible and hitherto unsuspected value for us.

We have seen how animals which we think we know such as dogs and cats, and animals built on the same backbone plan as ourselves, such as all beasts right down to the fishes, may all have their own peculiar-and authentic outlook on the world. Let us go on with the insects. We've seen that the fish doesn't see as we see, when we mean 'realize' and 'reflect'. It sees and does something which we can't do. It starts at once to change the colour of its skin. But it can't do what we can do, think what it is doing. Perhaps that is the real difference between us. To do things like that you have to know so well how to do them

that you have no idea how you do it. If you did, you couldn't. But what about insects? They are far away from us, but some of them we know best, the wasp, bees and ants, have big brains, that is, as brain size must always be judged, in comparison with body size. How do they see? Well we now know that bees actually see—their eyes show them rather a different world from that we see. They have ultra-violet vision. That means that for them some things which we scarcely notice, must stand out strongly. For it has been found that there are many flowers which bees favour but which to us look insignificant, yet if you look at these flowers through an ultra-violet screen you will see that they stand out remarkably. Still, does the bee or wasp really see? Can it reflect at all, can it make a choice as to what it will do when it looks over a job which it wishes to tackle? Is not the insect run entirely by instinct? Its eye simply stimulates it to move in a certain way and move it must as a moth to the light. That does seem pretty certain in most cases. But there are now on record quite a number of very odd exceptions. Observers such as Miss Cheeseman and other entomologists have pointed out that though in most cases the bee or wasp goes through its work as deftly as a sleep-walker, if you upset its piece of work then it is completely thrown out. Disturb the mason-wasp at work and it will generally become quite dithered and the job falls through. But just now and then that doesn't happen. Accident is changed from checkmate to opportunity. The mason-wasp is known to hammer smooth the cement of its grub's cell with its head.

But several times now the wasp has been seen, for some reason, to find that its head won't do the job neatly. Then, instead of giving up, the insect was seen to pick up a grain of gravel and with this paviour's tool, dress the cement. That looks suspiciously like invention not instinct—a break through by the wasp's mind—a real insight.

(c) Why living creatures cease to take things in

I think we must follow up that clue because we use that word Instinct as a sort of shut-down and hood. We mean by it that we can never learn anything real about the world around us but that we are tied down just to see what serves our animal needs. But if insects sometimes see through even a little way when they try, well, we may see even further if *we* try. There's nothing commoner than to hear people say that because we are probably descended from an ape-like creature therefore we must be tied by instincts. But granted that we inherit all the instincts the apes have —that's a very big assumption—what are the ape's instincts? Study of the apes now begins to show that, even down at that level, the ape is what he is, not so much because he is tied by instinct but because he has not had the opportunity and the inspiration to become more. I have mentioned that fascinating book *The Ape and the Child* by the Doctors Kellog—how they brought up together their child and a chimpanzee and how the ape learnt things no one ever thought an ape could. And all chimpanzee babies are amazingly easily

trained. You know probably that the Chimpanzee Tea-Party at the Zoo is always made up of infant prodigies, for all infant chimpanzees are prodigies in comparison to what they will be when they grow up. It isn't then any inborn instinct that does them down, but simply growing up, or if you prefer it, growing down and losing interest. They begin wonderfully free. They end set, fossilized. And lately we've found that the monkeys even, creatures with simpler brains than the apes, even they are far less instinct-bound than we took for granted. Of all instincts the instincts of motherhood should be strongest and clearest, for the life of the race must surely depend on the mother knowing instinctively what to do with her child. Yet it has now been shown that such a typical monkey as the Macaque has only the haziest idea of what to do with its newborn helpless baby. It is true that both mother and child cling blindly to one another. But here is the strange thing, the startling lack of instinct. If the child cannot find the breast, the mother cannot help it. And the child may fail, and then in spite of the fact that mother and child are clinging to each other, the child will starve in its mother's arms. Could there be a more striking example of lack of instinct? Here we see how far back Nature took away the guide, the rigid guide of instinct. Why? Well, it seems that it is done because instinct and insight cannot go together. The creature that acts by instinct doesn't suffer and is safe—at least if things stay just as they have been. If they change, then the creature is like a blind person walking down a ladder, the lower rungs of which have fallen out.

The creature that acts by insight suffers doubt, misgiving and pain at every step, but he is alive. Instinct is the mind fossilizing. Insight is the mind cracking its way out of its shell. And the more we study our own earliest childhood, our age from nought to three, the more we are discovering that here is no little instinct-bound animal, but that the baby is almost terrifyingly receptive, sensitive, adaptable. For we are now learning that one of the chief reasons why so many people suffer from a whole number of nervous diseases in later life is because of damage done to them in this terribly impressionable period from nought to three. Indeed tests now show that a baby takes in when we think it can't be taking in, because we can't understand how a creature with such an undeveloped apparatus can take in. Dr. Aveling has pointed out that the baby notices changes in your face and translates them rightly as pleasure or anger when its eyes ought to be quite incapable of making out the tiny changes whereby you express these moods facially in that expanse of pinkey-grey which is your face. And further there seems to be evidence that when the baby can make no response then it may be most affected by some things. Like a photographic plate it may be taking up when it is quite silent. In fact, instead of our being instinct-bound, it begins to look as though we were really so plastic, so easily moulded, that perhaps no one should have charge of the really young child unless they are prepared never to let it gain any impression except those one should wish the child to have in its mind. It looks as though in this early state

the mind is so terribly free, has so little resistance and prejudice against anything, can take up anything, that it may become almost anything. Later on we settle down, stiffen, blame our instincts for what we don't like in ourselves and our fellows and get a sort of bitter comfort by repeating 'Human Nature can never be changed'. But you see it begins to look as though human nature could be changed every time a child is born—and we can't say how much. We see we are not instinct-bound at all. What does tie us up are the things we've been made to attend to and then got used to attending to, till we lose interest in anything else, till we can notice nothing else. All around us all the while are wider interests and inspiring sights—if we could only look around. For being interested in more things means gaining the power of seeing more things, yes even growing till we have a living contact with things outside our rut. Now that is why this attempt to use animals' senses is both useful to us and educative. Though animals only see the world through a narrow slit, they do look out at a different angle and so see part of the world we don't see. Seeing the other fellow's point of view may be very good moral exercise for widening our sympathies, but seeing some other creature's point of view is even more expanding —it opens one's mind as well as one's heart. The small minds of animals are 'magic casements' however cramped, opening on 'perilous seas'. Through them we can gain true insight.

(d) Light for us from animals' points of view

But are such glimpses really any good? Can we make any practical use of these living receiving stations? Well you know of the white mice which have to travel in submarines because, being so much more sensitive to fumes than we, they can signal when the air is going wrong, long before our clumsy senses warn us. And there is the catfish now being used as an earthquake forecaster because he is so sensitive to electric currents. We are all familiar with the queer migrating sense of birds, still a mystery, and how we have used another variety of this sense of direction by employing pigeons to carry messages. Another case of our finding a use for an animal's hypersensitiveness is the common frog. He responds so quickly to one deadly poison, strychnine, that he can tell when it is present when a chemical test will miss it. And remember we have only just begun to take stock of these living recording instruments. Perhaps every animal can tell us something when we learn to watch it properly. Look how many years of search it took before Dr. Schmidt discovered the eel's inexplicable power of finding its way home out of its pond, into the river, so to the sea and so to its ancestral home across the Atlantic near the Bermudas. But odd knowledge belonging to animals under our feet has escaped notice. 'Go to the ant'? Surely enough people have been doing that since Solomon's time? Has any other creature been so spied at and pored upon? Yet most naturalists who had specialized in ants have overlooked a strange

gift which ants have and a very useful one. They have a curious hypersensitiveness to the weather. By watching their behaviour, if you know the symptoms you can foretell coming changes as by watching the catfish you can foretell coming quakes. This is known to Tyrolese peasants and mountain climbers who certainly do and can rely on it, and more it seems it was also known to the ancient Chinese. But somehow in the modern world it has been overlooked. Perhaps because so many scientists were certain that animals were only little machines for getting food and laying eggs and could know nothing, far less detect things we didn't know. Now, however, we see that through the animals a new world is opening up to us. So one comes back to the thought that perhaps we may come to preserve species not merely because they are good to look at but good to look through. For if we let these strange windows close in death then perhaps we shall have blinded ourselves for ever to a unique insight into this amazing world we still know so dimly, we shall have lost for good a peculiar vision which no other instrument however sensitive can ever again be made to yield us.

It is clear then that if we have failed to notice how much even animals can take in we shall have overlooked much that we ourselves might take in. For though animals can every now and then beat us on particular points and peculiar outlooks, those outlooks are narrow. There can be no doubt that we, of all creatures, do see if we choose to see the greatest range of all the world. But it is also clear that we do not choose nearly often enough, we are not sufficiently

interested to use our capacities and faculties to a tithe, to one per cent, perhaps not to a thousandth of their powers. It is also clear that till we do so our science must be sadly inadequate. Odd facts will be half noted off and on, never seen sufficiently to be really known but seen enough to upset our accepted outlook and theory. The empiricists, those friends of science who are interested in facts regardless of theories, will say, 'Something is there. I don't see how it fits in but I do say it must make a difference and must be allowed for.' The systematists, those other patrons of science who are interested in order and agreement and suspect reports if they vouch for facts outside the accepted system, say, 'If you can't define your new fact and describe its path, its law, then I am free to deny its existence.' This attitude found classic expression when a famous curator issued the instruction to an official sent to inspect the remains of a putative 'Sea Serpent': 'It is of the utmost importance that the animal should be found to be of a species known to science.' It is no use for the layman to ask Why? Since in the nineteenth century science owed so much to the systematist, his representation in its councils has become dominant until another famous curator can ask to-day: 'What is a species?' and reply, 'A species is whatever division of animals or plants a competent systematist rules to be.' Though, however, we can understand how such a situation has arisen and realize its naturalness, it is none the less unfortunate. It largely accounts for the layman's suspicion of science—as a study concerned to disregard or to cold shoulder facts if they damage the

authoritative system, and the scientist's suspicion of the layman as a creature desiring to damage that system not for the sake of growing truth but of mouldering superstition. These symptoms are signs of a crisis in science. It shows in physics and in psychology.

But when we examine the problem more closely we see it is not merely a squabble between people who know and are satisfied and people who do not and are not! Below this lies a deeper friction between the field naturalist, who notices a fact but notices it poorly because he does not know what to make of it, and the laboratory judge, who feels his jurisdiction has right to compel any fact to come into his court and submit to whatever limitations he chooses to impose on its behaviour under pain of being dismissed otherwise as fraudulent. It is clear then, from the one end of science, from physics where experts are already involved in the riddle 'What is there when no one is there to see' to the other end of science, psychology, the whole science front has come up against the profound problem, the great crisis, How shall we manage to see the world yet more clearly? For our present way of taking it in we discover too often takes us in. So science is now testing over its apprehensions and impressions which it used to call its data, which it thought were given complete, intact, but which it now sees it took and shaped to what it could take in.

So there is no branch of science which is giving more surprising or more promising results than the study of how we have found and do find things out, and especially how inventions are made.

(e) News on how we invent

The oddest thing that science has found is the strange way that it finds things. That is more wonderful really than any of its other discoveries. For it is a very wonderful thing that science can make these finds. We take it for granted because we live at a time when the tree of knowledge is bearing its autumn harvest. So we think that making discoveries and inventions is really as easy as shelling peas. All you have to do is to pick an idea and, in your hand, it breaks up into half a dozen new and useful things. Yet that isn't at all the way things have been discovered. The course of science, even less than the course of true love, has seldom run smooth. We forget this too easily. The truth is, we hardly ever get things straight, straight away.

Look at the motor—the symbol of our modern efficiency—Why is the bonnet in front? Not because that is the best place for it. On the contrary the engine would do much better if it were where it has to do its work, over the back wheels. But you see even in a new thing, like the motor, we could not get rid of habits and customs. Cars had always had in front whatever drew them. So the engine-driven car had to have its power-centre in front. Now—but only after a generation of motor car designing—we are slowly becoming capable of thinking clearly on such a simple matter. So you see even in the making of machines there is still a lot of blind prejudice mixed up with what should be pure invention. Ships, also, need to be

as efficient as motor cars but even in their building we find custom getting in the way. Why, in steam ships is the screw at the back? Very largely because people have always sculled boats from the stern. The stern seemed the natural place for a screw. But is that so? There has just been reported work done for ship building research, on the problem of how fishes manage to swim so fast. It shows they get their top speeds not from the tail and tail fins but from the front fins. If you push a ship through the water by screws at the back you get a wave ahead and waves around and it is the difficulty of getting through these waves that mainly holds up a screw boat. But nature has got over this very largely. For the front fins, and in the case of swimming birds the wings, make waves which cancel out the wave made by the main body of the animal going through the water. It looks then that if we really thought about nothing but making our ships go faster for less effort, and were not tied by old ways of doing things, we should put the screws in front instead of at the back.

And of course we have not only overlooked inventions which nature has made. We have actually made inventions and then forgotten them. Archæology has shown us that the safety-pin was in common use among the prehistoric peoples who lived here thousands of years ago. Somehow, however, this most useful invention got mislaid and it was not till last century that it was brought back into use again. And, beside such small but very useful little gadgets, many very important inventions have been on the brink of being

made, indeed some have actually been found but no one could see quite how to make use of them and so quite often some other invention not really so good cut in and cut them out. Take just two: one to cause pain and the other to stop it—explosive gases and anæsthetics. The latest research now seems to show that the government of the Eastern Empire of Constantinople, in what we call the Dark Ages, was given by someone we should call a Semite, Callinicus of Damascus, the recipe for making gunpowder and other forms of explosive fire. It is true the invention was kept a close secret by the Eastern Empire, with far more sense than modern states show about such inventions to-day. But in the end it leaked out. By the time of the Crusades it was the Christians who were terrified of the Saracens using it on them and not vice versa. Why then did not the invention sweep across Europe and bring modern war to birth half a millenium before its time? That's the puzzle. It is true they could not make cannon then, but the people of Constantinople had shown how to make flame-casters which flung the blazing stuff on ships and men and actually burnt on water. And the Saracens improved on these guns until even the tremendous nerve and courage of the Crusader was shattered by this use of chemical warfare and frightfulness. Of course soldiers are always the most conservative men and consequently dislike all new inventions. So that may explain why gunpowder and fire-and-gas war waited till our own days. But anæsthetics? What reason kept people back from finding out about these? Research

here has also lately shown that some mediæval doctors were actually experimenting with the strange drug Hyoscyamine—which they got out of the common weed Henbane, and made use of it to make their patients painless. Why was it given up? And then of course there is the famous case of John of Gaddesden, physician of Edward II, who discovered that smallpox patients did not scar if put in rooms hung with red. This discovery was also mislaid. Though it was known, it was dismissed by doctors who thought that such a thing as light could not affect disease. Such a notion was a pitiful piece of mediæval nonsense. Then, five hundred years later, it was rediscovered in the United States civil war. Think how all radio-therapy—all healing by light—might have advanced if we had been studying for the last five hundred years instead of for the last fifty or sixty the way light can cure disease, as Finsen showed with lupus and as we have gone on discovering further cures ever since.

And in the last century, when doctors were slowly finding out about anæsthetics, the different discoveries as it were collided with one another. Just at the time when Simpson and other doctors were trying out Ether and Chloroform, some other doctors were carrying on Mesmer's work, making it scientific and studying how to bring complete painlessness, for as long as required, by hypnotism. Doctor Elliotson performed a large number of major operations with no anæsthetic but hypnotism and what is even more interesting is the fact that the deaths after the operation were much fewer than when hypnotism was not used.

It looks as though this were the true path to painlessness because it not only saved the patient agony but also kept up his resistance to infection which drug anæsthetics do not do. The discovery of Ether and Chloroform, however, drew off attention from this other way of bringing about the same result. Naturally people in a materialistic century preferred trusting to a drug than to a method. Now, however, that everyone knows how much more dangerous chloroform is than those nineteenth-century doctors realized, one cannot help wishing that research into this other discovery of how to take and keep people out of pain had been followed up.

And in our own time discoveries have been made and lost because still another discovery was needed to make the first quite clear. One of the last times I was with the late Sir Walter Fletcher, who so often gave me science news for B.B.C. science talks, he told me how a friend of his, twenty years before Banting discovered Insulin, made this great discovery. But he lost it because no one then knew enough about the ductless glands and so no one knew that if a cat gets cross —he was proving his theory with cats—the cat can put so much sugar into its blood, through those glands of conflict, the suprarenals, that for the time being you think the cat is a diabetic. It isn't. It is only a carnivore getting ready to go into action. But at that date no one knew this or much else about the ductless glands and so the discovery of insulin had to wait.

So it looks as though there were a great deal more chance about discovery than we usually think. It is not

a case of apples continually falling off a tree into our laps. It is much more like a strange fish coming into the bay—or the lough—for a little while, and then, if we don't land him, going off and disappearing again into the deep. In fact finds are not simply things we pick up but rather happy ideas. There is something of inspiration in every find. As has been said: 'The eye can only see those things on which it can bring to bear its power of seeing!' It is utterly untrue that any collection of facts put together will give you new discoveries. The great scientist is really just as much a composer, selecting here and rejecting there, as any musician or painter. Those latest historians, the men who are writing the history of science, point out how often a great scientific discovery has been made before the facts were found which proved it. The great idea came into the discoverer's mind just as the design of a picture or the idea of a building may come into an artist's mind, and then the discoverer went out and picked up the facts until he had built up what he had first imagined. If then science depends on intuition may not intuition give out. May not the sand heaps of sifted knowledge one day refuse to set in great concrete constructions, and may not we continue to accumulate still more and more facts and get out of them no more meaning than monkeys can get out of a sack full of printers' type? Now, however, I believe science foresees this danger and is trying to understand its own methods, trying to be scientific about itself. And it is also hunting back through the past and among backward peoples seeing if it can find other ideas like that

idea about light and disease which John of Gaddesden had. When such original ideas are lit on it is easy enough to put them to proof. The thing to realize is that often people have by a flash of insight or a chance experiment found the connection between two things though they could not say how they were connected. Quinine was known to the South American Indians as the cure for Malaria though they knew nothing about the Malaria parasite in the blood. And lately scientific druggists have for this reason been studying the medicines of unscientific peoples and have already been rewarded with some strange discoveries. Perhaps there is no people at whom we used to laugh so much as the Chinese with their unpleasant and grotesque drugs. But just the other day the reason for using one of them was proved to be quite a good reason. The Chinese doctors used to give powdered toads for heart disease. That seemed a typical piece of Dark-Age medicine. But it now appears it was based on a real observation. For the powdered toad contained a lot of Adrenalin—the ductless gland secretion which is a powerful drug for the heart. So, long before we knew anything about the ductless glands, some Chinese doctor had been sharp enough to see that something in dried toad helped the sick heart.

All these examples show I think that science is steadily becoming more open-minded and so, because it is ready to test out every intuition and idea, science will not dry up as it might, but will grow ever more freely. Einstein said the other day that it is just the odd fact which seems to upset orthodox science that

points the way to really new discoveries—but of course it needs an original mind to be able to use the new facts.

(f) Are our senses still growing?

Science then is teaching us how much we miss and how much science therefore loses because we do not pay attention to all that has been noted. We have let highly valuable observations slip. Yet we *are* becoming aware that we miss a great deal—that when we thought we saw everything we were really largely blind. And that fact, that we are recognizing that the world is full of things we have not yet learnt to notice properly, raises the fascinating question: Could it be possible that our senses are growing? Up to the present we have become aware that there is a lot of the world we never see or hear. We have found out that through our instruments, just as a blind man taps his way about with his stick. In this way we have discovered range after range, octave after octave of radiation of which we had no idea till we had instruments. And these radiations are as real as fire or water because for example the radiation of radium can give you disease and cure it, other much bigger radiations can send your temperature rushing up as though you had a fever and indeed we cannot say what new power these invisible forces may not give us. But can we ever enlarge our senses so as to see or sense directly these forces? There does seem some evidence that we may. Some years ago a French astronomer at Meudon proved that

he could find dark stars which no one else could see but which certain photo plates could record. A few sections back we saw that it looks as though all of us were growing in our sense of colour, because backward peoples do not seem to see all the colours with the distinctness we see them. And now it seems that we ourselves do not realize how much we see. For Dr. Goodeve, here in London, has shown that certainly many of us can see by ultra-violet light—what used to be thought to be an invisible radiation. This light seems to be violet; to see by it you must hold anything you want to see within four inches of your eye, then it seems about a foot away, while if you do move it more than four inches away it suddenly goes out of focus. This power of seeing 'invisible light' seems to disappear with age and to vary very much with different people. We see then how such a sense may have been there for some time but overlooked. There is nothing unnatural in the notion that our senses might grow and some of us be advanced and others behindhand: a colour-blind person, it seems clear, is a person with a very early form of vision. We have, without a doubt, got packed up inside us not merely half-formed capacities but capacities we seldom if ever use. Our senses are far sharper than we usually think and are ready to notice all sorts of unsuspected things if we would only let them pay attention. The trouble is we are mostly too busy to notice things as fully as we could. Look at our eyes again. There is authentic evidence that some people, if they don't distract themselves by thinking how they are doing it, can actually

see and recognize with all its detail the minute reflection of a picture only mirrored in your eyeball. While it has been proved that a hypnotized person—which simply means someone who has managed to attend to one thing and nothing else—can, with their naked eye, describe the object on a microscope slide—an object quite invisible, we think, to our ordinary eye. It looks then, that one of the chief obstacles to our taking in more is our difficulty in giving our whole attention to anything new. We are like animals, so easily distracted. As we say, we only take things in with half an eye. Another difficult thing about tracing the growth of our senses is, as we have seen, that people seem to vary very much on this frontier of 'the growing edge' of awareness. Take the comparatively common case of water divining. That seems an extra sensitiveness which certain people inherit. It also seems a faint, partly grown sense which needs developing. It cannot force itself on the attention. It has to be watched for and tended. Additional senses, or shall we say an extension of our power of taking things in, seem then to depend on two things—on being one of the lucky ones born with a keener sensitiveness, but also on knowing how to cultivate and pay attention to this sense. But how does this carry us much beyond what we have known up to the present? We have evidence to suppose that there is round us a much greater world than we can take in. We know our senses may expand a little beyond the narrow field in which we usually exercise them. But beyond that? When the scientists have, for instance, tried to find out how such a faculty

as telepathy worked, far from finding out, they could not even find that there was any faculty to test. Now, however, we seem at length to be getting ready to find out how such an apprehension works and so in the end how to make it work when we want to and under control. From Leyden and from Gröningen came the first traces of evidence that this faculty might work in the laboratory. Now we have recorded a very large number of experiments over a couple of years undertaken by a psychologist in the psychological laboratory at Duke University in the U.S.A. It certainly looks as though at last some principle might be emerging in the study of this strange faculty. His book *Extra-Sensory Perception* is, I think, the best study ever made of what we may perhaps call the upper fringe of consciousness. Briefly what he did was this: he made a simple series of cards, marked with very distinct patterns, and tried out with a number of University students whether they could guess the right card; first, when he himself looked at it and then when he himself did not look at it but simply put it aside. He has carried out some 90,000 experiments and what they show is this. First, that when a person starts giving these answers for some time they only get a chance number right. Then after a few hundred guesses a queer thing happens. The person begins to guess wrong (to give more wrong answers) than by the law of chance they should. That really is almost as queer as if they guessed more often right than the law of chance allowed. But of course if you don't know about the law of chance such results seem pure

nonsense and you give up. But if you go on then the thing turns round and instead of getting more mistakes than you ought, you get far less. A mysterious faculty is at work. How does it work? Dr. Rhine found it works just as well at a mile's distance as across a room. So it wasn't ordinary extra sensitiveness of eye or ear that helped. Then where was the faculty? With scientific thoroughness Dr. Rhine searched the body over for this gateway. Some people had said the Pineal gland at the top of the head must be the receiving instrument. The cards were put on top of the receiver's head but that made correct detecting no easier or harder. 'Try the solar plexus,' said other people. The cards were pressed against the receiver's stomach. It made no difference. It was suggested that radiations came from the cards themselves. The ink and the paper were both tested and found inert. But there were two very valuable results from all these tests to find out how the faculty worked. One was that if the receiver thought that a new way of working would help or hinder, certainly for a time it did. But it was the belief that mattered not the method. The other important result was that any sense of strain—for example new people brought in to watch the work—threw out the faculty for a while. It was clear then that this faculty was some sort of super-delicate attention, more easily thrown out than the power to add columns of figures is thrown out by people talking to you. That idea put Dr. Rhine on the track of another fruitful experiment. He gave his workers in carefully calculated amounts a harmless drug which

makes you careless. He tested them with the cards and found the point where they lost the power to give right answers beyond chance, and then tested them with simple calculations and found they could still do these all right. He increased the dose and then bad mistakes appeared in their arithmetic also. Then he gave them caffeine to clear their heads. Back came the power to do sums correctly but not till some time later returned the power to detect the cards by this new faculty. That is the most important result discovered in these experiments. For it looks as if the faculty were a dawning one and not a lower one. We have taken for granted that such powers as telepathy if they exist only do so among backward peoples. It is true some such peoples do seem often able to do such things. The explanation I think is this: it looks as though we have made our particular advance because we have got used to attending only to certain things in a certain way. So we have gained much in our power over the outer world and we may have lost as much in being able to control our minds. Again it seems a question of what we attend to. We become aware of what we wish to know. Here is an illustration from astronomy which makes clear what I mean. The other day I was being shown the finest photos of the moon. I asked why if you could see blazing bright every ridge and furrow on the lit crescent, you could not see a glimmer of anything where the rest of the moon lay in shadow or rather in 'Earth-shine'. I was told you could show this shadowed part but only by changing the aperture of the telescope and that would make it

impossible to take photos of the lit part. You could study the sunlit quarter or the shadowed quarters but not both at once. You must choose which you would attend to. The same is true of our eyes themselves. We have two distinct kinds of seeing. You can see by full daylight or you can see by 'night sight'. When you go out of a lit room you are blind for some considerable time. Then if you choose to stay in the dark and have this power of night seeing—some people are without it—the new sense comes into play, but only reaches its full capacity after some twenty minutes. It is quite a different sort of sight because for instance it is always colour-blind. That is an example of a faculty which lies alongside our ordinary faculties and can only come into play if we give it time and opportunity—in short if we choose to attend to it. Now can this extra-sensory faculty, this combined telepathy and clairvoyance be trained? Evidently yes. Does it vary among people very much? Again Dr. Rhine's work answers yes. Some people are naturally better at attending than others, as some people can learn languages or calculate better than others. But the faculty may lie in everyone, a power waiting its development. Perhaps in this direction may lie the next great advance in science. Whether that be so or not I think we have evidence here of a new sense attempting to emerge.

(g) Does human nature change?

That study of extra-sensory perception is the very limit of the science front, its furthest advanced salient.

We come in from that and find ourselves at the part of the front which lies at the base of that salient. We have been looking at some bulletins about how our apprehension grows. Now we must go on and look at the news as to how those bodies of ours which carry our minds have grown and what science has lately found out about that growth. For if our minds are growing our bodies will be changing. Is there any news of that? To put the question crudely, can human nature really change? That question must now be faced. Is there any new evidence on this point? Are there coming to light any signs that human beings are developing? But first, what do we mean when we say human nature never changes? I think we mean that because men are only animals they must change very slowly, because we know from studying the fossil bones of animals that they have always changed with the utmost slowness. The argument then runs like this: You are only an animal. It takes millions of years for an animal to change. All your civilization is only a few thousand years old. So you can't expect to make any real progress. You are only an unchanged animal dressing itself up and playing at being something better. So it is no use your attempting to abolish unrestrained competition, or war or highway robbery or indeed anything which animals or men have ever done. Well let us leave aside the odd question we might ask: Why does an animal dress itself up and imagine it is a reasonable being who must try and obey moral laws? Let us just see very briefly what is the evidence as to whether we do change and if so

how fast? First of all let us start with ourselves—a more or less average lot of people living in the North of Europe. Are we changing? Yes, we are. Take a quite small but definite change: nine out of ten of our Anglo-Saxon ancestors, when you dig them out of their graves, have front teeth that meet edge on. Their lower jaws are just as long as their uppers. Nine out of ten of our jaws don't bite edge on, the upper jaw overlaps the lower jaw. A small change, you will say, in a long time, but in terms of evolution that is a big change in a very short time. But not enough to make any difference? Are we sure? What does this change mean? It means a change in the whole facial bones and that may mean a change in that master of the ductless glands, the Pituitary gland; for it is tucked away on one of the puckers of bone just in behind the root of our noses. We can't be sure whether it is the pituitary which is changing our faces—or something which we are doing with our faces—may be softer food, making us use and need our jaws less—which is changing the room in which this gland can grow. But we now do know that this gland has an almost unbelievable control over our bones and can change us bodily out of all recognition. But that is not all. The pituitary can change our characters. As we saw in the section on glands, if one side of it grows at the expense of the other we can become active, full of curiosity and curiously hard. If the other side develops, we can become excessively gentle and sensitive. And further it has been lately shown that this gland makes no less than eight different hormones or self-brewed

drugs and each of these can effect our body or mind in three different ways, so you have no less than 6500 activities possible to this one gland. So it is clear that this gland can really change human nature. Sir Arthur Keith, some time ago, suggested that the difference between the Chinese and ourselves—their finer taste in many matters of art and what we call their callousness, their indifference in matters of human suffering, may be due to racial differences in this gland. So a small change in the face may mean big things for civilization. Is there any further evidence of what direction our change may be taking? To-day that is a very practical question. For the Germans are all now being taught to think that they are nearly all of them Nordics and very soon all will be and that there is nothing like a Nordic. First what is meant by Nordic and secondly is this change going on? There are, roughly speaking, three types in Europe, the southern lot of people called Mediterranean, a central lot called Alpine and a northern lot called Nordic. We are mostly mongrels bred from various mixtures of these three. The Nordic is pale-eyed, haired and skinned. There is no scientific evidence at all that this type made civilization. Quite the contrary: some of the latest evidence is that the people called the White Huns, the deadly savages most dreaded by the ancient Chinese civilization, were Nordics. Further it has been found that this type is a rare type. Skin, hair, eyes, all point to one conclusion. For it is rare for human beings to have these eyes with practically no colour and this transparent skin. It looks then as if the Nordics

who are now so much in the limelight, must have grown, as they have, through keeping away in some shady corner of the world shut off by themselves. And it looks also as if, now the world cannot be locked up again into small, sealed quarters, the Nordic, do what you will, will disappear. Certainly here in England brunettes are pushing out blondes. For some reason the blond cannot hold his own. It may be because he cannot stand the city. If that is the reason, well then the Nordic's future in civilization on this count alone, doesn't seem very secure. Certain it is that in all our cities the brown is gaining against the pale. But whether the Nordic advocates will face that or not, it is certain that they will go on saying they are superior to all the Browns, theirs is 'the Great Race', whether it 'passes' or dominates, and all other races are nearer the beast. What has research to say to that? Let us avoid getting muddled by discussing who and what is a Jew. Let us be bold and go clean outside Europe and Asia and take the Nordic's real aversion, the Negro. Is the Negro nearer the ape than we? There is no evidence of that, not even the features that we choose to think least advanced. Take the thick lips—well, none of the apes have them—an ape has as thin-lipped a mouth as any superior person. And as we go carefully over the negro we find that, instead of being nearer the ape than we and a more primitive type, it looks as though he were after all a more specialized, more advanced type than we. And if we go back further to the cave man himself, the extinct Neanderthal man, even he seems in some ways more advanced than we.

His teeth are more of a vegetarian's than ours. Yet he was no ape. He had a large brain and he used it. We now know from Dr. Leakey's finds in Africa that he made inventions in tool-making which our ancestors were glad to learn from his work. Indeed he may have died out because he advanced in one direction too far and so was too highly specialized. What is clear is that if he had survived and driven us into the trees he would have regarded us, with our flimsy rickety bodies and little sharp teeth, as a kind of carnivorous spider monkey, a disgusting object. That's of course not to say that negroes and cave men are abler types than we. The words I used were more specialized, more advanced. For in those words, it seems, there lies a completely new outlook on our past and on how we may change. It looks as though we'd assumed far too easily what evolution was, and now have to make a truer picture from the facts. Here is quite a definite example of what I mean. It used to be thought that evolution was making the bones of our skull simpler and simpler by blending them into as few as possible. So, an amphibian had so many separate bones, a reptile had some less, a mammal still fewer and mere man at the top ought to have fewest. But that isn't so. It isn't true even of the apes. The prize for fewest bones in the head and so, on this important count, being the most advanced of all living creatures, is held neither by man, ape or monkey but by a queer little pig, even off the main pig line, away in America, the peccary. That shows how careful one has to be in following any rigid clue. It may land one in the most absurd

conclusions. Of course the new clue to evolution is much harder to hold and follow. For two reasons chiefly: first, because it is now believed that evolution is not by becoming specialized but by avoiding becoming specialized. That makes it harder for the searcher to know what to look for. And, secondly, as what he is looking for will anyhow be rather small and fragile, there is much less chance of his finding it. Huge Saurians leave vast skeletons and even their armoured skin will fossilize; small, slender, thin-skinned creatures leave little trace. Yet it is these we want to know about; for when all the huge saurians died out, evolution was carried on by some such wisp of a creature. Progress went with the creature which never set hard. What light does this throw on our race problems to-day? Are we changing, are we progressing? The evidence shows perhaps that we are, though in a paradoxical way, perhaps the only way. We are changing by preventing ourselves from becoming set. Let us turn again to Dr. Leakey's revolutionary finds in Africa. We have seen he believes he has discovered fossil skulls a million years old, so similar to our own as to be almost indistinguishable. At that time we know there were several other quite different species of men. These more specialized types died out. Man, our man, alone kept his balance, refused to become peculiar and so went on. Take a new example from our friend the horse. Lately there have been found even earlier horses than had been known—tiny creatures like small dogs, and what is more with five fingers, a hand, not for millions of years to be fused into

a hoof. But that hand was never used and so we ride the horse. Can we link up this evidence with that I was giving at the beginning of this section about possible rapid changes in ourselves? This way, I think. The changes we are watching in ourselves are reducing changes. All other kinds of animals, when they have been given the chance we now have of being at the top of the tree, have added to their bulk, and many have added new armour and weapons to their bodies. We haven't. We have become tall but we've kept our suppleness. It looks even as if we had added to our adaptability. And it may be that, with our new and growing knowledge of glands, we may be gaining a new power to preserve and add to that essential suppleness. For that pituitary gland, when it is diseased, we have seen is the gland which makes our bones grow much beyond their proper size, and those Dinosaurs which grew fantastic frills of bone like Elizabethan collars round their necks, may have had diseased pituitaries. We may, then, be about to add to our energies at the expense of our bulk, for living bodies like the heavenly bodies can turn mass into energy. There is no reason to suppose that the clock of evolution has always run at the same pace in every epoch. And now in this our own time we may be able, with the new powers we are getting over growth, to make that clock go as fast as we like. Because we have kept flexible and unspecialized, therefore we can change, perhaps as fast as we like. And that gives the Nordic some hope too. His wonderful past—that's mainly moonshine. But he can claim one thing. He

is one of the most, perhaps *the* most, negative, unspecialized types of man. So he may have the future even if to get there he will have to mix with some of the more sophisticated stocks. But it must be repeated, that future is not a cave-man, blond beast, 100 per cent male future. It is, on the contrary, the future that belongs to the least set, the most supple, the youngest. Perhaps it is too much for us to swallow that the meek shall inherit the earth, but at least it looks as though the fierce and brutal have no better chance. The future which we and the Nordic can look forward to is not that of the all-conquering hero but of the enquiring, all-curious child.

(h) How we may accelerate that change

The enquiring, all-curious child? If we are to become like children that raises the question of education. If the child has capacities it never realizes, can that be due to our way of training it? Certainly some scientific works seems to suggest that to-day. And certainly if we are to change fast enough, if we are to open up our capacities speedily enough to keep our knowledge of the outer world growing, we must apply all science tells us to education. Our children must be better apprehenders, more interested, more aware, less frightened of facts and more fertile in using them than we have been. Child psychology is thus a very vital part of the science front, for on advances here depend all the advances on the other sectors of that line. There is a good deal of fresh news to hand

on this vital subject. Nothing matters so much because as we are educated so largely we act, and as we are trained to notice and attend so our science grows.

The first thing that is clear is that we are finding that we must go back further and further if we are to find the age when education takes most effect. For, the younger the child the more deeply it can be impressed, and those impressions given in those very tender and plastic years may set afterwards like steel. In fact many teachers now think that there is evidence to show that the child can be best educated, or most profoundly modified, when it seems least conscious—when it is still in its first year. And some child psychologists have talked of conditioning children, that is impressing certain patterns and ways of behaviour on their unconscious minds so that they would never really have to learn anything, and would never be able to disobey what they had been taught, what had been built into their characters. They would go through life as punctually, as dexterously and as unconsciously as a good clock goes through the twenty-four hours.

Now what light does fresh research news throw on these hopes—or fears? A couple of years ago we learnt that in America child psychologists had determined to study identical twins—those twins which are always of the same sex and often almost indistinguishable because they have grown from the same germ. It was decided to give one member of these pairs careful treatment and to leave the other member alone, so as to discover exactly how much education could really affect a child and where, if anywhere, heredity was

too strong for education. Now reports are beginning to come to hand of some of the most interesting of these experiments and they are throwing a good deal of light on the mystery of our minds and how they do actually take in and how they form. The most remarkable case reported so far is that of two twin boys, one of whom was let start his education when he was only twenty days old, a record 'get away' as Americans say, while his twin was let stand by or rather lie by comfortably in his cot, acting, as scientists say, as control. This sleeping partner was simply waited on as all babies are waited on. Otherwise his calm was undisturbed. But the other was watched and on every occasion when he stirred, instead of being made easy again, he was encouraged to stir a little further. He reached for things and they were held out for him. He turned over and he was let roll and scramble if he liked. He stretched and turned over on his face and at once he was helped just to see whether he would like to try and crawl. Every couple of hours through the day there was someone ready to make every one of his little moves go a little further than it would have gone had there been no one by to help. If his feet and toes wriggled, a warm board was put gently against them to see whether he would like to try and make steps with his foot. Of course the first thing was to see about his instincts, to settle how far he had inherited certain completely untaught ways of behaving. These instincts turned up all right—just that queer couple which it seems must be survivals from some kind of ape-like past—the power of hanging on by your hands

and so supporting the whole weight of your fat round baby body, and that other queer one, that sudden sweeping grasp made by both arms if the baby feels anything give under him and so believes that he may be going to be let down.

These two instincts turned up in both the twins and it was proved that education could do nothing to hurry up their departure. The played-with baby had to go through his stage of instinct just the same as the one who was left unstimulated. And both babies at the same time took to sitting up. Nothing that could be done to encourage the tested baby could make him sit up before the left-alone baby also decided to sit up and take notice.

But after that the curtain went up for the constantly encouraged baby. He began to swim when he was not yet eight months old and at nine months he was a real swimmer. Before he was a full year old, as soon as he began to walk, midget roller-skates were got for him. He liked these attachments to his feet, he liked sliding about on them and in three months he was a finished skater. He was encouraged to climb, and rapidly he became a really alarming climber—at least to those people who had decided what a baby can and cannot do and had never let it try for itself. Then to show that he was really growing up, at his first birthday he was offered a ladder. In two days he had learnt how to get to the top of it and after a dozen of what one may call encouraged trials, he was coming down, also on his own. At fifteen months old he was coming down from a perch six feet high. His

twin, on the other hand, never made such efforts. If he found himself placed anywhere where movement and negotiation was required, he just looked about, smiled and waved his arms to show that he wanted and expected help. At sixteen months the go-ahead partner twin had become a practised diver. But when he was given a tricycle, that proved too much for him, he was completely nonplussed as to how to make it go. That I think is peculiarly interesting. Evidently everything that has to do with balance he did perfectly, simply because all babies have the knack and, if let show it, they will. But something that has to be thought out, like the pedalling and steering of a tricycle, that still stumped him. Then came the turn for the sleeping partner twin also to be encouraged in the same way. As he came to it when he was older, the tricycle didn't put him out, but skating he found just as hard as his brother had found it months earlier. And he was altogether slower in a number of ways. For it was found he was more cautious, less inclined to follow a lead, more prone to think that it would be wiser not. In fact he was already showing signs of a shrinking and a timidity which made his advance slower even at his considerably greater age. Somehow he was less able to respond to encouragement just to try.

Now what do these important experiments show? In the first place they indicate that in very young children's lives there is an area, a belt when the simple instincts they inherit are present and nothing can hurry up the disappearance of these. That suggests that the child may be 'screened', as it were, during that brief

period from catching any chance impression. But that screen is soon removed. Then the child is amazingly responsive. What however this child responded to was not suggestions or conditioning or any of those automatic methods with which some psychologists have said a child could and should be turned into a robot. What he responded to was encouragement, interest. He got constant encouragement to do whatever he made an effort to do. Far from being told 'Oh! Baby be good!' 'Be still,' 'Don't fidget,' 'Don't do that,' every effort of his was prompted still further. So he began to look at strange things as problems which should be solved and could be solved, and that very valuable initiative he seems to have kept and it is just that which his brother seems to find it hard to gain—though, remember, the brother himself was never discouraged, only not definitely encouraged until later. Another very important discovery which should help us in education was that the powers to tackle different kinds of problems which need different sorts of skills, open out at succeeding ages. There evidently is, in a very queer sense, a time for everything and a tide of opportunity which one should catch. At one age you learn most easily to skate, climb and swim, and so on evidently up to drawing and writing. And where the real skill of the teacher comes in is in the patient interested watching of the child until the moment when it stirs in the direction of a new skill and the teacher follows up that stirring. You can be too hasty and you can be too slow in catching the child's tide of development. Some skills come unexpectedly

soon but none can be forced. The born teacher must always be on the watch, never in a hurry, never late. Even if the foundations have gone crooked, though we can't start again, we can build the upper stories so as to compensate. I'm glad these experiments give no encouragement to those moods in which many of us are inclined to put the whole blame on things done to us in our extreme youth for our ineptitude in making as much as we might of our grown up years. It looks as if we always remain rather more flexible than we've assumed. We may be damaged but we can make compensatory repairs just as the architects of the leaning tower of Pisa managed to make their tower stand up though the foundations were so bad that they gave. Even the child which has not had the great advantage of this skilled encouragement can catch up, though it may have to make more of an effort to do so. And another side of the same truth is that even with the child which made such a wonderful and easy progress under this encouragement, it was found it could lose its skill and forget its powers if it did not keep them up. Indeed the whole picture which these twin-experiments give as to how we may learn and have to learn are, I think, themselves uncommonly encouraging. Some people think that new ways of education will make the young soft. On the contrary, we see this newest, earliest and very successful teaching continually roused the child to make efforts and adventures. It was the sleeping partner twin, the one undergoing normal bringing up, who used to smile and hold out his arms when he wanted to be moved. The other

knew he must try and enjoyed trying. Here was no weakening of the will. It is true he did learn without tears or punishment, but not without what must have been for him an exciting sense of risk. He learnt, he took risks because his attendant was always ready to catch the little spark of interest, of striving, and to blow on it and to give him the energy and confidence to do what we have thought till now to be quite beyond baby powers. That, then, seems the direction in which these new original and important experiments in very practical education seem to point. Here is a middle way between spoilt slackness and harsh driving. Every learning creature must make an effort. The job of the teacher is not to save it effort and not to impose effort on it, but to inspire it to make the effort by which alone it can grow. How is that to be done? I think these experiments prove that the answer lies in that word interest. That points the path between the horns of the dilemma which seem to face so many thinkers on education to-day; the choice which seems to be only between an indulgence which makes people incapable of effort and a dragooning which makes them incapable of enterprise. Rouse interest and the creature which is being taught, whether young or old, will surpass itself. Even experiments in muscular fatigue have shown that such a physical thing as that, comes on much more slowly if the person tested is doing work which interests and not work which bores. And these experiments with children have come not a moment too soon, not merely to help us with the young but to help us with the grown up,

with ourselves. The problem we are faced with to-day is the problem of leisure. Can people be interested and creative on their own? If we don't find things for them to do, can they find them for themselves? That question is one of the most serious we have to face. Our education has been so mistaken in that it hasn't drawn on people's power of being interested. So, as soon as no work is found for them, most can find nothing to do. So to-day in Europe hundreds of thousands of people are playing at soldiers because they like to be drilled. They are at a loose end by themselves. And if they don't bring on a war that way, well, the leisure will go on growing. Science will see to that. And all the time, there is round us this amazing world to be understood and as never before in the history of man we have through science the means of understanding it. That then is to what I look forward most from these experiments in rousing interest in children from the very start. I think we can look forward to a people so alive, so interested, that instead of time hanging on their hands they will grudge every moment they have to spend on routine jobs and find fifty years of leisure all too short to look over half the wonders that lie to their hands—a world in which the word 'bored' won't be understood.

(i) Our new alliances with animals and how we may advance them

Science thus shows we are not more bound but more flexible than we assumed. Yet science continu-

ally reminds us of the other fact for fear our vanity would make us forget it—we are kin with all other life, quite close kin with the animals. That thought, however, with our new knowledge, instead of making us despair about ourselves, should make us extend this new hopefulness, this new vision of living possibilities, not merely to all humanity but to our fellow creatures the beasts. If animals have far more wonderful possibilities than we have thought, then two things are clear. First they are going to be of much more use to us than we have thought, and second they are not only going to teach us more but we are going to become much more companionable with each other. What is the science news here about animal activities and animal intelligence? We know that the great discovery of evolution was that all life is one, but we often think that that discovery was spoilt by the other discovery that all life is blind struggle in which everyone's hand is and must be against his fellow. Here then is some of the latest news about how life actually carries on. It is important, because as we think life as a whole behaves so we shall feel it is natural we should behave to each other. First then about some of our animal allies. Lately we have discovered still more of these invaluable supporters. The most remarkable, I think, of these latest recruits is the toad—a creature for which we have always had a strong distaste, even maligning it by saying it is venomous. The toad instead of distributing venom has turned up as a rescuer of sweetness, for the largest of the toads has lately saved the sugar crop of Porto Rico from destruction. It was

found that a grub was destroying the plantations. Man tried in vain to pick away these pests by hand. Then an entomologist suggested trying the largest of the toads. Though the toad can hardly be called a sleuth it stuck to its job so thoroughly that the grub became a rarity and the sugar industry was saved. The geese saved Rome, but only indirectly. The Romans, after the warning cackle had to save themselves. But in Porto Rico the toad has done the work itself. But after all this is only a case of man setting a devourer to catch a devourer and himself being cunning enough to benefit by a reptile's voracity. Man is simply exploiting the struggle to survive. And much the same has been said about an animal which does not guard our sweets but actually manufactures them. It has been pointed out often that we simply exploit that blind mechanic the bee. It is no ally but only a dupe of ours. There can never be any real relation between bee and man for the individual bee isn't an individual. It is only an interchangeable standardized part of the machinery of that honey distillery we call a hive. Still even here we have probably overdrawn this picture of the bee as a creature without personal mood, temperament or character. At least that is how this piece of news strikes me. It seems to suggest that even bees may be a little more like us than we have thought. Expert bee students have now shown that bees have a maximum stinging age, a time when they will go for you much more probably than at any other. And that time is when the bee reaches the end of its domestic duties—that appalling, incessant rush

of work in the crowded, close hive—and is just about to go off on its next stage of duties, the out-of-door collecting of nectar from the flowers—a job which however strenuous, must be less nerve-racking than work in the hive. That does look as though the bee, after all, is more human than we have thought: liable to that human weakness of overstrained nerves and irritability. Next time one is stung, that thought may check one's anger. At least we share a weakness. But do we share with animals anything else? Surely there is no co-operative spirit among animals or any real kinship among beasts. Soft a moment, listen to the latest news about the howler monkeys. A careful study of these vociferous little fellows has lately been made and a remarkable social state has been discovered among them. It looks as though these groups of howlers live without a dictator, at peace with each other, not quarrelling over food or room. That however may only be immediate self-interest. But, further, they are found to show real kindliness, a sense of kinship which self-interest does not dictate, for not only do they co-operate in defence, they actually take care of the infirm and even of the old. That looks as though the law of the jungle after all need not be the bloodthirsty thing we assumed. Of course, however surprising this is, this 'humaneness' is only within a species. Outside the species there is no general law. We must, however, remember that most animals do not attack each other unless provoked. The law of life seems to be much more: You mind your business and I'll mind mine, than: Your life or my life, and, as has

been reported by competent naturalists from time to time, there are actual cases of animals of one species going to the rescue of animals of another species. But such acts are certainly very uncommon. Still we are learning that at least all social animals have a certain fund of kindliness, a certain ability to work in with someone else which often can be developed far beyond the stage to which its own social needs have drawn it out. We have seen the effort we are now making to see the world through animals' eyes; now for some news of how we are, as it were, helping animals to see through our eyes so that we may understand more fully how they understand. It certainly begins to look as though many animals may be much more like us, capable of beginning to think as we think, than we have thought possible. We must begin of course with the chimpanzee, for he has a brain sufficiently close to ours to make it possible to experiment very thoroughly with him. Here is some of the latest news of these very important studies. Chimpanzees have been taught to use money. That was done by showing them how to pick up various coloured discs, slip them into an automatic machine and so get out the particular food they wanted. It was hard for them to learn this, but once the teacher had managed to show a couple of the brightest in his class how to do the trick, then—and surely this is particularly interesting to all who teach —the bright couple were able to teach the rest far faster than could the human teacher. Teaching is much more than talking, and 'showing how' means not merely oneself understanding the problem but why

the pupil doesn't understand. Then, to make it quite certain that they were grasping what they were up to, two machines were brought in. The discs which worked in one wouldn't work in the other. You had to pick your disc, find the right machine, put your penny in the slot and then only did you get what you wanted. The next step was to see whether the apes could grasp what money stood for. Could they understand enough, just to work for money only? They did. They had to raise a heavy weight to get their pay disc with which they then could get out of the automatic the food they wanted. They learnt this connection and would exert themselves to get the money which only afterwards would earn them the food. Still that might only be an unconscious connection: the disc and the food, both concrete things, making a single picture in the ape's mind. It would be far better evidence of intelligence if the chimpanzee could use his disc to convey ideas. That further step was taken. It was, of course, hard to take because what abstract things could compare in the mind of a chimpanzee with the pleasure of food? There are however two things which can count for nearly as much with chimpanzees as with us. One is the wish for company, to start playing, and the other is to stop working. The chimpanzees were shown that if they wanted to stop doing well-paid puzzles and just fool about with their teacher they had only to put the right coloured disc in the right place and school was over and you could let yourself go. On the other hand, if they felt that after school they would rather just go back to their own

rooms and have a nap or groom themselves, well, they had only to put another coloured disc in another place, the door was politely opened for them and off they went to have a rest. They learnt both these ways of signalling, perfectly. They couldn't learn to speak, because chimpanzees, though they have sounds of their own, have no tendency to imitate other sounds, as have parrots—though perhaps we shall find those social, kindly howler monkeys have—but they could undoubtedly learn to use signs to express their wishes. So these experiments prove, I think, that apes are much more teachable, much more able to hold on to ideas than we've thought. The real obstacle in the way of their expressing themselves seems to be a mistake we made about them at the very beginning. We say 'As curious as an ape'. The description is unfortunately a libel. If they were curious just to imitate things they would learn far quicker. The ape is severely practical. He won't do anything unless he sees the reason for it. It was noticed not merely that they never try to imitate sounds because they can't see the use of all this chatter we humans make. They never fiddled about with the food machines just for curiosity, just for the fun of it. So again we see that 'childish curiosity', may after all be one of the best guides to understanding. The ape stops short because he is sure that if he can't see the use of doing a thing there can be no possible reason for taking any further interest.

That brings us to news about encouraging other animals to explore the world around them and to enlarge their minds. There is one animal, which though

far behind the chimpanzee in brain power, yet has a link with us that the chimpanzee lacks—that is the dog. The dog's mind is linked to ours because he wants to understand not merely to get food or fun but simply to please us, to be approved. That mutual sympathy gives us an immense help in trying to understand each other. But certainly some experiments done lately with dogs have startled me that mutual understanding could go so far. At the Institute of Environmental Research in Hamburg, Dr. Sarris has shown that dogs can grasp the sense of whole sentences and that the tone or pace at which the sentence is said does not throw them out. They really do recognize the meaning of sounds, and not merely, as we have thought, the emotion expressed with the sound. But can they really associate the sounds with anything but the simplest actions and things? Of course it is remarkable that they can run to the proper place and fetch the required thing if told to do so only in a colourless voice and with their teacher not looking at them. But what if he asks them to do something and that something is not at all clear? What then will they do? Surely they can only work almost automatically and any uncertainty would throw them out completely? On the contrary. They do seem able actually to size up a situation and make a satisfactory compromise. One of the dogs was called into the room and his teacher told him, without looking at him, to get on the chair. But when the poor dog looked about him the room was bare of a chair. To be sure that he was not mistaken the dog went carefully round the room. Then, satis-

fied that he must make the best of a bad job, and as he could not carry out the order to the letter he must understand its general meaning and carry it out in its general sense, he found a stool on its side and mounted on this. A bench, a chair disguised in paper, one stool on the top of another, all these he interpreted quite rightly as being the nearest he could find to what his master meant when he said, 'Get up on the chair'. And so he sat himself on these objects and certainly deserved the approval he desired and was given. He had shown himself a dog of good sense and he heightened man's opinion of his race. These details of research do then, I think, all tend to show that quite a number of animals scattered up and down the tree of life are ready to co-operate with us, ready to learn from us, and to develop what I think it is ridiculous not to call a real, if small, mind, if we draw them out. Perhaps in the future, when we have learnt not to have quite such a low opinion of animals, they will respond still further to our encouragement, and when we have learnt to tame and educate the ape and the wolf outside us we may hope to tackle with greater faith the ape and the wolf in ourselves?

Part III

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The Front of History

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The time has come now to look back along the way we have come, review our diary and see what it points to. We began with what science has lately found out about the whole outer world that presses on us. We started with a standard piece and saw what advanced physics—the sharpest instrument we have to pick that piece to pieces—told us about what it really was. We saw the piece was a violent play of forces. But we know the moment we come out of the laboratory that there is the material world, 'dead matter' as solid and stolid, as tough and passive as though all this talk of fabulous unceasing energy being the real stuff of the universe were the merest moonshine. So then we went to the other extreme and tried to see what the universe really looks like, not down the electron microscope—which magnifying ten thousand million times actually shows you the starry atom—but through the super telescope. There we saw something really very much like the same pattern—central globes and round them mazes of other smaller circling globes —and the same action—the whole cosmos driving

like a whirlwind blizzard. But there again the moment we took our eye away from the lens we saw the sun rising and setting upon a firm, unmoving earth. We turned to the earth to find it was pulsing and vibrating to the very core and above it rose and fell the diaphanous folds of its garment, the atmosphere. Yet the moment we left our instruments all we knew of all this was an occasional report of an earthquake and an even rarer glimpse of some northern lights. Common sense then says all this spying and probing really does not matter. Science has only proved that we can get on quite well if we take the common sense view—that the universe is what we have always taken it to be, something that minds its business and leave us to mind ours.

There is a great deal of truth in that, though of course the critic can pull to pieces the way it is put. After all, it is only lately that men have thought the universe to be indifferent to them and they safely able to be indifferent to it. Common sense is the science of yesterday, yesterday's daring assumptions become today's dogmas, because, in that tiny space of time, no sudden irruption has shot in its crashing refutation. Still, in one great particular, common sense has scientific support: Whether the universe is 'dead', is 'blind' or indifferent (these are all inductions), it *is* leaving us alone, that is the fact. All the physical sciences show that. The universe, 'dead nature', is not pressing on us. We see that it is standing back. We see we have been left with a fair field and no favour, with a non-interventionist opportunity which no other generation

imagined the children of men would ever be granted —either by luck or design.

The many generations which looked for design thought the universe overshadowed their petty lives, growled in thunder and tempest when they offended it and smiled in plenty when they were subservient. The few generations which thought they had established accident as the explanation of the same universe nevertheless also thought that man was none the less petty, none the less overshadowed—his time passed a swift shadow in that shadow, he was driven away more easily than he drove a grasshopper. The sun would cool, his world freeze. He had peeped out for one ineffective moment into the warmth and movement of creature life between the black zero in which all had been frozen and the same black zero in which all was to be sealed up again. Our generation is the first to realize that this radio-active sun (as we have discovered it to be) may give us life here for as many years ahead as there lie years behind. Mild and genial ages can be ahead of us for scores of millions of years. The universe is giving us enough rope to measure and order all about us—and to hang ourselves. That, it is clear, is the main life-size common sense conclusion of this amazing advance in the tested common knowledge we call science. If we smash up before we have completely transformed our place in the world and our vision of the universe, before we have used this opportunity of say 100 million years that lie ahead of us, the opportunity granted us of this securely stable situation, then it is to be a case not of murder but of suicide

—not of the universe overlaying us but of our flinging ourselves over the edge.

That then is the conclusion, the main practical conclusion of all physics, and that then is why the sciences of life have been given a big number of entries in this diary of advance. When we reached that part of the line—the life part of the line—there also we saw ground for a far brighter outlook on the future than earlier science used to give. If the universe is far more forbearing than we thought, life is far less stubborn and intractable. We are not 'up against' the gigantic outer universe, what we call the overwhelming mass of everything, the irresistible weight of dead stuff. It is treating us with the tolerance or indifference with which a mastiff treats a toy terrier puppy. What we are up against is that infinitely smaller division, living stuff, living creatures, all more or less kin to ourselves. That division of the outer world, it used to be thought, made up in malice for what it lacked in blind strength. The mutual struggle of all life to survive made the world even more dangerous for us than the insensate catastrophes of the cosmic machine. That picture is also much changed. There is no war in organic nature any more than in inorganic nature. The term is not scientific. The term is prescientific, anthropomorphic. Except among a few rare species such as ants and termites and, again very much more rarely, when a bee swarm goes off its head and instead of setting up at the ancestral business of honey-making takes to looting other hives—war doesn't exist in nature. Animals mind their business almost as much as the universe

minds its, and interfere with each other as a general rule almost as little as the vaster outer universe interferes with us. There are the exceptions of parasitism—though even this is quite often a queer co-operative partnership,[1] and there is the food preying of the carnivores. But war, as the deliberate organization of one large group to subject another and take its possessions, that is not natural but unnatural. When a species or a genus succeeds to the place of another species it is not through direct-action but through indirect action—not through mass attack but through better capacity to get food or rear families. Breeds are bred out and not stamped out in nature.

So not only does the inorganic universe stand aside, life, too, is, we now see, strangely non-interventionist. Man therefore cannot carry over sanctions for certain behaviour, of which he might otherwise be ashamed, from any of the sciences outside man. It is a romantic not a scientific description of himself—'homo homini lupus'.

(a) 'The proper study of mankind'—anthropology

We have therefore to turn to the sciences of man if we would be scientific about man and not borrow from those other earlier sciences which we have re-

[1] When we have deducted symbiosis—two creatures sharing a life and, Janus-like, each facing up to a different problem and pooling the profits, and commensalism—two creatures sharing common board, what is left of true parasitism is small.

viewed and seen do not apply to, but rather clear the way for, this final investigation. There remains only this latest of sciences, the science of man as a being in his own right, as a being with his own unique natural history and with his own wonderful social pattern. Can this last science help clear up our human problems, as the physical sciences helped clear up and order our picture of the outer universe, and the biological sciences are helping to clear and order our map of the way of life? Whether these latest can help or no, it is evident that these are the latest and furthest of the sciences, and in this review we must see what news has lately come to hand of advances in knowledge here. And certainly just at present we do need, perhaps more than anything else, that science should make an effort to help history. If Hitler has been able to tell the Germans where they are to go, it seems very largely because he first told them so forcibly where they came from. That appeal to history seems an essential starter for most dictators. But few of us ever thought history was going to make all this difference. Of course it's not what historians call history. In fact they are all astounded at these descriptions which Hitler gives of the Germans' past. But all the historians, with all their detailed facts don't seem able to check this queer and dangerous folk-tale telling. Why? I believe the reason is that the historians haven't been able to make history into a science. Why are there all these bitter confusions all appealing to history, going on now? These Nordic notions? These Aryan clauses? The French making a friendly critic ask: Is God a Frenchman? The Turks

teaching in their history books that all civilization began with a Turk! The answer to all this is that history isn't yet a science. We must then try and see how science may help to make history scientific. You see how important it is that science should advance here? History matters. For as men believe the past to have been so they believe they have particular rights, precedents and authority to shape the future. Why then isn't history turned into a science without further delay? Because there isn't enough of it. History is often called a tapestry woven by Fate—a good simile. But if you only had a snippet six inches long how could you say what the picture was meant to be? That's the main trouble with history—we haven't enough of it. With the little scraps we have we can't be sure what the pattern is, and if we can't show that pattern quite clearly, well, then, all the dictators make up stories to prove that they and their peoples are as Americans put it, 'God's own people', and so everyone else must give way to them. Our documents don't go back nearly far enough. They only get us back some 150 generations and by then they are absurdly sketchy and we can't even be sure of the very dates themselves. Besides, historical writers, even when they profess to be writing history and not private letters, even then they only tell us what they want us to know. The history of the Roman Empire was carefully kept and much has lasted. But till science got to work with the spade we never knew that York, as important a city then as now, had been sacked when it was still supposed to be in the Roman Empire: we never knew why the

Roman wall across the waist of Scotland, the Antonine Wall, was surrendered. The Irish had cut in behind it by landing on the coast to the south. We have only just learnt, through digging, that large parts of the outlying Roman Empire had long collapsed before Rome dared own it had lost anything. And the so-called Dark Ages that followed, when our race and customs were growing up here, they had been dark because undocumented. Now the scientific spade is letting in light. Take for instance Offa's Dyke, for most of us only a dim name for a dim ridge of mounds on the Welsh border. Now the spade like a master detective can certainly tell us more about it than Offa himself would have let his historian say. Laying bare its tracks we find it was no grand assertion of Saxon expulsion against the beaten British. It is no great Wall of China but the result of a frontier agreement and demarcation. Sacred places are respected in a way which must have scandalized strategy, and even Welsh fishing rights down on the Wye are given courteous room. Still, such detailed facts, though interesting to us on the spot, do not help us to understand history as a whole, to make a science of history. But it's at that task where scientific spade-work comes most into play —where even names, sagas and folk-tales stop and we are faced with the night of absolute ignorance. The spade isn't merely correcting and amplifying history. It and it alone can write all those first chapters, those chapters without which we can never have enough history to see the pattern as a whole and so to make a science. Look, for example, at the work which has

been done since the war in Mesopotamia. Not only have scientific diggers, such as Mr. Woolley, made real, by finding their houses and jewellery, the names of numbers of kings who lived round about the Flood, yes and found what is pretty certainly the silt of the deluge itself—but he has found the work of kings who till then had been even unnamed. Just now we have learnt that after twelve years digging at the bottom of a fifty-foot pit at Ur of the Chaldees Mr. Woolley has at last reached the end of that particular chapter of this story which has never been read before. He has traced to its origin a city which had already forgotten its beginnings when Abraham lived there,[1] and yet the spade shows that this city itself when it began was not at the beginning of civilization. For that we shall have to search elsewhere. The spade has laid bare the site where and when Ur, the fabulously ancient, was simply a town of squatter colonists as raw as any new Australian mining village to-day.

(b) The new detective hunt in history

And, as in all scientific work, the method of finding is really as wonderful as the find itself. Detective stories interest all of us not because the criminal gets caught but because he is caught so neatly, because of the skill which goes to his catching. Well, history revived by science (for that's what archæology is) is detective work far finer than any Sherlock Holmes ever used.

[1] If indeed this Ur itself is not a more ancient city than the more northern Ur from which possibly Abraham trekked.

As most of us have learnt, the super-sleuth as a catcher of criminals is more in the magazine and our fancy than in Scotland Yard. But detective science in reconstructing the vanished past has brought detection to such a pitch that with bits of pottery which look to the casual onlooker no more than fragments of a well-broken jam-jar the trained archæologist can now trace the movements of tribes and peoples right across Europe; in fact the movements of our ancestors before they were Englishmen. Behind that again we get the age when men were giving up bronze and learning to forge the new terrible iron-weapons—a discovery in destruction which upset civilization even more than did the discovery of explosives. That's a time we need to know more about. It was one of the great turning points of history. But you have to be a detective to find out exactly where it was taking place and how this deadly invention spread. For iron is like an explosive, deadly but soon dispersed. Bronze remains. On some sites, then, you have to test the site chemically to find whether iron weapons had been buried there or not. All trace of them has gone and to the ordinary searcher it seems obvious in such a place that the people of that date could not yet have had iron. Still further back go these detectives, searching out our past and with camel's-hair brushes and scalpels they are laying bare the remains of stone-age men who lived and died and vanished so long ago that no civilized people, however ancient, had ever heard of them. There has been at the British Museum a wonderful show illustrating finds of these stone-age peoples made

in the caves of Mount Carmel in Palestine. Though the bodies had been buried for many thousand years in stony earth—earth which had set in those millenia until it is hard rock—yet so skilfully were they recovered that you can see their heads still wreathed with the shell-garlands with which they were crowned on the day they died. What was the world like then, we wonder, and at once this detective science starts reconstructing not merely the people—alas the number of cleft human bones suggests they were cannibals—but we can also reconstruct their climate. The gazelle bones found at an upper level suggest desert—that gazelle is now only found in desert Persia. Deeper are found bones of a forest-loving deer. Evidently we are getting back to a damper climate. Deeper again are found the bones of a hyena now living far down in tropical Africa, crocodile bones and a small bit of the soft-shelled turtle, a species which likes warm-damp. Here are clues which suggest a tropical climate with steamy swamps and rivers. About these clues there is no doubt in experts' judgment, but when you look at these worn flakes of crumbling bone you are amazed at the detective skill that can read the important message carried by fragments we'd toss aside as rubbish. And this skill at deciphering what seems nothing to the untrained eye, is always growing. All the sciences are drawn on to help. Chemistry is always to the fore—testing for traces of iron weapons, testing iron weapons that remain. That led to finding the answer to an old question and an odd one: Why did the people who first had iron, think it was magical? Not

merely because it cut so well. No: they called it the Metal of Heaven. Chemistry discovered what that name meant. It was quite true. The earliest iron weapons called by that name are made of nickel-iron, just that nickel-iron that meteors are made of.[1] No wonder people thought that knives made of meteorite must be magical. Go further back: Whence did the first people who used copper get their ore? Again chemical analysis has shown that this copper comes from one place. They sent from Sumeria on the Euphrates, far down the Arabian coast to a copper mountain in Oman. So we track out one of the world's first trade routes.

But chemistry itself is a clumsy detector beside the latest methods, the use of ultra-violet radiation. This helps us peculiarly with documents. When the Sinai codex of the Bible was being bought, many people objected: 'Haven't we got perfectly good life-size photographs of it. Why want the original?' The answer is that we really don't know whether we have yet read all of it, and these parts, of which it can be said that they certainly don't start to the eye, may well prove the most startling and important. No ordinary photograph can tell us all, because the common photo plate only records the surface. We have to search under-

[1] The latest Report of the Iraq Investigations of the Oriental Institute of the University of Chicago, however, notes that a fragment of an iron blade dated 2700 B.C. has been found made of earth iron-ore (telluric). This is by a number of centuries the earliest known iron object. Perhaps the secret of smelting was lost.

neath. For the people who wrote these MSS and first took care of them did not respect the letter or the parchment very much. If you knew of another version you often wrote in your rendering on to the MSS. Some of these other readings are immensely important. Sometimes the only knowledge we have that there was another version are these casual notes which the unknown reader jotted on the official text. Later on people scratched out most of these valuable notes but often ultra-violet photography can detect the writing. So these sunken comments, these second thoughts which third-rate authorities thought they had censored and expunged for ever, glimmer through to us again, far down in the well of years, sunken but not lost. Indeed this scientific detection applied to history makes us ask: Is anything lost? Can anything be concealed? A generation ago it would have seemed like magic the way we can put together what had seemed shattered for ever, and read what is obviously no longer there. Can we be sure that we have reached the limits of scientific detection? I think not. The more science tells us about matter the more we have to realize that all materials, even the hardest and least impressionable, are nothing of the sort. They are all made up of forces which are always being influenced by the conditions which surround them, and we don't know how long they may retain such impressions. Look at steel—the hardest of the common metals and yet through magnetization it can be made so that it is sensitive to the earth's magnetic current, a thing of which our senses are utterly unaware. You probably

know also about the steel tape recording machine through which important speeches can be preserved and then given out 'on the air' when listeners are ready to switch on. The way it does that illustrates vividly how our unaided senses can fail utterly to tell us how full of information a perfectly plain-looking object may be. I'm still surprised when I look at a gramophone disc and see the tiny dints and scratches which can preserve the music of a whole orchestra; one is reminded of Tennyson's fine phrase 'The plain eggs of the nightingale in which sleeps the music of the moon'. But at least there are these dints as evidence that the disc is loaded with something. With the steel tape recording machine the record is only a plain strip of metal about as broad as a shoe lace. Simply by electrically charging it, it can be made to carry the sound record with voices, music, cheers, etc. of some historic occasion and keep it perhaps for ever. But looking at an uncharged and a charged strip—even under the microscope or under ultra-violet light—you could not discover which is plain metal and which loaded with history. Only running it through the machine between two magnets, which detect the charge it carries, will tell you that. So, when one sees how helpless one's ordinary senses are to help us here, one realizes how we cannot yet say whether all the other relics we study have yet yielded up all the impressions that may be stored in them. One thing is however coming to light. With these new methods we can make a history so clear and ample that at last we may know something really about our past, we may get rid of the fairy tales

based on ignorant vanity and prejudice which are such a danger to-day, and I believe we shall see a picture of mankind which will make us realize our unity as a single human race, the unity of civilization and the necessity that we shall not make vain the great effort of the past by childish misrepresentations. That is what science can do and is doing for history. It and it alone can recover for us the true history. Of all our immediate needs perhaps that is now our most pressing need.

(c) The new natural history

It is here that science is doing us its final service, and it is here, in viewing the science front, we must follow up the latest advance in scientific theory. People used to say in the last century that science has banished romance from life. Then they became graver. Men began to question. Has not science banished reason and meaning from life? Samuel Butler, that courageous thinker who would call a spade a spade, attacked what he felt to be the disingenuousness of the Church, but he was just as prepared to attack what he felt was the disingenuousness of current scientific theory. He challenged Darwin as frankly as he challenged a bishop. To Darwin he said 'You have banished mind from the universe.' Natural Selection certainly had reduced Mind to a rare and insignificant accident, and so of course this theory, Natural Selection, could not itself be very deeply founded; for if Darwin's mind was an accident, his conclusions could not claim any less relative a

standing. This fact, which specialists might fail to see, anyone who wished to apply these findings had to recognize. For a time people who were concerned that men should recognize what science has found and what powers it gave, had been inclined to say that science, 'organized common sense', had made a complete philosophy of existence and that philosophy made man insignificant, his mind an irrelevancy and his values—his morals and ideals—only his private concern.

His morals and ideals were explained as having force because some were, and the rest were imagined to be, of social value. Himself and his mind were explained as an odd freak of nature—an accident that managed to survive because it was curiously and unexpectedly efficient through its intense activity, but which, now that it had no rivals to destroy by its natural cunning, destroyed itself through aimless megalomaniac speculations, and this theorizing which, as it hypertrophied, took the place of practical scheming; even as the teeth of rodents or the beaks of wood-tearing birds, if they are denied proper material to work on, grow on until the animal starves, or the weapon, failing to bar the creature's mouth, pierces its throat or brain. This of course was ingenious and might have been valid had it not proved too much. The demonstrator, as he put the final and conclusive strokes to his argument, cut off the branch he sat on and both he and his thesis fell with some shock to the ground. In trying to get rid of superstition and its stranglehold on reason, the biologist, turning, without sufficient preparation, philoso-

pher, had destroyed reason itself. Hence, if only for the practical consideration that otherwise superstition would in the next move 'mate' reason (so rashly put in 'check' by its unskilled champion) advocates of science withdrew from the impossible position. Science ceased to be advocated as an adequate, radical philosophy, superseding and rendering demonstrably obsolete all other philosophies. Science was said—in order still to claim its autonomy—to have nothing to do with general meaning. Science was to be seen as neutral in pure thought as it was in applied thought and as inherently indifferent to how its 'pure' findings were used to construct rival cosmologies as it was and is inherently indifferent as to how its applied findings are used to construct rival state armaments.

But to-day this second phase of scientific thought is yielding to yet a third. As in a spiral, science after failing, because of the inadequacy of its general theory, to make a general philosophy, is now driven, after a temporary retreat, once again with more facts and a fuller understanding to help make a broader philosophy. Driven is literally true. Outer events no longer permit the scientist to hope that if he renounce the effort to help make a generally valid philosophy of life, his retreat will be respected and his autonomy guaranteed. Like an immensely rich young man finding himself with a number of none too reputable but very powerful uncles, science must learn to run its own property, or find itself 'certified' before it knows it. Science must become one of the world's triumvirs or it will find itself with a life sentence. The middle way, it

hoped it might take, of quiet irresponsible independence, is no longer open. It has found out too much, knows too much. It has a third of reality in its property. It must combine to make a whole or it must see the development of its part, its free capacity to explore, rigidly forbidden. Science must choose either to help make general sense or to be stopped making its own restricted sense. If it will not support reason and help with the other faculties which are needed to establish reason, to make a philosophy which shows reason is not an accident, but that understanding, judgment, the open mind, charity as well as tolerance, insight as well as analysis, and the other supreme values are absolutely valid, then science will be crushed. This was clear to any thinker before the war. Since then it has been forced on the attention of the practical man, the expert and the specialist by the inevitable rise of the dogmatic and violent authorities which call themselves dictatorships but which are precisely what the Greeks would have called tyrannies—states of government which will not and cannot permit any free enquiry, because such enquiry might challenge their claim to inspiration.

It is clear, then, that science both in its own inner development and through the process of events around it, has reached a crisis and must try again to help to construct a philosophy through which reason shall be preserved and man may live 'according to nature', according to a reconciliation of his inner and outer experience. Science's task is the construction of Natural Philosophy.

Is this however possible? The length of this introduction to a final chapter shows at least the present writer's recognition of the difficulty. That there is this final chapter shows also his belief that, though difficult, it is possible that science can make its essential contribution to understanding, understanding the universe and understanding our relationship to it and our fellows.

We, then, start again our review of the science front and here, at the point we have reached, we see that science has been thought inhuman very largely because it was not at that time studying humanity. It was studying the outer universe and then, with pupils narrowed from focussing those vast distances, it turned on man a cold regard—he looked so minute, expressionless and insignificant. A moment after, however, it became obvious that this was simply a mistake of apprehension. 'Glory to man in the highest', for is he not (if not the master and maker of things) the sole maker of sense of things?

Yet a second scrutiny showed him only an ape standing uneasily on its hind legs. This could not be the universe's understander. This creature, passion's slave, was it the master of the truth? Here was the dilemma: Either the vast picture of the universe must be let vanish or you must allow an ape capable of dreaming like a god, capable of understanding the whole universe. There was, however, a third possibility: Mind must be valid. Man must submit to mind's verdict on him: that, though mind inhabited him, he was largely animal stock. Here then was the

third way which would preserve both the validity of mind and also the naturalness of man. Mind inhabited man and so he could obtain an increasing expansion of consciousness, of understanding and of valid inference of the universe around him and of his essential part and place in it.

Is not this however philosophy and not science? It is here, then, that this the last and latest of the sciences, anthropology, the science of history, comes in. It vastly extends the small shred of tapestried story which was all we had, and on these huge unfolded, smoothed-out sheets it begins to show us this actual story of how mind gradually awoke in man and how with bolder and still more embracing constructions man has gone on making vaster, more detached and yet more sensible pictures of what may be the meaning of the whole process (of which he now sees himself as the pin-point focus). With archæology we can now see how man's main civilizing and humanizing ideas came slowly upon him and how as he understands himself and his fellows, he comes to see his part in the gigantic process of life which in its turn arises out of the still vaster, more diffused process of the astronomic universe.

We have seen that man began as an animal but as a creature which advanced, not by being the animal which knocked out most of its animal rivals, but by being the animal which of all animals took the most in. Our advance is due to the fact that we never wholly stop learning. Man is the curious child-like being which can never wholly cease feeling curiosity,

that pure wonder at everything strange. In consequence, his history shows that wonder growing until with science and philosophy it grows so intense that he forgets himself, the shortness of his time, the minute frailty of his form, and makes those vast pictures of the vast universe.

(d) The latest outline of man

We can now trace the growth of that wonder-inspired power. First Dr. Leakey has claimed to show us our type, modern man, shaping his flint tools in Central Africa perhaps a million years ago. Then also quite lately Dr. Frobenius in the Sahara had found the rock carvings and incised drawings which begin to link up those amazing cave carvings, which we have long known in South-West France and Spain, with the carvings and rock paintings in Central and South Africa. Some of the same stone types of tools are found now from Derbyshire to the Coromandel coast and from Portugal to the Gobi Desert, while quite lately we have learnt of there being found in Australia more of these life-like incised rock drawings, showing, for example, the crocodile, long extinct in that southern continent, and in other ways indicating their great age and complete difference from any drawings now made by the present aborigines.

These finds tell us two things: one about man's mind and the way it was exploring the world round it, and another about his body, the way he was spreading over the globe. We get from his pictures and tools

two impressions. In the first place we see how strong in him was the wish to create. He sees the beast his mind broods upon and he brings away the impression so vividly that he can set it down on the rock face as true to life as though it had been photographed. He does this no doubt because he would master the beast, but like all artists he is mastered by what he would master and so art and pure science, the contemplation of the thing regardless of the use which it can serve, begin to arise. In the second place it looks increasingly as though picture-makers and tool-makers spread from some one centre, so strangely similar are the designs and techniques. Then, after a slow unfolding of these simple but sure arts and crafts, we reach the age of the first revolution—the discovery of farming. Till then, we see, man the hunter must have been sparse and migrant—only few could live on the wild supplies nature afforded, and they must glean widely to get bare sufficiency. With agriculture came settlement and surplus; and discovery which for millenia had only oozed drop by drop, began to trickle. These primal civilizations, the dairy dynasts, not only discovered a new economy, but launched themselves, from the new platform they had made for themselves above the tide of circumstance, out into daring speculation, and the loftiest and purest of the sciences, astronomy, dawned. We see now how it is that as man's body can stay still his mind can begin its gigantic flight.

The next great break away is probably not till almost in what we now call the historic age. The dairy

dynasts initiated a civilization which joined earth and heaven in one focus of the human hearth or altar. This linking of the sky and the earth, with man as coupling, was a tremendous effort of creative imagination. The evidence which gathers makes it increasingly likely that this great conception occurred to some group of men at one place and then spread across the world like a ripple over a pool from where a stone has been cast. The latest work from the buried cities in the Indus valley seems to show that here may be the nearest form so far uncovered of this primal civilization, and the comparison of the signs on the characteristic seals with signs from some of the Easter Island inscriptions suggest that there must once have existed a common sign-linked culture stretching from Persia to the Pacific and into Africa and Europe on its west. So firm was this sacrificial-auguristic, astrologic construction, so well did it seem to man to explain where he was and how he was, what was about him and how he should behave, that, as we have seen, no great rift in that arch and vault was made for thousands of years. Then a crack appeared. Man saw the world around him as a vaster thing and himself as a more mysterious body than he had imagined. He must break out of the narrower vaults and make himself 'a dome more vast'. Now archæology can let us trace the break out of this new vision. The earliest tombs so far found in China, which have lately been fully described, leave us in no doubt about that. Valuable as are the treasures of jade and bronze which have come out of these mausoleums at Lao Yang, they are as nothing in com-

parison with the light these burial customs throw on the minds which made these objects and grouped them here. We see the old dairy-dynast idea, that the dead ruler must take not only his wealth but his dependents with him, has gone. Only pottery images still show the unbroken succession of thought, but human sacrifice has vanished leaving the toy image as the vestigial remnant. We are in the age of the great ethical teachers. Man henceforward will gain his peace of mind not by bribing unknown powers with his possessions but by so ordering his action and thought that he may study the universe around, serene in the knowledge that it can be understood and that he is the creature that can understand it.

The picture, then, which archæology gives us to-day of man and his history is of discovery which began drop by drop and now is a pelting deluge—man's mind spreads through the universe at progressive speed. And this power to understand not only shows man his kinship with all his fellows, all endowed with this strange gift, but also shows him that this is his true nature and vocation, the creature which has been set free from circumstance in order that he may render account of the universe.

The Science Frontier in 1934

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These running commentaries on current science have now glanced along the whole front of discovery, from the physics which explores the ultimate make-up of matter and its furthest extent, to the psychology and anthropology which studies the thing which tries to understand—man himself. This book has attempted to keep to what is contemporary science-in-the-making in a particular year. This is necessary, for science is an unique activity in this respect. Art-in-the-making or architecture-in-the-making could of course be studied and the state and progress of art and architecture in the current year estimated and illustrated. Such descriptions would, however, scarcely fill a volume and the examples, however interesting, could hardly hope to show a striking development of art or architecture in such a short time. In science the opposite is the truth. Not only is there far more news than can be reported but all that news is of a consistent development and progress. It is doubtful whether art and architecture in 1934 is better than art and architecture in 1933. There can be no doubt each year's science is in this sense

better than that of the year before. It renders past science obsolete, out of date in a way that developments in the arts do not make past works of art inadequate and unimportant. Yet though it is necessary that estimates of the front of science should be dated, showing the year in which they were drawn, it is not easy to keep in mind that curious fact of the unique speed at which science (of all our activities) advances. This line was drawn in 1934 but in drawing it, it had to be broadened and made less sharp, here by recalling how the present advance had come about, there by showing how that advance will probably develop.

So in conclusion it were wise to let the diary outline show up clearly in its exactest definition. This final summary dates this collection, but perhaps it may add, and not detract from the usefulness of such a record. For in the first place it does undoubtedly emphasize the importance of science, for, showing the speed at which that advance is being pressed, it must impress us with a sense of the vital necessity that we should watch this progress—the distinctive and characteristic activity of our age and also that age's transformer. In the second place it gives us a datum line from which to watch the further advances. This book would hope to be not only a new sort of diary of a peculiarly exciting piece of the past that we have all just lived through, but also a new sort of general collector's catalogue or stamp album. Here, it is suggested, are various spaces and squares, definite areas which science progress will in the next year fill up further. Here are the parts of the pattern to be completed. Here is a huge jig-saw puzzle

being put together or a huge front going forward, and every month if this rough outline or map is kept in mind by the layman, he may pick up from the science journals new pieces to fit in, new bulletins which will allow him to place his coloured pins along the sectors which are pushing ahead.

Where did science leave us at the end of 1934 in our knowledge of the world around us? Where stood the advance of this tested common knowledge as 1935 began?

A Year's 'Records': A flash-back

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We must begin with plain, common sense, life-size exploration. How much further during 1934 have we pushed our discoveries of the world around us? We have practically finished our discovery of the surface on which we live. The aeroplane has allowed us to glimpse the huge mountain chains and tablelands of the Antarctic continent—we know that the earth's surface holds no further completely strange surroundings for us to find. A huge frozen continent, Antarctica, is the complementary Pole to the vast frozen ocean which is the main area of the Arctic. So now the way ahead lies up and down. Down, Dr. Beebe's bathosphere has taken us to 3028 feet. That seems little, but it is a great stride considering that he has extended diving distance some ten times further. It is also wonderful because he has found large fishes down there. That is a point worth another reference, for this is a surprise. Of course, now that the echo-sounding gear is allowing us accurately to measure the deep—another triumph completed this year—we know the ocean goes down in one place nine miles, off the Philippines—so we are

now only a fifteenth of the way to the bottom. Our deepest into the earth now stands at 8380 feet. But here we are finding heat and pressure rising so that our limit may lie not much further down, for down there not only do walls and roof tend to fall in, but the floor itself rises against you to close this rash disturbance of the primal pressure. The crushing strain is so great down there that any bore hole may collapse on itself. Up above, however, the path is more open. The frontier there now stands at some twelve miles for man and twenty for his machines,[1] as we saw when glancing at the stratosphere. As one of the chief dangers to life beyond that frontier is the cosmic radiation, it is somewhat amazing to find that life has now been traced up to 20,600 feet. Again it looks as though life could push out and on much further than we imagined. Beebe found 20-foot long fishes living where we thought life could not be, in absolute dark, in a chill which never rises above four degrees over freezing, under a pressure which would smash us like an egg. Now planes have gathered bacteria at heights where life should be sterilized and frozen. These bacteria seem to be the harmless basic forms of life, the bacteria which make soil but not those specialized few which spread disease. Further we have just had proof that life can grow below freezing point. Yeasts have been found spreading healthily in such a deadly temperature. That stirs up our notions as to where life can

[1] Fitting stop press news, the Soviet reports (April 1935) twenty-five miles up for a sounding automatic-recording balloon. No doubt this summer will break that record.

and cannot live. It must be advancing its frontiers, for no one can think that where and when life began it was able to disregard being frozen.

And while on records as to what life can do beyond what we thought, why leave out ourselves? The earthly motherhood record is now certified as held by an Indian woman aged seven. Mother and child doing well. The fact is certified by Dr. Hilda Keane of the Victoria Zenana Hospital, Delhi. The most important news of new power to see life at work is the microscopic discovery that we can now at last see the Genes —those packets which load like tablets, those tubes, the chromosomes, which bunch like ravelled tassels in the germ of all seeds. So we are getting down—in a sort of house-that-jack-built way—to the minute level at which all living things are built up into their various forms. For these gene-packets seem to carry each of them certain bunches of characteristics, blue eyes, long legs, sharp noses, etc. Still, though we can see more, the mystery does not become less. That I think is best illustrated by the most striking piece of 1934 gland-knowledge. Rats now fed on Thymus gland extract—the gland which is in the centre of our chests when we are children and which it seems must disappear if we are to grow up—these rats not only grew much faster but their children inherited this queer vitality. These rats have been fed and studied for seven generations and up to the present each generation seems to be growing faster than the last. Rather an upsetting find in two important ways, for first it looks as though this gland were working the

wrong way round and also that this change which brought about this acquired characteristic, were being inherited. That is all the room we have got for life's advances and how our knowledge of its frontiers has grown in 1934.

We must clear up a few more physical records, records of what nature can do. Here also we have had to enlarge our notions and widen the boundaries we had set. Again to start with simple things: the record for high wind is now standing at 231 m.p.h. measured in Mount Washington by Harvard metoreologists last April. 'And after the raging wind the fire': the record for the hottest spot we can get at, the centre of an electric arc flame is now found to be 3810 degrees above absolute zero—a very respectable heat to have at our disposal and only to be surpassed if we could get to the centre of the earth or out to the stars. And mentioning the stars calls up another frontier. You know we had a picture of ourselves, sun and planets, all belonging to a super solar system—the Galaxy. And beyond that there being spaced out quite regularly other super solar systems, island universes. There was, however, one puzzle in this picture. Our Galaxy appeared to be much bigger than all the other galaxies. That seemed suspiciously provincial—to find ourselves so much bigger than everyone else. To-day we have pricked that vast bubble reputation. It has been found that our home Galaxy looked big because many of its stars looked red, and because of that colour they were estimated to be immensely far away. Now it is thought those red stars are much closer and so the

whole ball of us is much smaller than we had calculated—in fact this supposed local inflammation has been reduced to the same size as the other galaxies. That is not a dull conclusion, however. Quite the reverse. It means that the red stars look red because they glower at us, as our sun does, through a fog. But this fog, this smoke is floating in great banks far out in space. And what is more, the fog is thickest at the centre of the Galaxy. What does it hide? A super-sun which would otherwise blind and radiate us to death? Perhaps, but here at least is a full scale cosmic mystery. That thought may daunt our hope of exploration: so here comes news of how our powers of finding out have grown in the twelve months. You have learnt that the 200-inch mirror has at last at the second shot been successfully cast—not only twice as large as any mirror man has ever made but perhaps the largest mirror he will ever make, for, though a 300-inch has been planned and is technically possible, the chance that such a mirror would have strains in it, which would distort the images in it, is very great and as the larger the mirror the more it must magnify, not only the stars, but the quivering air through which we must see the stars, so the number of nights on which seeing would be good with such an eye would be correspondingly rare. And, beside this eye for exploring the infinitely far and large, we have the electron microscope now, for exploring where light fails because of sheer minuteness. It can magnify 10,000 million times and so with it you can at last see the atom itself. And as science is not merely seeing but

being able to measure, we have also a new hand, in the instrument which will divide up, no less than ten thousand times, an angstrom, which itself is a section of only a hundred-millionth of a centimetre. We have seen that the lock which shuts up the secret of how living forms grow and change lies down in the infinitely little, just as the secret of alchemy, transmutation of metals, lies down there too. It begins to look as though with these new keys we may soon pick that lock. But life-size nature is still revealing to us how many mysteries we have overlooked. Earthquakes are the largest of disturbances and seem to spring from the simplest causes. But last year confirmed the evidence for something very mysterious about them. The Japanese seismologists report now definitely that inexplicable bright lights are seen, but no true fire, for they shone over the sea, in the waves and on the sea floor when the sea drew away from the coast. And 1934 science has shown not only that the present world around us can still do things which still are inexplicable. It has also shown further how much more mysterious than we thought is the story of life which lies behind us. The story of evolution is getting yearly more extraordinary. Does life mimic itself? However odd that sounds it begins to look as if it must be so. Perhaps the most remarkable fossil find last year was of a marsupial sabre-toothed tiger. We have seen in museums the fossil heads of that odd, horrible beast, the sabre-toothed tiger—surely it was such a freak of a beast, with those outrageous teeth, that it could never happen twice! But here we find

that quite another branch of the tree of life did give rise to a monster freak of almost the same sort. Indeed it looks as though in the marsupials, the animals which carry their young in the pouch, life mimicked, or rather tried out, many models of animals which appear again in our lot of animals, the placenta mammals—but this repetition of such an odd beast as the sabre-tooth is quite the strangest evidence we have so far found of this uncanny sort of thing. What a strange force this Life must be. How little we have grasped its secret. It used to be said science has banished wonder from the world. On the contrary it begins to look as though we had never been able to imagine in the least what an amazing world we live in and, more, what a mysterious life flows in us.

In this final section there has been given only one example of each of the great explorations pushed forward this year. But there are actually swarms of examples of each and beside the obviously startling explorations there are innumerable other discoveries, nearly all of which are fascinating and any one of which may prove a winner by completely transforming our lives. So 1934 closes for science. We have pushed to the frontier of the air and like chimney-sweeps have almost thrust our instruments above the roof into empty space. We have begun to take the first full steps into the ocean abyss. At either end we have found life has already pushed out much further than we supposed possible. We have reduced to scale our own galaxy—we who are sub-microbes on a grain spinning round a pip in that Sahara of stars

which makes up the Galaxy. We have made a twenty-ton glass-eye which will reach out toward the limit of space itself and another eye which can see almost to that other limit where matter ends. We can make heats that compare with the heat of stars and a cold which is within a fraction of a degree of the absolute zero, perhaps the coldest thing there is because outer space itself is now calculated to be a few degrees above that deadest of all dead levels. We have at last sighted the genes, the packets in which our physical inheritance is posted from one generation to another and through which device life triumphs and goes on developing in spite of death. And yet this rapid advance of knowledge only shows vaster fields to explore opening before us. In this advance it is not the strange which becomes familiar but the familiar which becomes the strange. Such seemingly simple things as earthquakes are found to be attended by odd, inexplicable phenomena. Empty space is found full of the intensest force. When we chill a metal to zero then electricity seems not frozen but to run all the freer with practically no resistance. Everything is on the move. The whole universe is showing an aliveness which must rouse adventure in any who still can feel a twinge of curiosity. Whatever 1935 may hold for other interests, for those who watch science what an exciting time to be entering upon. We are certain of reaching a dozen rich goals, yes and finding them gateways opening on to still more amazing prospects. Even time, familiar, inexorable time, as we study it, is beginning to unbend and what we took to be a beat

which no excitement could ever stir, begins to vary, to waver, and we glimpse a condition beyond which even time cannot go. Here lies the greatest mystery of all and perhaps the greatest triumph of the scientific mind, that we now study and calculate and work in dimensions which are outside Time. That is perhaps the most exciting question which 1934 can ask: What will time be to-morrow? Surely no question can interest more. Man has always called himself the Slave of Time. Is he nearing emancipation? In any case science is about to give him a leisure, a free time no men have ever had before. Can any interest fill that leisure so well and fully as natural philosophy, trying to see the universe as it is, science never ended but always in the making?

Conclusion

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So ended 1934, but science regards no dates and takes no rest pauses. With ever-growing acceleration it is rushing us on to the time when all animal spurs to action, all the pressures of physical needs will be withdrawn. The vast rivers of supply will swamp and silt in their own golden sands. Man, who has left to appetite the task of finding for him the worth of living, of being the sole sauce with which to give him the gusto to bite off and digest great chunks of the stubborn outer world, will find appetite sated almost before it can stir. Humanity will be bored. This mysterious word which first stole like a grey shadow over the court of *le Roi Soleil* and then spread to all places where men of taste lived beyond the struggle for meats and mates, will percolate down from class to class till all are leisured, all are idly rich with a wealth of time on their hands, no mass of people have ever possessed, ever been embarrassed with, before. If then mankind is not to weary of its life, to fly to making intentionally the accidents, the strains and anxieties which gave it thrills and spurs and sudden convictions that life is worth while (but

which Nature no longer makes for it) if it is not, through war, deliberately to break down into anarchy the order it has built up, it must find new interest and excitement. There is only one appetite from which this new stock of interest can spring and that is curiosity, the finest of the passions. Curiosity is impersonal and so can remain when all personal appetites have been paid off. Curiosity is not utilitarian and so can carry on when men are sated with means. Curiosity is inexhaustible and so can find fresh fields and new explorations when all the world that man can exploit is ordered, every sight has been seen and every power exercised.

Our education has frowned upon idle curiosity, the power to be interested by anything and, no doubt, has done much to crush this general capacity, by discouraging the sensitive, until all knowledge seems drained of wonder, and by canalizing the energetic until they can only attend to what pays. The specialist is held to be justified in his hypertrophied interest in the restricted and his atrophied interest in the whole because by so doing he makes money. To-day we see the pressing and ever more pressing need of pure interest. It is not merely an additional servant which we are requiring. The crisis is much more serious. We are being driven to find nothing less than a new way of life. Till now, for nearly every human being, there was only one real business in life, and that was to get his living and that of his dependents. All his other interests had to be fitted in, in the interstices of that iron structure which framed life for him. Now what has been prim-

ary structure is becoming secondary and it is on the random fillings and screens, the odd interests and spare time hobbies, that we are discovering that the future purpose and meaning of our life is to depend. Probably no profounder change-over and revolution has ever shaken the customs of men. So swift and profound is this change that it is doubtful whether most people will be able to adapt to it. They will seek rather to recreate the economic necessity, which applied science has banished, in order that they may still enjoy the psychological satisfaction which being engrossed in a subject entails. This economic necessity can of course be recreated by banishing machinery or by the more traditional and romantic method of war which destroys sufficiency of goods and so restores the scarcity in which leisure is once again a rarity.

It does not then seem an exaggeration to say that here in this problem of plenty leading to leisure, leisure to boredom and boredom to disgust and even to a savage wish to destroy; we have again Natural Selection beginning to play on the human species, and the riddle of the sphinx stated in our contemporary speech. Natural Selection has been screened from our bodies by the power of our minds; we can have inefficient teeth, weak chests, poor sight, low vitality because and only because we still have brains which compensate for all these handicaps. But Natural Selection has not ceased to work—its brunt is borne by our brains instead of our bodies—that is all. And Natural Selection plays upon our brains by insisting that when we have taken away every keen physical spur to living

we shall in our mind, in our power of interest, find the meaning of existence.

It is clear then that the only step we can take to ward off this bankruptcy of interest and this collapse back to cruder ways of living is to change our education. We must shift the emphasis from teaching how to do things, how to convert stubborn dull raw material to our purposes, to how to be interested in things for themselves. The attitude of the artist and that of the philosopher are ones which we must all try and adopt. But the artist is too largely born, too little made, for us to hope to educate large masses of people to find the purpose of life in art. The philosopher is also one who by a natural detachment has cultivated a power of insight too exhausting for the ordinary man to sustain. Science, however, because it began by being organized common sense and with practical and direct interests, can draw out an ordinary curiosity. From the child's interest in growth, the boy's interest in machinery, the detective interest which never dies in the pattern-making animal which is man at all his ages, science can spin an unbroken thread which will draw out the human mind, keep it from falling back on itself and link it up with the inexhaustible variety of the universe. There is no subject which is not fascinating if we can understand how it is linked up with ourselves, and the triumph of science has been to show that there is nothing with which we are not linked in some strange relationship.

Nor need we feel that such interests are fanciful and such relationships merely subjective. If a new form of

Natural Selection is beginning to play on us and to demand of us a new effort, the relaxation of the old form of Natural Selection will release in us capacities to meet that further challenge. For we have now realized that Natural Selection, the blind force which selected only such types as could survive, narrowed instead of enlarged our capacities, for only those powers which would help us in our physical struggle could be permitted to count. Every taste for things which did not serve this vital need, every 'idle' curiosity, every apprehension of interests, happenings and meanings beyond bare physical requirements, had to be restricted, penalized, denied.

Now, however, the tables are turned. The new Natural Selection will pick out those who can be most widely interested and are least self-centred, least concerned with immediate use and physical advantage. That man will be most pleasing to life, most able to survive, who is most widely interested. We may go further. For as the elder, physical Natural Selection cramped and pruned capacities, so under this new stimulant, this new need for pure interest, these crushed and stunted apprehensions may expand. We can, it seems already proved, see much which we have up to the present disregarded. We do not use even our present senses to anything approaching their full capacities. In a free world where new power of interest will be at a premium, we may expect to find ourselves using our senses to their full capacities and so apprehending a world far richer in colour, form and variety, yes and in sound, scent, flavour and texture than we at

present take for granted. Nor should our advance be stayed, even within those immensely enlarged frontiers. For when our attention and interest press upon the utmost limit of our senses then we may hope our senses, in their turn, will expand still further to enrich and enlarge the impression which we have already obtained of the universe around us.

That, then, it seems is the crisis—a crisis of opportunity—to which applied science has brought us and over and beyond which pure science—not highly specialized but widely appreciated and apprehended science—will best carry. It is true we may fail and fall back in confusion and into still greater confusion, but it is also true that there is no inherent necessity why we should; on the contrary, every reason and inducement why we should not. It is not science which has taken meaning and interest out of life but rather it is through science that we can now look forward to a life of awareness, interest and fascinated self-forgetfulness beside which the most engrossing passion and the intensest devotion were narrow, weak and blind. Man is only about to live fully as man when animal needs no longer drive him: he will only be completely humane when everything interests him for its own sake. Applied science has set him free and pure science, I believe, can help him more, than any other interest to fill to capacity this freedom.

Index