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CHAPTER I

# INTRODUCTION

To many it may seem presumptuous of anyone to attempt to unravel the mysteries surrounding the origin of the Earth and, in a wider sense, of the Universe itself; to others it may even seem irreverent that the great act of Creation should be regarded as a field for scientific speculation. In his pursuit of knowledge of the external world the scientist, however, is not held within precise limits of time, past or future; for example, the measure of progress in astronomy through the ages can be expressed, in some respects at least, in terms of the increasing capacity of man to see still further into the future and to peer still more deeply into the mists of the past. There may be—and I think that there is—a point in the remote past where an 'iron wall', of cosmic fabrication, shuts us out from scientific contemplation of the antecedent state and the primeval evolutionary history of the Universe; but, until this point is reached, scientists have a legitimate domain of exploration in which, indeed, many triumphs have already been won.

The doctrine of Evolution as it concerns the biological sciences is familiar, in its general aspects at least, to all intelligent people in this scientific age; it is not always realized that evolution is an active principle in the material Universe. The Sun itself, or any star, is slowly evolving, its physical and chemical characteristics undergoing, slowly but relentlessly, changes which find their eventual expression in the heat and light radiated from the Sun's surface into space. Occasionally there is a violent discontinuity in this orderly transformation; a 'new star' (or *nova*) appears suddenly in the firmament, rising from obscurity to become perhaps one of the most brilliant objects in the sky and, after a brief period of grandeur, returning to the insignificance of the pre-*nova* stage. In the



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phenomenon of evolution of the continuous kind the scientist can trace the progressive changes in development—and this applies also to the post-explosion changes in the life of a 'new star'—with perhaps as much certitude as is claimed in the biological sciences.

The probing of the past is a feature of many human activities: the detective, for example, is concerned with actions, words, motives referring to past weeks or months or even years; the historian deals with much longer temporal spans of human activity and is bounded in time only by the absence of such documentary evidence as is necessary for his full appreciation of the past; the archaeologist goes still further back in his investigations of early man and the contemporary state of civilization; the geologist and the biologist take an immense leap into antiquity which is surpassed only by the astronomer or cosmogonist. In comparison with the historian, archaeologist, geologist and biologist the astronomer's presumption is just a matter of degree. We are concerned, then, in this book with the study of the past, pressing as far back as our means permit, and perhaps coming in sight of a barrier, as already suggested, beyond which it would seem we cannot pass. Our survey will cover a wide range, from the almost unbelievably minute atomic constituents of matter and particles no bigger than a grain of sand to stellar systems of unimagined grandeur; however, our main preoccupation will be with the Earth, its fellow planets and the Sun.

To this task we apply the scientific method which consists in making innumerable observations of the external world, measuring all that our most accurate instruments can measure, reaching general conclusions on the basis of consistent and reliable evidence, formulating natural laws which testify to the reign of order in the Universe, testing these laws continuously by further observations and predictions, modifying, refining and simplifying as the occasion demands. The expression of the natural law is itself a process in evolution; what seems to be thoroughly established to-day is found

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to-morrow to be not the whole truth but perhaps only a significant part of it or perhaps only a close approximation. Innumerable examples in the history of science are readily called to mind of which the following suffice for the present. The law of 'conservation of mass' in chemical reactions was an article of scientific faith for many decades; for example, in the formation of carbon dioxide from carbon and oxygen by combustion, as in a fire, this law asserted that the total weight of carbon and oxygen taking part in the reaction was precisely equal to the weight of carbon dioxide produced; although it is true that the measurements made with the most delicate balance ever constructed are in full accordance with the law of conservation of mass, yet the reaction cannot be reduced to the simple terms stated, for the union of carbon with oxygen produces carbon dioxide *and heat*, the latter eluding the functional capacity of the balance. But in recent years mass has been identified with energy, and vice versa, and as heat is a form of energy the combination of carbon with oxygen is an example, not of the law of conservation of mass in the sense indicated previously, but of the great law of conservation of energy the expression of which in this particular instance is:

The total energy, before combustion, of the participating substances—that is, the energy-equivalent of the mass of carbon and oxygen entering into combination—is equal to the total energy produced—that is, the energy-equivalent of the mass of carbon dioxide resulting from combustion, together with the heat energy liberated.

Kepler's laws of planetary motion, with their subsequent generalization by Newton, provide another striking example. Kepler's first law states that a planet $P$ (Fig. 1) moves in an elliptical path around the Sun $S$, the latter being situated at one focus of the ellipse. This law was deduced from a long series of observations of the planet Mars made mainly by the famous Danish astronomer Tycho Brahe. To-day we know that it applies to all the planets and this conclusion might well



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have been reached by Kepler if he had been in possession of the appropriate observational material such as he had in the case of Mars. The law itself may be said to be a generalization which can be submitted to the test of verification as regards planets for which Kepler had insufficient information and for such planets as Uranus, Neptune and Pluto discovered long after his time. Kepler's second law was concerned with the

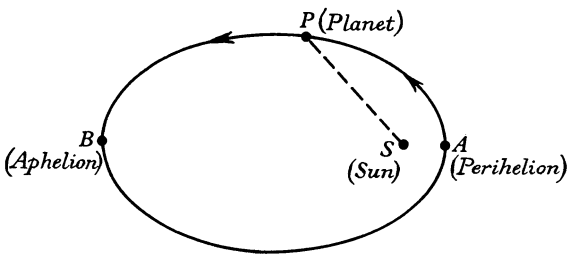


Fig. 1

rate at which the line *SP*, called the *radius vector*, joining the Sun to the planet rotated in the direction indicated by the arrow in Fig. 1; this rate is greatest when the planet is nearest the Sun at *A* (called *perihelion*) and least when the planet is furthest from the Sun at *B* (called *aphelion*).

The third law may be described most simply perhaps as follows. The Earth is of course a planet circulating around the Sun in an elliptic orbit such as is shown in Fig. 1 in the period we call a year; *AB* is called the *major axis* of the orbit and half this the semimajor axis; the length of the Earth's semimajor axis is used by astronomers as the astronomical unit of distance. If then $T$ denotes the period (in years) required by any other planet, say Jupiter, to complete its path around the Sun, Kepler's third law in effect states that the semimajor axis of the planet's orbit (expressed in astronomical units) is equal to $T^{2/3}$. One of the significant facts about Kepler's three laws is that, for more than half a century, they were regarded as wholly independent of one another, with no conceivable bond uniting them in any way. The synthesis was effected by

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Newton with the discovery of the famous law of gravitation which states that any particle of matter attracts any other particle with a force proportional to the product of the masses of the two particles and inversely as the square of the distance between them. From this single law the three laws of Kepler were easily deduced.

But the law of gravitation did more than introduce unification and simplification into the planetary field; it replaced observational generalizations by a physical principle—that of the power of a mass to attract any other mass—and it gave astronomers the means by which the position of any planet at any time could be accurately calculated and, its most sensational achievement, the means by which a planet hitherto unseen was added in the fullness of time to the solar family; to these achievements the laws of Kepler could in no real measure aspire. The discovery of the law of gravitation naturally evoked the question: By what means or process or mechanism can the apparent capacity of one chunk of the material universe for exerting the force of attraction on another chunk be explained? Through a further integration the theory of relativity, which asserts, it may seem mysteriously, that gravitation is simply a property of the four-dimensional world of space-time, allowed us to advance one step more in elucidating the mystery.

In the sequel we shall be concerned mainly with that aspect of the scientific outlook which relates to the inferring of antecedent conditions and processes of the material world from phenomena that have come under observation and from natural laws that have been established. The very remarkable achievements of scientists in the last few years have suggested to many lay minds that it is science alone that attains success through a close attention to the scientific method of description and interpretation, of seeking the causes that produce observed effects, of answering the questions 'how?' and 'why?' which are the expression of man's curiosity about the phenomena in his immediate or remote surroundings. It is well to

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realize, however, that the scientist is not unique in his approach to the satisfying of his intellectual curiosity; it is sufficient to mention the methods of the historian which have as much claim to the descriptive adjective 'scientific' as those of the atomic physicist occupied in producing that most lethal weapon, the uranium-bomb. Of course it is true that the historian is unable, as a rule, to advance step by step with the precision and confidence of the physicist; that, however, is not the fault of his method but of the paucity or incompleteness of the records on which he is forced to rely for his information. The historian, it is sometimes alleged, is prejudiced in favour of one summing-up of a particular phase of history rather than of another but, given honesty of purpose, such 'prejudice' is nothing more than the result of the weighing of motives and actions to the best of his ability according to the evidence available.

Let us not then exalt the scientific method unduly as the close preserve of the scientist nor, which is much more important, as the only means by which we attempt to discover the secrets of Nature. It is easy for the scientist to be a materialist if he sees only in the Universe the apparently relentless unfolding of natural law and forgets that there are domains where the laws of physics are irrelevant. But, more and more, scientists are realizing that they are exploring only one section of the great world of Nature in all its manifold complexity; beauty, moral conduct, spiritual values, religious experience are all outside his domain, yet all come necessarily within man's scrutiny when he attempts to interpret the Universe as a whole and strives to discern purpose therein. A great work of pictorial art could be analysed by the scientist in terms of chemical constitution, atomic and molecular structure, the laws of physical optics and all the rest; he might reduce Beethoven's Fifth Symphony to a collection of mathematical formulae in the theory of vibrations; in neither case would his interpretation be more than bare bones, incomplete and unsatisfying.

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Even to the scientist the sense of beauty is as real as an atom or a star; he can explain the phenomenon of Saturn's Rings by means of complex formulae without ever having seen that wonder of the skies; but when he applies his eye to the telescope, he sees more than a collection of mathematical symbols, for then he sees beauty and, unless he be very dull indeed, he sees mystery and he experiences the feelings of awe and wonder. So too, for example, he can measure the relative positions of the two stars forming the twin-star Gamma Andromedae, he can ascertain their motions and calculate the masses and temperatures of the two stars and determine how far away the system is; but all these things do not specify the twin-star completely, for who can forget the beauty of colour—the rich yellow of one star and the wonderful blue of the other? Even in mathematics the appeal to the aesthetic sense is not as infrequent as may be supposed; I remember, just after the total solar eclipse of 1919 which did so much to support the new and strange theory of relativity and to arouse the intense interest of a war-weary world, discussing with the late Sir Arthur Eddington the *beauty* of Einstein's mathematical presentation; his face lit up with an enthusiasm and deep feeling such as many of us frequently experience in contemplating a moving work of art or in listening to heart-stirring music or in viewing a sublime spectacle of Nature.

It is suggested, then, that the reader should bear in mind the incompleteness of the picture which science gives of the beginnings of things; as we shall see, it can account in a surprisingly successful way for several elements in the story but it fails to discern any motive behind Creation, any omnipotent Mind, any guiding hand in the evolutionary process; that this is so is not a fault of the scientific method but of its limitations in a critical survey of the Universe from every possible angle. The story, then, we have to relate is only one aspect of the whole grand theme; perhaps we may go so far as to say that the conclusions of science in the present connexion, so far as

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these are definitive or even plausible, form the skeletal framework of the integrated organism, the flesh and living spark of which can only be perceived by eyes other than those of the scientist *qua* scientist.

Since man first acquired the power of rational thought he has speculated on the origin of the Universe as he knew it; in a sense, such speculations reflected the standard of his intellectual powers and of his knowledge of natural processes. At an early epoch of human history the association, however vague, of cause and effect with reference to the simplest of observed phenomena represented an important milestone in man's intellectual development; the planting of an acorn in the earth resulting in the growth of the oak, and the power of the Sun's heat to melt ice or snow are simple examples illustrating this relationship. But there was a class of phenomena, such as lightning and volcanic eruptions which could not be associated with an understandable natural origin and so the hypothesis of some supernatural agency was invoked to provide the link between cause and effect. It is not surprising then that as man, in successive ages, speculated on the origin of the Universe he was led to the acknowledgement of an all-creating Power who made 'the Heavens and the Earth and all that in them is'. The earliest known description of the Creation is the polytheistic account of the Babylonians about two thousand years before the beginning of the Christian era. Later came the superb account in the Book of Genesis with which most of us are familiar and which has dominated European theology and philosophy until comparatively recent times. As a result of the rapid march of science, especially in the last century, attention has inevitably been focused on the theme of the Biblical story and in the following pages we attempt to present a report, as it were, of what has been achieved.

Perhaps, here, we may ask legitimately if in probing, in the deepest sense, the mystery of Creation science has *really* been more successful than the poetic expounder of Hebrew cosmo-

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gony; the answer seems to be emphatically 'No'. Genesis begins with the majestic hypothesis of a divine Creator, implied in the words: 'In the beginning God....' As we shall see, the cosmogonist has on his part to postulate hypotheses which to him must be reasonable and conformable to established scientific laws. However far on the road of exploration these hypotheses take him, the ultimate goal seems to be as far out of sight as ever, although neighbouring landmarks continue to be investigated with ever-increasing thoroughness and understanding.

This book, then, deals mainly with the landmarks referred to. Although the whole grand synthesis has not been revealed to us by science—and possibly never will be—the story of the scientific adventure into the past is nevertheless an enthralling one and in its sum-total represents one of the loftiest achievements of the human mind.

From what has already been said in a general way about evolutionary processes, it can be accepted without cavil that the present state of the Earth, and of the Universe in general, represents a development from some antecedent state with marked differences as regards physical characteristics; for example, the fact that practically every cosmic body is dissipating heat (that is, energy) into space, with no substantial means of replenishment from external sources so far as we can see, is enough to suggest one aspect of this evolutionary process; in particular, the Earth is becoming cooler—very slowly, it is true, and at a rate that need not cause any serious perturbation to the human race for almost countless centuries—even allowing for the fact that by radioactive processes some of the energy locked up in the heart of the atom is being slowly released to counterbalance, but partially, the general tendency of our planet to lose heat by radiation into the voids of space.

In discussing the origin of the Earth we shall be concerned with three principal questions. The first question is: 'Whence came the Earth?'—or in the abbreviated form which we

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shall use: 'Whence?'. An alternative form, perhaps more suggestive of the problem set by the question, is: 'What is the Earth's parentage?' The question, in whatever form we use it, suggests that in the distant past the Earth was very different from what it is at present, that the material of which our planet is composed perhaps formed part of another cosmic body, and that somehow the Earth is a result—or, at any rate, one result—of some immense metamorphosis of part of the material Universe, perhaps explicable in terms of natural processes which are consonant with established scientific principles or perhaps explicable only, in the last resort, by the recognition of Creative Power. The problem of the origin of the Earth is but one aspect of a much wider problem, namely, the origin of the Sun's family of planets (Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, Neptune and Pluto), their attendant satellites (or moons), the vast horde of minor planets and other bodies associated with the Solar System. Nor is the problem eventually circumscribed even by these inquiries, for our survey will touch on the formation and development of stars—the Sun, in particular—and the evolution of the Universe itself. In Chapters II–V we shall attempt to answer the question 'Whence?', including in these chapters such preliminary information as is necessary for an understanding of the arguments.

The second question is 'When?', or in extended form, 'When was the Earth formed as a planetary entity?', or more briefly, 'How old is the Earth?' This stage of our inquiry will introduce us to the celebrated controversies of the late Victorian decades when the conclusions of geology and biology on the one hand appeared irreconcilable with the conclusions of physical science on the other, in discussing the problem of the Earth's age. We shall be further introduced to the fascinating developments in physics during the present century which were inaugurated by the discovery of radioactivity in 1896 and which have enabled us to obtain what seems to be a definitive answer to our question.

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