SCIENCE AND THEOLOGY

By the Same Author

SCIENTIFIC METHOD

ITS PHILOSOPHY AND ITS PRACTICE

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SCIENCE AND THEOLOGY

Their Common Aims and Methods

BY

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O, I wad like to ken—to the beggar-wife says I—
The reason o' the cause an' the wherefore o' the why,
Wi' mony anither riddle brings the tear into my e'e.
—*It's gey an' easy spierin'*, says the beggar-wife to me.

—STEVENSON.

PREFACE

One object of this book is to show on what evidence some of the great fundamental principles of science have been established, and to make clear that these principles are provisional only, since they are always liable to revision in the light of new knowledge.

A second object is to present a picture of the structure and evolution of the universe as conceived in the light of the discoveries of the last forty or fifty years. But it is important to remember that the conception is *only* a conception. The difference between fact and hypothesis must be carefully discriminated.

A third object is to show that modern science has become a great fundamental factor in human life and progress. Its continuous growth is a proof of its vitality, and its innumerable applications to our daily wants a proof of its ability. No religious system can possibly prevail if it cannot assimilate the great truths of science. The characteristic of the scientific mind is its determination to test every dogma, whatever the authority on which it reposes.

A fourth object is to show that permanent and final truth, whether in science or in theology, is very rare and very hard to come by; and that what we call truth is usually an affair of a greater or less degree of probability. The revelation of truth is conditioned by our ability to receive it. In this world it is always partial and incomplete. Reinterpretation of truths already established are therefore constantly necessary in the light of new knowledge. Most of the divisions amongst Christians may be traced to the fact that men have taken part of the truth as its whole sum and have ceased to look for further knowledge.

The final object of the book is to appeal to each and every branch of the Christian Church to abandon its claim to be the special favourites of heaven, and to abandon, too, all that this implies ; for instance, ecclesiastical exclusiveness, exclusive validity of sacraments, dogmas, forms, and rubrics ; and to present a united front to the common enemy.

It is of little avail for the student to seek a philosophic basis for his theology before he has mastered the main principles of mathematics, of science, and of scientific method. If, for instance, he resorts to metaphysical arguments concerning the infinite before he has made himself acquainted with the nature of infinity in mathematics, he is violating the first principles of common sense.

Training in scientific method has brought into being a thinking fraternity whose bond of loyalty is respect for the truth. Is it too much to hope that all students of theology will enrol themselves under the same banner ?

The author is well aware of the incomplete treatment of several of the topics in the last chapter, and that the relations of certain vexed theological questions to the metaphysical and scientific principles discussed in the earlier chapters are worthy of fuller discussion. Pressure of professional work compels him, however, to bring the book to a close, though he hopes to be able, later on, to expand the last chapter into a second volume, and to deal, in particular, with the questions of (1) God and the problem of evil, (2) spiritualism and superstition, and (3) the permanent and the transient values of the Bible.

So far as accuracy would allow, technical language has been avoided, and it is not assumed that the reader's knowledge of science and mathematics exceeds that of boys and girls of sixteen or seventeen who are in attendance at a reasonably efficient school.

A large number of authorities who are recognised as most eminent in their different departments of knowledge have been freely consulted. Those works to which reference has been chiefly made are named at the ends of the respective chapters. Special attention may be called to those marked with an asterisk. The non-scientific reader will find that the volumes belonging to the Home University

Library form a valuable sequel to several of the chapters ; the books are clearly expressed with a minimum of technical language, and include most of the latest researches and discoveries. (Note, in particular, those marked with two asterisks.)

It is a pleasing duty to acknowledge the kindness of Professor D'Arcy Thompson and the Syndics of the Cambridge University Press for permission to make use of matter and diagrams from *Growth and Form* for the first section of Chapter X. ; of Professor A. Keith and Messrs. Williams & Norgate for permission to adapt, for the purpose of the diagram on p. 199, a genealogical tree from *Ancient Types of Man* ; of Professor T. C. Chamberlin and the University of Chicago Press for permission to quote from *The Origin of the Earth* for inclusion in sections six and seven of Chapter V. ; of the Open Court Publishing Company, Chicago, for permission to make use of certain passages, for inclusion in Chapter IV., from Mr. Bertrand Russell's *Our Knowledge of the External World* and Professor Schubert's *Mathematical Essays*. The author's greatest debt is to the late Lord Rayleigh, whose invaluable help was most ungrudgingly given for many years.

F. W. W.

August, 1919.

Since the above was written, the claim has been made that Einstein's hypothesis of Relativity has been verified. But, more accurately, the results of the solar eclipse expedition have verified merely a particular consequence which Einstein said would logically follow from his hypothesis, namely, that light is refracted in a gravitational field. It certainly does not follow that the hypothesis as a whole is thus verified. True, the hypothesis seems to gather into its ambit more observed facts than the Newtonian hypothesis it supersedes, and, to that extent, probability is on its side. Further, the curvature of space, which the hypothesis demands, may also perhaps be conceded. But the hypothesis involves two consequences which at present seem impossible of acceptance—the action of gravity across a void and the variability of time. A time which is not unique is contrary to the notion of the logical principle of non-contradiction, whereby a thing cannot both be and not be *at the same time*. (Compare Chapters III. and IV.)

November, 1919.

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The things which are seen are temporal, but the things which are not seen are eternal.

ST. PAUL.

When they who condescend to tutor us
Do prompt to deck false systems in Truth's garb,
And tangle and entwine mankind with error,
And give them darkness for a dower, and falsehood
For a possession,
Then one may feel resentment like a flame.

BROWNING.

Sanabimur, si modo separemur a coetu : nunc uero stat contra rationem, defensor mali sui, populus. Itaque id euenit, quod in comitiis, in quibus eos factos praetores iidem qui fecere mirantur, quum se mobilis fauor circumegit. Eadem probamus, eadem reprehendimus : hic exitus est omnis iudicii, in quo secundum plures datur. Quum de beata uita agitur, non est quod mihi illud discessionum more respondeas : 'Haec pars maior esse uidetur.' Ideo enim peior est. Non tam bene cum humanis rebus agitur, ut meliora pluribus placeant : argumentum pessimi turba est.

SENECA.

SCIENCE AND THEOLOGY

CHAPTER I

THE PROBLEMS OF PHILOSOPHY[1]

1. The Quarrels of Philosophers

IT has been said that most philosophic systems are so many spectres—so many enchanted corpses which the first exorcism of the sceptic reduces to their natural nothingness; that the mutual polemic of these systems is like the warfare of shadows: as the heroes of Valhalla they hew each other to pieces, only in a twinkling to be reunited and again to amuse themselves in other bloodless and indecisive contests.

Why are there such fundamental differences of opinion amongst philosophers? Why does the philosopher of one school refuse to admit that the philosopher of another school possesses any philosophical knowledge on the subjects that he treats? Which is right, Monist or Dualist, Materialist or Idealist, Empiricist or Rationalist?

2. The Borderland between Philosophy and Science

It is a perfectly natural thing for the uninstructed plain man to place implicit reliance on the evidence of his senses. He sees the sun in its daily journey from east to west across the sky, and, like the ancient astronomers, he makes the assumption that the sun goes round the earth. To him the assumption involves no element of doubt; to him it is not an hypothesis, it is a fact. When it is pointed out to him that the heliocentric hypothesis provides a simpler explanation of the celestial motions and is more consistent with ascertained facts, he is puzzled, and his respect for authority may

[1] Parts of this Chapter appear in the Second Edition of the author's *Scientific Method: its Philosophy and Practice.*

make him feel that his senses, at all events his sense of sight, may sometimes deceive him. If he becomes a student of science, he finds that many of his established notions are hopelessly wrong. In thinking about ordinary material things, for instance, he had always thought that they were coloured and resonant, quite independently of their relation to himself. The evidence of his senses he soon learns to accept with greater caution ; and he comes to understand that, so far as physics distinguishes reality and appearance, its criterion is not sense-perception alone, but consistency with an elaborate and complex system of more or less definitely established facts which embody the combined results of many perceptions and inferences. Science has continually to explain to uninstructed common sense that what really happens is often something quite different from what appears to happen.

The chemist performs a number of quantitative experiments, examines his results and detects amongst them certain common quantitative relations, sums up these constant relations as "generalisations," and so establishes the "laws" of constant, multiple, and reciprocal proportion, and the "law" of Gay-Lussac. These laws constitute important principles of chemistry and form the basis of the theory of the subject. Their justification is a great number of definitely established facts. They involve no assumption, no hypothesis, save that of the great induction of the Uniformity of Nature.

But the chemist may now cast about for an "explanation" of these different laws. The atomic hypothesis covers and explains all the facts of the first three, and Avogadro's hypothesis covers and explains all the facts of the law of Gay-Lussac. But these hypotheses are *assumptions* ; they are constructions of the chemist's mind ; they may or may not correspond to objective fact. In making these assumptions the chemist is trying to get behind his observed facts, behind his phenomena, in order to discover the hidden secrets there. In doing this he is passing over the border-line between the domain of science and the domain of philosophy.

Such assumptions often prove to be wrong. Again and again in the history of science one hypothesis has been discarded in favour of another. But each hypothesis served at the time as an explanation to cover all the facts then known, and to link them up. Sometimes a new hypothesis has superseded an old one because the latter did not cover new facts and was therefore obviously wrong ; sometimes an old hypothesis has been discarded because seen to be held on insufficient grounds ; sometimes an old hypothesis has been reduced to a simpler form : the mind always prefers a simple explanation to an elaborate one. Thus Copernicus showed that the Ptolemaic hypothesis was wrong ; Lavoisier, that phlogiston had no existence ; Darwin, that the fixity of organic species must be abandoned. Scientific knowledge has thus progressed not merely by the acquisition of new facts, but by correcting or discarding provisional hypotheses. Around and beneath the more settled portions of physical science, in the region where knowledge is growing in range and depth, there is constant conflict and controversy as to the truth of new conclusions, for the controversy centres round assumptions which are unproved and often seem unprovable. Natural science, so recent a growth, is necessarily infected with error.

It has been said that the truths of philosophy bear the same relation to the highest truths of natural science as each of these bears to the lower truths of natural science. But the term truth is hard to define, and it would be safer to say that as each widest generalisation of science embraces and consolidates the narrower generalisations of its own division, so the generalisations of philosophy embrace and consolidate the widest generalisations of science. It has, however, to be borne in mind that the main concern of science is with phenomena, for the investigations of science yield mainly phenomenal knowledge. Philosophy aims at a knowledge of the concealed realities behind phenomena. There is, however, a great deal of common ground between science and philosophy, and the purely speculative side of science properly belongs to philosophy. A philosopher unversed in science is like a man of science unversed in philosophy : neither can claim to be an authority in his own subject.

Such philosophical points as are touched upon in this chapter are mainly logical, psychological, and metaphysical. With ethics and aesthetics the chapter has nothing to do.

3. Psychology, Metaphysics, and Logic

Nominally, psychology differs from physical science only in the nature of its subject matter and not in its method of investigation. Regarded as an empirical study of the mind, it proceeds by methods of observation, experiment, and induction, analogous to those used in natural science. But the phenomena of the mind—thoughts, cognitions, judgments, beliefs, the facts with which psychology deals—are obtained by introspection, not, as in the case of the phenomena of natural science, through the senses. The difficulties of ascertaining the facts are therefore greater, and psychological interpretation is not always easily distinguished from metaphysical reflection.

The psychologist cannot begin at birth to register the history of his mental operations; he has to begin when a grown man, and the more cultivated his mind the farther away he is likely to be from the primitive mental operations of his infancy. The system of knowledge which he attempts to formulate is thus of a highly problematical character, for about the beginnings of knowledge there can be no certainty.

Text-books on psychology usually encroach on metaphysics. For instance, they sometimes attempt to investigate valid beliefs as conceived to exist for an ideal mind independent of the peculiarities of development of particular minds. There is, in fact, often such an admixture of metaphysical speculation with the empirical facts of psychology that the intelligent reader is apt to attach a very sceptical value to the whole subject. Many of the ultimate problems of psychology are, however, necessarily metaphysical, and are never likely to be brought within the range of experimental investigation and solved by the methods of science. The newer experimental psychology is laboriously accumulating valuable facts, but many competent authorities are of opinion that it is attacking an unsolvable problem. At bottom, it is based upon the fundamental hypothesis that every phase of consciousness has its counterpart in nerve changes. That our conscious life is inseparably associated with the changes that go on in the grey matter of the brain there is now hardly any room for doubt, but *how* the two are connected is unknown, and all explanations are conjectural. That our thoughts, cognitions, judgments, and beliefs are *nothing more* than mere molecular changes in the grey matter of the brain is an hypothesis unsupported by any acceptable evidence.

Unlike positive philosophy which contemplates the world as a whole from the point of view of natural science, and is satisfied with empirical evidence and with such inferences as can be drawn therefrom, metaphysics aims at ascertaining facts concerning matter and mind and their relations *beyond* such knowledge as is based upon or is verifiable by particular empirical cognitions. The method of metaphysics is a distinctive dialectical method; it begins by making *a priori* pronouncements, and by applying to these the rules of formal logic arrives at final conclusions which do not admit of any form of methodical proof, or any sort of appeal to experience.

Such conclusions, based as they are ultimately upon hypotheses which cannot be verified, are necessarily always uncertain.

The traditional methods of metaphysics have come down to us from classical times. Great thinker as Plato was, he did not possess a very orderly mind, and although in his writings it is possible to discover nearly all the principles of the methods which his more systematic pupil, Aristotle, afterwards formulated, the reader soon sees that Plato pinned his faith to *a priori* methods, had little sympathy with empirical methods, and was at heart a mystic. Aristotle's methods were different. All that was then known of natural science Aristotle mastered, and he was an original investigator as well. With him, observation and experiment occupied a foremost place. But the amount of indubitable positive knowledge then available was so little that he not only sometimes fell into grave errors but frequently fell back on *a priori* methods; and although his flashes of intuition occasionally served him to good purpose, too often they lead to conclusions that do not harmonise with facts.

The great weapon which Aristotle forged was formal logic, and for many centuries his followers showed a child-like faith in the omnipotence of reasoning according to the rules he laid down.

In mediaeval times, especially, the most implicit trust was placed in Aristotelian logic, and a correct chain of deductive reasoning from some original hypothesis dogmatically asserted was quite sufficient to stifle any doubts about strange conclusions; and gradually the opinion became almost universal that the most important truths concerning reality could, by mere thinking, be established with a certainty that no subsequent observation and experiment could shake. And even to the present day there are philosophers who claim that *a priori* reasoning can reveal otherwise undiscoverable secrets about the universe, and that therefore reality can be proved to be quite different from what by direct observation it appears to be.

In the light of modern science, great numbers of old *a priori* errors have been refuted, and it is now natural to suspect a fallacy in any deduction of which the conclusion appears to contradict patent facts. The fallacy is not usually in the actual chain of reasoning: philosophers do not often make elementary blunders of that kind. It is traceable rather to an untenable original major premiss, adopted, perhaps, because of the royal confidence felt in some unexamined intuition, or because of some unsuspected prejudice, political, social, or theological. This major premiss, the original hypothesis adopted, may look plausible enough, but if the consequences logically traceable from it violate the first principles of common sense, the hypothesis must, without hesitation, be rejected. A conclusion is by no means necessarily correct because the rules of formal logic have been exactly observed. The unacceptable conclusions of educated men are far more frequently traceable to false premisses than to false reasoning.

The formal logic of tradition is merely a logic of consistency. As a well-known writer [1] on modern logic says, " the trivial nonsense embodied in this tradition is still set in examinations, and is defended as a propaedeutic, that is a training in those habits of solemn humbug which are so great a help in later life." Modern logic is something very different. Its chief business is to examine the validity of premisses, and it deserves the closest attention.

In ancient philosophy the fundamental contrast was between things as they appear and things as they are supposed to be in themselves ; between appearance and reality. In modern philosophy the fundamental contrast is between mind and matter, between man who knows, and the things known to him.

4. How the Mind acquires Knowledge

If we inquire into the origin of the stock of knowledge of which we are conscious, how it has been acquired, how it has been built up, and of what materials it is composed, we find it impossible to give entirely satisfactory answers, for we are forced to make assumptions that admit of no ultimate verification. It is, however, easy to construct an hypothesis that will cover all the known facts, and of the different hypotheses in vogue it will suffice to outline the details of one.

We may assume that the mind is originally characterless like a sheet of white paper or an empty unfurnished room, or better still, perhaps, like a sheet of wax, for a sheet of wax may receive impressions and retain them. We may now imagine the mind to receive its first experience of external reality. For instance, let an electric torch be flashed across the field of vision. The mind experiences a sensation, namely, the sensation of a bright light. It is perfectly conceivable that a sentient being should have no sense but vision, and that he should have spent his existence in absolute darkness, with the exception of one solitary flash of bright light. The whole content of his consciousness would then be limited to this single sensation which his mind has received and registered.

[1] Bertrand Russell.

Now an ordinary sentient being is endowed with other sense-organs besides that of vision, and from the first his mind is constantly experiencing, through the agency of these sense organs, sensations of smell, taste, hearing, sight, touch, and resistance (the muscular sense), in addition to sensations of pleasure and pain. All these sensations which the mind thus receives and registers form the raw materials of our stock of knowledge, and we cannot imagine our knowledge of external reality being derived from any other source.

Every sensation impresses itself on the mind, and the mind is thereupon conscious of a vague organic feeling, a feeling that scarcely amounts to an awareness, certainly not the awareness of an object of any kind. *Sensation* is the most primitive form of mental product. But universal experience compels us to make a further assumption—that the mind, whatever the mind may be, is endowed with some kind of active power by means of which it can use the raw materials supplied to it in the form of sensations; and this brings us to *perception*. Perception is the mental completion of a sensation. When the mind perceives, the vague feeling of awareness of the sensation becomes focussed on some object and is localised in time and space. Perception therefore gives us *knowledge* of the thing presenting itself to the senses. Perception follows sensation and springs out of it. But in addition to localising external objects in time and space, the mind in the act of perception plays other important rôles.

We imagined an electric torch to be flashed across the field of vision of a sentient being who had no other sense but that of sight, and who had hitherto spent his existence in darkness. The whole content of his mind is thus limited to the single sensation of a flash of bright light. Now suppose a second flash to follow the first. If there was no memory of the latter, the state of mind on the second occasion would simply be a repetition of that which occurred before. There would be merely another sensation. But suppose memory to exist, and that an idea of the first sensation is revived. Then there would arise in the mind of the sentient being two entirely new impressions, one the feeling of the *succession* of two sensations, the other the feeling of their *similarity*. Yet a third case is conceivable. Suppose the two flashes to occur together. Then a third feeling might arise, namely, the feeling of *co-existence*. These feelings are fundamental and are not susceptible of further analysis. They are ultimate irresolvable facts of conscious experience. In order that they may be generated, the pre-existence of at least two sensations is required. Thus the materials furnished by the senses are taken up by the active mind, and their fundamental relations discovered. Unless the mind is assumed to be endowed with an active power, the discovery of these fundamental relations is inconceivable.

Apparently, then, knowledge consists primarily of a series of perceptions, the materials for which are supplied, in the form of sensations, by the sense organs, and these materials are sorted out and rearranged by the active conscious mind. The mind has the power, however derived, of detecting co-existences, successions, and similarities amongst the materials supplied, and is thus able to synthesise knowledge. Complete knowledge consists of the perception of sensations *and* of the perception of the relations amongst these sensations.

But it should be observed that most of our sensations are not simple but complex. For instance, we pluck a rose and smell it, and we experience simultaneously at least three sensations, the visual sensation of colour, the tactual sensation of softness, and the sensation of smell. These complex sensations are blended and unified, and it is clear that the mind has the power to take this complex to pieces by analysis, and afterwards to rearrange it, with or without elements of other analyses, into new groups. We thus ascribe to the mind the powers of analysis and synthesis, though these are reducible to the more fundamental powers of perceiving co-existence, succession, and similarity.

All explanations of the nature of perception are hypothetical, the relation of the perceived thing to the perceiving mind being exceedingly obscure. In the transmission of the message from the object to the percipient, some of the pathways are wholly unknown; for of the physiology of the brain and of nerve processes we know little, and of the relation between psychological and physiological processes we know nothing. It therefore follows that, since perception is the foundation on which the whole fabric of psychology is raised, and since the nature of perception is entirely hypothetical, psychology is less a body of positive knowledge than a body of hypotheses.

We are able not only to acquire knowledge, but to retain it and to reproduce it when wanted. Sensations are more or less vivid and are perceived more or less clearly, but with the removal of the external object they tend to pass away though they leave images behind them, and these images, which we use in thinking and reasoning, we call *ideas*. The retentive power of the mind we call *memory*. Further, we can not only recall knowledge out of consciousness, but we have the power of re-presenting it in consciousness. This re-presentative power is *imagination*. But these retentive and re-presentative powers are subsidiary; the work they do is comparable to that of labelling and docketing, sorting and re-sorting, in an office. It is subsidiary to the mind's main function of perceiving co-existence, succession, and similarity. This function of comparison implies the power to divide and separate, conjoin and compose, analyse and synthesise. *Judgment* involves the discrimination and comparison of two or more terms or notions directly together; *reasoning* the comparison of two terms or notions with each other through a third. Judgment and reasoning are thus both special forms of comparison, and are therefore directly developed derivatives of the perceived fundamental relations aforementioned.

So far we have made no assumption as to what the mind is, beyond suggesting what seems to be fundamentally necessary, namely, that it is an active something, capable of detecting relations amongst the materials supplied to it by the various sense-organs. If we assume that it can detect co-existence, succession, and similarity, and their opposites, in a word if it can compare things, everything else can be accounted for. As its knowledge grows, its powers grow. If, then, we need not assume that it was born into the world, endowed with any other power than the one mentioned, what are the innate ideas about which philosophers hold such fundamental differences of opinion?

5. The Categories. *A priori* Knowledge

In the perception of any of the relations of co-existence, succession, and similarity, all involving as they do an act of comparison, the mind forms a primitive judgment. In the last resort a judgment invariably consists either in the discrimination of a difference or in the determination of an agreement between two or more things. Such fundamental and irreducible relations which the mind thus judges to hold universally among the particulars of experience are sometimes called *categories*. But while categories are grounded in experience and only formed on the contemplation of experience, they contain an inexperienced, inexplicable *a priori* element which we are driven by the necessity of thought to accept unquestioned. The mind contemplates experience and in it perceives the truth; it does not create the truth.

Different lists of categories have been drawn up by different philosophers, but any list can only be accepted provisionally. Every logical process necessarily originates in experience, and with fuller knowledge we may find it necessary to extend the list of categories. For the present, the three, Co-existence, Succession, and Similarity, will sufficiently explain all the known facts of consciousness, and it is unnecessary to assume that the mind is endowed with any other original power than that of comparison in its different forms, or that it came into the world endowed with innate ideas of any kind.

How the mind has acquired its power of perceiving the fundamental relations amongst the facts of experience, and thus of pronouncing its primitive judgments, is unknown. The claim is sometimes made that the *a priori* element in these primitive judgments is the result of intuition, a subject to which we shall return in a later chapter.

All other knowledge, save, perhaps, that of our own existence, is *a posteriori* knowledge, that is, empirical knowledge or knowledge derived from experience. *A posteriori* knowledge admits of verification and demonstration; *a priori* knowledge does not. Some metaphysicians hold that, besides the categories, there are other *a priori* elements in our knowledge, that, for example, there is a personal God, or that the soul is immortal, or that every effect has a cause; and on such assumptions they build up whole systems. But it is a cardinal rule of sound philosophy never to admit any facts *a priori* that admit of demonstration *a posteriori*; and in accordance with this rule, as we shall see later, such metaphysical assumptions as those just referred to are neither justified nor necessary. Apart from the categories, in fact, none of our knowledge need be assumed to be innate.

Consider, for example, how the mind probably establishes the maxim—Every effect has a cause. No universal or necessary truth can be established without a process of *a posteriori* induction. For all primitive judgments of the mind are individual. The mind observes a particular relation of succession, and pronounces the judgment that the first element in the succession is a "cause" of the second. The mind does not metaphysically announce that every effect must have a cause, but it declares that of this given effect there must have been a cause. Numberless similar individual judgments lead ultimately to the conclusion that *every* effect has a cause. The general maxim is obtained by a process of generalisation of the individual judgments. It is not, strictly, a generalisation of an outward experience, but of inward and immediate judgments of the mind, which carry in them the conviction of necessity; and this necessity will therefore tend to attach itself to the general maxim. Even if the general maxim be regarded as a generalisation from outward experience, the mind obviously has to make a leap from that experience, necessarily limited, to the universality implied by the maxim. This leap may perhaps be justified by the still greater induction known as the Uniformity of Nature. Even so, the mind makes a leap beyond experience, and an *a priori* element is unavoidable. Thus absolute certainty can never be reached, only a very high degree of probability. To say, as some metaphysicians do, that the maxim, every effect has a cause, is entirely innate in the mind, that it is wholly *a priori* in its nature, and is wholly independent of experience, is reminiscent of the scholasticism of a thousand years ago.

6. The Contrast of Subject and Object

All consciousness must in the first instance present itself as a relation between the distinguishable parts of a duality, the person who is conscious and the thing he is conscious of. In order to be conscious at all, a person must be conscious of something. This contrast has been indicated, directly or indirectly, by various names: mind and matter; person and thing; subject and object; self and not-self; the ego and the non-ego. Mind, the ego, as knowing subject may therefore be at once connected and contrasted with its known objects. That an external material world exists independently of our knowing it, and that its existence is not affected by our knowledge of it, is a belief that seems at once instinctive, inevitable, and necessary.

Introspectively, at any moment, I am aware that I exist and continue to exist through changing states of consciousness. I know that I exist, but what I am, how my ego is constituted apart from my material organism, I do not know. I am not justified in assuming, from the evidence of introspection alone, that my ego is, for instance, a self-existent entity indestructible by the forces that ultimately destroy my material organism, or that my consciousness is to be attributed to anything of the nature of a phantom-like double of the body. All that I can with certainty say is that when I concentrate my attention on the simplest act of perception, I have the irresistible conviction that I exist and that something else exists, and that I am conscious of both existences at the same moment.

We may therefore lay it down as a necessary conviction that consciousness gives us, as an ultimate fact, a knowledge of both the ego and the non-ego in relation to and in contrast with each other; and it gives these elements in equal independence. In other words, mind and matter present themselves in absolute co-equality. This fact, however, is by no means universally accepted, and even when it is accepted it is accepted with such qualifications as it suits a particular philosopher to devise. In short, there are almost as many philosophic systems originating in this fact as it admits of various possible modifications. As might be expected, therefore, no consistently logical classification of the different schools of philosophy is possible. We may, however, give some indication of the broad distinctions amongst them.

7. The Different Schools of Philosophy

The first distinction may be drawn between those who accept, wholly and without reserve, the fundamental fact that mind and matter are separately clear and distinct to consciousness, and those who do not. Thus we have:

A. *Natural Dualists* who regard mind and matter as real entities, distinct and separate from each other.

B. Those who do not so accept the fact.

Now it is undoubtedly true that the only *positive* knowledge we have of mind and matter is a knowledge of *phenomena*, and we may therefore suppose and consequently assert that all our knowledge of mind and matter is only a consciousness of various groups of mere appearances. But on the other hand, we might assert that the known phenomena of mind and matter must necessarily be referred to underlying substances or substrata of some kind, though actually unknown. Thus our class B may be subdivided into:

I. *Nihilists* who deny that the testimony of consciousness can guarantee a substratum or substance underlying the phenomena of either the ego or the non-ego, and who assert that perceptions and ideas are the only realities.

II. *Realists* who affirm that the testimony of consciousness can guarantee the existence of a reality, a substance or substratum, underlying the phenomena of the ego and also of the non-ego.

Realists are of many kinds, but they may be grouped into two main classes:

1. *Hypothetical Dualists* who accept the testimony of conscious-

ness as to the ultimate duality of the ego and non-ego, but maintain that our consciousness gives us no *direct* knowledge of anything beyond phenomena; that we therefore have no immediate knowledge of the existence of matter or of mind, though we are compelled to assume the existence both of a substance or substratum in which the qualities of matter inhere, and also of an entity—mind, subject, or spirit—which perceives the facts of consciousness, though the nature both of the substance and of the perceiving entity is unknown.

2. *Monists* who reject the testimony of consciousness as to the ultimate duality of the subject and object, the ego and the non-ego. Monists fall into two classes, according as they do or do not preserve the equilibrium of subject and object.

(i.) *Objective Idealists* who hold the doctrine of Absolute Identity. They admit the testimony of consciousness as to the co-equality of mental and material phenomena, but not as to the antithesis of mind and matter as existent entities. They maintain that mind and matter are only phenomenal modifications of the same unknown absolute reality; for since the impenetrability of matter is intelligible only as a mode of resistance, the essence of matter must be some kind of power which it possesses in common with spirit. Matter and mind, or body and spirit, are therefore different aspects of a common substratum.

(ii.) Those who deny the evidence of consciousness as to the co-equality of mental and material phenomena, and subordinate the one to the other entirely. Thus we have:

(*a*) *Idealists* who maintain that the subject, the ego, was the original and is the only fundamental, and that the object, the non-ego, is evolved from it as its product. The fundamental reality is psychical; all matter is, at bottom, of the nature of thought.

(*b*) *Materialists* who maintain that the object, the non-ego, was the original and is the only fundamental, and that the subject, the ego, is evolved from it as its product. There is nothing but matter. Mind, thought, consciousness are all by-products, epiphenomena, mere débris resulting from material processes. Life and consciousness cease absolutely with the disintegration of the matter with which they are associated.

Thus both Idealists and Materialists believe in a reality, but in a single reality. They are therefore at the same time Monists and Realists.

It will be observed that all the different schools mentioned, Nihilists excepted, are Realists of some kind. The four main schools may be grouped in this way :

1. Dualists :
   (*a*) Natural Dualists (sometimes called simply Realists).
   (*b*) Hypothetical Dualists (sometimes called Phenomenalists).
2. Monists :
   (*a*) Idealists.
   (*b*) Materialists.

But the dividing lines are by no means so clear cut as this simple classification would seem to indicate. One school tends to shade off into another, and sometimes they are scarcely distinguishable. Indeed the terminology is most confusing, and is of very varying connotation.

A few other terms require brief explanation.

Sensationalism maintains that all our knowledge comes to us through the senses and refuses to admit that the mind is a co-contributor. *Empiricism* is sometimes confused with sensationalism, but empiricism admits that the mind must be something endowed with power to compare and contrast the data supplied by the senses, and thus to form judgments. All evidence derived from the senses is of particular truths. In every general truth there is an element of knowledge independent of such evidence, that is, independent of the data of the senses. Contrasted with sensationalism is *Rationalism,* which asserts that the knowledge which comes to us through the senses is fallacious, for perception and experience can give us information concerning only particular instances, and can therefore never provide us with universal truths. The rationalist claims that *reason* is the sole source of real knowledge. Metaphysical rationalism must not be confused with theological rationalism, which is the doctrine that denies the existence of any supernatural revelation. But in both cases rationalism is an uncompromising assertion of the absolute rights of reason throughout the whole domain of thought. Both sensationalism and rationalism are dogmatic, as with both it is an article of faith that we have the power of acquiring complete knowledge, in the one case exclusively by perception, in the other exclusively by reason. In contrast with this dogmatism is *Scepticism,* which always doubts and sometimes denies the possibility of our acquiring true knowledge at all.

Agnosticism asserts that our knowledge is limited to the phenomena of the external world and of the mind, and that we know nothing of the ultimate reality which may lie behind phenomena. The agnostic disagrees both with the man who asserts and with the man who denies the existence of reality underlying phenomena, for neither can prove his case. The agnostic says that "he does not know" whether it exists or not. He will not agree even with the Hypothetical Dualist who assumes an unknowable. Agnosticism is negative. It differs from *atheism*, which positively denies the existence of a personal God. Agnosticism "does not know" whether there is a personal God or not.

Positivism, like agnosticism, accepts all positive facts, but adopts a less negative attitude in all other ways. In its outlook it is somewhat supercilious, stating that any man with a claim to intellectuality first discards his theology, then his metaphysics, and comes finally to rest in a contented acceptance of positive facts, though, curiously enough, one form of positivism fabricates a new kind of theology, or rather of religion, for itself. This "Religion of Humanity," which theoretically is admirable, is coldly received, mainly because of the grossly irregular life led by its founder.

The less liberal type of theologian naturally dislikes not only atheism but also materialism, for a materialist is necessarily an atheist. And he has no great love for agnostics and positivists, or even for phenomenalists, and he invariably speaks of them in disparaging terms and of their materialistic tendencies. Towards Idealism he is much less hostile, though this attitude he finds it impossible to defend logically.

8. Hypothetical and Natural Dualism

We have referred to the unknown real thing, the substratum or substance, which the Hypothetical Dualist assumes to underlie phenomena, the substance in which phenomena are supposed to "inhere." The term phenomenon is equivocal. In science it refers to the positive facts of perception, as distinguished from their causes. Scientific thought, in dealing with the concrete things of physical science, investigates their nature, their causes, and their effects, and so goes beyond mere sense-perception. It assumes the existence of atoms and of the aether, neither of which can be directly perceived at all. The atoms and the aether are inferred from a combination of observations and hypotheses. This inferential process is an imaginable one, for any conceptual region is necessarily conceived as though it might be perceived; and by its means the atoms and the aether may be seen as if under an indefinitely powerful microscope. We can verify perceptually only up to a certain point; the weakness of our senses leaves a great deal unperceived and imperceptible. This conceptual region would, if our inferences and hypotheses are correct, and if our senses were sufficiently keen, be perceptible. It has to be admitted, unfortunately, that while the human understanding attempts to construct conceptual systems because it is not satisfied with the contents of sense-perception alone, it sometimes uses these conceptual systems of its own construction for the purpose of disparaging sense-perception as an illusion, although aware, of course, that it is from the data of perception that the suppositions of the conceptual system derive the whole of their vitality. Sometimes attempts are made to construct conceptual systems which are not clearly imaginable: that way lies inevitable danger.

(*a*) *Substance*

The Hypothetical Dualist's substratum is not phenomenal, for it cannot be made to appear to the senses. But although it is claimed to be more real than phenomenal, its existence is merely inferred. Since, however, the inference is not verifiable, we may deny its legitimacy, especially as the substratum cannot be made part of any conceptual system, for it is wholly unimaginable; and this means denying the existence of the substratum, and therefore the existence of matter. Such a denial admits of no answer, though it certainly carries no conviction. It carries no conviction because we cannot bring ourselves to believe that the external world would cease to exist if our minds were annihilated. We feel bound to believe in the existence of an external world which is quite independent of any percipient.

"Substance," then, is the term given by the Hypothetical Dualist to that elusive yet necessary something, that obscure substratum, common to all material things, without being discoverable in any one of them, something which is never actually experienced, but something which is thought into things, nevertheless a real thing though a transcendent thing. It is some kind of undiscovered basic reality, transcending all experience, and the aether of space may perhaps be regarded as the first stage of its phenomenality.

(*b*) *Primary and Secondary Qualities*

All the "phenomena" of the external world known to us in sense experience are logically reducible to a comparatively small number of common " attributes " or " qualities " which are (as the Hypothetical Dualist claims) inherent in the assumed underlying " substance." These qualities are usually distinguished as primary and secondary. Primary qualities are those derived from our muscular sense of resistance; *e.g.*, solidity, extension or size, and motion. They are those attributes of the external world that are regarded as independent of the observer. Secondary qualities are those derived from our other senses; colour, sound, taste, smell, temperature, are examples. Science teaches us that the things of the external world have only the primary qualities, and that these are among the causes of the secondary qualities, though the secondary also depend upon the existence of a sentient being. The primary qualities are permanent in time; the same whether we are present or absent; objective, and that about which there is no difference of opinion; measurable in three dimensions of space, in duration of existence, and in energy. The secondary qualities are not permanent in time, do not exist in the absence of a sentient being, and are not satisfactorily measurable in any way except by referring their phenomena to primary standards. The secondary qualities have no independent existence in the external world: this is a scientifically established fact. If we think of the world or any part of it in the absence of all sentient beings, we think of it as absolutely dark and absolutely silent.

The secondary qualities are really subjective reactions excited by the primary qualities and objectified by association with them. The primary qualities are the most constant and unconditional in experience. Illusions are chiefly of seeing or hearing; whereas to touch or grasp a thing usually produces conviction. Since it is in their primary qualities that things are most exactly measurable in dimensions, weight, and movement, it is natural that science should regard the primary qualities as pre-eminently real. But it must never be forgotten that the primary qualities are, as truly as the secondary, grounded in sensations and therefore liable to mis-interpretation.

The nature of the Hypothetical Dualist's " substance " is admittedly extraordinarily elusive: an unperceivable support of perceivable qualities necessarily seems to be something without assignable character, resembling nothing in experience and therefore explaining nothing. But if it exists at all, there is one quality we are bound to ascribe to it, and that is permanence in time, for this corresponds to the continuity of the experienced external world in the past and in the present. But, even so, permanence in time does not seem to help us to establish any connection between other primary qualities and the assumed substance, and such terms as "underlie" and "inhere" are mere metaphors having no significant meaning. Still, the notion, though necessarily vague, of permanent transcendent substance, does give coherence and unity to the phenomena of the external world with which we are familiar.

If we accept Hypothetical Dualism, it is best to regard "substance" as a category—as one of those unverifiable, unanalysable, fundamental, ultimate, concepts which the mind is driven by necessity to try to form. If we reject the category as illusory, the argument as to the possible coherence of phenomena seems to be reduced to nothing. If we accept it, that is, if we recognise substance as a category indicating the reality which is not immediately given to us in perception, yet felt to be necessary for the understanding of phenomena, and accept it either *a priori* or as the result of reflection upon experience, the term seems to suggest something which is not very far removed from the ordinary matter of Natural Dualism after all. Yet the distinction may be usefully preserved. The distinction is just what is required to make the doctrine of transubstantiation intelligible, for a change in the *substance* of the sacramental elements, though unimaginable, is not inconceivable, all the *qualities* of the elements, primary and secondary, remaining unchanged. Ultimately, perhaps, physical science will solve the problem of matter and substance, and there can be little doubt that the primary qualities of matter—resistance, extension, weight, motion—will give us the key to the solution.

The position of the Hypothetical Dualist as contrasted with that of the Natural Dualist ought now to be clear. Both are Realists, but in the case of the Hypothetical Dualist the real is only inferred; to him, perceptions are perceptions of qualities only. In the case of the Natural Dualist, the real is apprehended immediately; he takes the common-sense view; he kicks against a stone and perceives it immediately and objectively—it is something solid and extended before him, and it can be measured and weighed. That object he takes to be matter. Common sense revolts against regarding the object merely as an idea or as nothing beyond an integrated heap of sensations; and the view of science is that of common sense. But the view is difficult to maintain in its entirety, for it is certain that our positive knowledge, the knowledge that admits of no question, of external reality, is limited to our perceptions of qualities. Whatever we know beyond these qualities is known by inference only, and such inferences seldom admit of complete verification.

9. Monism: Its Logical Consequences

The greatest antithesis in present-day philosophy is that between the two monistic systems, Idealism and Materialism. Between these there is an unbridgeable chasm. A particular system is, however, sometimes prevented from falling into absolute Idealism or absolute Materialism, and is held in a kind of vacillating equilibrium, because in some of its opinions an idealistic tendency is counteracted by a materialistic tendency in others.

It will be understood that the term monism applies to any philosophic system which seeks to exhibit all the complexities of existence, both material and mental, as modes of manifestation of *one* fundamental reality. Idealism assumes that all fundamental reality is psychical, is, in fact, consciousness or mind. Materialism assumes that consciousness or mind is a mere by-product of the one fundamental reality, matter. Idealism reduces matter to mental elements. Materialism identifies thought or feeling with the nerve process which accompanies it.

(*a*) *Idealism*

We may consider Idealism first. Idealism maintains that whatever we know directly is reducible to ideas, and that ideas have an existence more real than the fleeting transient objects of sense; and that the existence of matter is nothing but an illusion. But there are so many forms of Idealism, and its terms are used in so many senses, that it is difficult to come to close quarters with its fundamental assumptions.

If "consciousness" be regarded as denoting the recognition by the mind of its own acts, and "mind" as that which thinks, wills, and feels, it may be said that consciousness is to the mind what extension is to the body. Though the analogy is imperfect it is suggestive, for both consciousness and extension are essential qualities; we can neither conceive mind without consciousness, nor body without extension. But "mind" is sometimes spoken of as if it were precisely synonymous with "spirit." Yet while mind, like spirit, is always regarded as an unknown conscious something, mind is never conceived as extended in space; whereas spirit, though incorporeal, immaterial, and invisible, is usually conceived as so extended, to be invested in human form, and to be a personality somehow associated with the body; it is always thought of as a substantial though immaterial entity which thinks, wills, and feels;

it is of necessity invisible if only because our human sense of vision is limited to material things. But whereas a spirit is always conceived as an entity distinct from, though during life closely associated with, the body, the mind is seldom spoken of as if it were something that could exist independently of the body. The reader who takes up a book on Idealism must assure himself of the precise meaning attached to these terms by the writer. If the writer describes mind and spirit as, for instance, " transcendent realities of reflection," it may safely be assumed that he is trying to conceal, behind a rather pretentious definition, the fact that he despairs of finding a solution to the problem in hand.

All Idealists deny the existence of matter, though some of them say that all they really deny is the unknown substratum, " substance." Some Idealists recognise the existence of spirit as an entity which thinks, wills, and feels. Others limit their recognition to the much vaguer thing, mind, still conceived, however, as an entity of some sort. Still others assert that, since all we positively know of mind are the facts of consciousness, we are not justified in assuming the existence of mind as any sort of separate entity; and they maintain that the only real things in existence are mental facts, ideas.[1] They make vague statements about a universal consciousness, all men's minds being alike in this respect, that each is a sort of temporarily separated portion of this universal consciousness.

Now if we are sure of anything, it is that consciousness is personal and individual; men's minds may in many respects be alike, but their differences are great and fundamental. A common consciousness is not only unimaginable, it is inconceivable. But more than this: Idealism altogether fails to explain the primary qualities of matter—extension, inertia, impenetrability. Despite his clever paradoxes, the Idealist cannot get rid of matter by dissolving it in mind. When material objects are in question, common sense refuses to admit that *esse* and *percipi* are identical. It is impossible to accept the ultimate logical conclusion of Idealism, that, with the expiring breath of the last sentient being, the whole universe disappears into nothingness.

(*b*) *Materialism*

To materialism, the only real world is the world of matter, the

[1] A distinction may be drawn between two main forms of Idealism, the Platonic and the Berkeleyan, as they may be called. According to the first, the real consists of ideas, intelligible realities, eternal values, which are not dependent on mind for their being; according to the second, all reality consists of minds and the contents of minds.

world of atoms with their primary qualities and motions. Life and consciousness are the products of matter and manifest themselves in complexities of atoms. From such complexities life is, in favourable circumstances, spontaneously generated, and spontaneously generated living matter has, by blind chance, passed through the various stages of evolution until the human being reached his present state of development. The cause of the order of the world is not God but the evolution of matter. There is no God, no soul, no freedom, no immortality. All psychical activity, all consciousness, is ultimately nothing more than a motion in and amongst the cells of the grey substance of the brain, possibly some form of wave-motion or of radiation set up by the movement. All thoughts and feelings are not merely accompaniments but are identical with these nervous processes. The mind is nothing more than a function of the brain. All psychical facts are merely effects, though unexplained effects, of cell movements in the brain. Thought bears much the same relation to the brain as bile does to the liver.

The weakness of materialism lies not only in its vast assumptions, but in its failure to give any explanation of the ultimate origin of either matter or motion. It is impossible to believe that the thinking, feeling self, of which each one of us is conscious, is only an automaton; and even the materialist is forced to admit that we simply do not know whether there is any causal connection between the psychical facts and the physical changes which accompany them. Materialism fails to give any satisfactory explanation of the nature and origin of life and consciousness. Common sense refuses to admit that consciousness is nothing but a movement of matter.

The claims of materialism lead to far-reaching logical consequences. For the materialist asserts that all our volitions are mere links in mechanical chains of blind causes and effects. Now men act in consequence of motives, and their motives are thus the result of preceding facts, so that if we knew the antecedents of these facts and the laws that connect them, we could with infallible certainty predict the consequences, immediate and remote. If Adam had been a super-mathematician, he might, automaton though he was—assuming that he was acquainted with all molar and molecular masses, their initial positions, direction of motions, velocities, and accelerations—have predicted the whole course of the world's history; he might have written out a complete account, complete to the last detail, of the great European War; he might have predicted the date, place, and manner of death of the world's last mosquito; nay, he might have foretold the very terms of the marriage-contract between the Tellurian Kaiser and the Martian Queen, to be sealed a couple of centuries hence. To the materialist, the human will counts for nothing and can effect nothing; our every decision is the infallible consequence of particular cerebral changes. The individual who, while balancing two courses, is under the impression that he is at liberty to pursue either, is completely under a delusion. The most calculating selfishness, the most heroic self-sacrifice, equally have been determined by chance aggregations of molecules. Newton did not write the *Principia*, or Shakespeare, *Hamlet*; they were not creative personalities; they merely looked on while blind causes were at work. They were merely chance aggregations of molecules, constituting automata with fortuitously specially active cerebrations. So with all things that ever have been or ever will be produced. It is mere fancy, says the materialist, that we ever act from rational motives. No criminal is morally reprehensible; he is simply morally irresponsible. How can a materialist give his support to any sort of penal code? But to this question he can only logically answer that he, too, is irresponsible for his actions.

10. Conclusion

It cannot be said that, although they are mutually destructive, either Idealism or Materialism is in itself a fundamentally illogical system. Each is logically worked out, but neither is acceptable because of the ultimate consequences traceable from its hypotheses; in each case the consequences are such that common sense declines to accept them, and this really means a rejection of the hypotheses on which the systems are constructed. In fact, every system breaks down that refuses to accept the cardinal fact of the duality of consciousness. Mind and matter are two entirely distinct things present to our consciousness; they cannot be reduced the one to the other, in the first place because resistance is incompatible with the attributes of mind or spirit, and in the second because consciousness is inexplicable by the qualities of matter. We may, if we like, recognise materialistic monism of body and an idealistic monism of spirit, combined in a unified dualism of substances, namely, the unified substances of body and spirit or matter and mind in the single personality of man. But the refusal to accept the great underlying fact of duality of consciousness is an act of philosophic suicide.

There is not a philosophic system but is open to attack, for every system rests on hypotheses which, ultimately, are not verifiable. Dualism of both kinds is attacked, Natural Dualism because it takes too much for granted, Hypothetical Dualism because of the assumption of unknown and apparently unknowable entities. Still, the ultimate consequences of Dualism are not so destructive as are the consequences of Monism.

No philosophic system is closed and final. No philosophic system can give complete repose. Philosophic finality is still a philosophic dream.

There are some philosophers who are less anxious to understand the world of science than to convict it of unreality. They shrink from the laborious study of the detailed knowledge derived from the senses, and prefer to pin their faith on the wisdom, sudden and penetrating, which they believe will reach them by reflection and reasoning. In their more emotional moods a belief in the unreality of the world of science arrives with irresistible force, and when this emotional intensity subsides they seek for logical reasons in support of that belief.

The attitude is altogether wrong. Like the man of science, the philosopher must lay aside his hopes and wishes when he studies his subject. There must be no shrinking from hard facts, no demand in advance that the world shall conform to preconceived desires. Knowledge of the universe is not hidden by a flimsy veil that can easily be torn aside ; it is very hard to come by.

Common opinion prevails that metaphysical disquisition is idle, because the problems discussed are really never solved. It is quite true that philosophy has made greater claims and achieved fewer results than any other branch of learning. It has made many rash assertions and many rash denials. Yet some of the greatest thinkers since the age of ancient Greece have devoted their lives to philosophical problems, and no one would dream of calling them either shallow or insincere. That progress has been slight is inevitable, for the great mass of philosophy is necessarily purely speculative. There is very little philosophical truth finally established, and additions can be made only at the cost of much labour, very slowly, and only then if the method of science is made the method of philosophy. Existing systems are often ingenious, even sublime, but they nearly always lay claim to finality and completeness. And it is for this reason that many philosophers are still the playthings of the gods.

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CHAPTER II

OPINION AND TRUTH

1. English and German Modes of Thought

THE contrast in the ideals of neighbouring nations is often remarkable, even when the nations belong to the same original stock. A particularly interesting example is afforded by Britain and Germany, between whom, during the great war, the contrast has been intensified by a mutual severity of criticism. One well-known German recently wrote of us that we "preferred sport to labour, selfishness to sacrifice, and wire-pulling and patronage to efficiency; that we despised knowledge, that we had no sense of organisation, and that we were shallow, conceited, and insincere." And the writer went on to try to prove that all these and many other faults were traceable to the defects of our system of education. It is only natural that we should resent such criticism, but our sense of justice compels us to admit that not only is much of it justified but that there are certain phases of German education that command respect.

German education has stimulated a thirst for knowledge; it has made the nation alert to science; it has made systematic co-operation a habit; it has taught patriotic duty; it has made the people industrious and thorough; it has given them the strength of discipline; and it has made profitable use of second-rate intelligences. On the other hand, there can be no question that German education has deliberately been converted into a formidable engine for controlling conduct and swaying purpose, for it tends to make the people think in herds; thought is thus deflected from the pursuit of truth, and is converted into a kind of predominant instinct, and the workings of this instinct reason tends to become merely a means of justifying. Where a lie will serve their country better, Germans do not acknowledge any moral obligation to tell the truth to foreigners. They believe that they attain to righteousness and truth by surrendering their sense of both to their country, for to Germans it is Germany that makes truth true and righteousness righteous.

In our natural dislike of the Germans we are often unjust to them. To single out the defects to which any type of mind is liable, and offer that as the whole account of it, is a misrepresentation that the strongest dislike cannot justify. It is sometimes said, for instance, that German scholarship is mere industry in accumulation, accompanied by only a very small measure of fine perception. Both English and German types of mind have their special limitations and defects, more pronounced in the second- and third-rate men, and tending to disappear in the men who stand up above the common level. But the main reason why German scholarship should appear as the dull industry of mediocrities is a reason which does not reflect on Germany. Through the elaboration and organisation of its scientific work, a large number of mediocrities are always employing themselves in work in which they can be useful, in the industrious accumulation and digestion of masses of material—texts, historical facts, linguistic phenomena—and in the prosecution of systematised scientific research in hundreds of laboratories. The scholars of the first rank who make use of all this material and combine with it ability of a high order, originality, and imagination, are to some extent lost for foreign view among the crowd. In England, workers of the first rank stand out in much more individual prominence.

Yet there is one fundamental difference between English and German scholars. Taught by Bacon, English scholars seem to have acquired an instinctive desire to accumulate all possible facts before attempting to frame anything of the nature of a general law. But German thinkers tend to generalise before the accumulated facts afford the necessary justification. Their curious love of abstraction, and their desire to deduce a whole universe from a few general propositions, constantly lead to their illegitimate use of deductive reasoning; they seem to be unsuspicious of the dangers of loosely established generalities.

If we forget the leaders and consider merely the average men, there is probably little to choose between the German and the Englishman. The former's subservience to his rulers leads to the acceptance of his rulers' opinions. The latter's faith in the party newspaper and the party politician leads equally to the acceptance of ready-made opinions. Neither the German nor the Englishman thinks for himself, the German because he is intellectually servile, the Englishman because he is intellectually lazy.[1]

It is characteristic of certain nations, ourselves not excluded, that not only is the average man disinclined to think for himself, he is apt to make misstatements concerning the incidents of every-day life. Passing feelings prompt stronger words than are justifiable, and the desire to interest listeners leads to inaccuracy of statement, even to exaggeration. If there is exaggeration over trivialities, it is hardly likely that a more judicial tone will be adopted when the things discussed are momentous. It is not a question of intentional lying. Direct lies told to the world are as dust in the balance when weighed against the falsehoods of inaccuracy, and in this country the falsehoods of inaccuracy are in no small measure traceable to the political partisanship which is so characteristic of our national life.

2. In Opposition to Truth: Political Partisanship

Party spirit affects for the worse even minds which are not commonplace. Each party has ends of its own, and is not always scrupulous in its method of attaining them. Each party claims to be able to set the world right, given only unlimited power.

It would, of course, be untrue to say that any party is now corrupt, unless the term can be applied to the common practice of purchasing honours by making contributions to the party funds; but each party does its best to draw to itself the allegiance properly belonging to the State. Each party passes lightly over everything that would do the party harm, and dwells unduly on everything that increases its credit. Party men who are sincere and whose probity is beyond reproach may occasionally prove to be the most dangerous type of all, for they are apt to identify the cause of their party with the cause of righteousness.

Votes in Parliament are rarely affected by the arguments advanced on one side or the other, for members are elected to give a general support to a particular party and to the policy with which that party is identified. The art of political reasoning differs from the art of pure logic in this, that whereas the latter consists in drawing sound conclusions from premisses assumed to be true, the former consists for the most part in fitting plausible premisses

[1] The embers of the great war are still glowing, and the author is therefore well aware that he may have appeared to be harsh and unjust in his judgment of a nation once great and no doubt to be great again. But the judgment is based upon facts well known for many years.

to foregone conclusions. It is sometimes argued that in proportion as the process of forming opinions has been slow, circumspect, and deliberate, so should the process of changing them be equally slow, circumspect, and deliberate; that we pay our opinions scant respect if we hold them at the mercy of the first clever advocate who assails them with arguments to which we cannot produce an answer on the spur of the moment. This is precisely the reason put forward by the party politician in excuse for the automatic registration of his vote. But he knows full well that he is not at liberty to give expression to an opinion based upon the weighing of the evidence for and against a proposed measure: not that way lies his reward.

A member of Parliament is elected by a majority, but a decision by a majority is, in general, opposed to the principle of judgment. Decision by a majority places all members of the body on the same footing, and gives an equal value to the opinion of each. It makes no distinction between them as to competency, but allows equal weight to the votes of the persons most able, and of those least able, to form a correct judgment on the question to be decided. Attention is not paid to special fitness, only to numbers. An astute politician makes a careful study of the psychology of the crowd, for he well knows not only that the majority of the men who compose his local audiences are men with little insight, with undeveloped intelligence, with little knowledge, and with a narrow range of experience, but that a crowd as such is devoid of intellect and is possessed only of emotions. His stock of rhetorical devices enables him to make to the crowd a suggestion which they think is their own; he thus anticipates the direction in which the crowd will move, and then loudly directs it to go that way. A crowd is a new entity differing in mind and will from the individuals who compose it. Its intellectual pitch is lowered, its emotional pitch raised. It takes on something of the character of a hypnotised subject. It tends to be irrational, lacking in self-control. At a political meeting, and even in the House of Commons, it is interesting to watch how even highly intelligent men are carried away by the words of an orator—men who have every rhetorical device at their own finger-ends, and are fully aware of the artificiality of much of what the orator is saying.

Political prejudice is intensified by two special influences. The first of these is that of the newspaper press. The newspaper press of the last century was a great educational force. Day by day it exerted its power to influence its readers to better citizenship, and its enterprise was directed to the provision of authentic and accurate news. The newspaper press of the twentieth century is tending to substitute the business man for the man of letters. A certain number of present-day newspapers are seriously inaccurate in their statements of facts. There is competition amongst them not only for news but for news served up in an attractive form, and the desire to interest the reader is tending to become greater than the desire to inform him. Then, nearly every daily newspaper is a party newspaper. To ensure a large circulation it must provide its readers with what they want, and it must therefore make concessions to political prejudice, and sometimes even to uncultivated taste. It must push into prominence everything that is derogatory, and keep out of view everything that is favourable, to the character of the person whom it may suit the needs of the moment to belittle. The daily press is said to be independent, and that in a sense is true, but if it ceased to be partisan it would cease to be profitable. If all daily and weekly newspapers could be induced to confine themselves to facts and to state these facts accurately, the educational gain would be considerable, if only because people would then be under the necessity of forming opinions for themselves. Happily there is still a section of the press worthy of the best British traditions. *The Times*, for instance, is rightly regarded as a great national asset.

The second influence intensifying political prejudice is that of the legal profession. In his professional work every lawyer employs his energy, eloquence, subtlety, and knowledge " to make the worse appear the better reason." If he has a bad case, he sets himself to deceive the jury; he uses every device known to rhetoric to appeal to the emotions and to obscure the facts; he tries to injure the character of his opponents' witnesses. He is not paid to establish the truth but to win his case, and if he does this, few will think any the worse of him. In private life he may be the most moral, the most religious, of men. His professional work is supposed to meet a public want, and in any case it forms an admirable training for the platform of party politics. Who then would deny him his reward, or begrudge the honours so liberally bestowed upon him?

Now the mere fact that he has acquired the art of making the worse appear the better reason makes him specially welcome to the ranks of a political party. Forensic advocacy in the law-courts does comparatively little harm, provided the judge is just and able, for insincerity is there recognised as a necessary part of the atmosphere. It is doubtful if any judge ever seriously listens to the concluding speeches of counsel for the defence and the prosecution, for his business is to get at the facts, not to listen to opinions which he knows to be partial. It is common knowledge that in a court of justice a lawyer is exempt from the ordinary rule that binds an honest man to use only arguments which he believes to be sound. But when the lawyer carries his professional methods into the political arena, the unsuspicious public are apt to accept his advocacy as that of a trustworthy person, whereas the advocacy is often full of subtleties of which the unsuspicious public never dream. The advocacy is often insincere, purposely designed to intensify political prejudice, and sometimes deliberately dishonest. As it is too much to hope that a lawyer shall be disqualified from holding political office, what can be done to get rid of the unfortunate influence he exerts in the political world ?

Probably nothing. The party system is the result of historical causes and social conditions, and developed in the same natural and largely accidental fashion as other elements in our working constitution. It is so ingrained in English political life that the evils are hardly likely to be uprooted, and as long as it remains it will certainly retain the props that give it greatest support. Still there is some reason to hope that a more judicial frame of mind on the part of an increasing proportion of the people will ultimately result from a more enlightened education and from a more general training in scientific method.

3. In Favour of Truth : Scientific Investigation

The student of scientific research must before all things look upon himself as one who is summoned to serve on a jury. He has only to consider how far the statement of the case is complete and clearly set forth by the evidence. Then he draws his conclusion and gives his vote. And in acting thus, he remains equally at ease whether the majority agree with him or whether he finds himself in the minority. Scientific discovery almost always depends upon a man's looking at something in the dry light of the intellect, and isolating himself from previous thoughts both of himself and of others about it. In the higher sense of the word, discovery is the serious exercise and activity of an original feeling for truth ; the truth is sought, laboriously and silently, in the hope that it will suddenly flash out into fruitful knowledge.

Many of the facts of science can be verified by repetition, and many of them measured quantitatively. Hence the investigator acquires a definiteness of grasp and a clearness of view of the relations between cause and effect not otherwise attainable. By patient observation and experiment, by classification and inference, by framing and testing hypotheses, by rejection of the inadequate, and by verification of the valid, the investigator establishes the generalisations of science. The great generalisations of the inorganic world—the laws of the conservation of matter and of energy, the law of universal gravitation, the laws of chemical combination—all these have resulted from the long-continued efforts of many minds. In the organic world there is more room for doubt. Such generalisations as the laws of heredity and evolution cannot, from the nature of the case, be established on a quantitative basis, but they are the result of equally zealous and careful research, and of their truth there is a greater or less degree of probability.

People unversed in science frequently impugn scientific method because of the hypotheses to which science constantly resorts. But this is due to a misunderstanding of the nature of hypotheses. An hypothesis is devised to account for, to link together, and to explain, a group of objective facts. It is a mentally constructed and quite imaginary mechanism, and though a pictorial conception it is not in any way supposed to be necessarily representative of the actual machinery of nature. Whether, for instance, there are such things as atoms, and whether the atomic hypothesis is actually in accordance with nature, we do not know. We form an hypothesis in order to endeavour to deduce from it conclusions in accordance with facts, the supposition being made that if the conclusions to which the hypothesis leads are verifiable, the hypothesis is likely to be true. An hypothesis is only one conception among many possible alternatives, and must never be thought of as if it were a real fact. A scientific investigator hazards a number of hypotheses to explain a group of facts, and he tests them one by one to see which is nearest to the truth. For every hypothesis that proves acceptable, he may frame a score that may prove invalid. An hypothesis is sometimes described as a guess. So at bottom it is; but, after all, it is an intelligent guess and is the outcome of an inference from real data. It is wrong to call it idle speculation, though of course popular writers on scientific subjects are apt to indulge in speculations that are outside the scope of probability. A layman necessarily fails to appreciate a scientific hypothesis, for it is in the highest degree unlikely that he can understand the evidence that led up to it. If new facts are discovered that show an hypothesis to be invalid, a new hypothesis is devised to cover both the old facts and the new: this in itself is sufficient to show the provisional nature of an hypothesis. Of course an hypothesis *may* correspond to objective fact, and this may be ultimately proved. If, for instance, an optical instrument is ever constructed to render atoms visible to the eye, the atomic hypothesis will cease to be a mere supposition and become a fact. The great characteristic of scientific method is verification at every stage, the guaranteeing of each separate point, the cultivated caution of proceeding to the unknown solely through the avenues of the known. Science demands that every hypothesis shall be treated as provisional until it has been confronted with fact, tested, and verified. The man of science always loves truth better than his system. He is ever ready to throw his system overboard, once new facts prove it to be wrong. He knows that without hypotheses he can achieve nothing, but he has the wisdom to reject all deductions from them unless such deductions are confirmed by experience.

A credulous person is one who is uncritical in regard to beliefs, and shows an ignorant disregard of the nature of evidence. But in this world we have, for practical purposes, to believe or disbelieve many things about which there is no certain proof. Life is too short to investigate everything for ourselves. But practical incredulity is very different from the theoretical incredulity which governs the action of an unbeliever. A man who is theoretically incredulous, for instance, about ghosts, not only refuses to investigate them himself, but also denies that they are a proper subject for inquiry. Of course it is true that many lies have been told about ghosts, and that from time immemorial men have been predisposed to believe in them, and we are therefore naturally inclined to hold that all ghost stories are suspect. But this does not mean that science must not or cannot concern itself about ghosts, for the method of science is most valuable where the subject-matter makes it most difficult of adoption. Science refuses to accept fashionable assumptions, and it always suspects just those dogmas that are repeated most often and with the greatest confidence. Thus, when disbelief in ghosts became an article of faith, then was the time for science to concern itself about them, for it scented danger in the orthodoxy of disbelief. Its business is to be sceptical about denial as much as about assertion, and, being sceptical, it knows when scepticism has stiffened into incredulity.

For instance, the hypothesis has been advanced that ghosts are aetheric memories. The hypothesis has been derived from analogy. We know that sensations are constantly impressing themselves on the mind. The impressions vary greatly in strength; some may possibly be transient and some obliterated; others are certainly permanent. Some return often, some seldom. Now it may be conceded that everything that happens makes an impression on the surrounding matter and on the aether, though such impressions are often imperceptible to the senses. Such impressions certainly vary greatly in strength. We do not know enough about the properties of matter to understand what the ultimate nature of the process may be, but it is quite legitimate and in keeping with the modern trend of physical science to suppose that a phenomenon originally perceptible to the senses may impress itself on the aether, continue to exist aetherially, though now imperceptible, and become again perceptible under favourable conditions. Such an hypothesis would account for most of the authenticated cases of visible ghosts, and of audible but invisible ghosts; also for the fact that the visible ghosts are always seen wearing the clothes they wore in life. If such an hypothesis is put forward—and it certainly seems to cover the facts—it is the business of science dispassionately to examine it: it has no interest in the result one way or the other. If sufficient evidence is forthcoming to justify the hypothesis, science accepts it; if not, science rejects it. Science has but one aim, and that is to discover the truth.

4. Fact and Opinion

When a witness reports that he saw an object of a certain shape or size, or at a certain distance, he describes something more than a mere sensation, and his statement implies a judgment concerning the phenomenon. When, however, this judgment is of so simple a kind as to be wholly unconscious, and the interpretation of the appearance is a matter of general agreement, the perception may be considered to present us with a fact. Thus matters of fact are decided by an appeal to our own consciousness or perceptions, or to the testimony, direct or indirect, of the original and percipient witnesses. Doubts, indeed, frequently arise as to matters of fact in consequence of the diversity of the reports of original witnesses, or the suspiciousness of their testimony. The credibility of a witness to a fact depends on these conditions: that the fact fell within the range of his senses; that he observed and attended to it; that he possesses a fair amount of intelligence and a reasonably good memory; and that he is a person of veracity even when his personal interests are concerned. Statements of fact rest entirely on the credit of known or assignable witnesses. With arguments it is different. These have a probative force quite independent of the person by whom they are propounded.

The essential nature of opinion seems to be that it is a matter about which doubt can reasonably exist, a matter concerning which two persons can, without absurdity, think differently. The existence of an object before the eyes of two persons would not be a matter of opinion, nor would it be a matter of opinion that the sum of three and two is five. But when testimony is divided or uncertain, a supposed fact may become doubtful and therefore a matter of opinion. We are satisfied with the testimony that Caesar invaded Britain, and the invasion we regard as an indisputable fact. But we are not satisfied with the testimony as to the Noachian deluge which, though recorded as a fact, is obviously open to doubt, and is therefore a matter of opinion. The ultimate source of our belief or disbelief in matters of opinion is always a process of reasoning.

Though it is scarcely possible to avoid forming a judgment, in some way or other, on almost everything which offers itself to the thoughts, yet many persons never exercise their judgment upon what comes before them in such a way as to determine whether it be conclusive and holds. The universal tendency of the human mind is to shrink from the trouble of thinking out any of its so-called opinions. People form the habit of letting things pass through their minds rather than of thinking about them. They become mentally indolent, too indolent to judge for themselves. Upon every conceivable subject they take their opinions ready-made. The memory thus becomes a store-house of unorganised facts and conventional ready-made opinions, and these eventually harden into irrational convictions.

People are influenced in their opinion by the prevailing fashion. They fear singularity more than error; they accept numbers as the index of truth, and they follow the crowd. The dislike of labour, the fear of unpopularity, the danger even of setting up individual opinions against established convictions, contribute to strengthen this inclination. People take their opinions from their favourite newspaper, from the accepted beliefs of the society in which they move, or of the party or church to which they attach themselves, from tradition, from custom, from hereditary association, from social environment, from any source except that of careful independent thought. If they are asked why they believe a particular thing, they will say, I have it on good authority, or I read it in a book, or it is a matter of common knowledge, or everybody in the village believes it, or I learned it at school. These replies mean that they have accepted information from others, without making any attempt to verify it, and without thinking the matter out for themselves. The causes of such beliefs are thus obvious, though such causes are clearly not reasons. But the causes may become reasons if we are able to recognise that our teachers, our family, and our neighbours are competent and truthful persons, and possess adequate information. Reasons of this kind are probably the principal ground on which, in mature life, we accept the great mass of our scientific, historical, and other convictions. I believe, for instance, that the diameter of the sun is about 850,000 miles for no other reason than that I believe in the competence of the persons who have made the necessary observations and calculations. In this case, the reason for my belief and the immediate cause of it are identical.

The prevalence of an opinion is no proof of its soundness, for the opinion may have sprung from the most impure sources. Mere unauthenticated rumour, or tradition, imperfect or unverified observation, hasty and illogical generalisation from a few facts, uncorrected by any analytical process, and even deliberate imposture, are often the originating causes of wide-spread opinions. Sometimes these errors are deeply rooted in the popular conviction, and descend from generation to generation. Common superstitions and unscientific weather-lore are instances of this. Fallacies of all kinds are still accepted unquestioned,—for instance, that sugar is a bad thing for the teeth, and that the sun shining into a room tends to put the fire out. Even ministers of religion have been known to maintain that Adam and Eve were turned out of the Garden of Eden for eating of the forbidden fruit; that this fruit consisted of an apple; that the ark rested on Mount Ararat; and that the crucifixion took place on Mount Calvary. Such statements point to an inexcusable neglect of careful reading.

5. Opinion and Conviction. Belief

Men are apt to pride themselves that they are tolerant and respect the opinions of others, but their weakness is that they do not respect their own, because they come by them so easily. Opinions are quite different from convictions. A conviction is something that is acquired slowly, from knowledge and experience; it is the reward that men get for intellectual honesty, and they are slow to get it because, when once it is theirs, they must act upon it or lose it. Often they are hardly conscious of its existence, or only discover it when there is need for action. No man fully realises what opinions he acts upon or what his actions mean, for opinions are less to be acted upon than to be talked about. The man who has clear and firm convictions is by them protected from the indiscriminate invasion of opinions, for he tests opinions by his convictions and, if they are contrary to his convictions, rejects them. Convictions have effect because they produce action. Convictions are active; opinions are passive.

The meaning of belief is less settled than that of knowledge, opinion, and conviction. It sometimes stands for the region of opinion, or the doctrine about which we are not quite confident, so that degrees of belief or of subjective assent are recognised. Belief admits of all degrees of intensity, from the subjective feeling of "necessity," through degrees of probability, to doubt and suspension of judgment; and again through degrees of improbability to disbelief. Suspension of judgment implies that incompatible beliefs are felt to be equally balanced in a mind susceptible to their influence at the same time.

6. Reason and Authority

When a person forms an opinion without any appropriate process of reasoning and without compulsion or inducement of interest, but simply because some other persons whom he believes to be competent judges on the matter entertain that opinion, he is said to form his opinion on authority. If he is convinced by a legitimate process of reasoning from the evidence supporting the question, his opinion does not rest on authority. A large proportion of the general opinions of mankind are derived merely from authority, and are entertained without any distinct understanding of the evidence on which they rest, or the argumentative grounds by which they are supported.

In order that a person may be recognised as a competent authority in matters of opinion, certain qualities are necessary. In the first place, he must have devoted much study and thought to the subject-matter. No person, however penetrating his intellect, can master any one of the more important branches of knowledge unless he devotes to it years of study and reflection. Four or five years' strenuous work at a university is usually a good beginning, but it would be absurd to call it more than a beginning. In the second place, the person's mental powers must not only be equal to the task of comprehending the subject but ought to be superior to the average. His mind ought to be more wide-ranging and far-seeing than that of ordinary people. He ought to be able to trace the remote consequences of a particular principle. In the third place, he must be exempt, as far as possible, from personal interest in the matter: honesty is indispensable. A man's judgment is often blinded by the ardour of contention, by the desire of gaining an argumentative victory over an antagonist, and by the dislike of a confession of error. The dislike of listening to unpalatable truths often induces a man to close his ears to evidence and arguments opposed to the views which he considers favourable to his own interest; on the other hand, the desire to discover new arguments to support his views leads him to read the books and to frequent the company of only those persons whose opinions are in accord with his own interests.

Qualities which render a man a trustworthy authority in matters of opinion are much rarer than those which render a man a credible witness in matters of fact. Hence the honesty which induces a man to speak the truth is more common than that which induces him to form sound opinions.

One clear indication of trustworthy authority is the agreement of competent judges. This is analogous to the agreement of credible witnesses. If ten credible witnesses agree, the value of their concurrent testimony is more than ten times the value of the testimony of each. So with the joint probability of the agreement of ten competent judges in a right opinion.

Authority is both insidious and far-reaching in its action. It is contrasted with reason, and stands for that group of non-rational causes, educational, social, political, and moral, which produces its results by psychic processes other than reasoning.

At first sight, reason and authority seem to be opposed, but the one cannot be held to exclude the other. For a person who chooses his own guides chooses them by the light of his own reason; he exercises a free choice and is therefore ultimately responsible. And it cannot always be assumed that an appropriate process of reasoning upon any subject is a better or wiser principle of judgment than a recourse to the authority of others. Where special attainments and experience are necessary for a safe decision, a man who prefers his own judgment to that of competent advisers certainly does not follow a wise course; and when a man is necessarily ignorant of the grounds of decision, to decide for himself is an act of folly.

The theory commonly held is this. Everybody has the "right" to adopt any opinion he pleases. It is his "duty" before exercising this right, critically to sift the reasons by which such opinions may be supported, and so to adjust the degree of his convictions that they shall accurately correspond with the evidence adduced in their favour. Authority has therefore no place among the legitimate causes of belief. If it appears among them, it is as an intruder, to be jealously hunted down and mercilessly expelled. Reason and reason only can be safely permitted to mould the convictions of mankind.

But the identification of reason with all that is good and authority with all that is bad, among the many causes of belief, is, as Mr. Balfour reminds us, a prevalent delusion. The tacit assumption so commonly made that reason means right reason is absurd. Reason can no more be made to mean right reason than authority can be made to mean legitimate authority. Authority moulds our ways of thought in spite of ourselves and usually unknown to ourselves. But when we reason we are the authors of the effect produced; we set the reasoning in motion and are responsible for all the consequences.

If people disagree with us, we are apt to be so far uncharitable as to attribute their beliefs to causes which are not reasons. But only a very small number of the most important and fundamental beliefs are held by persons who could give reasons for them, and of this small number only an inconsiderable fraction are held in consequence of the reasons by which they are nominally supported. It is a noteworthy fact that beliefs which are really the offspring of authority, when challenged, invariably claim to trace their descent from reason. Needless to say, such an improvised pedigree is often purely imaginary. Even in those cases where we may most truly say that our beliefs are the rational product of strictly intellectual processes, we have in all probability only to trace back the thread of our inferences to its beginnings, in order to perceive that it finally loses itself in some general principle which owes its origin to the influence of authority.

7. The Search for Truth

The historian who sets out to record truth gives a faithful record of events, extenuates nothing, conceals nothing, and distorts nothing. He exercises the greatest care in selecting his materials, and abstains from inventing details to fill up gaps. Past ages can be reconstructed only after the most painstaking and minute research, and at the best history is a record honeycombed with false data which must for ever remain uncorrected. But few historians are free from prejudices of some kind, and their search for truth is not impartial.

Very few ordinary people seem to search for truth. Some do not make the search because they are intellectually indolent; some, because they have an exaggerated respect for authority and feel a deference to long-established custom; some lack faith in their powers of forming an independent judgment; some are temperamentally averse from remaining in any sort of doubt; some seem to feel that truth is endangered if that side of it which they regard as particularly theirs is submitted to scrutiny. Only the few resolve to be intellectually free.

The consciousness of truth seems to involve both cognition and intuition. In the mind's attempt to discover truth, there are feelings of belief, hesitation, perplexity, and disbelief. Still the mind strives to know, and the success or failure is a knowing or not knowing. Truth, therefore, is essentially cognitive, and its primary tests are cognitive, namely, clearness and distinctness, and agreement with reality. But over and beyond that is the self-evidence of intuition. Necessary conviction never comes without definiteness of conception, rigour of verification, and the complete confidence of intuition. The essence of truth is the verifiable agreement of judgment with reality.

Although one of the primary tests of truth is clearness and distinctness, it must not be assumed, as Descartes assumed, that clearness and distinctness are alone sufficient to establish a judgment as necessarily true. The things which may be clear and distinct—definitions, generalisations, syllogisms, and the like—are usually things of our own creation. But the great facts of the universe—life, the relation between mind and body, freedom, causation, infinity, God, and the rest—are never clear and never distinct. On the contrary, they are necessarily always obscure and always confused. If we imagine that we have formed clear and distinct ideas of them, we shall, on further examination, find that we are deceived, for our positive knowledge of them is *nil*. Unless verification of agreement with reality is possible, complete confidence must not be placed in ideas to which we have contrived to give an appearance of clearness and distinctness, for such fabricated products of our own minds are ever likely to lead us astray.

Suppose we wish to describe a tree which we can just discern at a distance through the fog. If we remain where we are, the description is necessarily very imperfect and probably inaccurate. If the fog clears away and we draw nearer to the tree, we can make the description more complete and less inaccurate. If we walk round the tree and view it from many points, the description can be made still more clear, accurate, and complete. If we uproot the tree and cut it into sections, our knowledge of it increases further; but however far we may carry our examination, we can never obtain *complete* knowledge of the tree. Our description, as far as it goes, may be clear, distinct, and adequate, and every stated fact we can verify. But the description cannot be complete, and our idea of the tree, though true as far as it goes, does not contain the *whole* of the truth about the tree. As we obtain more facts, so additional truth to our idea of the tree becomes possible. But at every step our judgment is involved, and upon the truth or falsity of our judgment depends the truth or falsity of our knowledge.

The popular notion is that a true idea must copy its reality. Certainly our ideas, especially of concrete things, *are* copies, more or less accurate, more or less complete. But absolutely faithful copies are never possible, inasmuch as the ideas are derived from the reports of the senses, in the imperfections of which they must share. Absolute truth is therefore never discoverable. We may, in fact, say that truth belongs less to ideas as such than to our judgment concerning their agreement or disagreement. The excellence of an idea lies in its being clear, distinct, and adequate; the truth of our judgment concerning it depends upon its agreement with reality. Fundamentally, truth is the *relation* between an idea and reality.

Our idea of the Copernican system of astronomy is clear and distinct and apparently adequate, but to people who lived in pre-Copernican times, so was the Ptolemaic system. Yet the relation between the idea and reality in the latter case is now demonstrably false; and who can say but that new evidence may some day be brought forward imperiously demanding the supersession of the Copernican hypothesis?

Modern hypotheses concerning the constitution of matter seems to be clear, distinct, and adequate, but no competent person would be rash enough to say that the truth-relation between idea and object has been finally established. It is improbable that our ideas of electrons, of atoms, and of the aether are faithful copies of reality.

Sometimes possible alternative hypotheses are put forward and are equally consistent with all the truths we know, and then for subjective reasons we choose between them. It would be poor scientific taste and bad economy to choose the more complicated of two equally well-evidenced conceptions, and the choice of the less complicated gives us the maximum satisfaction. Truths gradually emerge from facts and become new facts, in their turn to produce new truths, and so on indefinitely.

But the truths to which thought attains are always finite; indeed, perception of truth is the recognition of the finite amid all the chaos of apparent infinity: it is the hearing of music where before there was only a conflict of discords, the result of cognition and intuition working upon an almost limitless number of combinations of sound. When we hear it we feel sure that the choice is not arbitrary; it seems to us discovery rather than invention; and so it is with all the truths which the mind of man establishes.

The absolutely true, that is what no further experience will ever modify, is that ideal vanishing point towards which we imagine that all our temporary truths will some day converge. Since all knowledge is relative, all truth is relative. Absolute truth is as far distant as perfect wisdom. We have to live to-day by what truth we can get to-day and be ready to-morrow to call it falsehood. Much of what appeared to our ancestors to be absolutely true we now know to be only relatively true, and therefore at least in some measure to be false. As our limits of experience are extended, we detect errors in supposed truths and catch glimpses of higher truths, and the glimpses serve to inspire us with the hope that continued search will meet with great reward.

Any great generalisation newly established is not the ultimate fact of an old series; it is the first fact of a new. Every general law is only a particular fact of some more general law presently to reveal itself. There is no enclosing wall. No truth is so sublime but it may be trivial to-morrow in the light of new thought. It is well for our peace of mind that a great thinker is so seldom let loose in the world, for existing truths are all at the mercy of a new generalisation. The world owes far more to those who tear up our conventions than to those who calmly accept them. But conventional society is an affair of elegance in trifles; it has neither ideas nor aims except to increase its comfort; it hates those who attempt to disturb its serenity by delving for the truth.

Complete repose is ours if we care to clothe ourselves in the dogmatism of the first creed that comes along. But if we make that choice we close the door to truth. Repose and truth cannot both be ours. To engage in an unremitting search, and thus to keep ourselves for ever unanchored and afloat, compel us to submit to the inconvenience of discomfort and suspense; but, after all, the inconvenience is worth while, for the unremitting search may unexpectedly enable us to open the doors of truth we never dreamed of.

The wise man knows that in his search for truth he can never meet with complete success. If any one is so vain as to persuade himself that he has attained it, he is self-deceived. Claiming to know all things, he is convicted of not knowing himself. Scrupulously honest he may be, but he possesses a modicum of wrong-headedness which induces him to refuse to accept the view that truth is necessarily impregnated with error; to him truth is a perfectly pure and crystal-clear abstraction. What does it matter if we do not enjoy the full confidence of those who foolishly believe that they have already attained complete knowledge of the great mysteries of the Universe? Better that than forfeit our intellectual honesty.

It is often necessary to accept apparently irreconcilable propositions, and to recognise that in our present state of knowledge it is impossible to correlate them with each other, or make them fit in with anything like a symmetrical system of thought, though each claims a place in the full circle of truth. The hypothesis of the sovereignty of a Supreme Intelligence, for example, is difficult to correlate with the hypothesis of man's free-will, yet because we find it difficult to bring the two hypotheses together in a logical synthesis, that in itself is no justification for denying the one or the other.

We must ever beware of the intellectual atmosphere of past ages when there was no recognition of dominant natural law. Plato and Aristotle were intellectual giants, and took all knowledge for their province; but their ignorance was necessarily profound. In our search for truth it is of little avail to go to them for help, though as guides to wisdom they are still supreme.

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CHAPTER III

MATTER

1. The Conception of Great Numbers

BEFORE proceeding with the main subject-matter of this chapter it is necessary for the non-mathematical reader to get some idea of the significance of large numbers.

A million is a thousand times a thousand, *i.e.*, 1000×1000 or $(10 \times 10 \times 10) \times (10 \times 10 \times 10)$. This may be conveniently written $10^3 \times 10^3$ or 10^6.

A billion is a million of millions, *i.e.*, $10^6 \times 10^6$ or 10^{12}.

A trillion is a million of billions, *i.e.*, $10^{12} \times 10^6$ or 10^{18}.

A quadrillion is a million of trillions, *i.e.*, $10^{18} \times 10^6$ or 10^{24}. And so on.

A quadrillion is a number so vast as to be almost beyond comprehension. It is a billion of billions, and even a single billion is very much larger than is usually recognised. We give some illustrations.

On a very bright starry night, the total number of stars visible to the naked eye is about 3000. This number, if counted at the rate of five per second—very rapid counting, of course—would be counted in ten minutes.

At the same rate it would take about fifty-five hours to count a million. The number of letters in the Bible is rather over $3\frac{1}{2}$ millions; it would therefore take a little more than a week to count them, counting five per second and keeping on day and night.

A billion is a million of millions, and at the same rate of counting would take 7000 years to count. Hence, if an ancient Babylonian had commenced, say, in the year 5000 B.C. to count a billion, and had counted at the rate of five per second, keeping on day and night to the present time, he would not yet have finished his task. And yet this is only a billion. To count a trillion (10^{18}), would take a million times as long; to count a quadrillion (10^{24}), a billion times as long, *i.e.*, seven thousand billion years.

The area of England and Wales is 58,000 (or $5{\cdot}8 \times 10^4$) square miles, *i.e.*, $2{\cdot}3 \times 10^{14}$ square inches. Now consider some fairly fine sand, viz., of such a degree of fineness that there are 41 grains to the inch. This would give 1681 to the square inch, or about 70,000 to the cubic inch. If the whole surface of England and Wales were covered with this sand to the depth of a foot, the total number of grains of sand would be about 2×10^{20}, *i.e.*, 200 trillions, and this is the approximate number of molecules estimated to be contained in a single cubic centimetre of gas at normal temperature and pressure.

The area of the whole water surface of the globe is about 150,000,000 square miles, and the average depth of the oceans is about 12,000 feet. The number of cubic feet of water in all the oceans is thus 5×10^{19} cubic feet, and the number of *drops* [1] of water in all the oceans about $2{\cdot}4 \times 10^{25}$, *i.e.*, about twenty-four quadrillions, and this is approximately the estimated number of molecules in the amount of water contained in an ordinary wine bottle.

The number of molecules in a single drop of water is about $1{\cdot}7 \times 10^{21}$, *i.e.*, about 1700 trillions. To count this number at the rate of five per second would take nearly twelve billions of years. If we imagine a solid sphere the size of our globe uniformly covered with water to the depth of about $7\frac{1}{2}$ inches, the volume of water would contain approximately $1{\cdot}7 \times 10^{21}$ drops, and each drop would contain $1{\cdot}7 \times 10^{21}$ molecules.

2. More about Hypotheses

A hundred years ago, John Dalton, during his researches on the chemical composition of various substances, analysed two gases, olefiant gas and marsh gas, both of which consist of carbon and hydrogen, and obtained the following results :

Olefiant gas, 85·7 per cent of carbon and 14·3 per cent of hydrogen.

Marsh gas, 75 per cent of carbon and 25 per cent of hydrogen.

[1] The word " drop " applied to liquids is rather indefinite, but the medical man sometimes uses it instead of the technical term " minim " ; 480 such drops make a fluid ounce. A gallon of water contains approximately 277 cubic inches, and a cubic inch of water contains approximately 277 drops. A cubic inch contains between 15 and 16 cubic centimetres, and a cubic centimetre contains 18 drops. An ordinary port or sherry glass contains 3 fluid ounces, or 80 cubic centimetres, or 1440 drops.

Drops of water of the size 18 to a cubic centimetre may be discharged from a vertically held pipette with a nozzle 3 millimetres in diameter, at a drop rate of one per second, the temperature being 20° C. A variation in any one of these factors will lead to a variation in the size of the drops.

On comparing these numbers he found that the ratio of carbon to hydrogen in olefiant gas is 6 : 1, whereas in marsh gas it is 6 : 2. The mass of hydrogen combined with a given mass of carbon is therefore exactly twice as great in the one case as in the other. Further researches followed, and in all the compounds examined analogous regularities were discovered. The uniformity led Dalton to *generalise* his results and so to formulate the *empirical law* of multiple proportions.

He now cast about for an *explanation* of the composition of matter, an explanation which would entail the formulated law as a mere consequence. He felt convinced that he could not account for the facts unless he assumed that the structure of matter was *discontinuous*, and he therefore made the assumption that all elements consist of minute indivisible particles termed atoms (the idea of molecules came later) having a definite weight; that the atoms of each elementary substance are alike among themselves and are different from the atoms of every other element; that the atoms of a chemical compound are not alike among themselves but are composed of the different elements by the interaction of which they are produced. This is the famous *atomic hypothesis.*

If the truth of the hypothesis be granted, the laws of chemical combination may be deduced directly, and are made intelligible. There is therefore a presumption in favour of its truth. Moreover, the possibility of its truth has been strengthened by a vast number of confirmatory experiments.

It is, however, important to note that the hypothesis is nothing more than a *mentally constructed and quite imaginary* mechanism accounting for the facts. We must be under no illusion that our pictorial conception is representative of the actual machinery of nature. All we *know* is that chemical reactions take place *as if* the hypothesis were true.

The function of an hypothesis is of such fundamental importance that the reader's further attention must be drawn to it.

Physical science seeks to explain natural phenomena by means of the minimum number of the simplest and most probable fundamental assumptions it is possible to conceive. An explanation is a description in greater detail, giving a feeling of greater satisfaction. But sometimes we get this satisfaction by an explanation which is not a description of additional *facts* but of some hypothetical inner mechanism. In science there is no such thing as a final explanation. We may discover *reasons* that will give us temporary satisfaction, but we can never get back to ultimate *causes*.

In physical science the term *generalisation* is often used to denote the process of passing from a limited number of facts to a multitude of unexamined cases which we believe to be subject to those invariable conditions that determine the common nature of the phenomena. Such a generalisation is often known as a *law* or a "law of nature." Laws of nature may be looked upon as the generalised results of experience conveniently stated in a form suitable for future reference. Such a generalisation is at first usually more or less empirical, and it necessarily has a hypothetical basis, for it can never be altogether free from conjecture. At bottom a generalisation is an hypothesis.

When we proceed to *imagine* an explanation, an important part of the hypothesis which we then formulate consists in developing some kind of mechanical model whereby we may visualise the unknown processes involved in the experimental facts and mathematical laws. But the chance of hitting upon objective reality by such guess-work is obviously remote, and we must never forget that our hypothesis is nothing more than a mentally constructed mechanism.

Hypotheses do not always perform quite the same function, and distinctions are sometimes drawn between descriptive hypotheses, hypotheses of law, and hypotheses of cause; but they all have the same fundamental common factor, that is, we assume the existence of some sort of secret inner organisation of real things and processes.

Conjecture enters largely into the everyday work of men of science, who are thus constantly constructing working hypotheses which, it is confidently felt, will be verifiable by experiment. For instance, when it was discovered that Glauber's salt gave a definite pressure of water vapour, the supposition was made that other hydrates would do the same, and experiment showed that the supposition was correct. The hypothesis was thus replaced by absolute fact. Such working hypotheses are subjected to verification as quickly as possible, and if verifiable they become truths of great fertility.

But hypotheses like the atomic hypothesis and the aether hypothesis perform a different function from the everyday working hypotheses of science. Their entire verification is improbable. Their main function is to play the part of an imaginary mechanism welding the facts together and provisionally accounting for their known inter-relations. If after formulation they cover new facts they are strengthened; if they clash with new facts they are either revised or abandoned altogether.

Thus the existence of a class of fictitious phenomena which cannot be perceived by the senses is assumed by science; properties are assigned to them, similar to those known to be true of a class of real phenomena which can be perceived by the senses; and the nature of the phenomena thus conjectured may be modified at any time in order that new facts may be brought within the hypothesis. Certain important hypotheses, for instance that of the wave theory of light and the atomic hypothesis, have proved eminently useful, since they have reduced very complex relations to a few simple laws. Further, the main hypotheses of physics tend to a unification in which the axioms of mechanics are the first principles. Yet hypotheses must be employed with caution and judgment, for their too free use leads to confusion with objective fact. Metaphysical hypotheses are, from their very nature, necessarily unverifiable, and since some of the best-known hypotheses of physical science are really metaphysical, the danger of their constant use is an inevitable tendency to give an objective reality to things which in the beginning we knew to exist only in our own minds. The specific claims of science are seriously weakened if the limits of possible knowledge are not recognised, and if facts and speculation are not clearly distinguished.

The term *theory* should not be used for hypothesis. More properly it refers to an aggregate of conceptions, wholly or partially verified generalisations, and laws, which constitute the abstract statements of some branch of science. Thus we talk of the theory of chemistry.

In science it is sometimes said that many quantities are assigned on "theoretical grounds" which cannot be verified. For instance, it is stated that 600,000,000,000,000 light undulations strike the retina of the eye in one second. Clearly this number could not be verified by direct counting. Is, then, the statement a fact or an hypothesis? It is neither. It is an inference which follows, quite logically, from the two premisses: (1) the length of light undulations and (2) the velocity of light; and its validity depends upon the validity of these premisses. Now, of the two premisses, the second is definitely known as a fact, but the first—the wave-length of light—is involved in inferences from a particular hypothesis as to the nature of light. Evidently an inference from an hypothesis falls short of objective fact, and a slight presumption in favour of its corresponding with reality is all that we can give it.

The study of chemical changes from a quantitative standpoint has led to four great generalisations from the results of actual experiments. Three of these—the laws of constant proportion, of multiple proportions, and of reciprocal proportions, respectively—refer to quantitative relations as respects *weight*; the fourth—Gay-Lussac's law—expresses quantitative relations with regard to *volume*, and relates to matter in the gaseous state only. When these laws were first formulated they were based on the results of comparatively few experiments, and they were largely of the nature of unverified hypotheses, but they have since been confirmed by an overwhelmingly large number of additional experiments performed by chemists all over the world. It is true that, ultimately, they all rest upon an hypothesis that has never been completely verified, but that hypothesis, the far-reaching induction commonly known as the Uniformity of Nature, is co-extensive with all human experience, and the hypothetical element underlying the four great laws is thus reduced to the vanishing point. The laws therefore rest firmly on the basis of experiment, have really passed beyond the stage of hypothesis, and are true statements concerning objective facts. It is for this reason that the wise teacher of chemistry provides his pupils with a sufficient number of experimental facts, and sees that they clearly apprehend the four great generalisations based upon those facts, before he introduces any serious considerations of a theoretical nature. But he then feels the need of a more comprehensive explanation, and the necessary introduction of the atomic hypothesis at once adds to the difficulty and danger of his work, for his bed-rock facts now begin to take a subordinate place.

3. The Kinetic Hypothesis of Gases

Matter exists in three states, gaseous, liquid, and solid. The nature of gases and liquids is understood, but relatively little is known about the conditions that determine a solid. It is the nature of a gas to " fill " completely any closed vessel that may contain it; it never settles; and, if given an opportunity, it fills uniformly any other available space, larger or smaller, offered to it. It matters not whether the space is a vacuum or is already occupied by another gas. Each gas by diffusion seems to fill the whole space uniformly as though the other was not present. A given quantity of gas will expand without assignable limit, and it is therefore impossible to imagine it as a homogeneous substance *absolutely* filling the space in which it exists. We cannot imagine that the same amount of substance absolutely fills, at different times, volumes different from each other. The difficulty at once disappears if we make the assumption that the gas consists of a number of discrete particles which can be pressed nearer together or allowed to move further apart. In fact, we seem to have no alternative but to form this hypothesis as soon as we discover that a gas does not settle, is compressible, and is diffusible ; and all observed experimental facts are completely satisfied if we further assume that at ordinary temperatures and pressures the particles are at great average distances apart, and that they are in perpetual motion and have perfect elasticity. To these discrete particles the name " molecules " has been given.

Further, since every gas is found by experiment to be homogeneous throughout any space that may contain it, we infer that all the molecules of the same gas are alike ; that since a constant relation, that of inverse variation, is found between pressure and volume, we infer that the pressure is produced by the impacts of the molecules and is proportional to the degree in which they are crowded together ; that since a constant relation is found between volume (or pressure) and temperature, we infer that an increase in temperature increases the velocity and therefore the kinetic energy of the molecules ; and, finally, that since the volumes of different gases that combine are either equal or stand to one another in the ratio of small whole numbers, we infer that chemical union consists in the combination of different kinds of molecules of which there are, at the same temperature and pressure, equal numbers in equal volumes of different gases. All these inferences are fully justified, though, of course, they depend upon the first assumption that a gas really does consist of discrete particles which are called molecules. The reader should dwell upon the results of the different experiments and on the inferences drawn therefrom. It should be quite clear, for example, that the phenomena of diffusion seem to point conclusively to the fact that gases (and liquids) must consist of particles in motion relatively to each other, capable of penetrating the interspaces between the similar particles of contiguous bodies. Given sufficient time, diffusion may go on even between solids, as has been shown when gold and lead are placed in intimate contact with each other.

It was at one time thought that the particles of a gas repelled one another, but in reality they tend to move together ; and when the temperature is lowered so much that, owing to the reduction of the kinetic energy of the molecules, this tendency can produce its effect, the gas condenses to a liquid. But the essential difference between the gaseous and liquid states is confined to the surface of the liquid. Inside the liquid, the molecules move as in gases, but, being more closely packed together, they collide more frequently, and their "free path" is exceedingly minute. In the solid state, a translatory motion of the molecules is, presumably, impossible, but a vibratory motion in constrained paths there must be. This vibratory motion increases with the temperature until the molecules effect their complete freedom; the vibratory motion becomes a translatory motion, and the solid melts.

Although it is impossible to see the movements of molecules, some idea of their commotion may be obtained from the well-known Brownian movement. If some turbid liquid, that is a liquid containing very fine solid particles in suspension, be observed under a high-power microscope so that the particles are visible, it will be seen that every particle is in motion, darting about, turning and reversing continually. The movements continue for an indefinite period. If the particles are small enough, the commotion observed is extraordinary. If this is so in the case of visible solid particles, imagine the commotion amongst the molecules of liquids and gases, for the molecules are smaller than the visible solid particles, almost beyond comparison.

4. Molecular and Atomic Hypotheses

The conclusion seems to be inevitable that matter is made up of discrete particles—molecules—each of which has the same composition as the body as a whole. And the great experimental generalisations of chemistry force us to the further conclusion that the different materials in each molecule of a compound exist as distinct and separate varieties of matter. We therefore make this the basis of a new hypothesis, and attribute to these constituent parts of the molecules the properties which determine the weights so closely related to them. When these constituent parts move out of one combination into another, they move without alteration in their *mass*. That each element enters into partnership with other elements only in certain fixed proportions by weight is a definitely established experimental fact, and we cannot but conclude that, underlying the laws of quantitative equivalence, there must necessarily be some far-reaching unifying principle, could we but find it; and the atomic hypothesis is an attempt to provide one. All the facts are harmonised if we assume that chemical combination takes place between the differentiated constituents of the molecule, and that these constituents have specific weights of their own. The constituent parts of molecules that are assumed to have permanent coherent masses are the *atoms*, and the relative weights of these imaginary masses are called atomic weights. Each atom may be imagined to be some sort of a ready-made little packet, of specific weight, for use in building up molecules. Molecules of the elements are built up of similar atoms. Molecules of compounds contain one or more atoms of each of the elements of the compound. The actual number of atoms in a molecule is usually doubtful, though we often know the number of each of the contained kinds relatively. The number of atoms in a molecule of iron rust, for example, is known to be some multiple of five, there being two atoms of iron to every three of oxygen ; but what this multiple is we do not know.

Atoms are the units of which molecules are aggregates. Those of like kinds have equal masses and differ from those of all other kinds both in mass and in the kind of material of which they are made. The fundamentally different kinds of materials are the chemical elements. Atoms may be fictitious, it is true ; but that specific masses of the different elements always take part in chemical combination is an experimentally established fact. If the atomic weights do not represent the relative weights of atoms, what *do* they represent ?

5. Molecular Dimensions

Although the estimates of molecular dimensions are all based on the results of experiments—experiments concerned with diffusion, with viscosity, with deviations from Boyle's law, with the thickness of films, and so on—still various mathematical and other hypotheses enter largely into the calculations, and the results are therefore necessarily wanting in certainty. But the various solutions of the problem, though arrived at by such entirely different methods, all tend to give results of the same order of magnitude. In fact, the differences are so far negligible that there need be no hesitation in accepting the results as substantially true. Molecules are conveniently conceived to be elastic spheres, but of course we are not justified in making any such assumption. They are undoubtedly far more complex than that.

At normal temperature and pressure, the number of molecules in one cubic centimetre of gas is about 2×10^{20}, that is 200 trillions, a number equal to the number of grains of sand, 70,000 to the cubic inch, in a layer a foot deep, covering the whole surface of England and Wales.

In water, the molecules are closer together. The number in a *single drop* is about $1 \cdot 7 \times 10^{21}$, that is 1700 trillions, a number just about equal to the number of drops of water in a layer $7\frac{1}{2}$ inches deep, completely covering a sphere the size of the earth.

At ordinary temperatures, the mean speed of the molecules of the principal gases of the atmosphere is about 1000 miles an hour, that is nearly 1500 feet a second. But, on an average, each molecule collides with about 6,000,000,000 other molecules in a second, and the 1500 feet is thus pursued in a zigzag course of 6,000,000,000 little straight paths. The average length of these little paths is thus about 3/1,000,000 of an inch, and each is covered in 1/6,000,000,000 of a second. This fraction of time is almost inconceivably small, yet the periodic times of light vibrations are almost immeasurably smaller still. For during the 1/6,000,000,000 of a second that a molecule has been travelling between one collision and another, no less than 60,000 double vibrations of red light have taken place, and nearly twice that number of violet. And as the periods of all the motions of the atoms within a molecule that give rise to visible rays of the spectrum must lie within these limits, it follows that, either that immense number of atomic orbital motions has, on the average, been executed within the molecule during each of its journeys of 3/1,000,000 of an inch, or that some other periodic motion, resolvable into the same vast number of constituents, has been in progress.

There need be no hesitation about accepting these figures as approximately correct. They may be a few times too small or a few times too large, but they certainly indicate, fairly closely, the *order* of the magnitude concerned. The full significance of such vast numbers is not likely to be grasped without prolonged reflection.

The assumption that molecules and their constituent atoms are the ultimate limit of the subdivision of matter by physical and chemical means, carries with it the necessary corollary that molecules and atoms must be perfectly elastic and frictionless. Otherwise, the ordinary molecular collisions would result in a loss of kinetic energy of motion. But there is no such loss. Friction and imperfect elasticity are properties of the gross world. Molecules are necessarily frictionless, perfectly elastic, and in perpetual motion.

Although both the molecule and the atom are, at bottom, metaphysical creations, we are constrained to believe that entities more or less analogous to them actually exist. Some physicists are absolutely convinced of the existence of atoms and of their uniformity and invariability, just as if they could actually see them. And probably to a majority of physicists and chemists the existence of unit weights (atomic weights) seems to furnish a positive verification of the hypothesis that matter is composed of atoms. It seems scarcely thinkable that each element should, in entering into many different combinations, always use the same proportions by weight unless it consisted of ready-made particles the weight of which is fixed and unalterable. Other hypotheses are, however, conceivable. One is that there may be undiscovered properties capable of directing quantitative selections of material for chemical change, without the permanent segregation into particles of unalterable dimensions. But this hypothesis is much less simple than the accepted atomic hypothesis, and the simplest hypothesis is always to be preferred.

Until 1896, the atom was considered to be the ultimate limit of material sub-division, but radio-active discoveries have led to the view that, although the atom is still the ultimate limit of the subdivision of matter in every artificial process, it is not the natural limit.

6. The Periodic Law

If the elements be written down in the order of their atomic weights, beginning with the smallest, the successive numbers will form a repeating series. After a certain number have been set down, usually eight, the general characters of the elements will recur in the same order. Proceeding in this way to the end, we may plan a scheme of vertical columns and horizontal rows; each vertical column will then form a family group, the elements in the group being closely related to one another. We thus have a "periodic" classification of the elements, which, however, do not all quite fit into the general scheme in the simple manner here outlined. There are certain exceptions the place of which in the scheme is a little uncertain. The last three elements are radium, thorium, and uranium, and are the three with the heaviest atoms known. These are unstable, breaking up spontaneously and exhibiting in the process the property of radio-activity.

The classification reduces the properties of the elements to order and system. So much so is this the fact that chemists have established a generalisation known as the Periodic Law: "all the properties of the elements are periodic functions of their atomic weights." The principle has proved fertile to the investigator, but, so far, its inner significance has baffled both the investigator and the philosopher, who, however, are convinced that the numbers expressing the relative weights of the atoms have a profound meaning.

Men of science feel almost instinctively that the Periodic Law suggests a common origin of the elements. As we pass from light to heavy atoms we seem to be going from simple to complex structures containing different numbers of some common constituent. In 1897, J. J. Thomson showed that in the cathode rays of a vacuum tube we can detect minute particles possessing about 1/1000 of the mass of the hydrogen atom. Whatever the nature of the gas in the tube and whatever the metal employed as an electrode, the particles are identical. The particles are common to all kinds of matter. Are they the constituents out of which all atoms are made ? Certainly it has become abundantly clear that matter is by no means so simple as chemical analysis alone is able to reveal.

Many recent discoveries have tended to emphasise the truth of the conception that matter of all kinds has a common basis. The atoms of different elements seem to *behave* as if they consisted of small particles of the same kind, but before we can consider these further it is necessary to discuss the aether of space.

7. The Aether of Space

If the influence of the other celestial bodies be neglected, the sun and the earth may be regarded as revolving around their common centre of gravity ; the case is comparable with that of a small boy "running round" a strong man, the two holding opposite ends of a stretched rope. The pull between the sun and the earth, if transmitted by steel rods, would require a billion rods each 30 feet in diameter. Such a force necessarily involves an enormous tension in the intervening medium. But concerning the actual mechanism of gravitation, scarcely anything is known, though for its explanation Newton saw clearly the necessity for assuming the existence of a medium of some kind. The most convincing arguments as to the existence of this medium—the aether as it is commonly called—are derived from the wave hypothesis of light.

It can be shown conclusively by experiment that light consists of waves of some kind, and that these waves travel at a velocity of 3×10^{10} centimetres, or 186,000 miles, a second. For the propagation of any undulatory disturbance a medium is necessary.

Ordinary matter cannot transmit waves at anything like the speed of light. The velocity of the waves it does transmit is comparable with the velocity of sound waves, a velocity, say, of from one-fifth to two miles a second, and therefore hardly comparable with the enormous velocity of light. Hence the luminiferous medium—the aether—must be a substance entirely different from ordinary matter and peculiar to itself.

Any medium capable of transmitting wave motion must possess elasticity ; it must also enable the disturbed substance to oscillate to and fro beyond its place of equilibrium, that is it must possess inertia.

It is possible to produce aethereal waves by direct electrical means, for instance in the discharge of a Leyden jar. The spark that can be seen and heard is a mere secondary disturbance, the true aethereal waves being emitted by the electric oscillation going on in the neighbourhood of the dielectric. The result of this wave motion is a kind of light which travels at the same rate and is reflected and refracted according to the same laws as the visible light we are familiar with. But this light is invisible, for the number of vibrations per second are too few to get any response from the retina of the eye ; they are less than a million a second, whereas the retina responds only to vibrations between 400 billions (4×10^{14}) and 700 billions a second. On the other hand, the vibrations are too many for the ear, which responds only to vibrations between 40 and 40,000 a second. Between the highest audible (4×10^4) and lowest visible (4×10^{14}) vibrations, there has hitherto been a great gap imperfectly known. The waves have been plentiful enough, but we have not possessed an intermediate sense that could respond to them.

Our sense of touch is in no way affected by the aether. In fact, the aether does not seem to resist motion in the slightest degree. Even such large bodies as the planets can rush through it at enormous speed without showing the least sign of friction, and no mechanical connection between matter and aether can be traced. True, our sense of radiation enables us to detect, in some small measure, the quiverings of the aether, and it is conceivable that the skin is a rudimentary aethereal sense, still to be evolved in the course of future ages.

An estimate of the *density* of the aether can readily be made, but it is based upon considerations which are in some degree hypothetical, for they are ultimately traceable to the electrical hypothesis of matter. The hypothesis is that matter is composed of particles, electrical in nature, which have been structurally differentiated from the aether itself. To these aethereal particles the name *electrons* has been given. Experimental evidence now seems to show that the *mass* of an electron is somewhere about 1/1000 that of an atom of hydrogen.[1] Its diameter, which is easily calculated, is about

[1] See p. 60.

1/100,000 that of an atom which itself is roughly equivalent to 1/100,000,000 of a centimetre or 1/250,000,000 of an inch. Hence, the *mass* and the *volume* of an electron being known, its density is easily determined, provided its mass is all dependent on what is contained within its boundary, though available facts suggest a greater complexity.

Although estimates of the density may be made in various ways, differing entirely in principle, the resulting differences are only slight, and the results all come out of the same order of magnitude, that is 10^{12} grammes or 10^{6} tons per cubic centimetre, that is a density a billion times as great as that of water, or nearly a hundred thousand million times as great as that of lead.

It is necessarily assumed that the aether is incompressible, otherwise it would be composed of parts, and we should have to seek for something still more fundamental to fill the interstices. The aether being incompressible, and it being assumed that an electron is composed simply and solely of aether, it follows that the electron cannot be either a condensation or rarefaction of that material, but some peculiarity of structure or some portion otherwise differentiated. The differentiation may be of a kinetic character, possibly something of the nature of a rotating vortex-ring; or of a static character, perhaps a strain-centre, or perhaps an ultra-microscopic region of twist. Though it cannot at present be imagined very clearly, it is convenient to think of it as somewhat analogous to a knot in a piece of string. Just as the knot differs in no respect from the rest of the string except in its tied-up structure, so the electron has the same density as the aether from which it is derived. If we could devise a means of "untying" the aether knot (if it is a knot), the electron would be revolved into the general body of the undifferentiated aether of space. The important point is that the density of the undifferentiated or simple aether is the same as that of the modified aether constituting the electron.

Various theoretical considerations all tend to show that ordinary matter is a very porous substance, with interspaces great as compared with the space actually occupied by the electrons which constitute it. The average density of the aggregate mass of the material electrons, compared with the space they occupy, is exceedingly small. The density of lead, for instance, is, as we have already seen, extraordinarily insignificant as compared with the unmodified aether which occupies by far the greater part of its bulk.

If we consider the density of an ordinary cloud, the density of each particle is the density of water, but the group density per unit cloud-volume is almost indefinitely smaller, a cloud being quite an impalpable substance. So when we speak of the density of ordinary "matter," we do not express the density of the individual electrons of which it is composed, for that would be the density of the aether; we express the *group* density. Electrons are grouped into atoms, atoms into molecules, and molecules into gross matter; and in every case there are aethereal interspaces. All matter may be regarded as clouds of electron groups, the difference in groupings accounting for differences of density. The aether in the interspaces between the electrons, although of the same density as the electrons, does not enter into the estimation of the density of matter at all, for the differentiated aether particles—the electrons—move without friction through the undifferentiated aethereal continuum. The ultimate units of matter are few and far between, and are exceedingly small compared with the intervening distances. The density of the aethereal continuum is thus necessarily far greater than the density of the disconnected assemblages of particles composed of the material of that continuum, for in the former there is no break, while in the latter there are great gaps.

The reader not versed in physical science may be puzzled about the easily permeable and fluid-like character of a medium with such an enormous density as the aether. But he should remember that friction and viscosity are two entirely distinct things and have no necessary connection. If there is no fluid friction, a fluid may have *any* density, without interposing any obstacle to constant velocity. But this does not apply to acceleration.

Since both the density of the aether (10^{12} grammes per cubic centimetre) and the velocity of the waves transmitted (3×10^{10} centimetres per second) are known, the elasticity can be calculated, for the ratio of the elasticity to the density is equal to the square of the velocity. The elasticity must therefore be 9×10^{20} times the density. According to Lord Kelvin's theory of elasticity, this extraordinary rigidity must be due to an ultra-microscopic finely-grained rotational vortex motion throughout the aether. The irresistible conclusion at once follows that the internal energy of the aether is almost, perhaps wholly, inconceivably great. For according to this view, in *every cubic inch* of space we have a mass equivalent to what, if it were matter, we should call 16,000,000 tons, every part rotating or vibrating internally with a velocity comparable to the velocity of light, and therefore containing, stored away in that single cubic inch of space, an amount of energy equal to that of an 800,000,000 horse-power station working continuously for 800,000,000 years!

It must not be forgotten that these estimates ultimately depend upon the experimental measure of the mass, and the mathematical estimate of the volume, of the electron. Calculation shows that however the mass is accounted for, the estimate of the ratio of mass to effective volume differs only in a numerical coefficient, not as regards order of magnitude.

It is not advisable to call aether *matter*, for, while matter appears to be *derived* from the aether, the two must be differentiated. The essential distinction is that matter *moves*, in the sense that it has the property of locomotion and can effect bombardment, while *aether* is *strained* and has the property of exerting stress and recoil. The aether is a vast reservoir of enormous potential energy. We do not conceive it to be composed of parts, for then we should have to postulate a second aether to fill up the spaces between the parts. We conceive it to be a continuum, stationary as regards locomotion, yet in a state of jelly-like quivering or possibly rotational motion, motion of such enormous velocity as to be immeasurable in its violence, though on a scale of measurement almost indefinitely small. The rotational motion can be imagined if we think of the aether as a closely packed conglomerate of minute grains, but this aid to the imagination is really not permissible, for the aether cannot be discrete. A satisfactory mental picture is not, in fact, possible. It is useful, however, to note that the properties of a solid—rigidity, elasticity, impenetrability—can be imitated by a perfect fluid such as the aether is supposed to be, if the fluid is in motion. A jet of water moving with sufficient velocity can be struck with a hammer, and resists being cut with a sword. So a flexible chain, set spinning, can stand up on end while the motion continues.

8. Electric Hypothesis of Matter

When a Crookes' vacuum tube approaches a very high degree of exhaustion, the dark space nearest the cathode gradually extends and eventually fills the whole tube. A new phenomenon is now noticed: a greenish phosphorescent light appears on the anode and on the sides of the glass. It is, however, the dark space which has the greatest interest, and if a flat disc is used for the cathode, we can the more easily discover the properties of that space. For instance, if a solid object, such as a screen of mica, be introduced into the dark space, a sharp shadow is thrown, and the obvious inference is that the dark space is full of something shot off from the cathode. These cathode *rays*, as they are called, are invisible until they strike an obstacle ; like bullets from a gun, they produce a perceptible effect only when stopped ; the region of their flight is the dark space ; the boundaries of that space are illuminated where they strike. The path of the rays can be traced by smearing a sheet of mica with phosphorescent powder and placing it edgeways along their path, an experiment which shows conclusively that they travel in parallel straight lines. The rays possess energy, for a light windmill placed in their path can be made to rotate. If they are brought to a focus, a piece of platinum placed at the focus will show signs of being red-hot. They have a remarkable penetrating power ; a thin metal diaphragm is powerless to stop their passage completely, as can be demonstrated by the phosphorescence and other effects appearing in the further half of the tube beyond the diaphragm.

Now it can be experimentally proved that these cathode rays consist of minute particles, that the particles have a constant negative charge, that they have a constant mass, that they move with a velocity comparable with the velocity of light, and that they are always the same whatever be the nature of the matter present. They behave like an electric current and are deflected by a magnet. They cannot be matter in the ordinary sense, for it is inconceivable that ions (charged atoms) could travel at such a high velocity. But if they are regarded as electric charges which have become detached from the ions and have left the atoms behind them, their extreme mobility and great velocity are perfectly natural. The particles are electrons. Electrons are invariably negatively electrified, and all bodies can be made to emit them. They are the same from whatever source they are derived.

We have already referred to the " mass " of an electron. An electron is immaterial in the sense that it is not ordinary matter. But any moving particle, whether material or not, possesses kinetic energy, and the kinetic energy of a moving electron is electric energy. Possessing electric energy, and able to drive windmills and make metals red-hot, an electron, although an immaterial particle, has *mass*, but the determination of this mass is rather a complex problem.

The ratio *charge/mass* of a substance can be determined with great accuracy from electrolysis ; it is the reciprocal of the electrochemical equivalent of a substance ; and many experiments have been devised for establishing this ratio in the case of the charged cathode particles. The velocity of the particles is determined by an experiment based upon the deflection of rays by a magnetic field, and by other means ; it is about one-tenth the velocity of light, that is a million times as fast as a fast express train.

Now although it is easily possible to determine the ratio *charge/mass* and the *velocity*, we cannot determine the absolute mass alone until we have disentangled the terms of the ratio. The difficulty of measuring either the mass or the charge separately is that we are dealing with an aggregate of an enormous and unknown number of particles. The difficulty disappears if we can count this number, for then the various quantities can be equated in such a way that the ratio can be split up and its terms separately determined.[1] A remarkably ingenious experiment for counting the particles, due to Sir J. J. Thomson and Mr. C. T. R. Wilson, was based on the discovery that the charged particles act as nuclei round which small drops of water condense when the particles are surrounded by damp air cooled below the saturation point. True the method of counting was indirect, but the result remains unquestioned. The mass and the charge of an electron are thus known. The *mass* is about 10^{-27} gramme, or about 1/1000 that of an atom of hydrogen.

Mass must not be confused with *weight*. If we could remove, say a piece of iron, to a place in space remote from worlds of all kinds, its weight would practically disappear but its mass would remain unchanged. Under such conditions, the more fundamental attribute of matter would come into prominence—its *inertia*, that is its disinclination to move when at rest, and its disinclination to stop moving after it has started; its tendency to overshoot the mark; its tendency to run up the opposite hill after running down into a valley.

Although the inertia of ordinary matter has never been explained, the inertia of electrons is considered now to be understood. The important question arises as to whether the former is a different thing from the latter, or whether matter is composed entirely of electrons. Electrical inertia is due to the reaction of the electric and magnetic fields during acceleration periods, and is known as self-induction. It seems likely that there is no other kind, and that what we observe as the inertia of ordinary matter is simply the electric inertia or the self-induction of a vast number of electrons. At all events the hypothesis covers all the known facts. But while the inertia of an electron is undoubtedly purely electrical, we are not yet certain that the atom is composed solely of electrons, and we cannot therefore say with absolute certainty that the inertia of the atom is wholly electrical.

The main substantial doubt about the electrical hypothesis of matter concerns the *positive* units of electricity, for these have never

[1] The various quantitative data which have been experimentally determined in the Cavendish laboratory are more than sufficient to determine *m* separately.

been identified with certainty. When the cathode is perforated, rays are seen to emerge from the back of it: they have been called "canal rays," and the view has been seriously put forward that they consist of positively charged atoms of the substance, or atoms deprived of the negative electrons. More probably, however, they are atoms of helium. There can be no doubt that the units of positive charge are always associated with the atoms in some way, and there can equally be no doubt that the units of negative charge, the electrons, sometimes have a separate existence. In fact, it seems necessary to differentiate the electrons into two kinds, the one, "free" electrons which can be withdrawn from or added to the atoms, the atom itself being supposed to remain unaltered; and the other, "structural" electrons, out of which the atoms themselves are supposed to be built up.

In the highly vacuous space of a Crookes' tube, the atoms of the comparatively few molecules still left are broken down by the electrical discharge. They are, as it were, blown to pieces into their constituent particles, the electrons. This ultra-dissociation of the atom in no way conflicts with the views based upon its chemical and physical properties under ordinary conditions. The dissociation gives us facts concerning the inner mechanism of the atom as a discrete particle of matter. But in the course of all the ordinary chemical transformations which matter undergoes on the earth, the atom may still be regarded as the indivisible particle.

The only portion of the atom about which we have definite knowledge is that fraction of its mass which confers upon it an electric charge. As to all the rest of the atom, at any rate if we consider the hydrogen atom, the most probable of the various hypotheses which have been put forward seems to be, that the bulk of the atom consists of an indivisible unit of positive electricity, a sort of fluid sphere, in the midst of which an electrically equivalent number of electrons are scattered and revolving at a rate of thousands of billions of times a second. Of these orbital revolutions of the electrons there seems to be hardly any doubt at all.

It has been suggested, on experimental grounds, that the number of electrons in an atom is comparable with its atomic weight, hydrogen being reckoned as unity. It seems more probable that this applies to *free* electrons; or perhaps the number of *structural* electrons is *proportional* to the atomic weight. If this be so, the inference is that the specific properties of the atom of a particular element are in some way closely dependent upon the *number* of electrons within the atom.

The general hypothesis that the constitution of matter is electrical obviously has a firm experimental basis. If the hypothesis be true, what we have been accustomed to regard as an indivisible atom of matter is built up out of electricity ; it is constructed of electrons, and atoms of all substances are built up out of these same ultimate units. But though parts of the hypothesis have been experimentally verified beyond doubt, and additional confirmatory evidence is constantly being brought forward, no absolute proof of the hypothesis as a whole is yet forthcoming. We are not yet certain that mass is entirely due to electrons. If, as seems probable, it is so due, the spaces inside an atom must be enormous compared with the electrons which compose it. The atom is possibly a kind of astronomical system, not with a central sun but with some kind of vast enclosing sun, containing a large number of equal bodies possessing inertia and subject to mutual attractive and repulsive forces.

But while it has been virtually indubitably established that a free electron has no independent material substratum, and is best regarded as a spherical electrical aggregate of some sort whose volume does not undergo shrinkage, yet the inner aethereal meaning of the mutual relations of the negative and positive charges is puzzling. If a piece of solid rubber a few inches long and square in section be twisted and the ends then brought together and welded, it is obvious that we have an example of a self-locked intrinsic strain. We can thus imagine right- and left-handed interlocked intrinsic strains in an aether gyrostatically stable. Conceivably this gives us a clue to the relations between the positive and negative electrical charges.

The relative sizes of the atom and electron are deserving of special attention. The diameter of the electron is 10^{-13} centimetre, and of the atom, 10^{-8}. The diameter of the planet Neptune is 36,000 miles, and his distance from the sun, round which he takes 160 years to revolve, is 2,700,000,000 miles. Hence the diameter of the planet's orbit is to the diameter of the planet itself in roughly the same ratio as the diameter of the atom is to that of an electron. An atom with its electrons may thus be compared with the sun and the planets, but the reduction factor necessary to bring down the solar system to the atomic system is the stupendous one of 10^{22}. In one atom of hydrogen there would have to be about 1000 electrons to make up the complete mass of the atom, and in the atom of mercury about 200,000. Now consider the atom of mercury as a sphere 10^{-8} centimetre in diameter, with its contained 200,000 electrons. Each electron is 10^{-13} centimetre in diameter, and thus there can be only about 75 of them in a row along any diameter of the atom, whereas there might be, of course, 100,000 of them in the same length. The empty space inside the atom is therefore enormous. The whole volume of the atom is, roughly $(10^{-8})^3$ or 10^{-24} cubic centimetre. The aggregate volume of the contained 100,000 electrons is about $(10^{-13})^3 \times 10^5 = 10^{-34}$ cubic centimetre. Hence the space left empty is nearly 10^{10} times the filled space. Clearly, then, the electrons are no more crowded in the atom than are the planets in the whole of the available space of the solar system. The mean free path of an electron inside a mercury atom is 10^9 the diameter of the electron, so that if the electrons moved about uncontrolled they would be able to travel in a straight line an average distance equal to a thousand million times their own diameter before colliding with a neighbour; and in a less dense medium the free path would be greater still. Imagine one hundred gnats roaming about in a sphere with a volume equal to one of the largest halls in the world, the available free paths of the electrons within the atom are at least as great as those of the gnats within the hall.

The minuteness of the electron and the relatively large space in which it moves within the atom partly explain the penetrating power of the electrons. The wonderful penetrating power of the cathode rays is thus more easily understood. It is true that, in the case of electrons plunging into a dense metal, the actual distance achieved is very small, only a small fraction of a millimetre; platinum, for instance, stops them very near its surface. Still, relatively to their size, they penetrate a great distance.

9. Radio-activity

If atoms consist of electrons performing orbital revolutions, it might be expected that the electrons would be continuously emitting waves and radiating away energy. In the case of the majority of substances, no such radiation can be detected, but certain substances have been found in which it is easily perceptible. This radiation is especially marked in the elements uranium, thorium, and their compounds. Madame Curie discovered that the natural ores of uranium possess a greater degree of activity than can be accounted for by the uranium they contain, and she at least proved that other radio-active elements, in excessively minute quantity, are present. The most interesting of these, radium, was eventually isolated, and it proved to be a metal very similar to barium.

Ten tons of pitchblende, the mineral richest in radium, contain only one grain of the pure metal, and the total amount of radium that has ever been prepared probably does not exceed one or two ounces. The chemistry of the radio-active elements, of which uranium, thorium, and radium are the chief, is in no way exceptional; but in addition to, and totally unconnected with, their chemical properties, they exhibit properties of an entirely new kind.

In considering these radio-active properties, the nature of the rays emitted by the radio-element first calls for notice. Three kinds of rays are distinguished, *alpha*, *beta*, and *gamma* rays, as they are called. The α rays possess feeble powers of penetration; they are absorbed by a single sheet of paper or by a few inches of air. Yet they are the most important class and possess over 95 per cent of the energy evolved from radio-active substances. They are bulkier than electrons and are probably atoms of helium; they are identical with canal-rays. The β rays are identical with projected electrons and cathode rays. They possess 100 times the penetration of α rays and are capable of traversing metal foils. When cathode rays strike a solid obstacle, they are converted into aether pulses known as Röntgen rays or x rays. The γ rays possess the highest powers of penetration. The γ rays of radium traverse half an inch of lead before they are half absorbed. These γ rays seem to be aether pulses, not projected particles of any kind.

The radio-active elements are the elements of highest atomic weight: uranium, 238·5; thorium, 232·5; radium, 226·5 (*cf.* lead, 207; mercury, 200·8). The pure radium compounds are many millions of times as radio-active as those of uranium and thorium. The radio-activity of a radium compound seems to consist, in ordinary circumstances, of all three kinds of rays in unvarying proportions.

10. Transmutation

Quite by chance it was discovered that the radio-active elements were disintegrating, and that those of higher atomic weight transmuted themselves into others of lower atomic weight. In the radio-active process there seems to be a long succession of distinct and separate changes, part of the energy being evolved at each change. Hence there exist, intermediate between a given initial radio-active element and its final transmuted form, a number of intermediate forms of matter more or less transitory. Nearly thirty of these transitional forms have been recognised in the changes of the various radio-active elements. For anything we know to the contrary, numerous other and more subtle changes may be going on, not only in radio-active elements but in all elements. It seems probable that all matter is slowly disintegrating.

Whenever an α particle is thrown off by a radio-active element, the atomic weight must change, presumably by an amount appropriate to the loss of an atom of helium, for, in every known case, α particles have been proved to be atoms of helium. Now it is known that three α particles or helium atoms are expelled in the change of a uranium atom into radium. The atomic weight of uranium is 238·5 and that of helium is 4. If then we subtract three helium atoms from a uranium atom we obtain 226·5, which is almost exactly the value of the atomic weight of radium by experiment. Again, five more α particles or helium atoms are known to be expelled during the subsequent stages suffered by radium. Subtracting these five helium atoms from a radium atom, we have 206·5. If nothing but the helium atoms are expelled (and the mass of the β particles is too small to be considered) the atomic weight of the final substance should be 206·5. The element with the nearest atomic weight is lead (207).

In all these determinations, the quantities available for experiment are minute, and the experiments are of the utmost delicate character. So far, there is no direct experimental proof or disproof that lead is an eventual stable product resulting from uranium changes, but the proof is confidently expected in time. Moreover, lead is a constant companion of almost all uranium minerals, and the older the geological formation from which the mineral is derived the higher the percentage of lead seems to be, a telling fact in favour of the expectation just mentioned. It is unquestionable that in the radio-active elements we are witnessing spontaneous transmutations, though much experimental work has still to be done before numerous points of doubt can be cleared up.

The group of inert gases of which helium is the most interesting have not yet been found in chemical union with each other. Even their atoms do not unite in pairs to form molecules, a process which is so characteristic of elements higher in the scale of evolution.

If science ever succeeds in uniting the members of this series amongst themselves, it will probably be found that the product is not a chemical compound in the ordinary sense of the term, but a chemical element higher up in the periodic scale, and probably one with which we are familiar. Apparently these inert gases are virtually half-way stages between electrons and ordinary elements, but the energy conditions required for effecting the transformations involved are unknown. The transition from any element to the next in the periodic scale is, presumably, merely the addition of a certain number of electrons to the lower atom. The higher the atomic weight, the greater the number of electrons and the greater the store of energy per unit of matter. Between any two elements there are probably numerous transition products, none of them in stable equilibrium, and all tending to pass forwards or backwards according to prevailing conditions. Such conditions are to be found in the suns where the temperature is exceedingly high, and there is spectroscopic evidence that in those suns reversible actions of the kind are in progress.

Transmutation is a natural process which we cannot imitate, and we cannot therefore make use of the vast supplies of the primary sources of energy stored up within the atom. It is true that at high temperatures molecules are decomposed or dissociated into their atoms, but there is no reason to believe that, at any known temperature, heat will decompose the atom into electrons. Transmutation does not take place under the action of the most intense heat available, and we have no means of bringing about transmutation artificially.

The vast forces which may become available if we can discover means to control the rate of the disintegration of the atom may be realised from the fact that weight for weight radium gives off 1,000,000 times as much energy as any substance in any chemical reaction hitherto known. The mystery of the source of the energy of radium is increased a thousandfold when the nature of its "emanation" (the first transitional product) is considered. From a gramme of pure radium the gaseous emanation obtained occupies only ·6 cubic millimetre at normal temperature and pressure, that is the volume of an ordinary pin's head. If one-thousandth part of this volume were mixed uniformly with the air of a very large hall, the amount in a single cubic inch of the air could still be detected by a sensitive gold-leaf electroscope. The energy given out by pure radium compounds is extraordinary. Every hour radium generates sufficient heat to raise the temperature of its own weight of water from freezing-point to boiling-point, and from observation it is known that this has gone on regularly year after year ever since the substance was discovered.

The approximate rate at which radium disintegrates has been experimentally determined, and the average period of life of a radium atom, before its complete transformation, is thus easily estimated to be about 2500 years. The average life of uranium can also be definitely estimated: it is 3,000,000 times that of radium, or 7500 million years. Physicists no longer hesitate to give geologists all the time they demand for the evolution of the earth from a gaseous form!

The energy evolved in radio-active changes puts into the shade all previous known examples. Mass for mass, the most violent explosion known (in which the molecules are broken up though the atoms composing them remain unaltered) liberates scarcely a millionth part of the energy set free when atoms fly to pieces. Only the kinetic energy of motion is sensible and knowable. Within the atom potential energy so vast in amount exists that it is almost beyond conception. The natural processes in which atomic energy is evolved are necessarily either excessively slow or are shown by extremely minute quantities of materials. Radio-activity is altogether uninfluenced by external conditions. It proceeds at its natural rate, and we have discovered no process by which to hasten it. It is true that when we have reduced matter to an exceedingly attenuated form, as in a highly exhausted Crookes' tube, we can bring about, in a very slight degree, something of the nature of atomic disruption, but for the most part the atom stands defiant, four square to all the forces we can bring to act upon it. If at any time an appreciable fraction of the potential energy within the atoms of matter were to get free, the vast explosion which would inevitably take place would, in a fraction of a second, convert the earth into a gaseous nebula.

It must be borne in mind that what we commonly call radiation, whether light or heat or magnetic disturbances, is the vibration of the aether. It is not the atom pulsating as a whole which disturbs the aether but the vibrations or orbital revolutions of its electrons. If an electron vibrates or describes a small orbit $(4{\cdot}1)^{14}$ times a second (a number equal to the number of seconds in 14,000,000 years) the radiation will result in the lowest kind of visible red light. If it revolves faster, it will yield light of higher refrangibility.

11. Laws of Conservation of Energy and Matter

The law of the conservation of energy is the generalisation that in every complete material system, subject to any kind of internal activity, the total energy of the system does not change, but is subject merely to transference and transformation. But things as distinct from one another as light, heat, sound, rotation, vibration, elastic strain, gravitation, electric currents, and chemical affinity, have all to be brought under the same heading to make the law true; and how are we to know that these form an exhaustive list of the categories of energy? It is conceivable that a new form of energy may some day be discovered that will not come within the law. The study of radio-activity, for instance, urges caution in this direction. Meanwhile the law holds good for all known cases.

The law of the conservation of matter is the generalisation that, in any operation, mechanical, physical, or chemical, to which matter can be subjected, its amount as measured by weight remains unchanged. The law is the corner-stone of chemistry. But it is not self-evident, for why should any particular property of matter remain unchangeable when all other properties seem to be subject to modification? So far as we know, so far as the most delicate balances can tell us, the law is true. Yet we cannot be quite certain that the weight of a body does not vary slightly with some physical property, say its state of aggregation, or even its temperature, though even if this proved to be the case we could not say that the amount of *matter* was different; it would be sufficient to say that weight is not so fundamental a property of matter as hitherto supposed. When an atom breaks up into electrons, its weight *may* disappear, for we do not know whether weight is a property of the grouping called an atom, or whether it belongs to the individual electrons of that atom. But whether the weight disappeared or not, its inertia would certainly *not* disappear; inertia is the most fundamental property of matter we know. Hence at our present state of knowledge we must hold that the constancy of fundamental material still holds good, even though atoms are resolved into electrons. Even though it should eventually turn out to be the fact that inertia is not the absolutely fundamental property of matter (in which case there would then seem to be no single material property that could be specified as absolutely constant), yet, so long as the electrons, whatever they are, remain constant, we may fairly say that at least the *basis* of matter is fundamentally conserved.

Instead, however, of matter and energy being separately fixed in amount, there is good reason to think that they are mutually convertible. We have assumed that electrons are knots or twists, or vortices, or some sort of either static or kinetic modification of the aether—small bits separated from the rest and individualised by reason of this identifying peculiarity. Imagine these knots untied, twists undone, vortices broken up; the identity of the electron would be lost and its substance resolved into the original aether, without parts or individual properties. If this happened, the properties of matter would have disappeared and "matter" itself would be destroyed. It may be that electrons are aethereal indestructible entities, but if in the future science discovers that they can be destroyed, no physicist would be surprised. That being so, why should he be surprised if the correlative phenomenon happened —that new knots or twists should one day occur in the aether? At all events the destruction and creation of "matter" are easily imaginable and may come within the sphere of experimental possibility. But matter would thus be resolved into, and created from, the pristine aether, and it would be the aether which alone would persist, the aether with such states of motion or strain which it possesses eternally. Aether would thus be the material substratum and the fundamental entity. Even so, it would be rash in the extreme to deny the existence of other fundamental entities, as we shall see later on.

12. The Electrical Hypothesis difficult for a Layman to conceive

It is very difficult, though not impossible, to form a mental picture of matter as constituted according to the electrical hypothesis. The salient facts may be repeated. Gross matter consists of molecules of which there are 1700 trillions in a single drop of water; the molecules of liquids and solids are held together by cohesion, which, however, is much greater in the case of the latter than of the former; the nature of cohesion is unknown, but it is perhaps a residual or differential chemical affinity over molecular distances. A molecule is, as a rule, a complex structure of atoms bound together by chemical affinity which is probably intense electrical attraction at ultra minute distances. Atoms consist of electrons, of which there are usually many thousands to each atom. The diameter of an electron is 1/100,000 part of that of an atom, which itself is about 1/250,000,000 of an inch. These small dimensions are utterly beyond the limits of the most powerful microscope, so much so that it is exceedingly difficult to picture electrons, atoms, or molecules, and the mind unconsciously magnifies them enormously. The molecules are in a bodily movement of locomotion, travelling at a speed of 1000 miles an hour, and each colliding with its neighbours 6,000,000,000 times a second. The motions of the individual atoms within the molecule are not known, but it is highly probable that there is motion of some kind.

Further, each of the many thousands of electrons within each atom performs every second nearly four hundred billions of orbital revolutions. This amazing picture may to some readers prove extremely unconvincing, especially as at first sight it does not seem to convey to the mind anything of the nature of rigidity of ordinary solid matter. But such readers as may have any practical acquaintance with hydraulics and hydrodynamics ought not to experience difficulty in making this part of the picture convincing, as they will be acquainted with the remarkable force that may be exerted by rapidly moving liquids. Still, what experiments can be devised to give even a faint notion of a liquid rotating billions of times a second? None. But though we can form no conception of the orbital motions of the electrons, the vast number of revolutions per second enable us to form an idea of the resulting electronic inertia. And when we remember the thousands of electrons within the atom, the atoms within the molecule, the fact that there are 1700 trillion molecules in a single drop of water, and that molecules are far more numerous in a solid, and that even in a solid the individual molecules must be performing very rapid vibratory movements, we begin to feel that rigidity is an inevitable property of solid bodies.

13. Is the Hypothesis justified?

It must never be forgotten that the aether, molecules, atoms, and electrons are all purely hypothetical. They are all creations of the imagination. The great laws established on a basis of experimental fact are true, but the hypotheses as to the unknowable causes underlying the laws are still hypotheses. Other hypotheses might be created to cover all the facts. For instance, we might assume that matter is made sensible to us by its inherent property of inertia or mass, and that the energy which we call heat and light passes to the earth from the sun through *empty space*, but is neither absorbed nor otherwise modified until ponderable matter is reached. This hypothesis makes some appeal to common-sense, but there is one fatal objection to it: the radiation which we call light is *known* to travel at the rate of 186,000 miles a second, and it is inconceivable that anything can travel at such a speed through absolutely empty space. The inconceivability of the hypothesis renders it unacceptable. It is, however, true that there is no crucial experiment to decide between the electrical hypothesis of matter and any other formulated hypothesis which covers all the facts. We may deny the existence of the aether, but we are bound to postulate *something* in order to account for light undulations travelling at a speed of 186,000 miles a second, and although we are uncertain of the nature of that something we know a good deal about its properties. We may deny the existence of molecules, but we are bound to postulate discrete particles of *some* kind to account for the diffusion of gases. We may deny the existence of atoms, but we are bound to postulate *something* representative of the atomic weight. We may deny the existence of electrons, but we are bound to postulate the existence of particles of *some* kind possessing a mass 1/1000 part of the mass of a hydrogen atom. That there are entities of some kind admits of no question. The doubt is as to the *nature* of the entities, only a small proportion of the properties of which we can claim to know. When science states that the aether, electrons, atoms, and molecules exist, its claim is not that it has complete knowledge of them or is in any way familiar with their individualities, but rather that it has definite knowledge of entities of *some* kind, and of *some* of the properties of those entities.

To such a wide subject, such a short chapter can do scant justice, and unless the reader has had considerable experience in chemical, physical, and mechanical laboratories he is hardly likely, from the very nature of things, to be able to estimate the worth of the experimental evidence on which the main hypothesis is based. Molecular, atomic, and electronic dimensions, molecular and electronic velocities, are, to him, likely to exceed the limits of credibility; whereas if, by long experience, he has gradually become accustomed to experiments of greater and greater refinement, and is practically acquainted with the extraordinarily small measurements which it is the everyday business of the physicist to make, his difficulties and doubts will vanish. Conviction is not brought about by isolated experimental facts, but by vast numbers of facts converging in many lines to the same point.

The electrical hypothesis of matter, as defined by science, possesses a high degree of credibility. The *nature* of the aether, molecules, atoms, and electrons is a metaphysical question. Science simply gathers up the facts, and unifies them into a whole by means of an hypothesis. The very act of unification involves an addition—some sort of inner framework; and here we hazard a guess. To science this guess is merely provisional. If the guess is converted into dogmatic assertion, it becomes an unverifiable metaphysical concept.

The difficulties of the electrical hypothesis are many, and there is sometimes a disposition to deny the existence of electrons and of the aether. But science is too cautious to deal in negations. Denial is no more infallible than assertion. Scepticism can become arrogantly dogmatic, and science has to be as much on its guard against personal predilections in the negative as well as in the positive direction. It is as easy to doubt everything as to believe everything, and each course is a common refuge of the intellectually lazy. For dogmatic assertion, a wide range of knowledge is necessary; for dogmatic denial, a far wider range.

Assuming that the existence and nature of the aether becomes definitely established, can it be said that the old metaphysical problem as to the nature of matter and substance is finally solved? No. Science will have solved the problem only in part. It will have taken us merely one step further back. If matter is resolvable into and created from the aether, the question remains, what is the origin of the aether? Gross matter disappears from our list of metaphysical categories, but its place is taken by the aether. Science *may* unravel the mystery of the aether, but when that veil is penetrated it will have to set to work anew and try to penetrate the one that lies beyond. How can the work of science ever be completed?

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5. Lothar Meyer. *Outlines of Theoretical Chemistry.* (Trans. by P. P. Bedson and W. C. Williams.)
6. J. S. Mill. *System of Logic.*
7. Karl Pearson. *The Grammar of Science.*
8. A. Sidgwick. *The Applications of Logic.*
9. Alexander Smith. **Introduction to Inorganic Chemistry.*
10. F. Soddy. ***Matter and Energy.*
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12. Sir J. J. Thomson. **The Corpuscular Theory of Matter.*
13. F. W. Westaway. *Scientific Method: its Philosophy and its Practice.*
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24. Thomas Preston. *The Theory of Light.*
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26. Sir W. A. Tilden. *The Elements.*
27. S. P. Thompson. *Light, Visible and Invisible.*

*** In Sir Oliver Lodge's two books the reader will find exceptionally clear expositions of a subject usually found difficult by people unversed in science.

CHAPTER IV

INFINITY. SPACE AND TIME

1. "Z^Z"

BEFORE attempting to consider the nature of infinite quantities, the reader should endeavour to form a still clearer conception of very large finite numbers.

It takes rather less than ten minutes for light to reach us from the sun, for it travels at the rate of 186,000 miles a second, that is at the rate of six billion (6×10^{12}) miles a year. The distance (6×10^{12} miles) that light travels in a year is known as a "light-year."

The nearest fixed star is the star *alpha* of the constellation Centaur. Its distance is about 24 billion miles, that is four light-years. In other words, it takes light four years to travel from that star to the earth.

If the earth be represented by a grain of sand one-hundredth of an inch in diameter, the sun will be represented by a sphere 1 inch in diameter 10 feet distant. The star α Centauri will be represented by another sphere about 1 inch in diameter but 500 miles distant.

The remoter nebulae are so distant that their light, travelling at the rate of 186,000 miles a second, probably takes a million years to reach the earth. Since light travels 6×10^{12} miles in one year it travels 6×10^{18} miles in a million years. We may assume that 6×10^{18} miles represents the extreme limit of the visible universe.

Now conceive the visible universe to be of the form of a sphere with a radius of 6×10^{18} miles, the earth occupying the centre. It is easily calculated that the volume of such a sphere is about 10^{57} cubic miles.

Imagine this vast sphere to be filled with very fine dust 1000 grains to the inch, or 1,000,000,000 to the cubic inch. The total number of grains of dust that would fill the sphere is about 10^{80}. Represent this number by Z.

Let the reader imagine further—if he can—this sphere and all its contained grains of dust to expand uniformly so that every one of the Z grains becomes as large as the original sphere, and let this expanded sphere be filled with dust of the same degree of fineness. Neglecting interspherical spaces, the total number of grains is Z^z, that is, not $(10^{80})^{80}$ but $(10^{80})^{10^{80}}$. The more the reader reflects on such a number as this the more he will realise the extreme difficulty of forming an adequate conception of it.

Such a distance as Z^z light-years may legitimately be called indefinitely great or unimaginably great, perhaps inconceivably great; but inasmuch as the distance is still finite it cannot be "infinitely" great. Compared with an infinite distance, the distance Z^z light-years is as nothing. It is particularly necessary to guard against confusion of the two terms "indefinite" and "infinite," for there is a fundamental distinction between the indefinitely great and the absolutely unlimited. It is extraordinarily difficult to conceive such a distance as Z^z light-years, even dimly. Still it may perhaps be conceded to be within the bounds of possibility, whereas the conception of an infinite distance is absolutely impossible. Whether a belief in infinity is justified or not the reader must decide for himself after considering a few illustrations.

2. The Notion of Infinity

Poincaré imagined a world enclosed by a large sphere and subject to the following laws: (1) the temperature is not uniform, but is greatest at the centre and gradually diminishes towards the circumference where it is absolute zero ($-273°$ C.); (2) all bodies in this world have the same coefficient of expansion, so that the linear expansion of any body is proportional to its absolute temperature; (3) a body transported from one point to another is instantaneously in thermal equilibrium with its new environment. Obviously any moving object that approached the inner surface of the sphere would, under such conditions, become smaller and smaller; and, although from the standpoint of ordinary geometry such a sphere-world is finite, its inhabitants could believe it to be *infinite*. For as they approached the surface of the sphere they would become colder and colder and at the same time smaller and smaller; the steps they would take would therefore be always shorter and shorter, so that they could never reach the sphere boundary. As we shall see later on, it is possible that our own universe is finite, though we have the feeling that it must be infinite.

The reader is probably familiar with the spherical mirror: examples are to be seen in toyshops at Christmas time. Such a mirror depicts all the surrounding objects in miniature. Any given object in front of it is apparently represented by a fixed image behind the mirror. The more distant the object, the nearer is the image to a focal position half-way between the spherical surface and the centre of the sphere, and the smaller does it become. When the object is indefinitely distant, the image is indefinitely near this focal position, and it is indefinitely small; but it can never become infinitely small or actually reach the focal position, for this would mean removing the object to an infinite distance, which is impossible. The image of a man measuring with a rule a straight line normal to the mirror would contract more and more the farther away the man went, but with a shrunken rule the man in the image would count out exactly the same number of feet as the real man. But no matter how long a line the real man measured, he could never measure more than a finite line, and his image would thus never reach the focal position. The more distant stars might be reflected in the mirror, but their images would never quite reach the focal positions on the surface of the imaginary inner concentric sphere of half the radius of the mirror sphere. The men in the mirror could thus never reach the surface of this focal sphere. They would imagine the space between the two spheres to be infinite in extent, though we know it to be finite.

A common statement in algebra is, "sum to infinity" such a series as $1, \frac{1}{2}, \frac{1}{4}$, etc. But the word "sum" as applied to an infinite series is used in a purely conventional and artificial sense. We cannot deal with such a series as if it consisted of a finite number of terms. An infinite series cannot be "summed." But we can find a *limit* to which the sum of any number of terms of the series continually approximates more and more nearly. The limit of the sum of the above series, for instance, is 2, but the sum of even such a number as Z^z terms of the series is less than 2. When mathematicians write, "the limit of $\frac{1}{x} = a$ as x approaches zero as a limit," all they mean is that, by taking x small enough, $\frac{1}{x}$ can be made to exceed any pre-assigned number, however large. The mathematician's infinitesimal is not a "small quantity," but a "variable" which, under the conditions of the problem in which it occurs, can be diminished indefinitely, and thus approach as near as we please to zero as a limit, without ever absolutely reaching it.

If we accept the view that a line is composed of points, it is clear that the line cannot be composed of a *finite* number of points; otherwise, if the number happened to be odd, the line could not be bisected. Again, it is well-known that no two whole numbers will express the ratio between the side and the diagonal of a square, but if each of the lines contained a finite number of points there would be a definite numerical ratio. The existence of incommensurables proves, in fact, that every *finite* length must, if it consists of points, contain an *infinite* number. In other words, if we were to take away the points one by one we should never take away all the points however long we continued the process. The number of points, therefore, cannot be *counted*, for counting is a process which enumerates things one by one. The most characteristic property of an infinite collection is that the collection cannot be counted.

Consider two concentric circles. Take a number of points on the circumference of the outer circle, and from the centre draw a radius to each point. Each radius cuts the circumference of the inner circle, so that there are as many points on the circumference of the inner circle as on the circumference of the outer. Imagine the outer circle to be so large as to extend to the remoter nebulae, and the smaller one to be so small as to be only just visible to the eye. Further, imagine an indefinitely large number, say Z^z, of points taken on the circumference of the outer circle, and all the radii drawn; the number of points on the circumference of the inner circle is also Z^z. Evidently there are, in any line, however short, more points than any assignable number.

A sheaf of rays emerging from any point in space is defined as the infinite totality of rays completely filling the space around the point. Let such a point be the centre of two concentric spheres, one indefinitely large, one indefinitely small. Then, since the number of rays is infinite, and since every ray pierces both spheres, and all the points on the outer sphere are paired with all the points on the inner sphere, the number of points in each case is infinite. Now on the surface of the larger sphere take an area equal to the surface of the smaller sphere. This area contains the same number of points as the surface of the smaller sphere, a number which is equal to the number of points in the larger sphere. Thus the number of points in a *part* of the surface of the larger sphere is equal to the number of points in the *whole* of the surface of the larger sphere. We therefore have a second characteristic of infinite collections, that the whole is not greater than its part. It should be noted that the equality in the above example does not subsist between *areas* but between *point-collections*. The proposition, "the whole is greater than its part," cannot be universally true, for in the world of infinities it must be invalid.

The terms finite and infinite are mutually exclusive and correlative. We think of a line as finite in length, that is as finishing here or there; or we try to think of it as infinite in length, that is as unfinishing, finishing nowhere, extending without limit. Such expressions as "extending both ways *to* infinity," "*at* an infinite distance," are mathematically convenient, but they have no correspondence with reality.

That there can certainly be something beyond the whole of an unending series is easily seen; for instance, 1 is beyond the whole of the infinite series $\frac{1}{2}$, $\frac{3}{4}$, $\frac{7}{8}$, $\frac{15}{16}$. . . . But an infinite number can never be reached by successive additions to finite numbers. The acquired habits of mind derived from the consideration of finite numbers must not be extended to infinite numbers, for they do not represent logical necessities.

Given any infinite collection of things, any finite number of the things can be added or taken away without increasing or diminishing the number in the collection. Even an infinite number of things may, under certain conditions, be added to or taken away, and an infinite number still left. For instance, imagine the infinite series of natural numbers, 1, 2, 3, etc., written down in a row, and the even numbers, 2, 4, 6, etc. written immediately underneath them—

1	2	3	4	5	6	7	8 . . .
2	4	6	8	10	12	14	16 . . .

so that under each number in the top row stands its double in the bottom row. Then the number of numbers in the two rows is the same, yet the second row results from taking away all the odd numbers (themselves an infinite collection) from the top row. Thus the number of all finite numbers is not greater than the number of all even finite numbers. Again, therefore, we have an instance of a whole being not greater than its part. (The words "greater than" mean containing a greater number of terms.)

Suppose a man undertakes to write a history of the world and it takes him a year to write up the events of a day. Obviously if he lives but for a finite number of years, the older he gets the farther away he will be from finishing his task. If, however, he lives for ever, no part of the history will remain unwritten.[1] For the series of days and years has no last term; the events of the *n*th day are

[1] The paradox of Tristram Shandy.

written in the nth year ; for a suitable value of n, any assigned day is the nth ; hence any assigned day may be written about, and therefore no part of the history will remain unwritten. Since there is a one-to-one correlation between the times of happening and the times of writing, and the former are part of the latter, the whole and part have the same number of terms. In ordinary life, it is true, the similarity of whole and part is impossible, but the supposition that it is therefore always impossible is the result of an induction which is not legitimate unless we pronounce infinity to have no meaning.

If geometrical points are real, between any two points in a line there must be an infinite number of other points. A common mathematical series will help to make this clear. Consider any number of fractions less than 1 arranged in order of magnitude. Between any two of these there are possible others, for instance the arithmetical mean of the two. Thus between any two, however little they differ, there is an infinite number of other fractions. *Consecutive* fractions (that is, fractions between which, for instance, a mean cannot be inserted) are inconceivable; so also are consecutive points in space or, if instants are real, consecutive instants in time. Between any two points, there must be an infinite number of other points, and between any two instants an infinite number of other instants. A space may be halved and halved again, and so on indefinitely, and at any stage of the process the parts are still spaces, not points. In order to reach points by such a method, it would be necessary to come to the end of an unending process, which is impossible.

Zeno argued that the swift-footed Achilles could never overtake the tortoise, since, before he could overtake it, he must first reach the place from which the tortoise started ; by that time the tortoise will have got some way ahead. Achilles must then make up that, and again the tortoise will be ahead ; and so on, without end. The argument assumes that the halving process may go on for ever, and so presupposes that space is infinitely divisible, or already consists of an infinite number of points. The assumption is perhaps legitimate. But it is further assumed that an indivisible moment of time is required for the transition from one point of space to another, and thus it is concluded that an infinite number of moments must elapse before any space whatever is got over, since any space contains an infinite number of points. If we admit this premiss, the conclusion is quite correct ; but the assumption that an infinite number of instants make up an infinitely long time is entirely unjustified, and therefore the conclusion that Achilles will never overtake the tortoise does not follow. An instant does not last for a finite time; there is no beginning and end to an instant, with an interval between them. As Zeno's argument is obviously invalid, we are forced to conclude either that the number of points in any finite space and the number of instants in any finite time is infinite, or that space and time do not consist of points and instants at all.

The reader must decide for himself which of the two alternative hypotheses he can accept. Points and instants, which are regarded by mathematicians as a convenient fiction, are both logically possible and are consistent with the facts of experience, but there is no conceivable evidence for or against them. We cannot with our senses discriminate between very similar objects, and it is impossible to decide between different hypotheses which differ only as to what is below the margin of sense discrimination. Two sense data may be, and must sometimes be, really different even when we cannot perceive any difference between them, and it is not justifiable to assume that sense data of a given kind, such as weights and colours, really form a continuous series. That space and time are continuous, that the number of shades in the spectrum is infinite, and so on, are unverifiable hypotheses, possible logically, perfectly consistent with known facts, simpler than any other tenable hypothesis, but not the only hypothesis.

Etymologically, the term infinite is somewhat misleading. The term signifies, literally, "having no end," but some infinite series have ends, some have not. The series of instants from any earlier one to any later one, is infinite but has two ends. Fundamentally, the notion of infinity seems to be involved in the properties of certain *classes*. A class which is infinite is, by its defining concept, given all at once, and cannot be reached by successive enumeration. Thus an infinite set of points can be given all at once as making up a line or area or volume, though points can never be reached by the process of successive division.

Euclid defined a point as that which has neither parts nor magnitude. But the definition has no positive meaning and no significant connotation. Modern geometers do not attempt to define point at all. Clearly we cannot reduce it to an absolute nothing, for an infinity of nothings is still nothing. Nor can we regard it as an infinitesimal. It is best looked upon as a convenient term for whatever entity may be found by intuition and trial to satisfy the hypotheses we feel coerced into forming when considering the nature of the infinite The reader must carry in his mind any image of a point that he can reconcile with what is said about it. A line may be defined as a "class" of points, but the geometrical element called point seems to be undefinable.

We cannot form any conception of the infinite by addition or multiplication, for this cannot give the unlimited; nor by generalisation, for generalisation only groups things by means of their known qualities, and unless we have infinity in the individual things, we cannot have it in the group; nor by any process of reasoning, for unless the infinite is in the premisses, it cannot find a place in the conclusion. True the mind is driven to believe that there must be something beyond its widest concept, but the actual imagining power of the mind can never go beyond an expansion with a boundary. The mental picture is that of the very large or the very long, but still the finite. No sort of clear conception is possible when we speak of infinite space, infinite time, infinite force, or infinite power. Both the infinitely great and the infinitely small are unimaginable, inconceivable, and incomprehensible. But although it is a case where we can neither conceive nor comprehend, it is, after all, a case where dogmatic denial is not possible to justify. We are, however, certain that an infinite reality can never be *perceived*. Infinity must always be *merely* a matter of idea, merely a necessity of thought.

3. Geodesic Lines. The Plane and Sphere compared

Every section of a sphere made by a plane is a circle. If the plane of section passes through the centre of the sphere, the section is a *great circle* of the sphere. All other circles are called *small* circles. The plane of a great circle obviously divides the sphere into two equal parts. The earth's equator and meridians of longitude are examples of great circles; parallels of latitude (as they are conveniently, though not accurately, named), of small circles.

As a rule, only one great circle can be drawn through two given points on the surface of a sphere, for its plane must also pass through the centre, and three points not in the same straight line are sufficient to determine a plane completely. If, however, the two given points are at opposite ends of a diameter, the straight line joining them passes through the centre of the sphere, and an infinite number of great circles can be drawn through them; examples are the meridians of longitude. "The arc connecting two points" on a sphere usually means the shorter segment of the great circle passing through the points.

The *shortest distance* that can be traced on the surface of a sphere between two points on it is the arc of the great circle passing through them. It is obviously the shortest of all the circular arcs that can be drawn between them and most nearly approaches a straight line. All the other circular arcs are parts of small circles. The shortest arc is that which belongs to the circle of greatest radius, and the circle of greatest radius which can be drawn on a sphere is the great circle. If a string be stretched between two points on the surface of a sphere (or on any surface) it will evidently be the shortest distance that can be traced on the surface between the points, since by pulling the ends of the string its length between the points will be shortened as much as the surface will permit, and the string will lie in the plane containing the normal to the surface ; thus the string must lie on a great circle.

A line so drawn upon a surface as to coincide with the position of a string stretched across the surface between any two points on the line is called a *geodesic* line. The geodesic line is therefore the shortest line between any two points on the surface. In a plane, a geodesic line is the straight line joining two given points. On a sphere it is part of the great circle passing through the two given points. Although it is true that in a plane two geodesic lines cannot enclose a space, it is not true in the case of a sphere, for any two great circles must intersect each other.

Any great circle divides the sphere into two hemispheres. If a second great circle intersects the first, the surface of each hemisphere is divided into two *lunes,* and that of the whole sphere into four lunes. A lune is thus the portion of the surface of a sphere bounded by the halves of two intersecting great circles. If a third circle intersects the other two, each of the four lunes is divided into two *spherical triangles,* and the whole surface of the sphere into eight spherical triangles. A spherical triangle is thus the portion of the surface of a sphere bounded by the arcs of three great circles. Mathematically, all the eight triangles are so closely related that, in any given case, only one of them need receive detailed consideration, and it is usual to select that one which has all three sides less than a quadrant of a great circle. This is usually possible, but not always ; for instance, if the three great circles cut one another at right angles, like the equator and the meridians 0° and 90°, all eight triangles are alike, and all the sides of all of them is equal to a quadrant.

The angle between two great circles is equal to the angle between their planes, and therefore the angles of a spherical triangle are respectively equal to the dihedral angles between the faces of the trihedral angle, the apex of which is the centre of the sphere, and the base the spherical triangle in question. In the eight equal triangles just considered, it is evident that each angle of each triangle is 90°, and that the sum of the three angles of each triangle is equal to three right angles. In fact, *in every spherical triangle the sum of the angles is always greater than two right angles.* This has very important logical consequences in what follows later.

The larger the sphere the "flatter" its surface, that is, the more nearly does the surface in the neighbourhood of a particular point approach to a plane. If the radius of the sphere becomes indefinitely great, the curvature becomes indefinitely small, and if an *infinitely* large sphere were possible, the curvature would become infinitely small; in other words, the surface would be a plane, and then the sum of the angles of any contained triangle would be equal to two right angles. But a sphere of infinite radius is inconceivable. Even in the case of a sphere with a radius equal to Z^z light-years the sum of the angles of any triangle on its surface would still be greater than two right angles.

Parallel lines on the surface of a sphere are impossible, for any two geodesic lines on a sphere meet and enclose a space, and non-geodesic lines are by their nature excluded from consideration; they correspond to curved lines on a plane. And since no two radii of a sphere can be parallel, it follows that the prolongations of radii beyond the surface cannot be parallel; hence "vertical" lines, as they are called, cannot, geometrically, be parallel to each other. Two poles, for instance, so fixed in the ground that they answer every practical test of verticality cannot be absolutely parallel, geometrically, for each points to the centre of the spherical earth. (The departure from exact sphericity does not materially affect the argument.)

The best example of a plane that we have is the surface of still water, but, even so, it is only approximately plane, for it partakes of the general curvature of the earth. The truest planes which human ingenuity can produce are not, strictly speaking, planes at all; they are small portions of the surface of a sphere some 8000 miles in diameter.

4. "Points at Infinity"

Take in a plane an unlimited straight line p (Fig. 1), a point S not in the line, and a line q drawn through S and intersecting p in the point A. Let the line q rotate about S, as indicated by q_1, q_2, q_3, q_4, q_5.

The point of intersection A will move along the line p to the right (A_1, A_2, A_3, etc.) until it is lost to view, then will appear to the far left, moving along the line in the same sense as before. Mathematicians make the conventional assumption that the two lines p and q have not at any time ceased to intersect, and that the point A has moved continuously along the line p, disappearing at the far right and reappearing at the far left *immediately* after passing through but a single position which lies outside the accessible region of the plane. For very near positions, say A_1 and A_2, of the point A, the angle of

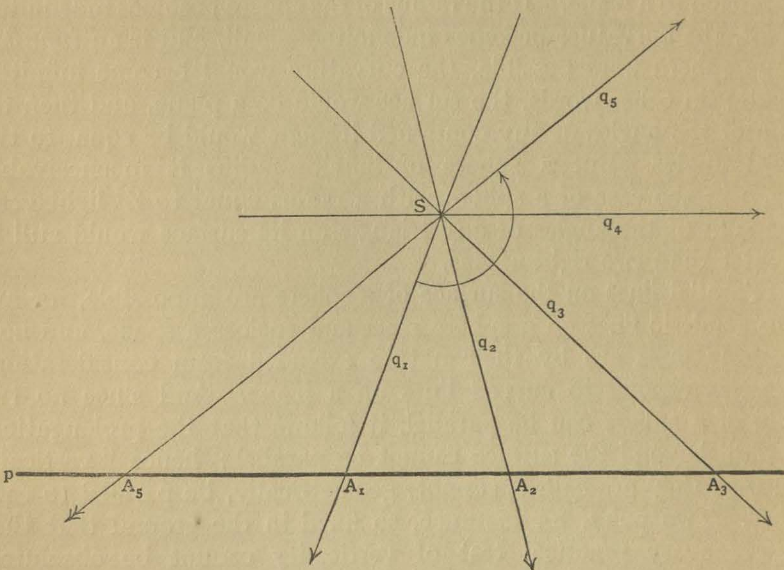

FIG. 1.

rotation A_1SA_2 is very small; and conversely it may be said that the smallness of this angle is the test of the nearness of A_1 and A_2. Hence if A_1 and A_3 were indefinitely remote from some specified intermediate point A_2 in p, we may still pass from A_3 to A_1 by turning q through an indefinitely small angle.

There is one intermediate position q_4 where q does not cut p, that is where q is parallel to p. In every other position it cuts p in some finite point. It is customary to say that in the parallel position, q_4, q cuts p in A at an *infinite* distance, and that though q does not then cut p in any *finite* point, yet q and p meet at infinity. Parallel lines are thus assumed to meet at an infinitely distant point, and this ideal point is called the point at infinity in the line.[1]

But it must never be forgotten that points at infinity are purely imaginary. The geometrical results which are based on the assumption that such points exist are true for that finite region of space which is within our reach ; beyond that region the results may or may not be true—we do not know.

5. Euclid's Parallel Postulate

"If a straight line meets two straight lines in such a way as to make the two interior angles on one side of it together less than two right angles, these straight lines will meet if continually produced on the side on which are the angles which are together less than two right angles."

This so-called twelfth axiom of Euclid is not an axiom in the sense of being self-evident ; it is more correctly described as a postulate, for it involves an improved assumption. Indeed, in some manuscripts of Euclid, axioms eleven and twelve are found placed respectively as the fourth and fifth postulates.

Euclid's statement of the parallel postulate obviously lacks that simplicity and intelligibility which ought to characterise a fundamental proposition. This objection cannot be urged against Playfair's version : "Through a point not in a given straight line, there cannot be drawn in the same plane with it more than one straight line that does not cut it." But though the phrasing is simpler, the proposition is precisely the same, as all mathematicians readily recognise.

The postulate admits of definite rejection, and a rigorously logical and independent geometry may be developed on the assumption that *more than one* straight line through the point (Playfair's version) is parallel to a given straight line. This geometry gives results empirically undistinguishable, within the limits of observation, from those of Euclid.

It was after innumerable vain attempts to prove the truth of the postulate that non-Euclidean geometries were thought out. These geometries do not refer to those that have taken the place of Euclid

[1] The point at infinity in a line is supposed to be reached whether we move a point in the one or in the opposite direction of a line to infinity. A line thus appears closed by this point, and we speak as if we could move a point along the line from one position A_1 to another A_2 in two ways, either through the point at infinity, or through finite points only. Hence the geometrical statement, opposite points at infinity coincide ; or every straight line or system of parallels has only one point at infinity.

in schools, all of which are at bottom Euclidean. They are something essentially different and they follow from *a denial of the truth of the parallel postulate.*

But it is first necessary to consider the nature of an axiom.

6. The Nature of Geometrical Axioms

Geometry has sometimes been defined as the " science of space," but such a definition is open to criticism. If space is infinite, it cannot be measurable. *Things* in space can be measured, but, when the things are removed, the space they first occupied cannot be measured, for, although such space is finite, its boundaries are now lost. To say that geometry is the science of space is something like saying it is the science of emptiness or even of nothingness. It is more correct to say that it is the science which deals with the sizes, shapes, and distances of things. We perceive the shapes of bodies by means of the senses of sight and touch and the muscular sense, but as we have no recollection of the long laborious process of the manner in which we learned to perceive, the actual origin of much of our geometrical experience is unknown to us. When we began to philosophise about it, we realised that the origin was lost in a past that we could not recover.

Such past geometrical experiences as we can remember are usually an inextricable medley of facts, and inferences more or less doubtful ; and it is difficult to reduce them to order. But, of course, it is a matter of everyday experience that we are constantly detecting differences and resemblances of sizes, shapes, and distances, though these are mainly qualitative, not quantitative. The quantitative experiences are often deceptive, and even from the qualitative experiences we are apt to draw wrong conclusions. For instance, take a strip of paper 18 or 20 inches long and about 1 inch wide, and throughout its length on each side draw a median line ; bring the two ends together, bracelet fashion, and secure them by two pins. With a pair of scissors, cut along the median line. Clearly the result will be two loops, each exactly like the first but half its width, and separated. Now repeat the experiment, but, before bringing the ends together, give one end one or more half twists, that is turn it through one or more times 180°. As the reader will find, it is difficult now to forecast the result of cutting along the median line.[1] To forecast the result of a quantitative spatial experience is sometimes more difficult still. Take two similar coins, preferably

[1] The series of 1, 2, 3, 4, 5 . . . half twists give an instructive succession of results.

with milled edges, say two florins ; fix one to the table, and let the other roll clockwise (without sliding) once completely around it. To many people it is almost impossible, before actually performing the experiment, to determine the angle of revolution performed by the moving coin. To represent on paper the path in space of a particular point on the surface of the moon while the moon revolves round the earth and the earth round the sun is most baffling ; and only those who have tried to determine the actual motion of a planet from its apparent path amongst the stars can be aware of the difficulty of the problem. There are many pitfalls for the plain man who attempts to generalise his spatial experiences.

When we define a thing, we define it in terms of something else, this in terms of again something else, and so on. Evidently some term or terms must be left undefined, and thus in a rigorous treatise on geometry we find no definitions of such terms as *point, straight line,* and *between,* the very terms which a layman might think it easiest to define. Again, when we prove a proposition in geometry, we prove it by virtue of some other proposition, so that at least one proposition must be left undemonstrated. When for purposes of instruction accumulated geometrical knowledge was first systematised, the simplest principles, those apparently free from doubt and contradiction, were placed at the beginning. These principles were reduced to a minimum, and gradually they came to be regarded as higher truths than demonstrated truths, and their empirical origin was not unfrequently forgotten.

Axioms cannot be *a priori* truths or necessities of thought, for they would then impose themselves upon us with so overwhelming an authority that we could not conceive their contradictories, or on these found different systems of geometry. Nor, strictly, are they generalisations from experience. They are rather *abstractions* from experience, but somehow in the process of abstraction an assumption is made and becomes involved in it. That, ultimately, they repose on experience there is no doubt whatever, and since this experience is limited to a finite region and usually a very small finite region, there is a danger in asserting that the axiom holds universally. The certainty which we attribute to generalisations of empirical science, for instance the laws of chemical combination, arise from our finding no exception to them, and it is true that, within the small finite region of space with which we are familiar, we find no exception to the axioms ; but it does not by any means follow that we can legitimately extend the generalisation to all space. The axioms are the result less of generalisation than of idealisation of our spatial experiences. It is true that the choice of the concepts is suggested by the choice of facts, but the choice remains free.

Since the axioms are not necessary truths, and since those we use are entirely a matter of choice, it follows that there is a possibility of displacing them by others. Geometry being purely deductive, the choice of premisses is a matter of indifference.

The axioms are sometimes regarded as propositions concerning some of the more fundamental geometrical conceptions. When *definitions* of these conceptions are given, the statements commonly appear to be of a different kind from the axioms. But, under the guise of definitions, statements may be introduced which are really axiomatic propositions. It is often said that a number of axioms are hidden away in Euclid's definitions. Some mathematicians [1] say that axioms are nothing but definitions in disguise, others [2] that definitions are nothing but axioms in disguise. The reader can take his choice.

The modern differentiation of axioms and postulates is due to Euclid's successors who urged that the former are undemonstrable principles of demonstration and the latter undemonstrable principles of construction. But, again, the distinction is rather shadowy. Thus axiom ten is generally worded "two straight lines cannot enclose a space"; but if we recast it and say "only one straight line can be drawn between two points," what appeared to be a principle of demonstration seems to have become a principle of construction. Whatever distinctions are drawn between definitions, axioms, and postulates, they are open to criticism.

It is exceedingly difficult to pick out from geometry a list of unassailable axioms, and in any case they are to be regarded not as self-evident but as improved. But at least two axioms, one relative to the notion of magnitude, and one relative to the notion of direction, seem to be absolutely necessary. Euclid's axiom of "Free Mobility" (which he uses but does not formulate), that is, that figures may be freely moved about without change of shape or size, also seems to be necessary. Apart from these, the premisses of geometry may perhaps best be regarded as propositions which merely attempt to define the fundamental geometrical abstractions. We say attempt, advisedly; for the abstractions do not seem to admit of precise definition. Primitive ideas are explained by means of descriptions intended to point out what is meant; but since the explanations really involve the ideas they explain, they cannot be said to constitute definitions.

[1] *E.g.* Henrici. [2] *E.g.* Poincaré.

7. The Origin of Non-Euclidean Geometry

The reader will remember that Euclid i. 32 (the angle sum of a triangle) depends on Euclid i. 29 (properties of parallels), and the latter on the parallel postulate. It is scarcely necessary to remark that these two propositions (i. 29 and 32) are inseparably connected and represent merely different aspects of the same experience.

Increasing doubt concerning the truth of some of Euclid's axioms gradually led to increasing certainty that different systems of geometry, each internally consistent but inconsistent in many respects with each other and with Euclidean geometry, could be developed. Non-Euclidean geometry seems really to have begun with Gauss (1779–1855), a German mathematician. He saw that Euclid's parallel postulate was possibly, if not probably, false, and that it ought to be empirically tested by measuring the angles of large triangles. But Lobatchewsky, a Russian, was the first to publish a non-Euclidean geometry, and this embodied the consequences of rejecting the parallel postulate.

It was assumed (on p. 84) that the two co-planar straight lines p and q (where p is of unlimited length and q rotates about a fixed point S) have not at any time ceased to intersect, and that the point A has moved continuously along the line p, disappearing at the far right and reappearing at the far left *immediately afterwards*. Euclid's parallel postulate stated, in effect, that, *at the very instant* when A disappeared at the far right, it reappeared at the far left, and that there is only one position in which the lines do not intersect, viz., when q and p are parallel. But Lobatchewsky argued that there must be a finite angle through which q must be turned, after A had disappeared at the far right, before it could reappear at the far left, or at all events that the two hypotheses are alternative and mutually exclusive. Let q_1 (Fig. 2) be perpendicular to p and let ASM be a right angle. Then the two hypotheses are: (1) as Euclid affirms, every straight line q through S which falls within the right angle ASM will cut p; (2) only those straight lines through S which fall within the acute angle ASN (of uncertain magnitude) will cut p, the straight line q_3 to the right of q_1 being the limit between those lines which cut p and those which do not. Similarly to the left of q_1. Of course the angle ASN can in any case be only very slightly less than a right angle, for, if it were not, a slight prolongation of q_3 would bring about an obvious intersection with p. The true perspective is necessarily distorted in any possible figure, for the supposed actual variation from a right angle cannot be within the range of sense perception. Lobatchewsky admitted, of course, that, within the limits of any measurable plane, Euclid's conclusion must be correct, but he denied our right to extend that conclusion beyond such limits, and this is what we do if we accept the parallel postulate. He maintained that, for all positions between SM and some other line SN, there was no intersection with *p*. It therefore follows that, no matter how small the angle MSN may be, an infinite number of parallels to *p* may be drawn through S. And from this it follows directly that the sum of the angles of a triangle is less than two right angles.

Lobatchewsky retained all Euclid's axioms except the parallel axiom or postulate, but his theorems are very different from Euclid's.

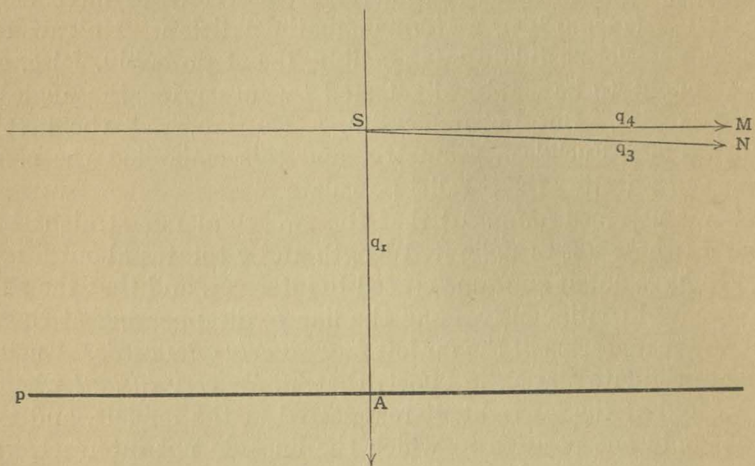

FIG. 2.

For instance: "the angle-sum of a triangle is less than two right angles"; "it is impossible to construct a figure similar to a given figure but of different dimensions." Yet his geometry is as rigorously logical as Euclid's. The many differences are the direct consequence of the non-acceptance of the parallel postulate.

A little later, Riemann, a German mathematician, discovered that there was another of Euclid's axioms that ought not to be accepted, viz. the tenth: "two straight lines cannot enclose a space," or "two straight lines cannot intersect twice." A denial of this axiom is logically necessary if the surface which is commonly called "plane" is considered to be really spherical, as is actually the case with all planes, so-called, on the earth's surface. Since all "straight" lines are then parts of great circles, they should be called " shortest " or geodesic, and they all intersect twice ; on such a surface there can be no parallels ; and in any triangle the angle-sum must be greater than two right angles. Thus Riemann's geometry gives us a third system, though it is really equivalent to spherical geometry.

The fundamental distinctions are easily seen. In Euclid's geometry there is only one parallel, and the angle-sum of a triangle is equal to two right angles ; in Lobatchewsky's, there is an infinite number of parallels and the angle-sum is less than two right angles ; in Riemann's, there are no parallels, and the angle-sum is greater than two right angles.

Lobatchewsky's real intention is, in point of fact, open to some doubt. If, as seems possible, he meant his system to apply to the Euclidean surface and line, that is, the surface and line which Euclid calls, respectively, plane and straight, then Lobatchewsky's planimetry only contradicts the parallel postulate, and is merely an alternative system to Euclid's geometry. But if he intended his system to apply to *some other surface* than that which Euclid calls plane, then he does not contradict Euclid, and he does not establish a different system of geometry, but he gives us a geometry of a pseudo-spherical surface, that is, a surface of constant negative curvature. Whether this was his intention or not, his plane geometry (as we may call it) was shown by Beltrami to be identical with the geometry of a pseudo-spherical surface. Similarly, Riemann's geometry is identical with that of a surface of constant positive curvature, for example a sphere. The whole question thus assumes an entirely different aspect when it is stated that the three geometries concern different types of surface, and not the same Euclidean plane surface. But more than this : Riemann extended the notion of measure of curvature from surface to *space.* In fact, Riemann's work contains two fundamental conceptions, that of a *manifold* and that of *measure of curvature* of a manifold. Space he regards as a particular kind of manifold. He gives proofs to show that observation cannot establish the fact that space is strictly Euclidean, and he demonstrates that there is a possibility of space being finite, though, like Euclidean space, unbounded ; in such a space every " straight " line would return into itself and be closed. But we must pause to explain the meaning of " manifold " and " measure of curvature."

8. " Dimensions "

A " manifold " is concerned with space " dimensions." The statement " every material body has three dimensions " means that the body is *extended* and is measurable in three different *directions* ; these are usually taken at right angles to one another, like the three edges meeting in the corner of a rectangular block where the three principal directions, indicating length, breadth, and thickness respectively, are easily distinguishable. In the case of such a thing as a sponge, the different directions are more arbitrarily chosen, though, like the block, the sponge also has three " dimensions."

Magnitudes which have only one dimension are an example of measurement in its simplest form. If we wish to determine the precise position of some given point in a line, it is sufficient to state how far that point is from one end of the line or from some other fixed point in it. The position of the given point is therefore given by a *single number*. The end of the line, or other fixed point in it, from which we measure is regarded as the zero point. The fact that a single number is sufficient to determine the place of a point in a straight line is the real reason why we attribute to the straight line a single dimension. Every totality of things in which one number is all that is necessary to determine any particular one of them is called *one*-dimensional. Another instance of a one-dimensional magnitude is the circumference of a circle. So is the totality of all concentric spheres having some one fixed point in space as a centre, the radii of which can be expressed by successive numbers of increasing magnitude.

The term *two*-dimensional is applied to all totalities in which *two* numbers are necessary and sufficient to determine some particular thing in a given totality. The simplest case is that of the plane. If we had to determine the position of a particular point on this rectangular page, it would be sufficient to drop perpendiculars from the point to any two adjoining edges. *Two* numbers would then determine the position. If the plane is unlimited in extent, it is customary to adopt, arbitrarily, some zero point, and from it to draw two lines, usually at right angles to each other and called axes, and to drop perpendiculars from the point on these. The two perpendicular distances, known as the co-ordinates of the point, give the point two definite numerical values. Descartes saw that, since every point in a plane could be determined in this way, it was easy to treat geometry algebraically. The surface of the earth is another two-dimensional totality. As, however, the surface is spherical, the rectilinear axes are replaced by two arbitrarily chosen great circles at right angles to each other, from which angular distances are taken. But only *two* such distances are necessary, latitude and longitude. Still another two-dimensional totality are all the possible straight lines that can be drawn through any point in space. For consider a plane through which all these lines pass. Then every point in the plane will belong to some one line; but every point in the plane is determined by *two* measurements; hence the totality of all the straight lines—the sheaf of rays, as they may be called—are of the same dimensions as the totality of the points in the assumed plane, that is, of *two* dimensions, for every point in the plane is determined by two measurements.

When we pass from the plane, a two-dimensional totality, to the space in which we live, we come to a *three*-dimensioned totality. To determine any given point in space, three measurements are necessary. From an arbitrarily chosen zero-point, three lines at right angles to one another are drawn, like the three edges that meet in a corner of a rectangular block, giving three axes. These three lines determine three planes, corresponding to the three sides of the rectangular block that meet in a corner. The position of the given point is determined by the three perpendicular distances—the three co-ordinates—from the three planes.

It would therefore seem to follow that an n-dimensional totality of things is such that the specification of n numbers is necessary and sufficient to determine any individual in that totality. But as the world-space which we inhabit is a three-dimensioned totality, are totalities of *more* than three dimensions possible?

Imagine all possible spheres in space. Any particular point in space may be the centre of an infinite number of concentric spheres, forming a one-dimensional totality, as already stated. But *every* point in space may become the centre of such a totality of spheres. Since all these centres form a three-dimensional totality, it follows that all conceivable spheres in space are a *four*-dimensional totality. The totality is easily conceivable, but imaginable only with difficulty. It is best to consider, at first, a limited number of points in space at equal finite distances apart, and each of these points to be the centre of a finite number of concentric spheres of radii constantly increasing by a finite amount. When a clear mental picture of these series of intersecting spheres has been formed—by no means an easy task—the finite distances may be diminished indefinitely. Of course if the distances are diminished *infinitely*, the imagination is unable to follow.

Again, consider a straight line of invariable length to assume every conceivable position in space: a lead-pencil if its thickness be ignored may be used as an illustration. One of the ends of the pencil may be imagined to assume a position at every point in space ; then we have a three-dimensional totality for this end alone. But as we saw when considering two-dimensional totalities, there proceeds from every such position of this end, a two-dimensional totality of directions ; and by considering the pencil to be placed lengthwise in every one of these directions, we shall obtain all conceivable positions which the second end can assume, and the case is therefore one of a *five*-dimensional totality.

Similarly it can be shown that the totality of all equal plane rectangles which differ from one another only by their positions in space is *six*-dimensional. All conceivable triangles in space form a *nine*-dimensional totality, for *any three* points in space can be joined to form a triangle, and each of these points is itself a member of a three-dimensional totality. All conceivable cubes in space form a totality of still higher dimensions.

We have used the term "totality" because its meaning is correctly suggested by the word "total." But the term in common use is "manifold." Thus we may speak of all conceivable spheres in space as a "quadruply extended manifold," and space itself as a triply extended manifold the elements of which are points. If an object in a manifold is completely specified by n co-ordinates, then every different group of n co-ordinates will specify a different object in the manifold. The entire totality of such objects will form a "continuously extended manifold."

It is well known that a single algebraic equation, of the first degree, in two variables, *e.g.* $7x+5y=50$, has an infinite number of solutions, for any value may be given to x and then the corresponding value of y determined. Two independent such equations admit of a single definite solution, *e.g.* $3x+2y=14$ and $2x+5y=13$ give the single solution $x=4$, $y=1$.

A single equation of the first degree in three variables, *e.g.* $3x+2y+5y=18$, admits of a two-fold infinity of solutions. Two independent such equations admit of a one-fold infinity of solutions ; three, of only one solution.

All such equations admit of a geometrical interpretation and can therefore be mentally pictured in space. Every equation of the first degree in two variables represents a straight line, that is, an infinite number of points, corresponding to an infinite number of solutions of the equation. Every two independent such equations represent two independent straight lines. These will, in general, intersect in one point, corresponding to the single definite solution of the equations.

Every equation of the first degree in three variables represents a plane, that is a two-fold infinity of points, corresponding to the two-fold infinity of solutions. Two such equations represent two independent planes which must, in general, intersect in a straight line, corresponding to a one-fold infinity of solutions. Three such equations represent three independent planes, and every two of these must, in general, meet in a straight line, and the three resulting straight lines will, in general, meet in a point, corresponding to the one and only one solution of the equation. This may be compared to the three adjacent faces of a rectangular block, every two of which meet in an edge and the three edges in a point.

As we have already seen, manifolds of *any* number of dimensions may be conceived; and it is well known that equations of any number of variables are possible. Yet our world space, that is the manifold of all conceivable points that differ only in respect of position, cannot, in agreement with our ordinary notions of things, possess more than three dimensions. We cannot bring the theory of space into connection with the theory of equations of more than three variables simply because space, as we picture it, has only three dimensions. Manifolds of more than three dimensions are *conceivable*[1] but not clearly imaginable. Although, however, we cannot picture manifolds of more than three dimensions as clearly as we can picture ordinary spatial magnitudes, that is regular three-dimensional point-totalities, yet there are advantages in extending the notion hypothetically.

If we have equations of the first degree in four variables, x, y, z, u, and if we attribute to each of the four variables every possible numerical magnitude, we have a four-dimensional manifold of numerical quantities which may be regarded as a four-dimensional point-totality. Just as two equations of three variables give us two planes (two-dimensional point-totalities or manifolds) which intersect in a line (a one-dimensional manifold), so two equations of four variables may be considered to give us two three-dimensional point-totalities (two solids) which intersect in a two-dimensional point-totality, that is, in a surface. And when we note that a^2 stands for the area of a square, and a^3 for the volume of a cube, we naturally inquire after the contents of a structure which is produced from the cube as the cube is produced from the square, and is represented by a^4. But our mental picture of this four-dimensional structure is certainly hazy; indeed, to many people the picture is not improbably altogether unimaginable. Every schoolboy knows how to develop on paper two-dimensional "nets" which will fold

[1] See pp. 93, 94.

up into the three-dimensional polyhedra, and Victor Schegel claims to have made models of three-dimensional nets for the analogous structures in four-dimensional space; but all attempts to "fold up" the nets seem to have baffled him.

9. Flatland and Sphereland

In order that a four-dimensional space may be better conceived, and in order that a generalised conception of space may be made, use is sometimes made of the fable of two-dimensional reasoning beings living in two-dimensional space.

Imagine such beings, infinitely attenuated as to thickness, that is beings of two dimensions, living and moving on the surface of an infinitely extended plane from which they cannot emerge. They have no power to perceive anything outside the surface, and if they worked out a geometry they could assign only two dimensions to their space. They would discover that a point in moving describes a line and that a line in moving describes a surface; in fact the geometry would be much like ours, and they would say that only one straight line is possible between two points, also that only one parallel to a line can be drawn through any external point. But they could as little imagine what further spatial construction would be generated by a surface moving out of itself as we could imagine what would be generated by a solid moving out of the space we know. They could form no conception of a third dimension, or of a movement to a third dimension, any more than a man blind from birth could conceive colours. But their space would appear to them to be infinitely extended, just as ours does to us, although our bodies cannot leave the earth and the range of our vision is limited.

But such beings might be imagined to live on the surface of a sphere. Their space would still be of two dimensions, but their shortest and straightest line between two points would be an arc of a great circle. If two points were taken at the ends of a diameter of the sphere, the spherelanders would see that the axiom "there is only one shortest line between two points" did not always hold. Of parallel lines they would know nothing. They would maintain that any two straightest lines must finally cut in two points. The angle-sum of a triangle would be always greater than two right angles, increasing with the area of the triangle. No conception of geometrical similarity between greater and smaller figures of the same kind would be possible. The space of sphereland would be *unbounded* but would be *finite* Spherelanders would set up a very different set of axioms from that of flatlanders, or from ours in a space of three dimensions, though the logical powers of all three peoples would be the same. It would therefore seem that geometrical axioms must vary according to the kind of *space* that reasoning beings inhabit.

The fable is so ingenious that it is apt to be accepted without the necessary cross-examination. Clearly we have no right to assume that the abstractions we draw from our own three-dimensional experience must be the same as the actual spatial experiences of the flatlanders and spherelanders, for a concrete three-dimensional experience is a necessary condition for forming those abstractions. We can hardly but conclude that their experiences would be as inconceivable to us as ours would be to them. Though analogically useful, the fable is to be distrusted, and it forms no necessary part of the theory of space of dimensions higher than three. But just as an imaginary sphere-dweller, living on a very large sphere, and finding that his space appears to be similarly constituted throughout, would regard that space as infinite because experience had never suggested the contrary, so we in our three-dimensional space, finding it everywhere the same, almost unconsciously conclude that it is infinite because the contrary has never been suggested by any part of our experience.

Is space finite or infinite ? that is the problem. It must be one or the other, and neither alternative can be regarded as logically impossible.

10. Measure of Curvature

Every system of geometry is founded on the assumption that any given fixed figure may, without changing its form, be transferred from one part of space to another. This axiom of Free Mobility was made use of by Euclid,[1] though not formulated by him. Now, although it seems obviously possible, within the limits of a plane, to take a plane figure, for instance a triangle, out of one position of the plane and bring it into another, without altering its sides and angles, can this be done on other surfaces ? The test is easily made by the use of some flexible and inextensible material like paper, from which may be cut, say, a triangle and applied to the surface in question. Such a triangle can be applied to the surface of a cone or cylinder, and although there will be a bending of the figure there will be no distension or contraction, and the figure will touch

[1] *e.g.* in I. 4.

the surface at every point, no matter to what part[1] it is applied. It can be made to slide about the surface which it will closely fit all the time, just as if the surface were plane. During any bending that may be necessary, lengths and angles remain constant. Just as a plane surface has no curvature, so with the surfaces of a cone and cylinder: all are said to have a "zero" curvature.

It is obvious that a plane triangle could not be similarly applied to the surface of a sphere. Without crumpling, the triangle could not be made to touch at more than one point. But if we imagine a triangle drawn on the surface of a sphere, and then lifted and placed on any other part of the sphere, it would fit exactly, and could be made to slide freely over the whole spherical surface. The surface is therefore *constant* and it is obviously *curved* and the curvature must be *measurable*, and the smaller the radius of the sphere the greater the curvature. The curved surface of an egg is evidently not constant; no closely fitting figure could be made to slide over the whole of it.

When a surface like that of a plane or a sphere admits of a figure sliding over it in close contact all the time, the surface possesses certain special properties, and its "measure of curvature" is constant. In the case of a plane, the measure of curvature is *zero*, in the case of a sphere it is *positive*.

But there is a third kind of surface, that of the pseudosphere, the geometry of which is similar to that of the plane except that the parallel postulate does not hold good. The surface is not easy to describe, for at every point it exhibits, in directions proceeding from the same side, a partly concave and a partly convex character, something like the mid-point of the surface of a saddle, or of the top of a mountain pass, or a point on the smallest circumference inside a hollow ring. The radii of curvature at such a point have opposite signs, and the measure of curvature[2] is therefore *negative*. As in the case of the plane and the sphere the measure of curvature is constant. Thus we see that in the case both of the plane, the sphere, and the pseudosphere a figure that fits in one place may be moved about freely in all directions without any change in the lengths of its lines or in the magnitude of its angles. But only in the case of the plane is the postulate of similarity applicable, for this postulate requires the possible construction of a figure, on any scale,

[1] The conical and cylindrical *bases* form no part of the conical and cylindrical surfaces proper.

[2] In its simplest form, the algebraic expression for the measure of curvature of a surface is, for any point of the surface, equivalent to $1/R_1R_2$, where R_1 and R_2 are the greatest and least radii of curvature at the point.

similar to a given figure, and in practice this really depends upon the ordinary doctrine of parallels. Euclid's geometry is the geometry of the plane; Riemann's is identical with that of the sphere; and Beltrami has shown that Lobatchewsky's is identical with that of the pseudosphere.

Riemann conceived the idea of generalising the notion of measure of curvature. Just as the two-dimensional surface of a sphere is unbounded but finite, and just as that surface may be regarded as a two-dimensional space, so, according to Riemann, we may by analogy assume the existence of a three-dimensional finite unbounded space of constant positive curvature. Our own world space would thus be conceived to be *finite*, not infinite, though *unbounded*. Just as figures drawn upon surfaces of constant curvature, whether zero, positive, or negative, can be displaced, without distortion, on those respective surfaces, so should analogous conditions, according to Riemann, hold for rigid bodies, which therefore would be capable of free motion only in a space of constant curvature. Just as all lines on a sphere are of definite finite length, closed and returning into themselves, so Riemann conceived in his three-dimensional space of positive curvature, analogues of the straight line and the plane, *finite* but *unbounded*. Is this an illusion? But Riemann went further. He conceived the idea of generalising space itself. Just as two-dimensional space may be regarded as a particular case of three-dimensional space, Riemann conceived three-dimensional space to be a particular case of four-dimensional space, the four-dimensional space a particular case of five; and so on. Thus the space we know would be a three-dimensional manifold in an n-dimensional manifold. The theory of multi-dimensional spaces is useful in mathematical research, but whether such spaces actually exist, whether even a four-dimensional space actually exists, is a problem apparently insoluble.

11. Four-Dimensional Space

From very elementary geometry we know that the congruence of two triangles is demonstrated by the superposition of one triangle on the other, and by then ascertaining whether they completely coincide. Even a flatlander, if he could picture to himself motion in a plane, might become convinced of the coincidence of two congruent triangles; he would simply have to push one triangle out of its place into the position of the other. But he could not convince himself of the congruence of the two symmetrical triangles

A and B (Fig. 3). He would discover the equality of the sides and angles, but he could never superpose one triangle on the other and make them coincide. A three-dimensional being can do this easily enough by simply turning one of the triangles about one of its sides until it is "upside down," and then pushing it into position. A

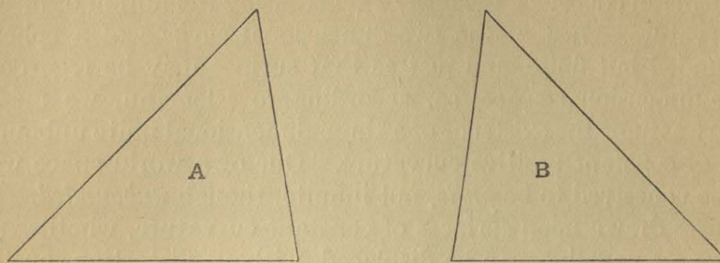

FIG. 3.

flatlander, having no knowledge of a third dimension, could not do this. To him the turning of a thing "upside down" would be inconceivable.

Now let the reader develop two oblique triangular pyramids in

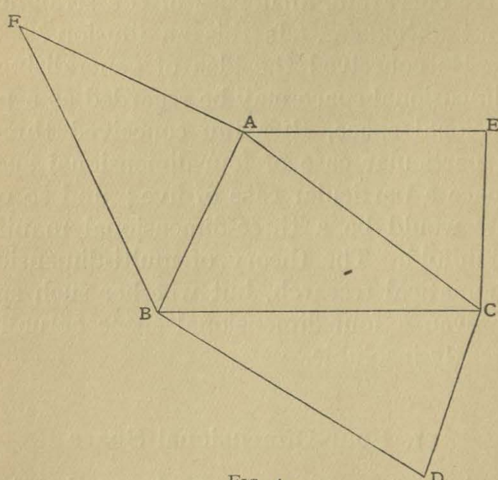

FIG. 4.

this way. Cut out in paper two figures exactly like Fig. 4. Cut the paper half-way through its thickness in the lines AB, BC, CA, in the one case on the front and in the other case on the back. Fold the paper on these cut edges until D, E, and F meet in a point, in the one case above and in the other below. (AE = AF, BF = BD, CD = CE.) The result is two pyramids which, in all lengths and all angles, are congruent, yet which cannot be made to coincide. One is the *reflected* image of the other. They are right-handed and left-handed, like a pair of gloves, symmetrical. Now just as it was impossible, by simple displacement, to bring into congruence the two two-dimensional triangles A and B, so it is impossible to bring into congruence the two three-dimensional symmetrical pyramids. But just as a right-handed glove may, by turning it inside out, be converted into a left-handed glove, and the symmetrical pair thus be made a similar pair, so, if we could turn one of the pyramids inside out we should convert the symmetrical pair into a similar pair. And we are told that, by analogy, we may conceive the same thing to be effected by moving one of the pyramids out of the three-dimensional space of experience, "turning it round" (whatever this may mean) through a four-dimensional space, and then bringing it back again into our experiential space.

A flatlander could not conceive how any two-dimensional object lying within a given circle in his two-dimensional space could reach any position outside that circle without passing through the barrier of the circumference, yet a three-dimensional being could easily bring this about simply by lifting the two-dimensional object into three-dimensional space and putting it back again but outside the circle. Such an object would therefore suddenly disappear before the eyes of the flatlander and after a time would reappear outside the circle without having passed through the circumference. If now we imagine a four-dimensional being doing similar duty in three-dimensional space, we may, it is said, conceive how an object might suddenly disappear from before our eyes, even though we were within a hermetically sealed room, or how a "ghost" might appear in such a room. Even the "thing-in-itself," the "substance" in which all the "qualities" of matter "inhere," has been similarly explained. Just as the shadows of three-dimensional objects cast on a wall are controlled in their movements by the things that project them, so it has been claimed that there exists at the back of everything of this sense-perceptible world a real transcendental and four-dimensional thing-in-itself, the projection of which in the space of experience is what we falsely regard as the independent thing.

In this way it has been sought to establish the existence of a four-dimensional space. But however helpful the hypothesis of a four-dimensional space may be to the mathematician, the hypothesis remains an hypothesis after all. Four-dimensional space is just a mathematical abstraction derived, analogically, from algebraic considerations, and its real existence is improbable. All the material *actualities* we know are certainly three-dimensional, and to speak of four-dimensional *matter* is as self-contradictory as the notion of two-dimensional matter. Nevertheless it may be conceded that a four-dimensional world might conceivably exist in some manner other than material, though it does not admit of representation. And if outside our three-dimensional world there exists another world of four dimensions containing ours, it is not unreasonable to conclude that worlds of still higher dimensions exist. Although most of the phenomena to which spiritualists appeal are probably founded on sense illusions, yet it cannot be denied that there possibly do exist psychical phenomena, for instance telepathy, which cannot be harmonised with the natural laws now known. But whether such phenomena are to be explained by the existence of four-dimensional space is entirely hypothetical. The absurdities which had their origin in Flatland are not due to mathematicians but to the baser sort of spiritualists who found in the fourth dimension an unexpected means of providing a plausible rationality to many of their far-fetched theories.

12. The Obscurity of Riemann's Notion

It seems impossible to form a definite and stable conception answering to Riemann's description of a "multiple extended magnitude," which shall include the notion of space as a particular case of it. But if we ignore the idea of magnitude and consider that of manifold only, then, as we have already seen, a "multi-dimensional manifold" admits of a possible algebraic interpretation, and, to this extent, space may be regarded as a particular three-dimensional case of it.

Riemann probably used the term "measure of curvature" in connection with the conception of a multi-dimensional manifold because the algebraic expression involved is analogous to that for the measure of curvature of a surface at any point of the surface, that is the expression $1/R_1R_2$. Hence his multi-dimensional manifolds may involve nothing beyond mere notions of quantitative relations, and thus "measure of curvature" as applied to manifolds of dimensions higher than three would seem to have no spatial significance. Nevertheless, the possibility of the ordinary three-dimensional space of experience being curved and, as a consequence, finite, is the very core of Riemann's theory.

It is fairly safe to assume that, within the portion of the space of experience of which we are cognisant, space has the special property that a given body can be transferred from any one point to any other, without suffering in the transference any distortion or any contraction. The space of experience has therefore a constant measure of curvature. But it does not follow that this applies to *all* space. We have no right to dogmatise concerning the unknown. There is, moreover, the further assumption that space is homaloidal, in other words, that its constant measure of curvature is equal to zero : the assumption appears in Euclidean geometry under the guise of the parallel postulate. But it is clearly impossible to be cognisant of the parallel lines contemplated in that postulate. All we really know is that the limited portion of space that falls within our experience is practically homaloidal. *If* space has a constant measure of curvature and *if* it is homaloidal, it must be infinite.

But if the measure of curvature is positive, the premisses not of Euclid's but of Riemann's geometry follow, and then space must be *finite*, that is the extent of space must be limited to a finite number of cubic miles. For, in that case, no matter how slight the difference the curvature constant might be from zero, any point which moved continuously onward in a " straight " line (more accurately, in a shortest line or a geodesic) would ultimately, though perhaps after having traversed a distance to which Z^z light-years is an insignificant trifle, arrive from the opposite direction at the place from which it set out. If the point had started upwards, it would return from below. The notion seems incredible, but so, too, to primitive man would the notion have been that, if we start round the world to the west and keep on in the same direction, it would be from the east that we should return to the starting-point. If, then, the space constant is positive, space must in some way return into itself. Its volume must be finite, just as the surface of a sphere is finite. But although the conception of a straight line regarded as a shortest line or geodesic, and therefore finite and returning into itself, is simple, for we get it on the surface of a sphere, does the statement, *space* is finite and returns into itself, lead to any clear conception ? Can we conceive a three-dimensional analogue to the surface of a sphere ? Probably not. But then we cannot form an adequate conception of the aether, of the origin of consciousness, of the nature of life, of the soul, of the First Cause, of a hundred other things. It is rash dogmatism absolutely to refuse to believe merely because we cannot adequately conceive.

13. Can Riemann's Notion be put to a Practical Test?

Apparently the question could be definitely settled if we could actually measure the space-constant, and the only possible means of doing this seems to be by astronomical observation, that is by measuring vast stellar triangles and finding out whether the angle-sum is equal to or greater than two right angles. But the degree of accuracy of such triangles as have been measured, that is accuracy confirming Euclidean geometry, is remarkably great. In no case has the angle-sum differed from two right angles by as much as the one-hundredth part of a second. But these triangles of parallax investigation, though based on distances of billions of miles, are utterly insignificant when compared with the dimensions of space itself. Viewed in its true relation to space itself the whole of the visible universe must, in any case, be an inconceivably small microcosm. Our means of measurement are therefore utterly inadequate to enable us to pronounce authoritatively on the presence or absence of curvature of space. We say "absence" because, if the curvature is zero, space is homaloidal.

But the same problem involves other difficulties. The application of Euclidean geometry to astronomical mensuration assumes that light is propagated in lines which are straight in the Euclidean sense. But, strictly, light "rays" have no existence. A body which emits light creates a disturbance which according to the wave theory is propagated outwards in all directions through the aether. The disturbance reaches points equidistant from the body at the same time. Neglecting corrections for aberration and atmospheric refraction, the assumption is thus made that the line of vision, which is normal to the advancing disturbance, is in the direction in which the body lies. When in considering the effect of the earth's atmosphere we say that the "rays" are "refracted" or bent, what we really mean is that the wave-front of the disturbance is deformed in its passage through the obstructing atmosphere, so that, in general, the line of vision does not coincide with the direction of the body. Neither the rising sun nor the setting sun, for instance, is seen in the direction in which it really lies.

Suppose, then, that stellar triangles with an angle-sum greater than two right angles are discovered. The Euclidean would attribute the curvature of the triangle to some physical cause, perhaps to refraction of the aether, at all events to some unknown obstruction to the uniform propagation of light. The non-Euclidean would argue that the cause is not necessarily physical, that the result is perfectly consistent with the uniform propagation of light, that the directions of vision do coincide with the directions of the star from the observer, but that the lines of direction are not straight in the Euclidean sense: they are the "straight" lines (more properly geodesic lines) of Riemann's geometry, which return into themselves. Hence if such stellar triangles are discovered, we shall have to abandon either Euclidean geometry or the hypothesis that the propagation of light is rectilinear.

Different kinds of space appear to be conceivable, but the co-existence of different kinds of space is not. The independence of each is a logical necessity; so also are the properties of each. Hence if in order to render intelligible the alleged conception of a non-Euclidean space we import into it some characteristic feature of Euclidean space, this logical condition is violated. For each conception of space must involve a notion of direction peculiar to itself, just as each of these conceptions involves a space-constant or specific measurement peculiar to itself.

Since it is impossible for ordinary notions of direction to find a place in the conception of non-Euclidean space, and since it is difficult to avoid introducing such ordinary notions into any spatial conception we may form, it is doubtful if after all we are justified in saying that different kinds of space are conceivable. Certainly it seems to be quite impossible to form any clear conception of a space in which a shortest line would not be a straight line. Yet this does not mean that we may question the logical integrity of either of the non-Euclidean geometries. They are on precisely the same footing as Euclid. But whether any one of the three geometries, and, if so, which, has an external validity as an exact description of perceptual space, it is impossible to say.

There is a widespread fallacy that the possibility of the geometry of three-dimensional space being other than Euclidean depends on the physical existence of space of four or more dimensions. Such an idea is baseless.

14. The Properties of Space

It is natural for primitive man to identify space with the illuminated atmosphere which forms the background of the visual picture before his eyes. And all ingenuous people who, like the astronomers of antiquity, rely upon direct perceptions, see the heavens approximately as a sphere, finite in extent. But as soon as the mind has acquired the power of forming abstractions, it begins to idealise its space of sense-experience. By untrammelled orientation, by progressive motion in every direction, we invest this space of experience with identical constitution at all places, and we assume that it extends to an infinite distance in all directions. But all that experience makes certain are the correlated spaces of the several senses. Even this single correlated space is only a logical construction and is therefore not necessarily an independent reality. It is particularly desirable, therefore, to guard against looking upon the infinite space which we construct intellectually as necessarily a reality.

Space is sometimes described as the correlative of matter. When we say " there is something there," we mean, " there is *not* empty space ; " and when we say " there is nothing there," we mean, " there *is* empty space." Phenomenally, space is nothing. Our recognition of it is, in fact, a recognition of absence of response to our senses, the effort to touch or see but the finding of nothing. In the phenomenal universe, space is that which gives us no sentience and offers to us no resistance, so that it does not exist in the manner in which we suppose particular portions of the universe to exist. The non-existence of space cannot by any mental effort be imagined. We cannot get rid of the idea that space surrounds us on all sides. We are compelled to think of it as everywhere present, and we cannot conceive its absence either in the past or in the future. Since the non-existence of space is inconceivable, its creation is inconceivable.

The properties of idealised space, that is the space of Euclidean geometry, therefore seem to be: (1) it is continuous; (2) it is infinite ; (3) it is of three dimensions; (4) it is homogeneous; (5) it is non-resistant ; (6) it yields no response to our senses.

Of bodies absolutely at rest, we know nothing. The earth revolves round the sun ; the whole solar system is rushing through space, in relation to the Milky Way, at an enormous speed ; and it seems probable that the Milky Way itself is rushing through space in a similar fashion. A celestial body absolutely without motion in space is inconceivable. If space is infinite, all the celestial bodies may continue to rush through space for an infinite time. There is nothing to distinguish one part of space from another except in its relation to the position of material bodies. We cannot describe the position of a body except by reference to some other body. All our knowledge is essentially relative. The absolute position of a point is unknowable. It is doubtful even if we are justified in saying that we know the absolute distance between two points on the earth's surface. Suppose, for instance, that one night all the dimensions of the universe increased a thousand times. Everything would remain similar to itself, but everything would have grown in the same proportion. On waking, we should be unconscious of any change and should be unable to detect it. As space is relative, nothing would appear to have happened. As with space, so with motion: only relative motion is directly measurable. Absolute motion seems intrinsically unmeaning. Imagine the universe to consist of a single body travelling through infinite space. Obviously it would be impossible to determine its velocity, for there would be no standard of reference.

15. Time

It is probable that, in its most primitive form, the idea of time is the recognition of an order of sequence in our states of consciousness. If our memory were perfect, we might be able to refer every event within our own experience to its proper place in a chronological series. But it would be difficult, perhaps impossible, to compare the interval between one pair of events and that between another pair.

Mathematical time, "duration in itself," is considered as progressing constantly and uniformly. It is an abstraction from the mere succession of events which we arrange in order, before and after one another. The pauseless flow is sometimes conceived as a succession of instants, but the mathematical instant itself has no duration, just as the mathematical point has no spatial magnitude. Events of which we are conscious do not last merely for a mathematical instant, but always for some finite time, however short. Impressions on our sense-organs produce sensations which are never strictly instantaneous. Instants are therefore not among the data of experience; they are inferred, and, so far as they are constructed at all, are constructed mentally. Two events may be simultaneous, or one may be earlier and the other later. One event may begin sooner than another, but may continue after the other had begun and therefore be also simultaneous with it. If it persists after the other is over it will also be later than the other. As long as we are concerned with events which last for a finite time, however short, the terms earlier, simultaneous, and later are quite consistent with one another, but they become entirely inconsistent when we are dealing with something instantaneous.

All dates are determined by events. An *absolute* date cannot be given, for we cannot point to a time itself but only to some event occurring in that time. Experience does not give us times as opposed to events. Like instants, therefore, time itself is merely a mental construction; it is inferred. All that experience gives us are events ordered by the relation of simultaneity and succession. Every experience has a certain duration, it may be for the tenth part of a second, or, of course, for very much longer; the amount is variable and cannot always be determined. Every experience also involves change, and duration and change are sometimes described as the elements of time.

Empty time, a time in which nothing happens, is a false conceptual abstraction which has no place in real experience; it is simply equivalent to the suspension or standstill of time. It involves the assumption that our experienced consciousness is to be conceived as a series of illuminated points from one to another of which we stride across an interval of darkness. But the experienced consciousness is a moving and continuously changing whole, and it is this continuous movement which constitutes the reality of time. For our measure of time we select some arbitrarily chosen motion, for instance, the angle of the earth's rotation. But all cases of motion which came under our consideration are essentially *relative*, as before stated. Equal times are generally defined as those intervals during which the earth turns through equal angles relative to the "fixed" stars, and any duration of time may then be measured by the angle turned through by the earth during the interval. But since the whole scheme of time measurement ultimately depends upon the testimony of the various heavenly bodies, we may legitimately ask, after duly allowing for all the forces which we know are acting on those bodies, whether the length of the day (or the rate of rotation of the earth) is the same now as formerly. There is reason to believe that it is not the same, for it is now an established fact that the solar year is slowly diminishing in length; and we cannot therefore base our fundamental notions of the measurement of time upon the earth's rotation simply. But the flow of mathematical time or duration must be conceived to be unaffected by the speed or slowness of the motions of material things, and the measurement of relative, apparent, or common time, based upon the motion of the earth, is merely a scheme for meeting the requirements of man's convenience.

Infinite time cannot be imagined, for to follow the regress of movement to infinity requires an infinite time in which to accomplish it. But infinite time may be adequately conceived as exceeding any assignable limit. In order to conceive an existence beyond the first moments of time, and to connect that existence as cause with the subsequent temporal succession of effects, we must conceive time itself as non-existent and then commencing to exist. But when we make the effort to conceive time as non-existent, we find it impossible to do so. Time, as the universal condition of human consciousness, clings round the language in which we speak of an existence *before* time. Nor are we more successful when we attempt to conceive an infinite regress of time.

Whatever meaning we attach to the term " eternity " necessarily has its roots in our temporal experience. In its ordinary meaning it usually suggests lasting through all time, enduring for infinite time. But an endless progress and regress afflicts the mind with helplessness, and many philosophers therefore insist on the essentially *timeless* nature of reality.[1] But this is an overstatement. Absolute timelessness may more correctly be said to belong to different kinds of truths. The *knowledge* of any truth is, of course, an event in time; it is part of the history of some mind. We all feel certain at the moment in which we feel any truth that we have not created it for the first time, but merely recognised it; it was valid before we thought of it, and will continue so without regard to an existence of any kind. The inductively established laws of the physical sciences, if true at all, are timeless truths.

The meaning of the term eternity is not exhausted, in fact does not primarily consist, in the idea of mere continuance or the indefinite prolongation of existence. It is charged with emotional value, derived from the worshipper's indestructible confidence in the permanence of the Divine character.

Space, time, matter, and motion are all ultimately traceable to the same experience, namely, to the muscular and visual sensations. It is true that we form a separate conception of each, but what right have we to assume that separate concepts stand for possibly

[1] The reader should try to grasp the modern philosophical distinction between durational or clock time, and qualitative time.

Time, as the consciousness of succession, is not, as we feel at first sight tempted to assert, bound up with the permanence of physical motions, by which at present we measure it; but it *does* seem to depend upon our consciousness of Change or Becoming in the wider sense, of which physical motion is but a single example. If, therefore, there were no Change, time would not exist for us, *i.e.* would not exist at all. Apparently, therefore, we ought to be able to conceive a state of things in which Change is transcended. If this be so, we begin dimly to perceive that the beginning of time and the birth of our present universe may have been a coincident transition from equable and unchanging Being, from the harmonious Now of Eternity, into the unrest and struggle of Becoming.

But all this being granted, the question still arises, How was the unrest initiated ?

separate existences? The results of mental analysis are not necessarily independent factors of creation. There is no reason to suppose that either space, or time, or matter, or motion ever existed separately. Certainly we have never experienced them separately, and we deceive ourselves if we think that they can be separately explained. When we talk of *motion* we really mean *matter* traversing *space* in *time*. The four seem to be inseparable.

16. Conclusion

The ordinary negative definition of infinity, as formulated by mathematicians, is legitimate enough, but it is purely subjective; it makes no reference to reality. The vagueness which inevitably attaches itself to our idea of infinity is indicative of our intellectual limitations; the idea concerns reality only in so far as our thought interprets it.

We must regard the infinity of space as resembling the valid negative conception, and not the invalid positive conception, of infinity. By the infinity of space we need not mean anything more than that we cannot clearly *think* a limit to space, cannot think of any space which is not bounded by spaces. So with time: we can conceive no time which was not preceded by an earlier time. The infinity of space and time can never be given as an actual *fact*. Infinity can never be anything real, never more than an imperfect thought construction.

If we argue from the infinity as constructed in thought to the infinity of the spatially extended universe, we relapse into the illegitimate conception of infinity as something positive and actual. If we say that the universe is infinite in space and time, we are really confessing our inability to think of space and time being exhausted and limited by successive additions of spaces and times. But this tells us absolutely nothing as to whether the real universe is infinite. To infer the infinity of the universe from a mere thought-constructed infinity is to assume a complete agreement between reality and thought, and this assumption is utterly unjustifiable.

That which is infinitely great cannot form a totality or a whole; the notion involves a contradiction in terms. Thus the notion of infinite space conflicts with the conception of the universe as a whole, and the notion of infinite time with that of the universe as a process. All hypotheses of evolution imply that the universe had a beginning in time. A process is necessarily and essentially finite, and limited by the two points between which the process lies. If, then, we wish to assert that the universe has a real history, and that evolution is a fact, we must think the universe finite in space and time.

We cannot avoid the inference that the energy of any finite part of the universe must be undergoing gradual dissipation, and would have been entirely dissipated if it had existed infinitely in the past. And as this has not as a matter of fact happened, the conclusion is that the universe, with its store of energy which is now being dissipated, came into being at some definite point in the past. In infinite time a finite universe must have gone through all possible changes already and thus have arrived at a condition of equilibrium and a changeless state of existing as contracted with its actual evolving.

There is no justification, then, for imposing an ideal infinity upon the real universe, for our assumption that space and time are infinite may turn out to be due to the present limitations of the evolving human mind. So far as space is concerned, Riemann's idea of space curvature may, after all, form a clue to the ultimate solution of the problem. But time is admittedly one-dimensional, and no intelligible hypothesis which would enable us to form a conception of the *beginning* of time has yet been put forward. Yet nothing can be urged in favour of the infinity of time or space except a disability of our imperfect thought. At bottom, it is merely a question of a lack of correspondence between the constitution of our minds and that of the universe. Why should we regard such a conflict as necessarily permanent? Why should not the conflict cease when, in the course of ages, the human mind more closely approaches its evolutionary goal?

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CHAPTER V

THE GENESIS OF THE EARTH

1. The Evidence of the Spectroscope[1]

THE greater part of the evidence of the origin of the solar system is obtained from the principal instruments of the astronomical observatory—different forms of telescopes, the camera, and the spectroscope. Most people are more or less familiar with the telescope and the camera, but they are often a little shy of the spectroscope, and are inclined to regard its evidence as speculative and doubtful. It becomes necessary, therefore, to refer briefly to the subject of spectroscopy generally, though it is doubtful whether the reader can regard himself as sufficiently equipped to weigh the evidence in question unless he has done a certain amount of practical work in physical and astrophysical laboratories.

In principle, the spectroscope is quite a simple instrument. The most important part of it is just a plain glass prism, almost identical with the "lustres" attached to the old-fashioned glass chandeliers. By the help of this prism, the sun, the stars, and other objects in the heavens tell their own stories in a series of beautifully coloured pictures. With a little patience the reader may be able to gauge the general worth of the evidence, and he will probably decide that the inferences drawn therefrom by men of science are fully justified.

Water-waves are a familiar feature at the seaside. The distance from the crest of one wave to the crest of the next is known as the "wave-length," and on the sea this may exceed fifty feet. The air-waves generated by a man's voice in ordinary conversation are about ten feet in length, and those by a woman's voice about three feet. But the aether-waves of light, originating in the orbital

[1] By the reader unversed in physics, this section on spectroscopy will be found a little difficult and may be omitted.

motions of the electrons composing the constituent atoms of the molecules of hot bodies,[1] though differing in length amongst themselves, are all incomparably smaller than air-waves. Any simple kind of coloured light (not composite white light) can be described either by stating the particular *colour* sensation it produces on the eye, or, more accurately, by stating (1) its wave-lengths or (2) the frequency of its vibrations. Waves of red light are about 1/39,000 of an inch long; waves of violet light are about 1/60,000, that is, about two-thirds the length of red. In the case of other simple kinds of light, the wave-lengths are of intermediate values; for instance, the wave-length of yellow light, such as that of the sodium flame, is 1/43,000 of an inch. Since the velocity of light in air is 186,000 miles a second, the "wave-frequency," that is, the number of vibrations per second, of yellow light is the number of times that 1/43,000 of an inch is contained in 186,000 miles, that is, 510 billions. In other words, all waves of yellow light impinge on the retina of the eye 510 billions of times per second. The frequencies of the waves of all other simple kinds of light are all different, but they are of much the same order of magnitude. And the particular colour of any homogeneous light depends entirely on this vibration frequency. Thus while the velocity of light is the same for all colours, the wave-length and time of vibration differ for different colours.

When a wave of light passes from one medium to another, the velocity is altered; so also is the wave-length, the changes taking place in such a manner that the ratio of the wave-length to the velocity remains constant, for this ratio measures the time of vibration. Thus the frequency, and therefore the colour, are constant. Of two given waves, we cannot say why one, on entering a medium such as glass, should prove to be say, red, and the other violet.

If light impinges normally on a slab of glass, its velocity is reduced; the waves may be pictured as having a greater difficulty in finding their way through the more densely packed molecules, and being retarded. When it is said that the index of refraction from air to glass is 3/2, all that is meant is that the ratio of the velocities of light in air and glass is 3/2; in other words, the velocity in glass is 2/3 of 186,000 miles a second. But if instead of impinging normally the light impinges on the glass obliquely, its reduced velocity will entail, as a natural consequence, a deviation in direction.[2]

[1] Sometimes in bodies not hot, as in phosphorescence.

[2] This may be simply illustrated. Stretch over one half of a table a piece of rough cloth. Mount on an axle two small similar metal wheels, and place them on the uncovered part of the table. Now gently tilt the table and let the wheels run

The deviation of direction is best observed by allowing a beam of ordinary white light to fall on a triangular glass prism. The visible result is a band of colours, identical with a section of the rainbow—violet, indigo, blue, green, yellow, orange, red. The beam of light will be seen to bend, as well as spread out, on entering the prism and again on leaving the prism. Now the length of the violet waves is only about two-thirds the length of the red waves, and they therefore make about three vibrations for every two vibrations of the red. Hence the retarding glass will obstruct the violet waves more than the red, for the higher the frequency the greater the obstruction encountered; the violet waves are therefore the more displaced, the more "refracted." The waves of the intermediate colours will be displaced to an intermediate extent, and the net result is that, when all the waves of the composite light have emerged from the prism and are travelling with their original velocity, they will be separated and will diverge.[1]

The separation, which the prism effects, of the constituents of composite white light is known as *dispersion*, and the constituents thus separated or dispersed are said to differ in *refrangibility*. The coloured band which is formed when the prism decomposes white light is called a *spectrum*. The wave-length of the red light is greatest and its refrangibility least; with the violet light, the converse is the case. The general deviation of direction is a simple consequence of retarded velocity; the differences of deviation on the part of the elementary constituents of the light is a consequence of differences of wave frequency. Inasmuch as all the colours of the spectrum have different wave-lengths, they are comparable to the notes of a musical scale.

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down, normally, on to the cloth. Clearly the speed will be reduced, but the direction will remain unchanged. Now let the wheels run down obliquely to the edge of the cloth. The wheel that first meets the cloth will slow down, but the other will retain its original velocity until it also strikes the cloth, and then both will run on together at the reduced speed, and in a direction oblique to their original direction. So with a row of soldiers marching, in line, obliquely to the line of separation between a hard road and soft sand.

[1] Imagine a row of soldiers of varying height, from very tall to very short, drawn up in line according to height. Oblique to their front is a line dividing the hard ground where they are placed, from some deep sand, the shorter soldiers being nearer the sand. They are ordered to march, in line, all at the same speed, but all in their natural strides. Even though they were of the same height and their strides the same length, their line of front would change, but the front is further modified by the small men having to step in the sand much more frequently than the tall men, and therefore experiencing more obstruction to their forward movement. When they emerge from the sand on to the hard road again, their front will be more or less fan-shaped, and although they will once more all be moving at the same speed, they will diverge from one another, somewhat as if they were marching outwardly along radii of a circle.

It is commonly supposed that the colour of an object is something added to it, just as a painter adds pigments to a canvas. But the supposition is wrong. Virtually, the contrary is the case. If we enter a photographer's developing-room, and close the red window, we have evidently not increased the light but diminished it; the red light is less than the white. The red glass allows the red constituent of white light to pass through it but stops all the other constituents.

Spectra are best viewed with a spectroscope. The light to be examined is received through a very narrow slit and is dispersed by one or more prisms specially mounted. The resulting spectrum is magnified by a small telescope.

If ordinary white light after passing through the slit falls, not on a prism, but, say, on a piece of white paper, there will be, of course, just an ordinary image of the slit; there will be neither displacement nor dispersion. If ordinary white light were simple and not compound, and after passing through the slit fell on a prism, there would be displacement but not dispersion, and again the image would be a simple image of the slit. If, therefore, instead of compound white light we view through the spectroscope some kind of simple homogeneous coloured light, there will be no dispersion, and only a displaced simple image of the slit will be seen. If the light examined is not white yet composite, that is, consists of waves of more than one length, say a mixture of red and blue, then in the spectroscope two images of the slit will be seen, one red and the other blue, a considerable distance apart. If the light be a mixture of several colours, there will be just as many coloured images of the slit. The gaps between the colours represent the missing constituents of ordinary white light. If ordinary white light is used and all its coloured constituents be thus present, we have as many coloured images of the slit as all these constituents; the images will unite, or even overlap, and we have the continuous spectrum. Every species of coloured light preserves its own relative place in the general scale of the spectrum, and every elementary light-constituent present gives its own image of the slit in its own particular colour. Thus if constituents of all degrees of frequency are present, the coloured spectrum is continuous; if certain constituents are absent, there are gaps in the coloured spectrum. These gaps may be very narrow, may even have the appearance of fine black lines, but every one indicates the absence of one or more elementary light-constituents.

Spectra are commonly grouped into three classes, according to their relative degrees of continuity.

1. Continuous spectra, viz., those of incandescent solids, liquids, and dense gases. They are unbroken bands of colour, containing light of all refrangibilities, from the extreme red to the extreme violet. It is interesting to examine the growing spectrum of a gradually heated piece of iron. At first red light appears; gradually, as the temperature increases, yellow is added, then green, then blue; as the temperature rises still higher, the spectrum extends towards the violet, and at incandescence the whole spectrum appears, though from the first it was continuous as far as it went. But such bodies must not be heated to a degree that brings about vaporisation, or the spectrum will assume another form. Nearly all the light from an ordinary gas-flame or candle-flame is due to the incandescent particles of solid carbon, and the spectra are therefore continuous.

2. Spectra nearly continuous but broken by numerous very narrow gaps—dark lines as they are commonly called, showing that numerous elementary light-constituents of different refrangibilities are absent. Ordinary sunlight gives a spectrum of this kind.

3. Spectra markedly discontinuous, containing such wide dark gaps that the general appearance is that of a definite series of bright lines. These spectra are characteristic of all flames that do not contain solid particles, that is, of all incandescent vapours (from solids or liquids) and gases at ordinary pressures. Every gas and every vapour has its own particular series of bright lines; in particular, every chemical element when vaporised gives a characteristic bright line or series of lines. For instance, if incandescent sodium vapour be examined by a spectroscope, its spectrum will be seen to consist of two brilliant yellow lines, always in the same relative position. Obviously we are here provided with a means of determining the chemical composition of any given source of light; it is merely a matter of making ourselves familiar with the different bright lines peculiar to each element.

The electric arc is a suitable light for giving a continuous spectrum. If between this light and a prism some incandescent sodium vapour be interposed (for instance, by burning a pellet of sodium in a colourless bunsen flame), the continuous spectrum of the arc-light will be broken by two dark lines in the orange-yellow section. If the arc-light be now cut off, the sodium flame remaining, the continuous spectrum will, of course, disappear, but the two characteristic *bright* yellow lines of sodium are now seen, and they occupy precisely the same position as the dark lines did. The obvious inference is that certain elementary constituents of the arc-light were cut off

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If a prism be arranged in such a way that, while a beam of sunlight is decomposed by the upper half of the prism, a beam proceeding from such a light-source as that of incandescent vapour of sodium, iron, or some other metal, is decomposed by the lower half, the bright lines of the lower, metal spectrum, occupy absolutely the same relative position as some of the dark lines in the upper, solar spectrum. The inference seems to be that the elementary constituents of the solar light which, as indicated by the dark lines of the solar spectrum, are missing, have been cut off by incandescent vapours of different chemical elements between the sun and the earth, and that these vapours are therefore in the sun's atmosphere. Innumerable experiments of a similar kind all suggest that the various elementary light-constituents which have failed to reach us from the sun have been arrested by those particular vapours and gases in his atmosphere that possess the same wave frequency. And the assertion that this or that metal exists in a state of vapour in the sun's atmosphere is based upon the non-arrival of the corresponding light-constituents. So various and constant are the positions of the bright lines of the spectra of the various chemical elements, and so exactly do they correspond with certain dark lines in the spectrum of the sun, that the chances in favour of the hypothesis being correct are estimated to be at least 300,000,000 to 1.

But *why* should waves of the same frequency be thus cut off?

In the rarefied condition of a gas at ordinary pressure, the spectrum of its light consists of bright lines; in the condition at high pressure, the spectrum tends to become continuous, either by the bright lines becoming broader and less defined, or by new lines appearing between them, until the spectrum becomes identical with that of solid or liquid bodies raised to the same temperature. The gradual transition from a bright-line spectrum to a continuous spectrum illustrates the transition of an ordinary gas to an ordinary liquid. Obviously the movements of the molecules, with their constituent atomic groups of vibrating electrons, which are the source of the emitted light, must be different in the two cases.

The motion of a gaseous molecule is probably of a four-fold character; it is moving as a whole, with uniform velocity, in a straight line between one collision and another with its neighbours;

it is rotating; there are intra-molecular complex motions due to attractive and repulsive forces of the constituent atoms; and within the atoms are the orbital motions of the contained electrons. When a spectrum consists of a number of bright lines, the motions of the molecules concerned must be sustained in a regular manner. For when a gas is under low pressure, collisions of molecules are relatively infrequent; regularity of atomic motion, and therefore of electronic motion and of aethereal wave motion, predominates; and thus the spectrum lines are bright. It is true that at every impact the constituent atoms of a molecule, with their contained electrons, will be set in all kinds of fresh vibrations, but, unless the impacts are frequent, only those vibrations which correspond to the *natural* periods of vibrations of the atoms and electrons will survive; the normal molecular motions will therefore not be appreciably modified, and the wave-length of the light emitted will be definite and regular. But under increased pressure, molecular collisions will be more frequent, with a resulting increasing irregularity of atomic and electronic motions, and therefore of aethereal wave motions; and thus instead of a spectrum of clear-cut coloured lines, the lines show an increasing tendency to widen out. If the pressure is increased sufficiently, intra-molecular vibrations of all periods will take place, and the widening colour-bands will stretch out into a continuous spectrum.

Since the spectrum of the vapours of most substances contains a large number of bright lines, each line corresponding to a particular mode of vibration, it follows that intra-molecular motions even in rarefied gases are of a very complex character.

Now any vibrating system, a pendulum or a child's swing for example, is set into violent oscillation if impulses are given to it exactly timed to coincide with its own natural period of vibration. Just as a piano wire which is tuned to a particular note will be set in vibration when that note is sounded, say, by a tuning fork in its neighbourhood, so the atoms of a gas-molecule will be set in vibration by waves of light which possess a vibration period corresponding to their own. Suppose, then, a complex wave of light, say the arc-light, passes through such a collection of molecules as those of sodium-vapour. Those constituents of the complex light-wave that are tuned to the natural vibration periods of the electrons within the atoms of the sodium molecules are stopped by these vibrating electrons and absorbed by them. Like all other vibrating systems, the partners are perfectly matched and now waltz together. But all the other constituents of the complex light-wave have passed on, as their spectrum shows; the dark lines indicate the constituents arrested on the way.

Since molecules of matter take up or absorb those light vibrations which synchronise with their own vibration periods, vapours are said to *absorb* the same colours which they themselves *radiate* or emit when incandescent. It is merely a particular case of the general law that bodies readily absorb that kind of vibratory motion which they are themselves capable of giving out. This applies to water-waves, sound-waves, light-waves, or waves of any other kind.

The so-called black lines of the spectrum are only black by contrast. The bright lines are really present, but by comparison with the very bright background which belongs to the continuous spectrum on either side of them, they appear black.

The meaning of the dark lines in the solar spectrum ought now to be obvious. The inner, hotter part of the sun gives a continuous spectrum, but there is an outer atmosphere containing vapours which absorb certain elementary light-constituents, and thus dark lines appear in the spectrum. The inner, hotter part of the sun that gives the continuous spectrum might be either a solid, or a liquid, or a very dense gas, so far as we can tell from the spectrum; but the solar atmosphere undoubtedly consists of incandescent vapours, and the composition of these vapours the spectroscope reveals to us. The incandescent vapours may, during an eclipse of the sun, be spectroscopically examined alone; the resulting spectrum of bright lines shows clearly the presence of sodium, iron, hydrogen, and a very large number of other substances, each by its own characteristic group of coloured lines. In a similar way it has been discovered that some of the stars have much the same composition as the sun. Briefly, the spectroscope reveals to us the composition of the sun, the stars, and the nebulae. More than this, it gives us a great deal of information about the movements of the stars and about various other kinds of celestial phenomena. Spectroscopy has, in fact, revolutionised astronomical science.

The ultimate truth of spectroscopic evidence turns upon the truth of the wave hypothesis of light and of the kinetic hypothesis of gases. But neither of these hypotheses can be said to be finally verified experimentally. We cannot, for instance, definitely prove the existence of either the aether or molecules. There are, however, many converging lines of evidence all pointing to the great probability of the truth of at least the fundamental features of both hypotheses. But even if one or both proved to be false, and the lines of the spectrum had, in consequence, to be interpreted in some other way, nevertheless the remarkably precise coincidence in the very large number of different groupings of light and dark lines admits of only one general interpretation. To question that interpretation would be as unreasonable as to question the common origin of two photographs printed from the same plate on two kinds of sensitised paper. If spectroscopic evidence of the composition of the sun and stars, and of the movements of stars, is to be questioned, then the laws of probability can have no meaning.

2. The Visible Universe

On a clear moonless night it is possible to see with the naked eye about 3000 stars, and the total number so visible in both hemispheres is about 6000. But even with a small telescope the number increases greatly, and, with the most powerful telescopes, no less than about 20,000,000 may be seen. Their distances from the earth vary enormously. If we represent the sun by a sphere 1 inch in diameter the earth would be represented by a grain of sand 1/100 inch in diameter at a distance of 10 feet. The nearest star would be represented by another sphere about an inch in diameter, but at a distance of 400 miles. The sun is known to be rushing through space at a speed of 12 miles a second, or about 1,000,000 miles a day. Hence if he took the shortest route to his nearest neighbour,[1] his journey would take 70,000 years. There is no reason to think that the stars are anywhere gathered together much more closely than this, except in the star clusters. It is much as if all the living things of Europe were limited to some twenty-five animals of the size of very small birds or mice, each with 160,000 square miles to roam about in. Suggestions that collisions amongst the stars are frequent cannot therefore be entertained.

The spectroscope has proved that the stars are suns like our own, and that the substances found in the crust of the earth are present in the glowing vapours of both the sun and the stars. Apparently, therefore, matter is much the same throughout the visible universe.

Winding among the stars is the Milky Way, a belt of pale light which divides the sky into two nearly equal portions. The telescope resolves this belt into stars which, however, are so faint yet so numerous that to the naked eye they present only a continuous glimmer. No less than 18,000,000 of the 20,000,000 visible stars

[1] See p. 74. Since the above was written it has been discovered that the faint star Gilpin in the constellation Ophiuchus is nearer than α Centauri. In our illustration we neglect the star's own movements.

lie in or near the Milky Way, but it is probable that they are not really close together; the apparent closeness seems to arise from their lying in the same general direction at varying distances.

Scattered about amongst the stars are the *nebulae*, dim cloud-like forms usually only visible with the telescope. A few, for instance the great nebula of Orion, can on a clear, moonless night be seen by the naked eye. At one time nebulae were supposed to be clouds of stars but so immensely distant that the stars could not be separately distinguished; spectroscopic examination has, however, proved that nebulae are by no means all of the same kind. The spectra differ greatly; there are, for instance, (1) a continuous spectrum, visible as a very faint background upon which stand out bright lines; (2) a dark-line spectrum similar to that of the sun and indistinguishable from that of the star clusters, though indicating a different composition from that of the sun and the ordinary stars. The latter is the most common.

The nebulae with a bright-line spectrum on a fainter continuous spectrum seem to be surrounded by an envelope of intensely hot gas, the inner part consisting of a denser gas; and when this outer envelope has cooled down it may produce a dark-line spectrum. Or they *might* be star-clusters surrounded by a continuous zone of gas, so far away that the light from the gaseous envelope predominates over that of the stars within. That *some* of the nebulae are wholly gaseous there is, however, hardly any room for doubt; the great nebula of Orion, for instance, is a cloud of self-luminous gas containing hydrogen, helium, and nebulium (the last is not found on the earth). It is, however, difficult to form a clear conception of a gas which, without any inner denser body, is free in space and excessively rarefied, yet shining by its own light even when exposed to the absolute cold of space. A rough estimate of the size of the great nebula of Orion is easily made; it is about 6×10^{22} times the volume of the sun, and from this it is possible to obtain some idea of the density of the gas of which it is composed. The density is perhaps *one-billionth* of that of ordinary atmospheric air at the earth's surface. How such an excessively rare gas can shine by its own light is puzzling in the extreme. But the gaseous nebulae are not very common, and most nebulae yield spectra of the second kind mentioned, that is, dark-line spectra. The finest and most interesting of these, and perhaps the commonest, are the spiral nebulae.

Spiral nebulae are formed of spiral arms, generally two, springing from two diametrically opposite points of a nucleus, round which they wind more or less regularly; and studded along these arms are bright knots that look as if the nebulous material might there be condensing into stars or planets. The nebulae have the appearance of rotating round the central nucleus, with the arms lagging behind, but we cannot claim to have much certain knowledge either of their movements, distances, or sizes, or whether the knots are condensing centres or otherwise, though presumably the nucleus is a parent sun. We cannot be certain even that the spiral nebulae are members of the stellar universe, and it is conceivable that each one is in itself a separate and distinct stellar universe, comparable to our own Milky Way. All that we can with safety infer from the dark-line spectra is that the stars and the spiral nebulae have much in common, probably as regards origin and growth as well as constitution.

We now come to our own part of the universe, to our own star—the sun—with his attendant planets. The ratio of the diameter of the earth to that of the sun is 1 to 100, so that the ratio of the volumes is 1 to 1,000,000. But the ratio of the densities is 4 to 1. The great size combined with the small density can be accounted for only by supposing that the sun is neither solid nor liquid, but some kind of very dense gas; denser than water, viscous and fluidiform, but yet a gas and possessing its elastic properties. In the shining surface—the photosphere—of the sun, formed of bright cloudlets in rapid motion, are large "spots" where the cloudlets appear to have been sucked away; they seem to be great holes. Covering the shining surface is a rose-coloured stratum of gaseous matter called the chromosphere, great masses of which, called prominences, rise up here and there above the general level, like tongues of flame; and outside this again is a mysterious halo of faint light called the corona; but these phenomena are observable only at the time of total eclipse. The sun, like the earth, rotates on an axis, the axis being inclined to the plane in which the earth revolves round the sun. The period of rotation is about twenty-five days.

The immense supplies of heat poured out from the surface must be brought up from within, and the sun must therefore be even hotter inside than on the surface. The sun is able to maintain the heat within because he is contracting. A falling body acquires a store of energy which, when the body stops, is converted into heat, and the same amount of heat would be produced if the stoppage were gradual. If, then, the sun's diameter contracts, say, 1000 feet, every particle at the surface falls through 500 feet, and every particle within falls in proportion. The amount of heat which would thus be generated would suffice to supply all that the sun radiates in five years. At this rate the sun's diameter would decrease about 40 miles in 1000 years, and it is therefore evident that even in 100,000 years there would be no appreciable decrease in his apparent size. And he is growing hotter all the time and must continue to grow hotter as long as his materials obey the laws of gases.

Geologists require 100,000,000 years for the evolution of the earth into its present condition, but, until the beginning of this century, physicists, basing their estimates on past supplies of solar heat, would not allow more than 20,000,000 years since the birth of the earth. Since the discovery of radium, however, physicists have been willing to concede to geologists a period vastly greater than even 100,000,000 years. The enormous stores of energy now known to be locked up in atoms of matter, though in terrestrial matter normally quiescent, may very possibly be free under such conditions as prevail in the interior of the sun, and it now seems a little difficult to explain why the sun's supply of heat is not greater than it is. The sun must also derive heat from the fall, upon his surface, of vast quantities of material from what we call empty space. The combined efforts of shrinkage, radio-activity, and fall of matter from without, are amply sufficient to maintain the sun's heat for a time to which we can set no limit.

The solar system consists of the central sun and of a series of smaller bodies which revolve round him. The largest are the eight planets which travel in regular elliptical orbits. Two or three of these orbits are, however, so nearly circular that, if drawn to scale on paper, they cannot be distinguished by the eye from actual circles ; the earth's orbit is one of these.[1] Arranged in order of their distances from the sun, the eight planets are Mercury, Venus, the Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. These distances vary from 35,000,000 miles in the case of Mercury to 2,700,000,000 in the case of Neptune ; and their periods of revolution vary from about three months in the case of Mercury to 160 years in the case of Neptune. Mercury is the smallest and Jupiter the largest of the eight, the diameter of the former being one-third, and of the latter ten times, that of the earth. Just as the planets travel round the sun, so moons or satellites travel round most of the planets ; in number they vary from one to eight to a planet. The best known of the satellites is, of course, our own moon, where there is no trace of atmosphere, no trace of cloud, no trace of water-action, and no twilight.

[1] A circle is, of course, a particular case of an ellipse.

Between the orbits of Mars and Jupiter some 500 planetoids revolve round the sun. Relatively these are very small, varying from 20 to 400 miles in diameter. Still smaller are the planetesimals, that is indefinitely small planets, enormous numbers of which are revolving round the sun. Included also in the solar system are the comets and meteorites, the latter existing in countless multitudes. Large numbers of meteorites enter our atmosphere as shooting stars or meteors, though many of them do not weigh more than a grain, and few are large enough to escape vaporisation by friction with the air.

The remarkable accuracy with which astronomical events can be predicted, even to the second, inspires great confidence in astronomers' work, but few people realise the extremely difficult mathematical nature of much of that work. For instance, the moon is revolving round the earth, and both together are revolving round the sun; [1] at each instant, the motion of the moon which, were it not for the sun, would be very nearly a simple elliptic motion round the earth, or were it not for the earth, would be very nearly a simple elliptic motion round the sun, is subjected to the competing attractions of both, and not only so, but by the quite appreciable attractions of the planets. Now we start with the Newtonian law of gravitation: every particle in the universe attracts every other particle with a force which varies as the product of the masses of those particles and inversely as the square of the distance between them; and we have to disentangle this vast number of actions and to calculate the path which each body will describe, and the way in which it will be gradually modified by lapse of time. But, hitherto, mathematicians have failed to discover a solution of the problem, even where only three bodies are concerned. In other words, if only the three bodies, sun, earth, and moon existed, it would be impossible to determine their motions due to the influence of their mutual attractions. When instead of three a great number of bodies is involved, the problem is naturally still more impossible of solution. True, approximate solutions may be found for such cases as it is necessary to deal with in connection with the solar system, but no layman can possibly appreciate the extraordinary difficulty of the problem.[2]

It is impossible to be quite certain that the gravitational law is

[1] For simplicity we neglect the modification of the earth's orbit owing to the attraction of the moon. Really the earth and the moon are twin planets, and each revolves round the other.

[2] Kepler's laws are only rough approximations. No planet really moves in an ellipse, but in a kind of hypocycloid, and not accurately in that either.

rigorously true. Until we have some physical explanation of gravitation, there is no convincing reason why, for instance, the attraction should vary inversely as the *exact* square of the distance, though as far as we can tell it certainly appears to do so.[1] And other causes may be at work besides gravitation. For instance, the length of the day may be modified in several ways: tidal friction and the deposit of meteoric dust must lengthen it; shrinkage due to cooling and denudation must shorten it. Then, again, it is conceivable that the planetary orbits may be modified by planetary friction with the aether, and by light-pressure upon the planets. Here, as always, unknown and unsuspected causes may be at work.

3. The Nebular Hypothesis

Certain remarkable features seem to point unmistakably to the fact that the members of the solar system had a common origin: (1) all the planets and all the planetoids move round the sun in the same direction, and most of the satellites move round their planets also in that direction; (2) the planets, as far as they can be observed, rotate on their axes, and in the same direction as they revolve round the sun; (3) all the planets and many of the planetoids have their orbits very nearly in the same plane, just as if they were swimming round the sun all half immersed in some vast ocean, though it is true that some of the planetoids rise above and fall below this plane. The odds against this uniformity of movement of 500 bodies being due to any other cause than that of a common origin in the sun has been calculated to be about 10^{160} to 1. Such an extraordinarily high degree of probability amounts to virtual certainty. Opinion is still divided, however, as to the original nature of the parent body and as to the mode of birth of the planets.

Laplace assumed the existence of a primeval nebula which, when it threw off its first ring, extended so far out as to fill at least all the space equivalent to that within the present orbit of Neptune. It must therefore have had a minimum diameter of between five and six thousand million miles, and in its earlier stages must have been vastly greater. This gigantic nebulous mass, of which the sun was only the central and presumably rather more condensed portion, is supposed to have had a movement of rotation on its axis. As

[1] The gravitational law is based on various assumptions depending, ultimately, on the heliocentric hypothesis which, after all, is only an hypothesis. The inverse square law which is here involved often enters into physical considerations, as a mere consequence of space properties, *e.g.* in potential and in intensity of illumination. But the reader must not be misled by a superficial analogy.

the mass cooled, it must have contracted towards its centre, and as it contracted it must, according to dynamical principles, have rotated more rapidly. The time would therefore come when the centrifugal force on the outer parts of the mass would more than counterbalance the attractive force towards the centre, and the outer part would thus be thrown off as a ring. The inner portion would still continue to contract, and the same thing would be repeated. In this way the original nebula would throw off a series of rings all revolving in the same direction as the main central mass. The materials of each ring would continue to cool and contract. If the condensation was uniform, the formation of a large number of planetoids and planetesimals might be expected; but if it was not uniform the effect would be to draw the materials of the ring into a single mass, and so a planet would be formed; and from the planets satellites would be developed in the same way. Uniformity of direction and rotation is thus accounted for, for from the first the mass of each planet would continue to partake of the original rotatory motion of the nebula. This is the famous nebular hypothesis.

Astronomers have ever been on the look-out for any features of the visible universe that might give support to the hypothesis. One fact in particular seemed to support it, and that was the rings around Saturn. The nebulae were also closely scrutinised, and this or that detail seized for purposes of verification. The immense number of spiral nebulae seem to be at very different stages of condensation, and it is possible to pick out a sequence that is somewhat suggestive of an imitation of the successive stages of the process assumed; the knots in the spirals are particularly suggestive. But it is more probable that a spiral nebula represents the evolution of a whole gigantic system of stars, not a single star with its attendants; and it is very rash to infer that in such a stupendous system the same moulding force is at work as in a puny system like our own.

4. The Nebular Hypothesis Untenable

There are, however, certain definite facts which make the nebular hypothesis quite untenable.

In the case of the gaseous envelope of a planet, the retaining power is the gravity of the planet. But permanent retention is difficult, for molecular velocities are high. The velocities of a certain proportion of the molecules are bound to rise well above a mean value, and will suffice in some cases to overcome the attractive force of gravity. If the earth were alone in space, its gravity would, in all cases in which the velocity of the molecules is less than a certain critical velocity, overcome the motion of the molecules moving away from it. This critical velocity is the velocity the molecules would acquire if they fell from an indefinitely great distance, and for the surface of the earth is about seven miles a second. Hence, if a molecule acquires this velocity, is directed away from the earth, and has a free path, it will escape from the earth's control. But no planet is isolated in space, and the counter-attraction of the sun is alone sufficient to make an enormous difference to the result. Only within a comparatively short distance of the earth is the earth's gravity differentially greater than that of the sun, and only within the lower strata of the atmosphere is it impossible for molecules to escape. Thus, while both the earth and the sun have a sphere of control, between the two there is presumably a constant interchange of molecules.

It is known that the great planets have great atmospheres, the smaller planets, including the earth, small atmospheres, and the planetoids and satellites little or none at all; and there is good reason to believe that planets can hold an atmosphere proportionally to their masses.

Now it is possible to determine mathematically whether the earth, at any particular stage of its history, was able to retain the constituents of an atmosphere, regard being had to the critical velocity of molecular escape, to the size of the earth, to the velocity of its rotation, and to its temperature. When the earth was white-hot, it is just possible, but hardly likely, that it could have retained its atmosphere, except perhaps the present large proportion of water vapour; even now, with its lower temperature and greater gravity, it is scarcely able to hold hydrogen permanently. At a much earlier stage, when the earth was a gaseous globe, the temperature was probably so high that hydrogen must have been liberated by dissociation. If we go still further back, namely, to that time when the earth is assumed to have been a gaseous ring of an exceedingly high temperature, recently thrown off from the rotating nebula, it is certain that such a ring could not possibly have held together by its own gravity. General dispersion would have been inevitable, a fact which is fatal to the acceptance of the nebular hypothesis.

But there are other fatal objections to it. One of its fundamental assumptions is that the original nebula had a certain rotation when it was in its most expanded condition, and that, to preserve the value of its rotatory momentum, its rate of rotation increased with the shrinkage due to cooling. The constancy of the rotatory momentum in such a system is a definitely established dynamical principle, of necessity involved in all centrifugal theories of celestial genesis. In the application of this principle to the hypothesis, it is possible to calculate not only the diameter of the original nebula but also the velocity of the equatorial rotation at each stage when a ring is assumed to have been thrown off. When the nebula had contracted to the present diameter of the sun, it ought to have had a velocity of 270 miles a second. But its actual velocity now is only $1\frac{1}{3}$ miles a second. There seems to be no way of accounting for such an enormous discrepancy. The effect of possible solar tides, for instance, on the rate of rotation of the sun may be demonstrated to be negligible. In fact, the discrepancy makes the rejection of the hypothesis inevitable.

A third objection arises from the varying orbital planes. If the sun threw off parts of itself by centrifugal action, these parts should have travelled in orbits lying in the plane of the solar equator. But the plane of the earth's orbit is inclined $7^\circ\ 15'$ to the plane of the solar equator, and the orbits of all the other planets are similarly inclined, some more, some less than this, and some of the planetoidal orbits very much more; and these variable planes by no means cancel one another. The average inclination still gives a discrepancy of 5°.

A fourth objection is to be found in the retrograde motion of one of Saturn's satellites and two of Jupiter's. A spherical nebula rotating so fast as to throw off, by centrifugal action, a series of rings to form satellites must impart to them its own rotation, and any exception is fatal to the nebular hypothesis. The explanatory hypothesis of planetary inversion does not call for serious mention.

A fifth objection arises from the serious difficulties attending the notion of a ring breaking up and collecting into a sphere. Even if a large nucleus were formed at some point on the ring to serve as a collecting centre, it is improbable that it would gather to itself bodies from a sector greater than one-sixth of the ring. And Saturn's rings, which gave rise to the ring theory, are now known to consist, not of gas as Laplace thought, but of small bodies revolving independently. Now if a ring rotated as a unit, the outer parts of which move faster than the inner, the rotation of any sphere into which the ring might be gathered would be forward; but in the case of a ring made up of small bodies revolving independently, the inner bodies would move faster than the outer, and the rotation of the resulting sphere would be retrograde.

Obviously, any acceptable hypothesis must account for retrograde motions. Have we a clue here ? If for a gas we substitute small bodies, would the hypothesis hold ?

5. The Meteoritic Hypothesis also Untenable

According to the meteoritic hypothesis, the whole of space is more or less filled with meteorites (this is in all probability a fact) which had their origin in collisions of celestial bodies. For there can be no doubt that the stars, including our sun, must eventually become cold and dead, and if in their journeys through space one cold star happens to collide with another, the two bodies would be shattered with explosive violence, and from the fragments a nebula would once more be formed. A mere glancing collision might also bring about such a catastrophe. In fact, if the two did not actually collide at all, but approached each other near enough for the attraction of at least one to be sufficient to overcome the cohesive force amongst the materials of the other, a part if not the whole of the latter would be disrupted. Even in this last case the violence of the disruption might dissipate some of the materials into a gas, though the intense cold of outer space would probably bring about a good deal of immediate recondensation. The haze of a nebula is thus satisfactorily accounted for, for although the meteorites resulting from interstellar collisions or disruption must be normally cold and dark, they are probably frequently heated by collisions with one another, and the heat due to these collisions is assumed to convert parts of them into hot incandescent vapour. Of this there must be a continuous supply, for, despite condensation, collisions cannot but be frequent.

All three of the cases mentioned are very probably common, but since either of the two kinds of collisions, *i.e.* direct or glancing, would probably lead to excessive dispersion, perhaps even to atomic dissociation, for the velocities at which collisions would take place would probably be as great as 200 or 300 miles a second, it follows that only in the third case is any sort of stable and permanent reorganisation of the scattered materials possible. Yet even in this case it is difficult to imagine how the disruption could yield a central mass of the magnitude of the sun which would become surrounded, at once or ultimately, by eight other relatively large masses and many small,

all revolving in practically the same plane. Yet this an acceptable hypothesis demands.

There are fundamental difficulties in the way of accepting the meteoritic hypothesis. The first is the chemical composition of the meteorites. This is definitely known from fragments which have been found. Iron is a principal ingredient in a very large number, and minerals which give basic oxides are common in most of the others. Now the bright-line spectra of ordinary nebulae show only the lines of the gases hydrogen, helium, and nebulium ; metals are entirely absent. Hence these nebulae must be of different composition from that of meteorites. The dark-line spectra of the spiral nebulae do not tell a sufficiently convincing story concerning the composition of the nebulae; their light is too faint; and the meteoritic composition of the knots of the spirals is uncertain.

A second difficulty is the collection of the scattered meteorites into compact swarms. Meteorites flying haphazard through space would have such high velocities that gravity would have little effect ; their great momentum would prevent them from being seriously deflected by the attraction of other bodies as small as themselves. If, however, a single central collecting centre or knot were once established, and all the other meteorites or planetesimals were revolving round it in elliptical orbits, a solution is possible ; for many of these planetesimal orbits would inevitably intersect, and meetings at their junctions would lead to the beginnings of small aggregates and new knots. The difficulty is with the *first* knot.

A third difficulty is the non-conformability of the hypothesis to dynamical law. The momentum would not be better distributed than in the case of a gas. This objection is absolutely fatal to the hypothesis.

While it may be allowed that the meteoritic hypothesis shows a possible mode of growth of the planets subsequent to formation, it gives little or no clue to their possible origin. But even if the hypothesis did give such a clue, the meteoritic growth would be almost negligible. The meteorites which plunge into our atmosphere are seen as meteors when, rocket-like, they rush across the sky at night. These exist in myriads. Some of them may enter the solar system from outer space, but others, the planetesimals, are already members of that system. It has been estimated that 400,000,000 a day may reach the earth, but their average size is so small that they can add to the earth a layer of only a single inch in 1,000,000,000 years.

6. Professor Chamberlin's Sun-bolt Hypothesis

Any acceptable hypothesis must stand the tests of known dynamical laws, and, in framing it, it is necessary to bear in mind that—

1. Our planetary system consists of a number of bodies revolving round a primary in an approximately invariable plane ;
2. The total mass of all the revolving bodies is only 1/745 of that of the primary, the sun ;
3. If the sun and the planets are the divided parts of a common nebula, the process of partition must have been such as to result in this very unequal division in this very specific form. It is highly improbable that such an extreme inequality of partition can have been due to the action of a centrifugal force on a common mass ;
4. The flatness of the discoidal form of the system points to some powerful genetic agency competent to enforce on the system the geometrical configuration it now bears ;
5. The hypothesis must provide for deviating agencies to explain the departures from symmetry in the discoidal form, especially as regards the eccentricities and inclinations of the orbits ;
6. The invariable plane of the planetary system formed by the algebraic summation of the respective planes of the various members of the system is inclined to the plane of rotation of the sun, though gravitatively the sun is the controlling body and possesses 744/745 of the entire mass of the system ;
7. Although the sun possesses such a very large proportion of the mass, it carries less than 2 per cent of the revolutionary momentum of the system. The remaining 1/745 of the mass carries more than 98 per cent of the momentum ;
8. Certain directions of revolution are retrograde.

Professor Chamberlin puts forward an hypothesis satisfying all these points. It was suggested by considerations of the consequences of disruption due to the too close approach of two stellar bodies. It is conceivable that if only a portion of one of these bodies was disrupted, the remainder might, by its attractive force, control the dispersion, and, continuing its own orbital journey, draw the scattered material after it, not unlike a tail, with an increasing curvature impressed upon it. It was this imagined curved tail, or spiral arm, that really formed the germ of the new hypothesis. But such an origin of spiral nebulae implies a single spiral arm, springing from that side of the nucleus where the disruption takes place ; whereas spiral nebulae always have two arms or sets of arms, diametrically opposite each other.

7. The Hypothesis Developed

In the sun there is known to be such a persistent eruptive tendency that huge masses from the interior, conveniently termed "sun-bolts," are frequently shot forth at velocities of 100 miles or more per second, and they rise some thousands of miles above the glowing surface. This constantly takes place without any obvious outside attraction. If at any time there happens to be a sufficiently strong outside attraction, such as that of a passing star, bolts of greater mass would be ejected with greater violence. Thus from so simple a cause as the gravitational attraction of a star approaching the sun, there may arise a series of violent eruptions graded according to the closeness of approach. Each of the ejected masses will swing into an orbit of its own, the particular orbit being determined by the forces of attraction brought into play by the changing relations of the two bodies, both of which are necessarily in rapid curving motion relative to each other. No very close approach of the star would be required in order to call forth even a great response in such a highly eruptive body as the sun, but only relatively small ejections for the birth of the planets are necessary, for only 1/745 of the sun's substance was required for the whole planetary system of many hundred bodies ; the average mass of the planets alone is only 1/6000 that of the sun. Thus it may be assumed that the passing star kept well away from the sun ; also that it was so large, dense, and inert that its own response to the reaction of the sun was negligible.

The attraction of the star would gradually increase to a maximum at the position of closest approach, and then diminish. Its general effect at any one time would be that made familiar by the study of the tides, for the attraction would reduce the gravitational pressure in the interior of the sun along the line joining the centres of the star and sun, and there would be a tidal response which would take the form of bulges on each side, one towards the attracting star and one on the opposite side ; and according to the law of least resistance, the bulges would tend to allow the eruptive forces within the sun to ease themselves along the lines of this reduced pressure. Eruptive action would thus take place in the direction of the axes of the bulges, and, in accordance with tidal principles, one set of bolts would be shot out directly towards the passing star and another set, rather smaller, in the opposite direction.

While a bolt is moving out and falling back, it would be drawn aside in the direction of movement of the passing star, since the pull of the star is always moving to a new line directed from its new position. A tangential element is thus introduced. The relative amounts of the forward and tangential pulls are obviously dependent on the distance to which the bolt is projected. For instance, the bolt may actually fall back into the sun, just as ejected bolts are doing every day ; but it would carry with it such transverse momentum as it had gained by the forward motion imparted to it by the pull of the star ; its only effect would be slightly to increase or to retard the sun's rotation. But if the ejected bolt were pulled sufficiently far forward by the star, it would, on its return journey, fail to strike the solar disc, and, sweeping by, would swing into an elliptical orbit about the sun. The farther it was pulled out, the more open would be the orbit, and in an extreme case it might be pulled out so far that it would escape from the sun's control altogether. It was the bolts which took on elliptical orbits that, according to the hypothesis under consideration, gave rise to the members of the solar system.

When one star passes another, each causes the other to deviate from its straight course, and usually to describe a hyperbolic curve. At long distances the deviations are slight, but the closer they approach the greater the curvature ; and, during the stages of their nearest or perihelion approach when their speeds are greatest, their relative positions are rapidly changing. The tidal bulges are therefore caused to shift their positions rapidly, as well as their directions in space. Hence, in the particular case now under consideration, each of the succession of bolts ejected from the sun must have taken on a new direction, and, of mechanical necessity, the chain of bolts must have assumed the form of a spiral.

The planes of the orbits of all the projectiles must obviously lie in or near the plane of movement of the passing star, the whole group of orbits forming a discoidal configuration. It seems, however, to be in the highest degree improbable that this plane should coincide exactly with the plane of the rotating sun's equator, for there is no reason to think that the respective motions could be otherwise than absolutely independent.

It is assumed that, at the time of the birth of the planets, or rather the birth of the knots which acted as collecting centres for the planets, the greater eruptions of the sun were, as now, concentrated in two belts not far from the solar equator. It is also assumed that, as the star approached from a distance, its first feeble pull led to the ejection of only small bolts which, for the most part, fell back on the sun, merely modifying his rotation. With nearer approach, some of the projectiles would, on their return, fail to strike the sun's disc and would swing round into orbits. So far, the pull of the star is assumed to have been mainly on the polar regions of the sun and therefore oblique to his equatorial belts of great eruptions; but when the star approached the perihelion part of its path, it would pass directly over the first belt of these great eruptions, and a maximum co-operation between the star and sun would thus be realised.

Nearly simultaneous bolts would now issue from the proximate and distal sides of the sun, and the first pair of great planets, viz. Neptune and Uranus, would be born. At the crossing of this first eruptive belt, the action would be particularly effective, for the stored-up eruptive energy within the sun would be at a maximum, and the bolts would be projected with great velocity. A second pair of great eruptions is assigned to the stage when the second belt of solar eruptions, on the farther side of the solar equator, was crossed, and Saturn and Jupiter were born. As the star passed on in its perihelion curve towards the polar latitudes of the sun, its action once more would become very oblique to the solar equator; nevertheless, the maximum approach which would here take place would lead to a multitude of imperfectly associated eruptions giving rise to the planetoids. The star having taken its perihelion turn,[1] its return journey over the two solar eruptive belts would be attended by the eruption of two more pairs of bolts giving rise to the four interior and smaller planets, first Mars and the Earth, and secondly Venus and Mercury; and, with these, the larger order of eruptions would cease, though many smaller eruptions, like those which attended the early approach, would continue until the star's pull became inappreciable. But from first to last myriads of small bolts would be ejected, these scattered products of dispersion giving rise to the planetesimals. The whole process must, of course, have extended over a vast period of time; even at perihelion the passing star must have been a stupendous distance away.

It is thus assumed that the solar system was originally a spiral nebula—a pair of spiral arms[1] of nebulous matter shot out from the sun, studded with knots, and the whole enshrouded in haze due to the vaporisation by collisions of some of the scattered products of dispersive action. Although a spiral form was of mechanical necessity at first imposed upon the chain of knots, each knot

[1] For illustrations, see Professor Chamberlin's book.

pursued an independent elliptical orbit of its own. But the nebula was relatively small and sufficed to give rise only to a relatively insignificant system.

Theoretically, the genesis of the system might have been very different from what it was, for the star's path might have taken any other direction and have moved in a plane at any inclination to the plane of the sun's rotation, and the rotation of the sun might have been either to or fro. Actually, the case requires, dynamically, that the path of the star should have lain nearly, but not quite, in the invariable plane of the planetary system ; that the movement of the star in its path should have had the direction in which the planets now revolve ; that the equatorial plane of the sun should have differed from its present plane in accordance with the modification imposed upon it by returning projectiles after they had been carried forward by the star ; and that the original rotation of the sun should have been modified as a further consequence of the same thing. The present degree of concurrence is a result necessarily brought about by the mutual reactions of the agencies that happened to enter upon a particular chance combination.

When the earth-bolt was about to be lifted from its place deep in the sun, it must have been gaseous or potentially gaseous, and it must have contained all the chemical substances present in that part of the sun from which it came. On being ejected into the approximate vacuum of surrounding space, it must have undergone great expansion and great reduction in temperature. But the mean specific gravity of the earth is now high (5.5), and the greater part of it must therefore be made up of far heavier materials than the surface atmosphere and hydrosphere. Few of these heavy substances could remain gaseous except at very high temperatures. We therefore infer that the more refractory materials on emerging from the sun into the cold of space probably condensed to the liquid or solid state. Despite an original tendency to dispersion due to the projective force outwards, gravity must have effected the concentration of a considerable portion of these heavier materials. The very existence of the knots implies this, dynamically. It seems probable that the greater part of the nebulous matter controlled by the ejected earth-bolt gathered into a knot soon after emergence and became the collecting centre of further material. It is difficult to say what proportion of the adult planet the original knot formed ; 40 per cent is probably a fair estimate.

It was inevitable that the main bolts ejected from the sun should have been attended by great fragments torn from them during their eruption, and that these should, under the control of the main masses, have taken on independent orbits. These were the knots of future satellites. And for a similar reason, myriads of minute satellites—satellesimals—would be formed, destined to become food for both planets and satellites. But the process of gathering in the matter must have been slow in the extreme, and the growth of the original knot into the adult earth must have taken vast periods of time.

Of course the sun-bolt hypothesis is still an hypothesis, but it covers all the facts and satisfies all dynamical principles, and this cannot be said of any other hypothesis yet put forward. It has been put to various mathematical tests, such factors as known masses, velocities, distances, ellipticities, and inclinations, all being considered ; and in every case the result has been to confirm the probability of the truth of the hypothesis. Analogical evidence from observations of the spiral nebulae is also wholly confirmatory.

8. The Earth's Infancy

With the ejection of the sun-bolt that became the earth-knot in the planetary nebula, the earth may be said to have been born. Its earlier infancy covered the period when the knot and myriads of planetesimals were gathering together into a compact, dense body. Of the vast collections of molecules which went to the formation of this body, the heavier materials such as the metals, their alloys, oxides, and sulphides, and the basic silicates, would respond most readily to gravity, and play a leading part in the early segregation. The core of the earth would thus consist mainly of metallic and basic material.

The refractory materials thus composing the core and, indeed, the greater part of the earth-knot were such as would condense to a liquid and solid form at high temperatures, and it is very doubtful if they retained a vapour temperature for any appreciable time after they began to sweep through interstellar space. But we can arrive at no certain conclusion about the primitive temperatures of the deep interior of the infantile earth, nor therefore about its original state of fluidity or solidity.

No doubt the heat resulting from continual contraction would suffice to keep in a liquid state some of the materials near the surface, but the pressure in the deeper layers would tend to keep the central portion of the mass solid. The more easily melted materials in the outer layers would float to the surface. The action would be not unlike the smelting of ores in a furnace : the molten rocky materials would be slowly forced to the surface and there solidify like a slag to form a crust.

The materials which form the crust of the earth have an average density of 2·5, while the density of the earth as a whole is 5·5. From this fact alone it follows that the materials of the inner earth are very much heavier than the rocks on the surface, and that they therefore consist largely of metals. The same conclusion follows from the velocity of earthquake waves; and from calculations based on that velocity it would seem that the rocky crust of the earth has a thickness of about 40 miles. The vast core below this is called geite, a substance presumably closely allied to iron, for iron is known to exist in large quantities in the sun, and many if not most of the planetesimals—meteorites—consist mainly of iron.

The formation of the atmosphere, both as regards composition and volume, must in the main have depended upon the power of the young earth to hold the molecules of the various constituent gases. Even if the earth had had a considerably smaller mass, it would have had sufficient gravitative power to hold molecules of water-vapour; but as molecules of water-vapour have somewhat higher velocities than those of nitrogen, oxygen, and carbon dioxide, the formation of the waters of the ocean almost certainly followed rather than preceded that of the atmosphere, the liquid form of water condensing, of course, from water-vapour. The mere fact that water-vapour condenses to the liquid form at temperatures which prevail at the surface of the earth now, is sufficient to have brought about the formation of the great oceans.

9. The Final Shaping of the Earth

(i.) *The Forces Concerned*

Why was the young earth forced to depart from a perfect spherical form and even from a spheroidal form? Not only does its general shape differ substantially from that of a spheroid, but there is a marked irregularity of its surface as shown by continental elevations and oceanic depressions.

Careful examination of the distribution of land and water over the surface of the globe suggests some kind of ancient basal planning. We notice, for instance, a predominance of land in the northern, and of water in the southern, hemisphere; that many of the geographical units are of triangular shape; that the great continents form a nearly complete ring round the northern hemisphere; that only about 1/27 of the land has land antipodal to it, the other 26/27 being antipodal to water; and that in the northern land hemisphere there is a polar ocean and in the southern water hemisphere a polar continent.

The floors both of the shallow waters around the continental shores and of the shallow seas were admittedly once dry land, but there is little doubt that the main elevated and sunken areas have always occupied the same positions as at present. If on a geographical globe we extend all the land masses seaward to the 1400-fathom contour line, thus lowering the level of the oceans to that extent, the whole surface of the globe is then divided into two equal parts, one half being dry land, and one half being deep water, nearly all the dry land forming one unbroken continent, and the deep water forming two separate and opposed L-shaped oceanic regions, viz., the basin of the Pacific Ocean and the basin of the Atlantic and Indian Oceans. There is little doubt that these are the main lines of original and inevitable separation between oceans and continents.[1]

The chief shaping agency was gravitation, and, could this have acted alone, the form of the earth would have been that of a perfect sphere, the standard from which deformations are measured. The chief deforming agency was rotation, an agency which has brought about polar flattening and equatorial bulging, the consequent difference in the earth's radii being over 13 miles.

Another deforming agency was the attraction of the moon. At one time the moon was much nearer the earth than it is now, and the two bodies once rotated almost as a rigid system about their common centre of gravity. Relative to the earth, the moon was nearly fixed in the sky and the month and day were about equal. The earth must then have been drawn out towards the moon, so that its shape was an ellipsoid with three unequal axes, though this inequality is now very much less marked.

Another important factor in the problem of shaping the earth is the position of the centre of gravity, for this cannot coincide with the centre of figure; it must be eccentric.

A steel knitting-needle a foot long will stand up; if several feet long, it will bend over. In order that a deformable body may be stable in an assigned configuration, there must be some relation between the size of the body, the forces which make for instability, and the resistance which the body offers to change of size and shape.

If there is any difference of density in different parts of a gravi-

[1] This seems to be proved by the application of spherical harmonics to the measured surface of the earth. (See Love's *Gravitational Stability of the Earth*.)

tating body, the denser parts attract with a greater force than the rarer parts, and thus more and more of the mass tends to be drawn towards the parts where the density is in excess, and away from the parts where it is in defect. There is thus a tendency to instability. If in the case of an infantile planet this tendency were not checked, it would result in a concentration of the mass towards some point, the centre or other. But concentration of the mass means compression of the material, and compression cannot proceed very far without being more or less checked by the resistance which the material opposes to it. Thus ensues a sort of competition between the two agencies, gravitation making for instability, and the elastic resistance to compression making for stability.

Now in the case of the infantile earth, where there were unquestionably differences of density, the resistance to compression is known to have been altogether inadequate (the necessary limit is represented by the compressibility of granite). The planet was therefore unstable, homogeneity was impossible, and the centre of gravity was necessarily eccentric.[1]

Under the influence of rotation, the parts of greater density tend to recede further from the axis than the parts of less density, and since the centre of gravity is eccentric, the effect must be a disturbance of the surface. Surface disturbances would also be brought about by any other of the deformative agencies.

Apparently, then, the general form of the earth and the irregularities of its surface may be regarded as the effects of simple causes of a dynamical character : gravitation ; rotation ; a tendency to an ellipsoidal figure, associated with the attraction of the moon in a bygone age ; shrinkage due to cooling ; the eccentric position of the centre of gravity arising from a past state of inadequate resistance to compression ; and variations of and interactions between these various causes.

(ii.) *How the Forces Acted*

Although gravitation in conjunction with rotation gave the core of the earth its initial form, a change in the rate of rotation would lead to deformative effects. Shrinkage due to cooling must have led to an increase in the rate of rotation, and this to an increase of equatorial bulging and polar flattening. On the other hand, the effect of infalling matter would be a decrease in the rate of rotation.

[1] The resistance is now sufficiently great to keep in check any tendency to gravitational instability. This is known from observation of the propagation of earthquake waves. The centre of gravity must therefore be gradually changing in such a way as to get nearer and nearer the centre of figure.

The rate would thus tend to oscillate about an equilibrium value. But the reciprocal swellings and sinkings of the equatorial and polar regions would be accompanied by compressional and tensional stresses, and the way in which the earth accommodated itself to these would naturally depend on the state of the interior, a state which the facts of the case compel us to assume was, at all stages of the final shaping, an elastic solid of high rigidity.

When rotation slackens, the equatorial belt tends to sink and suffer compression, while the polar regions tend to rise and suffer tension. Between these rising and falling tracts are equilibrium zones, about 30° N. and S. latitude, from one side to the other of which there must be a shift of material sufficient to relieve the sinking equatorial tract and supply the rising polar tract, the equilibrium zone acting as a sort of fulcrum. If rotation increases, the effects are of a reverse kind. The shifts would tend to take place by movements which not only involve a minimum strain throughout the body, but also throw as much deformative action as possible on zones of easiest yield.

Relief by disruption of the surface would certainly have to come somewhere, and since relief of this kind comes more easily in the case of tensional stresses than in the case of compressional stresses, and since the stresses near the poles would be much greater than at any point on the equator, it is probable that surface fission began under tensional conditions near the poles, and that the other primary lines of accommodation developed from these initial ones. The basaltic columns of Giant's Causeway and Fingal's Cave afford instructive illustrations of how tensional stresses are relieved. Under the shrinkage tension of cooling, the rock parts along planes that radiate from the points where the greatest tension has been developed. The parting planes are normally three in number, and diverge at angles of about 120°. These cases embody the principle that, where tensional stresses are concentrated about a given point or line, the most natural mode of relief is a partition of the mass into three equal parts radiating from the point or line of greatest stress. The tensional stresses that probably took precedence at the earth's poles would thus be eased most naturally by three fissure-tracts radiating from the poles at angles of about 120°; these would extend 60° over the spherical surface to the fulcrum zone, and so divide the circumpolar area into three triangular segments. The polar unit must have acted reciprocally with an equatorial unit of the same angular value, and thus three other triangular segments would extend over another 60° of spherical surface, base to base on the fulcrum zone with the circumpolar triangular segments, and their apexes in the opposite direction and extending over the equator to the opposite fulcrum zone. The three pairs of reciprocating triangles would thus be fitted to see-saw across the fulcrum zone, and the three equatorial triangles would appropriate half the equatorial belt, saw-tooth fashion. From the opposite pole would develop three other pairs of like triangles, three circumpolar, and three equatorial, the latter fitting between their opposite equatorial neighbours, and their apexes extending to the first fulcrum zone.

Thus the whole globe would be divided into six pairs of triangular segments, and the zigzag division of the equatorial belt would give it great flexibility. Moreover, the pairs of triangles lying base to base, and each member of a pair being under stress to yield what the other demanded, they would fulfil almost ideally the see-sawing requirement of the motion across the fulcrum zones in response to changes of rotation.

Of course the deformation involved the whole earth, for the rotational stresses extended to the earth's centre. The triangles are thus the bases of pyramids with their apexes at that point. Each adjustment to a new rate of rotation may be pictured as being, primarily, a readjustment of the positions of these twelve pyramids. All secondary effects would be consequential.

Each equatorial pair of triangles forms a quadrilateral, and the three quadrilaterals and the polar triangles form a basis on which to build a complete scheme of continents and oceans by no means unlike those that exist at the present day, though "tetrahedral flattening" was probably also an important factor in their final shaping.

No doubt one hemisphere or the other took precedence in the tri-segmentation; the equatorial members of the first three pairs of reciprocating triangles thus defined the outlines of their equatorial neighbours, and only the second set of polar lines was then needed to complete the segmentation. But the initial action at the one pole resulted in one important polar difference, viz., in prevalent land in the one case and in water in the other, there being by some means a net rise in the former case and a net fall in the latter. And this brings us to the question of tetrahedral flattening.

In consequence of the contraction of its internal mass, the earth, though originally spherical in form, must have tended to become tetrahedral. Hence other stresses were set up besides those due to change of rotation.

In proportion to their volume, a sphere is the body which has the smallest surface, and a tetrahedron is the body which has the largest surface. Any hard-shelled body which is contracting by internal shrinkage is encumbered with excess of surface, and a spherical body can most easily dispose of this extra surface by approximating to the form of a tetrahedron, this being the shape that most easily relieves the tangential stresses. In other words, the excess of surface is disposed of with the least movement by flattening on four faces. Balloons composed of a skin of uniform thickness pass, during their collapse, through a tetrahedral form. A short cylindrical metal tube, under external pressure, collapses on three sides and becomes triangular.

A model of a tetrahedron is easily constructed by cutting from a piece of stiff paper an equilateral triangle, bisecting its three sides,

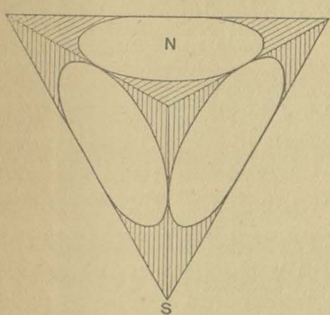

FIG. 5.

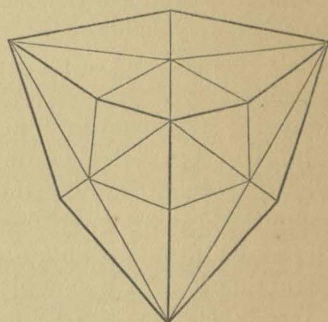

FIG. 6.

joining the points of bisection so as to form four equal equilateral triangles, and folding the three outer triangles on the edges of the inner triangle until the three angles of the original triangle meet in a common apex. It will be observed that each of the four corners is antipodal to a face. Within each triangular face construct as much as possible of a circle, concentric with but rather larger than the "inscribed" circle, so that the inner circular part is five-sevenths of the whole triangle. Then the total area of the four inner circular parts is five-sevenths of the area of the whole tetrahedral surface, and the total area of the angular portions (shaded in Fig. 5) is two-sevenths of the area of the tetrahedral surface. Hence if the inner circular parts represent water and the corner parts land, we have the correct proportions of water and land on the earth's surface. N will represent the Arctic Ocean, which is seen to be surrounded by a nearly complete ring of land;

S will represent the Antarctic continent, which is seen to be surrounded by oceans into which the three great northern land masses project southwards and end in triangular apexes. The three great oceans are represented by the unshaded circular portions of the three lower tetrahedral faces between these triangular projections. Thus there is a striking resemblance between the corner portions of the tetrahedron and the distribution of the land upon the earth's surface, and between the inner parts of the tetrahedral faces and the distribution of the oceans.[1]

If the edges of the model be made of thin strips of whalebone and the faces of elastic tissue, and air be pumped in, the tetrahedron will be blown out into a sphere. (In practice this is difficult to carry out as the yield of the whalebone is almost certain to be different from that of the rubber, but a model good enough to show the spherical tendency is easily made.) When the tetrahedral surface becomes spherical, the shape of the land and water masses becomes in many ways more similar to the existing continents and oceans.

But the tetrahedron underlying the hypothesis is really less simple than the tetrahedron just described. The model should be replaced by a *hexakis* tetrahedron,[2] where each plane face is surmounted by a squat hexagonal pyramid (see Fig. 6). The circles may still be drawn on each set of pyramidal faces, though the construction is a little troublesome ; and when the model is blown out into a sphere, the shapes of the continents and oceans are striking.

Had the earth been a fixed body it would probably have acquired a definite tetrahedral shape, but this shape cannot be maintained by a body rotating at high speed. The earth thus merely *tended* to become tetrahedral, and in effect this means a slight flattening of four faces. But by virtue of the rotation of the sphere, the flattenings on the four faces would really form depressions, and in these depressions the waters would collect to form the oceans.

The simplest explanation of the periodic expansion of the sea

[1] It will of course be realised that Fig. 5 is only a diagrammatic sketch of the tetrahedron, and that the fourth triangular face is supposed to be at the back of the figure. For further details and illustrations, see Professor Gregory's *The Making of the Earth*.

[2] For its construction, accurately copy, on stiff cartridge paper, the figure shown on the next page (Fig. 7). Then with a sharp penknife cut on each line halfway through the thickness of the paper. The "net" will then fold up into the "solid." If the various lappels be gummed, the solid can be preserved in permanent form. (Note the similarity or symmetry of the twenty-four triangles, which are, of course, all of the same dimensions.)

is the slow uplift of the sea-floor causing a shallowing of the ocean basins. This uplift is probably due to the partial restoration of the spheroidal form of the earth from the tetrahedral deformation. For flattening would continue until conditions became unstable, when disruption would take place; the buckling of the angular edges would result in a collapse of such a kind that the spheroidal form would be partially recovered, though the size would be smaller. Then on this smaller sphere tetrahedral flattening would begin again. And so on alternately.

But any reduction that may now be taking place in the size of the earth is probably very slow. The horizontal marine rocks of the cretaceous period occur up to the height of 11,000 feet on the high plateaus of Western America, and these beds give no indication of having been uplifted; the fractures in them imply that the surrounding areas have sunk. Apparently, therefore, the diameter of the earth may be five or six miles shorter than in the cretaceous period. But it is highly probable that the earth has not shrunk perceptibly during geological time. The buckling of the surface into the existing great land elevations and great ocean basins must have been the last great stage in the earth's making.

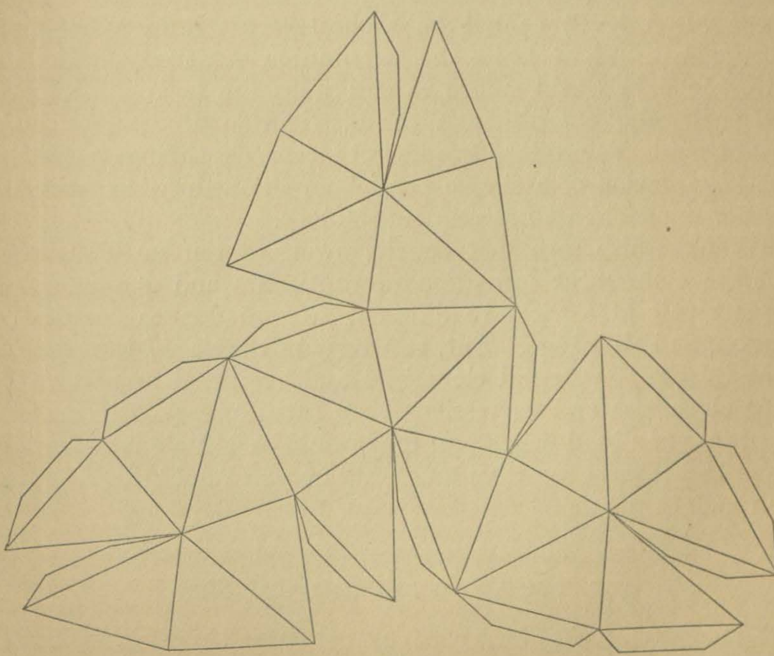

FIG. 7.

Nominally, the hypothesis of relief of tensional stresses by tri-segmentation is distinct from and independent of the hypothesis of tetrahedral flattening. But the two hypotheses are best regarded as mutually complementary. Dynamically, they are two aspects of the same thing. Gravitation, rotation, and shrinkage all have to be considered together. The stresses set up are exceedingly complex, and the relief of these stresses necessarily yields a complex result, as we see in the shapes of the continents and oceans.

It will now be understood that the figure of the earth is not only not a true sphere ; it is not even an exact oblate spheroid (a sphere with polar flattening and equatorial bulging), though the difference from spheroidal form is not great. The south polar area probably projects more than the north ; hence the shape of the earth is somewhat like that of a short egg. But a horizontal section of an egg standing on its end would be circular, whereas a section through the earth's equator is not circular but elliptical. If an egg be selected for its shortness, boiled hard and shelled, and then slightly flattened equatorially, we obtain a shape approximately like that of the earth. But of course our knowledge of the general shape of the earth is very largely hypothetical and inferential. The precise form of the geoid (that is, the earth with all the land removed down to the ocean level) cannot be accurately ascertained by direct measurement. If we knew the distribution of density within the earth, the data would suffice to determine the form of the geoid mathematically, but although the distribution of density can to some extent be determined by indirect means, depending on the local time of vibration of a simple pendulum, the deductions as to the shape of the geoid are not very satisfactory.

We have also seen that the furrowing of the earth's surface, with the consequent formation of continents and oceans, is the simple result of a yield to different stresses due to gravitation, rotation, and shrinkage. But, relatively to the size of the earth, so slight are the continental elevations and oceanic depressions, that if the elevations and depressions were actually carved to scale on the surface of a hard-boiled egg, they would be entirely inappreciable except to the most sensitive touch, for no scar would exceed 1/1000 of an inch in depth.

10. The Dawn of Geological Time

The original rocks of the earth's crust formed by the solidification of gravitationally lighter slag from the largely metallic molten material are called primary rocks. When exposed to the surface of the earth, these are broken up and their constituents redeposited; thus we get secondary rocks such as sandstones and limestones. The telling of the story of the competitive struggles, during the earth's adolescence, of the outer crust, the water, and the atmosphere is the task assumed by geology. At the time when the first stratigraphic record becomes distinctly legible, the struggle amongst the three had attained the working relations much the same as they are to-day; the continents had been formed, and about five-sevenths of the planetary surface was submerged. The water and the atmosphere have always joined forces in a ceaseless endeavour to wear down the continental elevations, but they have never more than half succeeded before the accumulated stresses of the solid earth have brought on a new series of deformative re-adjustments of the surface, by which the elevations were renewed, the basins deepened, and more of the waters withdrawn into these deepened basins. But can the earth continue the struggle indefinitely? Will its powers of renewed shaping cease when its internal contraction ceases? If so, will the forces of denudation ultimately wear down the land and leave us with a universal ocean? Or will future generations have so harnessed the forces of nature that the present rôles of master and servant will be interchanged?

11. The Origin of the Universe

There is no clear evidence of a sudden and independent primitive creation of the world, as distinguished from an indefinite backward extension of cycles of celestial evolution. The genesis of our planetary system was probably but an incident in the history of the sun, the genesis of the sun but an incident in the history of the whole stellar system, and the genesis of the stellar system perhaps only an episode in the evolution of the real universe, by far the greater part of which is believed to be quite beyond the reach of our most powerful telescopes.

On the hypothesis of the formation of matter from the aether, and the destruction of matter with consequent reconversion into aether, the problem of creation ceases to be formidable. And there are now traces of actual evidence which are highly suggestive of the continuous creation of matter even at the present day. For in the enormous temperatures of the hottest suns, spectroscopic evidence seems to prove either that dissociation of matter into its first and simplest forms is proceeding, or that the available high energy concentration at such a temperature is actually synthesising and producing from the aether those first and simplest forms of matter. Such reactions may run in either direction, according to the particular level of temperature. The first stage of all is the evolution of the electron from the imponderable aether ; from the electrons arise the atoms of the inert gases of the helium group and hydrogen ; and presumably by various unions of these with each other and with other electrons, arise the atoms of the elements we know. In all probability the more primordial constituents of matter are, in the hottest suns, constantly forming ; as the temperature falls the ordinary elements become synthesised, though even then the temperature far exceeds anything we can produce artificially. Our only means of imitating energy of such an enormous magnitude is by the high tension vacuum spark,[1] but, at the very best, such attempts are but feebly effective.

But all this indicates progress, progress from an almost inconceivably remote past down to the present, and presumably progress in the future. And does not this very notion point to a time when progressive change must come to an end and be followed by a mere sequence of unfruitful events ? Must not eternity outlive any progressive change ? We cannot avoid thinking of an infinite future, but can we conceive of infinite progress ? Can we avoid the expectation of a cessation of progress ?

But what of the infinite past ? If present events are merely one stage in an infinite progress, why is not the present stage long ago passed over ? Since we can push back any stage of progress to as remote a period as we like, can we assume an evolutionary progress from an infinite past ? Or, did a progressive activity suddenly emerge from an eternal, unfruitful, and unprogressive activity ? If so, how ?

A *progressive* activity must have had a beginning. For if our universe is the result of material aggregation progressing over an infinite time, we are driven to admit a primitive separation of all particles at an infinite distance from one another. But what force can have acted between particles separated by infinite distance ? Gravitational force falls off as the square of the distance and must therefore vanish at infinity. The condition of particles separated by infinite distances must be one of neutral stability. How, then, can we imagine the beginning of aggregation of such particles ? No *finite* movement of infinitely separated particles could initiate interaction. In fact, no hypothesis of permanent material stability

[1] See p. 58.

will hold, for, from the known properties of matter, such stability must have been permanent if ever existent. If primevally diffused matter had ever been held in equilibrium, it must have remained so. But this means no progress, which is obviously contrary to fact. Since equilibrium of gravitating particles would have been indestructible by internal causes, gravitating matter alone does not afford a rational account of the past. Evolution must have had a *beginning*.

If, as seems probable, matter is derived from electrons and electrons from the aether, it is easy to conceive a pre-material condition of the universe in which uniformity as regards the distribution of the vast stores of aethereal energy prevailed. In its pre-material state, the universal aether must have been in a state of unfruitful motions, rotational or other, motions unattended by progressing changes. Such energy entities differed from matter in not possessing gravitational attraction. But once they were released to form aether-strains—aether-knots, or electrons—the coming into being of a material universe would presumably be possible. The whole difficulty lies in the *origin* of this release. When did the breakdown of the past eternal equilibrium take place, and how? Given the key to this riddle, evolution follows, and the "creation" of the universe becomes an easily conceivable process. It has been suggested that, at some moment in infinite time, a particular configuration of the original non-gravitational elementary aethereal motions was attained and that a breakdown of equilibrium then became inevitable, the process being in some ways comparable to a breakdown in the equilibrium of a clear supersaturated solution. But neither in the one case nor in the other is a breakdown conceivable without the application of some sort of stimulus, external or internal.

But what does it avail even if we admit the breakdown to have been a mere consequence of a particular configuration of non-progressive motions in past eternal equilibrium? We still have to account for the origin of the aether and of those non-progressive motions.

The origin of our planetary system is a comparatively simple problem, for the sun-bolt hypothesis satisfies the most rigorous exactions of dynamical law. True, it rests upon other hypotheses—those of the molecular constitution of matter and of the kinetic composition of gases—and calls to its aid the evidence of the spectroscope. But all these things now find general acceptance among those who are practically acquainted with the experimental evidence on which they are based. When, however, we attempt to find an origin of the universe itself, any hypothesis is necessarily highly speculative. The mind is baffled, as it always is baffled when it attempts to follow up an infinite regress. If, however, the mind can bring itself to admit a First Cause, the rest is easy. If it denies a First Cause, the problem admits of no conceivable solution. It may be urged that neither can a First Cause be adequately conceived. But, once more, are we not sometimes bound to believe what we cannot conceive?

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CHAPTER VI

THE EVOLUTION OF ANIMAL SPECIES

1. The Hypothesis of Organic Evolution

THE hypothesis of organic evolution—the hypothesis that all the different kinds of animals[1] have successively come into existence by the growth and modification of some primitive form of life—is based on a number of definitely established generalisations from actually observed facts :

1. Living animals exhibit related gradations of structure, ranging from extreme simplicity to great complexity.

2. The same fundamental plan of structure is possessed by large groups of species of widely different habits.

3. There is a close analogy between (*a*) the series of gradations exhibited by the different species which compose any great group of animals, and (*b*) the series of embryonic changes which apply to the highest members of that group.

4. In one species of a group there are often structures of a rudimentary and apparently useless condition, but in the other species of the same group the same structures are fully developed and have definite functions.

5. Living animals vary according to the varying conditions of their environment.

6. There is a definitely successive development of animal forms in the geological strata. The farther we go back in time, the less the fossilised specimens are like existing forms. In the successive periods of the earth's history, higher and higher animals appear. The first appearance of some of the great groups is shown in the following table :

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[1] We purposely neglect any consideration of plant forms.

Animal Groups.	Geological "Eras" with their "Periods."														
	Eozoic.	Primary or Palaeozoic.					Secondary or Mesozoic.			Tertiary or Cainozoic.				Post-Tertiary.	
	Pre-Cambrian.	Cambrian.	Silurian.	Devonian.	Carboniferous.	Permian.	Trias.	Jurassic.	Cretaceous.	Eocene.	Oligocene.	Miocene.	Pliocene.	Pleistocene.	Recent.
Protozoa . .	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Echinodermata .		×	×	×	×	×	×	×	×	×	×	×	×	×	×
Mollusca . .		×	×	×	×	×	×	×	×	×	×	×	×	×	×
Fishes . . .			×	×	×	×	×	×	×	×	×	×	×	×	×
Amphibians .					×	×	×	×	×	×	×	×	×	×	×
Reptiles . .						×	×	×	×	×	×	×	×	×	×
Birds . . .							×	×	×	×	×	×	×	×	×
Mammals . .							×	×	×	×	×	×	×	×	×
Man . . .													(?) ×	×	×

The core of the hypothesis is that evolution consists in a succession of changes in the form, structure, and functions of a primitive germ, by which it has passed, step by step, from an extreme simplicity and relative homogeneity of structure to a greater or less degree of complexity and heterogeneity ; that there has been a progressive differentiation from plane to plane of higher development.

The hypothesis involves certain important assumptions which, though in many cases possessing a high degree of probability, must not be confused with the facts by which they are supported. But before they can be adequately examined, some knowledge of the principles of animal classification, and of the phenomena of cell-division, is necessary, and to these matters we first turn.

2. The Classification of Animals

(*a*) *Homology and Analogy*

If the classification of animals is to be a grouping together of forms which are fundamentally alike, it must rest, not on mere analogies, but on the recognition of *homologies*, *i.e.*, of structural and developmental similarities. Homology and analogy are terms employed to express, respectively, the morphological and functional resemblances between the parts of different animals. Homologous structures reveal a deep-seated resemblance in build and in manner of development ; analogous structures resemble one another merely in discharging the same function. In classifying animals it is necessary to see through deceptive suggestions of mere functional resemblances and to get down to the sure foundation of homological resemblances, structural and developmental. Homologous organs, though structurally formed on the same fundamental plan, may be greatly disguised in form ; and not only do they not always perform the same function but they are often fitted for very different purposes.

The wing of a bird and the wing of an insect are analogous organs, since they are both organs of flight. They are, however, in no way similar except when regarded functionally ; morphologically they are radically dissimilar, being formed on an entirely different fundamental plan. But the arm of a man, the arm of a frog, the foreleg of a horse, the wing of a bird, the wing of a bat, the flipper of a whale, and the paddle of a turtle, are all homologous, not only as regards bones but as regards muscles, nerves, and blood-vessels. The close structural similarity in the seven cases is remarkable, and, in spite of the obvious differences, the inevitable interpretation seems to be that the resemblances are ultimately due to blood relationship, in fact that there is descent from a common progenitor.

It ought now to be clear why the wing of a bird is homologous with but not analogous to the arm of a man, analogous to but not homologous with the wing of a butterfly, both homologous with and analogous to the wing of a bat ; also why whales are classed with mammals and not with fishes, and bats with mammals, not with birds.

Homological resemblances are a safe guide to real affinity, enabling us to trace the genuine relationship which may subsist between animals outwardly very dissimilar. Theoretically, then, classification would seem to be a very simple matter, but, in practice, difficulties are many and great, for it is often virtually impossible to disentangle the homological from the merely analogical resemblances.

(*b*) *Principles of Grouping in Classification*

Horses and asses are commonly regarded as different " kinds " of animals. It is true that they are alike in having a vertebral column, mammae, four legs, and feet each consisting of a single well-developed toe provided with a hoof ; but while a horse has a bushy tail an ass has a tufted tail, and while a horse has callosities on the inner sides of both the fore- and the hind-legs, an ass has callosities on the inner side of the fore-legs only. The differences in the tails and in the callosities are constant, and these morphological peculiarities are sufficient to stamp horses and asses as of different " species " ; the differences are " specific."

Dogs and cats are like horses and asses in having a vertebral column, mammae, and four legs, but they differ from them in having five toes on each fore-foot and four on each hind-foot. And just as there are characteristic differences between horses and asses, so there are characteristic differences between dogs and cats. Dogs have 42 teeth, cats 30 ; a dog's claws are blunt, only slightly curved, and non-retractile ; a cat's claws are very sharp, strongly curved, and very retractile. The well-marked and definite morphological peculiarities of teeth and claws (there are many others) are constant, and dogs and cats are therefore regarded as constituting different " species."

To a " species " a double name is always given. The domestic dog, for instance, with all its subordinate varieties, forms the species *Canis familiaris*. The binomial is not unlike a man's Christian and surnames, but in reverse order. *William* distinguishes an individual in a group of *Smiths*. *Familiaris* distinguishes an individual " species " in the group or " genus " *Canis*. The dog, whilst specifically recognised by the epithet *familiaris*, belongs to the genus *Canis* in which are included other related species, such as the wolf (*Canis lupus*) and the fox (*Canis vulpes*). So also the genus *Felis* includes several species, *e.g.* the lion (*Felis leo*) and the tiger (*Felis tigris*). These animals are correctly called " cats," though each species differs characteristically from all the others ; for instance, each species has a coat with distinctive markings.

The genus *Canis* and certain other closely allied genera are grouped together and constitute the " family " *Canidae*, all " dog-like " animals. The genus *Felis* and certain other closely allied genera are grouped together and constitute the " family " *Felidae*, all " cat-like " animals.

Just as the " dog-like " genera are united into one family, the *Canidae*, and the " cat-like " genera into one family, the *Felidae*, so there are other families, *e.g.* the *Ursidae*. The various families grouped together constitute the " order " *Carnivora*, or beasts of prey. All carnivora have claws, and never less than four well-developed toes on each foot ; also strong, pointed, characteristically curved, canine teeth. In all cases the condyle of the lower jaw is a transversely placed half-cylinder working in a deep groove of corresponding form. And the radius and ulna are always distinct.

The Order *Carnivora* is grouped with others Orders, *e.g.* the Order *Ungulata*, hoofed vegetable-feeding animals (elephants, horses, oxen, sheep, etc.), and the Order *Rodentia*, gnawing animals without canines but with chisel-shaped incisors (squirrels, beavers, rats, etc.). Together, such orders form the " Class " *Mammalia*. All mammals are warm-blooded and suckle their young. The Class *Mammalia* is grouped with four other Classes, viz. *Birds, Reptiles, Amphibians,* and *Fishes,* and together they form the " Sub-Kingdom " *Vertebrata*.

The zoological position of the Dog may be shown thus :

Kingdom,	*Animalia.*
Sub-Kingdom,	*Vertebrata.*
Class,	*Mammalia.*
Order,	*Carnivora.*
Family,	*Canidae.*
Genus,	*Canis.*
Species,	*Canis familiaris.*
Variety,	*Fox-terrier.*

It is customary to place the five great Classes of Vertebrates in the following order: Mammals, Birds, Reptiles, Amphibians, Fishes. But it is a mistake to suppose that the order necessarily indicates a line of ancestral succession. Mammals are, it is true, by far the most highly organised of all animals, but in looking for their progenitors amongst the other vertebrates we probably have to pass over all known forms of birds and reptiles and go straight to the amphibians. There are two reasons for this : (1) the amphibians are the only air-breathing vertebrates which, like mammals, have a dicondylian skull ; (2) in birds and reptiles the aorta, after leaving the heart, arches to the right, while in mammals it arches to the left. If we suppose the earliest form of mammals, and of birds and reptiles, to have had a common amphibian origin, there is no difficulty in the supposition that from the first it was a left aortic arch in the one series, and the corresponding right aortic arch in the other, both derived from the different aortic arches of the amphibian, which became the predominant feeder in the arterial system. If the arterial systems of typical mammals, birds, and reptiles be actually examined and compared with the arterial system of a typical amphibian, the observer will probably be convinced of the truth of this supposition.

The following is a very probable pedigree :

Fishes
|
Amphibians
|
Reptiles — Mammals
|
Birds

The whole Animal Kingdom is divided into two great sections, the Vertebrata being one and the Invertebrata the other. The distinguishing characteristics of the two sections are these. In all invertebrates, the body, if divided transversely, shows only a single tube, containing all the vital organs; and if there is a skeleton it is usually external. In all vertebrates there are *two* tubes, the second containing the brain and spinal cord; and there is always an internal skeleton. The central stem of this internal skeleton usually constitutes a true backbone or vertebral column, though a notochord occasionally takes its place.

The invertebrate animals are divided into a number of groups commonly known as Sub-Kingdoms which are conveniently regarded as of co-ordinate rank with the Sub-Kingdom Vertebrata. These include—(1) the *Protozoa*, the lowest division of the animal kingdom; most of the organisms are visible only under the microscope: the amoeba and foraminifera are examples. (2) *Porifera* or sponges. (3) *Coelenterata, e.g.* sea-anemones and corals. (4) *Echinodermata, e.g.* sea-urchins and star-fish. (5) *Annulosa, e.g.* spiders and insects. (6) *Mollusca, e.g.* oysters and snails.

(*c*) *Species: First Test—Degree of Resemblance*

The greatest as well as the least differences amongst animals are of degree rather than of kind, and consequently no rigorous and unexceptionable definition of "species" is possible. In many cases it is difficult and in some it is impossible to decide what degree of difference between given specimens shall be considered sufficiently "specific" to entitle the specimens to be placed in different binomial systems. A species is commonly defined as a group of animals distinguishable from all others by certain constant morphological peculiarities. Hence, as we have seen, dogs and cats are different species. But if animals were discovered having the general characters of the dog, but sometimes with 30 teeth and with more or less pointed and retractile claws; or animals having the general characters of the cat, but with 42 teeth and with more or less blunt and non-retractile claws, besides being intermediate in other respects, the two species would have to be merged into one. They could no longer be regarded as morphologically distinct. In point of fact, new forms are often discovered which are intermediate between two recognised species, and the question then arises whether the two species should be merged into one or whether a third shall be recognised. But so limited is our knowledge that by far the largest proportion of existing species are known only by the examination of their skins or bones. The physiological characters of a few have, however, been carefully investigated, and as this knowledge increases many of the existing difficulties of classification ought to be overcome.

It is indubitable that offspring *tend* to resemble the parents, but it is equally true that the similarity attained never amounts to identity either in form or in structure. There is always a certain amount of deviation, not only from the precise characters of a single parent but from an exact mean between the two parents. Be the cause what it may, the co-existence of this tendency to minor variation with the tendency to general similarity is of great importance in its bearing on the origin of species.

As a general rule, the extent to which an offspring differs from its parent is slight, but occasionally the amount of difference is strongly marked, and then the divergent offspring may receive the name of *Variety*. Multitudes of such varieties are known. There are, for instance, nearly 200 varieties of the domestic dog, though the origin of most of them is uncertain. But it is often difficult to decide whether groups of similar forms should be ranked as species or varieties, for the question is, are the differences "specific" or not? So long as a genus is imperfectly known and its species are founded upon a few specimens, the species seem clearly defined, but as intermediate forms flow in, doubts begin to arise as to the specific limits. The terms variety and species therefore appear to be somewhat arbitrarily applied to indefinable groups of more or less closely similar individuals.

A "race" is a propagated variety, but a race is no more fixed and immutable than the stock whence it sprang. Variations arise among its members, and as these variations are transmitted like any others, new races may be developed out of the pre-existing one, and so on indefinitely. A remarkable example of this is to be found in the rock pigeon, which has been demonstrated to be the progenitor of all our domestic pigeons, of which there are over a hundred well-marked races. The four most noteworthy of these races are the tumblers, pouters, carriers, and fantails; birds which not only differ most singularly in size, colour, and habits, but in the form of the beak and of the skull, in the number of tail feathers, in the size of the feet, and in the number of vertebrae in the back ; in short, in precisely those characters in which the genera and species of birds differ from one another.

(*d*) *Second Test—Hybridisation*

As morphological differences seem to be an uncertain guide for distinguishing species, an entirely different test has been proposed, namely, that of hybridisation.

However different individuals belonging to different races of the same species may appear to be, they not only breed freely together but the offspring of such crossed races are quite fertile with one another. Thus the spaniel and the greyhound, the dray-horse and the arab, the pouter and the tumbler, breed together freely ; so do their mongrels if matched with mongrels of the same kind.

On the other hand, individuals of many species are either absolutely infertile if crossed with individuals of other species, or, if they give rise to hybrid offspring, the hybrids are infertile when paired together. The horse and the ass, for instance, if so crossed, give rise to the mule, and there is no certain evidence of offspring ever having been produced by a male and a female mule. Hence have we here a means of distinguishing species from varieties ? If a male and a female selected from two given groups produce offspring, and that offspring is fertile with others produced from the same groups, can we say with certainty that the groups are varieties and not species ? If, on the other hand, there is no result, or if the offspring are infertile with others from the same groups, can we say that the groups are true species ?

Careful investigation has shown that these questions cannot always be answered in the affirmative. No clear-cut line can be drawn. Sterility is variable in individuals of the same species and is eminently susceptible to favourable and unfavourable conditions.

The value of fertility or sterility as a test of species is therefore rather uncertain. But the important fact remains that there are groups of animals the members of which are incapable of union with those of other groups ; and that there are such things as hybrids which are absolutely sterile amongst themselves. We may summarise thus : Animals are divisible into groups of individuals which breed freely together, tending to produce their like. Normally resembling their parents, these offspring are still liable to vary.

The variation may be perpetuated by selection, and the resulting race or variety often presents all the characteristics of a morphological species. It is not yet proved that such a race ever exhibits, when crossed with another race of the same species, those phenomena of hybridisation which are exhibited by many species when crossed with other species. On the other hand, not only is it not proved that all species in crossing give rise to hybrids infertile amongst themselves, but there is reason to believe that, in crossing, species exhibit every gradation from perfect sterility to perfect fertility.

Thus neither this test nor the former test seems, in practice, to be of much use. The reason is obvious: the clear-cut group we label species has no counterpart in nature.

(*e*) *The Origin of Species*

(*a*) *Not due to a Creative Act*

There are only two hypotheses respecting the origin of species that demand attention. The first, held by the great majority of persons fifty years ago, was that every species is, within certain definite limits, fixed and incapable of modification; and that every species was originally produced by a distinct creative act. The only serious reason advanced in support of this hypothesis is the supposed necessity of making science accord with the Hebrew cosmogony. But there is probably no single minister of religion in any one of the Christian Churches who would now defend the literal interpretation of the first chapter of Genesis.[1] The evidence against this first hypothesis is, in fact, so overwhelming that any attempt to justify the hypothesis would inevitably be regarded as a sign of untrained intelligence.

(*β*) *Species arose by Natural Selection*

The second hypothesis is that of Natural Selection, according to which all existing species arose from the modification of pre-existing species, these of their predecessors, and so on, backwards, indefinitely, as the result of the action of natural agencies similar to those producing varieties at the present day; and it is a probable, though not a necessary, consequence of this hypothesis that all

[1] I am assured that this statement is, unfortunately, not correct; that even in the year 1919 a minister of the Christian religion may here and there be found whose intellectual outlook is scarcely distinguishable from that of his mediaeval forbears.

animal forms have arisen from a single stock. With respect to the origin of this primitive stock itself, the hypothesis of the origin of species is not necessarily concerned, though we shall deal with that origin in the next chapter. The Natural Selection hypothesis is, for instance, perfectly consistent either with the conception of a special creation of a primitive germ, or with the supposition of its having arisen, as a modification of inorganic matter, by natural causes.

If there is one conclusion from geological investigation that has emerged more clearly than any other, it is that the vast series of extinct animals is not divisible into distinct groups with sharply defined boundaries. In fact, the evidence from all sources taken together seems to be almost irresistible that any group of animals we term a species is separately distinguishable merely because the links in the ancestral chain are missing. If, for instance, we could arrange in line an ordinary dog and all his ancestors right back to the original protozoon, it is highly probable that as we traversed the line we should at no point detect any sensible variation between one ancestor and the next. A thousand generations back the dog would still be a dog, much as we know him now. A hundred thousand generations back, he would probably be a much earlier mammalian. A million generations back, he might possibly have ceased to be vertebrate. But the gradation would be so fine that, unless we made huge gaps in the line, we should never see appreciable differences of type. Now such gaps have unquestionably been made by nature; multitudes of the types representative of the dog's ancestors have become extinct, and it is impossible to say which other living organism can be regarded as most nearly representing one of the ancestors of the dog.

Thus we are totally unable to reconstruct the complete genealogical tree of the animal kingdom. Our knowledge is confined to the surviving twigs and few—very few—stray branches. What sort of an animal, for instance, was the common ancestor of the man and the ape, or of the cat and the dog, or of the mouse and the elephant, or of the sparrow and the crocodile, or even of all these animals? We do not know. The destruction, during the possibly hundreds of millions of years of the geological period, of the vast majority of the branches of the genealogical tree has left what now appears to be clearly differentiated groups, and this explains not only the specific but also the generic, ordinal, and still broader distinctions now recognised. Exceedingly few animals from remote ages are likely to have survived racially to the present time, and to have maintained their specific characters as we now find them. Yet the persistence of some forms, through countless generations, under no greater variation than that usually accounted generic is known to be a fact. A case in point is the genus *Lingula* (a brachiopod) whose members have survived from the Silurian to the present period, with only specific variation. This is remarkable.

Whatever classification of animals we adopt, then, there is bound to be some measure of artificiality. Nature is continuous: gradation of characters is almost always the rule; precise lines of demarcation between groups are rare. All is a matter of degree. There are no *natural* groups; the groups are of our own making. There is no fixity of species. To tie a label marked "dogs" to a particular group of animals is certainly convenient, but nature does not know dogs as an absolutely differentiated animal group, for she keeps all extinct forms within her memory.

3. Cells and Cell-Division

If the recently laid egg of some such common animal as the newt be examined under the microscope, it will be seen to be a minute structureless spheroidal body, enclosing a fluid with granules in suspension. With a moderate amount of warmth, the body undergoes rapid changes; it divides and subdivides, grows and takes a definite shape, just as if an invisible modeller were at work —moulding the form of the body, tracing out the line to be occupied by the vertebral column, and fashioning in due proportion head, tail, and limbs. It is all done in so marvellously artistic a way that one becomes almost involuntarily possessed by the notion that, if the microscope were but powerful enough, the hidden artist would be revealed with his plan before him.

With a little help from a biological friend, the reader may watch the development of an embryo chick. The eggs may be taken from an incubator kept at a temperature of about 40° C., and the successive embryos floated off in saline solution on to a glass slide for observation. The first egg may be taken after 24 hours' incubation, others at intervals of 12 hours. At the end of 24 hours, the brain, the rudimentary spinal cord, and the cubical masses into which the vertebral plate is segmenting, may be seen. At the end of 36 hours, blood-vessels and a rudimentary heart are visible. At the end of 48, the circulatory system has developed considerably, and the eyes and ears have begun to form. And so on.

A living organism always originates in a single cell and, when fully developed, is simply an aggregation of cells, though these vary in arrangement, shape, and function. However varied the pre-natal course which different animals have to pursue, all have to start from the same point. Whether man or ape, cat or mouse, frog or sparrow, mackerel or oyster, all begin their existence under forms which are essentially undistinguishable. During their earlier stages, all living animals seem to develop in precisely the same way; at all events it is absolutely impossible to distinguish between the initial embryonic forms of one animal and another. Eventually, of course, they begin to differentiate, but *why* they differentiate is one of the profound secrets of nature.

The protoplasm which forms the contents of a cell is semi-fluid in character, and within it can be distinguished a small round body; this is the *nucleus* of the cell and its most important part, for it seems to direct and regulate all that goes on within the cell-body. The cell draws its nourishment from the surrounding medium, assimilates it, and so converts it into new protoplasm. In this way the cell grows. When it has attained a certain size, which varies for different cells and may be from 1/250 to 1/12 of an inch in diameter, it divides into two daughter cells, each with its own nucleus and cell-body. Some of the lower organisms, for instance the amoeba, consist, it is true, of a single cell only, but in all higher organisms there are aggregations of cells. As an organism develops from its original cell, differentiation arises among the new cells; inner and outer layers are formed, each assuming a different structure and different functions. With further development, further differences arise, and tissues and organs for different purposes are gradually formed. But however great the difference between one animal and another, they agree fundamentally in one respect: they are both made up of cells and both originate in a single cell.

Since evolution is closely wrapped up with heredity, and since the secret of heredity probably lies within the cell, it is necessary to consider in some detail cell structure, growth, and division.

Until the advent of the present very high powers of the microscope, it was thought that the protoplasm of the cell was simple, homogeneous, and undifferentiated. But it is now known to be extraordinarily complex, and in the process of cell-division the nuclear changes that take place are of the most impressive character.

The nucleus of the cell has an enclosing membrane of its own, and within its fluid contents is a delicate network on which, during the resting phase of the cell, may be seen numerous granules

(Fig. 8). These are the *chromatin* granules, so called because they are easily coloured (and therefore easily examined) by stains; they play a fundamental part in cell-division. Immediately outside the nucleus and adjoining it is a minute body called the *centrosome*.

When the cell is fully grown and ready for division, remarkable changes take place in the nucleus. The changes are perfectly

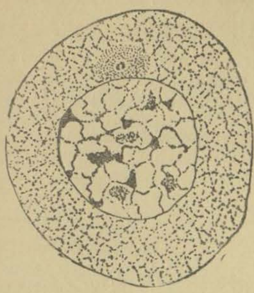


FIG. 8.

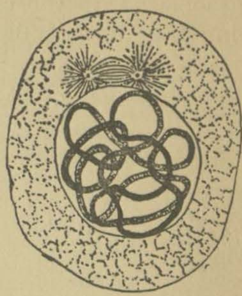


FIG. 9.

regular, always similar in character, and always exactly the same for the same species. The process is initiated by the scattered chromatin granules first arranging themselves into a single long thread, twisted round and about like a tangled skein (Fig. 9), which immediately breaks up into a number of small equal pieces, rods

FIG. 10.

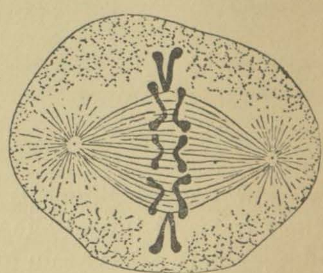


FIG. 11.

or loops, called *chromosomes* (Fig. 10). The number of chromosomes is always the same for all ordinary cells of the same organism, and for the same species. At the same time the centrosome just outside the nucleus divides into two, each new centrosome becoming surrounded by radiating fibres which not only give them a star-like appearance but serve to keep them attached (Figs. 9, 10). The two centrosomes now move apart and take up polar positions at opposite ends of a diameter of the nucleus, the radiating fibres stretching between them (Fig. 11). Meanwhile the membrane enclosing the nucleus has disappeared, and the chromosomes take up a regular equatorial position between the star-like centrosomes, the whole presenting the appearance of an elaborated spindle (Fig. 11). Each chromosome now splits lengthwise and forms a pair, the members of each pair lying close to each other, obviously closely associated, in the equatorial plane (Fig. 11), the successive pairs lying round the bulging part of the spindle (Fig. 11). Each equatorial set of chromosomes now moves off towards its nearer polar centrosome (Fig. 12) ; the stretching fibres seem to part, the two sets of chromosomes become quite separated, and each set

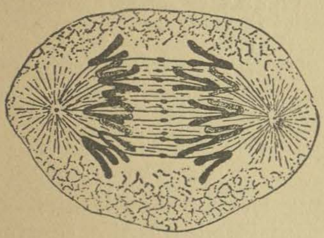


FIG. 12.

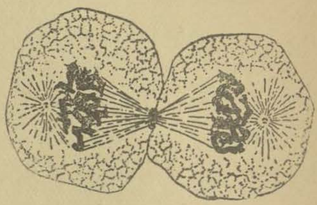


FIG. 13.

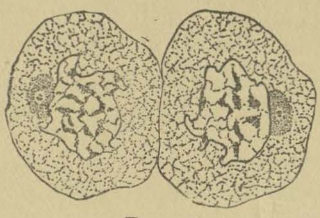


FIG. 14.

forms a new daughter nucleus (Fig. 13). Finally, the chromosomes lose their rod and thread-like appearance and break up again into granules ; a network is again formed, and each new nucleus becomes surrounded with a new membrane (Fig. 14). The cell substance has also meanwhile divided, and we have at last two complete daughter cells, each exactly the same as the mother cell with which we started (Figs. 8, 14). The process of division effects the *exact halving* of the chromatin substance, and results in each daughter cell having the *same number* of chromosomes as the original cell. Such is cell-division (" karyokinesis," as it is called), and the process never fails to impress an observer, especially when he remembers that the nucleus—the seat of the remarkable process—is invariably invisible to the unaided eye.

Every living animal originates in two special cells, the germ-cells ; and these, the ovum and the spermatozoon, possess all the qualities of ordinary cells, and in their fundamental functions behave like them. The size of the ovum varies greatly. It is often very minute, as in the case of mammalians, but sometimes very large, as in the case of birds ; the nucleus, however, is always microscopical.

Both the germ-cells contain the same number of chromosomes as ordinary body cells, but before fusion takes place between them they undergo certain changes which have the effect of leaving them with *only half the number* of chromosomes they had previously. In the case of the ovum this process is called *maturation*, while the same end is achieved for the spermatozoon by *spermatogenesis*.

Maturation is effected by a curious kind of cell-division, curious because, in order that the chromosomes may be halved, a doubling first takes place, and then a process of halving twice over. Each step is like that of ordinary cell-division, but the smaller daughter cells that result from the process seem to be lost. When the process is completed, the chromosomes that remain lose their identity and break up into chromatin granules and network, just as in the case of ordinary cells.

When fertilisation takes place, the nuclei of the two germ-cells fuse to form a single " segmentation nucleus." Since the segmentation nucleus derives half its chromosomes from the maternal, and half from the paternal, germ-cell, its total number of chromosomes is the same as in each of the original germ-cells before maturation and spermatogenesis. Thus by these processes the normal number of chromosomes in a cell is maintained, and a doubling of the number with each new generation prevented.

Immediately the segmentation nucleus is formed by the fusion of the nuclei of the germ-cells, the process of segmentation sets in, and by repeated cell-division continues until the fertilised ovum has developed into the adult organism. As we shall see, there is evidence to show that the hereditary qualities that pass from parent to offspring are contained in the chromosomes. Indeed, this might be expected, since the chromosomes are derived in equal portions from the two parents.

We are now in a position to turn to the main subject-matter of the chapter.

4. Geological Considerations

(a) The Geological Age of the Earth

The action of running water on the surface of the land is a familiar phenomenon. Loose soil is washed away and the newly exposed rock, subjected to various kinds of weathering influences, is disintegrated and in its turn washed away. Denudation is almost universal. Much of the easily soluble matter finds its way into the general ocean, but the greater part of the sediments are deposited near the continental coasts. These deposits have been traced back into the past, layer by layer; and as they are traced downwards the fossilised remains of life embedded in them grow less diversified in character. Mammals, birds, reptiles, amphibians, fishes, die out successively as we reach deeper and more ancient strata; life-forms become fewer and simpler, and ultimately we reach strata apparently barren of the remains of life of any kind. Below these barren sediments is a floor of primary rocks dating from pre-sedimentation times.

If a reasonably clear notion of the evolution of organic life is to be formed, some estimate of the geological age of the earth is necessary.

One recognised method of forming this estimate is based upon the measurements of the collective thickness of the sediments forming the strata of the successive geological periods. Variable as these thicknesses are, there is general agreement as to their approximate averages. These average thicknesses, expressed in miles, are as follows:

Pre-Cambrian Era . . .	16 miles
Primary ,, . . .	23 ,,
Secondary ,, . . .	13 ,,
Tertiary ,, . . .	11 ,,
Post-Tertiary ,, . . .	1 mile
Total	64 miles

We now require to know the average rate at which these deposits were laid down. Opinions differ widely, for the conditions vary enormously, but a *probable* average rate is between two inches and six inches in a century. At the rate of four inches a century, it would take about 100,000,000 years for the 64 miles to be laid down. Although this vast period is only a rough approximation, it probably correctly represents an *order* of time-magnitude not very far from the actual fact.

A second method is based on the measurement of the *mass* of sediment deposited. Nearly all the salts supplied by the rivers to the ocean are continually given up again, but there is an important exception, viz. the salts of sodium, which are so soluble that they have gone on accumulating in the ocean during geological time. It is easy to determine the proportion of sodium salts in the ordinary primary and sedimentary rocks, and since we can also easily estimate the total amount of sodium salts in the waters of the ocean, we can, by a simple calculation, determine the total amount of sediment that has been deposited in the ocean during geological time. Now we know that all this sediment has been transported to the oceans by the rivers, and if therefore we can estimate the average annual rate of the river-supply of sediments to the oceans, we are in a position to calculate the geological age of the earth. This average annual rate is known to a fair degree of accuracy. From these data we obtain almost the same result as before, viz. 100,000,000 years.

A third method is based on radio-active transformations. This gives an age greatly in excess of that determined by the two previous methods, in fact nine or ten times as great, or about 1,000,000,000 years in all. But we have still much to learn about radio-activity, and too much confidence must not be felt in this third estimate.

But whether the geological age is of the order 10^8 or 10^9 does not much matter. Either approximation is sufficiently near for our present purpose. It is safe to assume that at least 1,000,000 years have elapsed since the beginning of the Pleistocene or Glacial Period, and that the Tertiary Era (Pliocene, Miocene, Oligocene, and Eocene Periods) extended over at least 10,000,000 or 15,000,000 years, and perhaps over 20,000,000 years. The first faint indications of man's rationality seem to be traceable to a time at about the end of the Tertiary Era.

(*b*) *Fossilised Animal Ancestry*

The Geological Periods are continuously successive; there are no intervals between them. The successive series of extinct animals are not divisible into distinct groups, separated by sharply marked boundaries. A very considerable proportion of the fossilised genera which typify any given geological formation appear both in the immediately preceding and in the immediately succeeding formations. A gradual continuous development is everywhere noticeable. The stratigraphical terminology of the geologist is convenient, but there are no corresponding clear-cut boundary lines in nature.

Even the most cursory examination is sometimes sufficient to show that a particular succession of fossilised animal forms is closely allied. One of the most instructive examples of such a succession is to be found in the fossil horses which have been unearthed from Tertiary strata in America. Specimens of the series are on view at the University of Yale, and the conclusion is irresistible that such remarkable structural resemblances must be due to close blood relationship.

The horse probably originated from an extinct stock known as *Condylarthra*, which had flat feet and five toes on each foot. The most primitive form is *Hyracotherium*, not unlike a rabbit; and, commencing with this, twelve stages have been recognised, showing the gradual evolution of the race into its modern form. The best-known forms and the Periods to which they belong are the following:

Form.	Period.	Approximate Size.	Characteristics of Toes.
1. Eohippus . .	Eocene	Fox	Reduced to 4 in front (with rudiment of a 5th) and 3 behind.
2. Protorohippus .	Eocene	Airedale terrier	4 in front and 3 behind, the side ones behind touching the ground.
3. Mesohippus .	Oligocene	Sheep	3 in front (little toe reduced to a splint) and 3 behind; side toes only just touch the ground.
4. Protohippus .	Miocene	Small Shetland pony	3 on each foot, but only 1 touching the ground.
5. Hipparion . .	Pliocene	Ordinary pony	1 large toe and 2 very small ones, the latter not touching the ground.
6. Equus caballus .	Pliocene	Common horse	1 toe only, the 2 side toes being represented by mere splint bones.

The pedigree is not complete, and at present we have no means of constructing a simple linear series showing the gradual reduction of toes from five to one. Moreover, it is known there were several collateral series, and we cannot always be certain of the series to which a particular individual belongs.

During Eocene times North America was for the most part covered with forests, but in Oligocene times, owing to climatic changes, the forests began to give way to meadow lands, and these in Miocene times became extended into the great western prairies. It is to this gradual development of grass-lands that the evolution of the horse is traceable. As the environment changed, the animal adapted itself to the new conditions. During the course of long ages, the descendants of the small five-toed hoofed quadrupeds of early Eocene times gradually lost toe after toe until only one remained; they became taller and swifter, they acquired longer necks, more complex teeth, and larger brains. They needed longer necks to reach the low grass; and they needed more powerful grinding teeth to enable them to subsist on the tough grasses of the dry plains, as compared with the softer green food of the swamps and forests. As the forests diminished, they had to take more and more to the plains, and they needed longer limbs for swifter locomotion. Thus from the short-legged, five-toed, small animals of the Eocene marshes were evolved long-necked, light-footed horses running on tiptoe on the dry plains.

It is a very impressive fact that it took *the whole of the Tertiary Era* (at least 10,000,000 years, probably much longer) to evolve the existing horse from the ancestral Eohippus.

Complete linear series of fossilised animal forms are not common, but this is not surprising, for the odds against the preservation of complete records are enormous. Only hard parts make good fossils; only certain kinds of deposits make suitable tombs; many rocks have been made and unmade several times. Hence the geological record is necessarily very imperfect. Still, the record is being constantly extended, and it is significant that the more complete the record is made, the more convincing is the character of its testimony as to the probability of the truth of the evolutionary hypothesis.

In spite of still existing wide gaps, geologists have the greatest confidence in certain important conclusions they have drawn. One of these conclusions is that birds, quick, hot-blooded, and feathered though they are, have sprung from slow, cold-blooded, and scaly reptilian or saurian ancestors. In spite of appearances, there are numerous structural resemblances between birds and reptiles, from the scales on the feet to the composition and articulation of the lower jaw. There are also remarkable similarities of embryonic development, for throughout the early stages the embryo bird and embryo reptile pursue an identical course, and only gradually diverge. Then there are distinct intermediate types which go far to bridge the wide gap. The most notable of these is the ***Archaeopteryx***, the oldest known bird, about the size of a crow, of which two fossilised specimens have been discovered. While it is not far from a typical bird in its skull, its merrythought, and its legs, it is much more like a reptile in certain other respects. It has, for instance, teeth in both jaws, a long tail like a lizard's, and a strange wing with three digits ending in claws. The wings and legs prove that it was very far from being a beginner in the bird line of evolution, and of course it may have been an offshoot from the direct line, and not ancestral to any bird now living. But there can be no doubt that it is a connecting link, and the general conclusion as to ancestry is almost irresistible.

5. Variation and Heredity

(*a*) *The Kinds of Variation*

The causes of resemblance and difference between parents and children is a baffling problem.

Without variation, all the offspring of the same parents would, of course, be exactly alike, but, as we have already seen, the hereditary relation is such that, while like tends to beget like, every new creature has in some way a tendency to vary from its progenitors and to develop an individuality of its own. The study of heredity is really the study of the manner and cause of the inheritance of variations.

There is no organ of the body of an animal that does not occasionally vary more or less from the normal type, and these variations may, by suitable selection, become the foundation of a race. All the methods of improving the breeds of domestic animals depend on that principle. Colour, form, size, texture of hair or wool, speed, strength, intelligence—the possibility of the strengthening of all these characters is within the everyday experience of breeders.

When we compare a number of members of the same species, we find that the differences are many, but for our present purpose all those which concern age and sex may be ignored. Of the remainder, those differences which are the direct result of environment or use are technically known as *acquired characters*.[1] An example of the result of environment is the pallid skin of the toiling needle-worker of slumland, and an example of the result of use is the

[1] Or " modifications."

muscular arm of the blacksmith. Such structural changes, directly induced by the peculiarity of environment or use, transcend the limits of organic elasticity and thus persist after the inducing conditions have ceased to operate. This does not apply to such passing changes as a sunburnt skin after a summer holiday. The evidence that acquired characters can be transmitted to an offspring is unconvincing.

But if from the total number of observed differences between the members of the same species we subtract not only those which concern age and sex but also the acquired characters, there is an important remainder known as *innate* or *germinal* variations. These are inherent in the individual and are largely independent of the manner of life. Innate variations are usually described as either *Continuous* or *Saltatory*.

The term Continuous as applied to variations is a little ambiguous, but the intended meaning is easy to grasp. In almost every individual there is divergence—it may be pronounced or it may be scarcely perceptible—from the average type of the species; for instance, in height, in the length of the limbs, in the colour of the eyes and hair. If a large number of individuals be arranged in order, according to some selected variable character, the gradation from one to the other is so slight as to be almost inappreciable. It is variations of this kind that are known as continuous. They occur in all parts of every species and in every possible direction, though always within a limited range. Even the most extreme cases of stature, for instance, have definite limits. Usually the individuals are progressively rarer as the size of the structure considered diverges more and more from the most frequent value. If, for instance, the heights of a large number of men be taken, there is every gradation between 60 and 76 inches. The mean value is 68 inches; the next most frequent is 67 and 69; the next, 66 and 70; and so on. (Fractions of inches are, for simplicity, neglected.) Approximately there are equal numbers at equal distances from the mean of 68 inches. If the results are graphed, the base line giving the heights in inches and the ordinates the number of individuals exhibiting the different heights, the resulting curve of variability is seen to be identical with the well-known bell-shaped curve in mathematical probability. This important fact has become a fruitful source of special investigation, and variability is receiving careful attention at the hands of both mathematicians and men of science. The work involves the taking of an enormous number of measurements, but the results cannot fail, ultimately, to be very instructive. If, for instance, the recording of the dimensions of a particular character be carried on year after year, and show a consistent increase in the skewness of the curve, this must mean that the species is moving in a definite direction as regards the particular character measured. Similarly, the persistent occurrence of a well-substantiated double-humped curve may indicate the division of a species into two sub-species. Darwin believed that continuous variations were by far the most important, and that the origin of species was to be traced to them.

Saltatory variations, sometimes known as "discontinuous" variations,[1] indicate sudden "jumps," so to speak. The differences are larger and more abrupt than in the case of continuous variations, and do not range themselves easily on a graduated scale. A simple example is the variation in the number of petals in the primrose; the number varies considerably, and each additional petal seems to signify a sudden and saltatory variation of the flower. De Vries maintained that the origin of new species is to be traced to this type of variation, and it is true that experiments tend to show the possibility of a pronounced variation taking place suddenly, without any intermediate steps of the "continuous" character leading up to it gradually. Apparently, however, it applies only to certain characteristics of the organism.

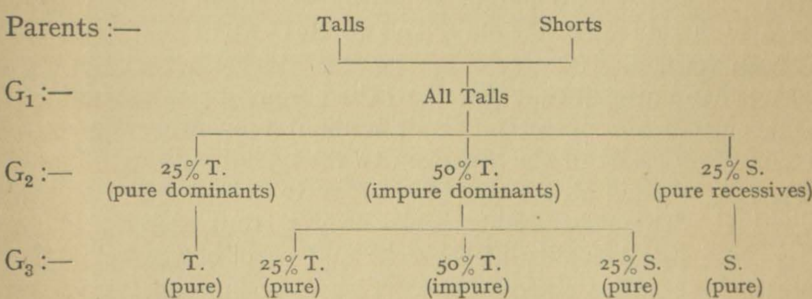
There is thus a difference of opinion as to the origin of new species. One school of thought, following Darwin, maintains that the distinctive characteristics of a species may very gradually arise as the result of the accumulation of continuous variations, and in support of this there are numerous cases where species are connected by intermediate forms. The other school of thought maintains, with De Vries, that the distinctive characteristics may arise suddenly by saltatory variations, and in support of this there is experimental evidence that certain characteristics refuse to blend.

The most interesting experiments of this kind were due to Mendel. He experimented with plants exhibiting certain saltatory characters, each character being considered separately. In the garden pea, for instance, he found that the character tallness was inherited in saltatory fashion. Certain varieties of peas grow stems about six feet high; others are short and do not exceed about two feet. The heights fluctuate in each case about a mean, but the shortest individuals of one race are taller than the tallest of the

[1] Also as "sports" and "mutations," but the latter term has a very variable connotation.

other, and each race gives rise to offspring of its own kind. Mendel crossed the two varieties, and the offspring were all tall. The character of tallness which appeared in the hybrid generation (G_1) to the exclusion of shortness, he called the " dominant character," and the character of shortness he called " recessive." The tall hybrids were left to self-fertilise; their offspring (G_2) were talls and shorts in the proportion of three to one. When the shorts of this (G_2) generation were allowed to fertilise, their offspring (G_3) were all shorts, and further generations bred from them were also all shorts. They may be called pure recessives, being pure as regards shortness.

But when the talls of the G_2 generation were left to fertilise, their offspring (G_3) were of two kinds: one-third of them produced talls only, and further generations bred from these were also all talls —they were pure dominants; the other two-thirds were impure dominants, for they produced talls and shorts in the three to one proportion. Thus the G_2 generation resulting from the self-fertilisation of the hybrids (G_1) consisted of 25 per cent of pure dominants, 50 per cent of impure dominants, and 25 per cent of pure recessives. The results may be shown thus:



and so on indefinitely.

However long the experiment be continued, the same results occur. Numerous experiments of this kind, with both plants and animals, have been tried, and the results are constant. The uniformity and simplicity of the results suggest many interesting inferences, but the one important inference at present is that the inherited characters of tallness and shortness do not *blend*.

Other examples of Mendelian inheritance are comb characters in fowls, many colour characters, horned and hornless condition in sheep and cattle, and the presence or absence of brown pigment in the iris of the eye of man. On the other hand, there are certainly many inherited characters which do blend and do not conform to the Mendelian mode of inheritance.

So much for the facts of the two kinds of germinal variations.

(*b*) *The Causes of Variation*

Very little is actually known of the causes which induce these variations. Still, many ingenious hypotheses have been put forward to account for them, and the most interesting is Weismann's germ-plasm hypothesis.

This hypothesis is based, ultimately, on the behaviour of the chromosomes during the division of the germ-cells. As we have seen, it is now a definitely ascertained fact that half the chromosomes of the new mother-cell are derived from each parent; and since special provision is made for halving the chromosomes in each of the contributory cells (the ovum and spermatozoon), so that the new mother-cell contains the normal number, it is reasonable to infer that all the inheritable characters are in some way contained within the chromosomes. And it is particularly interesting to note that Weismann formulated his hypothesis before the complete observation of the chromosome reduction was made. He predicted that a reduction was necessary, and to this extent his hypothesis has been verified.

Weismann argued that since half the chromosomes are removed in maturation and spermatogenesis without preventing the transmission of any part of the organism to the offspring, *every* chromosome must contain all the units necessary to determine a complete individual. These hereditary units which thus determine the nature and racial quality of the cells and parts of the body they represent, he called *determinants*. There are supposed to be as many different determinants in a chromosome as there are independently variable parts of the body, be these single cells or groups of cells. For as each part of the organism has its own character, if two parts had only one determinant, any change of this determinant would alter both parts simultaneously, whereas both parts can change independently. Every coloured scale on a butterfly's wing, for instance, each and all being independently variable, must be represented by a determinant. The whole of the determinants necessary for the development of the organism are grouped into *microsomes*, those smaller bodies of which the chromosomes are actually seen to consist. And it is assumed that the grouping is of such a kind that every single microsome contains a full complement of determinants and is therefore representative of the complete organism.

It is further assumed that the different microsomes, with their contained determinants, normally have a common tendency to act in the same direction, and the effects of their determining power will therefore be the combined effects of all. But if the determinants of the different microsomes are not collectively representative of the identical or homologous parts of the body, as might be the case if derived from widely different species, they will counteract one another's tendencies. Thus different species are extremely unlikely to be fertile with each other.

Weismann distinguished between the active part and the passive part of the protoplasm of the germ-cell. The former he called germ-plasm ; the latter, body-plasm. And he put forward the hypothesis that the germ-plasm, which is contained only within the chromosomes of the nucleus, is continuous from parent to child. He maintained that only in a secondary sense is the parent the producer of the child ; fundamentally, the parent is the trustee of the germ-plasm which thus has been preserved from an indefinitely remote past and will be preserved in the future as long as living things continue to exist.

This hypothesis of germinal continuity seems to be an acceptable explanation of why like tends to beget like, while the hypothesis of determinants furnishes a possible explanation of variations. The germ-plasm with its chromosomes, microsomes, and determinants is considered to have a definite architectural arrangement, not identical with the future developed organism, but in some way representative of it. As the embryo-body passes through its different phases of development, the right determinants come into activity, and determine the character of each cell as it appears. If, then, hereditary qualities are carried by their representative determinants in the germ-cells, the possible origin of variations is easily conceivable, for extraordinarily varied chromosome and microsome combinations may be brought about in the nuclei of the germ-cells. We may consider a simple case. Assume that in a given species there are 16 chromosomes per cell. The grandparents (first generation) will have 16 chromosomes each, which number is reduced in their germ-cells to 8 each. Thus 8 chromosomes from each grandparent unite to form a parent (second generation). The germ-cell of this parent will again contain half the number of chromosomes, that is, again 8. But the 8 may be derived from the 16 in several ways, and may appear in the third generation as 8 derived from the grandfather and 0 from the grandmother, or 7 from the grandfather and 1 from the grandmother, or 6 and 2, and so on. These, with another 8 chromosomes derived from another ancestral line, give again 16 chromosomes in the germ-plasm of the grandchild (third generation). The grandparent may thus be represented in the grandchild by any number of chromosomes from 8 to 0, that is, the quota of inheritance may be anything from $\frac{1}{2}$ to 0. The inheritance from more remote ancestors may be worked out similarly. Marked resemblance to a parent, grandparent, brother or sister, or even to uncle or aunt, is thus easily explained. Of course, if we consider the varied combinations of the microsomes as well as of the chromosomes, the possibility of complexity of germinal variations is almost indefinitely great.

Now Weismann's hypothesis is, after all, only an hypothesis, for though it has a firm experimental basis it is not susceptible of proof. The determinants are so exceedingly minute that they are quite beyond the range of the microscope and have therefore never been seen. And they must exist in almost inconceivably vast numbers, for every possible variation of even the minutest parts of the body must be represented by one, and yet representatives must all be contained within a single microsome of a single chromosome of the nucleus of a cell which itself measures only an extremely small fraction of an inch in diameter. But more than this, each determinant has definite work of a complex character to do, and must be anything but an insignificant and structureless particle. Thus the hypothesis involves tremendous assumptions. It is perhaps just, but only just, within the bounds of possibility. It is hazardous to assume any sort of confidence in the existence of determinants, for it is difficult to conceive how bodies so minute as to be almost of molecular dimensions can discharge functions so complex and purposeful.

Germinal variations, continuous and saltatory, form the raw materials of evolution, but our positive knowledge of their actual origin is of the slightest. The many important treatises which have been written on the subject are largely theoretical developments of the consequences of hypotheses supported by a small range of facts. Facts are accumulating slowly, but at present it is best frankly to admit that our ignorance of the causes of variations is profound. Every biologist tends to lean to a favourite hypothesis, usually because it covers most of the facts with which he happens to be personally acquainted, but no hypothesis is yet susceptible of anything like complete verification.

It is generally supposed that organisms are, in no small measure, affected by their environment, but to what extent and how we do not know. The continued use of an organ or structure, or the prolonged action of some external stimulus upon it, may alter its form or cause it to assume a new condition different from that which it would have had if these influences had not acted. But these acquired characters seem merely to render the organ or structure better fitted to its surroundings, and, as before stated, the possibility of their transmission is open to considerable doubt. Weismann regards the acquired characters as affecting the body-plasm only, and since the body-plasm cannot be converted into germ-plasm, it would seem to follow that the transmission of acquired characters is not possible. It is sometimes thought that short-sight and tuberculosis are inherited, but this is extremely doubtful; it is probably the *liability* that is inherited. If a parent, constitutionally liable to tuberculosis, had never been exposed to infection, the child would still inherit the liability. If the parent had actually suffered from the disease, the child, though constitutionally liable and therefore easily attacked, would not suffer unless exposed to infection. The tendency seems to be for any weak organ in the parent to be repeated in the child. What is inherited is therefore not the "acquired character" but the innate power of acquiring the same character. At all events, this is in accordance with all the facts at present available. It may be that the cumulative effect of an external factor acting for many generations will gradually alter the equilibrium of the germ-plasm and cause it to fall into a new condition of stability. This would explain a saltatory variation.

But the secret of variations remains unrevealed; it probably lies much deeper than we are aware of, in some unknown way in the very nature of the living organism itself.

6. Natural Selection: The Survival of the Fittest

If we could arrange in a series specimens of every kind of bicycle, from the most primitive form of a hundred years ago to the perfected machine of the present day, showing the different forms of "hobby-horses," "bone-shakers," "ordinaries," and modern "safeties," with all their successive improvements in construction—frames, tires, ball-bearings, brakes, speed-gears, and the rest—we should see clearly how the modern bicycle had "evolved." Each new make has outlived its less well-developed competitors in the "struggle for existence." The survival is due to differential selection, but in this case the selective agency is human. Equally interesting is the evolution of the steam-engine, the battleship, and the great gun. The " fittest " has " survived."

Darwin's hypothesis of natural selection now finds general acceptance, and his masterly exposition of the vast body of evidence he brought forward in its support leaves any other conclusion hardly possible. The acceptance of the hypothesis means the inevitable acceptance of its immediate corollary, the hypothesis of organic evolution. To some people the fundamental fact of evolution is the active living organism adjusting itself to its environment; to others, that which counts for most is the environment itself. But both of these must be regarded as factors of evolution; the organism struggles, and even chooses; the environment moulds, develops, strengthens, or weeds out and leaves to decay.

The breeder of animals is attracted by some slight difference arising, he knows not how, in certain individuals of his stock, and in order to perpetuate the difference, to form a breed with the peculiarity in question strongly marked, he selects such male and female individuals as exhibit the character in question, and breeds from them. Their offspring are then carefully examined, and again a selection for breeding is made; and the operation is repeated until the desired amount of divergence from the primitive stock is reached. By continuing the process of selection a race may be formed in which the tendency to reproduce itself is very strong. Although no limit to the possible amount of such divergence is known, no breeder has ever yet succeeded in producing a new type that could be regarded as a new species. The production of " specific " differences would be the work of a long period of time.

Darwin claimed to have discovered that what man thus does occasionally, nature is doing always; and that the *modus operandi* of " natural selection " is to be found in the " struggle for existence."

The term " struggle for existence " is used in a general and metaphorical sense. The rapid increase in numbers throughout the animal kingdom leads to an inevitable struggle between one individual and another of the same species, between the individuals of different species, and between all individuals and the physical conditions of life. Checks to increase are, of course, many. The extreme limit is determined by the amount of food. Eggs and young animals are destroyed in vast numbers, and the vast majority of adult animals are constantly open to attack by enemies. Changes of climate play an important part. Epidemics occur.

Individuals having any advantage, however slight, over their fellows will have the best chance of surviving and of procreating their kind.

This preservation of favourable, with the correlative destruction of unfavourable, variations is called "natural selection," or, less metaphorically, "the survival of the fittest," the one term referring mainly to the process and the other to the result.

Man selects only for his own purpose, but nature for the good of the creature; man imperfectly for a short time, nature by consistent accumulation during geological periods. Natural selection is ever rejecting variations that are weak, and preserving and adding up those that make for greater efficiency. This may apply even to the postulated determinants of the germ-plasm. Inequalities in the assimilating power of the determinants may result in an intra-germinal struggle and selection. A strengthened determinant will nourish itself more abundantly than its neighbours and may climb in an upward direction to a new plane from which there is no falling back. Such an hypothesis of germinal selection explains variations and many puzzling facts of heredity.

Objection is sometimes taken to the word "selection," since it seems to suggest that nature is an active agent. In one sense, nature *is* an active agent. In geology, for instance, she is constantly picking out the soft from the hard, the soluble from the insoluble, the fusible from the infusible. Natural agencies are not conscious, of course, but they are agencies all the same. No doubt it is best to use language strictly, not metaphorically, and thus never to attribute to nature any sort of intention. If, however, we adopt this principle we shall have to rob science of many of its most convenient terms. Strictly speaking, for instance, we must rule out such terms as "attraction" and "repulsion." Bodies may "move towards" or "move away from" each other: that is a matter of direct observation. But to say that this implies attraction or repulsion is pure assumption.

That individuals may and actually do sometimes survive by virtue of the possession of particular qualities, has been proved by a large variety of experiments. We mention one.

A voracious creature of the locust type, *Mantis religiosa*, occurs in Italy in a green and in a brown form. The former is usually to be found on green grass, the latter on grass browned by the sun. Mr. Casnola tethered among green grass 20 green mantis, and among withered grass 20 brown mantis. After 17 days they were all alive. He also tethered 25 green mantis among brown grass, and they were all dead after 11 days. The converse experiment was also made, 45 brown mantis being exposed on green grass, and of these only 10 survived at the end of 17 days. Most of the mantis were killed by birds; 5 of the green ones were killed by ants. Here there is a proof, conclusive though the numbers are small, of the selective value of the protective coloration of both races of mantis. If green mantis and brown mantis be exposed on green grass, the green ones will survive rather than the brown. All sorts of similar experiments have been performed, always with the same results.

How the most noteworthy evolutionary changes were actually effected we can only guess, but analogy sometimes suggests an hypothesis which the facts go far to support. Consider, for instance, how the first bilaterally symmetrical organism may have arisen. It was undoubtedly preceded by organisms having a radial symmetry, such as sponges and sea-anemones. The change was probably brought about by the need of seeking food or of fleeing from enemies. Radial symmetry is suited for a stationary life, the organism being supplied with food brought within its reach. Want of food would stir the organism into activity, and if we assume it gradually formed the habit of moving with one part of the body always in front, the rest is easy. For if one end of the body constantly experienced the first impressions of external objects, it is reasonable to suppose that sensitive and nervous cells would be most developed in that much stimulated head region. A rudimentary brain once formed, we have a chief motor and sensory and co-ordinating nerve centre for further developments, even of the most complex character. Thus during the course of vast ages, probably many millions of years, there would appear a definitely developed brain, a specialised nervous system, a segmented body, muscular jointed appendages, and so on. We know for certain what animal types first acquired certain organs. Thus hag-fishes and lampreys were the first animals with skulls; fishes were the first with jaws; amphibians, with fingers and toes, true lungs and a mobile tongue; the crocodile was the first creature with a four-chambered heart; birds and mammals are the only warm-blooded animals, and they show a great increase of brain development.

By such an hypothesis, environment as an evolutionary factor takes a foremost place, and it therefore logically follows that germinal variations are ultimately traceable to acquired characters. But how is this possible if acquired characters are not inheritable?

It seems likely that the difference between temporary and permanent variations—between acquired characters and germinal variations—is only one of degree. A week's exposure to the hot sun will lead to a passing change in the skin; ten years' exposure to a tropical sun will lead to a deeper change, which will last for life, the limit of organic rebound having been passed. And it may be that the limit of organic rebound will, if the new environment is sufficiently prolonged, also be passed in the case of the determinants. If so, germinal variations are mere consequences of the intensification of acquired characters, which, persistently renewed generation after generation, at last break down the opposition to permanent change.

7. Confirmatory Evidence

(*a*) *Embryological Analogy*

The familiar development of frog-spawn into tadpoles and young frogs is very remarkable in its recapitulation of the evolution of amphibians from fish ancestors, an evolution vouched for by the data of palaeontology and comparative anatomy. In fact the development of the individual seems almost to go out of its way to tell the story of its ancestry.

There is a striking resemblance between the embryos of different types of the same great groups. Thus in the higher vertebrates, viz. reptiles, birds, and mammals, there is an undeniable resemblance between the successive stages of the respective embryos. The embryos seem to travel a considerable distance, if not along the same paths, at least along closely parallel paths, before they diverge along their own individual paths of development.

In many cases the developing embryo pursues a strangely circuitous path instead of progressing straight towards its goal. It is as if the living hand of the past constrained the embryo to follow the old route of its race. If we examine the development of, for example, the heart of a mammal, we discover a series of stages which, generally speaking, are parallel to the historical evolution of the heart as we see it registered in the successive grades of fish, amphibian, and reptile. The same result follows from the study of the development of the brain, skull, kidney, and other organs. The conclusion seems inevitable that, in the embryonic development of organs, there is some sort of recapitulation of the stages in the evolution of those organs. The embryo of a higher vertebrate has still in some measure to recapitulate the steps taken by the developing embryo of a lower vertebrate. Something in the inherited blood-relationship seems to compel the repetition.

It should, however, be noted that the resemblance between the permanent lower form and the embryonic stage of a higher form is only general, and the general notion must not be pressed too far. For instance, a reptile was never at any point in the course of its development an actual fish. Still, all the organs of the reptile pass, in the course of their development, through conditions which are closely analogous to those which are permanent in some fishes. The recapitulation is probably never exact. Old-fashioned features may drop out, having no significance in embryonic life ; new features may be added, as adaptations to new conditions. Still, the broad fact remains that the development of the individual is, in general, a shortened recapitulation of the evolution of the race.

That embryos of entirely different forms should still retain, more or less perfectly, the structure of their common progenitor, is easily understood from the hypothesis that variations may supervene at a rather late embryonic period. The hypothesis affords a simple explanation of the remarkable fact that the embryos of a man, dog, rabbit, duck, lizard, etc., are at first hardly distinguishable from one another.

(*b*) *Vestigial Structures*

In animals it is common to find minute and more or less useless representatives of organs which are well developed and functional in related animals. These structures are sometimes described as "rudimentary," but a less ambiguous term is "vestigial." Darwin compared them to silent letters in many words.

In the human embryo, for instance, old structures are sometimes present, though normally not coming to anything in the adult. The visceral-clefts (or gill-clefts) afford an interesting example. By the time the adult stage is reached, only one, the first, remains, and this survives throughout life as the Eustachian tube. Then there are old-fashioned structures which persist in adult life but in much disguised forms. Thus the gill-arches, the primary function of which was, in the lower vertebrates, to support gills, persist in our body, almost unrecognisably transformed, in the skeletal support of the tongue and in the framework of the larynx. Then, again, there are dwindling residues persistent in adult life, but either functionless or relatively unimportant, such as the minute third eyelid in the median angle of our eye, or the vermiform appendix, or the mammae in males. Amongst ordinary animals there is no lack of examples. Whales have no visible hind-legs, yet many show vestiges with bones, cartilages, and muscles, buried deep below the surface and useless. Most snakes are absolutely limbless, but in the boa-constrictor there are quite distinctive hind-legs, though they are so diminutive as to require searching for. Since all these structures are apparently traces of the same structures much more highly developed in past times, and since closely allied species of animals possess well-developed and functionally important structures homologous with them, the phenomenon is quite readily intelligible on the hypothesis of evolution. For it is only necessary to suppose that a former progenitor possessed these now vestigial structures in a perfect state, and that, under the changed conditions of environment during succeeding generations, the structures became gradually reduced, either through simple disuse or through the natural selection of those individuals which were least encumbered with a superfluous part.

It is, however, impossible to prove that any structure, however rudimentary (if the term may be used), is useless, and it may therefore be preferable to explain such cases deductively from the hypothesis of evolution rather than endeavour to support the hypothesis by them.

8. Evolution in Retrogression

Natural selection produces wonderful things, wonderful organisms in the way of human beings, but it has also produced many abominable things by the same process. Evolution connotes progress, but this does not necessarily imply that the surviving fittest are always the best in the ordinary sense. There are many ugly chapters of natural history which show the degeneration of many forms of life into parasitisms almost incredibly loathsome; and pestiferous and repulsive creatures of all kinds abound. No intelligent person can possibly ascribe such hateful parasitisms to special creation, or their painful consequences to beneficent design. They become intelligible only if we regard them as extreme cases of the determination of organisms by natural selection. The more efficient is bound to be the victor in battle with the less efficient, but efficiency is by no means always accompanied by other good qualities.

The greatest product of evolution is the subject-matter of the next chapter.

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CHAPTER VII

THE EVOLUTION AND ANTIQUITY OF MAN

1. The Emergence of Man from Pliocene Times

IT must always be borne in mind that the geological record is at the best only an imperfect chronicle of the geological history of the earth. It abounds in gaps. Yet although these gaps occur in the succession of organic remains as recorded in the rocks, there have been no such blank intervals in the progress of animal life. It is possible to determine geological "eras," "periods," "ages," and "epochs," simply because the record of geological history has been frequently interrupted, now by upheaval, now by depression, now by protracted denudation. These interruptions serve as natural divisions in the chronicle. But if gradation is often thus lost, it must not be forgotten that one age always shades imperceptibly into another. Indeed, they are often, in some measure, concurrent. We live, for instance, in the age of steel, but in some of the more remote parts of the world the stone age still survives.

On the next page the Tertiary and Post-Tertiary eras are mapped out diagrammatically. (To save space, the framework is not drawn to represent the periods to scale. The reader should draw such a framework himself, for it is as well that the relative lengths of the periods should be accurately visualised.)

All through the "Recent" Period, historic and prehistoric, that is during the last 200,000 years, the fossilised remains of man are found modern in type and form. The evolution and origin of man must therefore be sought at an earlier date. The Recent Period was preceded by the Pleistocene or Glacial Period. It is doubtful how long it is since a more temperate climate settled over Europe, perhaps 100,000 years; but it is known that a series of ice-ages, alternating with warm intervals of long duration, lasted during the whole of the Pleistocene Period. No human remains can, with

Era.	Period.	Age.			Estimated Time in Years.
Post-Tertiary	Recent — Historic	Steel and Iron			200,000
		Bronze			
	Recent — Pre-Historic	Stone	Neolithic		
			Transition Period (unknown)		
			Palaeolithic	Magdalénien Epoch	
	Pleistocene or Glacial			Solutréen ,,	800,000
				Aurignacian ,,	
				Moustérien ,,	
				Acheuléen ,,	
				Chelléen ,,	
Tertiary	Pliocene		Eolithic		1,000,000
	Miocene				2,500,000
	Oligocene				3,000,000
	Eocene				3,500,000

certainty, be traced back to the Pliocene Period, and it is probable that, as far as Britain is concerned, man made his first appearance during the inter-glacial warm period which immediately followed maximum glaciation. The torrential streams resulting from the melting of the ice now began their work of excavating the river valleys, and there is ample evidence that men ("River-Drift" men) roamed about these river valleys and the primeval forests of South England and Central Europe.

The geological hypothesis of a Glacial Period comprising a succession of Epochs of extreme glaciation, with milder intervals, forms the basis of our present system of determining the series of events in Pleistocene times. Although the hypothesis is supported by a vast amount of indubitable evidence, the estimates of the duration of the successive ages are necessarily only rough approximations.

Among the different types of vertebrate animals, mammals began to predominate in the Eocene Period (at least ten or eleven million years ago), and the lowest forms of Primates were represented then. At the beginning of the Miocene Period (four or five million years ago), Primates had made great progress, and anthropoids had already appeared. But from that time to nearly the end of the Pliocene Period, that is during some two million years, there is at present virtually a blank in the history of the ancestry of man ; so far the Pliocene has kept most of its secrets unrevealed, and our knowledge of it is fragmentary and uncertain. But although no fossilised specimen of man has yet been unearthed from the Pliocene, numerous specimens have been discovered in the Pleistocene, and we are quite certain that the evolution of man with at least the glimmerings of rationality was complete at the very beginning of the Pleistocene Period.

On an accurately sketched profile of a modern human skull, draw two sets of equidistant straight lines at right angles to one another, the profile thus being covered with a network of equal squares. Now through the *exactly corresponding points*, structurally, of the profile of the skull of an ancient cave-man draw two similar sets of lines. The result will be somewhat different from the first, for the cross lines will not make exact squares, though the geometrical relations will still appear to be of a simple character. Now do the same thing with the skull of an anthropoid ape, a dog, and a sheep, always drawing the lines through the same corresponding points. The successive results will be still further from the first, though in every case a comparatively simple mathematical relation between the lines seems to be maintained. The results are somewhat suggestive of the different types of map-projections in an atlas. The farther we go back in the evolutionary line of ancestry, the less simple the relations between the lines become, but that fairly close relations of some kind are maintained is always apparent. Instead of the profile of a skull, the outline of any other prominent bone may be used, for instance the tibia, femur, or scapula ; the same simplicity of relationship amongst the successive crossed lines is immediately seen. If the crossed lines are regarded as mathematical co-ordinates, then the transformation of one set to the next is usually of a relatively simple mathematical character. Mathematical research is still engaged in working out these relations, but enough has already been done to confirm, in a remarkable degree, the general hypothesis of the evolution of man, through ape-like ancestors, from ancient mammalian and still remoter stocks.

The conclusion seems to be almost inevitable that the successive differences in form are just such as might have been brought about by a slight and simple change in the system of forces to which the living and growing organism was exposed. But it must not be thought that these investigations are likely to give an immediate key to all the riddles of evolution; they are far too difficult, and the results are too uncertain. It is unlikely that an organism should have varied in a uniform manner after the fashion of a homogeneous and isotropic body. Interfering causes must inevitably have been at work, with the consequence that the resultant as we know it seems to defy mathematical analysis. Nevertheless, we may hope to pass from the mathematical conception of form in its statistical aspect to form in its dynamical relations, and thus to a clearer understanding of the moulding forces of evolution.

2. Early Rationality

Some of the early fossilised remains of man are only slightly removed from the anthropoid type; in fact between man and the anthropoid apes there is a strikingly general similarity of structure. The real distinction between them is, however, not structural but in man's exclusive power of building up general ideas and of controlling his conduct in accordance with moral purpose. Man possesses many structural peculiarities, it is true, but the great characteristic differences are to be found in his finer brain and in the language, thought, and conduct associated therewith.

Man may have originated as a saltatory variation, but alas! we are bound to admit that the factors which led to his emergence are virtually unknown. The Primates to which he is zoologically affiliated are marked by great intelligence, and we find that they have acquired some very significant habits—of walking half-erect, of using sticks and stones, of building shelters, of living in families, of co-operating in bands, and of talking a good deal. But the uncertainties of man's pedigree and antiquity are still many, and the search for the factors that led to the emergence of his specific type is undeniably difficult.

Although the most man-like of the anthropoid apes, the gorilla, is not very human in appearance, yet every bone of man's body is identically represented in his, and occupies exactly the same place. Every bone shows the same leading features, the differences being merely those of proportion, size, and detail.

It seems probable that the anthropoid apes, in fact the whole of the Primates, took their origin from reptilian ancestors which had become bipedal and arboreal. In most quadrupeds, the fore-limb still remains a supporting structure, but when bipedal climbing became established amongst certain ancient mammals, the fore-limb was freed for use as an arm. The hand then became an increasingly useful instrument for grasping and hanging on to branches, for reaching ahead, for catching hold of fruit, for holding the young one securely; and the hind-limbs had thus gradually to take on all the body-supporting functions, and to learn the new art of gripping branches. Neither four feet nor four hands were likely to lead to victory in the struggle for mammalian supremacy, and it was probably the differentiation into two hands and two feet that provided the great strength of the stock from which man arose. It seems unlikely that man himself ever passed through a quadrupedal stage.

It is at all events an accepted hypothesis that the great superiority of man's reasoning powers is in no small measure due to his coming into possession of two hands with which he manufactured tools and weapons.

The dawn of rationality in primitive man was shown when he first chose a round stone as a missile, or a fish-bone as a pin, or the dried rind of the melon or some other gourd as a drinking-vessel. When at a later stage he gave a new shape to a flint by chipping, or a new edge to a cutting-stone by grinding, or fashioned in soft clay a gourd-shaped bottle or bowl for holding water, he showed power of invention and a marked intellectual advancement. But we are still quite in the dark as to the precise time when he first did these things, or when he first made a fire or first baked his clay. But we do know that while Europe was still shivering from the effects of the Glacial Period, say from a quarter to half a million years ago, it was populated with human beings so far like ourselves that they were alive to the advantages of a good fire, made useful tools out of stone and bone, painted and carved with considerable skill, and buried their dead in a ceremonial way.[1]

3. The Successive Advances during the Pleistocene and Recent Periods

On ancient Egyptian monuments are to be seen pictorial representations of African, Asiatic, and European people, differing in physical characteristics as widely as at the present time. Among

[1] Various writers have made an attempt to give a popular account of prehistoric man. See, for example, Jack London's *Before Adam*.

them are true negroes that might have been sketched to-day. The inference is that a period of 4000 or 5000 years is quite insufficient to produce, by natural means, any evolutionary morphological variations to an extent that can be readily recognised. In fact, an examination of pre-dynastic Egyptian mummies shows that types have not changed in 9000 or 10,000 years, for the mummies appear to be racially identical with the Egyptian people of the present day. Any appreciable variations of either man or animals since the beginning of historical times must therefore be regarded as extremely unlikely. It is probably 5000 years since the Bronze Age, and 8000 or 10,000 since the Neolithic Age; in Egypt, admirable specimens of Neolithic pottery have been found of an estimated antiquity of 13,000 years. Beyond the Neolithic Age and before we reach the Palaeolithic Age there is a vast unknown gap, and it is probable that more than 100,000 years have passed away since the Palaeolithic Age, which itself extends backwards to at least the beginning of the Pleistocene or Glacial Period, that is perhaps a million years ago.

Although no certain remains of man have so far been discovered prior to the Pleistocene Period, we may reasonably expect that discovery to be made some day, in the Pliocene if not in the Miocene, for flint implements of undoubted human workmanship have been found in Pliocene strata. In Europe, we can hardly expect to find proofs of man's ultimate ancestry, for our nearest relatives in the animal kingdom are confined to hot countries, and in these we must look for the earliest traces of the human race, work which geologists have not yet been able to undertake systematically. We may, however, safely assume that man had sufficient intelligence 400,000 or 500,000 years ago to do battle with the mammoth and to slay him, and that ancestors with some degree of rationality existed some hundreds of thousands of years before that.

The evidence that serves to distinguish one Post-Tertiary age from another consists of (1) the fossilised skeletons of animals and of man; and (2) specimens of man's handicraft work: the successive modifications of these reveal undoubtedly progressive developments in human intelligence.

1. The Stone Age extends at least from the beginning of the Pleistocene Period, and it seems highly probable that some day it may be definitely traced back to the Pliocene. Three[1] successive stages have been clearly differentiated.

(*a*) *The Eolithic Age*.—The period between the time when man

[1] Between the Palaeolithic and Neolithic Ages there is a long period, probably extending over many tens of thousands of years, at present entirely unknown.

exhibited the first signs of rationality and the time when he made his first flint implements is a period of which we possess no knowledge whatever. His earliest efforts must have been crude, so crude that his chipped flints could hardly have been distinguishable from ordinary stones. Even such eminent authorities as Sir Joseph Prestwich and Sir John Evans differed in opinion about Mr. Harrison's collection of Eoliths at Ightham in Kent.

(β) *The Palaeolithic Age.*—This period probably extends over the greater part of a million years, from the time when man, still half animal, first worked flints into definite shape until he arrived at a stage scarcely distinguishable from man of to-day. We shall return to him again.

(γ) *The Neolithic Age.*—This age is characterised by the introduction of a new art—that of polishing stone implements by rubbing them with some hard material in order to give them a sharper cutting edge. All Palaeolithic implements were left chipped; Neolithic implements were polished. It is doubtful whether Palaeolithic man ever made pottery or whether he ever domesticated animals. Neolithic man certainly did both, and he possessed the domestic dog, horse, ox, pig, sheep, and goat. He cultivated cereals. He was skilled in pottery-making, spinning, and weaving, arts which were therefore possibly born 40,000 or 50,000 years ago. He used bows and arrows in hunting. He built houses both for the living and for the dead, thus showing that religion had become a recognised principle in his social economy. The mammoth and woolly rhinoceros were now extinct. When most of the ruder people of the modern world were discovered by Europeans, they were at the Neolithic stage of culture.

These three divisions of the Stone Age are merely stages in the sequence of events, the three being sufficiently differentiated to be recognised as well-defined phases in a growing civilisation. After human organisation had, for several hundreds of thousands of years, groped its way forward with the assistance of such objects as could be manufactured from implements of stone and bone, the discovery of the art of making bronze tended to revolutionise all mechanical appliances for cutting purposes. There was therefore a more rapid advance in civilisation and culture.

It is an impressive fact that 10,000 years ago man was still semi-barbarian, and that it had taken him *a hundred times* 10,000 years to reach that stage from the first state of dawning rationality in his ape-like ancestors. For hundreds of thousands of years his intellectual advancement was extraordinarily slow.

2. THE BRONZE AGE.—Before bronze was discovered, copper and tin separately must have been known. There is evidence that implements of pure copper had been tried, though they were so soft as to be little better than those of stone ; there is also evidence that several metallurgical experiments were made before a proper bronze alloy was hit upon. During the Bronze Age far greater efficiency became possible because of the better cutting instruments. Sculptured stones, for instance, were abundant. In physical appearance man scarcely differed at all from man as we know him now.

3. THE IRON AGE.—The art of making bronze probably originated amongst the Egyptians. In south-east Europe the industry was cut short by the discovery of iron. Iron was known in Europe about 1500 B.C., 500 years before the building of King Solomon's temple, but it was not extensively used until the ninth century B.C., by which time the Greeks, Italians, and Phoenicians were settling down in their historic homes. Although no iron objects were among the relics of the pre-historic cities of Troy and Mycenae, the use of iron was general throughout Europe before Julius Caesar invaded Britain.

4. THE AGE OF STEEL.—This brings us down to the present day.

4. Palaeolithic Man

From the point of view of evolutionary interest, the Palaeolithic Age probably stands first, for it covers the greater part of the period from the dawn of man's rationality to man as we know him now.

The implements, tools, weapons, and other remains of Palaeolithic man have been arranged in chronological sequence, according to the degree of culture disclosed by the various relics found at certain typical stages. The whole Age falls into six well-defined Epochs. These are named after certain places in France where abundant Palaeolithic discoveries have been made.

1. *Chelléen.*[1]—The Chelléen remains date back to the earliest Pleistocene times and the boundary line between this Epoch and the earlier Eolithic Age seems to be completely lost. Of course there was no *natural* boundary, the earlier age shading imperceptibly into the later. The flint implements are nearly all of the *coup de poing* type ; they are of undoubted human workmanship, and are from layers resting on Pliocene deposits, and it is highly probable that Eolithic man originated in the Pliocene Period. Accompanying

[1] Named from *Chelles*, a small plateau above the bed of the Marne, east of Paris.

the Chelléen flints are the remains of fossilised animals which are survivals of the Pliocene Age.

2. *Acheuléen.*[1]—The flint implements are not very different from the Chelléen, but the *coup de poing* is thinner and smaller and more delicately and evenly chipped at the edge. Although the flint implements afford undoubted evidence than man lived during this and the preceding epoch, no human bones (with the exception of the Piltdown skull and the Heidelberg man) have been found that can be definitely assigned to either epoch.

3. *Moustérien.*[2]—There is now a scarcity of the *coup de poing* ; the flints are split up into smaller implements, such as scrapers and large flakes. Owing to the cold climate, man was obliged to seek shelter in caves or improvised huts, and to clothe himself with skins. These cave-men made little advance on their predecessors, the Drift men (Acheuléen and Chelléen), and continued their cave life for an immense period. The contemporary fauna were the mammoth, woolly-haired rhinoceros, cave-bear, and musk-ox. The known human skeletons are of the Neanderthal type.

4. *Aurignacian.*[3]—A great variety of flints belonging to this epoch have been discovered—knives, projectiles, sling-stones, etc. Bone-arrows (without barbs) and other tools made of reindeer-horn are also found. Accompanying these implements and tools are remains of the cave-bear, cave-lion, woolly rhinoceros, reindeer, and mammoth.

5. *Solutréen.*[4]—There is now a marked advance in the manufacture of flint implements, and the so-called laurel and willow-leaf lance-heads show beautiful workmanship. Sculpture on stone is practised. Bone needles perforated with eyes are found for the first time.

6. *Magdalénien.*[5]—In this epoch an extraordinary advance was made, especially in the manufacture of tools and implements. By this time it had become known that bone, ivory, and reindeer-horn are better materials than flints for the manufacture of different articles. Daggers and barbed harpoons are now used. Engraving on bone, ivory, and stone is common. The walls of the inhabited caves are decorated with sculptured friezes and life-sized paintings of animals. Polychrome painting of a high order is common. The

[1] From *St. Acheul*, a suburb of Amiens in the valley of the Somme.

[2] From the cave of *Le Moustier* on the right bank of the Vézère, a tributary to the Dordogne.

[3] From the grotto of *Aurignac*, in the Department of Haute Garonne.

[4] From *Solutré* in the Department of Saône-et-Loire.

[5] From the rock shelter of *La Madelaine*, on the right bank of the Vézère.

flesh of captured animals is now roasted and the skins made into garments. Tailoring is extensively practised, and bone needles, pins, and buttons are plentiful. But there is a complete ignorance of agriculture, of the rearing of domestic animals, and of the arts of spinning and weaving and of pottery-making. The principal occupation is hunting, and the most characteristic animal is the reindeer. The mammoth is almost extinct.

5. Palaeolithic and Neolithic Civilisations

It is at first a little startling to find what a relatively advanced state of civilisation Palaeolithic man had reached by the close of the Magdalénien epoch. His appliances were many and were skilfully made, and he was a highly skilful artist. In addition to his engraved and sculptured works which were brought to light a good many years ago, we are now able to add whole galleries of painted designs on the walls of caverns and rock-shelters. In their most developed stage, as illustrated by most of the figures in the cave of Altamira near Santander, these primeval frescoes display not only a consummate mastery of natural design but an extraordinary resource. There are many polychrome masterpieces on the ceilings of the inner vaults of the Altamira caves where the light of day has never penetrated. Nowhere are traces of smoke, and the inference therefore is that great progress in the art of artificial illumination had already been made. In the rock-shelter of Cogul, on the Spanish side of the Pyrenees, we find productions of Palaeolithic art rich in human subjects—the sacral dance being performed by women clad from the waist downwards in well-cut gowns. Yet all this dates back probably scores of thousands of years earlier than the most ancient monuments of Egypt. The Magdalénien epoch of culture was very widespread, but it was at its highest on either side of the Pyrenees.

After this great stride in human progress, it is difficult to understand what delayed the rise of European civilisation in its higher forms. But there is a great unknown gap of tens of thousands of years between the Palaeolithic and Neolithic Ages.

Our own later civilisation stands on a Neolithic foundation. The earliest extraneous sources on which our complex European culture drew lay in two directions, in the valley of the Nile and in the valley of the Euphrates. Hellenic civilisation is of later growth, and its relation to the ancient centres of Egypt and Babylon has now been established by its affiliation to the civilisation of prehistoric Crete. The thirty Dynasties of Egypt probably extend backwards to 4000 B.C., and, judging from excavations at Naga-ed-Der, it would seem that pre-Dynastic Egypt goes back to 8000 B.C. Hence Neolithic Egypt has an antiquity of something like 10,000 years. Even under the First Dynasty (say 4000 B.C.) royal property was habitually marked with the king's name and titles, and works on anatomy and medicine are known to have existed ; and in their moral law the Egyptians then followed the same precepts as in the Decalogue (ascribed to Moses 2500 years later). Far back in the pre-Dynastic age, pictures had been freely used to record events and convey information. In Crete there is indubitable evidence that Neolithic culture, with its carefully ground and polished axes and finely burnished pottery, had reached an advanced stage 10,000 years ago ; and 6000 years ago this earliest of European civilisations had achieved remarkable things. The many storeyed palaces of the Minoan priest-kings in their great days, by their ingenious planning and their successful combination of the useful with the beautiful and stately, far outdid similar works, on however vast a scale, of later Egyptian and Babylonian builders. Their scientific sanitary arrangements put to shame those of the present day at such English towns as Marlow and Spalding. Domestic arrangements were of the most elaborate kind, and ladies' clothing included flounced robes, fashionable jackets, and gloves. Yet all this goes back to a time thousands of years before ancient Rome was even thought of.

6. Early Types of Man

The evolution of man from what he was in the Chelléen epoch to what he became in the Magdalénien epoch covers a vast period of time, and it is unfortunate that the chain of evidence as to his bodily development is not more complete. While fossilised animal remains are plentiful, fossilised human remains are few. The few fossilised human skeletons and portions of skeletons that have been discovered have been minutely examined, and there is a gradually growing mass of evidence tending to confirm, almost at first hand, the inferences drawn from the implements, tools, and other relics that early man left behind him.

(1) *The Ape-Man of Java* (*Pithecanthropus*).[1]—This is the oldest fossil man yet discovered and is a veritable missing link. It is very probably proto-human, though it is just possible it is an ape related to the gibbon. Its intermediate character is shown in the form of the head. The brain was little more than half the size of the modern

[1] *Pithēkos*, an ape ; *anthrōpus*, a man.

human brain; if an ape, the owner had an enormous brain; if a man, he must have been of an extremely low intellect. The small brain and primitive skull indicate the Pliocene Period, probably rather late in that period. We are able to infer that his foot was like ours. No human foot has ever been seen in which the great toe was separated like the thumb, as is the case in all anthropoids, though from appearances to be found in the human foot itself the evidence is overwhelming that the great toe was once set like a thumb, and that the human foot was at one stage of evolution a grasping organ.

(2) *The Piltdown Woman* (*Eoanthropus dawsoni*).—This specimen was found in 1912 in Sussex, and probably belongs to the very early River-Drift, Chelléen epoch of the Palaeolithic Age, though possibly it had an earlier origin. If it belongs to the same age as the mammalian remains which accompanied it, it goes back to Pliocene times, but it is most probably of the same age as the Chelléen implements found with it.

(3) *The Heidelberg Man.*—The remains were found in strata near Heidelberg. Though very simian in character, the discovered jaw being suggestive of the gorilla, there is reason to suppose that the skull and brain were highly developed, and the teeth are human beyond question. The Heidelberg is probably as old as the oldest Drift implements and belongs to the Chelléen epoch.

(4) *The Galley Hill Skeleton* was found in Kent in 1888. It is probably the remains of a late River-Drift man, but its position is open to considerable doubt; in some respects it shows affinities to the Cro-Magnon type.

(5) *The Neanderthal Ravine Man.*—This skeleton was found near Düsseldorf. Though very different from modern man, he had a large, and, as we know from his flints, a very capable brain. The head was, however, narrow, and the forehead low and retreating, yet the brain capacity was twice that of the gorilla. In cranial development this man was probably half-way between Pithecanthropus and the lowest of present-day savages. His aspect was bestial. Other skeletons of the same type have been found, and we speak of the Neanderthal race. Up to a certain point they were ape-like in their head form, though almost all their features separately occur here and there amongst modern Australian natives. Yet they were men enough, and had brains enough, to believe in life after death. They buried their dead with ceremony, and to the best of their means equipped them for a future life. The mode of burial shows, for example, that a body is laid on its right side

with right arm bent so as to support the head upon a carefully arranged pillow of flints, whilst the left arm was stretched out so that the hand might be near a fine stone weapon, chipped on both faces, evidently placed there by design. Neanderthal men probably lived during the Moustérien epoch, that is in the mid-Palaeolithic Age.

(6) *The Magdalénien Race.*—These were the reindeer hunters of France, to whose remarkable works of art we have already referred. They are represented by three different skeletons found in France. The well-filled crania are indicative of intellectual power; the foreheads are large and lofty. The stature is small, from 5 feet 2 inches to 5 feet 4 inches.

(7) *The Cro-Magnon Race.*—One specimen, together with por-

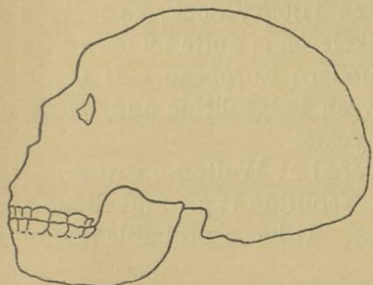


FIG. 15.—Neanderthal Skull (early Palaeolithic). Perhaps 500,000 years old.

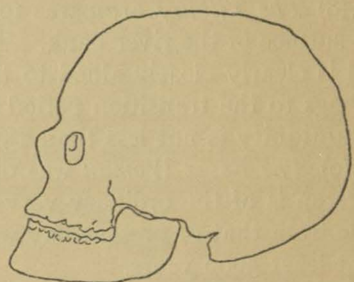


FIG. 16.—Cro-Magnon Skull (late Palaeolithic). Perhaps 100,000 years old.

tions of four others, were found in France, in the Cro-Magnon cave. The head-form is refined and highly developed; the forehead is large and lofty; the lower jaw does not protrude as in the case of the Neanderthal type. The stature is tall, about 5 feet 10 inches. Skeletons of the same type have been found elsewhere, and had undoubtedly been ceremonially buried. The skull bears some resemblance to those of the Magdalénien race, and hence it is sometimes classified with the latter, but the relatively great size of the Cro-Magnon skeletons makes it necessary to place them in a separate category. Certainly they belong to the later part of the Palaeolithic Age.

There is a certain amount of evidence which suggests that two varieties of man, Neanderthal and Cro-Magnon, must have existed in ancient Europe, and some authorities would trace the original divergence between them almost back to the time when man parted company from the apes. Whether the Cro-Magnon race now survives in Europe is doubtful, for it is not safe to take the skull alone as a certain guide. The skulls of the Neolithic Period, much nearer in point of time to the present, and much more similar in point of form to our own, are anything but uniform, and they suggest crossings between different stocks. But we may claim at least kinship to, if not direct descent from, the Cro-Magnon race.

The enormous advance in the development of the human race during the Palaeolithic Age may be seen from the profiles of the Neanderthal and Cro-Magnon skulls. The former is quite bestial in appearance, the latter is relatively quite modern in form. Although it would be unsafe to say that the Cro-Magnon traces his descent directly from the Neanderthal, they are undoubtedly separated in time by a vast period, perhaps half a million years.

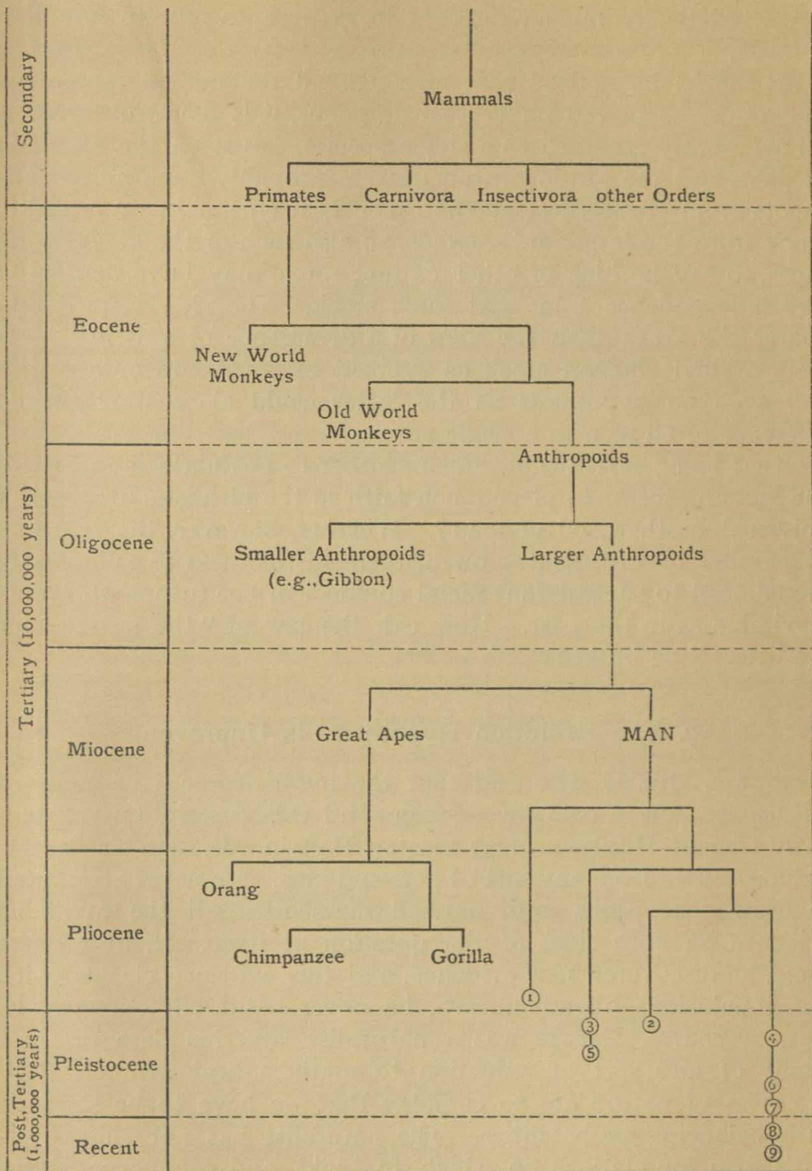
(8) *The Tilbury Man* was found at Tilbury dock, 34 feet below the surface of the river bank. The skeleton is quite modern in form and is clearly closely allied to the modern European. It probably belongs to the transition period between Palaeolithic and Neolithic. Its antiquity is not less than 15,000 years.

(9) *The Essex Woman* was discovered at Walton-on-Naze. The skeleton is of the ordinary very late Neolithic type, and differs but little from that of present-day woman. It has a probable antiquity of at least 5000 years.

The diagrammatic genealogical tree [1] on the next page is believed to show approximately the relative positions and the probable ancestry of these various early types of man. But it must be understood that the diagram is largely hypothetical, being constructed almost entirely from inferential evidence. The amount of direct evidence is small.

Thirty or forty years ago the view was held by certain competent authorities that there was a linear chain stretching from lemurs, through South American monkeys, Old World monkeys, and the great apes, to man. But it is now doubted if the lemurs have any place in human ancestry, and recent anatomical and palaeontological work is opposed to the view just cited. Man probably arose as a distinct branch of the anthropoids, the anthropoids themselves and the monkeys originating in distinct branches of the Primates. Thus the monkey and human stems were separate and distinct, though allied. The hypothesis that there is a very

[1] This diagram is based on Dr. Keith's figures in his *Antiquity of Man*, but the present writer's estimates of the length of the Geological Periods differ somewhat from those of Dr. Keith.



close affinity between man and the great apes is supported by the present-day tendency of physiological research. This has seemed particularly clear in investigations of the properties of the blood, and in the fact that it has been found possible to communicate some characteristically human diseases to great apes and to no other animals.

It should be noticed that although all the human races now living may be placed under a single genus, it is doubtful whether all are rightly regarded as a single species. Just as the ape-man of Java and the Piltdown woman were probably independent offshoots from the earliest ape-like men that emerged as a separate stock from the larger anthropoids, so also each of the great living races, to say nothing of other extinct races, may have arisen by like independence from that same stock. The view is probably nearer the truth than the view of a divergence of existing races from a single human stock as typified by an Adam or a Noah. Yet such an hypothesis as the latter could alone warrant the reference of all men to a single species.

That being so, is it not difficult either to postulate the unity of the human race or to place much faith in the idealist's dream of a universal brotherhood of man? Whether, however, the races be of parallel or divergent growth, their distinctness is sufficiently pronounced to suggest that racial conflicts in the future will be as inevitable as in the past. How can the law of "the survival of the fittest" be broken?

7. The Evolution Hypothesis is Unproven

It was Huxley who said that the mind of the true man of science is a clear, cold logic-engine, and this description is peculiarly true of Huxley's great master, Darwin. Darwin was extraordinarily free from any sort of personal bias. He never attempted to draw conclusions until he had marshalled all the available evidence on both sides of the question at issue. If, at a later stage, he discovered new evidence, and this evidence clashed with the conclusions already drawn, he never hesitated to record it. But, of course, Darwin was a naturalist, and his data did not admit of any sort of reduction to mathematical symbols. All processes of nature are so complex that we have to be satisfied with balancing probabilities. The naturalist has not the physicist's firm foundations on which to build, and can never attain the same kind of certainty. His experiments count for little, for he cannot do within the span of a lifetime what nature has taken almost untold ages to perform. The laws of variation and heredity, for instance, are still unknown, though the biometrician is now laboriously engaged in the task of trying to discover them, and it may be that he will ultimately meet with success, for his method is based on measurements; he calls for statistics, showing the range of variation; these he groups, codifies, and graphs, and tries to bring them into relation with the laws of mathematical probability. But the accumulation of the necessary facts is likely to be the work of many generations, and, after all, there is ever the possibility of numerical inquiries being vitiated by the assumption that there is an equivalence amongst the units on which they are based. And even though the laws may be found, the causes may prove beyond our reach.

It must never be forgotten, then, that the hypothesis of evolution cannot be logically demonstrated. It is not a simple induction from particulars, thoroughly as particulars support it. It is a scientific interpretation that has been suggested. It is a formula that fits the facts, and all the facts it fits are its evidence. On the whole it may perhaps be said that the hypothesis is well within the range of probability. Yet we must ever remember that the predominant interest of evolution is the question of human destiny, and such an interest is exactly calculated to make us forget that we are dealing merely with an hypothesis.

If evolution is a fact it is bound to continue. If human beings were only just emerging from intellectual darkness 10,000 years ago, what will be their intellectual condition 100,000 years hence? Nearly all our scientific knowledge has been acquired during a single century. Imagine the range of knowledge of our descendants 100,000 centuries hence. Imagine the results of evolution a million times 100,000 centuries hence. Imagine a race of beings as intellectually superior to ourselves as a Newton is to a protist. If there be a Creator, is it thinkable that he has finished his work in fashioning such puny creatures as ourselves?

PRINCIPAL BOOKS OF REFERENCE

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CHAPTER VIII

LIFE AND CONSCIOUSNESS

1. The Structure of Molecules. Valency[1]

ALTHOUGH in passing from inorganic to organic forms the route pursued is across a boundary line difficult to trace, we soon become quite certain that the new region is one of markedly increased structural complexity. The natural evolution of the more highly complex organic, from the comparatively simple inorganic, substances, may seem to present little difficulty, yet the new phenomena of life which accompanies the complexity suggest the question whether it is necessary to postulate a specific act of creation of the organic from the inorganic at some definite moment in past time. Before an answer can be given to this question, it is desirable to state the main facts known concerning the structure of organic molecules.

As already stated, there are now good grounds for believing that the specific atom of every chemical element possesses the properties of a microcosmic system with constituent groups of electrons in vibrational or orbital movements. It is undoubtedly the seat of enormous energy, and it is by virtue of its dynamical power that it enters into chemical union with other atoms in the building up of compounds. Yet the chemist has no force great enough to break up the atom, and in all ordinary chemical reactions the energy equilibrium of the various constituent groups of electrons is preserved.

The elements unite with one another with varying degrees of intensity, or, as is commonly stated, they possess varying chemical " affinities " for one another. Thus A has a certain " affinity " for B, and unites with it to form the compound AB, but C has a greater

[1] To the reader unversed in chemistry, the earlier part of this chapter may appear somewhat forbidding, but the general argument is easy to follow.

affinity for B, and might therefore turn out A from the compound AB and unite with B to form the compound BC.

It is rare for the atoms of an element to exist singly. When such atoms cannot find atoms of other elements to unite with, they unite with each other, usually in pairs. Hence a molecule of an element usually consists of two atoms; a molecule of a compound contains one or more atoms of each of the component elements. The composition of the molecule of any given element or compound is fixed and invariable.

The chemist has different methods of writing the formulae of chemical compounds. Thus the formulae for the chlorides of sodium, zinc, and aluminium are usually written, $NaCl$, $ZnCl_2$, and $AlCl_3$, respectively; but a graphic form sometimes more convenient is

$$\mathrm{Na}\text{——}\mathrm{Cl} \qquad\qquad \mathrm{Cl}\text{—}\mathrm{Zn}\text{—}\mathrm{Cl} \qquad\qquad \begin{array}{c} \mathrm{Cl} \\ | \\ \mathrm{Cl}\text{—}\mathrm{Al}\text{—}\mathrm{Cl}. \end{array}$$

In the latter method, as many lines proceed from each symbol as will represent the combining capacity of the element named. The graphic formulae are intended to show that the affinity of sodium for chlorine is satisfied or "saturated" by union with one atom of that element, that the affinity of zinc requires two atoms of chlorine for its satisfaction, and that aluminium requires three. This combining capacity of an element is called its *valency*. Sodium is said to be univalent, zinc bivalent, and aluminium trivalent.

In the case of water (H_2O), two atoms of hydrogen are required for each atom of oxygen; the atom of oxygen has thus double the valency of the atom of hydrogen. In the case of ammonia (NH_3), nitrogen has three times the valency of hydrogen. In the case of marsh-gas (CH_4), carbon has four times the valency of hydrogen. Thus carbon is said to be tetravalent.

The hydrogen atom or the chlorine atom may be taken as an example of the simpler kind of atom, both hydrogen and chlorine being univalent elements. Valencies higher than four are uncommon.

Valency is probably traceable to differentiated groupings of the electrons within the atom. In a univalent atom there is a single grouping, in a bivalent atom a twofold grouping, in a trivalent atom a threefold grouping; and so on. Each grouping seems to be a dynamic centre of activity, and when, during any form of chemical action, the molecules are disintegrated into their component atoms, each of the dynamic centres of every atom must interplay with some other dynamic centre, external or internal, before new molecular equilibrium is established.

In the reaction

$$Zn + H_2SO_4 = ZnSO_4 + H_2$$

the group SO_4 passes as a whole from its combination with two atoms of hydrogen to a combination with one atom of zinc. The SO_4 behaves as if it were a unit of a single bivalent element. This associated intra-molecular group of atoms is termed a *radical*. In the reaction

$$NaCl + HNO_3 = AgCl + NaNO_3$$

the radical NO_3 is seen to be univalent. A comparison of the composition of the compounds $CaCl_2$ and $Ca(OH)_2$ shows that the radical OH (hydroxyl) is univalent. It is to preserve the identity of such a radical as hydroxyl that we put it in brackets and place the factor outside.

Such radicals are believed to typify the probable groupings of atoms within molecules. During chemical reactions, all the atoms of a molecule may be separated, and every one of them enter into a new combination; but, more usually, the molecules break up into groups of atoms, and each group enters, unaltered, into some new combination.

Where chemical affinities permit, one univalent atom may replace another, a bivalent atom may be replaced by two univalent atoms, and so on. But elements with valencies higher than three have a marked tendency, in regard to external interactions, to assume lower valencies, this being brought about by some kind of internal interplay between certain of the electron groups within the atom. For instance, nitrogen atoms are pentavalent, but in the majority of nitrogen compounds two of the five internal dynamic groupings of electrons within the atom become satisfied by mutual interaction; only three dynamic centres are therefore left, and nitrogen thus becomes virtually a trivalent element. So carbon, which is normally tetravalent, is really divalent in such a compound as C_2H_4, though the constituent electrons of all carbon atoms are, of course, arranged in four groups acting as centres of dynamic activity. It is only when the necessary outside attractions fail that two of the four groups interplay with each other, and the atom is then said (rather inaptly) to be "unsaturated"; strictly, however, it is "saturated" unless and until something of superior affinity presents itself, and then these two interplaying dynamic centres give up their not very strong partnership and enter into relation with the outside body or bodies.

Carbon is the element which here concerns us most, because its high valency, and the remarkable power of its atoms of combining amongst themselves as well as with the atoms of other elements, enable it to build up single molecules containing very large numbers of atoms, and such molecules form the very basis of the structures of all living organisms.

2. Molecular "Compounds" or "Aggregates"

Many substances when dissolved in water and recovered by spontaneous evaporation of the solvents are found to have entered into combination with the water. The solid products are hydrates. When these hydrates are heated they usually give up their water rather easily. To avoid the disguise of the fundamental substance we write the formula for water separately. Thus for copper sulphate we write $CuSO_4$, $5H_2O$, not $H_{10}CuSO_9$.

At 100° C., copper sulphate loses $4H_2O$, and the rest of the water at a somewhat higher temperature, more slowly. All such actions are conditioned by temperature and vapour tension, and there is little doubt that in such compounds the water evaporates like ordinary water. Experiment shows that there are at least three hydrated sulphates of copper, $CuSO_4$, $5H_2O$; $CuSO_4$, $3H_2O$; and $CuSO_4$, H_2O ; and there may be others.

It is misleading to call this water "water of crystallisation." Water and crystallisation bear no necessary relations. Large numbers of crystalline salts contain no water. Common salt is a familiar example.

When substances formed by the union of two compounds have a prevailing tendency to break up again into the same two materials, and exhibit chemical properties of these constituents rather than individual ones of their own, such aggregates are often called "molecular compounds." Hydrates[1] are an example. Double salts such as $FeSO_4$, Am_2SO_4, $6H_2O$ are also of this character ; they are stable only in the solid form. The supposition is that, in these aggregates, the molecules of the constituent compounds retain their integrity to some extent, and are thus only loosely held together.

As compounds of carbon advance to greater and greater complexity, molecular aggregates play a more and more important part.

[1] Properly so-called. Hydroxides are sometimes confused with hydrates.

3. The Simpler Organic Compounds. Carbohydrates and Fats

If we represent the tetravalent carbon atom graphically by means of its four linkage lines, and attach to each of these the univalent hydrogen atom, we obtain the graphic formula for

$$\begin{array}{ccccc} & & H & & \\ & & | & & \\ H & — & C & — & H \\ & & | & & \\ & & H & & \end{array}$$

marsh-gas (CH_4). If now two atoms of carbon are united in such a way that one bond of the one is united to one bond of the other, only six bonds are free for union with other atoms. If to each of these be attached a hydrogen atom, the graphic formula for ethane (C_2H_6) results. Similarly three carbon atoms

$$\begin{array}{ccccccc} & & H & & H & & \\ & & | & & | & & \\ H & — & C & —— & C & — & H \\ & & | & & | & & \\ & & H & & H & & \end{array} \qquad \begin{array}{ccccccccc} & & H & & H & & H & & \\ & & | & & | & & | & & \\ H & — & C & —— & C & —— & C & — & H \\ & & | & & | & & | & & \\ & & H & & H & & H & & \end{array}$$

may be linked together by means of four of the available twelve bonds, leaving eight bonds free; and by attaching hydrogen atoms to each of these eight bonds, the graphic formula for propane (C_3H_8) is obtained. And on this principle we may continue to build up chains of carbon atoms.

As a result of this remarkable property of possible mutual linkage between different carbon atoms, single molecules containing several hundred atoms may be formed. Thus we often find organic molecules with molecular weights running into thousands, although in the case of inorganic molecules the weights are very often less than a single hundred.

In nature, carbon atoms in groups of six and multiples of six are common, and are more stable than other groups. In the following graphic formula we have a chain of six carbon atoms, with 10 of the 24 bonds linked together in pairs; in other words, there is mutual interplay between the members of each of five pairs of dynamic centres. To the remaining 14 available bonds are attached 7 atoms of hydrogen (which are univalent), 5 hydroxyl radicals (also univalent), and 1 oxygen atom (bivalent), respectively. This gives a molecule of 24 atoms, $C_6H_{12}O_6$, the formula for grape-sugar

$$\begin{array}{ccccccccccccc}
 & & H & & H & & H & & H & & H & & H \\
 & & | & & | & & | & & | & & | & & | \\
H & — & C & — & C & — & C & — & C & — & C & — & C{=}O \\
 & & | & & | & & | & & | & & | & & \\
 & & OH & & OH & & OH & & OH & & OH & &
\end{array}$$

(a mono-sugar). This organic substance is probably formed in the green plant,[1] from carbon dioxide and water, and in the following way. The first stage is the reduction of the carbon dioxide and water :

$$CO_2 + OH_2 = CH_2O + O_2$$

that is, formaldehyde (CH_2O) is formed and oxygen is liberated. The second stage is the union of six molecules of formaldehyde to form grape-sugar :

$$6CH_2O = C_6H_{12}O_6.$$

This simple sugar molecule may be regarded as the first great starting-point in the building up of organic substances generally.

If two of these mono-sugar molecules are united, by setting free one hydrogen atom in the one, and one hydroxyl radical in the other (these uniting to form water), we have :

$$\begin{array}{ccccccccccccc}
 & H & H & H & H & H & H & H & H & H & H & H & H \\
 & | & | & | & | & | & | & | & | & | & | & | & | \\
O{=} & C— & C— & C— & C— & C— & C— & C— & C— & C— & C— & C— & C{=}O \\
 & & | & | & | & | & | & | & | & | & | & | & \\
 & & OH & OH & OH & OH & OH & OH & OH & OH & OH & H &
\end{array}$$

that is $C_{12}H_{22}O_{11}$, the formula for cane-sugar (a di-sugar). The reaction may be shown thus :

$$2C_6H_{12}O_6 = C_{12}H_{22}O_{11} + OH_2.$$

The molecule contains 45 atoms.

The duplication may be continued as long as the energy conditions of the growing molecule will allow. The exact limit at which instability brings the process to an end is not known. But we may

$$nC_6H_{12}O_6 = (C_6H_{10}O_5)_n + nH_2O$$

note that $(C_6H_{10}O_5)_n$ is the *starch* molecule (a poly-sugar). The poly-sugars are of unknown but high molecular weight. The mole-

[1] As to the work of chlorophyll, see § 7 *infra*.

cular weight of soluble starch is said to correspond with the formula $C_{1200}H_{2000}O_{1000}$, a molecule of 4200 atoms.

All the common organic compounds built up by living plants and animals are included in three great divisions—*carbohydrates, fats,* and *proteins.* The carbohydrates consist of the sugars and starches and are much the simplest of the three, although, as already seen, their molecules may possibly consist of thousands of atoms. Fats are of greater structural complexity.

A beginner in chemistry learns at an early stage that a salt may be formed by neutralising an acid with a base. Thus calcium sulphate results from the action of sulphuric acid on the base slaked lime.

$$CaH_2O_2 + H_2SO_4 = CaSO_4 + 2H_2O.$$

A precisely similar thing takes place in certain reactions of organic substances. For instance, the fats of living cells may be regarded as salts formed by the action of a fatty acid upon the base glycerine ($C_3H_8O_3$). One of the commonest fatty acids in nature is Stearic Acid ($C_{18}H_{36}O_2$). We thus have

$$C_3H_8O_3 + 3C_{18}H_{36}O_2 = C_{57}H_{110}O + 3H_2O.$$

Glycerine stearate ($C_{57}H_{110}O_6$) is one of the common fats in beef and mutton. Its molecule [1] is a large one, consisting of 173 atoms.

4. More Complex Organic Compounds. Proteins

The last of the three great groups of organic substances are the Proteins. Proteins play an indispensable rôle in all living plants and animals.

The formation of protein molecules proceeds in a way somewhat analogous to that of the molecules of carbohydrates and fats, but in addition to carbon, oxygen, and hydrogen, all proteids contain nitrogen, and sometimes other substances as well. In the formation of proteid molecules, extraordinary complexities may arise, and the process can go on as long as molecular stability will allow. As the molecule grows, it will attain a size at which, under the special

[1] The reader can construct the graphic formula for himself. It must not be thought that graphic formulae give anything more than a very rough idea of the constitution of a molecule. Of course the molecule has three dimensions; and its atoms are almost certainly arranged in groups in some kind of vibrational or planetary motion of their own, motions different from and independent of the motions of the individual atoms. It is *just possible* that if a molecule could be brought to rest and its constituent atoms so planned out on the flat that their relative positions could be approximately preserved, we should have a result not altogether unlike the chemist's graphic formula.

complex conditions peculiar to proteins, the reverse process of breaking down tends to occur, and the degree of complexity established will depend on the particular balance that holds within any particular environment. At the equilibrium point it may happen that no atomic union between the molecules entering into the combination will take place, and thus we have multiple aggregates of molecules only feebly held together, the constituent atoms remaining relatively quiescent. Such aggregates are further examples of molecular compounds. The chemical reactions by which proteins are identified are probably usually due to certain atomic or molecular groups present in the molecular aggregates rather than to the molecular aggregates as a whole. It is in the form of these molecular aggregates that proteins occur in living cells.

Until recent years chemists did not believe it was possible for a fully saturated (in the atomic sense) chemical compound to enter into a new round of chemical activities, in which the whole molecule behaved as an atom, the individual atoms separately taking no part. But numerous cases are now known where, without any separate action on the part of the individual atoms, two or more molecules unite strongly to one another with evolution of energy. These molecular unions arise from molecular "affinity," in which atomic "affinity" seems to take no share. In such molecular combinations there are properties analogous to atomic affinity and atomic valency, and thus we speak of molecular affinity and molecular valency. But the numerical values of molecular valency are remarkably high, sometimes as high as 60. In practice it is therefore not possible to discover the relative numbers of molecules in the great majority of molecular aggregates.

Even the simplest proteins consist of such highly complex molecular aggregates that very little is known of them, structurally. There is, in fact, no trustworthy information as to the molecular weights of proteins.[1]

5. Still more Complex Organic Compounds. Colloids

Certain sticky, slimy, non-crystalline, and very slowly diffusible substances are known as *colloids*.[2] The "white" of an uncooked egg is a familiar example.

Colloids consist of molecular aggregates, feebly held together, in

[1] One protein (an albuminous compound) has been assigned the empirical formula, $C_{72}H_{112}N_{18}O_{22}S$, but it is probably incorrect.

[2] κόλλα, glue; εἶδος, a resemblance.

unstable equilibrium, responding to every change of environment. In some cases the equilibrium is completely upset even if the solution is slightly warmed.

There is a marked tendency for the molecular aggregates of a colloid to concentrate and accumulate on any interface, say between the solution itself and air, and such accumulations are accompanied by change in surface tension. Thus a colloidal solution readily forms a froth. And what happens between air and a colloidal solution may also happen between such a solution and particles suspended in it, for instance fat particles in milk. Concentration in the surface layer acts much as increasing pressure does in causing gases to liquefy or condense; such concentration is exemplified in the close network or skin which forms and re-forms as often as it is skimmed off a glass of warmed milk. In this way unicellular organisms often form their external envelopes, and cells provide themselves with cell-walls.

Inorganic reactions are usually swift, but colloidal reactions are slow. Any slight changes acting on a colloidal system may send it slowly pulsating up and down about the equilibrium point. A crystalloid is a static condition of matter; a colloid is a dynamic condition.

The proteins of living cells are examples of colloidal molecular aggregates, and we can now form in the laboratory individual carbon compounds with protein characters which, in some slight degree, approach in complexity to those natural proteins; and it is possible that the formation by natural means of some variety of protein material was a first step in the synthesis of actual living substance. Of the particular chemical substances which have been found in the body, an ever-increasing number can be formed artificially outside it, and there is no reason to think that any ultimate difficulty will be experienced in forming artificially any of the individual chemical substances which have been discovered or are ever likely to be discovered in the body.

But many of the colloidal molecular aggregates are extraordinarily complex, and it is quite possible that some of them contain even billions of atoms. Yet a portion of substance consisting of a billion atoms is so excessively minute as to be almost beyond the range of the highest powers of the microscope. To be visible to the naked eye it would have to be a million times as large again, and then would be only as large as a grain of lycopodium dust. But even if some day the analyst succeeds in discovering the actual composition of such colloidal aggregates, it does not follow that if, using this knowledge, he managed to build up similar substances artificially, such substances would be endowed with life. There is certainly no justification at all for assuming that the colloidal forms, though derived from chemical elements, exhibit no other properties than the chemical and physical properties shown by the atoms and combinations of atoms from which they are derived. New qualities are likely to be introduced at various stages. Moreover, the complex aggregates are composed of unstable parts, and are quite conceivably susceptible to influences of which at present we know nothing.

The specially interesting feature about colloidal molecular aggregates is that they form the borderland between the inorganic world and the world of life.

6. The Living Cell

The living cell is the biologist's unit, and all living organisms are composed of one or more of these units. For an understanding of the life processes of the organism as a whole, some knowledge of the functional processes of the individual cell is necessary.

The active part of a living cell consists in the main of a combination of colloids. The proteins of each colloid are probably united with carbohydrates and fats, forming a colloidal whole in which chemical oscillations are ever occurring and new products being elaborated. Associated also with the proteins of the cell is an appreciable amount of inorganic matter. It seems as if living matter is still unable to dispense with those simple inorganic substances from which, presumably, it originated. At all events simple inorganic salts are invariably present in all living cells. The organic colloids thus associated with the crystalloids take the form of a solution which is a living substance known as protoplasm. Surrounding and enclosing this living substance is a film, apparently also formed of colloid, which serves the purpose of a boundary wall and of an osmotic membrane, permitting of exchange by diffusion between the colloidal solution constituting the protoplasm and the surrounding medium in which it lives. Assimilation of new material from the medium seems to be effected by the changes produced under these conditions, associated with those caused by active chemical agents formed within the protoplasm and known as enzymes.

In appearance, protoplasm is not unlike the white of an egg, and it is hard to realise that something which, under the microscope, looks like an indefinite mass of gelatinous material can react to the minutest changes in its environment. But we must not be misled by microscopic examination. The most powerful microscopes fail to reveal the wonderful complexity and the intensely specific functional activities of even the simplest unicellular organism. Wonderful as the changes of karyokinesis are, it is practically certain that far more wonderful changes on a far more minute scale are always in progress in the protoplasm of the cell. A unicellular organism may be less than 1/1000 of a millimetre (1/25,000 of an inch) in diameter, yet there can be no doubt that such a unit of living matter is a vast series of separate laboratories, each with chemical processes going on, to some extent independently, to some extent in co-ordination. These protoplasmic chemical changes are of the most far-reaching character, and they are extremely complex, but our knowledge of them is slight.

A living cell is so highly organised that it is impossible it can represent primordial life. At some stage in the process of evolution, a nucleus must have been gradually segregated from the hitherto imperfectly organised complex colloidal mass, and this nucleus henceforth became the main centre of activity. The formation of such a complex nucleated cell represents a tremendous advance in organisation, for we now have a primitive living organism with a potential future development of a definite and precise kind. Every living thing is simply a nucleated cell or an aggregate of such cells, but the secret of that stupendous evolutionary advance from the unorganised colloidal mass of multi-molecules to the organised nucleated cell is completely hidden from us.

For their growth, all living cells require food. Some unicellular organisms can not only assimilate a fragment of matter which comes into contact with them, but they show signs of being able to sense it while not yet in contact, and can protrude portions of their substance or move their whole bodies towards the fragment, thus beginning the act of "hunting," and revealing incipient locomotory powers. But the power of locomotion is liable to introduce the organism to dangers, from which a sense of shrinkage seems to be acquired. Under the microscope the amoeba may plainly be seen taking in particles of food, digesting or rejecting them, seeking this object and refusing that.

It has been said that all such actions of the amoeba may be expressed exclusively in terms of physical attraction and surface tension, the organism, and indeed every other organism, being a mere automaton. But the truth of the statement is in the highest degree improbable.

That surface tension is an important factor in cell-division must be admitted. For as a cell grows in size, the decrease of surface relatively to the increased mass gradually diminishes the possibility of an adequate food supply. Hence continued growth is possible only if alterations in the internal processes lead to such changes that the mass, when it reaches a certain size, breaks up into two or more separate parts. The division of the growing cell is thus inevitable. But effects must not be mistaken for causes. If the most remarkable of all instances of cell-division be considered—the long series of co-ordinated cell-divisions in the growing embryo; the origin, from a single cell, in unfailing sequence, of all the many kinds of cells and tissues found in a higher plant or animal—surface-tension seems to play a relatively insignificant rôle. Physics and chemistry play their part in the cell, but it is scarcely possible to concede that they play the chief part.

The body of one of the higher animals consists of many billions of living cell-units, amongst which there is a co-ordination and regulation that human ingenuity can never hope to imitate. Similar types of cells are aggregated together into tissues designed to perform some specific function in the body, and various tissues are united together to form organs which again have an allotted task to perform. Nearly every tissue of the body secretes certain chemical substances which are carried by the blood-stream to some entirely different tissue in some other part of the body, always for a specific purpose. So absolutely necessary are these chemical substances—excitants or hormones as they are called—that the loss of one of them may lead to the death of the animal. More and more of these remarkable agents are being discovered, agents specifically manufactured in one part of the body for definite work in another. How this remarkable provision is to be reconciled with the view that life is merely a fortuitous concourse of chemical and physical activities, all resulting exclusively from natural selection, it is difficult to see.

7. The Origin of Life

When at some remote date in the past the earth had become sufficiently cooled to become a fit home for life, we assume that life appeared. But of the actual manner of its coming we know nothing. Kelvin and Helmholtz thought life was brought to the earth by meteorites, and, of course, a single seed-bearing meteoric stone falling upon the earth might, just possibly, lead to the earth becoming covered with vegetation. But one apparently fatal objection to this hypothesis is that it would take some 60,000,000 years for a meteorite to travel from the nearest stellar system to the earth, and it is inconceivable that any kind of life could be maintained during such a period. But, even if this were possible, it would not give us any clue to the mode of origin of life. The hypothesis is inherently improbable.

So far, no life has been known to make its appearance on the earth's surface except from antecedent life. Many attempts have been made to generate life anew by packing together suitable materials and subjecting them to a suitable temperature, but if the germs of pre-existing life have been rigorously excluded the attempts hitherto have been a failure. It is true that Charlton Bastian claimed to have obtained the evolution of living organisms from inorganic sources. He made a solution of sodium silicate and per-nitrate of iron in distilled water, and sterilised the medium at 110° to 115° in a hermetically sealed tube ; and after the solution had been left to itself for some months, micro-organisms of many types are said to have appeared. No other observer has succeeded in repeating the experiment, and it seems probable that the mixture used was imperfectly sterilised. At all events we should have expected not actual micro-organisms but far simpler organic bodies in some kind of colloidal solution. If spontaneous generation is possible, it cannot be expected to take the form of living organisms with so marked a degree of structural and functional differentiation as that claimed by Charlton Bastian.

As the result of an exhaustive series of experiments, Pasteur claimed to have proved conclusively that a perfectly sterilised culture would, in the absence of added germs from without, remain sterile for years. There is really no reason to doubt the truth of this conclusion. Yet, even so, this only proves that life cannot arise under a particular set of conditions ; it does not finally settle the question of the spontaneous origin of life. Competent thinkers urge that organisms which build themselves up from, and finally disintegrate into, the substances of which inorganic nature consists, must have originated primitively from inorganic compounds ; and that to deny spontaneous generation is to proclaim as great a miracle as to assert it.

We have no direct acquaintance with life as existing apart from matter, and in one sense therefore the problem of life is essentially a problem of matter. But although experiment tends to show that, from the point of view of physics and chemistry, living organisms are governed by laws identical with those which govern inanimate matter, we cannot escape the conclusion that in the former there is involved an additional, though at present unknown, factor. That primordial living things owe their origin to an evolutionary process is a possibility that must certainly be admitted, but how the new factor "life" first made its appearance when the molecular aggregates were ready for its manifestations we do not know. The first ultra-microscopic particles of living substance could have made no impress upon any geological formation. Vast ages must have elapsed before some sort of calcareous or siliceous skeleton enabled life to make any kind of geological record, and it is therefore useless to try to trace the evolution of living matter to its beginning in terrestrial history.

It has been suggested that conditions very unlike those now existing were necessary for the first appearance of life, and that these must be repeated if living matter is to be constructed artificially. Certainly it is possible that the conditions for the initial synthesis of protein are different from the conditions under which protein and living matter display their ordinary activities. There are numerous analogues between proteins and compounds of cyanogen, and the latter seem to rise in a state of incandescent heat. Hence cyanogen compounds may have arisen when the surface of the earth was incandescent, and in the process of cooling, compounds of hydrocarbons and cyanogen may have evolved gradually into protein compounds. Such an hypothesis is not improbable. Certainly the degree of chemical complexity capable of existing amongst the materials found on the earth seems to be definitely fixed by temperature. At a white heat such as exists in the sun's atmosphere, only elements can exist, and many of these apparently decomposed into proto-elements. At a somewhat lower temperature, binary compounds such as oxides can remain in equilibrium, and as the temperature falls, chlorides and carbonates may form. More and more complex forms make their appearance as soon as the environmental conditions make the presence of these forms possible. And although for the very complex compounds characteristic of living things the range of temperature is extremely narrow, it being highly probable that all life upon the planet would be destroyed if the temperature rose to about 60° C., still it is reasonable to think that as soon as the temperature allowed sufficient complexity of chemical structure for life to be borne upon the earth, then life appeared. The chemist can verify by experiment the possibility of the formation of more and more complex inorganic substances as the temperature falls from a white heat down towards the boiling point of water; but the complexity of living substances baffles him, and the actual nature of life is still completely hidden from him.

If the evolution of non-living substance into living be a fact, it does not seem reasonable to suppose that it happened only once, and may not be happening still. It is, however, true that there is no evidence of such happening, though there is no doubt that if living substance is still being so produced it is of a far simpler character than any yet discovered, and probably of such a kind that it could not be perceptually demonstrated. Even if the microscope is some day replaced by some far more powerful optical instrument, and the present great gaps in our knowledge of the colloidal borderland are filled up, it is highly improbable that we shall be able to say precisely where life begins. There undoubtedly exists a whole world of living creatures which the microscope cannot reveal to us, creatures originating somewhere down among the colloids, leading up to the bacteria and protozoa which, comparatively speaking, are really highly developed organisms. If, as seems not unlikely, the evolution of primordial living things is repeating itself, it is quite possible that, if all intelligent creatures were destroyed, in course of millions of years other intelligent creatures would out of the depths once more emerge, though conceivably such creatures might differ fundamentally from the present inhabitants of the world.

Suppose that chemists some day bring about spontaneous generation in the laboratory. Presumably they would be reproducing a process that must at some past age have occurred on the earth. But that would not prove that the earth generated the *life*. Quite conceivably life may be something not only ultra-terrestrial but even immaterial, as real as matter and energy but different, and utilising them for its own purpose. It certainly seems as if life is something which possesses the power of displaying itself amidst terrestrial surroundings by utilising for a time the energies of the complex molecular aggregates which come into existence on this planet, and then it seems to disappear whence it came. It is perpetually arriving and perpetually disappearing. Despite the success of the chemist in manufacturing artificially certain organic substances, he has not yet succeeded in manufacturing protein; and even so there is an immense gap between making organic matter and making an organism. On the whole it may be admitted that the hypothesis of the evolution of the organic from the inorganic may be held with considerable confidence; but what life is, how and whence it came, and why it should make use of highly complex molecular aggregates rather than of simpler forms, we have no positive knowledge whatever.

It is just possible that if ever the secret of the beginning of life upon the earth is discovered it will be traceable to the chlorophyll of the green plant. A plant feeds and grows, digests and breathes, as really as an animal, and in regard to these main functions there is no essential difference between them. Both, too, are so far structurally alike, that both are made up of cells, and both originated in a fertilised egg-cell. Of course, however, there is a profound difference between them, a difference which presumably had its origin in one of the great evolutionary bifurcations. It seems possible that, by means of a saltatory variation, some lowly protist became the first manufacturer of chlorophyll, a tremendous chemical and physiological achievement which made the life of plants possible, and, through them, that of animals and man. In the complex photosynthesis by which plants build up carbon compounds from the raw materials of water, air and earth, chlorophyll plays an indispensable part, though of the fundamental aspects of the process we are still ignorant. Chlorophyll is the great transformer of the energy of sunlight into the energy of the organic colloids, and directly or indirectly the energy of all living things is traceable to this single source. Chlorophyll is itself a colloid, and is far too complex to have arisen as a first step in the evolution of organic life. Of its actual origin we have no positive knowledge.

8. The Living Organism: Materialistic and Vitalistic Hypotheses not Acceptable

We have seen that the living, active, unified whole constituting an organism is the centre of a vast number of physical and chemical changes, and of apparently directed and regulated activities; that it appears to feed itself and reproduce itself; and that at any stage it is a phase in an evolutionary progress. As the secret of this inner organisation has not yet been discovered, various hypotheses have been put forward as possible explanations. Of these we select for brief consideration three: the materialistic, the vitalistic, and the hylozoistic.

The materialist first assumes that there can be no terrestrial manifestations of life without matter, and thus far it is difficult not to agree, for we do not know how life could be otherwise manifested. But he further assumes that, since we cannot detect anything in an organism except physical and chemical processes, these processes must include life itself. In fact, he reduces to molecular activity not only life but also thought, purpose, happiness, beauty, everything. All these things he considers to be somehow latent in the atoms themselves.

Now it is quite true that the organism, in its living, illustrates a number of physical phenomena, such as surface tension, diffusion, and elasticity ; and the process of living involves the most intricate chemical reactions. But observation clearly shows that it differs from the most perfect machine, not only in its far greater efficiency, but in the fact that it is self-feeding, self-preserving, and self-reproducing. Moreover, it has a persistent unified behaviour and has a power of profiting by experience. Such facts at once involve in doubt the whole materialistic assumption. The organism does not *seem* to be an automaton.

But there are weighty detailed objections also.

Physiological phenomena present remarkable evidence of activities co-ordinated in such a way as to conduce towards the survival of the organism. In fact, all the activities of the organism, including an almost inconceivable number of the most intricate and delicately adjusted cell activities, are co-ordinated, each occurring just at the right time. What is the explanation of such wonderful co-ordination ? The materialistic explanation is that many of the mechanisms by which co-ordination is brought about have already been discovered ; that the nervous system, the greatest co-ordinating mechanism of all, has been experimentally proved to be really nothing more than a system of reflex actions, though the reflex actions associated with consciousness are so complex that their analysis has not yet been effected ; and that a large number of other co-ordinating mechanisms is known in which the activity of one organ is excited by the products of chemical activity in other organs, response following stimulus in every case. And indeed it is a fact that the growth and maintenance of every part of a living organism seems to be controlled by the chemical stimuli derived from other parts or from the environment. Only in cases where very rapid control is required does the nervous system seem to play an important part. But this wonderful complexity and co-ordination of the physiological mechanisms found within the bodies of living organisms are accounted for by the materialist on purely mechanical principles. He regards evolutionary development as simply a mechanical process, natural selection acting automatically yet in such a way that the structure is, generation by generation, more and more perfected and elaborated.

All physiological activity is, it is true, *apparently* dependent on definite physical and chemical causes, but the physiologist usually calls the cause a "stimulus," and the materialist, without logical justification, identifies stimulus and response with physical and chemical cause and effect. For instance, a minute increase in the hydrogen ion concentration of the blood excites the respiratory centre of a normal warm-blooded animal to intense activity. In such a case the response depends upon the "excitability" of the responding tissue. Moreover, the excitability varies in response to very minute changes in the environment, just as is the case with the original response to the stimulus. The slight addition of some blood constituent, or it may be its entire absence, normally present, perhaps, in only the minutest proportions, may profoundly affect the excitability of any tissue. There is no experimental evidence that such a process is really one of physical and chemical causation, for no quantitative relation between the supposed physical or chemical cause and its effects can be traced. When we attempt to trace a connection, we are lost in a maze of complex conditions out of which the response emerges. We have no means of tracing the stream of matter or of energy through a living organism, and inferences drawn from the supposition that such a tracing is possible are necessarily invalid.

The response may perhaps be regarded as the last term of a long series of physico-chemical changes, initiated by the original stimulus; but how are we to account for the sequence and its apparently purposeful nature? The laws of physics and chemistry are, of course, fully operative throughout, but amidst them and supplementary to them there seems to be an incalculable and purposeful something, something exercising a controlling and directing action over them collectively yet conforming to each of them individually.

Another objection is presented by the remarkable problem of the recovery of functional activity after the destruction of nerve-centres or nerve-paths on which this activity normally depends. In the case of other parts of the body this recovery of function presents little difficulty, but in the central nervous system, differentiation of function is so complex and definite that the recovery of function stands out as a fact of extraordinary significance. For this phenomenon no physico-chemical explanation seems to be conceivable.

Even if we had a complete knowledge of every physico-chemical reaction within the body, the problem of the integration of those actions would remain unsolved. Similarly, in the development of the organism every cell behaves as if it knew what all the other cells were doing; and violent disarrangements of the organism are put right in a manner which makes any analogy with a machine seem absurd. Again, the same stimulus provokes very different responses at different times, or from different organisms of the same kind. Between the stimulus and the response the experience of the organism seems in some way to intervene.

The case against the materialist's hypothesis that the living organism is an automatic mechanism seems to be overwhelming.

The vitalistic hypothesis is that the co-ordination is effected by the presence of some kind of internal vital impetus or entelechy. Precisely what the vitalist means is not easy to understand. His impetus or entelechy does not seem to be a physical factor, but some sort of persisting originating impulse, expressing itself blindly and unconsciously in different kinds of creative effort in all parts of the body, an undiscovered and perhaps undiscoverable secret agent within the living organism. The vitalist thinks that this suffices to explain why living organisms always seem to go their own way and pursue their own ends despite all kinds of disturbing conditions.

But the simplest observations show that this vital impetus or entelechy is dependent on physical and chemical conditions of environment and on the physical and chemical structure of the organism. If, for instance, the temperature is too high or too low, or if the supply of oxygen is cut off, all the characteristic signs of life soon cease. Thus the vital impetus can manifest itself only under certain very limited physical and chemical conditions, and presumably therefore is determined in its action by those conditions. If so, how can it control and regulate those conditions? A further objection to vitalism is that it implies a breach in the fundamental law of the conservation of energy. Any internal "guidance" of the living organism would imply a creation or a destruction of energy. And still another and fatal objection is that, in order to guide effectively the excessively complex physical and chemical processes occurring in the living organism, the vital impetus would apparently require a superhuman knowledge of these processes. Yet the vital impetus, the entelechy, is assumed to act blindly and unconsciously. Indeed the materialistic hypothesis is less unintelligible than the vitalistic.

If the organism is neither an automaton nor regulated by an internal entelechy, can we escape the hypothesis of some kind of external directing agent?

9. The Hylozoistic View of Mind and Matter

Granted the main premiss, there is one form of materialism the logical development of which seems to be unassailable. This is hylozoism. The hylozoist holds the view that, since there is nothing in the whole that is not found in the parts, the rudiments of mind are, and indeed must be, present in the inorganic universe; that Nature in her evolutionary process has obviously interposed the most insensible transitions between what lives and does not live, and between what thinks and does not think. The contrast between the restless bird and the rigid bars of his cage is largely illusory, for the apparently inert metal consists of a vast number of molecules in almost inconceivably rapid motion, grouping and re-grouping themselves according to the metal's particular environment. Hence the difference between the metal and the bird is only superficial; deep down, each is a mass of activity. As to the mass of activities we call mind, we know just as much concerning its essence as we know concerning the essence of matter, and that is, nothing. Yet mind and matter appear to be inseparable, for we know of each only through the instrumentality of the other. It will readily be admitted that the mind of the genius is of a higher order than that of the ordinary man and still more so than that of the child, which in its turn is on a higher plane than that of the unborn babe: to say that mind is conferred on a babe at the moment of parturition is logically indefensible. But the mind of the unborn babe is developed from that of the embryo, and the mind of the embryo from that of the fertilised egg-cell. In this microscopic speck of living matter the individual mind has its genesis. But having reached the source of the individual mind we have to continue our journey along its racial path, passing by imperceptible gradation from the mind of parent and grandparent to distant ancestor, and so on to Eolithic man, to the ape-like man, and to the man-like ape, whose mind was colossal compared with that of the proto-mammals preceding him. From the mind of the proto-mammal we must pass to that of one of the Permian reptiles, thence to that of the Silurian fish, and so on through the mind of a Cambrian crustacean and a pre-Cambrian amoeba, until at last we arrive at the mind of the archaean protist. In this stupendous life-chain, stretching over certainly more than a hundred million years, there is no point at which we can consistently put our finger down and say, Here on this side is mind; there on that side mind ceases to be. If there were, we should be compelled to postulate at that point the coming into being of mind out of no mind, of something out of nothing. The hylozoist lays great stress on this principle of continuity.

But in tracing back mind as far as the primordial protists, we have not reached the end of our journey. If these protists evolved, as presumably they did, from solutions of the inorganic salts of the earth's crust, the principle of continuity compels us to believe that their " minds " arose in a parallel manner. How then can we escape the conclusion, continues the hylozoist, that mind of some kind exists not only in man and in the higher and lower animals, not only in the protists, present and past, not only in the colloids and chemical compounds antecedent to the colloids, but also in the very molecules and atoms themselves ?

Each of the sixty-odd trillion little cells making up the whole body of man lives a separate and independent existence, and has its own sensations and psychic life, though each owes allegiance to and is dependent upon the cell community as a whole. The mind of the whole cell community, man, is the integrated minds of all these cells ; the mind of each cell is the integrated minds of all its constituent colloidal molecular compounds ; the mind of each colloidal molecular compound is the integrated minds of all its molecules ; and so we gradually get back to the atoms, to the electrons, and to the aether. Logically, all this is unassailably consistent.

When a man falls asleep, his normal, individual, co-ordinated mentality is temporarily lost, because it has split up into a disconnected system of separate minds, each of which is associated with temporarily isolated groups of cells. In the unconsciousness of an anaesthetic state, the psychic individuality of each of those isolated groups of cells is further split up into yet lesser minds, each of which retires into and becomes isolated in the cell itself, which now in its turn forms a separate psychic individual. In the deepest unconsciousness compatible with the maintenance of protoplasmic life, there is a yet further decentralisation of the mind. Each cell now loses its own " consciousness " and " individuality," because the cell mind has undergone segregation into the " minds " of the ultimate protoplasmic units of the cell. In the recovery of consciousness, of course, the reverse process is assumed to occur. But if recovery does not take place, there is a continuation of the disintegrative processes. The individual " mind " of the protoplasmic unit of the cell suffers partition into the several " minds " of the molecules. If the individuality of the molecules is destroyed by resolution of the molecules into atoms, the " mind " of each molecule is broken up into the " minds " of the atoms.

If mind permeates all matter, we should expect to find evidence of a rudimentary form of both life and mind hidden in the background of all things. And this the hylozoist believes actually to be the case. One of the first things that strikes the observant student of Nature is the persistent way in which the two elemental forces " attraction " and " repulsion " run through the fabric of all phenomena. Atoms attract or repel other atoms, and seem to exhibit a decidedly selective power. Again, one of the most characteristic features of mind in the higher animals is memory. There is no lack of evidence to show that it is present in the lowliest of animals and even in plants; and there is reason to think that incipient " memory " exists in the inorganic world. An experiment of Hartmann's bears on this point. To one end of a rod of soft metal of uniform calibre was suspended a weight which was just too heavy for the rod to bear; the latter, of course, elongated, and began to thin out in its weakest part preparatory to breaking. However, before actual rupture occurred, Hartmann removed the weight and allowed the rod a prolonged rest in which to recuperate after its severe strain. During this period of convalescence a remarkable process of repair was apparently carried out; neighbouring molecules appeared to be moved up to the threatened zone to reinforce it, and so effectually was this done that what was the weakest part of the rod became the very strongest, as the second part of the experiment proves. After giving the rod sufficient rest, Hartmann rolled it to make it once more of uniform thickness. Again the rod was subjected to a breaking strain, and again it elongated and threatened to rupture, but never at the same place as on the first occasion. The inference Hartmann drew was that the metal in some manner retained the impression of past experiences and adjusted its internal parts in such a way as to strengthen them against future attacks.[1] The whole behaviour of the metal is exactly paralleled by that of bone during the process of repair following a fracture. In both cases the repaired zone is always the strongest region.

On these and other grounds the hylozoist argues that the supposed three fundamentals of the universe, matter, motion, and mind, may all trace their origin to some one thing, some mysterious and eternal reality. This seems to be the aether. The physicist

[1] To the author's knowledge, several very competent physicists have attempted to repeat Hartmann's experiment, but never with complete success.

has dematerialised matter into restless aetherial vortices, and mind may prove to be merely another aspect of this boundless ocean of primordial substance. Can it be the aether in perfect repose?

Truly the hylozoistic hypothesis is a daring conception, and in spite of its highly speculative character it is not to be hastily rejected. It has been half seriously suggested that the hylozoist is consistently bound to maintain that our tables and chairs have their own private opinions of us, and that when once a fire has gained the upper hand it must jeer at our futile efforts to conquer it. But the hylozoist's claims lead to no such absurdities. Concerning inorganic nature and all dead organic things, all he maintains is that there is still a rudimentary consciousness on the part of the individual molecules, and not that there is anything of the nature of a collective consciousness amongst them. Still, the hylozoist does make one serious mistake, a mistake which alone is sufficient to bring the whole of his edifice to the ground. He denies that a property can be possessed by an aggregation of molecules unless it is possessed in some degree by each of the separated individual molecules. He admits that new properties may come into existence, but only by combination of previously existing and analogous properties, for they are not created and cannot be destroyed. But there is no justification for assuming that a phenomenon exhibited by an aggregate of particles as a whole must be possessed by the individual particles composing the aggregate. The properties of any chemical compound, for instance, are entirely different from the properties of the constituent elements. Further, wholly new properties may make their appearance simply by aggregation. For instance, a meteoric stone may seem to differ from a planet only in size, but the difference in size involves many other differences, notably the fact that the larger body can attract and hold to itself an atmosphere. Hence life may then become possible. The earth is large enough for this purpose; the moon is not. Again, owing to the great size of the sun an immense quantity of heat is generated by gravitative shrinkage, and for vast periods of time the solar mass must be maintained at an excessively high temperature. A small permanent sun is an impossibility. It is a fallacy to maintain that whatever properties belong to a whole necessarily belong to the parts of which it is composed. The hylozoist is therefore wrong in assuming that the properties of life (whatever they may be) which pertain to a living organism necessarily also pertain to the ultimate particles of which it is composed. His hypothesis does not cover all the known facts, and cannot therefore be accepted.

10. Mind, Consciousness, Personality

We have spoken of "life," "mind," "consciousness." Do the three terms mean one and the same thing, or can they be distinguished?

Admittedly all three terms are a little vague, and there is a great difference of opinion as to their precise significance. But our notion of mind, like our notion of matter, seems to be a notion of a permanent something, contrasted with the perpetual flux of the sensations and other feelings or mental states which we refer to it. Though it seems impossible to form a clear conception of that something, memory is sufficient to convince us of its permanence. The phenomena of mind may be described as the processes of consciousness; and since memory is a tie which connects our present consciousness with the past, we obtain a conviction of the permanence of that which seems to constitute self.

Consciousness exists in different degrees of fulness and intensity. First, there is discursive thought; this is distinctly human, and constitutes self-consciousness. Secondly, there is the narrower region of perception, activity and feeling, which we share with the higher animals. In both these cases, consciousness is focussed in the attitude of attention. Thirdly, there is a marginal consciousness without attention; we may be devoting our attention to one thing and at the same time be vaguely conscious of many other things. Lastly, there is a vast region of dim consciousness, mere sentience, which probably never becomes distinct at all.

Inasmuch as the lowest organisms, for instance the bacteria, presumably profit by individual experience, it may be assumed that the life processes of such organisms are accompanied by sentience. We cannot imagine the mental state of a creature which is formed of a single cell, but that there is any kind of higher consciousness in such an organism is improbable. With increasing advance of animal organisation there is presumably increase of consciousness, until at last the power of attention is developed. Consistently, we seem bound to admit continuity. Consistently, therefore, it is difficult to grant consciousness to a newly-hatched chick but deny it absolutely to a newly-laid egg. If we do deny it, at what stage does consciousness come into being?

The simplest forms of life are indistinguishably animal or vegetable, and since it must be admitted that even the lowest forms of animal life have a rudimentary consciousness, it is arbitrary to deny a rudimentary consciousness to the lower forms of vegetable life; if so, it is still more arbitrary to deny it to more highly organised plants. Evidence of rudimentary plant-consciousness seems to be afforded by the phenomena of irritability, contractility, and purposive movement. Plants possess what may be called sense organs in relation to gravitation, contact, light, and perhaps other stimuli. These organs seem to have developed, like those of animals, from the epithelium. The principle of continuity seems indeed to carry us, ultimately, into the inorganic world, though here even the lowest form of consciousness—sentience—does not seem to be conceivable.

It is sometimes assumed that life is a wider conception than consciousness, and that consciousness is but an occasional accompaniment, an epiphenomenon, of organic organisation, just as it is sometimes assumed that the organisation itself is but a special arrangement of inert masses and the effect of natural forces. But it is not inconceivable that mind in some form is always implicated in life and is a function of life. On the whole, however, it seems more probable that in the evolution of the organic world there were at least three stages when new causes must have come into action: the stage when life itself appeared, the stage when consciousness appeared, and the stage when self-consciousness appeared.[1] It is not, however, unreasonable to assume that it was actually the same cause at work throughout, the effects produced depending upon the particular stage of evolution reached; self-consciousness, for instance, would arise only with advanced cerebral development.

During the course of its existence, from its embryonic condition to its death, an animal does not remain the same either in form, or in structure, or in the matter of which it is composed, and yet we say it is always one and the same individual. Obviously all living things have a distinctive identity, but, more than this, all thinking beings have a distinctive personality.

The realities underlying our sensations are known to us only by inference, and in their inmost nature they may be quite different from what they seem. So also our actual personality may be something quite different from the conception of it that is based on our present terrestrial consciousness, a form of consciousness no doubt suited to our few years of existence here, but not necessarily more than a fraction of our total self.

Every phase of human mental activity belongs to personality, and therefore cannot be dealt with from the merely biological or physiological standpoint. Personality forms the subject-matter of

[1] Cf. Chap. XII. § 12.

psychology, but psychology cannot be established on a physiological basis; for though it is vain to attempt to separate the personality of a man from his organic life, man as a person is more than man as an organism. The man as a person is the actual man, but of much that is in him as a person we can form only the blurred conception afforded to us by the biological or physical view of him. Only by degrees do we learn to read his character in his actions, words and features.

Physical science is concerned with the two great entities, matter and energy, and it teaches clearly that neither of these can perish absolutely but only change its form. In the human body there is nothing immortal or persistent except the material atoms[1] of which it is composed. The notion that these same atoms will at some future date be re-collected and united with the dissociated and immaterial portion, and so constitute once more the composite man as he appeared on earth, hereafter to last for ever, is an absurd pagan superstition. The superstition is still held by at least one great branch of the Christian church. To express a belief in the resurrection of the "body" is merely to emphasise the material aspect of religion, and is an entirely unnecessary accompaniment to the survival of the personality. The personality, in some mysterious way which we cannot understand, seems to embody, though not in the material sense, the intellect, the emotions and the will, and the whole of our experience. It seems more difficult to believe in the destruction of personality than in its continuance. Indeed, it seems impossible to conceive of the final destruction of either personality or matter. At bottom, "death" seems to be the mere dissociation of mind and matter, of soul and body, of the release of personality from its temporal home.

II. Life as a Category

The laws of physical science, regarded as a formulated summary of the working of the universe, are necessarily incomplete—incomplete to an extent that would probably amaze us, could we but realise the present limitations of knowledge. And in this respect the physiologist is in much the same position as the physicist. The physicist has no direct detailed knowledge of matter; his molecules, his atoms, his electrons, and his aether are all *inferred* from various sensuous data. So it is with the physiologist; the chemical and physical changes observed in the living organism are his sensuous

[1] More strictly, the electronic constituents of the atoms.

data ; all else is *inferred*. One physiologist may affirm and another deny (as actually happens) that the living organism is an automaton. But both the affirmation and the denial are exactly alike in being inferences from the same data. An outsider can but weigh the evidence and judge for himself which inference is *probably* correct.

The possibility that life may be a real and basal form of existence of a distinct and separate order from matter and energy, and therefore persistent, provides us with a working hypothesis. The hypothesis may also include the further assumption that life in some way exerts control on the energy already existing in the matter. That life is some sort of guiding principle and controlling agency is supported by the fact that a living organism is able to build up material particles into different forms : it may be a man or it may be a tree. Yet its powers cannot be internally created from the store of energy in the matter with which it interacts, for, as we have seen, life cannot be a form of energy ; its powers must be brought with it from outside. The forms it builds up, be it man or tree, last until they are abandoned by it, when they become more or less speedily resolved into their elements.

If evolution be a fact, it is difficult to avoid the conclusions that life is a dominating factor of the process, that living things are still subject to the process, and that human personality has not yet reached its goal. It is unbelievable that the human body, with all its imperfections (consider, for instance, the great imperfection of the human eye as an optical instrument), has reached the last stage of evolution, and it is most certainly unbelievable that human intelligence has yet proceeded much beyond its dawn.

The essential property of energy is that it can be transformed, remaining constant in quantity. But life does not add to the stock of any known form of energy, nor does death affect the sum-total of energy in any known way. Life seems to be something entirely outside matter and energy, and no relation has been established between them. If electrons are resolvable into aether, then the aether, with such states of motion or strain as it eternally possesses, is the single persistent material entity to which all matter and energy are ultimately reducible. This indeed is possible. And the hylozoist thinks that mind may prove to be merely another aspect of the aether, perhaps the aether in perfect repose ; but there seems to be no ground for denying the existence of life as something absolutely distinct and independent, something as persistent and as eternal as the aether itself.

Metaphysically, life is ultimate ; logically, it is universal.

In an earlier chapter reference was made to the "categories" or "general ideas," terms signifying philosophers' fundamental and irreducible notions. The lists vary greatly, and they are very artificial, scarcely any two philosophers agreeing about them. Now since, as we have seen, life is obviously fundamental, is at present irreducible, and seems to be ultimate, we are logically compelled to admit it as a category. A category of life is just as much constitutive of our experience as the categories of matter and of cause and effect. In point of fact, in dealing with the phenomena of life we almost unconsciously make use of such a fundamental conception as a working hypothesis, a conception entirely different from the fundamental conceptions of physics and chemistry, and certainly not reducible to them.

If we regard life as a biological category, it follows that we frankly admit the limitations of our knowledge, and for the present abandon all attempts to discover the ultimate mechanisms of vital activities. All bodily processes, for instance the apparently mechanical or chemical processes of breathing, of circulation, of digestive changes, then become nothing but the expression of organic activity in its different forms. And all mental processes, being merely phenomena of mind, and mind being a function of life, then admit of an equally simple, if provisional, explanation.

The categories under which our experience is ordered are so many separate conceptions unrelated to one another. They may be roughly compared with the chemical elements as they appeared to science before the discovery of the periodic law.

Our growing knowledge is a progressive defining of our experience in terms of fundamental conceptions or categories, and a gradual passing from lower, more abstract or indefinite conceptions, to higher, more concrete and definite ones. From the very nature of the categories themselves all true knowledge must be a gradual revelation of the lower or more abstract in terms of the higher or more concrete aspects of reality; and as the conception of a living organism is a higher or more concrete conception than that of matter and energy, it seems possible that ultimately the physical world of matter and energy will be interpreted in terms of the biological conception of the living organism.

Be that as it may, life is even now a category co-ordinate in rank with the physical categories. It is fundamental and irreducible. Whether in course of ages it will yield up its secret, who can say?

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4. VISCOUNT HALDANE. *The Pathway to Reality.*
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6. LEONARD HILL. *Further Advances in Physiology and Bio-Chemistry.*
7. G. H. LEWES. *The Physical Basis of Mind.*
8. SIR NORMAN LOCKYER. **Inorganic Evolution as Studied by Spectrum Analysis.*
9. SIR OLIVER LODGE. ***Life and Matter.*
10. R. C. MACFIE. *Science, Matter and Immortality.*
11. J. G. M'KENDRICK. *The Principles of Physiology.*
12. E. METCHNIKOFF. *The Nature of Man.*
13. BENJAMIN MOORE. ***The Nature and Origin of Life.*
14. F. G. POPE. *Modern Research in Organic Chemistry.*
15. CARVETH READ. ***The Metaphysics of Nature.*
16. F. C. S. SCHILLER. ***Riddles of the Sphinx.*
17. F. SODDY. **Matter and Energy.*
18. MAX VERWORN. *General Physiology.*
19. JAMES WARD. *Naturalism and Agnosticism.*

USEFUL SUPPLEMENTARY VOLUMES

20. SVANTE ARRHENIUS. *Worlds in the Making.*
21. THOMAS GRAHAM. *Colloids.*
22. E. HAECKEL. *The Riddle of the Universe.*
23. C. A. KEANE. *Modern Organic Chemistry.*
24. A. KEITH. *The Human Body.*
25. R. WIEDERSHEIM. *The Structure of Man.*

CHAPTER IX

INSTINCT AND INTUITION

1. Animal and Human Instinct

THE butterfly known as the White Admiral lays its eggs on the leaf of the honeysuckle. The larva hatches out in July and feeds until the honeysuckle leaves are about to fall in the autumn, when it proceeds to make a shelter for itself by pulling over the edge of the leaf, rolling it up, and securing it in position by means of silken stays ; but before taking up its winter quarters here, it travels up the leaf-stalk and binds it with silk so strongly that this particular leaf, even when it becomes faded and shrunken, does not fall but remains attached to the plant throughout the winter. The larva in the suspended hammock is thus not only sheltered and kept out of harm's way, but, on the return of spring, wakes up to find itself in the midst of a plentiful food supply. This plan is invariably worked out in precisely the same way, and it impresses the observer as being purposeful and apparently highly intelligent. But *is* such a lowly creature intelligent ? How is the apparently purposeful action to be explained ?

Of the many thousands of different birds all over the world, no two distinct species build nests exactly alike, though the differences are sometimes exceedingly slight. The willow-warbler and the wood-warbler, for instance, build similar oven-shaped nests on or close to the ground. But though outwardly similar they are easily distinguished by their interiors. The willow-warbler invariably lines her nest with a mass of feathers, but the wood-warbler never uses a single feather, no matter in what country the birds are found. What is the purpose of such an invariable difference ?

The nests of certain birds are so wonderfully concealed in the undergrowth of woods that it is next to impossible to find them unless the birds are watched. But the owner of a nest invariably flies straight home, never losing the way and never hesitating as to direction. If, however, the nest is removed ever such a little distance from the original site, the bird is baffled, and only by chance will she discover it. If there is intelligence in the bird's first action, how is the curious limitation of the intelligence, as shown in the second action, to be explained ?

A dog was placed in a box and sent by train, by a purposely roundabout way, to a town sixty miles off that he had never before visited. He was then set at liberty and found his way home in about fourteen hours, and by a route much more direct and entirely new to him. How did he find the way ? If by intelligence, how was the intelligence brought into action ?

A bee has no sooner dried her wings after emergence from the native cell than immediately she sets to work with apparently a perfect knowledge of what has to be done and does it accordingly. It is the same with all the bees of a hive. Is this intelligence ? If so, is it individual intelligence or collective intelligence ?

Ants are commonly described as extremely intelligent creatures. But if this be so, how are we to explain the fact that the ant seems to exhibit stupidity when she tries for an hour or more to drag a burden over the top of an obstacle instead of turning to one side for an inch or two ? In some way the ant seems to know that the burden must be picked up and borne in a certain direction, but while never at a loss for direction she seems to have no notion whatever of avoiding obstacles. But if on this account we deny intelligence to the ant, how is the following authenticated incident to be explained ?

A naturalist had for months been in the habit of sprinkling on his window-sill some fine sugar for a train of ants which passed in constant procession from the garden up the wall to the window. One day he decided to put the sugar in a vessel which he suspended by a string to the lower bar of the raised sash ; and in order that the ants might have information of the whereabouts of the sugar still available, he placed a number of them with the sugar in the vessel. These latter ants forthwith seized on the particles of sugar, and soon discovering that the only way open to them was up the string, along the sash and down the window-frame, they rejoined their fellows on the sill, whence they could resume the old route to the garden. Before long the new route between the sugar and the sill was completely established, and so passed a day or two without anything new. Then one morning it was noticed that the ants were no longer traversing the path *via* the string to the sugar, but were stopping at their old place and getting sugar there. This was not because the store of sugar above had been exhausted, but because some dozen of the ants were at work in the vessel, dragging the grains of sugar to the edge, and throwing them down to their comrades below on the sill which, considering their extremely limited range of vision, they certainly could not see.[1]

Such instances of apparently intelligent and obviously purposeful action in the animal world might be given almost without limit. It is customary to ascribe such actions to animal " instinct."

The term instinct is also sometimes used in connection with human actions, but in a more general manner ; for instance, in social relationships we speak of an " instinctive " liking or distrust, and we are told that the French have an " instinctive " appreciation of the beautiful. But in connection with animal actions the term has a narrower significance, for it is then generally, though not always, applied to certain hereditary modes of animal behaviour.

Truly instinctive acts are accompanied by consciousness. This differentiates them from such reflex acts as are certainly unconsciously performed, for instance during sleep ; and from such actions as the tropism of plants. But most, if not all, organisms undoubtedly profit by experience, as is obvious from the modification of their behaviour in accordance with circumstances. Apparently, therefore, we may differentiate between the purely instinctive behaviour which is inherited, and the intelligent behaviour which is traceable to experience acquired under the modifying influences of individual relation to the environment.

What in popular usage are spoken of as the instincts of animals are generally joint products of hereditary and acquired experience, but it is by no means easy to distinguish between what is dependent on individual experience and what on inherited experience. From careful observation of the behaviour of precocious young birds, it can readily be ascertained that such modes of activity as running, scratching the ground, swimming, and diving, with the characteristic attitudes expressive of fear and anger, are so far instinctive as to be definite on their first occurrence—they do not require to be learnt. No doubt they are subsequently guided to higher excellence and effectiveness by the experience gained in their oft-repeated performance. Indeed, it may be said that only on the occasion of their initial performance are they purely instinctive, all subsequent performance being in some degree modified by the experience afforded by previous behaviour of like nature.

[1] For a large number of other interesting examples see Mr. Bingham Newland's book.

The instincts of nest-building and the rearing of young, though they occur later in life than those concerned in locomotion and the obtaining of food, are none the less founded on an hereditary basis, and in some respects are less rather than more liable to modifications by the experience gained by the carrying out of hereditarily definite modes of procedure. Here the instinctive factor probably predominates over that which is experiential. But in the "homing" of pigeons there is little doubt that it is the experiential factor which predominates. In all cases the higher nerve-centres must, presumably, be modified by individual and intelligent use.

There is a vast amount of evidence tending to show that racial preparation plays a large part in bringing about instinctive response, in a particular way, on the part of an organism. For instance, a duckling only a few hours old, if placed in water, swims with orderly strokes. The stimulus of water on the breast may be regarded as a sensory presentation which is followed by a definite and adaptive action dependent on prolonged racial preparation.

Although instinctive actions are consciously performed, they are performed without necessary knowledge of the relations between the means employed and the ends attained. And they are not accompanied by any form of *self*-consciousness, for a self-conscious creature could reason for itself, and in consequence would be liable to error, whereas animals do not seem to be thus liable. In the case of the collective actions of communities of animals, for instance of bees or ants, a single consciousness seems in some way to serve the entire group, to which all the individual members are entirely subordinate. Various hypotheses have been put forward in explanation of this group consciousness, but none of them is convincing, and the process is admittedly beyond our comprehension.

A certain amount of evidence is available that even man continues to inherit, in some small measure, certain instincts of his remote ancestors. That some men still have the "gift" of "water-divining" is an established fact, but no water-diviner is able to explain his power; he makes his discovery as though he were merely a conscious automaton. All explanations that have been put forward are merely tentative hypotheses. The power is not, of course, supernatural but supernormal, and seems to be an instinct inherited from ancestors whose actions were guided by instinct and not by reason. The power is thus a survival of a faculty prevailing before the evolution of the self-conscious mind. Then, again, it is well known that many living savages have a "homing" instinct or sense of direction as marked as in the case of animals. They pursue a definite direction through dense forests even in the dark, and unerringly find their way, almost in a bee-line, home. And in such a matter as self-preservation, human instinct will act sometimes, though not always, with a swiftness and precision which are astonishing to the trained intellect.

Between this inherited human instinct which brings out our kinship with remote generations of animals and semi-human ancestors, and the instinct which often seems to guide our actions in everyday life, there seems to be a close though not a very clear relation. In the field of public affairs, men are chiefly guided by their reason, at all events when they are not guided by self-interest. But in nearly all the other fields of life, and especially in a man's private concerns, his affections and his tastes, instinct comes first, and reason is called in afterwards to justify it. We never make friends by reason. We like people, and then are pleased to find that we can show good reason for liking them. And in the domain of the senses, and of the fine arts which appeal to us through the senses, dependence upon instinct seems to be growing more and more common and avowed. Not one critic in ten calls the canons of reason into play in expressing his opinion. Like the general public, the critic likes or dislikes the work of art that is submitted to his notice. He tells us that he likes or dislikes it ; and if he commits himself to giving any reasons, we find that most frequently he has been out to look for a few in order to support the decision already formed by his instinct. There is little doubt that reason is sometimes a less trustworthy guide than instinct. Reason must always be shaped by the inheritance of other men's reasons, be tinged by unsuspected prejudices, and be deflected by that very instinct which it is encouraged to supersede. But instinct, which is admittedly older and profounder than reason, is certainly not always wholly trustworthy. Private and personal a power though it be, it is subject to the pressure of custom and convention, and is moulded by early training ; and no doubt it is frequently enfeebled by want of intelligent exercise. Instinct is especially liable to error over such matters as friendship ; a wrong impression may easily be given by reserve or flattery.

It is true that instinct has a convincingness which is lacking in reason ; while it is present it is almost impossible to doubt its truth. But its greater subjective certainty is a demerit, making it only the more irresistibly deceptive. Experience often proves that instinct is illusory, and that the slower and more groping methods of reason are in the long run more reliable. Instinct, untested and unsupported, is an insufficient guarantee of truth, in spite of the fact that much of the most important truth is first suggested by its means.

The term "intuition" is often loosely used as the equivalent of the human instinct just described—the instinct inherited from a remote past, and its natural developments during the course of evolution. But since instinct is necessarily unadaptable and unable to deal with any new situation, intuition really signifies rather more and something rather different. In fact, intuition is somewhat nearer akin to reason, and has come to have a philosophical meaning of its own. But philosophy is not one of those pursuits which illustrate our affinity with the past. It is a product of advanced civilisation, and for its success it demands a certain liberation from the life of instinct. At all events, in philosophy reason is superior to instinct.

But for the elucidation of the philosophical significance of intuition, certain subsidiary subjects must be touched upon.

2. Inconceivability

In its narrower sense the term "conception" is equivalent to the term "idea" when the latter signifies a revived image of an impression of sensation. But the term is frequently used to denote an idea of a more general kind, and sometimes it is used as a synonym for imagination. On the whole it is best to accept the usage which connotes not only the work of the imagination but also that final mental act which organises and unifies into a whole the materials the imagination has supplied. Imagination implies the power of modifying revived images or ideas, of combining the parts of different ones together, in order to form new wholes of our own creation. Qualities and circumstances which have been perceived in conjunction are thus separated from each other, and new combinations are formed. No conception can be formed in our minds unless it had its origin in earlier perceptions. A blind man could form no conception of colour, or a deaf man of music; in fact we cannot imagine anything that has not been derived ultimately from perceptions. Imagination can create nothing; all that it can do is to sort out and rearrange the contents of earlier perceptions. Conception implies re-presentation. The act of conceiving is the taking up, organising, and unifying of the materials supplied by the imagination, and the attempt to do this to meet the needs of a particular case is sometimes beyond a particular person's power.

A person's ability or inability to form a given conception depends largely on the experience he has already acquired, either through his own converse with things, or through the accumulated knowledge from other persons' converse with things. As experience grows, we are able to conceive things that we have hitherto regarded as inconceivable.

But the term *inconceivable* has come to have a special significance of its own. It is sometimes wrongly used as the equivalent of one of the terms *incredible*, *unimaginable*, and *incomprehensible*. Imagination must be distinguished from belief. If I look at the sun, I can easily imagine, though I cannot believe, that I am looking into darkness. It is *incredible* (or unbelievable) that a gun will ever be made to fire a shell that will reach the moon, but such a gun is quite *imaginable* (or mentally picturable). Anything which is believed as a fact, but of which the mode of existence or operation cannot be understood or grasped by the mind is said to be *incomprehensible*. The existence of a close relation between thought and the nervous changes which accompany it is neither *incredible* nor (to persons possessing wide knowledge or exceptional intellectual power) wholly *inconceivable*, but the form of the relation is both *incomprehensible* and *unimaginable*. Anything which cannot be pictured mentally is *unimaginable*, though not necessarily inconceivable. A concept does not necessarily involve an image; it is an intelligible rather than a picturable synthesis of attributes. That which is unpicturable (unimaginable) may not be inconceivable, and the abstraction which is impossible to imagination is often possible to conception. Inconceivability often results from the definition or meaning of the terms used. We pronounce a non-existent thing inconceivable, simply because it involves a contradiction in terms. An inconceivable proposition is one of which the terms cannot by any effort of the mind be brought into that relation which the proposition asserts between them, a proposition of which the subject and predicate offer an insurmountable resistance to union in thought. That one side of a triangle can be equal to the sum of the other two is not only incredible and unimaginable but inconceivable. The negation of the proposition $2+3=5$ is also inconceivable; it strikes the mind at once as being nonsensical and impossible. "The inconceivableness of the negation" of a proposition is in itself usually sufficient to stamp the proposition with a high degree of credibility. The negation of the propositions "whatever resists has extension," and "all extended surfaces are coloured," is incredible and unimaginable, but they are not inconceivable, for it is not impossible in thought, though it is impossible in imagination, to separate resistance and extension, or even colour and extension. But the negation of the proposition "Every effect has a cause" is absolutely inconceivable. A beginning in time is also inconceivable. But only those who are well practised in reflective analysis can be regarded as competent judges as to what is absolutely inconceivable.

Our capacity or incapacity of conceiving a thing has very little to do with the possibility of the thing itself, but is very much an affair of accident and depends on the past history and habits of our own minds. At first, extreme difficulty is felt in conceiving anything as possible which is in contradiction to long-established and familiar experience. When we have often seen and thought of two things together, and have never in any one instance either seen or thought of them separately, there is by the primary law of association an increasing difficulty, which may in the end become insuperable, of conceiving the two things apart ; and the supposition that the two things can be separated will at last present itself to our minds with all the characters of an inconceivable phenomenon.

There are instances in which men of great intellectual power have rejected as impossible, because to them inconceivable, things which men of a later age, with greater knowledge and perseverance, have found quite easy to conceive, and which everybody accepts as true. Such men could not, for instance, credit the existence of antipodes, not because the antipodes could not be imagined, but because they could not conceive, in opposition to old association, the force of gravity acting upwards. Thus it is natural that even men of great ability and wide knowledge should be incapable of conceiving, and on that ground of believing impossible, things which are afterwards found not only to be easily conceivable but proved to be true. For when past experience affords no model on which to shape a new conception, how is it possible for us to form it ? How, for instance, can we imagine a beginning or end of time ? We have never experienced any feeling without having experienced something preceding and following it. When, therefore, we attempt to conceive the first and last moments of time, the idea of still earlier and later moments arises irresistibly in the mind.

Principles which not only are not self-evident but which we know to have been discovered gradually and by great effort and patience, have, when once established, appeared so self-evident that, but for historical proof, it would have been impossible to think that they had not been recognised from the first by all persons of ordinary intelligence. We feel surprised that, during the Copernican controversy, intelligent men were unable to conceive the apparent motion of the sun on the heliocentric hypothesis, but those men were far from being prejudiced or unreasonable; they were merely cautious, not being satisfied that the evidence brought forward justified the hypothesis. And history is repeating itself all the time. For instance, it is easy to detect the charlatanism underlying phrenology, palmistry, and crystal-gazing, not one of which is supported by a shred of scientific evidence; and this makes intelligent people hesitate to subscribe to the claims of any hypothesis where the clear evidence, though incontestable, is only slight; telepathy is a case in point: because the process is unimaginable it is regarded by many as inconceivable and therefore impossible and false. But, as we have seen, inconceivableness is an accidental thing, not inherent in the phenomenon itself but dependent on the mental history of the person who tries to form the conception. A proposition is not necessarily to be rejected as impossible simply because it is inconceivable.

3. Necessary Truth

The system of necessary truth which any deductive science, including mathematics, is commonly represented to be, is indeed necessary in the sense of inevitably following from established first principles, that is, of being certainly true if the first principles are so, for the word necessity is here equivalent to certainty. But the claim to the character of necessity in any sense of implying evidence independent of and superior to observation and experience, must depend on the previous establishment of such a claim in favour of the first principles themselves. Essentially, the first principles are experiential truths; they rest on superabundant and obvious evidence; they are inductions from wide experience. But to the complete result the mind is an important co-contributor. For in what does the process of induction really consist? Induction is something much more than the summation of a number of facts. It is the process by which general propositions or universal judgments are established. It starts from particulars and eventually recognises that these exemplify some universal. The aim of induction is knowledge of universals—laws and principles. Such laws are abstract; and all abstraction, being a human process and therefore liable to error, may, in the light of further knowledge, need revision.

The trained mind compares the observed individual facts; arranges, classifies, and systematises them; observes similarities; and eventually believes it can detect the essential and invariable conditions which determine the common nature of those facts. It generalises, and so binds the facts together. It now goes a step further. It examines the conditions, and then feels a desire to explain how the facts examined (it may be only a small number) are subject to them. It therefore makes a tentative supposition—an hypothesis—to account for the facts. Having thus framed the hypothesis to explain the phenomena given in experience, the mind tries to verify it by appeal to fresh facts. Every such attempt to organise the facts of experience involves the invention of some hypothesis as to the underlying law of relation. If the hypothesis can be verified, it is as far as possible definitely formulated into a principle and then becomes an accepted law or general truth. If the hypothesis cannot be verified, another hypothesis is put forward and the process repeated. The formulated principle is thus the result of generalisation, abstraction, inference, hypothesis, and verification; in a word, of induction. The process is very different from the crude inductions of immature and uncultivated minds, which are apt hastily to ascribe to *all* the properties discovered in *some*.

Induction thus enables us to state the relation between a phenomenon and its conditions. But in order that this relation may be universally and necessarily true, it is necessary to assume the truth of the uniformity of nature. But about the truth of the uniformity of nature there is no absolute certainty, though there is a very high degree of probability. Further, it is necessary to assume that the determining conditions we have detected are *really* the determining conditions, and that all the steps of our inductive process are true. But we cannot guarantee these things, and therefore we cannot guarantee certainty. Only by good fortune does the judgment we pronounce express absolute truth. Absolutely necessary or certain knowledge is rare, though in mathematics, where there is very nearly complete knowledge of all the conditions, there is a high degree of certainty. In physical investigation, a partial knowledge of the conditions is alone possible, and it is wrong to attribute necessity to a newly discovered principle, the truth of which can only be a question of greater or less probability. In any other branch of knowledge absolute truth is still more difficult to discover. The reason why any individual holds a judgment to be true can only be found in the relation of that judgment to the totality of knowledge of the individual. We are yet far from a state of omniscience, and we must therefore acknowledge that our judgments about reality are tainted with a greater or less degree of uncertainty, and that the truth of our universal judgments is provisional. Greater certainty will come with increased knowledge.

We said that the highest degree of certainty existed in mathematical knowledge, but this does not mean that, for example, the axioms of geometry, any more than the first principles of any other deductive science, can in any way be regarded as *a priori* truths or necessities of thought, for if they were they would impose themselves upon us with so overwhelming an authority that we could not conceive their contradictories, nor on these found different systems of geometry.[1] Yet as inductions from experience they occupy an almost unique place, because of their presumably close approach to certainty. It must be remembered, however, that the points and lines we have in our minds are simply copies of those we have in experience. Those ideal points and lines which we define are unimaginable, and, except perhaps to a gifted few, are inconceivable. Hence the geometrical axioms seem to be something more than inductions from experience; they seem to embody idealisations of experience. But since they *are* inductions, and therefore contain an hypothetical element supplied by the mind, all subsequent reasonings from them must lead to conclusions that cannot be categorical but only conditional.

Those who contend that the axioms are necessities of thought admit that they were first *suggested* by experience, but urge that the truth is perceived by the mind *a priori* from the first moment when the meaning of the proposition is apprehended, and without any necessity for subsequent verification. But inasmuch as no direct proof of such a contention is possible, that for instance there is no means of showing that we had the *a priori* conviction in early infancy, they fall back on an indirect proof, and for this purpose they adopt the principle of "the inconceivability of the negation." They argue thus: necessary truths are those in which we not only learn that the proposition *is* true but see that it *must be* true, in which the negation of the truth is not only false but impossible; in which we cannot conceive the converse of that which is asserted. In other words, propositions the negative of which is inconceivable must rest on evidence of a higher and more cogent kind than any which experience can afford.

But consider the case of a geometrical axiom, say, "All right

[1] See Chap. IV. § 6.

angles are equal." How is it possible that the converse of the axiom *could* be otherwise than inconceivable to us? We have no analogy to facilitate such a conception. To call up in our imagination two right angles with the object of trying to conceive them as unequal is merely to repeat the experiment which establishes the contrary. How then in such circumstances can the inconceivableness of the negation prove anything against the experiential origin of the conviction?

Again, consider the laws of chemical combination which, by chemists, are regarded as axiomatic. Their truth certainly does not rest on the inconceivability of the negation, for just as substances can be *mixed* in any proportion, so we can conceive of nature *compounding* elements in any proportion, though the ultimate consequences of the absence of definite proportions are not, it is true, clearly imaginable. It seems evident, then, that this so-called Universal Postulate, "the inconceivability of the negation," is not an infallible test of the necessary truth of a given proposition.

While admitting that the test is not infallible, some philosophers hold that it may fail not from any fault in the test itself but because we are apt to mistake for inconceivable some things which are not inconceivable. For since our ability or inability to form a given conception wholly depends on the experiences we have had, and by a widening of our experiences we may be able to conceive things hitherto inconceivable; and since at any time the best warrant we can have for a belief is the agreement of all previous experiences in support of it, it follows that at any time the inconceivableness of its negation is the deepest test any belief admits of. But, assuredly, if our incapacity to conceive the negation of a given supposition is proof of its truth, because proving that our experience has hitherto been uniform in its favour, the real evidence for the supposition is not the inconceivableness of the negation but the uniformity of experience. That all swans are white was a uniform experience down to the discovery of Australia. It is true that uniformity of experience is very far from being a criterion of truth, but inconceivableness seems to be still further away from being such a criterion, though it may be arguable that, whether inconceivability be good evidence or bad, no stronger evidence is available.

At all events the truth of those very rudimentary axiomatic propositions to which the test of the inconceivability of the negation can really be made to apply, can certainly better be accounted for by the fact that they have a basis of wide experience; and it therefore seems neither necessary nor desirable to resort to the test.

We know that we have been seeing the fact all our lives and have never remarked any instance to the contrary, and that other people, with every opportunity for observation, unanimously say the same thing. It is true that, at least theoretically, this experience is always insufficient ; but its insufficiency, instead of being brought to light, is disguised if, instead of sifting the experience itself, we appeal to a test which bears no relation to the sufficiency of the experience, but at the most only to its familiarity. If, as seems probable, mental tendencies originally derived from experience are transmitted by inheritance, so that modes of thinking which are acquired by the race become innate in the individual, thus representing the experience of his ancestors in addition to his own, it might perhaps follow that a conviction is really innate, that is prior to individual experience. Even so, how could it follow that such a conviction would be necessarily true? Assuredly our ancestors, with their more limited knowledge, were more liable than we are to arrive at false conclusions.

It therefore appears that inconceivability is no sure criterion of impossibility. There is no ground for inferring a certain fact to be impossible merely from our inability to conceive its possibility. There are things which must be true though the mind is wholly unable to construe to itself their possibility. We must be on our guard against believing in the *a priori* character of even such a rudimentary axiom as the logician's "Principle of the Excluded Middle," viz., "one of two contradictory propositions must be true," that is, a given assertion must be either true or false. This can only follow provided that the predicate be one which can in any intelligible sense be attributed to the subject. To talk about the truth or falsity of such a proposition as, The fourth dimension is a principle of Economics, is obviously absurd.

4. Innate Ideas

When we wish to demonstrate a particular conviction to be true or false, we cannot bring forward for examination the psychological history of that conviction, for the facts regarding the gradual development of our early ideas have long been forgotten. If we discover in our minds, as we frequently do, some idea that we cannot trace to its source, and if there is nothing in the content of our experience to convince us of its truth, then to accept the idea as part of our belief and as true is irrational. More likely than not it had been implanted there in the impressionable days of our childhood by some dogmatist interested in furthering a particular creed, political, social, theological, or other. And not infrequently we find in the mind ideas which it seems impossible to uproot; there is sheer psychological inability to disjoin the parts of some indissoluble association which, originating no doubt in experiential conjunction, now always present themselves together in the mental picture.

We have seen that general truths cannot be inferred from particular truths alone. If they are not self-evident, they must be inferred from premisses of which at least one is a general truth. But all empirical evidence is of particular truths. Hence, if there is any knowledge of general truths at all, apparently there must be *some* knowledge of general truths that is independent of empirical evidence, that is, does not depend on the data of sense. Must we therefore conclude that there is some knowledge which is primitive and inborn?

The history of the theory of knowledge has in no small measure centred around the expression "Innate Ideas," a term which arouses considerable prejudice in many minds. But when we speak of that *quod a natura nobis insitum est*, we do not mean that a truth was stamped in upon the mind at birth, and became thenceforth a permanent acquisition, consciously known. We mean, simply, that the mind is, of its own nature, so constituted that, under certain operative conditions, it necessarily develops certain habitual modes of combining its experiential ideas. These modes constitute, to begin with, a method which the mind follows unawares; but eventually the rules of its procedure hitherto thus unconsciously followed become themselves the objects of its conscious reflexion. The mind seems to have a natural capacity for dictating the forms in which its particular experiential ideas should be combined. We may therefore correctly speak of the mind's innate *powers*, though not of its innate ideas.

The mind's undoubted power of detecting identity and difference, co-existence and succession, seems to be original and inborn. Still, the power is exercised only on the contemplation of actual things, from without or from within, and all such primitive judgments are individual. The mind compares two things, and proclaims them to agree or disagree. The judgment is *immediate* and felt to be *necessary*; it is irresistible and does not admit of doubt; it seems to be independent and to hang upon nothing else and seems therefore to be *primitive*. But although the *power* is innate, this does not mean that the judgments themselves are innate. Since they are formed only on the contemplation of actual things, no doubt some are formed, in a more or less vague way, at an early age, but others are certainly not formed until later, the objects to which they relate not being clearly presented until the intelligence is developed.

As primitive judgments are immediate they are sometimes described as intuitive.

That we are furnished at birth with an original stock of ideas is a doctrine firmly held by one school of philosophers. But why at " birth " ? Birth is a mere passing incident in the biological life-history of the child.[1] Can it be seriously contended that there is some fundamental difference in the mind of a child five minutes after "birth," as compared with five minutes before " birth"? Even if this were so, why should we suppose that such ideas contain a higher measure of truth than experiential ideas? The latter certainly force themselves upon us with a no less convincing evidence, according to our capacity and our previous experience. To each individual that alone can appear to be truth which follows from the modes of operation of his own mind. But things necessarily present themselves differently to different minds. Are we then to count as truth only that which appears equally necessary to *all* minds? The existence of innate ideas could be allowed only if such ideas are regarded as independent of the possible differences between one mind and another, and dependent only on the nature of the world of objects common to them all.

Even if it were admitted that certain ideas are innate and furnished at birth, obviously we could not arrive at a knowledge of them except by discovering them within us, that is to say, by inward experience; so that after all no real knowledge could come to us unless by experience of some kind. The argument seems to be unanswerable. To know a truth, we must be conscious of it; and, if we were not conscious of it before, then the passage to the knowledge of it is an event which we must necessarily experience. This objection is not, however, necessarily fatal to innate ideas. For supposing them really to exist, still the mind reflecting on them could, to begin with, only be aware of their presence as a fact given in its experience. Nevertheless there is no scientific warrant for the assumption that any sort of prescience was conferred upon us at birth. In short, the doctrine of innate ideas is indefensible.

Philosophers who hold this doctrine assert that the principles of

[1] One fundamental difference between birth and death is sometimes forgotten. Birth is a mere passing phase, but death is the final phase, in the life of the body.

right and wrong are also innate, and are immediately apprehended without reference to any other criterion and without appeal to experience. But the assertion is clearly disproved by the fact that primitive peoples have no intuitive conception of right or wrong, and by the great differences which exist between moral systems in different countries and ages.

The ambiguous term "*a priori*" is sometimes used as the equivalent of innate. So far as any truth can be necessary at all, it must present itself as the conclusion of some antecedent. *A priori* signifies that the knowledge to which the term applies is "from something prior to it," that is derivative, inferred, mediate. The metaphor involved in "prior" suggests an infinite series of premisses, though apparently these must come to an end somewhere in an ultimate premiss. But this difficulty, even if unsolved, does not justify the neglect of the plain logical differentia imposed by the term *a priori* upon all that claims to be known *a priori*, viz. that it shall be inferred from knowledge, whatever this may be, other than itself. But the term is not infrequently used to indicate that certain kinds of general truths are not derived by generalisation and induction from the particular instances which exhibit them, but come to the mind, to begin with, as cloud-born conceptions and truths of universal validity, and are thus *prior* to the particular instances, that is, previous to all experience. But all *a priori* truths are, strictly speaking, derived truths, and it is an abuse of the term to regard them as innate.

5. Perception and Intuition

Certain sensations, of which restlessness is an example, are vague, and we cannot assign any particular parts of the body to them. In the case of others, each feeling arises out of changes taking place in definite parts of the body; it is produced by a stimulus applied to that part of the body and cannot be produced by a stimulus applied to any other part; for instance, the sensations of smell, taste, sight, and hearing. Any portion of the body to which a sensation is thus restricted is called a sense-organ. In the case of sensations arising in special sense-organs, each results from the application of a particular kind of stimulus to its appropriate sense-organ. Thus the sensation of sound is brought about by the air vibrations originating in some sounding body, and the sensation of light by the vibrations of the luminiferous aether.

How mere air-waves can excite the terminal filaments of the auditory nerve and produce molecular changes which ultimately bring about the feeling that we call "sound," and how mere aether waves are converted by the retina of the eye into a suitable stimulus for producing such molecular changes in the optic nerve as, when transmitted to the brain, will bring about the state of feeling we call "light," are unknown. We are largely ignorant even of the physical changes; of the connection between these and the accompanying psychical effects we know absolutely nothing. There is invariable concomitance, and presumably therefore there must be some form of causal interdependence; but it is wholly unexplained.

Every sensation to be known must be *perceived*. Its mere presentation does not necessarily imply perception. While absorbed in thought, I may be subject to the warmth of the fire, to the light of the sun, to a noise in the street, to the odour of flowers, and though my sense organs will be affected I may yet remain unconscious of the affections; I shall probably become conscious of them only when they pass a certain degree of intensity, and not until then can I be said to experience them as sensations. In perception there is recognition or apprehension, and there is local fixation of sensations. The raw materials of knowledge—the sensations or sense-impressions—do not actually become elements of knowledge until recognised or apprehended and spatially fixed. In sensation the mind is passive and merely recipient. In perception the mind is active; it discriminates and identifies the sensations and refers them to the object.

The psychical processes connected with the perception of a particular object are evidently very complex, for perception is determined not only by the sensation which actually gives rise to it but also by psychical conditions remaining as the effect of former similar sensations. In nearly all perceptions, many of the elements are not presented but represented. When passing the finger over the surface of a body in the dark, the perception contains very much more than the co-ordinated sensations immediately experienced. Along with these there go the remembered visual impressions produced by such a surface, which cannot be kept out of the mind, and in the suggestion of which the perception largely consists; and there are unconscious inferences respecting the texture and density of the substance. Thus perception may be regarded as the discerning of the relations between states of consciousness partly presentative, partly representative.

But there is still another element involved in perception. When we pluck and handle an apple and receive together those sensations which we recognise as colour, smell, and "feel" of the apple, there is more than a mere sum of partial percepts; there is a synthesis of apprehension, and there is recognition of the apple as a *thing* having the colour, smell, and feel. Thus perception includes not only the apprehension and localisation of sensations, but the recognition of things. In the complex presentation of an apple may be distinguished its reality and the unity of its qualities, its extension in space, and its continuity in time. But in this synthesis of apprehension the mind is not aware of any mental process; there is no logical act; there is judgment, but the judgment is *immediate*; and it is this *immediacy of judgment* which is characteristic of all intuition.

The term perception is sometimes used as the equivalent of intuition, and both terms are common translations of *Anschauung*, but the two should be distinguished.

When we pronounce the judgment that the opposite angles of two intersecting straight lines are equal, how is the judgment effected? Regarded as a psychical event, the act does undoubtedly involve a certain succession of ideas. We first bring into consciousness the two straight lines themselves, then place them in the same plane and make them intersect, follow each to the point of section and then beyond it, and examine the two pairs of opposite angles. But all this is only bringing into consciousness the figure which determines the relation in question; it is *now* that intuition pronounces judgment on the relation, viz. that the opposite angles are equal, and it does this as if by an instantaneous revelation. How this final step is actually accomplished, and why there should be immediate intuition of the truth when the members of the relation are completely perceived, it is quite impossible to say. The term intuition always signifies this absolutely immediate apprehension of a truth amongst things perceived, in which thought seems to play no part.

An intuition thus seems to be a general judgment, immediately pronounced, concerning facts perceived. But an intuitive judgment is as liable to error as a reasoned judgment. The intuitions of even competent mathematicians are sometimes wrong.

6. Intuitive Knowledge

There is a natural tendency to ascribe to intuition a peculiar authority, for it seems to confront us with an irresistible force foreign to the products of voluntary reflective experience. But it is of fundamental importance to bear in mind not only possible subjective caprice, but that knowledge derived from intuition cannot be independent of experience. At bottom it is just as much experiential knowledge as is distinctly conscious knowledge, and it is therefore just as fallible.

For every individual all the facts in the universe fall into two distinct classes—those that have passed through the mind and those that have not. Some of the former class may be so completely forgotten that, for all practical purposes, they are as dead to the individual as the latter ; others can easily be recalled when wanted ; still others always seem to be ready for immediate use unconsciously, and it is these upon which the validity of an intuitive judgment is ultimately dependent.

Stored away in the mind there must be a medley of knowledge more or less positive, ideas, opinions, beliefs, and former reasoned and unreasoned judgments. To trace any of these to their origin, or even to disentangle them, seems an almost hopeless task. But reflection seems to convince us that our unreasoned judgments include not only primitive judgments but many of the complex judgments of everyday life ; the results of past observation and experience seem to be ready for use unconsciously and immediately. The characteristic of such unreasoned judgments, like that of primitive judgments, being immediacy, they must be classed as intuitive. Reasoning may follow but it never consciously precedes them.

But some of the complex judgments which seem, in mature life, to be intuitive in character were, in the first instance, undoubtedly reached by a process of rough inductive inference, and they seem now to have become so firmly established in the mind that they have assumed the appearance of independent beliefs. We forget their antecedents and regard them as original and underived. And no doubt tradition and habit, and the fact that the same beliefs are held by many other people, all help towards the same thing. Such beliefs are a perennial source of intellectual danger.

On the other hand, a large number of our judgments are reached by a conscious logical process of reasoning. But all reasoning seems to take for granted, as its primary evidence, the truth of certain ultimate propositions which we are compelled to accept independently of the reasoning which follows. If we can find a demonstration for any one of these primary truths, such demonstration necessarily depends upon an assumption of some kind, and we have either to get behind *that* assumption or accept it as it stands. These ultimate premisses are either primitive judgments, or have the appearance of being so fundamental that we are apt to accept them unreservedly; they seem to be immediate and necessary, and therefore intuitional. But it certainly does not follow that this appearance of necessity is a guarantee of their truth.

The principal act of ratiocination is the finding of agreement or disagreement between two ideas by the intervention of a third. In such a case we have "mediate" reasoning, as distinguished from intuitive or "immediate" reasoning.

If we put on one side our purely primitive judgments, it seems quite possible that, fundamentally, intuition and reasoning are identical, the former being instantaneous, the latter involving the notion of succession or progress. The difference would then be merely difference of time, *every* judgment of the mind being preceded by a process of reasoning whether the individual is able to recollect it or not.

The terms in which intuition is sometimes spoken of in contradistinction to reasoning have led to its becoming associated with the idea of a peculiar and mysterious form of *procedure* through which the apprehending mind achieves its purpose. But there is no justification for this notion, and it rests on no other ground than this, that while in reasoning the procedure of linking up the different single acts is describable, in intuition it is not. The work of intuition is done so completely at a single stroke that no steps or stages can be distinguished. Analysis of the process seems to be impossible.

7. The Intuitions of Great Minds

There are times in men's thinking when great truths seem to dawn upon the mind. On such occasions there is commonly not only simple intuition, but also the gathered wisdom of long and varied and ripened experience, refined analysis and generalisation, conscious reasoning, exceptional talent, and systematic methods of working. In nearly every great discovery there has been a combination of native gift, accumulated experience, and connected reasoning; at some particular moment a truth has flashed upon the vision as if light from many sources were suddenly focussed on the same point.

In science and mathematics, intuition is recognised as a legitimate mode of discovering truth. In the integral calculus, for instance, numerous results have been arrived at intuitively, and the clue to all mathematical problems is obtained by an intuition or insight which is due partly to native capacity and partly to knowledge and previous experience. As to the fruitful hypotheses that have led so often to verifiable results in natural science, they seem to be almost of the nature of inspired guessing: truth seems to flash across the mind of the inquirer immersed in his research. He becomes aware of something of which a moment before he was not aware. He is not conscious of having arrived at it by any process of logical thinking, but it has dawned upon him. Great scientific discoverers are men who appear to possess almost a genius for the intuition of hitherto unknown facts. So suddenly does the intuition come, without any conscious process of deductive or inductive reasoning, that it is sometimes regarded as a supra-rational faculty. For the moment it seems to be more akin to imagination than to logic, being creative and spontaneous, apparently independent of the mental processes of analysis and synthesis which constitute the ordinary machinery of thought. But in such cases reasoning and intuition are probably always complementary processes; alone, neither is sufficient. Logic does not discover the data with which it works; the premisses of a syllogism must be known before the inference can be drawn. Hence intuition is necessary. But, as we have seen, intuition is very largely the result of garnered experience, and this is brought suddenly into instantaneous action. But inasmuch as the experience is necessarily affected with error, the intuitions should always be scrutinised and put to the test of truth. Reason should always be called in, even though it be but to crystallise the findings of intuition.

Just as we talk of the mind being suddenly illuminated by a sudden idea, so we talk of the suddenness of a flash of lightning. We are apt to forget that every flash of lightning is the result of natural forces gradually but inevitably leading up to it, and could, if knowledge had been sufficient, been foretold in the remote past. Things are sudden only because we do not foresee them, and their suddenness is no inherent quality in themselves but the mere result of our ignorance. In reality, nothing is more sudden than anything else. It is from our lack of knowledge, understanding, and preparation that lightning borrows its suddenness.

All this seems to be equally true in the world of the mind. To the sudden idea long thinking has contributed—thinking which we seem now to be largely unconscious of. In our unconsciousness seem to lie some of the greater powers we possess. Not a little of man's capital work is done without his knowing it, and when it is done he is amazed at the apparent suddenness of results that reveal themselves in their maturity.

8. Are the known Senses the only Gateways of Knowledge?

Various natural modes of energy have, during the course of evolution, been at the expense of organising special means of communication with the nervous system of the living organism, and the sense-organs are the result. It is difficult to imagine how this could have happened unless the end to be attained was that of serving a purpose of usefulness; and it is doubtful if, once the specially organised means has ceased to be economical, it could maintain its activity. Certainly there are some organs of the living animal which, having ceased to be useful, have ceased to function: the vermiform appendix is an instance. The questions therefore arise whether any formerly existing sense-organs have ceased to exist, and whether during the course of evolution in future ages other sense-organs will be gradually developed in order that there may be a closer correspondence with other modes of energy in nature. Natural economy and usefulness suggest answers in the affirmative. Clearly, animals that can see and hear have a better chance of survival than those that cannot, but if seeing and hearing ceased to be useful and to serve any special purpose, the corresponding sense-organs could hardly be maintained; but if, as is presumably the case, they will continue to be useful, their maintenance and further development is almost beyond question. We have been provided with a special light sense, a special heat sense, and a special sound sense. But why have we not also been provided with a special electric sense and a special magnetic sense? Electricity certainly affects the organism, though so far it has not set up any special means of communication with the nervous system. And for all we know there may be other unknown energies of nature striving to establish an appropriate means of communication with our nervous system. It is quite conceivable that there are modes of energy in nature which, within the range of our experience, are as rare as the rare elements. With such forms of energy the establishment of a specific means of communication would hardly have been economical, in which case our present experience of the universe is necessarily only partial. Moreover, the structure of every one of our existing sense-organs is very imperfect; in every case there are very definite limits to the stimuli that can be sensed. There is a minimum stimulus below which no sensation is excited, and a maximum above which there is no increase of sensation intensity. If the eye were perfect, it would be able to dispense with even the most powerful microscopes and telescopes. It has been suggested that these limitations are a necessary outcome of natural selection ; for an unlimited increase of sensation intensity would be too engrossing, and sensibility to the innumerable minute stimuli always assailing us would be too distracting. Be that as it may, the remarkable imperfections of our sense-organs must always be borne in mind, and if only for this reason complete knowledge of the universe is apparently unattainable. It may be that we possess rudimentary senses of which we know nothing, by way of which new knowledge, perhaps in a very fragmentary form, may enter. And it may be that, by special preparation, such senses can to some slight extent be cultivated. Except on some such ground it is exceedingly difficult to account for the extraordinary spiritual insight unquestionably possessed by certain saintly men during the course of the history of the world. But of course the suggestion is purely hypothetical. Whether such rudimentary senses exist or not it seems impossible to ascertain.

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CHAPTER X

PROBABILITY

1. Fundamental Differences of Opinion

WHAT is the justification for the belief, or it may be the disbelief, in a personal God ? or for the belief or disbelief in evolution ? or for the belief or disbelief in atomism ? or for a thousand other things that are impossible of proof or disproof ? What is the real value of the evidence usually brought forward in support of such proof or disproof ? Before we attempt to answer these questions it may be useful to consider the evidence in a few particular cases.

(a) *The Limitations of Magnitude in the Organic World*

The area of the surface of a sphere being $4\pi r^2$, and the volume $(4\pi r^3)/3$, the ratio of the volume to the surface is $r/3$. From this it is easily seen that the greater the radius the greater will be the volume in proportion to the area. A fish in doubling its length multiplies its area by 4 but its volume by 8 ; in trebling its length, it multiplies its area by 9 but its volume by 27. In the case of bodies which are geometrically and dynamically similar, a variation in size may have far-reaching effects. The reason is this : the action of some physical forces on a body varies directly as the area of the surface of the body ; other forces, gravity for instance, act on all the particles, internal and external, of the body, and therefore exert a force which is proportional to the mass, and so usually to the volume, of the body. The strength of an iron girder obviously varies with the cross-section of its members, and each cross-section varies as the square of a linear dimension ; but the weight of the girder varies as the cube of its linear dimensions. Hence if we build two bridges geometrically similar, the larger is the weaker of the two. One of the first mistakes of a young inventor is to suppose that, because he has constructed the model of a bridge or a roof that seemed in every way excellent in the small dimensions, equal success will follow the construction in full working size.

If the skin of small animals were as porous as our own, the larger ratio of surface to mass would lead to excessive perspiration; hence the hardened and thickened skins of insects. Again, since the weight of a fruit increases as the cube of its linear dimensions, while the strength of the stalk increases as the square, it follows either that the stalk must grow disproportionately large compared with the size of the fruit, or that tall trees cannot bear large fruit on slender branches; melons and pumpkins, for instance, lie on the ground.

A bridge or a house cannot be built beyond a certain size if the same proportions be retained and the same materials be employed as suffice in the case of a smaller structure. The bridge or the house would fall to pieces of its own weight unless either its relative proportions were changed (and this, eventually, would give it a clumsy appearance) or a harder and stronger material were used. And here we are faithfully copying nature. Nature seldom constructs an animal beyond a certain size. The mammoth and the great lizards of past ages were too unwieldy to survive. A man sixty feet high could not live; he would collapse of his own weight—unless fed by Mr. Wells.[1] There are, in fact, inevitable limitations of maximum magnitude in both the animal and the vegetable worlds.

But there seems also to be a lower limit, below which the very existence of an organism is impossible, or at least if it does exist its nature must be profoundly modified.

A millimetre is the 1/1000 part of a metre, or about $\frac{1}{25}$th part of an inch. A micromillimetre (μ) is the 1/1000 part of a millimetre, or about 1/25,000 of an inch. A human blood corpuscle is about 7·5 μ in diameter, hence 10,000,000 will lie within the space of one square inch. But there are many organisms far smaller than this. Amongst the smallest known is a disease-producing micrococcus found in the rabbit (*M. progrediens*), the diameter of which is 0·15 μ, or 6/1,000,000 of an inch, which takes us very nearly to the limits of microscopic vision. Still smaller organisms are the so-called filter-passers, which are revealed by the ultra-microscope; an example is to be found in the "mosaic" disease of the tobacco plant.

A typical size of an ordinary bacillus is 1 μ in length. The height of a man is about 1·75 metres, or $10^6\ \mu \times 1{\cdot}75$. Thus the mass

[1] See *The Food of the Gods*, by H. G. Wells.

of a man is about 5×10^{18} (5 trillions) that of the bacillus. The question has been asked whether there may not exist organisms which to the bacillus bear the same relative size as the bacillus does to a man. But this is easily shown to be highly improbable, for we are already approaching a point where the question of molecular dimensions, and of the ultimate divisibility of matter, obtrudes itself as a crucial factor in the case.

For instance, the number of molecules of albumin contained by the micrococcus *M. progrediens* is about 30,000.[1] It therefore follows that an organism about $\frac{1}{10}$th the diameter of the micrococcus would contain only some thirty molecules of albumin, or have a diameter only about three times that of a single albumin molecule.

There is, however, considerable uncertainty about the assumptions and estimates upon which such calculations are based. For instance, the data concerning molecular magnitudes are, to a great extent, maximal values, above which the molecular magnitudes (or rather the sphere of the molecule's range of motion) are not likely to lie, but below which there is a greater element of uncertainty as to possibly greater degrees of minuteness. But making all allowances for uncertainty, it is still clear that the smallest known organisms draw near to molecular magnitudes. Thus we are compelled to conclude that the subdivision of the organism cannot proceed to an indefinite extent, and in all probability does not go very much farther than it appears to have done in already discovered forms. Further, the principle of dynamical similarity teaches us that long before we reach these almost indefinitely small magnitudes the diminishing organism will have greatly changed in all its physical relations, and must eventually reach conditions which must surely be incompatible with anything such as we understand by life in its complete manifestations.

[1] It is assumed that the micrococcus is spherical and its density equal to that of water. Hence its weight is

$$\frac{\pi}{6} \times (0{\cdot}15)^3 \times 10^{-9}\,\text{mgm} = 18 \times 10^{-13}\,\text{mgm}.$$

The bacteria contain about 14 per cent of albuminoids, these constituting by far the greater part of the dry residue. Hence the weight of the albumin in the micrococcus is $2{\cdot}5 \times 10^{-13}$ mgm.

It has been estimated that the molecular weight of serum albumin is 10,166. Since the weight of the hydrogen molecule is known to be $8{\cdot}6 \times 2 \times 10^{-22}$ mgm, the weight of the albuminoid molecule may be regarded as

$$8{\cdot}6 \times 10{,}166 \times 10^{-22}\,\text{mgm} = 8{\cdot}7 \times 10^{-18}\,\text{mgm}.$$

Thus the number of molecules of albumin contained by the micrococcus is

$$\frac{2{\cdot}5 \times 10^{-13}}{8{\cdot}7 \times 10^{-18}} = 29 \times 10^4 = 30{,}000 \text{ nearly.} \quad \text{(D'Arcy W. Thompson.)}$$

It is true that a film of oil may be reduced in thickness to 0·001 μ, that is, to 1/25,000,000 of an inch, but it is certain that long before we reach these almost molecular dimensions there must arise new conditions which it is not easy to imagine. Apparently in an organism 0·1 μ in diameter there can be no essential distinction between the interior and surface layers. An organism as small as 0·05 μ is probably merely a homogeneous structureless sphere composed of a very small number of albuminoid or other molecules. Its vital function must be extremely limited. Those theories of heredity which would place a whole world of separate laboratories within a body so small as to be almost beyond the limits of the microscope seem to be almost outside the limits of probability.

From precisely the same facts concerning maximal and minimal values of the magnitude of organic forms, different schools of thought draw fundamentally different inferences. One school infers that the values are the necessary limits of the action of blind physical forces; the other school infers that the limitations are due to intelligent purpose. *Why* should human reason lead to such different conclusions?

(*b*) *Analogous Forms in the Inorganic and Organic Worlds*

Forms closely analogous to the hexagonal and other prisms found in basaltic columns of the inorganic world exist in large numbers in the organic world; for instance in the enamel of teeth, in the fasciculi of muscles, and, as far as general outline is concerned, in the cells of the honeycomb, and in certain epidemic cells and pigment cells. There are also many cases of crystals presenting radiating, branching, and concentric arrangements which are likewise found in plants and animals.

Molecules seem to combine to form structures with plane, curved, and spiral surfaces, and these are found in great variety in both the inorganic and organic worlds. Common examples are angular crystals, dendrites, numerous kinds of spherical bodies, twining plants, spiral shells, spiral nerves, spiral bones, and spiral horns. The spiral formations seen in plants and animals are accompanied in many cases by spiral movements, and these movements have their analogues in nebular eddies, cyclones, spiral sandstorms, spiral waterspouts, and whirlpools.

Although, therefore, life separates the organic from the inorganic worlds, yet the two seem to be inseparably connected by many identical types of structure and movement. Any explanation of this identity of structure is necessarily a matter of opinion. One opinion is that such identity points irresistibly to identical forces being at work in both worlds, and that the evolution of organic from inorganic forms is due simply to these forces acting on particular chance molecular aggregations. Another opinion is that life is a new factor in the organic world and cannot have been evolved from the blind mechanical forces at work in the inorganic world, though it is useless to attempt to account for the origin of that factor. A third opinion is that no explanation is satisfactory that does not postulate intelligent guidance and purpose. But *why* should there be these differences of opinion when the actual basal facts admit of no question? All the opinions involve large assumptions, and not one of them admits of proof. Hence is there any reason why any one of them is more likely than the others to be in harmony with the actual facts?

(c) *Mathematical Relations in Organic Forms*

Mathematicians are now devoting special attention to the configuration of organic forms. Of a large number of interesting examples we select one, namely, the logarithmic spiral.

Let a straight line, starting from an initial position OX, rotate continuously in one direction about O, and at the same time let a tracing point P move continuously along the line, always receding from O. Then the curve generated by P is called a *spiral*. The point O is called the *pole*, OP the *radius vector* (or radius), and the angle XOP the *vectorial angle* for the point P on the curve. The vectorial angle in the figure is about 330°.

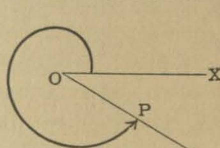

FIG. 17.

The simple screw or cylindrical helix is not a spiral, for it does not vary in its curvature. Thus climbing stems of plants are not true spirals; they are screws or helices.

The nature of the spiral depends on the law connecting the motions of P along the line and the line itself round O. The two best-known spirals are (1) the equable or Archimedean spiral, and (2) the logarithmic or equiangular spiral.

The spiral coil in which a sailor coils a rope upon the deck is an example of the equable spiral. In this case equal amounts of increase in the radius vector and in the vectorial angle accompany each other. Hence the successive sections of any radius vector as determined by successive convolutions form an *arithmetical* progression (AB = BP, etc.). And since the length of the radius vector (r) varies directly as the vectorial angle (θ), we have $r = a\theta$, where a is some constant quantity (Fig. 18).

But in the case of the logarithmic spiral the convolutions gradually increase in breadth, and do so in a constant *ratio*. As the vectorial angles increase by equal amounts and form a series in arithmetical progression, the successive radius vectors form a series in *geometrical* progression. Thus while $\angle AOB = \angle BOC = \angle COD$, etc., $OA/OB = OB/OC = OC/OD$, etc. Obviously the ratio of any opposite pair of radius vectors is constant ($OA/OG = OB/OH = OG/ON$, etc.). In this case $r = a^{\theta}$ (where a is again some constant quantity), or $\theta = \log r/\log a$, or, since a is constant, $\theta = k \log r$. Hence the vectorial angles are proportional to the logarithms of the successive

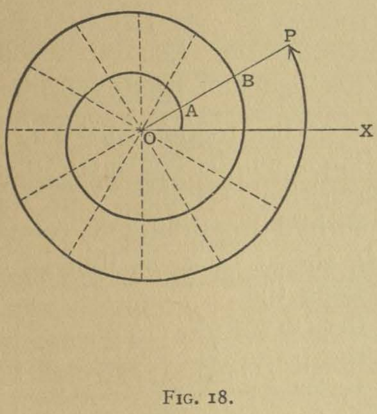

FIG. 18.

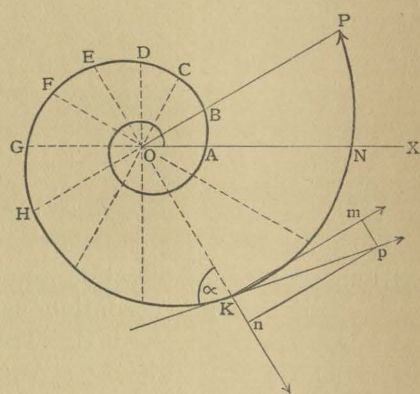

FIG. 19.

radii, whence the name *logarithmic* spiral. The constancy of the angle (α) between the tangent and the radius vector at any point is a fundamental property of the logarithmic spiral, and this gives rise to the alternative name of *equiangular* spiral (Fig. 19).

In nature, logarithmic spirals are abundant. They may be seen, for instance, in the horns of ruminants, in molluscan shells, and in the arrangements of the florets in the sunflower. Transitory logarithmic spirals may be observed in the coils of an elephant's trunk or of a monkey's tail. Biologically speaking, these spirals vary enormously; even physically they must differ fundamentally as regards the nature of the forces to which they are respectively due. Yet mathematically they are identical. There is a remarkable difference between such a spiral conformation as is built up by the separate and successive florets of the sunflower and that which in the snail or nautilus shell has grown as a single continuous tube. Despite mathematical identity, it is scarcely possible that there is a single physical and dynamical law of growth common to all cases.

In the ruminant's horn and in the molluscan shell the structure has been gradually built up by successive and continuous increments; and each successive stage of growth, starting from the origin, remains as an integral and unchanging portion of the still growing structure, and so continues to represent what at some earlier stage constituted for the time being the structure in its entirety. In a different yet cognate way the same is true of the spirally arranged florets of the sunflower. For here again we have similar portions of a composite structure serially arranged but differing in magnitude in a constant ratio according to their age.

We may conveniently look upon growth as a force, and if we assume that in a particular case, as in the case of a growing stem, its action is vertical, then, in the absence of other forces, elongation will proceed in a constant upward direction. But if some constant *external* force, for instance the wind, impinges on the growing stem, and this in a constant direction perpendicular to the normal line of growth, then the direction of actual growth will be determined by the resultant of the two forces. Hence the growing stem will tend to be bent into a curve, to which, at any given time, the force of actual growth will be tangential. This curvature is often exemplified by trees exposed to strong winds blowing frequently from the same quarter. In all such cases, however, the curve will never tend to assume the spiral form; the deflection from the normal will be limited.

But if the deflecting force be *internal*, within the growing body, and so connected with the force of growth in a system that its direction, instead of being constant, changes with the changing direction of growth, and in such a way that the angle between the two remains constant, then there is no such limit to the deflection from the normal, and the growing curve will tend to wind around its point of origin. In the typical case of the snail shell, such an intrinsic force is manifestly present in the action of the columellar muscle.

In the figure of the logarithmic spiral (Fig. 19) let a tangent be drawn at the point K in the radius vector OK. From any point p in the tangent, drop a perpendicular (90° is chosen as the constant inclination merely for convenience) pn to the radius vector, and complete the parallelogram. Then the ratio $Kn : Km$ is constant for any point on the spiral, Kn representing the normal radial direction of the force of growth, and Km the internal deflecting force. Obviously there is a constant angle (a) between the tangent (the resultant of the two forces) and the radius vector, and the constancy of this angle is, as we have seen, a fundamental property of the logarithmic spiral. In order, therefore, that the form of the outline of a growing structure may be a logarithmic spiral, it is necessary and sufficient that the above conditions may be fulfilled. It is simply a question of a constant ratio between the force of normal radial growth and some internal deflecting force.

In the growth of a shell we can conceive of no simpler law than the one nature actually follows, viz. that the shell shall widen and lengthen in the same unvarying ratio. The shell, like the creature within it, grows in size but *does not change its shape*, and the constancy of this similarity of form is the specific characteristic of the logarithmic spiral. Any part of a logarithmic spiral intercepted between any point whatever and the pole is always similar to itself. This property of constant similarity is the very property by reason of which it is peculiarly associated with the growth of horns and shells. Horns and shells do not change their shape as they grow. Each increment is geometrically similar to its predecessor, and the whole at any time is similar to that which constituted the whole at an earlier time. Despite asymmetrical growth, the shells and horns retain their unchanging form; they grow at one end only. And this remarkable property of increasing by terminal growth but nevertheless retaining unchanged the form of the entire figure is characteristic of the logarithmic spiral and of no other geometrical curve. If we look at a little nautilus shell through a magnifying glass, it becomes identical with a big one. But a little nautilus shell grows into the big one, not by uniform growth or magnification in all directions (as is approximately the case when a boy grows into a man) but by growing at one end only.

Now why, on the same facts before them, do some people see in these striking mathematical relations an intelligent purpose, and why do others ascribe these relations to the action of blind forces? Granted that forces must be at work to produce these results, are the forces due to chance or to intention? Granted that a logarithmic spiral must follow as a mere consequence of the constant ratio between the forces, is this constancy of ratio itself to be ascribed to intelligent purpose or otherwise?

(*d*) *The Forces within the Living Cell*

There are many phenomena which show that liquids behave as if they were enclosed within a stretched membrane. Thus, if we take a small wire frame and dip it into a soap solution in order to cover it with a liquid film, and then place on the film a closed loop of silk and pierce the film inside the loop, the film outside will pull the silk into a circle. The effect is just the same as it would be if the film were in a state of *tension*, trying to assume a minimum area, for with a given circumference the circle is the curve which has the largest area ; thus when the silk is dragged into the circular form, the area of the film outside is as small as possible. The tension of the film is called the *surface tension* of the liquid. The behaviour of any single drop of liquid is thus easily explained if we regard it as being covered with a thin, tightly stretched elastic skin.

Surface tension is sometimes described as the force by which we explain, for instance, the form of a drop or of a bubble, or of the surfaces external and internal of a froth or collocation of bubbles. It is a property of liquids manifested at or very near the surface, where the liquid comes into contact with another liquid, a solid, or a gas. The term *surface* is to be interpreted in a wide sense, for wherever we have solid or semi-fluid particles within a liquid, there we have a surface and surface tension.

Surface tension is supposed to be due to some force arising from inter-molecular action. It is assumed that within the interior of the liquid such molecular interactions negative one another, but that at or near the free surface, within a layer or film approximately equal to the range of the molecular force, there must be a lack of such equilibrium and therefore a manifestation of the force.

The action of the inter-molecular force has been explained in different ways. One explanation is that the molecules of the surface layer are being constantly attracted into the interior by those which are already more deeply situated, and that consequently the interior increases in volume while the surface diminishes ; and the process continues until the surface itself has become a minimum, the surface shrinkage exhibiting itself as a surface tension. This explanation is adequate where a portion of liquid is subject to no other than its own forces, and, since the sphere has, of all solids, the smallest surface for a given volume, it accounts for the spherical form of rain-drops, the spherical form of shot, and perhaps the spherical form of the living cell in many simple organisms. Many biologists see in surface tension the whole secret of the activity of the living cell, nay, the whole secret of life itself. But while we may freely admit that surface tension is a reality—so real, in fact, that it may be easily measured—its actual nature is wholly unknown, and all explanations which have been put forward are hypothetical. Further, the various hypotheses take for granted the truth of the molecular hypothesis, so that the assumptions are themselves based on an assumption.

It must always be borne in mind that our knowledge of the living cell is not only incomplete but is probably in some degree inaccurate, for it is based upon appearances which are incident to the artificial treatment which the microscopist is accustomed to employ. Histological methods of work often involve the sudden killing of the cell by strong reagents, and it is unsafe to assume that, because death is rapid, the potentially visible phenomena of actual life processes are retained in our preparations for the microscope. True, there is no doubt about the reality of such actually visible structures as the nucleus, centrosomes, and nuclear spindle of the living cell, but there are other structures seen under the microscope that are probably not truly representative of any phase of living processes.

In the phenomena of karyokinesis, the nucleus is undoubtedly a seat of energy, for movements within it are easily visible. It is these actions within the cell that seem to be of such fundamental importance, and biologists endeavour to discover how far the actions may be attributed to known physical forces. But it is almost vain to expect success if we search for the actual *nature* of the forces at work ; the most we can hope to do is, in some small measure, to account for the configuration which reveals their directions. We must be content with gleaning something of the abstract dynamics of the cell, remaining in the dark as to its specific inner nature.

Many of the visible effects within the cell tend to make us feel that the phenomena are, somehow or other, capable of being referred to dynamical laws, and it is justifiable to try to show that physical forces with which we are familiar may produce effects similar to the actions within the living cell. But it is certainly not justifiable to infer that, because such similar effects may be produced, the particular force we have employed is necessarily identical with the force actually at work within the living cell.

Just as uniform expansion about a single centre, to whatever physical cause it may be due, will lead to the configuration of a sphere, so will any two centres or foci of potential, of whatsoever kind, lead to the configuration with which Faraday made us familiar under the name of lines of force. Any region of space within which such action is manifested is a field of force, and a bipolar field is a simple example. In a bipolar field the action manifests itself symmetrically with reference to both the line joining the poles and the equatorial plane equidistant from both. But no matter what the actual physical phenomenon productive of the bipolar field may be, and no matter what its cause, beneath it is the well-known, abstract, purely mathematical relation, and this in its essence is simply and solely a property of three-dimensioned space. We have such a field of force within and around a living cell which is about to divide, and by the time the centrosome has divided the field is definitely a bipolar one. That forces within the cell exist which can bring about the result is beyond question, and analogy is strongly suggestive of a bipolar electrical field; but we must not be misled by such an analogy, for the nature of the forces within the cell is wholly unknown.[1]

Now certain phenomena apparently directly attributable to surface tension take place in obviously close association with the polar system. With precisely the same facts upon which to base a conclusion, some biologists declare that surface tension is sufficient to account for the whole of the fundamental activities of the cell, and that the surface tension is, in the last analysis, to be attributed to blind chance; while other biologists see in surface tension merely one stage of purposeful action, an action brought about by a Directive Intelligence setting free a certain number of primal energies, the primal energy we call life being that which is characteristic of the cell. Which is right? And why is there such a fundamental difference of opinion?

(e) *The Survival of Human Personality*

It is a well-known fact that an arrest of the development of the brain will result in imbecility, that a blow on the head may occasion unconsciousness, and that a brain stimulant may change the quality of our ideas. That there is a remarkably close relationship between consciousness and the brain is a fact established beyond doubt, and some authorities claim to have established not only that consciousness is a function of the grey matter of the convolutions of the cerebrum, but that the various special forms of thinking are functions of the special portions of the brain; and they have advanced

[1] For further details of these examples, and for a large number of other examples, see Professor D'Arcy W. Thompson's remarkable work, *Growth and Form*.

the interesting hypothesis that, in certain special convolutions, those processes of association go on which result in the more abstract processes of thought. Whether this particular hypothesis is true or not, there is no doubt that consciousness and the brain are connected by definite and precise laws of some kind.

When death takes place, the brain perishes. The alternative questions therefore arise: If thought is a function of the brain, does the function cease when the brain perishes? Or can mental phenomena have an existence of their own, independent of the brain?

Although, in some sense, consciousness does undoubtedly seem to be a function of the brain, our positive knowledge is so limited that we are not entitled to assert that the connection between the two is anything more than mere concomitant variation. When the brain activities change in one way, consciousness changes in another: that is all we *know*. Anything we may add is pure hypothesis, and metaphysical hypothesis at that. Of the different hypotheses advanced, we may consider two.

The first is the materialistic hypothesis. According to this hypothesis, the brain is an organ specifically destined to produce thought and all the stuff of consciousness of which the mind consists, just as the liver produces bile. The brain, receiving impressions of sensation from the various sense-organs, is forced to enter into activity, just as the stomach on receiving food materials is forced into a more intensified gastric secretion. The function of the brain is thus a productive function; and when the brain perishes, since the production can no longer continue, consciousness, the mind, the soul, must assuredly perish too. Recent forms of the hypothesis have likened consciousness to a "force" which the brain exerts, or to a "state" into which it passes; to a sort of perfume which the brain distils, or to an electric halo or glow which stimulated molecular action brings about. How a force displaying itself as a motion, as heat, or as light, can become a mode of consciousness the advocates of the hypothesis admit they cannot explain.

The second hypothesis is the spiritualistic hypothesis. It is stated in different ways, for example that consciousness had a pre-existence, possibly in some form of world-consciousness, our brains being organs for separating this world-consciousness into parts and giving these specific finite forms.

The brain is thus conceived to be specially adapted for receiving, enclosing, limiting, restraining, a stream of consciousness which it separates from the world-consciousness. The brain-cells are supposed to be specifically intended for the reception of such a stream, and the process of separation may begin when the first of such cells are formed within the embryo. If the material brain be coarse and simple, as in the lower organisms, it permits of only a slight manifestation of consciousness and, consequently, little intelligence ; if it is delicate and complex, it permits not only of a greater manifestation of consciousness but gradually of greater intelligence, and eventually of the development of self-consciousness. Thus the brain does not produce consciousness but receives it, and enables it, in association with its own specific molecular activity, to develop. It confers upon its own separated portion of the world-consciousness an individuality, with all those imperfections and variations which characterise the finite minds and souls we are familiar with.

When a brain stops acting altogether or decays, that special stream of consciousness which it subserved will be set free to rejoin the world-consciousness which supplied it, and with which even whilst here it was in some way continuous. But it would take back to that world-consciousness all the characteristics acquired during its association with the brain and thus in ways unknown to us preserve its individuality.

In both the materialistic and the spiritualistic hypotheses, consciousness is, in literal strictness, "a function of the brain," but in the latter case the brain is an independent variable, the mind varying dependently on it. Such dependence on the brain for this natural life would not make impossible the survival of the personality. According to the materialistic hypothesis, on the other hand, the mind—the soul—perishes with the body. On this point the spiritualistic hypothesis certainly seems more acceptable than the materialistic. And on another point, too : consciousness does not have to be generated *de novo* in a vast number of places. It exists already, behind the scenes, and has existed, presumably, for infinite time.

Thus the two hypotheses agree as to the connection of matter and mind, but they differ as to the interpretation of the connection. If a man loses consciousness as soon as his brain is injured, the one hypothesis explains that the injury to the brain destroyed the mechanism by which the manifestation of the consciousness was rendered possible ; the other that the machine, being put out of action, has necessarily ceased to discharge its productive functions. Clearly the former explanation is at least as good as the latter.

Does the spiritualistic hypothesis help us to conceive clearly and distinctly the possibility of the survival of our personality ? All those tendencies and peculiarities which constitute our identity; that very finiteness and those very limitations which characterise our individuality; our past successes and failures, our experiences, our hopes and fears, and the whole content of our memory: these are the things we are all so anxious to preserve. Does the hypothesis help us towards the necessary conception?

Perhaps not. It may even be admitted that the hypothesis is, in detail, as inconceivable as its rival. But the important point for consideration here is, why do the two hypotheses divide the world into two camps? Why with precisely the same facts before them do some people adopt the first and some the second hypothesis?

2. Mathematical Probability

Let us suppose that there are three perfectly sincere persons, A, B, and C, and that, on some particular subject, A holds one opinion, B another, and C has no opinion at all. One of them, say A, proceeds to burn B and C, or to hang them, or imprison them, or, at the least, to libel them in the newspapers, according to what the feelings of the age will allow; the pretext being that B and C are morally inexcusable for not believing what is true. If A is shown the absurdity of his own arguments, he promptly contends for a sort of absolute truth external to himself, which B or C, he declares, might attain if they pleased. Now let it be granted for a moment that the intellectual constitution of A, B, and C is precisely the same, and that there is ground for declaring that any difference of opinion resulting from the same arguments must be one of moral character. If then it were quite certain A is right, and if it be granted that State punishments are reformative of immoral habits as well as repressive of immoral acts, A might be justified in using, with B and C, methods which are reformative of immoral character, even if these methods amounted to direct persecution. But just as we are bound to admit that the same arguments will affect different minds differently—by differences not of moral but of intellectual construction—so we must admit that the only legitimate process of affecting a change of conviction must be that of argument and discussion.

Intolerance arises, as a rule, from inability to see how differently different persons are affected by real *probabilities*. It therefore becomes interesting to ask what it is that mathematicians, in their theory of Probability, actually number, measure, and calculate. Is it belief, or opinion, or doubt, or knowledge, or chance, or necessity, or what? Does probability exist in the *things* which are probable, or in the mind which regards them as such?

It ought to be clear that the subject of the theory cannot be "chance." Chance does not exist in nature. The exact form of every pebble on the seashore is the resultant effect of a succession of definitely acting antecedents. Chance is merely an expression for our ignorance of the causes in action, and our consequent inability to predict the result or to bring it about infallibly. There is nothing casual in nature, and in her laws there can never be any uncertainty. Such deficiency as there may be must lie wholly in our *knowledge*.

It has been said that by degree of probability we really mean or ought to mean degree of belief, and that probability may therefore be regarded as quantity of belief. But the nature of *belief* is not really more clear to the mind than the notion which it is used to define. The theory of probability does not measure what the belief is but what it ought to be. It is extremely difficult to obtain any measure of the amount of our belief. In the first place there is the disturbing influence produced on the quantity of belief by any strong emotion or passion; and in the second place there is the extreme complexity and variety of the evidence on which our belief in any proposition depends. It follows, therefore, that our actual belief at any given moment is one of the most fugitive and variable things possible, so that we can scarcely ever get sufficiently clear hold of it to measure it. Directly we begin to think of the amount of our belief, we have to think of the arguments by which it is produced—in fact, these arguments will intrude themselves without our choice. As each in turn flashes through the mind, it modifies the strength of our conviction.

We cannot but admit that the term belief is so far obscure that it cannot be measured. Yet there is undoubtedly a kind of Probability which is reducible to a definite theory and admits of calculation. The mathematical theory of probability deals with *quantity of knowledge*. When our knowledge of an event is diluted with ignorance, the event is only probable, and it is sometimes possible by exact calculation to discriminate how much we do and do not know. The theory of probability measures the comparative amounts of our knowledge and ignorance.

3. Fundamental Quantitative Notions

Fundamentally, the theory of probability consists in putting similar cases on an equality, and distributing equally among them whatever knowledge we possess. Throw a penny into the air, and consider what we know in regard to its way of falling. We know that it will certainly fall upon a side, so that either head or tail will be uppermost; but as to whether it will be head or tail our knowledge is equally divided. Whatever we know concerning head, we also know concerning tail, so that we have no reason for expecting one more than the other. The least predominance of belief to either side would be irrational; it would consist in treating unequally things of which our knowledge is equal. *We must treat equals equally.*

The theory does not require that we should first ascertain by experiment the equal facility of the events we are considering. The more completely we could ascertain and measure the causes in operation, the more would the events be removed from the sphere of probability. The theory comes into play where ignorance begins, and the knowledge we possess requires to be distributed over many cases. Nor does the theory show that a coin will fall as often on the one side as the other. It is almost impossible that this should happen, because some inequality in the form of the coin, or some uniform manner in throwing it up, is almost sure to occasion a slight preponderance in one direction. But as we do not previously know in which way a preponderance will exist, we have no reason for expecting head more than tail.

Suppose that, of certain events, we know that some one will certainly happen, and that nothing in the constitution of things determines one rather than another; in that case each will recur, in the long run, with a frequency in the proportion of one to the whole. Every second throw of a coin, for example, will, in the long run, give heads. Every sixth throw of a die will, in the long run, give ace.

The method which the theory employs consists in calculating the number of all the cases or events concerning which our knowledge is equal.

Let us suppose that an event may happen in three ways and fail in two ways, and that all these ways are equally likely to occur. Clearly, in the long run, the event must happen three times and fail two times out of every five cases. The probability of its happening is therefore $\frac{3}{5}$, and of its failing, $\frac{2}{5}$. Thus the probability of an event is the ratio of the number of times in which the event occurs, in the long run, to the sum of the number of times in which the events of that description occur and in which they fail to occur.

An event must happen or fail. Hence the sum of the probabilities of its happening or failing is certainty. We therefore represent certainty by unity.

The usual algebraic definition of probability is as follows. If an event may happen in a ways and fail in b ways, and all these ways are equally likely to occur, the probability of its happening is $\frac{a}{(a+b)}$, and the probability of its failing is $\frac{b}{(a+b)}$.

When the probability of the happening of an event is to the probability of its failure as a is to b, the *odds* are said to be a to b *for* the event, or b to a *against* it, according as a is greater or less than b.

Suppose that 2 white, 3 black, and 4 red balls are thrown promiscuously into a bag, and a person draws out one of them, the probability that this will be a white ball is $\frac{2}{9}$, a black ball $\frac{3}{9}$, and a red ball $\frac{4}{9}$.

Suppose that a bag contains 5 white, 7 black, and 4 red balls. The probability that 3 balls drawn at random are all white is $\frac{1}{56}$. For we have 16 balls altogether. The total number of ways[1] in which 3 balls can be drawn is therefore ${}^{16}C_3$, and the total number of ways in which 3 white balls can be drawn is ${}^{5}C_3$. Therefore, by definition, the probability in question is $\frac{{}^{5}C_3}{{}^{16}C_3}$, that is $\frac{1}{56}$. In other words, the odds are 56 to 1 against 3 balls drawn at random being all white.

It will not, of course, be thought that the theory of probability is ever likely to furnish us with an infallible guide. All that it can give is *the result in the long run*, as it is called; and this really means an infinity of cases. During any finite experience, however long, chances *may* be against us. Yet the theory is the best guide we can have, and if we follow it we may reduce error to a minimum.

4. Inevitable Uncertainty in the Theory

If, in estimating the probability of events, the only data we have are the mere frequency of events in the past, our inferences are necessarily much more precarious than they would be if they could be deduced from an accurate knowledge of the frequency of the occurrence of the *causes* of the events. But it is a fact that, in almost all cases in which chances admit of estimation sufficiently

[1] It is assumed that the reader is acquainted with the elementary theory of Combinations and Permutations. For some interesting experiments for testing the Theory of Probability see the author's *Scientific Method: its Philosophy and Practice*, pp. 264-5.

precise to render their numerical appreciation of any practical value, the numerical data are not drawn from the causes but from experience of the events themselves. The probabilities as to length of life at different ages; the probabilities of recovery from a particular disease; the chances of the destruction of property by fire; the chances of the loss of a ship on a particular voyage: all these are based on statistics on mortality, returns from hospitals, registers of fires, and registers of shipwrecks, and so on; that is, from the observed frequency not of the causes but of the effects. In all these classes of facts, the causes are not amenable to precise observation, and whatever inferences we draw are necessarily drawn from frequency of effects.

The element of uncertainty should always be borne in mind. If, for example, we are considering the prospect of a given particular man living another year, and we know from statistics that 9 out of 10 of his age do so survive, it does not necessarily follow that *he* will; we say that the chance of his surviving is reduced from certainty to $\frac{9}{10}$. Not only is there an element of uncertainty in the empirical law that has resulted from generalisation, but there is the further element of uncertainty in the inference we draw from such a law.

Again, since the successive powers of a fraction less than unity continue to diminish, an event which depends upon a series of very great probabilities may at last become extremely improbable. Imagine an incident to be transmitted to us by twenty witnesses in such a manner that the first has related it to the second, the second to the third, and so on; and suppose the probability of each testimony to be $\frac{9}{10}$. The probability of the accuracy of the twentieth witness's statement will be $(\frac{9}{10})^{20}$, or less than $\frac{1}{8}$, an enormous diminution in the probability. Now we all know that the further news travels the more distorted it becomes, but it is extremely doubtful if calculation will really help us to decide the degree of trust we may repose in a transmitted statement. In the first place, we make the large assumption that the probability of each testimony is (to take the above case) equal to $\frac{9}{10}$, that is, that a particular person speaks the truth nine times out of ten. Then, again, any given statement is either right, or it deviates more or less from the truth; and we might assign to it a greater or less degree of credibility according as it deviates more or less, supposing it to be possible to measure against one another the different amounts of those deviations. But this we can seldom do. The falsification of a statement depends less on the number of times it has been passed on, than on the size and sort of errors made in it each time it has been passed on. The eye-witness A may or may not have wished to communicate aright what he has rightly observed; his hearer B has or has not understood him aright, or he may have understood him and yet himself desire to hand it on in a distorted form; a third person C, who intended to distort afresh what he already misunderstood, may chance to hit upon the actual truth in what he communicated. It is hardly conceivable that the trustworthiness of a communication depends, in any regular manner, merely on the number of times it has passed from mouth to mouth.

Obviously, then, to the transmission of historical evidence the theory of mathematical probability can hardly be made to apply. It is, in fact, easy to show that, in its range of applications to affairs of every-day life, the theory has extreme limitations.

5. Non-Calculable Probability

As we have seen, the mathematical theory of probability deals with a special combination of knowledge and ignorance, the joint effect of which is to justify us in supposing that the particular collection of events with which we are concerned are happening at random. If we could calculate the complex causes which determine the fall of a penny, we might conceivably deal with pennies individually, and the theory of probability might be dispensed with. But we cannot, and ignorance is therefore one of the conditions required to provide us with the kind of chaos to which the theory of probability may most fittingly be applied. But a no less necessary condition is knowledge, the knowledge that no extraneous cause or external tendency is infecting our chaotic group with some bias or drift whereby its required randomness would be destroyed. But *how far* can we carry this process of extracting knowledge from ignorance? Suppose we argue in this way: the universe either has a Spiritual Creator or it has not; there can be no reason for preferring one alternative to the other; therefore the chances of the existence of God are even. Clearly such reasoning involves an entire misuse of the mathematical theory of probability, and rests on an imperfect analysis of the conditions under which any sort of calculation is valid. Nevertheless there is a good deal of doubt about the limits within which the theory may properly be applied. However, no matter where those limits are placed, there usually lies beyond them a kind of probability yet more fundamental, about which mathematics can tell us nothing.

The distinction between calculable and non-calculable probability is thus drawn by Mr. Balfour.—The doctrine of calculable probability has its assured application only within groups whose character is either postulated or is independently arrived at by inference or observation. These groups, be they natural or conventional, provide a framework marking out a region wherein prevails the kind of ignorance which is the subjective reflection of objective "randomness." This is the kind of ignorance which mathematical probability can most successfully transmute into knowledge, and herein lies the reason why the mathematical theory finds its happiest illustrations in games of chance. For in games of chance the group framework is provided by convention; perfect randomness is secured by fitting devices; and those who attempt to modify it, for instance by using marked cards or loaded dice, are rightly regarded as cheats.

The second kind of probability, "intuitive" probability as Mr. Balfour calls it, lies much deeper, and none of the observations just made applies to it. We rely upon it for solving many of the problems of every-day life, and it supplies the ultimate ground of all scientific theory. It has nothing to do with randomness; it knows nothing of averages; it obeys no formal laws; no light is thrown on it by games of chance; it cannot be reduced to calculation. How, then, is it to be treated? One important example of a belief which possesses the highest degree of intuitive probability, but no calculable probability at all, is the belief in an independent physical universe. Another belief of the same kind is the belief in the regularity of nature.

Philosophers differ in opinion as to the precise manner in which we pass from particular experiences to general laws, from beliefs about individual occurrences to beliefs about the ordering of the universe. Such beliefs are undoubtedly due to a long train of causes, and among these causes are some which claim to be reasons, but beliefs about what is not experienced cannot be logically extracted from particular experiences, multiply them as we will. It is vain to attempt to give an air of rationality to this leap from the known to the unknown by the use of logical terminology. Every process of induction involves an hypothesis of some kind. No induction is therefore capable of being absolutely proved or disproved. The greater the number of instances, the greater the probability of the general truth, but the completed generalisation necessarily takes a leap into the unknown. Absolute certainty is unattainable, though we may, it is true, approach indefinitely near to certainty.[1]

An inevitable belief is one which possesses the highest degree of intuitive probability. But probability being a matter of degree, a belief may evidently be more probable or less probable. Inevitableness, on the other hand, seems to be insusceptible of gradation. It is, or it is not. Thus our beliefs about the universe may be said to vary from irresistible coercion to faint and doubtful inclination. Our belief about the reality of the external world, and of the reality of nature, is of the coercive kind; other beliefs are merely probable —they are beliefs to which we feel inclined but are not driven.

Inevitable beliefs which are fundamental without being axiomatic; which lack definiteness and decision; which do not seem equally applicable to every field of experience; these are open to suspicion by many philosophers and many men of science, who regard it as a kind of sacred duty to abstain from seeking guidance from mere tendencies, fearing to be led into error instead of to truth; and any sort of antecedent preference for this or that sort of explanation they look upon as intellectual immorality. In theory, they resist any leaning towards one kind of conclusion rather than another. Too often, however, they unconsciously fail to practise what they advocate.

It is sometimes possible to detect, even in men whose intellectual probity is beyond question, leanings towards certain types of belief, inclinations towards conclusions in one direction rather than another. Few men can bring themselves to accept, for instance, any evidence that seems to contradict the law of causation; and no man of science can be provoked, by any seeming irregularities, into supposing that the course of nature is subject to lapses from the rule of perfect uniformity. There is also a reluctance to accept as final any scientific explanation which involves a belief in "action at a distance." Of tendencies feebler and less general there are also many. Why right down through the ages since the time of Democritus has there been a general agreement that matter is made up of atoms? Differences in detail there have been, but over fundamentals there has been complete agreement. Even in Newton's time there was no shred of experimental evidence to support the theory, and the original theory was most certainly not established by experience. How, then, did such a belief come into existence, anticipating evidence, guiding research, and now apparently turning out to be true? We can only ascribe it to a

[1] Cf. Chap. IX. § 3.

feeling of intuitive probability. The belief was never irresistibly coercive, and perhaps is not even so now. Nevertheless we instinctively feel that the belief has much probability to support it.

Such beliefs tend to grow or decay according to the intellectual tendencies current. They are often inconsistent, and they perpetually change their form under pressure of new scientific discovery. Atomism in one form, for instance, follows atomism in another. They must not be confounded with ordinary scientific hypotheses, for they are something more and something different. Like these they are guesses, but they are guesses directed not by immediate suggestion of particular experiences but by general tendencies which are enduring though sometimes feeble. Those who make them are not, when they attempt the interrogation of nature, free from certain forms of bias.

6. Intuitive Probability in the Solution of Every-day Problems

We asked why, with precisely the same objective facts before them, different thinkers draw different inferences and build up such fundamentally different systems of opinions and beliefs. The facts may be about the mathematical relations of organic forms, or the activities of the living cell, or the survival of human personality, or a hundred other things of equally fundamental and far-reaching importance. Two men, equally able, equally well-informed, equally sincere, seem to be coerced into arriving at diametrically opposite conclusions. Thus one may become a materialist and the other an idealist, or, it may be, the one an atheist and the other a deist. Why?

When we choose between alternative hypotheses which are equally consistent with all the facts available, the reasons for our choice are necessarily wholly subjective; and this is as much as to say that our reasons are in part due to temperament, in part due to the opinions and beliefs already stored away in the mind. Temperament is a virtually unchangeable factor: a pessimist, for example, will never see things with the eyes of an optimist. But the existing content of the mind at any time is very largely an affair of accident. In no small measure it is due to the particular environment of childhood. The mind of the pre-adolescent is readily susceptible to impressions, and receives opinions uncritically. Its content will therefore depend upon the society in which the child has moved and the education it has received. A parent or a teacher who desires a child to grow up with definite political, social, or religious leanings, takes in hand a very easy task ; the clay is readily moulded, and into it ineradicable prejudices are readily wrought. Each adult mind's stock of ideas, opinions, beliefs, convictions, doubts, and prejudices has, then, come to it, often unconsciously, through early environment and education, through language, from friends and acquaintances, from books and newspapers, and from other sources almost innumerable ; and little by little the stock is increased, each new addition modifying, and being modified by, the previously existing whole. Thus whilst it is true that the content is due to experience, the greater part of the experience has been unconsciously acquired ; and when in later life the mind attempts to bring this content under critical review it not only fails to trace the greater part of it to its origin, but all unsuspiciously is apt to accept it as something which has come to it from outside experience, as innate, and perhaps even as inspired. Reasoning thus proceeds with an unconscious bias in a particular direction.

It is precisely this bias which is apt to operate in all cases of intuitive probability, and since the choice between such alternative hypotheses as those referred to in the earlier part of this chapter has to be determined by intuitive probability, it follows that it is extremely difficult ever to arrive at a strictly impartial decision. For we are not weighing objective evidence, we are being coerced by an unconsciously personal predilection. It is not a question of insincerity of conviction or of analysable personal prejudice. Our choice is made simply because we have lived in a particular psychological climate. We ask which is the more probable of two hypotheses, and we allow our intuitions to decide, but our intuitions are coloured by our prejudices, and it is impossible to say whether the choice we have made is nearer to objective truth than the alternative choice would have been.

If we wish to decide whether or not, for example, there is a Supreme Intelligence, we must, in the dry light of the intellect, weigh the known opinions, for and against, and the evidence adduced in their support. At bottom, the question is one of degree of probability, into which pure reasoning can enter only slightly. The decision must depend largely on our intuitions, but if we allow it to be affected by our wishes, no matter in how slight a degree, it is of no value.

The spirit of natural science induces in the minds of its followers a certain fanaticism of veracity, a determination to see things as far as may be in a white light, a horror of allowing personal predilections and sentimental antipathies to lead astray the searching intelligence. But of course it may be carried too far, for the human world does not move in the rigid and changeless ways in which the physical universe does; personality and free-will are great factors to be allowed for. Those whose training has been altogether in the field of physical science are apt to reject or undervalue evidence of a less decided and definite character than that to which they have been accustomed. Their agnosticism is apt to be excessive, and they forget the necessity of arranging truth in a scale of degrees, ranging from absolute certainty, through moral certainty, high probability, low probability, possibility, slight possibility, down to impossibility. The important thing is not to place among things absolutely certain those things which our intelligent conscience pronounces to be uncertain. It is folly to try to drug ourselves into security by confusing certainty with probability and possibility.

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CHAPTER XI

CAUSATION [1]

1. Causation in Dynamic and in Static Systems

A VIOLENT ring of the bell startles the servant; the servant treads on the dog's tail; the dog jumps against my chair; I drop the sugar-tongs into my coffee; the dropping of the sugar-tongs is followed by a splash; the splash is followed by a coffee-stain in the table-cloth. It is common to say that the stain is "caused" by the splash, the splash by the dropping of the sugar-tongs, the dropping of the sugar-tongs by the movement of the dog, and so on, until we get back to the cause of the ringing of the bell. Any one of the sequence of actions might be selected as being the cause of the coffee-stain, but as it is customary to select that action which seems to be most immediately followed by the particular change to which attention is drawn, we say that the coffee-stain was caused by the splash. At every stage there is *action*, and there is a *change*; and the action is *followed* by the change.

The coffee-stain is the layer of coffee in contact with the table-cloth. This layer of coffee does not appear simultaneously with the splashing of the coffee; it *follows* the splashing. The *action* of the splashing is the *cause*; the *change* from a clean table-cloth to a stained table-cloth is the *effect*. Briefly, the splashing is the cause, the stain is the effect.

Dense white fumes of ammonium chloride are formed by mixing the two colourless gases hydrochloric acid gas and ammonia. The *cause* of the formation is an action, viz., the mixing, but the formation is not simultaneous with the mixing, it *follows* the mixing. The effect is the *change* from invisible gaseous particles to visible

[1] This chapter was largely rewritten on the appearance of Dr. C. A. Mercier's book, *Causation and Belief*. Modern conceptions of energy now make inevitable, however regretfully, the final abandonment of the main positions of Hume and Mill.

solid particles. If the action could be slowed down and we could actually witness the procedure of the molecular combinations, the intermediate stages would be identified ; but these being unknown we have to be content with saying that the action of the mixing is the cause of the combination. As science advances, we may become familiar with a more proximate cause of the formation. If we are asked to say why we conclude that the mixing is the cause of the formation, we say it is because of the *immediate sequence* of the appearance of the white fumes. The immediate sequence seems to compel us to recognise a *necessary connection* between the action and the effect.

Cancer of a certain kind is never found except among chimney-sweeps. We therefore conclude that chimney-sweeping is the sole cause of that kind of cancer. We do not know how the effect is brought about by the action, or what intermediate stages there may be between the action and the effect. The constant association seems to compel us to infer causation. We feel sure we know the ultimate cause though presumably not the intermediate causes.

It is wrong to say that the cause of the surprise of the army was the sentry's *being* off his post. The sentry's being off his post is not an action, and therefore not a cause. It is right to say that the sentry *deserting* his post was the cause of the surprise, for this implies action ; and for the same reason the bribery of the sentry may properly be called a cause of the surprise.

In all these cases we have been dealing with the relations within a dynamic, successive system. But there are other cases within an entirely different system, viz. a static simultaneous system.

To say that the weight of the atmosphere is the *cause* of the height of the mercury in the barometer is not strictly correct, for the height of the mercury is not a change. The fact here to be accounted for is not a change but the absence of change—the non-sinking of the mercury despite its tendency to sink under the action of gravity. In other words, the fact to be accounted for is the relations within a static simultaneous system.

The *rise* and *fall* of the mercury are caused by the increase and decrease of the air-pressure ; each variation of pressure is immediately followed by a *change* of level of the mercury. But when the mercury remains stationary at a particular level, the *reason* is the constant pressure of the atmosphere. In the former case we have action within a dynamic successive system ; in the latter there is no apparent action ; the system is static and simultaneous. It is, of course, true that, even in the case of the static system, the system is maintained by the action of the pressure of the air, but whereas in the dynamic system the action always precedes the change, in the static system the action is always contemporaneous with the maintenance of the absence of change.

It is thus incorrect to say that there is no causation unless the cause is always followed by the effect and the effect is always preceded by the cause. In all static systems, for instance in the maintenance of the motion of the locomotive, in the suspension of a weight by a cord, in the prolonged boiling of water, cause and effect are simultaneous, though, of course, every such system had its origin in a dynamic system where the effect followed the cause; and this being so, it is the dynamic successive system that claims our chief attention.

2. Cause and Effect. Reason, Result, Conditions

Cause and effect comprise something more than a dual whole, for there is a link which unites them together. With this link they form a triple whole. The link which thus unites cause and effect is *causation* or *effectuation*, according to the point of view from which we regard it.

Any change to which we are well accustomed, for instance, a change from day to night, or from rain to sunshine, we contemplate as a change merely; it rarely occurs to us to look behind the change for the cause, or to regard the change as an effect. Such changes are part of a changing routine whose changes rarely impress us because they are customary. But if the routine should cease to change in its customary manner, the break in the routine would form a change that would impress us at once, especially if it were rapid or sudden. Such a change would impress us as an *effect*, and the mind would inevitably be driven to seek for a *cause*. In such a case the change is identified with the effect, or is at least inevitably associated with it, for in occurrence they are inseparable. An unaccustomed noise is a noteworthy example of this. On hearing a sudden noise the mind instantly passes from change to cause, unconsciously regarding the change as an effect. The element of change that impresses us is unusualness.

But when we are dealing with a static simultaneous system, that is when there is an action tending to produce a change which yet does not take place, we inevitably assume, if our attention is drawn to the case, that the absence of change is due to some counter-action, and we regard this want of change as an effect. If we pull a drawer and it does not move, then the want of change despite our action tending to produce change is an effect, and drives the mind to seek for a cause: the drawer is locked, or the wood has become damp and swollen. It is that which actually produces a change that is properly called the *cause* of the change, and the term cause is therefore best applied only to a dynamic successive system. To that which is the cause of a want of change, it is preferable to apply the term *reason.* The pull we exert on the handle of the drawer is the *cause* of the drawer opening; the drawer being locked is the *reason* why it does not yield to the pull. In the latter case we have a static simultaneous system. Either a change, or an absence of change if regarded as an effect, is always associated in our minds with cause and causation.

The cause of a change must be sought in some action which precedes the change. But causation and antecedence are not the same thing. In a dynamic successive system, antecedence always goes with causation, but in a static simultaneous system the cause does not precede the effect. A drawer may be locked long before and long after it is pulled upon to open it; its being locked is the *reason* why it does not yield to the pull; the *cause* of the want of change is the resistance of the tongue of the lock, and this resistance is an action which effectually counters the action of the pull. The resistance begins with the pull and ends with the pull, but as long as the pull lasts the resistance lasts: the system is static.

We may therefore describe an effect as a change connected with a preceding action in a dynamic system, or an absence of change connected with an accompanying action in a static system, on the thing changed or not changed, respectively. When iron rusts, the rusting is an *effect,* for it is a *change* from metallic iron to oxide. It remains rusty, but it is not correct to say that the effect continues. What persists is not the effect, not the change, but the *changed state,* the new state that has resulted from the change. The changed state is the *result.* A result is the changed state of a thing on which an effect has been produced.

It is sometimes denied that a change is produced by the action of some agent. But we can no more imagine a change to be produced without the action of an agent than we can imagine resistance without extension or solid without surface. True, our notion of force or power is vague, but a change in a thing without action on the thing is inconceivable. Cause always carries with it the notion not merely of action but of the transference of action from the acting agent to the thing acted on.

Thus in a dynamic system we may define cause as an action connected with a following change in the thing acted on; and in a static system, as the cessation of action connected with the accompanying absence of change in the thing acted on. But in the latter case it would perhaps be more correct to speak of the cessation of action not as a cause but as the removal of a cause.

Medical men sometimes speak of "predisposing" causes of a disease, such as the age and sex of the patient, the climate and locality of his residence, and the like. But these are neither actions nor cessations of action, and are therefore not causes. Yet they undoubtedly have an influence on the effect; they are, in fact, *conditions* of the effect.

The distinction between a cause and a condition is that a cause is an action and a condition is a state; not necessarily a permanent passive state, though a state having passive endurance, however brief. Like the cause, the condition must be connected with the change in the thing acted on. The pulling of the trigger is the *cause* of the discharge of a gun; the presence of a cartridge in the barrel is a necessary condition of the discharge. The cause of the sound of a piano is the action of the hammer on the wires, but the effect could not be produced except for the air around the piano; the existence of the air is therefore a *condition* of the sound. Many necessary conditions are concerned not with the thing itself acted on, but with something around or near that thing.

But there are many things around or near the thing acted on that are in no way concerned with the effect produced by the action. The piano may be in a room containing furniture and a dog, but the presence of the furniture and that of the dog are not conditions of the emission of the sound. A condition must be *material* to the effect.

3. The Mark of Causation

It is sometimes said that *immediate sequence* is a mark of causation, but this cannot be admitted without qualification. If a man is stabbed to-day and in consequence dies 24 hours later, it is clear that, in the consideration of the cause of his death, time is an element that cannot be disregarded. It is true that the action of the stabbing probably starts off a long series of other actions which ultimately end in death; it is conceivable that this series is almost indefinitely great. Nevertheless at each step there is a *change*, and every change requires time, however short. Of course there is no time *gap*: that is inconceivable. The first cause A, the stabbing, produces the effect B, which then becomes an intermediate cause to produce a further effect C; and so on to the end. Although only a few intermediate stages are usually recognisable in such a series, we are certain there can be no time interval; the series is continuous, but every one of the changes must take time. The time element is essential; every action must endure for *some* time, however short. Even the formation of water when a spark is passed through a mixture of hydrogen and oxygen, even the lightning flash, takes time. It is easy to imagine any process slowed down, so that all the intermediate stages may be clearly seen. A change necessarily takes place *in* time, and *consumes* time. The very term change implies duration. Absolute immediacy is out of the question, though we may sometimes find it difficult to imagine even an indefinitely small fraction of a second between the initiation of the action and the change which becomes manifest to our senses.

The cause of a cause is the cause of the effect. The universe is a continuous series of changes. In this continuous series we may take any section we please and call the first change in this isolated section the cause of all or any that follow; the last, the effect of all or any that have gone before; and we can call the first the cause of the last, and the last the effect of the first.

It is sometimes said that the most characteristic mark of causation is *unconditionalness*, and yet those who make this assertion define cause as the sum of the conditions, or the totality of the conditions. Obviously that which depends upon conditions cannot be unconditional. A cause must not be confused with its conditions.

It is sometimes said that the most characteristic mark of causation is *invariability*. But the term is ambiguous. When it is said that the cause is the invariable antecedent, what is presumably meant is that the cause is that antecedent which does not vary. But an antecedent often does vary; for instance, the pressure of the gas of an exploding cartridge is the cause of the propulsion of the projectile, and this pressure varies from moment to moment as the projectile travels along the barrel of the gun. When it is said that the effect is the invariable consequent, what is presumably meant is that the effect is that consequent which does not vary. But a consequent often does vary; for instance, the speed of a train varies with the gradient of the track. If, however, invariably means always, and means that, so long as the present constitution of things endures, like causes under like conditions will always be followed by like effects, the term is less open to objection

It is sometimes said that the most characteristic mark of causation is *antecedence*. This does seem to apply to the relations that obtain within a dynamic successive system. The cause has a certain duration, and during every instant of that duration it is in action and is causing more and more of the effect. The effect also has a certain duration. As the cause begins to act, the change begins to occur; as the cause continues, the change increases; when the cause ceases to act the effect has reached its maximum, but the effect as an effect, that is as a progressing change, now also ceases, and becomes a result. The total effect is not reached until the cause ceases to act, and it is only in this sense that the effect succeeds the cause, and that cause and effect are antecedent and consequent. In the case of a static simultaneous system, antecedence is not applicable. Here cause and effect are simultaneous.

Can, then, a specifically characteristic mark of causation be found? Night always follows day and the two are connected, but yet night is not the effect of day. Mere connection in sequence does not *constitute* causation even when the sequence is constant (an acceptable meaning of invariable); yet it is clear that the connection in sequence does *depend on* causation. The connection between day and night is that they have a common cause, the rotation of the earth with reference to the sun. Thus the connection between antecedent and consequent is indispensable to causation.

Night follows day and is connected with it, but night is not the effect of day because, although there is a connection between them, the connection is not between an action of the day and a change in the thing acted on. Day does not act on anything to cause night. What, then, is the *nature* of the connection between cause and effect? The action is so connected with the change that if the action had not taken place the change would not have occurred; and the action taking place under the conditions it did, the change connected with it was unavoidable and unpreventable. Thus the specifically characteristic mark of causation seems to be the *necessary connection* between cause and effect.

4. Plurality of Causes

The term Plurality of Causes is open to some objection. When it is said that an effect is due to a plurality of causes, what is meant is that if several effects resemble one another in some particular, one may be due to one cause and another to another. The death of A is due to one cause, stabbing ; that of B to another, shooting. The causes are certainly different, but then so also are the effects. The effects are different, occurring on different occasions, in different circumstances, to different persons. Both effects include the factor death, but the effects are not death but different deaths. When we say that many causes may produce death, we mean that many different causes may produce many different deaths. If we generalise the common factor in many deaths, and call it death, we must generalise the common factor in all the causes of these deaths, and call it the cessation of the heart's action. If we seek the causes not of an effect but of a common factor in many effects, such as deaths, we are really seeking an *alternity* [1] of causes ; plurality of causes does not apply to the common factor but to the plurality of effects.

5. Regression of Causes

But there is a sense in which every event has many causes. The splashing of the coffee was caused by the dropping of the sugar-tongs ; the dropping of the sugar-tongs was caused by the movement of the dog ; the movement of the dog was caused by the action of the servant ; the action of the servant by the violent ring of the bell ; the violent ring of the bell was an action due to the impatience of the visiting tradesman ; the impatience of the tradesman was due to the peremptory orders of his financially embarrassed master ; the financial embarrassment was due to the torpedoing of a cargo by a submarine ; and so we can continue the series backwards as far as we like to go. There is a continuous regression of causes from the first effect to the last action, and a continuous progression of effects from the first action to the last effect. It is the same with every case of cause and effect. The actions stretch backwards in series as far as we like to trace them ; and the effects proceed forwards down to the present moment, in which, as actions, they are carrying on the chain of effects into a futurity of indefinite duration. The action of the submarine was due to the action of the gunner, the action of the gunner to the orders of the commander, the orders of the commander to the orders of the War Council ; and so we trace our way back to the causes of the war, to international jealousy, to primitive rivalry, to primitive man, to the beginnings of life, to the origin of the earth, to the origin of the universe, until we are lost in the regress. Every action in the long series was

[1] The term *alternity* is now almost obsolete, but in the text it represents the intended meaning more accurately than the commoner term *alternation*.

caused by some previous action, and produced as its effect a subsequent action. Action once taken goes on producing its effects, in succession, indefinitely. Thus there is a sense in which every effect has a plurality of causes, has an indefinitely great multitude of causes, stretching back in continuous series indefinitely in past time.

Actually, however, the series is much more complex. An effect is produced by action upon a certain thing under certain *conditions*, and, for the production of the effect, the thing and the conditions are just as necessary as the action that is the immediate cause. The thing and these conditions are themselves the results of causes which are therefore also necessary to the effect. The cause of the stain was the splashing of the coffee; this action was the direct and approximately immediate cause; but every action that went to build up the conditions necessary for the splashing was a cause, more or less remote, more or less indirect, of the splashing. A necessary condition of the splashing was that the cup should be sufficiently full of coffee for the dropping of the sugar-tongs to bring about the splash, and the pouring of sufficient coffee into the cup was the direct and immediate cause of this result, and as this result was a condition of the splashing, the cause of this condition was a cause of the splashing. So with all other conditions material to the effect. Every material condition itself has a cause, and as this cause is a cause of the condition it is an *indirect* cause of the effect.

The case may be carried even further. For all the actions involved in manufacturing the coffee-cup, the coffee-pot, and the sugar-tongs, are indirect causes of the splashing; the existence at hand of the necessary materials for the manufacture is a necessary condition of the manufacture; and the actions by which these conditions were brought about, by which the materials were obtained, are also indirect causes of the splashing, causes that are not only indirect but remote also. And so we may go back to the deposit of the clay and the minerals, indirect causes still more remote; and eventually we are again lost in an indefinite regress. In a similar way we may consider any other material conditions, for instance the purchase of the dog or the fitting of the bell. Each one leads to an indefinite regress.

But apart from the line of indirect causes, the line of direct causes may bifurcate at almost any point. The torpedoing of the cargo, for instance, was partly due to the action of the enemy, but partly to the captain and owners of the cargo-boat, or the boat would not have been where she was when the torpedoing took place. Obviously both the direct and the indirect causes ramify as we go backward from the effect. The conditions may be many, and each may have many causes, depending on other conditions, which again may be many ; and so on.

Out of all these different series of innumerable causes, it is usual to select *one* and to call it *the* cause. *The* cause is, of course, a *direct* cause and as nearly *immediate* as we can ascertain it to be, though oftentimes there will be many intermediate causes of which we have no knowledge. Speaking generally, the direct cause we select depends on the purpose in view, upon the aspect of the matter in which we are interested.

During rifle practice a wayfarer gets into the line of fire and is killed by a bullet. What is the cause of his death ? To the physiologist, it was the arrest of the heart's action ; to the student of ballistics, it was the low trajectory of the bullet ; to the marksman, it was the force of the wind which deflected the bullet from the line of aim ; to the squad-instructor, it was the failure of the marksman to respond promptly enough to the order, cease fire ; to one leader-writer, it was the deplorable carelessness of the soldier ; to another, the stupidity of the civilian in crossing the line of fire ; and so on. Every one of these may legitimately be considered as a cause, but if we are asked for *the* cause, we must know for what purpose the question is asked.

6. The Law of Universal Causation

The Law of Universal Causation may be thus formulated : Every event has a cause.

That every event has a cause is a general belief, and the belief is derived from experience. Man has always lived by action, and his every act has been an instance of causation ; it has been an action on something, and has produced a change in the thing acted on ; it has been a cause and has produced an effect. Hence with respect to his own action, the notion of causation is in every individual inescapable and perpetual. Further, there is his negative experience, equally inescapable and equally perpetual, that we cannot produce a change in anything without acting on that thing, either directly or indirectly. The conviction is perpetually enforced upon us that change cannot occur without action of or on the thing changed, or, in other words, that every event has a cause.

The warrant for our belief is experience repeated with incalculable frequency without a single contrary instance. The belief therefore seems coercive, and its truth certainly reaches a very high degree of probability.

7. The Uniformity of Nature

The uniformity of nature is usually regarded as axiomatic. The axiom may be thus formulated : Like causes under like conditions produce like effects.

The axiom commonly takes the form, The same cause is always attended by the same effect. But a state of things once passed can never in all respects be reproduced. To get the same effect the same cause must act on the same thing under the same conditions, but the cause is never the same, the thing is never the same, and the conditions are never the same. In this sense there is no such thing as the uniformity of nature. As far as our experience goes, nothing in the universe ever has or ever will exactly repeat itself. Still, the more nearly alike the actions, the things acted on, and the conditions, the more closely alike will the effects be.

Although the universal experience of mankind goes to show that the truth of the so-called axiom, Like causes under like conditions produce like effects, is empirically highly probable, it is doubtful if it ought to be put forward as an axiom. Its contradictory is certainly not inconceivable, though perhaps incredible. It would be rash to apply such an axiom to regions which never come within the range of finite experience, and even as regards regions which do come within that range we are bound to admit that nature does not always *appear* regular. But what we may indubitably assert is that the more we examine nature the more regular it appears. The reign of law is always extending. Anomalies vanish as knowledge grows.

The belief in the axiom is not based either on observation or argument but on intuitive probability. If we refuse to regard nature as liable to lapses from perfect uniformity, this is not because such a theory is inconceivable, not because it is contrary to experience, not because it is incompatible with knowledge, but because it is out of harmony with the ideal we have formed of what the material universe ought to be and appears to be ; and so strong is this speculative prepossession that there is no experimental evidence which would convince a man of science that when physical causes are similar and the conditions similar, the physical effects could be different.

Thus the so-called axiom is an ideal, not susceptible of proof, possibly true, but not *known* to be true in virtue of any available evidence. What is certainly known as a matter of empirical science is that certain similar causal relations are observed to hold amongst the members of a group of events at certain times, and that when such relations fail, as they sometimes do (and then we talk of "exceptions"), it is usually possible by enlarging the group to discover a new causal relation which will embrace the whole of the cases under consideration. Any such causal relation may conveniently be termed a causal law. But *all* such causal laws are liable to exceptions if the cause embraces less than the whole state of the universe, though every time we enlarge the group the law becomes more comprehensive.

8. The Metaphysical Problem

Hume was of opinion that our notion of causation is a generalisation from many individual experiences. But he further assumed that, because the notion of causation is a generalisation from repeated experiences, therefore causation itself not only does not exist in isolated or single instances, but does not exist at all—it is a mere mental fiction without any corresponding relation in fact. He denied that the idea of causation implied *necessary connection* or *power* between the cause and the effect; he asserted that what we call cause and effect is nothing but casual antecedence and consequence.

Hume's denial that power or force is ever revealed in a single instance is difficult to understand. The breaking wave carrying away cartloads of shingle in the undertow; a hurricane uprooting trees: surely these convey the idea of power or force. Hume says that experience only teaches us how one event constantly follows another, without revealing the secret of the connection which binds them together. This we may grant; the particular secret of the connection may be hidden, but the important point is that there is a connection and that the connection is necessary.

Professor Karl Pearson also denies that there is any "enforcement" of an effect by its cause, or any connection between them. The one merely happens to follow the other. Our notion of force is purely imaginary, and has no counterpart in the world outside. But if by cause is meant mere antecedence, and by effect mere succession, the old fallacy *post hoc ergo propter hoc* would be an unassailable truth, and Monday would be the cause of Tuesday. In forming the notion of cause and causation, the enforcement of the effect by the cause is an inseparable and necessary element.

Hume's and Professor Pearson's views are shared by several prominent writers, and the antagonism of some of these writers to the notion of enforcement is apparently due to the consequences that must logically follow. If everything is to be regarded as necessarily connected with prior things or actions, it follows that an investigation of existence must involve an indefinite regress. We are thus led to the postulate of a First Cause, and then we may, for example, either accept, with one metaphysical school, a personal and self-existent Creator, or, with another school, the doctrine of the Absolute.[1] Both explanations are alike in this respect, that at a certain point they pass from the sphere of the senses, the physical world, to a metaphysical sphere in which the data and the intellectual operations of cognising them are of a totally different character.

The apologist for the Absolute argues that the conception of cause, as involving a transition in time, cannot be ultimately valid, since the time-relation is not ultimately real. But this assertion, which is contrary to all ordinary experience, we have as much right to deny as the Absolutist to affirm. Its underlying assumption is that reality consists of a static system of universals, a view now held by only a few prominent philosophers who are temperamentally averse from admitting that progress is an essential part of nature's scheme.

The origin of our idea of " enforcement " is not easy to determine. Locke thought it was derived from the knowledge of our own activity, or, in more modern phraseology, that a man has a conception of cause primarily because he himself is a cause. The conception thus obtained we transfer to external objects, so far as we may find it useful to do so. Thus it is by a sort of analogy that we say that the bomb " caused " the destruction of the building.

Whether this be so or not, we may fairly confidently assert that our notion of enforcement is not derived exclusively from the generalisations of outward experience. Our conviction is, primarily, not of a general truth, but relates rather to individual facts presented to or contemplated by the mind. Our ultimate belief in cause and effect is probably largely intuitive, but to what extent conscious experience contributes to the contained essential notion of a necessary connection, it is impossible to say.

A cause is an action upon a thing. In the physical world, action means the transfer or liberation of *energy*. Energy neither appears out of nothing, nor disappears into nothing ; but every manifestation of energy is the release of energy from store or its transfer from one

[1] See the next chapter.

thing to another. If it is expended from store, then at some past time it must have been put into store by some action or other. If it is transferred from place to place, such transfer is action, and action was as necessary to put it into the place from which it comes as to put it into the place to which it goes. In short, action which is cause is also either effect or result. It is always produced by previous action.

In addition to the secondary qualities[1] regarded as effects of certain energies of a body upon a sensitive organism, a body is sometimes said to have "power" or powers whereby it acts on other bodies. These powers, like the secondary qualities, are traceable to the primary qualities or the modifications of them. They are powers of "attraction" or "repulsion"[2]; of absorbing, reflecting, or radiating light and heat; of generating or conducting electricity; of synthesis, growth, and reproduction: all generally regarded as reducible to movements or tendencies to move on the part of the atoms, molecules, cells, or whatever units constitute a body. In every case we are dealing with *energy*.

In making use of such words as energy, force, power, we seem to attribute to objects a feeling corresponding to our own feelings of muscular exertion, which is in fact the ground of all primary qualities. But all we mean is that the power or force, or whatever it may be, belongs not to the thing's feeling but to the thing's activity. Since the materialist argues that from nature comes all that we have, he should be the last to deny her some small negligible share of all she has endowed us with.

But though causation is concerned equally with human action and with the action of inanimate nature (we neglect other living things) the two actions are entirely distinct. Human action is determined by the will. Any particular action of inanimate nature that may attract our attention is but a momentarily and artificially isolated, and relatively infinitesimal, amount of nature's store of energy being transferred from one place to another. In pursuing her relentless course, nature has her own method of consuming her stores of energy, and though human effort may, in some slight measure, increase or retard that consumption, we can almost imagine her treating with contempt the puny efforts of her own creatures to thwart her will.

[1] See Chap. I. § 8 (*b*).

[2] Whatever these ambiguous terms may mean.

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CHAPTER XII

THEOLOGY AND RELIGION

1. Knowledge and Faith

It has been said that the difference between knowledge and faith is the difference between objective certainty and subjective certainty. But our knowledge even of the physical world is admittedly imperfect, since the rough mental sketches we form in our minds are but imperfect reproductions of meagre experiences. Despite the fear felt by earnest students of natural science of allowing personal predilections to lead the investigating mind astray, there are some things in natural science about which there is no certainty at all, only intuitive probability, which, however, may seem so overwhelming that it is unconsciously replaced by subjective certainty, and this in its turn tends to encroach upon the field of positive knowledge: a chemist may resent criticism of the atomic hypothesis; a physicist, criticism of the wave hypothesis of light; a biologist, criticism of his own views of the nature of life: so easy is it to forget the purely provisional nature of hypotheses of any kind.

Objective certainty implies positive knowledge, whereas subjective certainty transcends positive knowledge. But subjective certainty is not necessarily traceable to intuitive probability or to any sort of intellectual process; it may have its origin in mere emotionalism. Thus faith, as distinguished from knowledge, may or may not have an intellectual origin.

But no man who really cares for truth will be willing to place among things which have attained the rank of objective certainty those things which his reason compels him to admit are still uncertain. When he reaches the confines of positive knowledge, he will without hesitation admit it, and admit, too, that relative truth is all he can ever hope to attain.

Faith in our friends and acquaintances is based on our experience of their past behaviour or on our reading of their character, and the degree to which we trust them is largely determined by likes and dislikes imperfectly thought out. Such faith necessarily goes beyond our actual experience of them, for if we trusted them only in matters in which we had known them to take a right course, our faith in them would be shadowy indeed. Although faith goes beyond the point of knowledge it does so in the belief that its content and the content of knowledge will ultimately be found to be in harmony. The faith which assents to a proposition which is obviously full of doubt is a wrong faith ; there is no merit, intellectual or moral, in an assent of that kind.

The fundamental fact of all religion is belief in God. Since, from the first, this belief strives to express itself and to render itself intelligible, it can never be wholly emotional. In any act of religious faith it seems to be necessary to postulate that the thinking self is in ontological communion with a great spiritual Power, and if such an hypothesis be accepted, an acceptable religious doctrine may be formulated. It is wrong to identify religious faith with the acceptance of some particular creed, though faith must always seek to express itself in a creed of some kind. And it is not wholly right to identify faith with an allegiance to a recognised spiritual authority, though faith must always give rise to a feeling of loyalty. Religious faith is active rather than passive ; it seems ever to be striving to give expression to an inward experience of a communion with an unseen power, beneficent and wise, far greater than itself. The whole being seems to be put in an attitude of trust. Intellectually, the attitude cannot be justified ; logically, the position is untenable. All the same, the faith is there. The faith is probably rarely the outcome of intellectual conviction, for the ways of thought and life tend to lie apart. But a faith divorced entirely from intellectual conviction is the primitive emotion of primitive man.

All our religious beliefs necessarily contain a large admixture of myth, of illusion, and of illogical compromise, and it is unfortunate that the organised Churches have tended to discourage the efforts of those who would uproot the still existing superstitious notions of a bygone age. Our mental pictures of the spiritual world of which we can have no positive knowledge are undoubtedly full of absurdities.

All religious faiths are necessarily incomplete, if only because of the limitations both of our knowledge and of our intellectual power.

In the light of growing knowledge, a contented acquiescence in the faith of the moment is indefensible. A critical spirit of inquiry is now testing traditional beliefs,[1] questioning unverified assumptions, and demurring to the dictates of imperfectly informed authority. Since Faith is always trying to embrace a larger subject-matter, its expression must always remain a working hypothesis. It is, however, something far greater than the working hypotheses of science, for it can be held with a depth of feeling which those can never inspire. It is true that men sometimes adopt a false faith because of the comfort they hope to get from it, but in all real faith there is a strong desire for truth, and it is faith because it knows that that desire cannot be entirely satisfied. It never mistakes itself for the certainty of science, yet it delights in the tests of experience, because each new test makes it more sure.

After centuries of controversy, the differences of view among mankind as to the truth of the fundamental principles of religion remain very much as they were. No agreement has been arrived at, and religious truth as a definitely formulated universal doctrine seems to be as far away as ever. Spiritual experience admittedly demands expression in some form, for a mere spiritual glow will never satisfy the inner being; as, however, the expression will necessarily be peculiar to the individual, differences of opinion are inevitable. In such circumstances it is irrational to maintain that there is only one right way of religious thought. If, then, a person to the best of his ability gives sincere expression to his own spiritual experience, an organised religion is scarcely justified in labelling that expression heresy merely because it clashes with what the religion in question conventionally calls orthodoxy.

2. Inspiration

According to St. Jerome [2] it is necessary to distinguish between what the Early Fathers set down as truth and what they wrote by way of argument; they did not hesitate in argument to postulate matters which they well knew could not be maintained in fact. Even St. John Chrysostom [3] openly advocated the lawfulness of lying in a good cause. Thus all early ecclesiastical literature became tainted with a most unblushing mendacity. The Fathers

[1] Of course this is also, to some extent, true even of the Middle Ages, as a study of the works of Duns Scotus, Occam, and others will show. But very little came of it, as the Church was resolutely opposed to the spread of knowledge.

[2] A.D. 340–420.

[3] A.D. 347–407.

sought further to justify the accepted views of the Church by means of arguments often of the crudest kind.[1]

During the next ten or twelve centuries, there gradually grew up around the original deposit of Faith an accretion of matter which in form was often beautiful and poetic, but which in substance was often fantastic and false. The truth for which the apostles gave their lives thus became impregnated with error. Organised Christianity now freely admits that not only is the rigorous sifting of the evidence not an act of impiety but in the interests of Faith is absolutely necessary.

But in sifting the evidence we must go back not only to the time of the Early Fathers but to the Apostolic Age itself. The early disciples were not trained observers or cultivated logicians ; neither the weighing of evidence, nor the discrimination between cause and effect, nor the analysis of motives, is likely to have entered into the operations of their simple minds. They were unsuspecting men, living in an age full of legends and illusions. How could any records they made escape a large admixture of error ? No modern scholar would now for a moment admit that the New Testament, to say nothing of the Old, is miraculously free from error on the ground that it is divinely inspired.

Inspiration is commonly regarded as some kind of communion with the Divine. But it is certainly not the communication of infallible truth, if only because infallible truth cannot possibly be adequately and completely conveyed in human words.

The original hypothesis of inspiration was that of mechanical dictation. The faculties of the writers were supposed to be suppressed in order that God alone might be active in them. This hypothesis had long been losing ground, and was finally and necessarily abandoned when the revised version of the Bible was issued. A later hypothesis claimed for the Bible only such inspiration as was necessary to secure accuracy in regard to matters of doctrine and conduct ; the theology and morality of the Bible were inspired, but not its history, science, or philosophy. But this hypothesis had also to be abandoned, since it failed to explain how the same human mind can by divine inspiration obtain infallible knowledge in some matters, yet be left prone to err in others.

The hypothesis which now finds most general acceptance is that since the religious and moral superiority of the Bible as compared

[1] One question of St. Jerome is worth placing on record. Wishing to clinch the doctrine that the resurrection would be a bodily one, he asked, If the dead be not raised, how could the damned, after judgment, gnash their teeth in hell ?

with the other sacred literatures of the world cannot be denied, the minds of the writers must in some way have been influenced by the Divine Spirit; that this inspiration is therefore a religious and moral enlightening of the writers, but finding an expression conditioned by their individual limitations of knowledge, experience, ability, moral preparedness, and other personal characteristics. It is further assumed that revelation is progressive and is largely dependent on the capacity of the human mind as at present evolved, and that defects in doctrine in the earlier stages are inevitable and will be gradually corrected as development proceeds. Thus inspiration is not limited to the writers of the Scriptures.

Such views seem reasonable and acceptable.

The revised version of the Bible embodies the labours of many highly competent scholars and represents the best attainable certainty, in English, as to what the Bible really means. But its acceptance implies acquiescence in criticism. Its mere existence is an acknowledgment of the necessity for free inquiry into the Scriptural records, and into doctrines founded upon an imperfect apprehension of the text. It makes for progress and liberality in religious thought. It justifies the idea that the Bible on its literary side may be treated like any other literature and by the same principles of critical inquiry. It compels the abandonment of the notion of fixity in theology. The Bible is now definitely known to be full of errors, and the old notions of verbal and plenary inspiration are thus proved to be false.

3. The Application of Criticism to the Bible

The question of the existence of God is at the basis of all religion, and, if we accept the Bible as our authority, religion means one thing and only one thing, namely, communion with God; and since the deepening of that communion is the thing that matters most, lip-service to formulas and formularies is more likely to weaken than to strengthen it.

Theology is distinct from religion; it is the science of religion. Any writer has to express his faith in the language and thoughts of his age, but these must change and develop as generation succeeds generation and knowledge advances. Thus faith has always to endeavour to express itself in a developing theology. Theology attempts to systematise religious experience, and as this experience necessarily grows with increasing knowledge, no system of theology can ever be final. No statement of doctrine can ever be true save generally and in the spirit, for no formula can ever embody it. In the light of the greater knowledge of a later age, its expression is bound to change.

Half a century ago the Bible was generally regarded by English Christians as literally the dictated "word of God." But such an idea has now to be completely given up. The Bible is a collection of books containing poetry, poetical history and politics, collections of proverbs, the civil, ecclesiastical and ceremonial laws of the children of Israel, principles of ethics, and a descriptive theology. No doubt it may in general terms be said that all these things taken together are designed to reveal the will and the ways of God to man. But, manifestly, all the parts are not of equal value as guides to conduct in the twentieth century, and the relations of those of primary and permanent importance to those of secondary and transitional importance have not been defined. In consequence, confusion reigns; and to vast multitudes the Bible has become a cause of stumbling, and not a way to God. Moreover, the series of noble personalities forming the central feature of the Biblical picture are painted on a background of unedifying legends, Eastern imagery, and unauthorised additions. The text has now gradually been purged by the scholarly criticism which is rendered possible by the advance of scientific, historical, and literary knowledge. This new criticism is bringing us into closer and more intelligent sympathy with the prophets and evangelists, helping us to understand their points of view, their environment, their difficulties, and their triumphs. Revelation has never been more than partial. And wisely so; for the prophets could never have obtained a hearing for new truths if they had not shared some of the errors and illusions of their contemporaries. Progress was necessarily laborious; the ascent towards the truth was slow. Thus the Bible must no longer be regarded as infallible, and any system of theology based upon it cannot for a long time to come claim to represent more than an approximation to the truth.

Formulated doctrine is scarcely to be found in the earliest records of Christianity. The teaching of Christ was mainly concerned with the great realities of religious experience, and shows no attempt to base on these a scheme of doctrine. The opposite view, once commonly held, must now be given up, for it has been established that the speeches of the fourth Gospel did not come directly from Jesus but are of a later time. And it is now recognised that the fourth Evangelist constantly failed to express the truth. Like Plato and the other great mystics he tried to rise from the realm of sense to that of the spirit, but, despite his penetrating intellect, the truth for the most part escaped him ; the mists obscured his vision ; knowledge had barely reached its dawn.[1] It can no longer be maintained that Christianity came into the world as a supernatural revelation, complete and final. The divine purpose was only partially revealed even through Jesus.

The modern forms of belief which are taking shape at the present day are far nearer to those of the early Christian forms of nearly 2000 years ago than to those of mediaeval times, though it is of course true that popular early Christian and popular mediaeval eschatology had much in common. But the quaint and not infrequently absurd eschatological notions of bygone ages have now been finally abandoned. It must, however, be admitted that the crude pictures had their value, for they were at any rate symbols adumbrating a reality which those of spiritual insight believed to exist. And since any language we use about the divine and the eternal must be borrowed from the human and the temporal, it is necessarily symbolic. Symbols are necessarily illusive, for they are always inadequate representations of the truth, but they need not be delusive, giving error instead of truth, for they are not intended to be interpreted literally. Still, symbolism is an inevitable source of danger to uncultivated minds, and as far as possible it is best avoided. No religion will again be acceptable to thoughtful men if it is out of harmony with science, philosophy, and scholarship. In the name of intellectual honesty we now feel bound to claim the right to question, and if need be to deny, the validity of inherited and traditional dogma.

The fundamental question which has always exercised the intellect of the Christian Church is as to the nature of her Founder —whence He came, whither He has gone, in what relation He stands to God, in what sense He was a man. These questions must be discussed afresh, for the answers of antiquity and mediaevalism are wholly unsatisfactory. All that we seem able to say with absolute certainty is that there is some remarkably close relation between the spirit of Christianity and the Founder's Personality. But our expression of that relation cannot be precise or final, if only because our present positive knowledge of the nature of personality is so exceedingly slight.

The tolerance of the " Broad " Church of a generation ago was traceable to generosity of spirit and a love of liberty, but the

[1] This is not, of course, to deny that the fourth Gospel is the most valuable metaphysical document in the New Testament.

foundations of the modernist movement of the present generation are more deeply laid in philosophy and psychology. The movement is really based upon evolution in science and upon criticism in literature and history, and it demands not that the great truths of the Christian religion shall be given up, but that they shall be considered afresh in the light of growing knowledge and restated in a way suitable to the intellectual conditions of the age. Such a movement was bound to take place when the claim was conceded that methods of critical inquiry analogous to those employed in secular history should be applied equally to those documents and alleged facts which lie at the basis of the Christian tradition. In all historical writings, the conclusions represent the individual historian's guess at truth, a guess made, of course, only after weighing the evidence by the best methods available, but still at best the intuition of an individual. The documents from which the historian derives his data are already in some degree interpretations; the statements are rarely statements that admit of no question, if only because they are necessarily never complete, and because they almost always involve opinion, at least in some degree. And historians are often tempted to supply the deficiencies in their materials by mere conjecture, and this conjecture is almost inevitably tinged with their sympathies. Even the ablest of those who have dealt with the earliest annals of Christianity differ widely in their views. The modernist position therefore is that all Christian dogmas must be re-examined; they are not necessarily true because they are of Biblical origin or because they are enshrined in tradition. And in this re-examination, the part that emotion has always played in religion, to say nothing of life with all its hopes and fears, its purposes and prejudices, must never be forgotten.

Modern critical methods have dispelled the notion that in ancient history it is possible to ascertain the simple objective fact, save in certain cases. We can reach only probability, rarely certainty. We can discover what was believed to have taken place rather than what actually took place. Criticism must not, however, be unreasonable; it is not always wise to reject everything that does not reveal an immediate justification. Historic criticism that is scientific is full of caution and of reverence, and it recognises that what has been nobly thought and strongly felt in the past is almost sure to have roots going down to what is best and most durable in man.

The essence of modern criticism is comparison. It insists on placing the sacred books of Christianity among other books, investigating the purposes of the writers, discerning the limitations of their knowledge and the provisional nature of their ethics. The justification for applying criticism to the Bible is now undisputed except in a few obscurantist quarters, but at the time of the Reformation the Bible was, as a rule,[1] not only read uncritically but was utterly misunderstood. Even down to recent times the legends of the early chapters of Genesis and all the miracles of both the Old and New Testaments were believed to be literally true. It was considered the right thing to harmonise obviously inconsistent statements. It was not infrequently forgotten that the very language of the Bible, with its wealth of parable, metaphor, and paradox, is apt to mislead all but the ripest scholars.

Alike in the sphere of science and religion, there are great discoverers of truth, men with a special faculty of insight which enables them to see more deeply and with greater clearness than other men. In an intuitive flash the great scientific discoverer sees order where others see only chaos ; similarly the great religious teacher seems to see a far-reaching moral purpose slowly fulfilling itself where others see only blind force without purpose or direction of any kind.

The present tendency of religious thought is not so much to develop a scheme of theology out of sacred writings, as to attempt to discover what the facts of personal spiritual experience imply in regard to our relations with an overruling Spiritual Power. The necessary materials must be drawn partly from personal experience and partly from the spiritual experiences stored up in the memoirs and the writings of persons of unusual insight in matters of religion. The greatest obstacle to success is our present ignorance of psychology ; the difficulties of the research must therefore be great, and the dangers too ; and we seem to be a long way from the discovery of those fundamental principles which it may be assumed are embedded in the structure of the conscious religious experience of mankind as a whole. We have little reason to feel much confidence in either the perceptive or the reasoning powers of man, and, when we attempt to explore the shadowy recesses of the human soul, the way is soon lost in the ever-deepening darkness. Can it really be said that there is any certainty at all ? Can we be sure even of the existence of God ?

[1] The critical attitude of Luther and the great Renaissance humanists must not be forgotten.

4. Does God exist?

The notion that morality is binding merely because it is the command of an authority which can punish resistance stands condemned in the name of morality itself. The binding force of moral obligations is now conceded to be independent of religious beliefs. Goodness is a virtue only when it is independent of reward ; there is little merit in abstention from evil in order to avoid punishment.

Nevertheless, religious beliefs have their origin in the assumption of a living, personal, and supreme God, to whom religious devotion is directed ; and this object of devotion is commonly believed to be the ruler, if not the creator, not only of all men but of the universe in which they live.

With precisely the same facts of perception to go upon, the atheist and the theist come to diametrically opposite conclusions. The former ascribes the working of the universe to an impersonal Force, the latter ascribes it to a Personal Will. The theist is imbued with the profound belief that all explanations of the world of things and of the origin of human personality are mere shadowy dreams and intrinsically absurd abstractions unless based upon the hypothesis that the one Force of the universe from which all manifestations of energy proceed has, immanent in itself, a differentiating Mind.

The great advance in scientific knowledge during the last half-century impresses the imagination with the contrast between the vastness of the universe and the insignificance of man. The result is an increasing distrust in the powers of the human faculties to solve the great problems of human destiny. A reverent agnosticism is tending more and more to take the place of the dogmatism of a few years ago, a dogmatism which, it is now all but universally acknowledged, was built on foundations inevitably fated to crumble away.

But it is illogical for the agnostic to confine himself within the limited horizon of the known, and to renounce all ultimate inquiries. Knowledge is constantly increasing, and while there is, admittedly, still a vast region of the unknown, it would be rash to proclaim that region unknowable. The known can suggest the unknown, for the facts concerning the things we know are constantly suggesting a means of discovering more of nature's secrets. Unsolved problems are not necessarily insoluble, and we have no right to postulate an unknowable merely because we are at present baffled by the unknown.

If, as seems probably the case, evolution is a fact, we cannot but assume that the human mind is still in its early infancy, that its present position is a mere transitory phase in its growth and development, and that, if we look no farther into the future than a hundred thousand centuries hence, the minds of our descendants will be greatly superior to our own. But if we peer still farther into a future to which a hundred thousand centuries is but a day, the minds of then existing human beings may be reasonably supposed to be incalculably superior to those of existing men ; and, of course, the range of knowledge will be immeasurably greater. Clearly, then, all epistemological and psychological theories that may now be formulated must necessarily be imperfect, for they must all be formulated on the assumption that the human mind is a completely developed thing, admitting of exhaustive analysis. Thus, to deny the existence of an intelligent First Cause merely because we are at present unable to conceive it is virtually to confer upon the imperfectly developed human mind something akin to omniscience. Intuitive probability is wholly on the side of the existence of a Supreme Deity.

A religious man who examines his own experience seems at different times to be conscious of God in different ways. Sometimes he contemplates the universe as a great orderly system whose Creator and Ruler stands apart from it, a Spirit invisible, transcendent, observing, and contemplating. Sometimes he is impressed with the almost personal appeal which nature, especially animate nature, seems to make to him. God then seems to be immanent, an indwelling Spirit pervading the whole universe, from which it is scarcely distinguishable. Sometimes he seems to feel in the depths of his own soul some impulse directing and uplifting him ; he begins to think of God as transcendent and immanent too. But these things do not "prove" the existence of God. The term proof connotes the rigorous certainty which is demanded in mathematical demonstration and in physical science, and no such proof of the existence of God is possible. The existence of God is, in the main, a matter of intuitive probability, and, that being so, one intelligent person may affirm and another deny the truth of the proposition. Assuming that the two persons are equally sincere, we are no more justified in attaching a moral stigma to the latter than to the former.

The old "proofs" of the existence of God are now quite unconvincing. No method of demonstration can reach first principles. We cannot argue from the finite to the infinite or from what holds good in experience to what transcends experience. We have to be content with showing the probability of the existence of God. Even so, we cannot do more than show the probability of the existence of a finite God.

The increasing convincingness and eventual assent that come from intuitive probability has been well described by Newman: "The mind passes from point to point, gaining one by some indication, another on a probability; then availing itself of an association; then falling back on some received law; next seizing on testimony; then committing itself to some popular impression, or some inward instinct, or some obscure memory; and then it makes progress not unlike a clamberer on a steep cliff, who, by quick eye, prompt hand, and firm foot, ascends how he knows not himself, by personal endowments and by practice rather than by rule." Logically, such procedure cannot be defended, but it is precisely the procedure that even the most cautious men almost invariably, though perhaps unconsciously, adopt.

The inferences we feel bound to draw from the obvious growth, development, and progress around us justify us in assuming that the universe has had a history.[1] This implies a causality of the past with respect to the present, and it further implies the limitation of time as applied to that particular history, for every history must have had a beginning. The idea that things have fluctuated to and fro from all eternity in a confused and unintelligible series of indeterminate changes is fundamentally opposed to the idea of evolution or to purpose of any kind. It is reasonable to suppose that all sensible things have had an origin and their history a beginning. But this does not imply that time is finite. It is conceivable that the universe has had an existence of *some* kind, aethereal or other, for infinite time, and at some fixed point in the past entered, from some cause unknown, on some historical process of development.

Since existence cannot be derived from nothing, there must be at least one existence that has never come into existence. Such an existence would be an ultimate fact, and the question as to its origin would be unmeaning.

Evolution shows us an order in which matter leads to life, life to consciousness, and consciousness ultimately to a social existence in which lofty moral ideas appear. Throughout this chain, but

[1] Cf. pp. 148, 149.

especially in its final link, we seem to discern the purpose of the whole. The design seems to call for a designer. Moreover, in the moral nature of man, there seems to be a revelation of man's responsibility to some supreme authority. Thus we come to have an instinctive feeling that all existing things were produced by an intelligent Being for the end which they fulfil, and that no evolution was possible without a pre-existent First Cause. A Deity may have existed eternally and at some point in past time have initiated the process of the evolution of the universe we know. If nothing has existed eternally, nothing can have come into being. But if something has existed eternally, that something may at some point have caused the existence of our universe.

It is not improbable that there are many other phases of evolution different from that which constitutes the present stellar, or at all events the solar, system. It is scarcely conceivable that the postulated First Cause should have confined the apparently highest aspects of His work—the evolution of spiritual beings—to a single planet of one small sun in a universe so vast that the whole solar system is but an insignificant microcosm in it. For aught we know, there may be myriads of beings of a different order from ourselves, and some of them may have reached a stage of development that will still take untold ages for us to reach.[1]

If evolution were a purely mechanical and purposeless process, the existence of the aesthetic emotions would be incomprehensible. For how can such emotions have originated in a chance collocation of material atoms? In any work of art, there is always the sense of communication from its creator. Behind the picture is the painter, behind the symphony the composer; the particular combination of colours forming the picture, or the particular combination of sounds forming the symphony, must be a communication from one spirit to another spirit; it seems folly to ascribe to blind chance exquisitely beautiful combinations either of form and colour or of sounds. If we accept the view for works of art, we can scarcely deny it for the vastly greater works of natural beauty, and the value of the glories of nature is lost unless we conceive behind nature One who has designed it. Unless we are willing to sacrifice the aesthetic emotion

[1] This is not intended to suggest that life upon the earth will not ultimately be extinguished. But complete confidence may be felt that science will make such rapid strides that it will easily be able, for vast periods of time, to cope with any difficulties that may arise in connection with the continued existence of life upon the earth. Moreover, adaptation to changing environment is likely to count for much. And even when life ceases to exist upon the earth, there is no reason why it may not continue indefinitely elsewhere.

in its highest development, we seem compelled to believe in a great Spirit whose manifestations these things are.

Apparently, then, since cause is a category which is valid only if used by persons or of persons, we can hardly escape conceiving the Deity as an intelligent and personal Spirit. Evolution is meaningless if it is not teleological, and we cannot conceive a purpose except as the purpose of a personal Being. Still, we cannot reach demonstrative certainty. We have but faith, we cannot know ; and we must be aware of anthropomorphic picture-making.

5. The Nature and Attributes of God

By primitive thought, power is inevitably conceived in terms of physical force, and thus the power of God came to be regarded as simply the irresistible force with which He crushed opposition and punished the disobedient. God was conceived as a cosmic emperor, ruling the world as a relentless despot and consigning to eternal punishment those who disobeyed Him. Associations of oriental monarchy naturally found their way into the God conception, and in that conception the intolerable pretensions of the old-world potentates and the flatteries of their debased subjects have in consequence been perpetuated. The Deity thus came to be regarded as a sort of mighty king, even more arrogant and vindictive than the kings we know. Such a false anthropomorphism, involving, as it does, the assigning to the Deity of human qualities and attributes, is repugnant to all intelligent men and women.

There is a prevailing tendency to describe God as the ineffable, the infinite, the immutable, the incomprehensible, the unknowable. But description by negation is no description at all ; it produces no clear concept. On the other hand, a positive description is out of the question, for we have no positive knowledge.

The ordinary theological idea of God is that of a pre-existent God who, as one writer puts it, decided, *pour se distraire ou pour passer le temps*, to give himself the spectacle of the cosmic drama ; an omnipotent and absolutely self-sufficient Being, eternally realising a bliss ineffable in the contemplation of his own perfection ; a Deity whose superhuman intellectual powers are attested by the orderly arrangements and wonderfully adapted contrivances in the material scheme of things. But at least one of these postulated attributes, that of omnipotence, is no longer acceptable.

Omnipotence connotes infinite power, though this need not be taken to include power to override the laws of identity, contradiction, and excluded middle, power to make the sum of two and three amount to six; for, to the human intelligence, that would be unmeaning. But it is not possible to attribute to God infinite power even in the ordinary sense, for otherwise how are we to explain the existence of suffering and wickedness? Is the human reason satisfied by the statement that God is the cause of all things, and that it is part of His purpose to allow evil as well as good though His reasons are unknown to us? Is not the human reason far better satisfied if we attribute to God what is good and seek elsewhere for the cause of evil? It is impossible to reconcile in a Creator of such a world as ours infinite benevolence and justice with infinite power. If, however, we suppose limitation of power, there is nothing to contradict the supposition of absolute benevolence and absolute wisdom. But nothing obliges us to suppose that the knowledge, any more than the power, is infinite, though both the knowledge and the power must be of so vast an order as to be beyond human conception.

It is thus possible to see how the phenomena of cruelty, injustice, and suffering may be reconciled with the existence of an all-wise and all-beneficent Creator. If the existence of a Supreme Being is granted, the phenomena can be accounted for by the hypothesis of limiting conditions of some kind: either that the action of the Supreme Being is thwarted by the refractory nature of the material [1] in which the divine purpose seeks realisation, or that the Being is struggling with some intractable force or with some maleficent essence which he is slowly subjugating and subduing to His will and thus to final good. We refuse instinctively to sacrifice the Deity's attribute of benevolence to that of power, for, though forced to recognise the indubitable evidence of some limitation of attributes, we prefer to deem that of power limited rather than that of goodness. This is certainly a more reverent view of the Deity than the hypothesis of an omnipotent Being who could, by the mere expression of will, remove all cruelty, injustice, and suffering from the universe, and yet failed to do so.

When we remember that a newly-born child, a child that did

[1] The writer is well aware of the philosophical objections to dualism, but he believes that these are much less formidable than those to monism (cf. Chapter I.). There is a natural tendency in the human mind to desire unity, and the systems of thought that are most in vogue at the present day are those which appear to satisfy that demand. It seems to make very little difference whether we say, with the materialist, that all spirit is matter, or, with the idealist, that all matter is spirit. On the whole, the latter is perhaps the easier to maintain.

not ask to be born, is, from the moment of inhaling its first breath of air, by an irrevocable sentence irremediably condemned to evils which will in a few years drag it to the grave, we are appalled at the merciless tyranny which we should have to ascribe to the Ruler of the Universe if that Ruler were all-powerful. But on the hypothesis that His power is limited, our difficulty disappears.

This view accounts for all the facts of life as we know them ; for instance, the process of evolution whereby the higher and the better slowly emerge from the baser through long ages of pain and struggle, the forces of good slowly but surely winning to victory.

But more than this. To all realities, and therefore to God, the epithet infinity seems to be totally unmeaning. At all events it does not convey to the mind any significance that can be regarded as clear and distinct.[1] No evidence can prove an infinite cause of the universe, for no evidence can prove anything but a cause adequate to the production of the universe. To infer the infinite is a fallacy, and all arguments in favour of an infinite God must commit it. We argue from finite minds from finite data, and our conclusions must be of a like nature.

The attribute of infinity contradicts and neutralises all the other attributes of God, and makes it impossible to ascribe to God either personality, or consciousness, or power, or intelligence, or wisdom, or goodness, or purpose, or object in creating the world.

If God is all-powerful, everything is exactly what it should be, from God's point of view, otherwise He would instantly alter it. If, then, evil things exist, it must be because God wills to have it so, that is because God is, from our point of view, evil. Or, conversely, if God is good, He must put up with the continuance of evil because He cannot remove it. Nor can the responsibility for evil be shifted to the devil or to the perversity due to human Free Will, unless these powers really limit the Divine omnipotence. For if we or the devil are permitted to do evil, while God is able to prevent or destroy us, the responsibility rests with God. The inevitable conclusion of the doctrine of omnipotence is that God is the author of evil as well as of good. We see around us the success of evil and the defeat of good. If, therefore, God is omnipotent, what hope have we that the future He has in store for us will be better than the present ?

It is, perhaps, best to conceive of God's powers as the limit of an imagined progressive series, of which the earlier terms are supplied

[1] At our present stage of mental development, we feel bound, it is true, to admit that *time* is infinite. But it no longer seems absolutely necessary to admit that *space* is infinite. See Chapter IV.

by our knowledge of human personality in the various stages of human development. We may regard such a series as *indefinitely* great, but it is altogether inconceivable that such a series can be *infinitely* great. It is a fallacy to think that the series is in any way analogous to an infinite series in mathematics.

6. The Metaphysicians' "Absolute"

One metaphysical conception of God is that of some kind of unifying principle of the universe. It is expressed in a variety of ways, none of them clear and distinct, and differing substantially from one another: an all-embracing whole of which all things are parts; an underlying reality of which all things are manifestations, exist in virtue of it, though not identical with it; a supreme idea or an essence reposing statically in an eternal calm; something impersonal, ultimate, and unconditioned, fixed, final, and eternal. The conception is summed up in the term "The Absolute." Though beyond the sphere of known phenomena, the Absolute is supposed to appear partially in the phenomena, and yet it is not cognisable by us.

The distinction between Absolutism and Pantheism is this: Pantheism represents a monistic system expressed in religious phraseology; Absolutism is the philosophical exposition of the same point of view.

The Absolute is conceived in terms of mind or spirit. It is argued that as we turn our attention from lifeless matter to living organisms, from living organisms to self-consciousness, and from self-consciousness to self-directing mind, we seem to be on an ascending scale of individuality and concreteness; that it is only the lower-grade realities of which physical tests can be the main tests or reveal the essence; that while, therefore, the Absolute has not the same kind of reality as a stone or any other finite thing, its reality is, in point of fact, much higher.

For religion, however, there is certainly no satisfaction unless the conceived God is of a character which justifies the attitude of worship.

If God is conceived on the lines of the Absolute, the question of His existence does not call for discussion. He is no longer a probable or even a possible God, not an existing powerful spiritual Being, not one among objects, but the presupposition of all objects. He is conceived not as one who is here and not there but one who is everywhere. Thus the Absolute is a being of which all finite things are real though partial expressions, a being that is all-inclusive and all-pervading. In short, the philosophy of the Absolute identifies God with the whole universe.

Absolutism thus invites us to worship Nature, not the God of nature. It does not leave us a God with any sort of personality, or any place for Him, but only nature itself rather fancifully conceived. The personality of God disappears, and instead we have an inclusive unity of all persons and things. The Absolute is not, in short, God at all, but a sort of mystical unity in which the identity and individuality of God and all other persons are lost. It is a sort of impersonal whole of things, animated, at best, by a spiritual principle.

The atheist, despite his name, is a silent worshipper of a god of his own creation, namely, an abstraction of impersonal physical force. Does he differ, essentially, from the worshipper of the Absolute? If public esteem is denied to the one, can it consistently be given to the other? The Absolute is always thought of in terms of the infinite, and since personality is logically incompatible with the infinite, the worship of the Absolute seems to be almost a reversion to the worship of Woden and Thor.

The Absolute signifies that which is absolved from all relations, but how can a personality which is absolved from all relations be conceived as existing at all? All existences are in relation to one another and to the universe as a whole, and no existence can be conceived as absolutely unrelated to other existences. That God is in some way personal, self-conscious, and rational, though in our present state of intellectual development inconceivable, seems to be in the highest degree probable, and if He *is* personal, we *must* deny Him the attribute of infinity.

When the plain man asks for a proof of the existence of God, and is invited to contemplate the Absolute, he is puzzled and dissatisfied, for the philosophy of the Absolute seems to him to destroy the personality both of God and of man. The possibility of a personal relation between God and man seems to be an indispensable condition of all religion, certainly of the Christian religion. Consciousness of the personal self is an ultimate fact in all human experience. It is true that if we analyse the self into a number of separate faculties—reason, will, feeling—each of these appears incomplete and might perhaps be regarded as a sort of emanation of the Absolute. But what is fundamental in our experience of self is no one of these, but rather of an immediate self-existence. To merge human personality in an all-embracing Absolute and to make its independence an illusion, appears incompatible with moral responsibility. It reduces religion to nought, for religion implies such a conception of the human and divine that, in a real sense, there can be co-operation between them. A personal relationship with God is the very essence of religion and implies personality on both sides.

It is, however, true that when we come to close quarters with the term personality, it is hard to define it. Can we regard personality as something clear, fixed, and intelligible ? Is there in personality something permanent, essential, and individual, in addition to the something that is ever changing ? Can we assume that behind the will, the reason, and the emotions, behind all a man's interests and relations to others, behind all that changes and grows, there is a self—a something static and fixed ?

If we answer these questions in the affirmative, as we must, we shall probably be charged with materialism, on the ground that we are merely substituting a psychical for a physical " material." Be it so. The clamant cry of monistic philosophy must be denied. The simplest hypothesis is to deny neither mind nor matter, nor to reduce the one to the other, nor to reduce the two to nothingness, but to admit both. That, however, is not to state that personality is explicable. Personality is an enigma, though to deny it a concrete existence is to deny all that is worth living for.

We may freely admit the immanence of God, but we demand His transcendence too. We must strive to fuse the immanent and transcendent, even if to our limited faculties a clear conception of the necessary mental picture is denied.

Although the personality [1] of an eternally living and ceaselessly active God is vital to religion, yet if sincerity made it necessary to deny an external creator it would be spiritual cowardice to begin to count the cost of truth. But the denial is unnecessary, if only because it would involve the formulation of an hypothesis of greater complexity ; and it is a safe rule always to choose the simpler of two alternative hypotheses.

With the abandonment of the idea of infinity, many of the religious attributes commonly applied to God must be abandoned too. " An all-embracing person," for instance, is unmeaning. If it meant anything, it would mean something utterly subversive of religion, for the infinite personality would equally embrace and

[1] In claiming a personality for God, we must be aware of adopting the early Judaean conception of a Being in human form. This kind of faith is one of those childish things which a man is called upon to put away. Such a primitive anthropomorphising of God has gone far to alienate men's minds from the teaching of the Church.

impartially absorb the personalities of all finite individuals, and include all evil as well as all good. And since an infinite God would have neither personality nor consciousness, He would have neither intelligence nor wisdom, for His intelligence would have to be impersonal and His wisdom unconscious, and to such terms our minds can give no meaning. By assuming that the power of God is something less than omnipotence, we adopt the view of a struggling Deity and a progressing world. This life thus becomes a real fight in which something is eternally gained for the universe. Every effort made by every human being is thus a help to God towards His final triumph.

It has, of course, to be admitted that the hypothesis of human personality as something in the making, receiving from and giving to the whole, and so enjoying spiritual communion with the Absolute regarded as the integration of consciousness, attracts many thinkers. And the hypothesis is not altogether unacceptable if we assume that God is able to manifest His Personality in more than one distinctly different way, probably in ways quite inconceivable to us at our present stage of human evolution. Even so, the grave difficulty of the notion of an infinite Personality remains.

7. The Creeds

A distinguished theologian has recently written that the dogmas of the creeds were formulated as counter-statements directed against some heresy, and hence it is from what by implication they deny rather than from what they directly affirm that their true meaning or intention is to be gathered. The doctrine of creation out of nothing is, accordingly, he says, the denial that the world was merely shaped by God out of a pre-existing material. But assuredly he is unfortunate in this particular illustration. The creation out of *nothing* is so entirely inconceivable and incredible that the statement must be rejected, no matter by what authority made. The same thing applies to many other statements of the creeds, and, in the light of present-day knowledge, many thoughtful people shrink from reciting them. And as long as ministers of religion are compelled to repeat statements that are sometimes contradictory, frequently obscure, not seldom uncharitable, and occasionally inconceivable and incredible, so long will they fail to obtain any effective spiritual influence over the more thoughtful sections of the people. The repetition of a creed as a mere matter of memory and discipline is both irreligious and immoral.

In the early days of Christianity, generations of Christians lived holy lives, ignoring or denying doctrines that were only settled by some ecumenical council after perhaps generations of uncertainty. In the Roman Church, for example, the Immaculate Conception, now an Article of Faith, was a debated point until 1854, and it was actually denied by St. Augustine and Thomas Aquinas. And there are some zealous churchmen who would, in consequence, condemn those famous men to eternal punishment.

Some churchmen still seem to think that the creeds fell direct from heaven, forgetting that they embody the results of long and embittered controversies. Even the Roman Emperors took a hand in formulating the creeds, and there is no possibility whatever that the creeds can have escaped the human errors which mingle with all things.

About most of the things which in religion really matter, such as the goodness of God and the nature of sin, the Christians of the early centuries agreed. Hence those things find no place in the creeds, which are chiefly a record of differences. Still, so long as the Church was vigorous and intelligent, the creeds were continually being modified to suit new conditions of thought and life. Their development was cut short by the invasion of the barbarians, which for hundreds of years made progress, intellectual or other, impossible. When light began to dawn again in the twelfth century, the traditional formulas had become so firmly fixed that no one dared to raise any question against them, and thus the words of the Apostles' and Nicene Creeds remain unchanged to this day. Down to comparatively recent times, many of the clauses of the Apostles' Creed were believed to be literal statements of fact, but since present-day knowledge makes their literal truth inconceivable and incredible, it is immoral to compel the unintelligent multitude to give solemn utterance to statements which, to the multitude, convey only a literal meaning.

Is it conceivable to any reasonable being that the creed of any one Church is so far superior to the creed of any other that the consequential differences of destiny, as determined by God, are eternal happiness in the one case and eternal punishment in the other ?

The Athanasian Creed condemns to eternal punishment those who confound the three " Persons " of the Trinity or who divide the " Substance " into three. Yet the Council of Nicea decided that " Person " and " Substance " are the same. The two statements are diametrically opposed. Thus when we recite the one we are necessarily guilty of heresy as regards the other, and no amount of theological word-quibbling can alter this fact. It is no adequate reason to say that during the time that elapsed between the formulation of the Nicene and Athanasian Creeds, the connotation of the terminology must have changed.

The Athanasian Creed of the English Prayer Book is an exact translation of the original, and gives precisely the meaning the author intended it to have. It is safe to say that many of the statements, especially those concerning the Trinity, never evoke any sort of coherent conception in the minds of the vast majority of the people who recite them. Many of the statements are meaningless. And it is also safe to say that many of those which are most pregnant with meaning are precisely those that no intelligent person believes in. The creed ought no longer to find a place in our Church services. It is trifling with truth to say that the language is merely "symbolical."

Nor is it just to take refuge in the excuse that the creed may be regarded as a canticle. In any case it was not introduced as a canticle into Psalters until about the end of the seventh century. The important thing is, what meaning do the statements convey to the average intelligent person who recites them?

In a book which still has great influence among many churchmen (*Lux Mundi*) appears the following statement: "However unchristian it may be to say that A or B will perish everlastingly, the principle nevertheless is true, that the truth which the creed embodies, the truth of which Christ's incarnation is the pivot and centre, is *the only* deliverance from everlasting perishing." True this was written thirty years ago, but how deeply to be regretted it is that such a statement should ever have been made in a book destined to be read by large numbers of people who give an unthinking allegiance to any kind of constituted authority.

Let it be admitted that the intention of those who framed the creeds was to embody in them the spiritual content of the Christian religion, and let it be further admitted that it is part of the sacred duty of the Church to give explicit utterance to the accepted fundamental truths of that religion. But these are just the weighty reasons why the creeds should be expressed in simple and unambiguous language, why they should be stripped not only of their unmeaning philosophic terminology but also of those ancient superstitions and discredited myths which still lurk within many of the most important clauses.

Any Christian creed ought to give simple and unambiguous expression to the Christian faith, but in their present form the creeds of the Church do not meet the condition of simplicity and unambiguity. No doubt the spiritual truths which any creed may attempt to enshrine must involve spiritual mysteries, but that is no reason why churchmen should be compelled to express their solemn belief in the truth of statements which not only have come down to us from ages of ignorance and superstition but are contrary to common sense and known to be untrue. Any credal statement must, from its very nature, be an hypothesis concerning, at most, a truth only partially revealed, and, more likely than not, a truth at present wholly hidden from us. Many of the great truths of science (as they are called) are only hypothetical, and theology as well as science must, of necessity, remain content with just occasional glimpses of the great truths still almost wholly unrevealed.

8. Miracles

A miracle is sometimes defined as interference with the course of nature. It seems preferable to say that a miracle happens when some spiritual power produces a physical effect independently of the physical cause which is normally indispensable. Those who question the narratives of such events are not necessarily denying the existence of a spiritual First Cause, for, in every theory of evolution, there is usually a belief, explicit or implicit, that the process is under the control of a creative spiritual agent of some kind, and of necessity that agent seems to be not material but spiritual. Although, therefore, it would be rash to deny that God could intervene directly in the material world, the tendency of modern science is to confirm the belief in the uniformity of nature, a fact which raises a strong presumption against the accuracy of each record of a supposed miracle. Assuming that God set in motion certain primal forces to work harmoniously in accordance with certain laws, it is taken for granted that He allows those forces to act without any incidental interference on His part. Certainly the evidence for a miracle must be very much stronger than what we require in the case of an ordinary event.

Nevertheless, if miracles never happen, it may be asked how we are to explain those rather intangible phenomena to which the term Religious Experience is applied. In particular, does it not seem to be a fact that prayer is sometimes answered ? Does it not, therefore, seem necessary to admit the possibility of psychological miracles ? In the opinion of some thoughtful people, such manifestations of the

Divine purpose, seen *sub specie aeternitatis*, are predetermined, but can we be quite certain we are justified in denying that such manifestations may to some extent be contingent?

When a spiritual crisis takes place in a man, there may have been predetermining psychological causes at work by which he was subconsciously prepared. How the indwelling Spirit of God works in the human mind we do not know, but the hypothesis seems to be necessary that, by means of prayer, activity may be quickened and probably directed. If we once admit that the origin of human personality is traceable to a spiritual essence, we can hardly deny that conditions may conceivably be brought about whereby the personality may achieve success in its efforts to enter into closer communion with the Spirit of God.

The stories of the miracles of the Old Testament are the natural product of the imagination in a pre-scientific age, and criticism has now dissolved them away. Those of the New Testament belong to a different order: they are better attested; with few and unimportant exceptions they are attributed to one Man of unique personality. But those concerned with the healing of nervous disorders are now easily explained on natural grounds; those involving a supernatural control over matter probably had their origin in parable or are legendary; those in which the dead are reported to have been restored to life rest on evidence too slight to carry conviction. Two cardinal miracles, however, stand out by themselves. These are the miraculous birth of our Lord, and the resurrection of His flesh. With these two possible exceptions, all the miracles may be regarded as resting on evidence which is unsatisfactory.

9. The Virgin Birth and the Incarnation

The tendency still prevails to treat the historic Christ as simply a manifestation of Godhead in human flesh, and to ignore the completeness and genuineness of His manhood. But it is now recognised by leading scholars that, whatever be the ultimate mystery of His personality, His life on earth was a genuinely human life, involving a human experience that was real and not fictitious. That He was born of a mother Mary, was of Jewish peasant stock, worked as a village carpenter, was crucified and was buried, and was afterwards regarded as living by His disciples, all this seems to be established historic fact. That He was a man with human attributes and passions, and subject to human joys and sorrows, may also be regarded as certain. Such a touching episode in His life as the scene in the garden of Gethsemane loses all meaning if we deny the natural humanity of the sufferer.

But in the creeds the known facts are mixed up with assertions which are not historic at all, assertions which are only hypotheses or interpretations added to the history by the early disciples. It is stated that Christ came down from heaven, was incarnate by an exercise of the Divine power, after His death rose from the dead and ascended into heaven, and is seated on the right hand of the Father. Clearly, these events could not possibly be testified by actual witnesses. They are expressed in language of the time and conditioned by the opinions of the time; for instance, that the earth is fixed and immovable in space. It is true that the coming down, the going up, and the sitting are no longer accepted in the literal sense, but two of the statements, viz. the Virgin Birth and the Resurrection, are still accepted by some people. Yet criticism shows that the documentary evidence for even these is of the most unsatisfying description.

For some time past, the world of learning has been freely discussing both statements, and many persons of the highest competence and undoubted sincerity have now definitely concluded that the story of the Virgin Birth is untrue, and that our Lord did not rise physically from the dead. The question has therefore been raised as to whether the assertion of the tenets in question is essential to the Christian faith. On this point the official mind of the Church is at present divided, but the great majority of our leading scholars do not hesitate to express the opinion that the doctrine of the Incarnation may be held by faith and reason without belief in the Miraculous Conception and the Virgin Birth. So with the Resurrection: the essential part of the doctrine is that Christ's personality survived death; and that can certainly be held without belief in the resuscitation of His dead body.

The evidence for the Virgin Birth is altogether inadequate, and it must be remembered that similar stories were told in regard to many other great personalities of the ancient world, Plato, Alexander, and Augustus amongst them. The scriptural passages cited in support of the doctrine are culled without regard to the authorship or the purpose of the treatises from which they are taken; and though at first sight they seem to support one another by fitting together into an attractive framework, this framework falls to pieces at the touch of historic criticism. And when the question of the conception itself is considered biologically—and on this point only biologists are competent to express an opinion: the opinions of philosophers and theologians unversed in practical embryology can carry no weight at all—the difficulties are so insuperable that the whole event seems to be in the highest degree improbable. Further, the narratives in St. Matthew and St. Luke include genealogies which have no meaning unless Joseph was the natural father of Jesus. And why did St. Paul and the fourth Evangelist omit all reference to the story unless it was because they were sceptical of its truth?

If in the Creed there are two clauses more than any others that ought to be expunged, assuredly they are, "Was conceived by the Holy Ghost," and "Born of the Virgin Mary." It is scarcely possible without irreverence, and happily it is not necessary, to state in plain language what the inevitable implications of these clauses are to those who accept them in their literalness, as so many people do. Theologians contend that the clauses are intended merely to affirm the great mystery of the Incarnation. No doubt. But if the doctrine of the Incarnation is that the nature of the eternal Godhead has been revealed on earth in the life of the Man of Galilee, why should there be any endeavour to seek to interpret this mystery by calling in the aid of pagan legends? "The Word became flesh and dwelt among us." Is not that simple statement sufficient? Does it not make a far stronger appeal to the average man than the profoundly unsatisfactory interpretation "was incarnate by the Holy Ghost of the Virgin Mary"? Assuredly an acceptable doctrine need not be hardened into unacceptable dogma.

It has been said that the assumption of a miraculous birth is necessary in order that the taint of inherited sin might be broken. But the theory of the miraculous birth retains the human mother while dispensing with the human father. It is, however, illogical to maintain that the taint descends in the male line only. To meet this difficulty the Church of Rome invented the doctrine of the Immaculate Conception. But if an Immaculate Conception was possible in the case of the Virgin, who admittedly had a human father as well as a human mother, why may we not make the same assumption about the conception of our Lord?

Happily, however, no hypothesis of a miraculous conception is necessary for the support of the doctrine of the Divine nature of our Lord, for a much simpler and more acceptable hypothesis may be framed. It is that, though born of human parents, Jesus was endowed with a unique moral and spiritual personality, a spiritual personality of so high an order that His religious insight and moral goodness have had no equal in history. Unlike ordinary men, whose worldly outlook offers a persistent opposition to the influence of the Divine Spirit, Jesus represented the highest moral perfection of manhood, and in Him therefore the immanent God dwelt more fully and completely than in any other man. Just as His teaching was that of a prophet so His religious experience was that of a saint. He won His perfect holiness, as others have done in lesser degree, through the experience of moral weakness faced and overcome. A religious faith which finds in Him the supreme revelation of God is, therefore, fully justified. Hence in its essence the doctrine of the Incarnation remains. All that we abandon is the particular form of statement which was expressed in the terms of discredited history and misinterpreted Scripture. The divinity of our Lord is no longer regarded as an historical fact proved by historical evidence, but as an hypothesis about the religious significance of the historical Person Jesus. We are convinced, though we cannot prove that the divine Logos dwelt in the historical Person Jesus, who thus became the Christ. The conviction seems to have its origin in our reflection upon the known facts, and it finds strong confirmation in the collective personal religious experience of the last 1900 years. Hence although Jesus was a man, the Christ is rightly worshipped as Divine. As restated, the doctrine of the Incarnation seems to express the truth simply, clearly, and adequately, in harmony with reason, and not clashing with any of the fundamental principles of science; moreover, it is conceivable without any great difficulty, and it is credible and comprehensible. The Incarnation remains a miracle, even a stupendous miracle; but we regard the miracle as psychological, not biological. The moral perfection of one Man was miraculously brought about by the indwelling Spirit of God.

It may be objected that this is rank heresy—a return to Nestorianism, or even to Arianism. It may therefore be of some interest briefly to consider the nature of the heresies of the early Christians.

The great aim of the early Fathers was to conserve the traditional faith which they had received from Apostolic times. But much of that which in the Scriptures seemed to be most fundamental had been very vaguely expressed. Differences of opinion as to interpretation were, in consequence, inevitable, and there arose controversies which continued for hundreds of years, have indeed continued to the present day. On both sides, however, it was always felt that there was a Trinitarian distinction of some kind involved in the very root of New Testament revelation, in particular that the estimate put on the Person of Christ was the decisive thing for faith and for theology.

The first important hypothesis put forward was by Origen (*c.* 185–253). It was that of the " eternal generation " of the Son from the Father. By this Origen meant a timeless origination from the Father's essence, a process which, he insisted, was quite distinguishable from creation. He safeguarded the divine unity by means of his doctrine of subordination, holding that the Father, in His absolute, underived existence, was the primal source of the Godhead, whilst the Son had a *derived* existence. The Son was thus related to the Father as a derivative or subordinate Being. But although in this way the divine " Monarchia," the sole government of God, was upheld, the feeling gradually arose that the doctrine imperilled the true divinity of Christ, who was relegated to a second position.

Monarchianism was thus a doctrine which emphasised the unity of God, and rejected a personal Trinity.[1] But this rejection may take place in two very different forms. We may have an exaltation of the divine unity at the expense of Christ's true divinity (Ebionitic or Unitarian Monarchianism) ; or we may have the actual identification of Christ with the one Person of the Godhead, who is thus viewed as assuming this particular " mode " of manifestation. The latter form of Monarchianism is called " Modalistic."

Two different hypotheses of Modalistic Monarchianism were put forward. The first was the Patripassian hypothesis : the Father Himself became incarnate in Jesus and suffered in and with Him. The defenders of this hypothesis, when pressed to explain how the Father could at the same time be Son, said that the divine element—the immanent Spirit—in Jesus was the Father, and that the flesh which He assumed constituted Him the Son. The second hypothesis was worked out by Sabellius (*fl.* 230), who substituted for a Trinity of Persons a Trinity of *modes* or *aspects* of the Divine Being ; in this way he aimed at giving a rationale of the Trinitarian distinction in harmony with Monarchian principles. But the Monarchian movement culminated in the hypothesis of Paul of Samosata (Bishop of Antioch, 260–270), who is said to represent the phase of "dynamical" Monarchianism. Paul held that Jesus, commencing as a man, was

[1] We are so accustomed to speak of the three " Persons " of the Trinity that we are apt to overlook the difficulties presented by the term in early Christian times. The term must never, of course, be taken to signify three separate individuals, as if in some way comparable with three distinct men. Only passing reference is made in this chapter to the third Person of the Trinity.

raised by progressive development to the dignity of Son of God, obtaining for His excellence divine rank. The Logos [1] in God, he held, was simply what reason is in man. The union of the Logos with and the penetration of the divine power in Jesus did not differ except in degree from the union and penetration in any other man. In degree it did differ, and thus Jesus advanced progressively until He reached divine rank. The godhead of Jesus was thus a godhead of rank, not a godhead of essence, and the relation of the godhead to the humanity was a dynamical one.

But the Church rejected the hypothesis that godhead is a thing that can begin in time, or that it can be conferred as a degree of honour on a " creature " (a created being).

These Monarchian controversies of the third century were but preludes to the more famous Arian controversy of the fourth. The fundamental question at issue was as to the manner in which the relation of Christ to the Father was to be conceived in order that, on the one hand, His true divine dignity might not be compromised, and on the other, the divine Monarchia might not be endangered. Hitherto the tendency had been to exalt the divine Monarchia at the expense of the distinct hypostasis (ὑπόστασις) [2] of the Son; subordinationist tendencies had also been strong.

The Arian dispute originated in Alexandria in 318 when Arius, a presbyter, came into conflict with his Bishop on this question, *i.e.*, the question of the relation of the Son to the Father. He maintained the doctrine of the divine unity, and at the same time the doctrine of the distinct personality and separate existence of the Son. Lest he should confess two Gods, he treated the title Son of God as a title of honour only. As Son, the Son was later than the Father, and therefore not eternal, and therefore not God but a creature. Arius had numerous supporters, but the orthodox party in the Church were immediately up in arms, arguing that the placing of the Son in a subordinate position was absolutely inconsistent with the maintenance of the supremely important doctrine of the Son's eternal generation from and identity of essence with God. Embittered discussions arose, and the time soon came when the question had to

[1] In its Christian usage " logos " is the name for the second Person of the Trinity, incarnated in Jesus of Nazareth. Though usually translated as " Word," it signifies both reason and speech. The Logos is thus regarded as the word of God in actual operation ; it is God's self-revealing utterance. The logos doctrine has affinity with types of religion which emphasise the divine immanence. There are many who are ardent supporters of the logos idea in religious philosophy while they cannot accept the Johannine identification of the Logos with an historical individual. The translation " Word " is unfortunate as it is almost empty of meaning.

[2] Cf. p. 328.

be brought to an issue. The rival parties met at Nicaea in 325,[1] the conservative or orthodox party being led by the youthful Athanasius of Alexandria, and the progressives (at first) by Arius. There was also a small third party, led by Eusebius of Caesarea.

The Arian party developed their hypothesis in this way.—Their starting-point was the term Son which, it was held, necessarily implied the priority of the Father. The Son was a creature, though the first and greatest of creatures, and was brought into existence by the Father in order that the world might be created.[2] He was not eternal, and was therefore not of divine substance. It was on the ground of His merit as a man that He received the titles Son, Logos, etc. It was granted that He was pre-temporal, before all ages, but this, it was held, was because time began with the creation of the world. This idea they expressed by the formula, " There was when He was not " (ἦν ποτε ὅτε οὐκ ἦν).

The main hypothesis of the Athanasian party was that the Son was of the same essence (ὁμοούσιος) with the Father, very God of very God. Athanasius insisted that no creature, but only God, could unite us with God; and he argued that the formula " There was when He was not " necessarily implied a time-relation, and that since the suggested relation of Father and Son (the Son being a " creature ") was purely a causal one, it followed that, according to the Arians, the Son was not truly of the essence of God. He maintained further that it was folly to suppose the Trinity partly create and partly uncreate, in part eternal and in part not eternal. He also identified the Son with the Word (λόγος), and said that the Son must be eternal if only because the Father can never have been without His Word or Reason.

In support of their views both parties quoted extensively from the Scriptures. But the conservatives were in a large majority, and their victory was a foregone conclusion; and the formula that the Son was " of the same substance " with the Father was definitely adopted. Thus Arianism became a heresy. As the test-word ὁμοούσιος gave the Monarchians most of what they wanted, its adoption soon ended the hostility of that school, and orthodoxy and modalism came to something like a compromise.[3]

[1] This was the first of the so-called Ecumenical Councils.

[2] In this connection it is remarkable how many persons when reciting the Nicene Creed overlook the fact that the clause " By whom all things were made " refers to the Second Person of the Trinity.

[3] The third party, led by Eusebius, rejected the term ὁμοούσιος, but they were willing to admit that the Son was " like " (ὅμοιος) to the Father, or was " of like substance " (ὁμοιούσιος) with the Father.

But although the dominant party in the Church had adopted at Nicaea the hypothesis of the oneness of essence of the Son with the Father, controversy was by no means at an end, for it was an integral part of the faith of many of the prominent leaders that Christ had a true and perfect humanity, and the question still remained as to the manner in which the union of the divine and the human could be appropriately conceived. What was the real *nexus* between the divine co-essential Son and the humanity in which He appeared on earth? This is the question of Christology proper, and it was inevitable that various hypotheses should be put forward in explanation. One easy mode of solution was the suppression of one side or the other—either the divine side, as with the Unitarians; or the human side, as with the Docetists, who taught that Christ had no real material body or human nature but only an apparent body. But the dominant party in the Church would neither give up Christ's true humanity nor allow that He was divine only in a metaphysical or dynamical sense; they held fast to the hypothesis of a real incarnation of the eternal Son.

Nevertheless it was felt then, as it is felt now, that there is a grave difficulty in conceiving how a true manhood and a true godhead can be united in one historical personality.

Several hypotheses were advanced in explanation:

(1) Apollinaris (Bishop of Laodicea, *c.* 390) assumed that, in the constitution of the Person of the divine Son, the Logos replaces the soul of the ordinary human being. But Apollinaris did not deny to Jesus the possession of a human soul in one sense, for he distinguished in man three elements, viz. the body; animal soul (ψυχή), the seat of appetites, passions, and desires; and spirit (πνεῦμα). He granted that Christ had assumed into union with Himself a true body and an animal soul, but the place of the rational and self-determining element (πνεῦμα) in man was taken, he contended, by the Logos Himself. He maintained that the whole divine nature cannot be joined in the whole nature of man; "two separate Natures always remain two separate Persons," "two perfect Beings cannot become one." This hypothesis of Apollinaris obviously had affinities with both the Arian and the Sabellian hypotheses. The Church rejected it, declaring that Christ was possessed of a true and unimpaired humanity—had as truly a human soul as a human body.

(2) This decision roused in a still more acute form the question of how the union of the divine and human in one Person was to be conceived. The next hypothesis was put forward by Nestorius (Patriarch of Constantinople, 428–431), viz. that the Logos united

Himself in the closest form of *moral fellowship* with the man Jesus, without the latter thereby losing His independent personality. The Logos, he said, was not born of Mary but dwelt in Him who was born of Mary. God draws nearer to some of His creatures than to others, according to their moral dispositions; it is thus that He dwells in believers, and it was thus in a unique and pre-eminent way that the Logos dwelt in Jesus. The human spirit of Jesus so perfectly appropriated the divine that Christ's thinking and willing as man were truly the thinking and willing of God in Him; yet His human nature was not thereby annulled but rather raised to its highest degree of perfection. On the other side, the divine Son so entirely appropriated and united the human nature with Himself as to make it the organ of His Personal manifestation.

The Church rejected the Nestorian hypothesis on the ground that the Logos was made to inhabit a humanity that had a personality of its own. The unity of Christ's Personality was thus destroyed, for one Person was replaced by two.

(3) Nestorianism condemned, the controversy entered on a new phase. Eutyches (*c.* 380–*c.* 456), an abbot of Constantinople, was accused of denying the distinction of the "natures" of Christ, and of declaring that Christ's body was of different "substance" from ours, and he was excommunicated. The question was, however, reopened at the Council of Chalcedon[1] (451), and this Council decided to compose a new creed. It endorsed the creed of Nicaea and it defined the true doctrine of Christ's person as follows: "One and the same Christ, Son, Lord, only begotten, confessed in two 'natures' (ἐν δύο φύσεσι), without confusion, without conversion, without division, without separation" (ἀσυγχύτως, ἀτρέπτως, ἀδιαιρέτως, ἀχωρίστως). The two first predicates were directed against Eutyches, with his "confusion" and "conversion" of the natures; Eutyches regarded the union of human nature with the divine as a mingling, a mixing, a fusion, the result being a kind of composite nature; the two last predicates were directed against Nestorius, with his division and separation of the natures. The aim of the creed was to assert the unity of the Person along with the distinction of the natures. The creed did not, however, give any real help towards a positive solution of the problem involved.

(4) The Monophysite or "one Nature" controversy (μόνη or μία φύσις) centred around the same ultimate hypothesis as the Eutychian. The name denotes the new form which the controversy assumed after the decision of the Council of Chalcedon. The

[1] This Council ranks as the fourth Ecumenical.

Chalcedonian creed by no means met with general acceptance, the adherents of the "one Nature" doctrine regarding it as rank Nestorianism. The Monophysite controversy dragged on for a hundred years,[1] and eventually the Monophysites separated from the Church.

(5) An attempt in the seventh century to win back the Monophysites to the Church led to still another controversy, the "Monothelite" or "one Will" (θέλησις) controversy. The doctrine of the "Natures" could not remain where the decision of the Council of Chalcedon had left it, for to say that there is unity of Person and duality of Natures leaves difficulties unsolved. Apart from the *how* of the union, for instance, how much is included in the Person, and how much in the Nature? Does *will*, for example, belong to the Person or to the Nature? How, on the one hand, can there be a willing agent without personality? If we say there are two wills in Christ, does this not imply two egos? If, on the other hand, we say there is but one will in Christ, namely, the divine, does this not seem to rob Christ of true human volition? The Monothelite started from the unity of the Person, and his hypothesis could take two forms: either the human will might be viewed as altogether *merged* in the divine, so that the latter alone acts; or the will might be regarded as *composite, i.e.*, as resulting from a fusion of the human and divine. In either case there was involved a denial of truly human volition to Christ. A new Council[2] was summoned at Constantinople in 680, and the essential clause of the formula adopted was the affirmation of "two natural wills and two natural energies in Christ, without division, change, separation, or confusion," though it was added that the human will is invariably subject to the divine. It will be seen that the decision did little more than take over the Chalcedonian formula about the nature and apply it specifically to the will. It is, of course, open to the same criticism, for while it did ward off the "errors" of the Monothelite hypothesis, it did not afford any help to a positive solution of the problem.

Thus for four or five centuries controversies raged about the Trinitarian distinctions supposed to be involved in New Testament revelation. The creeds which were formulated were less schemes of developed doctrine unfolding the nature of a number of related fundamental hypotheses (for, at bottom, no clause of any creed can be more than a hypothesis), as they were schemes of disconnected

[1] Judgment was given in 553, at the fifth Ecumenical Council, held at Constantinople. [2] The sixth Ecumenical.

dogmatic assertions framed sometimes to meet specific heresies, sometimes to place on record the results of compromises.

The early Church must have been fully aware of the impossibility of framing a body of doctrine, final and complete, concerning the nature of the Trinity, based, as it must have been, on the fragmentary records of the life and teaching of Jesus in the New Testament, records that had had to pass through the sifting process of the imperfect minds and memories of His simple followers. How much He may have said that they did not understand, and therefore did not repeat! and some part of what they did repeat must almost certainly have been imperfectly and wrongly understood. No doubt the followers of Jesus gradually became conscious of three ways in which they thought of God. They were conscious of the working in them of the power to which they gave the name of the Holy Spirit; they were conscious of the influence on them of Jesus Himself, as something apparently divine; and yet there was one God—one Cause, one Principle, one Mind.

It was largely upon these vague intuitions of the followers of Jesus, and upon the interpretations, necessarily vague, that they, the followers, attempted to give to their intuitions, that the Church had to build up a doctrine on the nature of the Trinity. Of course the Church called to her aid other Scriptural statements as well, but as now, so then, these statements were mostly too obscure to be of much appreciable help, though no doubt the early Church held the conviction, now quite given up, that the Gospels really did give the *ipsissima verba* of Jesus. As to the oral tradition upon which they seem also to have relied, its adoption was merely to enshrine grave doubts and probably graver exaggerations.

The early Church felt that no hypothesis which destroyed the unity of the Godhead, or which attributed a merely temporary existence to any of the three modes in which the Godhead seemed to have been realised in human experience, would be satisfactory. This was the cardinal principle of her faith. The mistake she then made was to make assumptions concerning the actual nature of the Trinity, assumptions which not only could not be verified, but were without a shred of acceptable positive evidence to support them; and, worst of all, the Church turned these assumptions into dogmas, and pronounced worthy of the severest penalties those who would not accept them unquestioned.

Let the reader ask any half-dozen theological scholars of his acquaintance to give definitions—definitions which will convey to all intelligent minds the same perfectly clear and distinct ideas—of the term οὐσία, that is, the term used to signify "that which is common" to the Persons of the Trinity, the divine "essence"; also of the terms ὑπόστασις, φύσις, and πρόσωπον. Let him further ask the same scholars to show the successive changes in the meaning of the terms from the second to the seventh centuries, and to point out the consequences of the confusion that thus arose amongst the early Church leaders. Also let him ask which, if any, of the four terms just mentioned are supposed to denote something which is spatial, and let him trace the logical consequences of whatever answer is given.[1] He will probably be almost struck dumb with amazement, as the present writer was, at the extraordinarily shadowy character of important parts of the credal terminology and by the differences of interpretation placed upon some of the most fundamental doctrines of the Christian faith; and he will be driven sadly to the conclusion that portions of the creeds are, indeed, built upon foundations of sand.

Assuredly the time has come when theology can, without sacrificing any part of the primitive message, assimilate the new views of truth imposed upon us by modern knowledge, and can reconstruct her hypotheses accordingly. Assuredly no British theologian can any longer refuse to adopt the axiomatic principle of one of the greatest of his countrymen: "What is incredible to thee, thou shalt not, at thy soul's peril, attempt to believe."

10. The Resurrection

The Apostles' Creed contains not only the clause, "the third day He rose again from the dead," but also the clause, "I believe in the resurrection of the body." But it is important to remember that, in the latter clause, the word "body" should read "flesh," which is the correct translation of the Latin, and appears accurately in the Prayer Book in each of the three Baptismal offices and in the order

[1] The word οὐσία was used by Greek Christian writers to signify the divine "essence"; the Latin equivalent was *substantia*. The word ὑπόστασις (lit. "foundation," "support") was first used by Christians in the sense of "substance" (οὐσία); later, it came to be used to express the distinctions in the Godhead; men spoke of "one ousia, three hypostases," as denoting the unity in Trinity. In the fourth century Gregory of Nazianzus said that the οὐσία denotes the "nature" (φύσις) of the Godhead, ὑποστάσεις the "properties" of the three. Some of the Greeks used the word πρόσωπον as the Latins used *persona*, to denote the "Persons" of the Trinity. Thus in later days ὑπόστασις and πρόσωπον were used in the same sense. The sense of the word φύσις (nature) was far from fixed; it was sometimes used as a vague equivalent for οὐσία (*e.g.* in Athanasius). The connotation of all four terms is vague in the extreme.

for the visitation of the sick. The mistranslation appears in the Morning and Evening Services and in the Catechism. The early writers expressed a belief in the resurrection of the flesh, and the belief in such resurrection, which became dominant in the Church, was embodied in the creeds and remained almost unquestioned until modern times. Of course the phrase " resurrection of the flesh " bears an obvious materialistic interpretation, and in the creeds of Eastern Christendom the new form of expression " resurrection of the dead " was eventually substituted.[1] But in Western Christendom the belief in the " resurrection of the flesh " was intended to convey a literal interpretation, namely, a resuscitation of the corpse, and until recent times this was still the popular view. People could not imagine themselves thinking, loving, or acting, without the familiar body with its brain, heart, and muscular system. To them, personal identity seemed to reside in the body. But the advance of knowledge has revealed a number of reasons, scientific and critical, which make such a view entirely untenable.

During the last thirty or forty years there has been a widespread revolt against the Western and mediaeval view of the resurrection. Leading scholars are now in accord that the real meaning is the survival of the personality ; that in " the life of the world to come," not only will the identity of the man, whom in this world the flesh has embodied, be preserved, but the experiences in the flesh will be remembered and will abide with him for ever. We are therefore to think of the body as a temporary vehicle for the manifestation of spirit ; and the modern hypothesis is that at death the spirit, though disembodied from the flesh, will be re-embodied in a new (though at present unknown) vehicle of expression appropriate to the new order of existence, and of a kind ensuring not only the same personal and individual life which is expressed here by the body we know, but also the preservation of a personal continuity adequate for mutual recognition.

For it seems rational to assume that the future life of man's spirit necessitates some vehicle of self-expression, analogous to the present physical frame, some distinguishing medium for personal communion with other spirits ; and in that case we may correctly speak of the " resurrection " of the spiritual " body." But of the nature of that spiritual body we have no indication at all, and anything like dogmatism in regard to the manner of the resurrection is reprehensible. The fanciful imagery of a Great Assize may perhaps form a fitting, or at least an excusable, expedient for the

[1] Ἀνάστασις νεκρῶν for σαρκὸς ἀνάστασις.

purpose of presenting to a brutal murderer a picture of the corrosive action of sin, and for bringing him to a sense of his impending doom, but in all rational minds such pictures can foster only a sense of religious unreality. It is idle to defend such imagery on the ground that it is merely symbolical; in such circumstances the invention of symbolism is not only irreverent, it is childish. We may be content to acquiesce in the intuition that the dogma of the resurrection enshrines a deep spiritual truth, but that truth is wholly unrevealed.

Now if resurrection of the flesh is impossible in the case of man, can we logically infer the probability of the resurrection of the flesh in the case of Jesus? If the dead body of Jesus was actually resuscitated, and "ascended into heaven," we have to think of the translation of a living man, for an unknown, indefinite distance, through space. What of the laws of gravity? What of the time taken in the translation? What of the difficulties attending the conception of a material heaven? Assuredly the story of the translation of a resuscitated dead body is beyond the limits of probability. The old hypothesis that these things could be explained on the ground that Jesus was God in the sense that He could disperse and reassemble matter can no longer be held; it is contrary to reason. "Flesh and blood," wrote St. Paul, "cannot enter the Kingdom of God." And what he wrote of the resurrection in general must have been intended also to apply to the resurrection of our Lord. The body of Jesus may be said still to rest in Jerusalem; but that the Logos survives and will live for all time is the belief of every Christian Church.

We may believe that the recorded "appearances" of Christ were actual and not fictitious, that, however, there was no presentment of actual flesh and blood to the bodily eye but the manifestation of a spiritual body to spiritual perception. Or, if we are not convinced by the available evidence that the appearances actually took place, we may regard them as of a wholly subjective character; for it is well known from psychology and the history of religious movements that in certain conditions of health and of mind the inner sense throws its impressions upon the world outside.

Could the Church but bring itself to substitute for "I believe in the resurrection of the body," the alternative statement, "I believe in the survival of the personality," the present doubts of many thoughtful people would largely disappear.

11. Heresy and Intolerance

Any doctrine which is rejected by the authorities of a Church because contrary to the established creed of that Church is known as a heresy. It is sometimes gravely asserted that if a number of men disagree about the formulation of a doctrine, all being equally able, equally sincere, and equally versed in the available facts, then the minority must not only be guilty of intellectual " error," but their pertinacity in holding such contrary views must be a mark of moral defect. Such a contention is obviously absurd. Even if the minority were really guilty of unsound reasoning—and who in the circumstances could decide if such be the case ?—that is no reason why their morality or their religious views should be impugned. All the members of any particular Church are necessarily heretics in the estimation of any other Church, and are, therefore, more likely than not, considered to be deserving of eternal damnation.

At the Council of Trent, the Roman Church anathematised all the distinctive doctrines of the Reformation, but a little later the Protestants themselves became equally intolerant towards any departure from their own orthodoxy. All down through the ages heresy has been persecuted, but, when it has become contagious enough to triumph over the persecution, it has usually become itself an orthodoxy and has then been ready to stone new prophets in its turn.

At the present time the English Church is much less intolerant than the Roman Church, but the recent fractious opposition to the nomination of Dr. Henson as Bishop of Hereford, and the hostile reception in some quarters to *The Faith of a Modern Churchman*, are suggestive of a narrowness of outlook that would augur ill for the future welfare of the Church were it not known that the great majority of the leaders are much more enlightened. A spirit of diffidence in regard to one's own beliefs, and of tolerance towards the beliefs of others, is abroad. The growth of knowledge, the advance of science, the recognition that all human beliefs and opinions are liable to error, the changed view of the nature of inspiration, the admission that the Bible is full of errors, the revolt against ecclesiastical authority, the growth of Christian charity : all these things are tending to make the Churches cautious in their condemnation of heresy. The heresy of one generation is now becoming the orthodoxy of the next, and this is inevitable if religion is to keep pace with the advance of knowledge and the discovery of truth.

Allegiance to a particular Church is usually an accident of early surroundings. Few people have the moral courage minutely to examine the religious beliefs they acquired in their childhood; and the forsaking, as the result of intellectual conviction, of one Church for another is not very common. But we all ought to strive to learn what members of other Churches aim at in their worship and what their spiritual aspirations are. There is no record that Christ ever condemned to everlasting punishment the publicans and sinners for their heterodoxy. When He exhorted His disciples to go into the world and preach the Gospel, He gave them no instructions to impose theological definitions on their hearers.

Can it be said that any seceding Church has shown a manifest inferiority in wisdom, morality, and sanctity? Can the Church of God be identified with one particular Church rather than with another? When the dogmatist takes advantage of the impressionable nature of a young child's mind, does he, in thus furthering the cause of his own Church, further the cause of what is best in religion?

To-day the great conception of evolution is dominant, and former interpretations of spiritual values and formulations of religious truth must needs come under review. In fact, as one age succeeds another, it would be wise if the Churches adapted their forms of worship to the succeeding phases of thought. Doctrines need constant revision in the light of new knowledge. We may cherish the feeling that ultimate belief is unchangeable, but in any given age the expression of belief must be imperfect. Desiring to show that Divine forces were at work in a special degree, the forefathers of our faith described things as well as their simple and imperfectly informed minds would let them. But if the same things happened now, we, with our greater knowledge and feeling for caution, should, in receiving the evidence, describe them more in consonance with the truth of the facts as they actually happened. The Bible stories of the birth and resurrection of our Lord were no doubt honest attempts to express an inexpressible mystery—the relation between God and a unique human personality. The writers caught a glimpse of the truth, and they formulated an hypothesis to account for the whole. But the hypothesis must not be mistaken for sober fact. The evangelists could not know, and could not understand; but they did their best to devise a means of placing on record the great mystery of a unique spiritual relationship between one man and God.

Let religious disputants abandon the habit of casting aspersions on each other's honour, and of impugning each other's personal sincerity. How can either *know* that he is necessarily right and the other wrong ? As long as man remains man, he can never hope to discover final truth.

12. Immortality

It is now recognised as impossible to divide men into the righteous and the wicked, for we cannot tell where righteousness ends and wickedness begins ; and moral perfection has never been reached but once.[1] Hence to reward any one portion of mankind with eternal happiness and to consign the other to eternal punishment would be inconsistent with any ethical scheme ; in fact, it would be an intolerable act of injustice. Ostensibly, hell was invented for the purpose of punishing evil-doers, but its main object was to inspire fear in those who were disinclined to accept the prescribed forms of a particular creed.

The mediaeval idea of heaven was symbolised by all kinds of majestic imagery, a system crystallised in the great poem of Dante. The descriptions were usually based upon the pomps of imperial palaces, it being assumed that an unalloyed happiness was a natural concomitant to the glitter of imperial surroundings. All these accessories disappeared immediately reasoned criticism was applied to them, and it is now admitted that any sort of detailed description of the future state is wholly impossible. Only spiritualists [2] now profess to know for certain any details in regard to the future life. But while it is natural for hope to lean heavily for support on the imagination, there is no reason why, with the disappearance of the realistic superstitions of mediaevalism, hope should disappear too.

The almost universal belief in immortality does not seem to be the result of any reasoning process, nor apparently did the belief, historically considered, originate in the conscious reason. The doctrine has no basis on knowledge, whether knowledge of the physical world or of human nature. The history of the belief does not tell us whether the belief itself is justified. Weighty arguments may be brought forward in its support, but it is not the arguments that have brought the belief to those who hold it. The belief seems to be a craving of the whole soul, of which the reason is only a part ;

[1] Of course there is no historical *proof* of our Lord's sinlessness. The available historical evidence covers only about three years of His life and consists of a mere collection of stories and sayings, and the outlines of a biography, edited by men with no special gift for historical accuracy, and not put into writing until many years after the events had actually happened.

[2] This unfortunate term "spiritual-ists" is in common use, and "spirit-ists" is not a very elegant substitute.

for the instinct of self-preservation causes us to rebel against the thought of extinction. Amidst all wavering hopes and doubts and fears the belief in the survival of the personality is unfailing. But feeling and belief do not constitute knowledge, and any attempt at description is a concession to superstition.

The feeling is perhaps traceable in part to the recognition of the validity of moral obligation, for such recognition implies a belief in a permanent spiritual self which is really the cause of its own actions. The belief in God and immortality is not a postulate of morality in such a sense that a rejection of the belief involves a denial of all meaning or validity to our moral judgments, but the acceptance or rejection of the belief does materially affect the sense which we give to the idea of obligation. The belief in the actuality of moral judgment implies that the moral law is recognised as an ultimate fact about the universe, and the most acceptable hypothesis in explanation of this is that the universe is an expression of an intrinsically righteous rational will. If this hypothesis be accepted, the inference that the personality survives for an unlimited period seems to be inescapable.

Emerson declared that the impulse to seek immortality is itself a proof that we are really immortal. We expect immortality not merely because we desire it, but because the desire itself arises from all that is best and truest and worthiest in us. Nature seems to have planted in human beings a desire to continue existence. It is as strong as the desire to reproduce the species, and, linked with it, is an abhorrence of the idea of total extinction.

It is probably true that, isolated, the arguments from philosophy and theology are generally feeble, even valueless, and afford no sort of *proof* of immortality ; but, taken as a whole, the arguments show a cumulative force which logic seems unable to answer.

Could we but form a clear conception of the nature and origin of the soul (personality is a better term), some of the difficulties which are universally felt might begin to dissolve. But at the present stage of the evolution of the human mind, that clear conception seems to be denied to us.

Man is endowed with certain specific powers ; for instance, he is able to appreciate the beautiful, he possesses a mathematical power, and he is able to acquire wisdom. It seems impossible that such powers can have been developed under the law of natural selection, and we are therefore driven to assume that, during the course of man's evolution, without breach of continuity and without change, new causes must have been introduced. There seem to be at least three stages in the development of the organic world when new causes or powers must have come into action—the stage when the inorganic passed into the organic, when merely complex inorganic compounds became living protoplasm; the stage of sensation or consciousness; and the stage of complete self-consciousness and rationality. Is it possible to escape the conclusion that these stages point to a world of spirit to which the world of matter is subordinate? The successive changes thus introduced may be none the less real because imperceptible at the time of their introduction. When a star swims within the gravitational sphere of influence of another star, that influence is at first inappreciable, and deflection from the star's original orbit takes place by almost imperceptible degrees.

The introduction into inorganic compounds, first of life, later on of sensation, and still later on of rationality, led to a series of tremendous developments. How each of these causes originated, and how each of them was able to become fertile in the particular soil already prepared for it, we do not know. How the developments culminated in beauty, wisdom, and character we do not know. But how can we come to any other conclusion than that beauty, wisdom, and character must have been a purpose of creative intelligence?

If, as seems to be the case, the object and purpose of evolution, as we witness its operations here on earth, is the creation of Personality; if life is something of an essentially spiritual nature and creates Personality to secure its own highest self-expression; does it not seem to be in the highest degree probable that human personality as we know it now is but a sort of protozoon of perfected spiritual life? If spiritual self-realisation is never to be satisfied until it has absorbed all knowledge, all wisdom, and all beauty, how is it possible to concede that the death of the body is an end to all things?

That for its manifestations mind does depend on the brain must, of course, be conceded, but it has never been demonstrated that the dependence is so absolute that the function must cease with the death of the organ. And we feel we know for certain that man can distinguish himself from his body, that he is conscious of his personal identity through all the changes of his body, that in the exercise of his will he knows himself not controlled by but controlling his body, and therefore that his consciousness warrants his denying the absolute identification of himself and his body.

If we accept the truth that man has evolved from a protist, then it must be admitted that, if a soul exists, this soul must at some stage or other either have been evolved or have been brought from outside into intimate association with the body. At what stage of evolution does the soul first manifest itself?

Presumably at the dawn of self-consciousness. A conceivable hypothesis seems to be that just as protoplasm had developed cells peculiar to itself in which life might manifest its activities, so at a much later stage the anthropoid *homo sapiens* had developed brain-cells by means of which some all-pervading spiritual essence might begin to exercise and manifest its specific functions and thus make its presence known. Certain it is that man's development is predominantly cerebral, and that seems to be why man has so far outdistanced all other animals. The brain-cells themselves perish, but the work they have accomplished during life endures. The cells are mortal, their work is immortal. In some way it seems impossible to understand, the differentiated spiritual essence, not only embodying the work thus done but also preserving the character, the memories, and the affections that came to it during its association with the body, constitutes the personality, the soul. The advance from primitive life to the stage of sensation, from the stage of sensation to the stage of rationality, may represent phases of spiritual evolution; but how such advancing phases can be related, as presumably they must be related, to some form of differentiated aether waves which can do their work effectively only when specific cells of living things are sufficiently and specifically developed to respond to them, who shall say? Is the idealist philosopher to prove his case after all? Is the essential nature of the aether spiritual, and is all else derivative?

The brain has been compared to a Ruhmkorff coil or a Leyden jar, for it seems to live only while the electric fluid[1] of life is passing through it or residing in it. It does not produce the fluid, it is a temporary storage-house of it. What really matters, what really does the thinking, is not its convolutions, which are comparable with the windings of the induction coil, but the life—the spiritual essence—that may be regarded as flowing through it. At any rate, as was suggested in a former chapter, it seems much more probable that the brain's main function is in some way transmissive rather than productive.

In any doctrine of immortality that may be constructed, it is doubtful if the metaphysical arguments from the nature of the soul

[1] This convenient term demands an apology for its use.

are of great importance. At all events, it is more important to show that the soul is not so absolutely dependent on the body that the dissolution of the one must necessarily involve the cessation of the other. It must, however, be borne in mind that immortality would not necessarily follow even if we could demonstrate that the soul persists beyond the death of the body. Spiritualists sometimes forget this. The wraith which spiritualists claim to be able to call up may be as mortal as the body with which it was formerly associated.

Still, the death of the body is by far the strongest reason we have for doubting the immortality of the soul, and, if the appearance of ghosts could be definitely established, the greatest difficulty in the way of a more general belief in the soul's immortality would probably be removed. Much of the evidence about ghosts is of course utterly untrustworthy, and a good deal of it is unquestionably fraudulent, but there is nevertheless a good deal which investigation has failed to break down, and there seems to be a sufficient residuum to give justification to the belief held by some people that apparitions are in some cases caused by the dead man whose body they represent. But the mere proof that there was this causal connection between the dead man and the apparition would not suffice to prove that the man had actually survived his bodily death. A chain of effects may exist long after the original cause is destroyed. The ghost may be merely an aetheric memory,[1] destined to fade absolutely away with lapse of time. It is in any case impossible to conceive of any form of sensation in the total absence of bodily accompaniments, and the claim that such sensation would be proved if the evidence for clairvoyance and thought-transference could be finally established cannot for a moment be admitted.

It is perhaps hard to believe that each of us can be a permanent element in a universe in which nations, planets, and even stars are but momentary existences, and many thoughtful people find it impossible to believe in immortality merely on the authority of certain religions claiming to be revealed, for the revelation must, on any hypothesis, be untrustworthy. And thus one philosophy teaches a corporate instead of an individual immortality: man should give up the selfish personal desire to be immortal; he should be content to die with the knowledge that the good deeds of this life will survive him and exercise a beneficent influence on the future of humanity.

[1] Chapter II. § 3.

> " O may I join the choir invisible
> Of those immortal dead who live again
> In minds made better by their presence : live
> In pulses stirred to generosity,
> In deeds of daring rectitude, in scorn
> For miserable aims that end with self,
> In thoughts sublime that pierce the night like stars,
> And with their mild persistence urge man's search
> To greater issues."

Be it so. But corporate immortality and personal immortality are certainly not mutually exclusive.

Although few Christians now seem to believe in the pre-existence of the soul, the doctrine is held even at the present day by no less than 600,000,000 human beings who also, as a necessary corollary, believe in the doctrine of reincarnation and successive lives.

The doctrine was adopted by Plato himself, who embodied it even in some of his latest works. In his view the number of souls was fixed ; birth was therefore never the creation of a soul but only the transmigration from one body to another. Plato's acceptance of the doctrine is quite characteristic of his sympathy with popular beliefs and his desire to incorporate them in a purified form in his system. The doctrine was also held by certain early Christian sects, and it is part of the creed of modern theosophy.

At first sight there seems to be no reason why those who undertake to prove that we shall survive this life should deny the hypothesis of a former existence. The only explanation seems to be that in modern Western thought the great support of the belief in immortality has been the Christian religion, and any form of religious belief not supported by that religion would not be considered of importance. Yet there seems to be nothing in the hypothesis of pre-existence incompatible with any of the dogmas which are generally adopted as fundamental to Christianity.

If our existence began at some point in time, is it not rational to assume that that existence will end at some point in time ? But if we are to continue to exist eternally, is it irrational to assume that we must already have existed eternally ?

Clearly a life which stretched on indefinitely without death would in many respects be fundamentally different from our present lives. Any attempt to imagine how our present lives would be transformed if neither we ourselves nor our fellow-men had any chance of death will make this clear.

If we end our present life in a state of imperfection, as we must, it is not illogical to assume that there remains a further improvement and advance to be made in the next life, and that future death can only be regarded as improbable when at last we have reached absolute perfection. The natural inference therefore is that this life will be followed by others like it, each separated from its predecessor and successor by death and rebirth. Otherwise we should have to fall back upon the hypothesis that a process of development begun in a single life bounded by death would be continued as an indefinitely long life not divided by birth and death at all. And to suppose, without any reason, such a change from the order of our present experience seems impossible to justify.

There does, however, seem to be one fatal objection to the doctrine of reincarnation : personal identity depends on memory, and we do not remember our previous incarnations. Further, whatever the soul may be, all its qualities are influenced by the qualities of the body, and, on the whole, we are probably justified in rejecting the idea that the soul is a metaphysical essence which can pass indifferently from one body to another.

It is curious that, even amongst many intelligent people, the notion of the persistence of personality after death is often associated with the conviction that, in the world beyond, there will be a great exaltation of the ego, that the individual will attain to far greater power and place than has been permitted to him in this world, that his existence will be one of continued pleasure, not to say idleness. Assuredly the notion is absurd. If the continuance of personal life after bodily death offers no improved opportunity for the realisation of the ideals of personality, if we have just to live on and only that, is it really worth the while ? Do we not positively recoil from the prospect ? Do we not contemplate with far greater cheerfulness, with far more satisfaction, a future world where there are still heights to climb ? Happily, the full significance of evolution holds out such a prospect to us.

Dare we think we have reached finality in the evolution of mankind ? The elemental passions even of a Shakespeare are scarcely changed from those of Palaeolithic man of a million years ago. The ancient opinion that " there are many things in the universe more divine than man " is not unreasonable, seems even probable. The apotheosis of the stars in Plotinus is at any rate a doctrine more acceptable than the denial of a plurality of worlds containing intelligent beings on higher and higher planes of development.

But all discussion on our future destiny is necessarily based on a series of unverifiable hypotheses. All that we can say with anything like certainty—and even here we have no proof—is that our personality will survive and persist. But we have not the elements for the solution of the problem, and it is really useless to attempt it. "What visions beyond there may be, what larger hopes, what ultimate harmonies, if such there are in store, will come in God's good time; it is not for us to anticipate them or lift the veil where God has left it down."

13. Religious Individualism versus Ecclesiasticism

The hypothesis on which religious individualism rests is that there is a real affinity between the individual soul and the Divine Spirit. The present-day increasing belief, especially on the part of intellectual men, in the inspiration of the individual, due largely to the refusal of the Churches to rid themselves of their pagan superstitions, has given to spiritual life a new independence. Spiritual things, it is now asserted, are spiritually discovered, and the primary evidence for the truth of religion is personal religious experience. Such an attitude is opposed to any form of organised ecclesiasticism, for the individualist asks what intermediary can come between the soul and God. To allow a religion to be fettered by man-made formulas is, urges the individualist, to allow it to be debased.

Individualism has its dangers, however. In his reliance on the inner light alone the undisciplined individualist may fall into various kinds of superstitions, though some of these—a theosophy or a Christian Science, for instance—may be concealed in attractive-looking new garments. Since it must be admitted that, in any unorganised religion, there must run to waste a great deal of spiritual energy which a great Church would know how to utilise, and since it must also be admitted that only a great Church can preserve those ancient and consecrated traditions the steadying influence of which cannot be overestimated, it is interesting to ask why the Churches are losing ground and are failing more and more to attract the ever-increasing number of men who are learning to think for themselves.

Assuredly the collective voice of a Church, with its wealth of past experience, is less likely to be in error than the voice of the individual. And, admittedly, submission to authority is sometimes, perhaps often, the truest wisdom, for it cannot be denied that there is a place for that reasonable authority which is rightly attributed to accumulated experience, goodness, and wisdom, as seen in the lives of good and wise men. Although submission to a Church may appear to involve self-sacrifice, that self-sacrifice may be more than outweighed by the satisfaction that is felt in the subordination of individual beliefs to the common traditions and discipline of an historical body.

It is not that the individualist distrusts the parish priest. No man has a loftier conception of his duty than the average working parish clergyman—Romanist, Anglican, or Dissenter. The distrust is of the centralised bureaucracy. A bureaucracy necessarily lives for itself, and hostility to change is necessary for self-preservation.

The greatest of the Christian Churches is the Roman Church, and, despite its tyranny and its often unscrupulous methods, it has been the greatest spiritual force in the world for nearly 2000 years. But independent thought on the part of her clergy Rome suppresses by the heavy hand of authority, and on the part of her laity she brands it as impious and disloyal. Theoretically it is admitted by Roman casuists that an immoral order ought not to be obeyed, but it is not for a layman to pronounce immoral any order received from a priest; if the order is really immoral, obedience exonerates him who executes it; in all other cases disobedience is a deadly sin. The Romanist is taught that, in religious knowledge, no progress is possible and that in any case he has no active concern in the matter. The whole authority of the Roman Church has, in fact, ever striven to oppose advance in knowledge of any kind, and for centuries it made all scientific efforts practically abortive by making theology pass as revelation. Even to this day it is the duty of the Roman priest to hold that the Scriptures were dictated by God and were final in questions of science and history; also that there is no element of truth in any other religious system. To all search for historic truth Rome is implacably hostile.

The opinion commonly prevails that religious liberty was established by the Reformation. But the opinion is wrong. What the Reformation did was to bring about a new set of political and social conditions, under which religious liberty could ultimately be secured. But nothing was further from the minds of the religious reformers than the toleration of doctrines differing from their own. They replaced one authority by another. Although they set up the authority of the Bible instead of that of the Church, it was the Bible according to a particular reformer, Luther or Calvin. So far as the spirit of tolerance went, there was nothing to choose between the new and old Churches.

The sources of authority appealed to by the different sections of the Reformed Church are fundamentally different. The Anglicans stand by the Bible and the Prayer Book, some of the Nonconformists by the Bible alone, the Wesleyans by the writings of their founder. Although the divisions among Protestants are to be regretted, such divisions are, at all events, evidence of energy and vitality.

The Anglican Church is fettered by the historic views of primitive society and by the superseded theological views of the great Reformers. Even her beautiful communion service seems to be injured—it is certainly not enriched—by the inclusion of such inappropriate matter as the Jewish Decalogue, with its primitive and negative morality. But the dominant party in the Church are so hostile to change that they even resist the making optional of the reciting of the Athanasian creed.[1] It is scarcely too much to say that, if Anglican formularies were strictly interpreted and rigidly enforced, the Church would be the narrowest of all Christian Churches. But happily she redeems her original inconsistencies by remaining persistently illogical, and the rapidly increasing number of enlightened leaders augurs well for her future.

The Nonconformist Churches strongly dislike the application of research to the Scriptures. They cannot bear to hear that the Bible partakes of human weakness and fallibility. They think that the growing discredit in which miracles are held is a movement against Christianity. They are apt to be cold, harsh, and intolerant to both Anglicans and Romanists. In all ritual they see only the dangers, forgetting that if religion is wholly unattractive, and the aesthetic side of human nature neglected, spiritual promptings may remain dormant. Of their established prerogatives they are every whit as jealous as are the greater Christian Churches. Theologically, they have little claim to be called progressive.

All the Christian Churches are alike in devoting much of their energy to increasing their influence and power, and to that extent at least the great cause which they ostensibly represent is weakened. What is the real motive that prompts the Churches to devote so much attention to the reformation of the religious doctrines (not of the morality: that would be laudable) of the Chinese and other distant nations, while they are so indifferent to the deeper miseries at home?

It is this official work and official attitude of the Churches, the desire for increased power and the rooted dislike of change in the things that really matter, the ultra-conservatism and obscurantism

[1] Recent votes in Convocation have made the use of the Athanasian Creed optional, and have permitted Christ's summary of the Law as an alternative to the Decalogue, but formal sanction has not yet been given.

of many of the official leaders, that so strongly repel the religious individualist.

All the Christian Churches are at present under a cloud. They do not attract the great mass of the people, who, failing to gain from them what they need, have either abandoned all spiritual effort or have turned for the inspiration of great ideals elsewhere. There is a conviction abroad that, in their corporate capacity, the leaders of the Churches are unqualified for their task. Forms of worship with rites and ceremonies that are wholly out of date and are utterly unmeaning to the intelligence are still steadfastly preserved. All dynamic modes of thought they seem almost to abhor.

Sectarian differences may be easily bridged without the compromising of a particular man's loyalty to his own branch of the Church. Reunion of the Churches, involving identity of polity, may still be a dream, but unity of action in essentials is assuredly easily practicable. The war has made men increasingly impatient of emphasis on sectarian differences, and more than ever desirous that all who profess and call themselves Christians should recognise, as the great essential, the spiritual bond of union which results from a belief in the Christ.

The sincere Churchman refuses to admit the validity of the antithesis between religions of authority and religions of the spirit. His own religion he believes to be quite as spiritual as that of the individualist. "He who can see the inward in the outward is more spiritual than he who can only see the inward in the inward." Neither is it necessary to choose one type of religion and reject the other. The important thing is for those in authority to keep themselves free from all moorings and afloat; to realise that religious truth has still to be found, and their greatest duty of all is to devote their lives to the search for it.

14. Conclusion

It does not follow that, because mediaeval theology must be discarded, theology is therefore an unnecessary concomitant to religion. The theology must, however, be an honest interpretation of religious experience. It must deal with our fundamental consciousness and deep conviction of God's existence and of our relation to Him. Starting from the conviction that this relation is a real one, it must go on to express and interpret the facts on which it is based. Moreover, every man who has any religious experience at all and gives the slightest thought to it must, consciously or unconsciously, be a theologian.

The weighty matters of the nature of God and man, of life and death and the hereafter, are the realities whose presence we sometimes feel very dimly but powerfully enough to induce us to welcome a sympathetic interpreter of their meaning if only he can be found. We therefore feel a just resentment that so many of the accredited teachers of Christianity concern themselves so much with tithing mint, anise, and cummin, and frown upon the attempts of those who, dissatisfied with creeds that have come down to us from the dark ages, attempt to give a new interpretation to religious experience. The intelligent layman knows well enough that the literal interpretation of the Incarnation and of the Resurrection is entirely contrary to the first principles of science and to common sense, and that, although those two great mysteries are the central facts of Christianity, all explanations are hypothetical. Important as those central facts are, they are, after all, subsidiary to the fact of the Founder Himself, and it is that fact about which men are concerned and about which they want to know more. In their approach to Him men do not want to find themselves challenged by the banalities of threadbare controversies in which they can feel no abiding interest. What they do want is the guidance of leaders who are thoughtful and intelligent men, well equipped with knowledge, enlightened in criticism, receptive of new facts, seekers after religious truth, and believers in religious progress.

> "Progress is
> The law of life—man's self is not yet Man!
> Nor shall I deem his object served, his end
> Attained, his genuine strength put fairly forth,
> While only here and there a star dispels
> The darkness, here and there a towering mind
> O'erlooks its prostrate fellows: when the host
> Is out at once to the despair of night,
> When all mankind alike is perfected,
> Equal in full-blown powers—then, not till then,
> I say, begins man's general infancy."

The ministry of the Church must be a learned ministry. Why should the period of directed study end with ordination? More than this: why should not a much higher standard of scholarship be exacted from candidates for ordination? If, however, scholarship is to give of its best to the Church, it must be free. Any suspicion that the teachers of a Church are practising mental reserve lest they should be persecuted as heretics is fatal. Why should the teachers of a Church be fettered? Why cannot they be trusted to see the bounds which honour sets? Why should they be compelled to trim to tradition their intellectual convictions? Is it not wiser to trust the power of truth to take care of itself? Intellectual sincerity is nowadays a first essential, assuredly. If this is wanting, the modern man will tend more and more to remain outside the Church, and he may even abandon religion altogether. The modern man knows right well that "all Truths except the last are Shadows. But every Truth is Substance in its own place, though it is but a Shadow in another place. And the Shadow is a true Shadow, as the Substance is a true Substance."

Millions of men, dragged during the last few years from quiet and uneventful lives, have seen all the foundations of their upbringing shattered, all their beliefs exposed to new and terrible tests. Their changed outlook is bound to have a profound effect upon the opinions and beliefs, religious and social, of the past. How many of these men are likely any longer to sympathise with the discredited dogmas of bygone ages? Are the Churches preparing to help direct into a safe channel the mighty forces that are surely gathering to an attempt to bring about great changes, or will they drift on and so at last find themselves overwhelmed in a rush that may mean spiritual and social devastation for a hundred years?

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