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MODERN SCIENCE
AND MODERN THOUGHT

BY

S. LAING

AUTHOR OF "PROBLEMS OF THE FUTURE," "A MODERN ZOROASTRIAN," "HUMAN ORIGINS," ETC.

WITH A BIOGRAPHICAL NOTE ON THE AUTHOR BY
EDWARD CLODD

(ISSUED FOR THE RATIONALIST PRESS ASSOCIATION, LTD.)

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INTRODUCTORY NOTE

THE career of the author of this book was long, varied, and distinguished. His father, Samuel Laing, after service in the Peninsular War, became, on the death of an elder brother, Malcolm Laing, who was author of a meritorious "History of Scotland," owner of the family estates in Orkney, where, for a time, he developed the kelp industry with success. He is remembered as the author of "Travels in Sweden and Norway," which may still be read with advantage for its trustworthy sketches of the general conditions of life in Scandinavia sixty years ago. But, from the standpoint of scholarship, he did more valuable work in translating the "Heimskringla," or chronicles of the kings of Norway, compiled in the twelfth century by an Icelandic poet-historian, Snorri Sturleson. The lyrical portions of this old saga were translated by the subject of this brief notice.

After some vicissitudes of fortune, the father settled in Edinburgh, where Samuel Laing was born on 17th December, 1811. That is the date given by his friend Mr. C. C. Macrae, in a privately-printed memoir issued in 1899, and may be accepted as against the date 12th December, 1812, which is given in the "Dictionary of National Biography."¹ His education was begun at Houghton-le-Spring Grammar School, whence he passed as a "pensioner" (the term means one who pays for his commons out of his own income) to St. John's College, Cambridge. He graduated as second wrangler and second Smith's prizeman, and in 1834 was elected a Fellow of his College. For three years he was a mathematical "coach," and in June, 1837, was called to the bar, where his acumen seized an opening as counsel in connection with the many railway schemes then agitating the community. The place and prominence which he thus secured led to his start in political life as secretary to Mr. Henry Labouchere (afterwards Lord Taunton) who was then (1839) President of the Board of Trade, and in the following year he was appointed Counsel to the newly created Railway Department of that Board. Insistence on the detail of the enormous volume of work which this involved is needless here, but an example of its onerous nature may be cited from Mr. Macrae. "In one session, 1845, the Board reported on 331 separate Bills for various railways, and on these no less than 240 separate reports were presented, each of which, supplying

¹ In the ninth edition of "Men of the Time" (1875) the date 1810 is given.

exhaustive analyses and criticisms, was entirely drafted by Mr. Laing." His reputation as a great railway administrator was yet to be made, but his influence was manifest in many ways, notably in securing the daily running of the "Parliamentary" or penny a mile trains, and it is admitted that had his counsels been heeded, the results of the crisis which followed the wild railway speculation of that time would have been less disastrous.

In 1848, he accepted the Chairmanship and Managing Directorship of the London, Brighton, and South Coast Railway, a position which, in the first instance, he held till 1855. Three years before his retirement therefrom he entered Parliament as Liberal member for Wick, but in 1857 his farsighted and creditable opposition to the war against China cost him his seat. Two years afterwards he regained it, becoming in June, 1860, Financial Secretary to the Treasury, a position which was exchanged for the important post of Finance Minister of India, in succession to the eminent economist James Wilson, father-in-law of Walter Bagehot, a man never to be named without words of regret for the grievous loss to literature and economics which his early death involved. Wilson had been carried-off by dysentery in August, 1860, and Samuel Laing's reputation marked him as the fittest man to continue the task of reform rendered necessary by the financial disorganisation into which the Mutiny and other serious causes had thrown the revenue and expenditure of India. By prudent economies and readjustment of taxes, Laing converted a deficit into a surplus, but the laborious work so told upon his health that his return to England was compulsory. In 1865 he re-entered Parliament, and in 1867 resumed his old position as Chairman of the Brighton Railway, from which he retired only three years before his death, which occurred on the 6th August, 1897. He lost his seat in 1868, and four years passed before he was back at St. Stephen's; this time as representative of Orkney and Shetland, for which constituency he sat until his final retirement from political life in 1885.

It was then, when most men have warrant for margin of rest as fringe to an active career, that Samuel Laing began the writing of a series of volumes popularising the discoveries of modern science and the conclusions based on those discoveries. Of these, "Modern Science and Modern Thought" was the earliest, and remains the most acceptable. The veteran author wrote with no prentice hand. From time to time he had published pamphlets on political and social questions; his long training in the drafting of reports, and in the clear and compendious presentment of abstruse matters, was enviable qualification for the self-imposed task of his old age. Hence his skilful disentanglement of essentials from accidentals, and of the general from the particular, rendered his books as useful as they were opportune. Some twenty years before this he had done good and original work in science. Under the title of "Prehistoric Remains in Caithness," he published, in 1866, an account of stone implements, rude pottery, human and other bones found in "kists" in burial mounds, and in "middens" or shell-refuse heaps, in the neighbourhood of Keiss Castle. To this Professor Huxley

added a supplement of fifty pages, describing and illustrating the human skulls, nine in all, and other portions of skeletons, some of which were grouped as Iberian or pre-Celtic. Mr. Laing expressed an opinion, warranted by the split bones discovered among miscellaneous witnesses of feasting, that "these aboriginal savages were occasionally cannibals."

His interest in science was, therefore, no new-born thing, and the prominence given to the human theme in all his books was the sequence (interrupted by the claims of important commercial undertakings on his time) of years of observation, of reading, and of reflection. The main part of the book now reprinted deals with man physically and psychically, and the titles of three out of its four successors—namely, "A Modern Zoroastrian" (1887), "Antiquity of Man" (1891), and "Human Origins" (1892)—evidence what a foremost place the large question of man's evolution and destiny filled in his mind.

The first part of "Modern Science and Modern Thought" is now subjected only to such revision as is required by the advance of knowledge during the last seventeen years. The portions thus affected are those dealing with the continuity of Palæolithic and Neolithic man in Continental Europe; with the recent discovery of remains, probably of an intermediate form between man and ape, in Java; and with the remarkable discoveries in Babylonia, which appear to accord to that empire an earlier civilisation than that of Egypt. But the general conclusions, as stated by the venerable author, are strengthened by the newer evidence. In the second part, only a few verbal corrections have been made, since the arguments which are therein advanced against the theory of the supernatural origin of the several documents making-up the New Testament, and, consequently, against the claims as to revelation advanced on its behalf, need neither addition or revision. And for the rest, we have the author's confession of faith, and sage remarks on motives to right conduct, making appeal to minds of the most opposite beliefs in a spirit which must ensure sympathy, if it does not win assent.

The writer of this note had not the advantage of Samuel Laing's personal acquaintance, and it is, therefore, permissible to draw upon Mr. Macrae's memoir for some presentment of the man.

"He had the healthy body as well as the healthy mind; from youth till advanced age he delighted in all field sports. He was fond of good art and music; his tastes in both were classical and old-fashioned. Beethoven and the Italian operatic composers were his favourites; 'but he could not tolerate the formlessness of the modern school led by Wagner.' His conversation had distinction; he detested gossip and idle talk. He had a retentive memory, and 'his accuracy, even to historical details, was astonishing.' His favourite authors were Scott and Tennyson; in latter life, however, his reading was mainly restricted to scientific books. His charities, always unostentatious, 'were, in proportion to his means, liberal,' and their variety manifested his toleration. Open-minded, he harboured

never a prejudice : nor was his equanimity ever ruffled, 'so that the idea of a Stoic sage had become with him a habit of daily life and conduct.' . . . 'He believed in the people—in the masses—in their broad common-sense and honest judgment on large questions which they understood, and it was mainly to their instruction that he looked in the books that he wrote. His ideals were a plain, simple manner of life, manly conduct and honest work. His own long life was throughout an example of these things, and as he had lived, so he continued to the end.'"

EDWARD CLODD.

June 21st, 1902.

AUTHOR'S PREFACE

THE object of this book is to give a clear and concise view of the principal results of Modern Science, and of the revolution which they have effected in Modern Thought. I do not pretend to discover fresh facts or to propound new theories, but simply to discharge the humbler though still useful task of presenting what has become the common property of thinking minds, in a popular shape, which may interest those who lack time and opportunity for studying special subjects in more complete and technical treatises.

I have endeavoured also to give unity to the subjects treated of, by connecting them with leading ideas: in the case of Science, that of the gradual progress from human standards to those of almost infinite space and duration, and the prevalence of law throughout the universe to the exclusion of supernatural interference; in the case of Thought, the bearings of these discoveries on old creeds and philosophies, and on the practical conduct of life. The endeavour to show how much of religion can be saved from the shipwreck of theology has been the main object of the second part. Those who are acquainted with the scientific literature of the day will at once see how much I have been indebted to Darwin, Lyell, Lubbock, Huxley, Proctor, and other well-known writers. In fact, the first part of this book does not pretend to be more than a compendious popular abridgment of their works. I prefer, therefore, acknowledging my obligations to them once for all, rather than encumbering each page by detailed references.

The second part contains more of my own reflections on the important subjects discussed, and must stand or fall on its own merits rather than on authority. I can only say that I have endeavoured to treat these subjects in a reverential spirit, and that the conclusions arrived at are the result of a conscientious and dispassionate endeavour to arrive at "the truth, the whole truth, and nothing but the truth."

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MODERN SCIENCE AND MODERN THOUGHT

PART I.—MODERN SCIENCE

CHAPTER I

SPACE

Primitive Ideas—Natural Standards—Dimensions of the Earth—Of Sun and Solar System—Distance of Fixed Stars—Their Order and Size—Nebulæ and other Universes—The Telescope and the Infinitely Great—The Microscope and the Infinitely Small—Uniformity of Law—Law of Gravity—Acts through all Space—Double Stars, Comets, and Meteors—Has acted through all Time.

THE first ideas of space were naturally taken from the standard of man's own impressions. The inch, the foot, the cubit, the fathom, were the lengths of portions of his own body, obviously adapted for measuring objects with which he came in direct contact. The mile was the distance traversed in 1,000 double paces; the league the distance walked in an hour. The visible horizon suggested the idea that the earth was a flat, circular surface like a round table; and as experience showed that it extended beyond the limits of a single horizon, the conception was enlarged and the size of the table increased so as to take in all the countries known to the geography of successive periods.

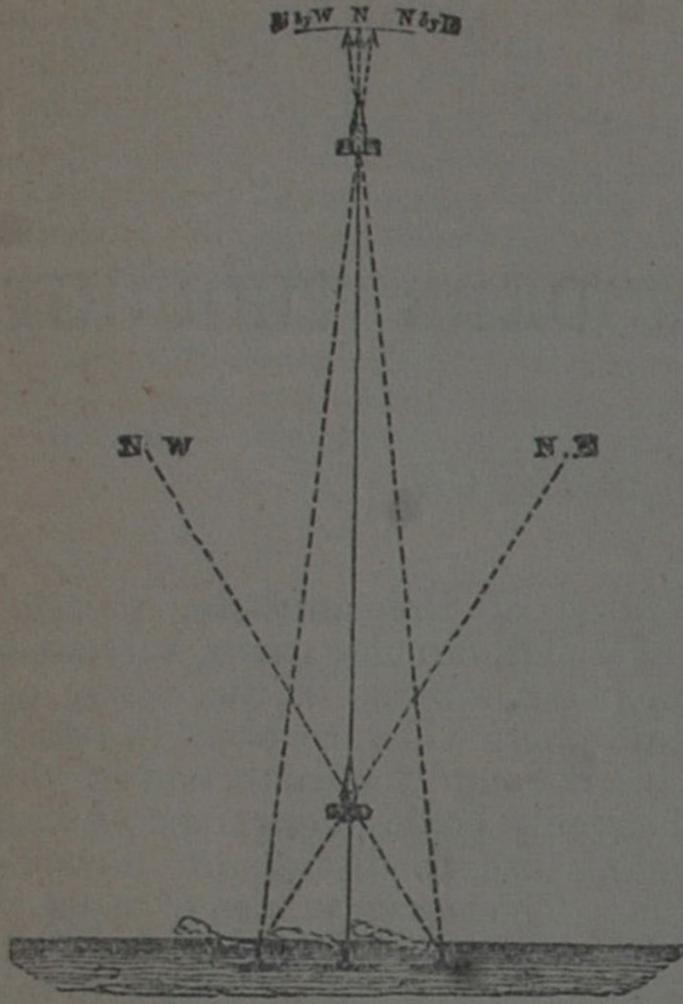
In like manner the sun, moon, and stars were taken to be at the distance at which they appeared; that is, first of the visible horizon, and then of the larger circle to which it had been found necessary to expand it. It was never doubted that they really revolved, as they seemed to do, round this flat earth circle, dipping under it in the west at night, and re-appearing in the east with the day. The

conception of the universe, therefore, was of a flat, circular earth, surrounded by an ocean stream, in the centre of a crystal sphere which revolved in twenty-four hours round the earth, and in which the heavenly bodies were fixed as lights for man's use to distinguish days and seasons. The *maximum* idea of space was therefore determined by the size of the earth circle which was necessary to take in all the regions known at the time, with a little margin beyond for the ocean stream, and the space between it and the crystal vault, required to enable the latter to revolve freely. In the time of Homer, and the early Greek philosophers, this would probably require a maximum of space of from 5,000 to 10,000 miles. This dimension has been expanded by modern science into one of as many millions, or rather hundreds of millions, as there were formerly single miles, and there is no sign that the limit has been reached.

How has this wonderful result been attained, and how do we feel certain that it is true? Those who wish thoroughly to understand it must study standard works on Astronomy, but it may be possible to give some clear idea of the processes by which it has been arrived at, and of the cogency of the reasoning by which we are compelled to accept facts so contrary to the first impressions of our natural senses.

The fundamental principle upon which all measurements of space, which are beyond the actual application of human standards, depend, is this: that distant objects change their bearings for a given change of base, more or less in proportion as they are less or more distant.

Suppose I am on board a steamer sailing down the Thames, and I see two churches on the Essex coast directly opposite to



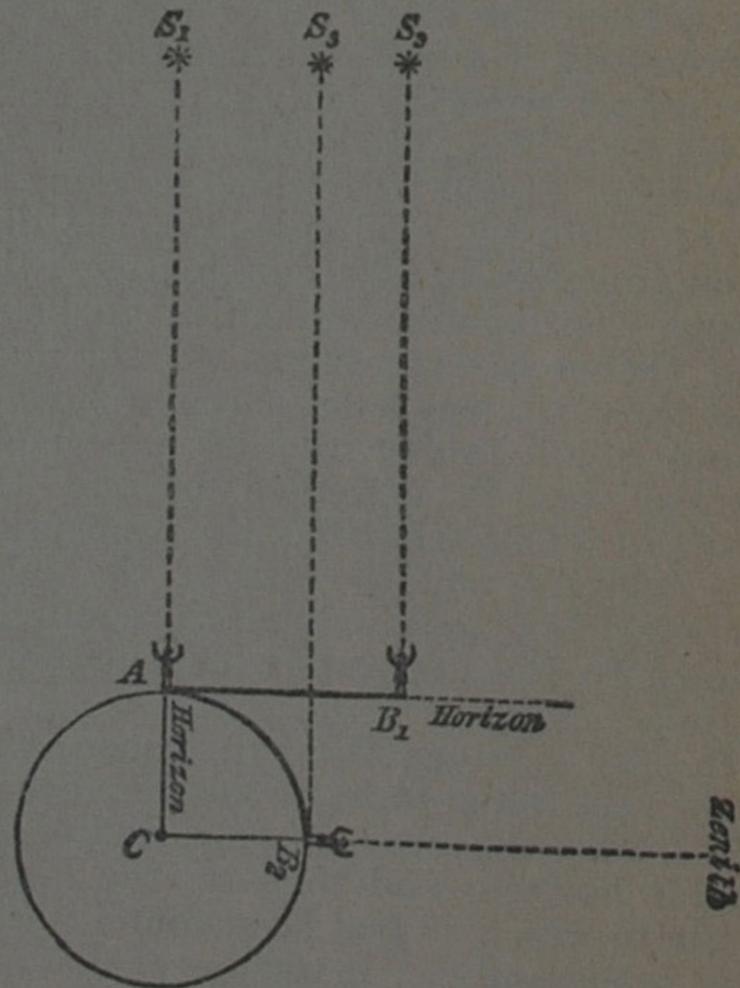
me, or bearing due north, the first of which is one mile, and the other ten miles, distant. I sail one mile due east and again take the bearings. It is evident that the first church will now bear north-west, or have apparently moved through 45° , *i.e.*, one-eighth part of the circumference of a complete circle, assuming this circumference to be divided into 360 equal parts or degrees; while the more distant church will only have altered its bearing by a much less amount, easily determined by calculation, but which may be taken roughly at 5° instead of 45° .

The branch of mathematics known as Trigonometry enables us in all cases, without exception, where we know the apparent displacement or change of bearing of a distant object produced by taking it from the opposite ends of a known base, to calculate the distance of that object with as much ease and certainty as if we were working a simple sum of rule of three. The first step is to know our base, and for this purpose it is essential to know the size and form of the earth on which we live. These are determined by very simple considerations.

If I walk a mile in a straight line, an object at a vast distance like a star will

not change its apparent place perceptibly. But if I walk the same distance in a semi-circle, what was originally on my left hand will now be on my right, or will have changed its apparent place by 180° . If I walk my mile on the circumference of a circle of twice the size, I shall have traversed a quadrant or one-fourth part of it, and changed the bearing of the distant object exactly half as much, or 90° , and so on, according to the size of the circle, which may therefore be readily calculated from the length that must be travelled along it to shift the bearing of the remote object by a given amount, say of 1° .

If, for instance, by travelling 65 miles from north to south we lower the apparent height of the Pole star 1° , it is mathematically certain that we have travelled this 65 miles, not along a flat surface, but along a circle which is 360 times 65, or, in round numbers, 24,000 miles in circumference and 8,000 miles in diameter. And if, whenever we travel the same distance on a meridian or line drawn on the circumference from north to south, we find the same displacement of 1° , we may be sure that our journey has been in a true circle, and that the



form of the earth is a perfect sphere of these dimensions.

Now, this is very nearly what actually occurs when we apply methods of scientific accuracy to measure the earth. The true form of the earth is not exactly spherical, but slightly oval or flatter at the poles, being almost precisely the form it would have assumed if it had been a fluid mass rotating about a north and south axis. But it is very nearly spherical, the true polar diameter being 7,899 miles, and the true equatorial diameter 7,926 miles, so that for practical purposes we may say roughly that the earth is a spherical body, 24,000 miles round and 8,000 miles across.

This gives us a fresh standard from which to start in measuring greater distances. Precisely as we inferred the distance of the church from the steamer in our first illustration, we can infer the distance of the sun from its displacement caused by observing it from two opposite ends of a base of known length on the earth's surface. This is the essential principle of all the calculations, though when great accuracy is sought for, very refined methods of applying the principle are required, turning mainly on the extent to which the apparent occurrence of the same event—such as the transit of Venus over the sun's disc—is altered by observing it from different points at known distances from one another on the earth's surface. The result is to show that the sun's distance from the earth is, in round numbers, 93,000,000 miles. This is not an exact statement, for the earth's orbit is not an exact circle, but the sun and earth really revolve in ellipses about the common centre of gravity. The sun, however, is so much larger than the earth that this centre of gravity falls within the sun's surface, and, practically, the earth describes an ellipse about the sun, the 93,000,000 miles being the mean distance, and the eccentricity or deviation from the exact circular orbit, being about one-sixtieth part of that mean distance. This distance, again, gives us the size of the sun, for it is easily calculated how large the sun must be to look as large as it does at a distance of 93,000,000 miles. The result is, that it is a sphere of about 865,000 miles in diameter. Its bulk, therefore, exceeds that of the earth in the proportion of 1,300,000 to 1. Its density, or the quantity of matter in it, may be calculated from the effect of its action on the earth under the law of gravity at the

distance of 93,000,000 miles. It weighs as much as 332,000 earths.

The same method gives us the distance, size, and weight of the moon and planets; and it gives us a fresh standard or base from which to measure still greater distances. The distance of the earth from the sun being 93,000,000 miles, and its orbit an ellipse nearly circular, it follows that it is in mid-winter, in round numbers, 186,000,000 miles distant from the spot where it was at midsummer. What difference in the bearings of the fixed stars is caused by traversing this enormous base?

The answer is, in the immense majority of cases, no difference at all; *i.e.*, their distance is so vastly greater than 186,000,000 miles that a change of base to this extent makes no change perceptible to the most refined instruments in their bearings as seen from the earth. But the perfection of modern instruments is such, that a change of even one second, or $\frac{1}{3600}$ th part of one degree, in the annual parallax, as it is called, of any fixed star, would certainly be detected.

This corresponds to a distance of 206,265 times the length of the base of 186,000,000 miles, or of 20,000,000,000,000 miles, a distance which it would take light, moving at the rate of 186,000 miles per second, three years and eighty-three days to traverse. There is only one star in the whole heavens, a bright star called Alpha, in the constellation of the Centaur, which is known to be as near as this. Its annual parallax is 0.976", or very nearly 1", and therefore its distance very nearly 20 millions of millions of miles. All the other stars, of which many millions are visible through powerful telescopes, are further off than this.

There are about eight other stars which have been estimated by astronomers to give indications of an annual parallax of less than half a second, and therefore whose distances may be somewhere from twice to ten times as great as that of Alpha Centauri. From the quantity of light sent to us from these distances, some approximation has been made to their intrinsic splendour as compared with our sun. That of Alpha Centauri is computed to be nearly $2\frac{1}{2}$ times; that of Sirius, the brightest star in the heavens, 393 times; greater than that of the sun. These figures may or may not represent greater size or greater intensity

of light, and they are quoted only to give some idea of the vastness of the scale of the universe of which our solar system forms a minute part.

Nor does even this nearly fathom the depth of the abysses of space. Telescopes enable us to see a vast multitude of stars of varying size and brilliancy. It is computed by astronomers that there are at least one hundred millions of stars within the range of the telescopes used by Herschel for gauging the depth of space, and a thousand millions within the range of the great reflecting telescope of Lord Rosse. As many as eighteen different orders of magnitude have been counted, and the more the power of telescopes is increased the more stars are seen. Now, as there is no reason to suppose that this extreme variety of brilliancy arises from extreme difference of size of one star from another, it must be principally owing to difference of distance, so that a star of the eighteenth magnitude is presumably many times further off than any of the first magnitude, the distance of the nearest of which has been proved to be something certainly not less than 20,000,000,000,000 miles. In fact, these stellar distances are so great that in order to bring them at all within the range of human imagination we are obliged to apply another standard, that of the velocity of light. Light can be shown to travel at the rate of about 178 millions of miles in 16 minutes, for this is the difference of the time at which we see the same periodical occurrence, as for instance the eclipses of Jupiter's satellites, according as the earth happens to be at the point of its orbit nearest to Jupiter, or at that farthest away. The velocity of light is therefore about 186,000 miles per second, a velocity which has been fully confirmed by direct experiments made on the earth's surface.

These enormous distances are reckoned, therefore, by the number of years which it would take light to come from them, travelling as it does at the rate of 186,000 miles a second. The nearest fixed star, Alpha Centauri, is seen by a ray which left it three years and eighty-three days ago, and has been travelling ever since at the rate of 186,000 miles per second. Sirius, the brightest of the fixed stars, if the determination of its annual parallax is correct, is six times further off, and is seen, not as it exists to-day,

but as it existed nearly twenty years ago; and the light we now see from some of the stars of the eighteenth magnitude can hardly have left them less than 2,000 years ago.

Even this, however, is far from exhausting our conception of the magnitude of space. Beyond the stars which are near enough to be seen separately, powerful telescopes show a galaxy in which the united lustre of myriads of stars is only perceptible as a faint nebulous gleam. And in addition to stars the telescope shows us a number of nebulae, or faint patches of light, sometimes globular, sometimes in wreaths, spiral wisps, and other fantastic shapes, scattered about the heavens. Some of these are resolved by powerful telescopes into clusters of stars inconceivably numerous and remote, which appear to be separate universes, like that of which our sun and fixed stars form one. Others again cannot be so resolved, and are shown by the spectroscope to be enormous masses of glowing gas, or cosmic matter, out of which other universes are in process of formation.

We are thus led, step by step, to enlarge our ideas of space from the primitive conception of miles and leagues, until the imagination fails to grasp the infinite vastness of the scale upon which the material universe is really constructed.

If the telescope takes us thus far beyond the standards of unaided sense in the direction of the infinitely great, the microscope, aided by calculations as to the nature of light, heat, electricity, and chemical action, takes us as far in the opposite direction of the infinitely small. The microscope enables us actually to see magnitudes of the order of $\frac{1}{1000000}$ th of an inch as clearly as the naked eye can see those of $\frac{1}{10}$ th. This introduces us into a new world, where we can see a whole universe of things both dead and alive of whose existence our forefathers had no suspicion. A glass of water is seen to swarm with life, and be the abode of bacteria, amœbæ, rotifers, and other minute creatures, which dart about, feed, digest, and propagate their species in this small world of their own, very much as jelly-fish and other humble organisms do in the larger seas. The air also is shown to be full of innumerable germs and spores floating in it, and ready to be deposited and spring into life,

wherever they find a seed-bed fitted to receive them. Given a favourable soil in the human frame, and the invisible seeds of scarlet fever, cholera, and small-pox ripen into full crops, just as the germs of a fungus invade the potato crops of a whole district, and lead to Irish famines and the extermination of more than a million of human beings.

The microscope also enables us to see the very beginnings of life and watch its primitive element, protoplasm, in the form of a minute speck of jelly-like matter, through which pulsations are constantly passing, and we can watch the transformations by which an elementary cell of this substance splits up, multiplies, and by a continued process of development builds up with these cells all the diversified forms of vegetable and animal life.

But far as the microscope carries us down to dimensions vastly smaller than those of which the ordinary senses can take cognizance, the modern sciences of light, heat, and chemistry carry us as much farther downwards, as the telescope carries us upwards beyond the boundaries of our solar system into the expanses of stars and nebulae. We are transported into a world of atoms, molecules, and light-waves, where the standard of measurement is no longer in feet or inches, or even in one-hundred-thousandth part of an inch, but in millionths of millimetres, *i.e.*, in $\frac{1}{25000000000}$ th of an inch. The dimensions are such that, as we shall see when we come to deal with matter, if the drop of water in which the microscope shows us living animalcula were magnified to the size of the earth, the atoms of which it is composed would appear of a size intermediate between that of a rifle-bullet and a cricket-ball.

This, then, is Nature's scale of space, from millionths of a millimetre up to millions of millions of miles. Throughout the whole of this enormous range of space the laws of Nature prevail.

Matter attracts matter by the same law of gravity in the case of double stars revolving about each other at a distance at which a base of 186,000,000 miles has long since become a vanishing point, and in the case of atoms which form the substance of a gas, as in that of an apple falling from a tree at the earth's surface. Comets, darting off into the remote regions of space, return after long

periods, in obedience to the same law. Clouds of meteoric dust revolve in fixed orbits, determined by the law of gravity as surely as the moon revolves round the earth, and the earth round the sun.

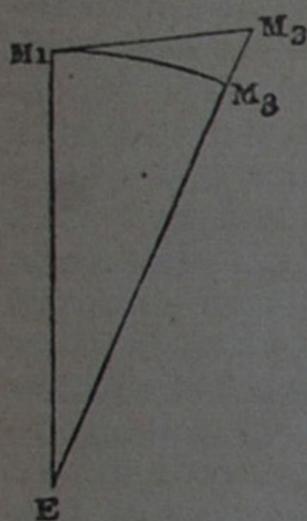
This is a conclusion of such fundamental importance that it is desirable to give the uninitiated reader some clear idea of what it means, and how it is arrived at. Newton's great discovery, the law of gravity, is this—that all matter acting in the mass attracts other matter directly as the amount of attracting matter, and inversely as the square of the distance. That is, 2 or 2,000,000 tons attract with twice the force of 1 or 1,000,000 tons at the same distance, but with only one-fourth of the same force at double, and one-ninth at triple the distance.

How is this law proved? This will be best answered by explaining how it was discovered. The force of gravity, or attraction of the earth on bodies at the earth's surface, is a known quantity. The whole matter in a spherical body attracts exactly as if it were all collected at the centre. The force of gravity at the earth's surface is, therefore, that of the earth's mass exerted at a distance of about 4,000 miles, and this can be easily measured by observing the space fallen through, and the velocity acquired, by a falling body in a given time, such as 1".

Does the same force act at the distance of the moon, or 238,850 miles? This was the question Newton asked himself, and the answer was got at in the following way. If we swing a stone in a sling round our head, it describes a circle as long as we keep the string tight, and its pull inwards just balances the pull of the stone to fly outwards, *i.e.*, to use scientific language, as long as the centripetal just balances the centrifugal force. But if we let go the string the stone darts off in the direction in which, and with the velocity with which, it was moving when the centripetal force ceased to act.

The moon is such a sling-stone revolving about the earth. At each instant it is moving in the direction of a tangent to its orbit, and would move on in a straight line along this tangent if it were not deflected from it by some other force. That is, if the moon were now at M_1 , it would, after a given interval of time, be at M_2 if no force had acted on it. But

in point of fact it is not at M_2 but at M_3 . Therefore it has been pulled down from M_2 to M_3 , or, if you like, fallen through



the space $M_2 M_3$ in the time in which it would have travelled over $M_1 M_2$ with its velocity at M_1 . How does this space correspond with the space through which a heavy body would have fallen in the same time at the earth's surface? It corresponds exactly, assuming the law of gravity to be that it decreases with the

square of the distance.

This may be taken as the first approximation, but the more accurate and universal proofs of the law are derived from mathematical calculations of what the nature of the attractions must be, in the case of the sun, earth, moon, and planets, to make them describe such elliptic orbits and observe such laws, as from Kepler's observations we know actually to be the case. The answer here again is the law of gravity, and no other possible law, and this is confirmed in practice by the fact that we are able, by calculations based on it, to satisfy the requisite of safe prophecy—that of knowing beforehand, and to predict eclipses, comets, transits, and occultations, and generally to compile Nautical Almanacs, by which ships know their whereabouts in pathless oceans.

This, then, affords us a first firm standing-point in any speculations as to the nature of the universe. One great law, at any rate, is universal throughout all space, and, as we shall see later, suns, stars, and nebulae are composed of the same matter as the earth and its inhabitants.

In like manner comets and meteors, though presenting in other respects phenomena not yet fully understood, are proved to obey the same laws and to consist of the same matter. Comets are bodies which revolve round the sun, and are attracted by it and by the planets, in obedience to the ordinary law of gravity, though their density is so slight, that although often of enormous volume, they produce no perceptible effect on the planets, even when entangled amidst the satellites of a planet,

as Lexell's comet was amongst those of Jupiter.

Their dimensions may be judged of when it is stated that the comet of 1811 had a tail 120 millions of miles in length and 15 millions of miles in diameter at the widest part, while the diameter of the nucleus was about 127,000 miles, or more than 15 times that of the earth. In order that bodies of this magnitude, passing near the earth, should not affect its motion or change the length of the year by even a single second, their actual substance must be inconceivably rare. If the tail, for instance, of the comet of 1843 had consisted of the lightest substance known to us, hydrogen gas, its mass would have exceeded that of the sun, and every planet would have been dragged from its orbit. As Proctor says: "A jar-full of air would probably have outweighed hundreds of cubic miles of that vast appendage which blazed across the skies to the terror of the ignorant and superstitious."

The extreme tenuity of a comet's mass is also proved by the phenomenon of the tail, which, as the comet approaches the sun, is thrown out sometimes to a length of 90 millions of miles in a few hours. And what is remarkable, this tail is thrown out against the force of gravity by some repulsive force, probably electrical, so that it always points away from the sun. Thus a comet which approaches the sun with a tail behind it, will, after passing its perihelion, recede from the sun with its tail before it, and this although the tail may be of the length of 200 millions of miles, as in the comet of 1843. In the course of a few hours, therefore, this enormous tail has been absorbed and a new one started out in an opposite direction. And yet, thin as the matter of comets must be, it obeys the common law of gravity, and whether the comet revolves in an orbit within that of the outer planets, or shoots off into the abysses of space and returns only after hundreds of years, its path is, at each instant, regulated by the same force as that which causes an apple to fall to the ground; and its matter, however attenuated, is ordinary matter, and does not consist of any unknown elements. The spectroscope shows that comets shine partly by reflected sunlight and partly by light of their own, the latter part being gaseous, and this gas, in most

comets, contains carbon and hydrogen, possibly also oxygen, in the form of hydrocarbons or marsh gas, cyanogen and possibly oxygen compounds of carbon. One comet has recently given the line of sodium, and the presence of iron is strongly suspected.

As regards meteors, which include shooting stars and aërolites, it has been long known, from actual masses which have fallen on the earth, that they are composed of terrestrial matter, principally of iron, which has been partially fused by the heat engendered by the friction of the rapid passage through the air. The recurrence of brilliant displays at regular intervals, as for instance those of August and November, when the whole sky often seems alive with shooting stars, had also been noticed; but it was reserved for recent times to prove that these meteor streams are really composed of small planetary bodies revolving round the sun in fixed orbits by the force of gravity, and that their display, as seen by us, arises from the earth in its revolution round the sun happening to intersect some of these meteoric orbits, and the friction of our atmosphere setting fire to and consuming the smaller meteors which appear as shooting stars. This shows the enormous number of meteors by which space must be tenanted. It is proved that the earth encounters more than a hundred meteor systems, but the chance of any one ring or system being intersected by the earth is extremely small, as the earth is such a minute speck in the whole sun-surrounding space of the solar system. On a scale on which the earth's orbit was represented by a circle of 10 feet diameter, the earth itself would be only about $\frac{1}{100}$ th of an inch in diameter, so that if, as astronomers say, the earth encounters about a hundred meteor systems in the course of its annual revolution, space must swarm with an innumerable number of these minute bodies all revolving round the sun by the force of gravity.

Has this law of gravity been uniform through all time as it undoubtedly is through all space? We have every reason to believe so. The law of gravity, which is the foundation of most of what we call the natural laws of geological action, has certainly prevailed, as will be shown later, through the enormous periods of geological time, and far beyond this we can discern it operating in those astronomical changes by which cosmic matter has been condensed into nebulae, nebulae into suns throwing off planets, and planets throwing off satellites, as they cooled and contracted. Double stars at a distance exceeding 20 millions of millions of miles revolve round their common centre of gravity by this law. Atoms and molecules almost infinitely smaller than millionths of millimetres derive from it their specific weights with as much certainty as if they were pounds or hundredweights.

We cannot speak with quite the same certainty of infinite time as we can of infinite space, for we have no telescopes to gauge the abysses of time, and no certain standards, like those of the known dimensions of our solar system, to apply to periods too vast for the imagination.

But we can say this with certainty, that the present law of gravity must have prevailed when the outermost planet of our system, Neptune, was condensed into a separate body and began revolving in its present orbit, and that it has continued to act ever since; while, as a matter of probability, it is as nearly certain as anything can be, that the law by which the apple falls to the ground is an original condition of matter.

What space and matter really may be, we do not know, and if we attempt to reason about the limits of the one and the origin of the other, if origin it had, we get into the misty realms of metaphysics, where, like Milton's fallen angels, we

Find no end in wandering mazes lost.

CHAPTER II

TIME

Evidence of Geology—Stratification—Denudation—Strata identified by Superposition—By Fossils—Geological Record shown by Upturned Strata—General Result—Palæozoic and Primary Periods—Secondary—Tertiary—Time required—Coal Formation—Chalk—Elevations and Depressions of Land—Internal Heat of Earth—Earthquakes and Volcanoes—Changes of Fauna and Flora—Astronomical Time—Tides and the Moon—Sun's Radiation—Earth's Cooling—Geology and Astronomy—Bearings on Modern Thought.

GEOLOGY has done for time what astronomy has for space—it has expanded the limited ideas derived from natural impression and early tradition into those of an almost infinite duration. This result is so important that it is desirable that all educated persons, without being professed geologists, should have some clear idea of the nature of the conclusions and of the evidences on which they rest.

This I will endeavour to give.

When we come to examine the structure of the earth—or rather of the outer crust of the earth which we inhabit—with the care and precision of scientific methods, we find that it is not of uniform composition, but consists mainly of distinct layers, or strata, lying one over the other. This is true not only of the larger beds, or distinct formations, but of the details of each formation, many of which are built up as regularly as the layers of the Great Pyramid, while others are made up of layers no thicker than the leaves of a book.

Now consider what this fact of stratification implies. In the first place it implies deposit from water, for there is no other agency by which materials can be sorted out and thrown down in horizontal layers, while this agency is now doing the same thing every day and all over the world. The Rhone flows into the Lake of Geneva a turbid stream, and flows out of it as clear as crystal. All the matter it brings in is deposited at the bottom of the lake, and in course of time will fill it up. This deposit varies with every alternation of flood and drought; the river depositing sometimes

boulders and coarse gravel, sometimes shingle, sand, or fine mud, and carrying this material sometimes to a greater and sometimes to a less distance, according to the velocity of the stream.

Ages hence, when the lake has been converted into dry land, it will be as certain, whenever a pit is dug or a well sunk in it, that it was the work of a river flowing into a lake, as it is to-day, when we can see them at work.

And what is true of the Rhone and the Lake of Geneva, is true on a larger scale of the Ganges, the Mississippi, and of every sea or ocean, with every river or torrent pouring into it.

Again, the sea is perpetually wearing away the coasts of all lands, and, where the cliffs are soft and the tides and currents strong, at a very rapid rate. The materials swallowed-up are rolled as shingle, ground into sand, or floated as fine mud, and all finally assorted and laid down at the bottom of the sea, not in a confused heap, but in regular succession. On some of them generations of shell-fish and other marine creatures live and die, and their remains are covered over by fresh sands or clays, and preserved for future geologists. All this is going on now, and when we examine the rocks we find that precisely the same sort of thing has been going on from the newest to the oldest strata. With the exception of a comparatively small amount of igneous rock, which has boiled-up from deep sources of molten matter, and been poured-out in sheets of lava, or masses of trap, porphyry, and granite, according to the amount of pressure it has undergone and the time it has taken to cool and crystallise, all the earth's surface may be said to consist of stratified matter, showing clear signs of having been deposited from water. Some of the oldest rocks, such as gneiss, may be a little doubtful, as they have clearly been subjected to great heat under great pressure, until they became plastic enough to crystallise as they cooled, and thus destroy any fossils embedded in them and obliterate most of the ordinary signs of stratification. But the opinion of the best geologists is that they were originally stratified, and have become what is called "metamorphic," or changed by heat and pressure into the semblance of igneous rocks. But even if these are not included, enough remains to justify the

general assertion that the outer crust of the earth, as known to us, is made up mainly of stratified materials which have been deposited from water.

Now this implies another most important fact, viz., that there must have been waste or denudation of existing land corresponding to the deposit of stratified materials under water. Water cannot generate these materials, and every square mile of such strata, say 10 feet thick, implies the removal of 10 feet from a square mile of land surface by rains and rivers, or of an equivalent amount of cubical content in some other way, as by the erosion of a coast line. This is a very important consideration when we come to estimate the time required for the formation of such a thickness of stratified beds as we find existing. There must have been a fundamental crystalline rock as the earth cooled-down from a fluid state and acquired a solid crust, and this rock must have been worn down by primeval seas and rivers as the progressive cooling admitted of the condensation of aqueous vapour into water. The waste of this primitive crust must have been deposited in strata at the bottom of those seas in thick masses, covering the original rock, and these again must have been partly crystallised by heat and pressure, and over and over again upheaved and submerged, and themselves worn down by fresh erosion, forming fresh deposits which underwent a repetition of the same process.

A third important inference from the fact of stratification is that all strata must have been originally deposited horizontally, or very nearly so, and in such order that the lowest is the oldest.

Suppose we fill a jar with water, and put some white sand into it, and when that has subsided to the bottom and the water is clear, some yellow sand, and again some red sand, it is clear that we shall have at the bottom of the jar three horizontal deposits or strata, one white, one yellow, and one red, and that by no conceivable means can the order in which they were deposited have been other than first white, secondly yellow, and lastly red. This law, therefore, is invariable, that wherever it is possible to trace a series of strata lying one above the other, the lowest is the oldest, and the highest the youngest in point of time.

If, therefore, all the great formations,

from the old Laurentian up to the newest Tertiary, had been deposited uniformly all over the world, and had remained undisturbed, and we could have seen them in one vertical section in a cliff twenty-five miles high—for that is about their total known thickness—we should have been able without further difficulty to determine their order of succession and respective magnitudes.

But this is plainly impossible, for the deposits going on at any one time are of very different character. For instance, we have at present the Globigerina ooze gradually filling the depths of the Atlantic with a deposit resembling chalk; the Gulfs of Bengal and Mexico silting up with fine clay from river deposits; vast tracts in the Pacific, Indian Ocean, and Red Sea, covered with coral and the *débris* of coral-reefs. How could these, if upheaved into dry land and explored by future geologists, be identified as having been formed contemporaneously?

Suppose that coins of Victoria had been dropped in each of them, the geologist who discovered these coins would have no difficulty in concluding that the strata in which they were found were all formed in the nineteenth century. The petrified shells and other remains found in geological strata are such coins. Every great formation has had its own characteristic fauna and flora, or aggregate of animal and vegetable life, varying slowly from one geological age to another, and linked to the past and future by some persistent types and forms, but still with such a preponderance of characteristic fossils as to enable us to assign the rocks in which they occur to their proper place in the volume of the geological record. Innumerable observations have shown that we can rely, with absolute confidence, on the fossils embedded in the different strata of the earth's crust as tests of the period to which they belong, however different the strata may be in mineral composition.

The next question is how we can ascertain the thickness and order of succession of these strata. We have seen that all stratified rocks are due to the action of water, and therefore were originally deposited horizontally. Had they remained so, in the first place, the process of forming stratified rocks must long ago have come to an end, for all the land

surface must have been worn down to the sea level, and, with no more land to be denuded, deposition must have ceased at an early period of the earth's history. In the second place, we could have known nothing more of the earth's crust than we saw on the surface, and in the shallow pits and borings which we could sink below it. But earthquakes and volcanoes, and the various fractures and pressures due to subterranean heat and secular contraction and cooling, have been at work counteracting the effects of denudation, and causing elevations and depressions by which the inequalities of the earth's surface have been renewed, the balance between sea and land maintained, and strata, originally horizontal at the bottom of the ocean, upheaved until sea-shells are found at the top of high mountains, so that we can walk for miles over their upturned edges.

Any one who wishes to understand how geologists have been able to measure such a thickness of the earth's crust has only to take a book open at page 1 and lay it flat before him. He can see nothing but that one page; but if he turns up the pages on the right-hand side of the book until their edges become horizontal, he can pass over them and count perhaps 500 pages in the space of a couple of inches.

This is precisely what geologists have been able to do at various points of the earth's surface where the upturned edges of the pages of its history are exposed, and they come out, one behind the other, in the due succession in which they were written by Nature. For instance, in travelling from east to west in England we pass continually from newer to older formations—Chalk comes in from below Tertiary; Oolite and Lias from below Chalk; then Permian or New Red Sandstone; Carboniferous, including the Coal Measures; Devonian or Old Red Sandstone; Silurian, Cambrian, and in the extreme north-west of Scotland and the Hebrides, oldest of all, the Laurentian.

There are some omissions and interpolations, but, in a general way, it may be said that within the bounds of the British Empire we have such a view of Nature's volume as would be got, in the case I have supposed, by travelling over its upturned edges from page 1 to page 500. And if each of the great formations

be taken as a separate chapter, each chapter will be found to be made-up of a number of pages, each with its own letterpress and illustrations, though connected with the pages before and after it by the thread of the continuous common subject of their proper chapter; as the chapters again are connected by the continuous common subject-matter of the complete volume. It must not be supposed that the volume is anything like perfect. We have to piece it together from the fragments found in the limited number of countries which have thus far been scientifically explored, and which do not constitute more than a small part of the earth's surface. We know nothing of what is below the oceans which cover more than three-fourths of that surface, and there are great gaps in the record during the times when portions of the surface were dry land, and when, consequently, no deposit of strata or preservation of fossils was possible. Still a great deal has been accomplished, and the general result, as given by common consent of the best geologists, is as follows:

The total thickness of known strata is about 130,000 feet or twenty-five miles, or the $\frac{1}{180}$ th part of the distance from the earth's surface to its centre. Of this, about 30,000 feet belong to the Laurentian, which is the oldest known stratified deposit; 18,000 to the Cambrian, and 22,000 to the Silurian. These earliest formations, which are grouped as the Primary or Palæozoic Epoch, have been so changed by slow crystallisation under great heat and pressure that all fossils and nearly all traces of stratification have been well-nigh obliterated.

In the Cambrian and Lower Silurian traces of life become more frequent, especially of low forms of seaweeds, and in the Upper Silurian we find an abundance of fossils, consisting of crustacea, shell-fish, and a few true fish in the upper strata. Some of the shells, as the *Lingula*, have continued without much change up to the present time; and on the whole we find ourselves in the Silurian period, if not earlier, in presence of a state of things in which substantially present causes operated and present conditions were in force. Rains fell, winds blew, rivers ran, waves eroded cliffs, shell-fish lived and died, and crabs and sand-worms crawled about on shores left

dry by each tide, very much as is the case at present.

The next great division, to which the name of Primary was given before the existence of fossils was known in the older or Palæozoic division, comprises the Devonian or Old Red Sandstone; the Carboniferous, which includes the coal; and the Permian or New Red Sandstone. The average thickness of these three systems, taken together, is about 42,000 feet. It may be called the era of Fern Forests and of Fish, the former being the principal source of our supplies of coal, and the latter being extremely abundant within the Devonian and Permian formations.

The third great division is formed by the Secondary group, which includes the Triassic, the Jura, and the Cretaceous or Chalk systems, and has an average thickness of about 15,000 feet. This epoch is emphatically the age of Reptiles as the preceding one was that of Fish, and the prevailing vegetation is no longer one of ferns and mosses, but of Gymnosperms, or plants having naked seeds, the most important class of which is that of the Coniferæ or Pine tribe. During this period the Plesiosaurs, Ichthyosaurs, and other gigantic sea-dragons abounded in the oceans; colossal land-dragons, such as the Dinosauria, occupied the continents, and Pterodactyls, a remarkable form of carnivorous flying lizards, ruled the air. Swarms of other reptiles, nearly related to the present lizards, crocodiles, and turtles, abounded both in the sea and land. A few traces of mammals and birds show that these orders had then come into existence, just as a few traces of reptiles are found in the Primary, and of fish in the Palæozoic strata, but the few mammalian remains found are of small animals of the marsupial or lowest type, and the birds are of a transition type between reptiles and true birds. This epoch concludes with the Chalk formation, which is one of relatively deep-sea deposit, where no trace of terrestrial life can be expected.

Above this comes the Tertiary epoch, when the present order, both of vegetable and animal life, is fairly inaugurated; mammals predominate over other forms of vertebrate animals; existing orders and species begin to appear and increase rapidly; and vegetation consists mainly of Angiosperms, or plants with

covered seeds, as in our present forests. The total thickness of these strata, from the lowest, or Eocene, to the end of the uppermost, or Pliocene, is about 3,000 feet. Above this comes the Quaternary, or recent period, which comprises the superficial strata of modern formation, and is characterised by the undoubted existence of man, and of animals which either now exist, or which have become extinct in quite recent geological times.

The details of this and of the Tertiary Epoch will be more fully considered when we come to treat of the antiquity of man, with which they are closely connected. But for the present object, which is that of ascertaining some standard of time for the immense series of ages proved by geology to have elapsed since the earth assumed its present condition, became subject to existing laws and fitted to be the abode of life, it will be sufficient to refer to the older strata.

The best idea of the enormous intervals of time required for geological changes will be derived from the coal measures. These consist of part only of one geological formation known as the Carboniferous. They are made up of sheets, or seams, of condensed vegetable matter, varying in thickness from less than an inch to as much as thirty feet, and lying one above another, separated by beds of rock of various composition. As a rule, every seam of coal rests upon a bed of clay, known as the "under-clay," and is covered by a bed of sandstone or shale. These alternations of clay, coal, and rock, are often repeated a great many times, and in some sections in South Wales and Nova Scotia there are as many as eighty or a hundred seams of coal, each with its own under-clay below and sandstone or shale above. Some of the coal seams are as much as thirty feet thick, and the total thickness of the coal measures is, in some cases, as much as 14,000 feet.

Now consider what these facts mean. Every under-clay was clearly once a surface soil on which the forest vegetation grew, whose accumulated *débris* forms the overlying seam of coal. The under-clays are full of the fibres of roots, and the stools of trees which once grew on them are constantly found *in situ*, with their roots attached just as they stood when the tree fell, and added to the accumulation of vegetable matter, which in modern times forms peat, and in more ancient

days, under different conditions of heat and pressure, took the more consolidated form of coal.

When these vegetable remains are examined with the aid of the microscope it is found that these ancient forests consisted mainly of trees like gigantic club-mosses, mares'-tails, and tree ferns, with a few resembling yews and firs. But in many cases the bulk of the coal is composed of the spores and seeds of these ferns and club-mosses, which were ripened and shed every year, and gradually accumulated into a vegetable mould, just as fallen leaves, beech-mast, and other *débris*, gradually form a soil in our existing forests.

The time required must have been very great to accumulate vegetable matter, principally composed of fine spore dust, to a depth sufficient under great compression to give even a foot of solid coal. Sir J. W. Dawson, who has devoted great attention to the coal-fields of America, says: "We may safely assert that every foot of thickness of pure bituminous coal implies the quiet growth and fall of at least fifty generations of *Sigillaria*, and therefore an undisturbed condition of forest growth, enduring through many centuries." But this is only the first step in the measure of the time required for the formation of the coal measures. Each seam of coal is, as we have seen, covered by a bed of sand or shale, *i.e.*, of water-borne materials. How can this be accounted for? Evidently in one way only—that the land surface in which the forest grew subsided gradually until it became first a marsh, and then a lagoon or shallow estuary, which silted up by degrees with deposits of sand or mud, and, finally, was upraised until its surface became dry land, in which a second forest grew, whose *débris* formed a second coal seam. And so on, over and over again, until the whole series of coal measures had been accumulated, when this alternation of slight submergences and slight rises came to an end, and some more decided movement of the earth's surface in the locality brought on a different state of things. This is in fact exactly what we see taking place on a smaller scale in recent times in such deposits as those of the delta of the Mississippi, where a well sunk at New Orleans passes through a succession of cypress swamps and forest

growths, exactly like those now growing on the surface, which are piled one above the other, and separated by deposits of river silt, showing a long alternation of periods of rest when forests grew, followed by periods of subsidence when they were flooded and their remains were embedded in silt.

Starting on the foregoing assumption that one foot of coal represents fifty generations of coal plants, and that each generation of coal plants took ten years to come to maturity, an assumption which is certainly very moderate; and taking the actually measured thickness of the coal measures in some localities at 12,000 feet, Professor Huxley calculates that the time represented by the Coal formation alone would be six millions of years. Such a figure is, of course only a rough approximation, but it is sufficient to show that when we come to deal with geological time, the standard by which we must measure is one of which the unit is a million of years.

This standard is confirmed by a variety of other considerations. Take the case of the Chalk formation.

Chalk is almost entirely composed of the microscopic shells of minute organisms, such as now float in the upper strata of our great oceans, and by their subsidence, in the form of an impalpable shell-dust, accumulate what is called the "*Globigerina ooze*," which is brought up by soundings in the Atlantic and Pacific from great depths. In fact, we may say that a chalk formation is now going on in the depths of existing oceans, and conversely that the old chalk, which now forms hills and elevated downs, was certainly deposited at the bottom of Cretaceous seas. The rate of deposit must have been extremely slow, certainly much slower than that of the deposit of the much grosser matter brought down by the Nile in its annual inundations, the growth of which has been estimated from actual measurement at about three inches per century. If one inch per century were the rate of accumulation of this microscopic shell-dust, subsiding slowly to depths of two or three miles over areas as large as Europe, it would take 1,200 years to form a foot of chalk, and 1,200,000 years to form 1,000 feet. Now there are places where the thickness of the Cretaceous formation, exposed by the edges of its upturned strata, exceeds

5,000 feet, so that this gives an approximation very similar to that furnished by the coal measures.

We have thus, on a rough approximation, a *minimum* period of about 6,000,000 years for the accumulation of a single member of one of the separate formations into which the total 130,000 feet of measured strata are subdivided. But this takes no account of the long periods during which no accumulation took place at the localities in question, and of the long pauses which must have ensued between each movement of elevation and submergence, and especially between the disappearance of an old, and the appearance of an almost entirely new, epoch, with different forms of animal and vegetable life. We may be certain also that we are far from knowing the total thickness of strata which will be disclosed when the whole surface of the earth comes to be explored. All we can say is that we have fragmentary pages left in the geological record, speaking broadly, for 100 millions of years, and that probably the lost pages are quite as numerous as those of which we have an imperfect knowledge.

Sir Charles Lyell, the highest authority on the subject, is inclined to estimate the *minimum* of geological time at 200 millions of years, and few geologists will say that his estimate appears excessive.

Another test of the vast duration of geological time is afforded by the oscillations of the earth's surface. At first sight we are apt to consider the earth as the stable and the sea as the unstable element. But in reality it is exactly the reverse. Land has been perpetually rising and falling while the level of the sea has remained the same. This is easily proved by the presence of sea-shells and other marine remains in strata which now form high mountains. In the case of chalk, for instance, there must have been in England a change of relative level of sea and land of more than two miles of vertical height, between the original formation of the chalk at the bottom of a deep ocean and its present position in the North and South Downs. In other cases the change of level is even more conspicuous. The Nummulite limestone, which is formed like chalk from an accumulation of the minute shells of low organisms floating in the oceans of the early Tertiary

period, is found in mountain masses, and has been elevated to a height of 10,000 feet and more in the Alps and Himalayas.

On a smaller scale, and in more recent times, raised beaches with existing shells and lines of cliffs and caves, are found at various heights above the existing sea-level of many of the coasts of Britain, Scandinavia, Italy, South America, and other countries.

Now the first question is, were these changes caused by the land rising or by the sea falling? The answer is, by the land rising. Had they been caused by the sea standing at a higher level it must have stood everywhere at this level, at any rate in the same hemisphere and anywhere near the same latitude. But there are large tracts of land which have never been submerged since remote geological periods; and in recent times there is conclusive evidence that the changes of level of sea and land have been partial and not general. Thus in the well-known instance of the columns of the ruined temple of Serapis at Pozzuoli in the Bay of Naples, which forms the illustration on the title-page of Lyell's "Principles of Geology," there can be no doubt that since the temple was built, either the sea must have risen and since fallen, or the land sunk and since risen, at least twenty feet since the temple was built less than 2,000 years ago, for up to this height the marble columns are riddled by borings of marine shells, whose valves are still to be seen in the holes they excavated. But an elevation of the level of the Mediterranean of twenty feet would have submerged a great part of Egypt, and other low-lying lands on the borders of that sea, where we know that no such irruptions of salt water have taken place within historical, or even within recent geological, times.

The conclusion is therefore certain, that the land at this particular spot must have sunk twenty feet, and again risen as much, so as to bring back the floor of the temple to its present position, which stood one hundred years ago just above the sea-level, and that so gradually as not to throw down the three columns which are still standing. A slow subsidence has since set in and is now going on, so that the floor is now two or three feet below the sea-level.

Similar proofs may be multiplied to

any extent. Along the coasts of the British Islands we find, in some places submarine forests showing subsidence, in others raised beaches showing elevation, but they are not continuous at the same level. Along the east coast of Scotland there is a remarkable raised beach at a level of about twenty-four feet above the present one, showing in many places lines of cliff, sea-worn caves, and outlying stacks and skerries, exactly like those of the present coast, though with green fields or sandy links at their base, instead of the waves of the German Ocean. But as we go north this inland cliff gets lower and gradually dies out, and when we get into the extreme north, among the Orkney and Shetland Islands, there are no signs of raised beaches, and everything points towards the recent period having been one of subsidence.

Again, in Sweden, where marks were cut in rocks in sheltered situations on the well-nigh tideless Baltic more than a century ago, so as to test the question of an alleged elevation of the land, it has been clearly shown that in the extreme north of Sweden, the marks have risen nearly seven feet, while in the central portion of the country they have neither risen nor fallen, and in the southern province of Scania they have fallen.

This would be clearly impossible if the sea and not the land had been the unstable element, and apparent elevations and depressions had been due to a general fall or rise in the level of all the seas of the northern hemisphere.

In fact, the more we study geology the more we are impressed with the fact that the normal state of the earth is, and has always been, one of incessant changes. Water, raised by evaporation from the seas, falls as rain or snow on land, wastes it away and carries it down from higher to lower levels, to be ultimately deposited at the bottom of the sea. This goes on constantly, and if there were no compensating action, as the seas cover a much larger area than the lands, all land would ultimately disappear, and one universal ocean cover the globe. But inward heat supplies the compensating action, and new lands rise and new mountain chains are upheaved to supply the place of those which disappear.

This inward heat of the earth is an ascertained fact; for as we descend from the surface in deep mines or borings, we

find that the temperature actually does increase at a rate which varies somewhat in different localities, but which averages about 1° Fahrenheit for every 60 feet of depth. At this rate of increase water would boil at a depth of 10,000 feet, and iron and all other metals be melted before we reached 100,000 feet. What actually occurs at great depths we do not know with any certainty, for we are not sufficiently acquainted with the laws under which matter may behave when under enormous heat combined with enormous pressure. But we do know from volcanoes and earthquakes that masses of molten rocks and of imprisoned gases exist in certain localities, at depths below the surface which, although large compared with our deepest pits, are almost infinitesimally small compared with the total depth of 4,000 miles from that surface to the earth's centre.

This much is clear, that, in order to account for observed facts, we must consider the extreme outer crust, or surface of the earth as known to us, as resting on something which is liable to expand and contract slowly with variations of heat, and occasionally, when the tension becomes great, to give violent shocks to the outer crust, sending earthquake waves through it, and to send up gases and molten lava through volcanoes, along lines of fissure, and at points of least resistance. It is clear, also that these movements are not uniform, but that one part of the earth's surface may be rising while another is sinking, and portions of it may be slowly tilting over, so that as one end sinks the other rises.

The best comparison that can be made is to a sheet of ice which has been much skated over and cracked in numerous directions, so as to have become a sort of mosaic of ice fragments, which, when a thaw sets in and the ice gets sloppy, rise and fall with slightly different motions as a skater, gliding over them, varies the pressure, and occasionally give a crack and let water rise through from below in the line of fissure. The difficulty will not seem so great if we consider that the rocks which form the earth's crust are for the most part elastic, and that an amount of elevation which seems large in itself does not necessarily imply a very steep gradient. Thus, if the elevation which towards the close of the Glacial period carried a bed of exist-

ing sea-shells of Arctic type to the top of the hill, Moel Tryfen, in North Wales, which is 1,200 feet high, were, say, one of 1,500 feet, this would be given by a gradient of 15 feet a mile, or 1 in 333 for 100 miles. Such a gradient would not be perceptible to the eye, and would certainly not be sufficient to cause any tension likely to rupture rocks or disturb strata.

Such movements are as a rule extremely slow. In volcanic regions there are occasionally shocks which raise extensive regions a few feet at a blow, and partial elevations and subsidences which throw up cones of lava and cinders, or let mountains down into chasms, in a single explosion. The most noted of these are the instances of Monte Nuovo, near Naples, 800 feet high, and Jorullo, in Mexico, thrown up in one eruption, and the disappearance of a mountain 2,000 feet high in the Straits of Sunda during an earthquake. The largest rise recorded of an extensive area from the shock of an earthquake, is that which occurred in South America in 1835, when a range of coast of 500 miles from Copiapo to Chiloe was permanently raised five or six feet by a single shock, as was shown by the beds of dead mussels and other shells which had been hoisted up in some places as much as ten feet. It is probable that the great chain of the Andes, whose highest summits reach 27,000 feet, has been raised in a great measure by a succession of similar shocks.

But for the most part these movements, whether of elevation or depression, go on so slowly and quietly that they escape observation. Scandinavia is apparently now rising and Greenland sinking, but most countries have remained appreciably steady, or nearly so, during the historical period. St. Michael's Mount, in Cornwall, is still connected with the mainland by a spit, dry at ebb tide and covered at flood, as it was more than 2,000 years ago when the old Britons carted their tin across to Phœnician traders. Egypt, during a period of 7,000 years, has preserved the same level, or at the most has sunk as slowly as the Nile mud has accumulated. Parts of the English and Scotch coast have risen perhaps twenty feet since the prehistoric period, when canoes were wrecked under what are now the streets of Glasgow, and whales were stranded in

the Carse of Stirling. There is even some evidence that the latest rise may have occurred since the Roman wall was built from the Forth to the Clyde. In any case, however, the movements have been extremely slow, and there have been frequent oscillations, and long pauses when the level of land and sea remained stationary. The evidence, therefore, from the great changes which have occurred during each geological period, points to the same conclusion as that drawn from the thickness of formations, such as the coal measures and chalk, which must have been accumulated very slowly, viz., that geological time must be measured by a scale of millions of years.

Another test of the vast duration of geological time is afforded by the changes which have taken place in animal life as we pass from one formation to another, and even within the limits of the same formation. The fauna, or form of existing life at a given period, changes with extreme slowness. During the historical period there has been no perceptible change, and even since the Pliocene period, which cannot be placed at a less distance from us than 200,000 years, and probably at much more, the change has been very small. In the limited class of large land animals it has been considerable; but if we take the far more numerous forms of shell-fish and other marine life, the old species which have become extinct and the new ones which have appeared, do not exceed five per cent. of the whole. This is the more remarkable as great vicissitudes of climate and variations of sea-level have occurred during the interval. The whole of the Glacial period has come and gone, and Britain has been by turns an archipelago of frozen islands, and part of a continent extending over what is now the German Ocean, and pushing out into the Atlantic up to the one hundred fathom line.

Reasoning from these facts, assuming the rate of change in the forms of life to have been the same formerly, and summing up the many complete changes of fauna which have occurred during the separate geological formations, Lyell has arrived at the conclusion that geology requires a period of not less than 200 millions of years to account for the phenomena which it discloses.

Long as the record is of geological

time, it is only that of one short chapter in the volume of the history of the universe. Geology only begins when the earth had cooled down into a state resembling the present; when winds blew, rains fell, rivers and seas eroded rocks and formed deposits, and when the conditions were such that life became possible by the remains of which those deposits can be identified.

But before this period began, which may be called that of the maturity or middle age of our planet, a much vaster time must be allowed for the contraction and cooling of the vaporous matter of which it is formed, into the state in which the phenomena of geology became possible. And if vast in the case of the earth, how much vaster must be the life-periods of the larger planets, such as Jupiter, which from their much greater size cool and contract much more slowly, and are not yet advanced beyond the stage of intense youthful heat and glowing luminosity which was left behind by our earth a great many tens of millions of years ago! And how vastly vaster must be that of the sun, whose mass and volume exceed those of Jupiter in a far higher ratio than Jupiter surpasses the earth!

And beyond all this in a third degree of vastness come the life-periods of those stars or distant suns, which we know to be in some cases as much as three hundred times larger than our sun, and not nearly so far advanced as it in the process of emergence from the fiery nebulous into the solar stage.

To give some idea of the vast intervals of time required for these changes, a few facts and figures may be given.

One of the latest speculations of mathematical science is that the rotation of the earth is becoming slower, or, in other words, that the day is becoming longer, owing to the retarding action of the tides, which act as a brake on a revolving wheel. If so, the effect of the reaction on the moon of this action of the moon on the earth, must be that as the earth rotates more slowly, the moon recedes to a greater distance. And *vice versa*, when the earth rotated more rapidly the moon was nearer to it, until at length, when the process is carried back far enough, we arrive at a time when the moon was at the earth's surface and the length of the day about

three hours. In this state of things the moon is supposed to have been thrown off from the earth, either by one great convulsion, or, more probably, by small masses at a time forming a ring like that of Saturn, which ended by coalescing into a single satellite. With the moon, which is the principal cause of the tides, so much nearer the earth, their rise and fall must have been something enormous, and huge tidal waves like the bore of the Bay of Fundy, but perhaps 500 or 1,000 feet high, must have swept twice during each revolution of the earth on its axis, *i.e.*, twice every three or four hours, along all the narrower seas and channels and over all except the mountainous lands adjoining.

Now these conclusions may be true or not as regards phases of the earth's life prior to the Silurian period, from which downwards geology shows unmistakably that nothing of the sort, or in the least degree approaching to it, has occurred. But what I wish to point out is that all this superstructure of theory rests on a basis which really does admit of definite demonstration and calculation.

Halley found that when eclipses of the sun, recorded in ancient annals, are compared with recent observations, a discrepancy is discovered in the rate of the moon's motion, which must have been slightly slower than it is now. Laplace apparently solved the difficulty by showing that this was an inevitable result of the law of gravity, when the varying eccentricity of the earth's orbit was properly taken into account; and the calculated amount of the variation from this cause was shown to be exactly what was required to reconcile the observations. But our great English mathematician, Adams, having recently gone over Laplace's calculations anew, discovered that some factors in the problem had been omitted, which reduced Laplace's acceleration of the moon's motion by about one-half, leaving the other half to be explained by a real increase in the length of the sidereal day, or time of one complete revolution of the earth about its axis. The retardation required is one sufficient to account for the total accumulated loss of an hour and a quarter in 2,000 years; or, in other words, the length of the day is now more by about $\frac{1}{84}$ th part of a second than it was 2,000 years ago.

At this rate it would require 168,000

years to make a difference of 1 second in the length of the day; 10,080,000 years for a difference of 1 minute; and 604,800,000 years for a difference of 1 hour. The rate would not be uniform for the past, for as the moon got nearer it would cause higher tides and more retardation; still, the abyss of time seems almost inconceivable to get back to the state in which the earth could have rotated in three hours and thrown off the moon.

It is right, however, to state that all mathematical calculations of time, based on the assumed rate at which cosmic matter cools into suns and planets, and these into solid and habitable globes, are in the highest degree uncertain. If the original data are right, mathematical calculation inevitably gives right conclusions. But if the data are wrong, or, what is the same thing, partial and imperfect, the conclusions will, with equal certainty, be wrong also. Now in this case we certainly do not know "the truth, the whole truth, and nothing but the truth" respecting these processes. Take what is perhaps the most difficult problem presented by science—how the sun keeps up so uniformly the enormous amount of heat which it is constantly radiating into space. This radiation is going on in every direction, and the solar heat received by the earth is only that minute portion of it which is intercepted by our little speck of a planet. All the planets together receive less than one 230,000,000th part of the total heat radiated away by the sun and apparently lost in space. Knowing the amount of heat from the sun's rays received at the earth's surface in a given time, we can calculate the total amount of heat radiated from the sun in that time. It amounts to this, that the sun in each second of time parts with as much heat as would be given out by the burning of 16,436 millions of millions of tons of the best anthracite coal. And radiation certainly at this rate, if not a higher one, has been going on ever since the commencement of the geological record, which must certainly be reckoned by a great many tens of millions of years.

What an illustration does this afford of that apparent "waste of Nature" which made Tennyson "falter where he firmly trod" when he came to consider "her secret meaning in her deeds"!

Yet there can be no doubt that vast as

these figures are, they are all the result of natural laws, just as we find the law of gravity prevailing throughout space at distances expressed by figures equally vast. The question is, what laws? The only one we know of at present at all adequate to account for such a generation of heat, is the transformation into heat of the enormous amount of mechanical force or energy, resulting from the condensation of the mass of nebulous matter from which the sun was formed, into a mass of its present dimensions. This is no doubt a true cause as far as it goes. It is true that as the mass contracts, heat would be, so to speak, squeezed out of it, very much as water is squeezed out of a wet sponge by compressing it. But it is a question whether it is the sole and sufficient cause. Mathematicians have calculated that even if we suppose the original cosmic matter to have had an infinite extension, its condensation into the present sun would only have been sufficient to keep up the actual supply of solar heat for about 15 millions of years. Of this a large portion must have been exhausted before the earth was formed as a separate planet, and had cooled down into a habitable globe. But even if we took the whole it would be altogether insufficient. All competent geologists are agreed in requiring at least 100 millions of years to account for the changes which have taken place in the earth's surface since the first dawn of life recorded in the older rocks.

Various attempts have been made to reconcile the discrepancy. For instance, it has been said that the constantly repeated impact of masses of meteoric and cometic matter falling into the sun must have caused the destruction of a vast amount of mechanical energy which would be converted into heat. This is true as far as it goes, but it is impossible to conceive of the sun as a target kept at a perpetual and uniform white heat for millions of years by a rain of meteoric bullets constantly fired upon it. More plausibly it is said that we know nothing of the interior constitution of the sun, and that its solid nucleus may be vastly more compressed than is inferred from the dimensions of its visible disc, which is composed of glowing flames and vapours. This also may be a true cause, but, after making every allowance, we must fall back on the statement that the

continuance for such enormous periods of such an enormous waste of energy as is given out by the sun, though certainly explainable by laws of Nature, depends on laws not yet thoroughly understood and explained.

Even in the case, comparatively small and near to us, of the earth, the condition of the interior and the rate of secular cooling afford problems which as yet wait for solution. The result of a number of careful experiments in mines and deep sinkings shows that the temperature, as we descend below the shallow superficial crust which is affected by the seasons, *i.e.*, by the solar radiation, increases at the average rate of 1° Fahrenheit for every 60 feet of depth. That is the average rate, though it varies a good deal in different localities. Now, at this rate we should soon reach a depth at which all known substances would be melted.

But astronomical considerations, derived from the Precession of the Equinoxes, favour the idea that the earth is a solid and not a fluid body, and require us in any case to assume a rigid crust of not less than ninety miles in thickness. And if the whole earth below a thin superficial crust were in an ordinary state of fluidity from heat, it is difficult to see how it could do otherwise than boil, that is, establish circulating currents throughout its mass with disengagement of vapour, in which case the surface crust must be very soon broken up and melted down, just as the superficial crust of a red-hot stream of lava is, if an infusion of fresh lava raises the stream below to white heat, or as a thin film of ice would be if boiling water were poured in below it.

All we can say is, that the laws under which matter behaves under conditions of heat pressure, chemical action, and electricity so totally different as must prevail in the interior of the earth, and *a fortiori* in that of the sun, are as yet very partially known to us. In the meantime the safest course is to hold by those conclusions of geology which, as far as they go, depend on laws really known to us. For instance, the quantity of mud carried down in a year by the Ganges or Mississippi, is a quantity which can be calculated within certain approximate limits. We can tell with certainty how much the deposit of this amount of mud would raise an area, say of 100 square

miles, and how long it would take, at this rate, to lower the area of India drained by the Ganges a sufficient number of feet to give matter enough to fill up the Gulf of Bengal. And if among the older formations we find one, like the Wealden for instance, similar in character to that now forming by the Ganges, we can approximate from its thickness to the time that may have been required to form it.

In calculations of this sort there is no *theory*, they are based on positive facts, limited only by a certain possible amount of error either way. In short, the conclusions of geology, at any rate up to the Silurian period, when the present order of things was fairly inaugurated, are approximate *facts* and not *theories*, while the astronomical conclusions are *theories* based on *data* so uncertain, that while in some cases they give results incredibly short, like that of 15 millions of years for the whole past process of the formation of the solar system, in others they give results almost incredibly long, as in that which supposes the moon to have been thrown off when the earth was rotating in three hours, while the utmost actual retardation claimed from observation would require 600 millions of years to make it rotate in twenty-three hours instead of twenty-four.

To one who looks at these discussions between geologists and astronomers not from the point of view of a specialist in either science, but from that of a dispassionate spectator, the safest course, in the present state of our knowledge, seems to be to assume that geology really proves the duration of the present order of things to have been somewhere over 100 millions of years, and that astronomy gives an enormous though unknown time beyond in the past, and to come in the future, for the birth, growth, maturity, decline, and death of the solar system of which our earth is a small planet now passing through the habitable phase.

So far, however, as the immediate object of this work is concerned, *viz.*, the bearings of modern scientific discovery on modern thought, it is not very material whether the shortest or longest possible standards of time are adopted. The conclusions as to man's position in the universe, and the historical truth or falsehood of old beliefs, are the same whether man has existed in a state of constant though slow progression for the

last 50,000 years of a period of 15 millions, or for the last 500,000 years of a period of 150 millions. It is a matter of the deepest scientific interest to arrive at the truth, both as to the age of the solar system, the age of the earth as a body capable of supporting life, the successive orders and dates at which life actually appeared, and the manner and date of the appearance of the most highly organised form of life endowed with new capacities for developing reason and conscience in the form of Man. Those who wish to prove themselves worthy of their great good luck in having been born in a civilised country of the nineteenth century, and not in Palæolithic periods, will do well to show that curiosity, or appetite for knowledge, which mainly distinguishes the clever from the stupid and the civilised from the savage man, by studying the works of such writers as Lyell, Huxley, Tyndall, and Proctor, where they will find the questions which here are only briefly stated, developed at fuller length with the most accurate science and in the clearest and most attractive style. But for the moral, philosophical, and religious bearings of these discoveries on the current of modern thought, there is such a wide margin that it becomes almost immaterial whether the shortest possible or longest possible periods should be ultimately established.

CHAPTER III

MATTER

Matter and Motion—Light, Colour, and Heat—Matter and its Elements—Molecules and Atoms—Spectroscope—Uniformity of Matter throughout the Universe—Force and Motion—Conservation of Energy—Electricity, Magnetism, and Chemical Action—Dissipation of Heat—Birth and Death of Worlds.

THE contents of the material universe may be expressed in terms of Matter and of Motion. Matter exists in the three-fold and interrelated states known as solid, liquid, and gaseous, and it is convenient to include with these the apparently fourth state called the ethereal. The existence of this last-named is an

hypothesis by which alone can we account for the phenomena of light and heat, and, as the marvellous researches of Hertz have shown, of the electro-magnetic waves which confirm the theory of connection between electricity, magnetism, light, and radiant heat. More than this we cannot assume regarding ether, for all ponderable matter,—solids, liquids, gases—consists of ultimate molecules, and we do not know whether ether is non-molecular or imponderable.

Dealing with Motion, it has been shown that light radiates in all directions from a luminous centre, travelling at the rate of 186,000 miles per second. Now what is light? It is a sensation produced on the brain by something which has been concentrated by the lens of the eye on the retina, and thence transmitted along the optic nerve to the brain, where it sets certain molecules vibrating. What is the *something* which produces this effect? Is it a succession of minute particles, shot like rifle-bullets from the luminous body and impinging on the retina as on a target? Or is it a succession of tiny waves breaking on the retina as the waves of the sea break on a shore? Analogy suggests the latter, for in the case of the sister sense, sound, we know as a fact that the sensation is produced on the brain by waves of air concentrated by the ear, and striking on the auditory nerve. But we have a more conclusive proof. If one of a series of particles shot out like bullets overtakes another, the force of impact of the two is increased; but if one wave overtakes another when the crest of the pursuing wave just coincides with the hollow of the wave before it the effect is neutralised, and if the two are of equal size it will be exactly neutralised and both waves will be effaced. In other words, two lights will make darkness. This, therefore, affords an infallible test. If two lights can make darkness, light is propagated, like sound, by waves. Now two lights do constantly make darkness, as is proved every day by numerous experiments. Therefore light is caused by waves.

But to have waves there must be a medium through which the waves are propagated. Without water you could not have ocean waves; without air you could not have sound-waves. Waves are in fact nothing but the successive forms assumed by a set of particles which,

when forced from a position of rest, tend to return to that position, and oscillate about it. Place a cork on the surface of a still pond, and then throw in a stone; what follows? Waves are propagated, which seem to travel outwards in circles, but if you watch the cork, you will see that it does not really travel outwards, but simply rises and falls in the same place. This is equally true of waves of sound and waves of light. But the velocity with which the waves travel depends on the nature of the medium. In a dense medium of imperfect elasticity they travel slowly, in a rare and elastic medium quickly. Now the velocity of a sound-wave in air is about 1,100 feet a second, that of the light-wave about 186,000 miles a second or about one million times greater. It is proved by mathematical calculation that, if the density of two media are the same, their elasticities are in proportion to the squares of the velocities with which a wave travels. The elasticity of ether, therefore, would be a million million times greater than that of air, which, as we know, is measured by its power of resisting a pressure of about 15 lbs. to the square inch. But the ether must in fact be almost infinitely rare, as well as almost infinitely elastic, for it causes no perceptible retardation in the motions of the earth and planets. It must be almost infinitely rare also because it permeates freely the interior of substances like glass and crystals, through which light-waves pass, showing that the atoms or ultimate particles of which these substances are composed, minute as they are, must be floating in ether like buoys floating on water or balloons in the air.

The dimensions of the light-waves which travel through this ether at the rate of 186,000 miles a second can be accurately measured by strict mathematical calculations, depending mainly on the phenomena of interferences, *i.e.*, of the intervals required between successive waves for the crest of one to overtake the depression of another and thus make two lights produce darkness.

These calculations are much too intricate to admit of popular explanation, but they are as certain as those of the Nautical Almanac, based on the law of gravity, which enable ships to find their

way across the pathless ocean, and they give the following results:

DIMENSIONS OF LIGHT-WAVES.

COLOURS.	NUMBER OF WAVES IN ONE INCH.	NUMBER OF OSCILLATIONS IN ONE SECOND.
Red	39,000	477,000,000,000,000
Orange	42,000	506,000,000,000,000
Yellow	44,000	535,000,000,000,000
Green	47,000	575,000,000,000,000
Blue	51,000	622,000,000,000,000
Indigo	54,000	658,000,000,000,000
Violet	57,000	699,000,000,000,000

These are the colours whose vibrations affect the brain through the eye with the sensation of light, and which cause the sensation of white light when their different vibrations reach the eye simultaneously. But there are waves and vibrations on each side of these limits, which produce different effects, the longer waves with slower oscillations beyond the red, though no longer causing light causing heat, while the shorter and quicker waves beyond the violet cause chemical action, and are the most effective agents in photography.

We must refer our readers to works treating specially of light for further details, and for an account of the vast variety of beautiful and interesting experiments with polarised light, coloured rings, and otherwise, to which the theory of waves propagated through ether affords the key. For the present purpose it is sufficient to say that modern science compels us to assume such an ether extending everywhere, from the faintest star seen at a distance which requires thousands of years for its rays, travelling at the rate of 186,000 miles a second, to reach the earth, down to the infinitesimally small interspace between the atoms of the minutest matter. And throughout the whole of this enormous range law prevails, ether vibrates and has always vibrated in the same definite manner, just as air vibrates by definite laws when the strings of a piano are struck by the hammers.

I now return to the consideration of matter.

What is matter? In the most general sense it is that which has weight, or is subject to the law of gravity, and, as shown above, it exists, as ponderable stuff, in the three forms of solid, liquid,

or gas, according to the amount of heat. Diminish heat, and the particles approach closer and are linked together by mutual attraction, so as not to be readily parted; this is a solid. Increase the heat up to a certain point, and the particles recede until their mutual attractions in the interior of the mass neutralise one another, so that the particles can move freely, though still held together as a mass by the sum of all these attractions acting as if concentrated at the centre of gravity; this is the liquid state. Increase the heat still more, and the particles separate until they get beyond the sphere of their mutual attraction and tend to dart off into space, unless confined by some surface on which they exert pressure; this is a gas.

The most familiar instance of this is afforded by water, which, as we all know, exists in the three forms of ice, water, and vapour or steam, according to the dose of heat which has been incorporated with it.

Pursuing our inquiry further, the next great fact in regard to matter is that it is not all uniform. While most of the common forms with which we are conversant are made up of mixed materials, which can be taken to pieces and shown separately, there are, as at present ascertained, some seventy-six substances which defy chemical analysis to decompose them, and must therefore be taken as elementary substances. A great majority of these consist of substances existing in minute quantities, and hardly known outside the laboratories of chemists

The world of matter, as known to the senses, is mainly composed of combinations, more or less complex, of a few elements. Thus, water is a compound of two simple gases, oxygen and hydrogen; air, speaking broadly, of oxygen and nitrogen; the solid framework of the earth, mainly of combinations of oxygen with carbon, calcium, aluminium, silicon, and a few other bases; salt, of chlorine and sodium; the vegetable world directly and the animal world indirectly, mainly of complex combinations of oxygen, hydrogen, and nitrogen with carbon, and with smaller quantities of silicon, sulphur, potassium, sodium, and phosphorus. The ordinary metals, such as iron, gold, silver, copper, tin, lead, mercury, zinc, nearly complete the list of what may be called ordinary elements.

Now let us push our analysis a step further. How is matter made up of these elements; Up to and beyond the furthest point visible by aid of the microscope, matter is divisible. We can break a crystal into fragments, or divide a drop into drops, until they cease to be visible, though still retaining all the properties of the original substance. Can we carry on this process indefinitely, and is matter composed of something that can be divided and subdivided into fractional parts *ad infinitum*? The answer is, No, it consists of ultimate but still definite particles which cannot be further subdivided. How is this known? Because we find by experience that substances will only combine in certain definite proportions either of weight or measure. For instance, in forming water exactly eight grains by weight of oxygen combine with exactly one grain of hydrogen, and if there is any excess or fractional part of either gas, it remains over in its original form uncombined. In like manner, matter in the form of gas always combines with other matter in the same form by volumes which bear a definite and very simple proportion to each other, and the compound formed bears a definite and very simple ratio to the sum of the volumes of the combining gases. Thus two volumes of hydrogen combine with one of oxygen to form two volumes of water in the state of vapour.

From these facts certain inferences can be drawn. In the first place it is clear that matter really does consist of minute particles, which do not touch and form a continuous solid, but are separated by intervals which increase with increase of temperature. This is evident from the fact that we can pour a second or third gas into a space already occupied by a first one. Each gas occupies the enclosed space just as if there were no other gas present, and exerts its own proper pressure on the containing vessel, so that the total pressure on it is exactly the sum of the partial pressures. It is easy to see what this means. If a second regiment can be marched into a limited space of ground on which a first regiment is already drawn up, it is evident that the first regiment must be drawn up in loose order, *i.e.*, the soldier-units of which it is composed must stand so far apart that other soldier-units can find room between them without disturbing the for-

Indivisible materially; rationally divisible: all that has extension is divisible.

mation. But the effect will be that the fire from the front will be increased, as for instance if a soldier of the second regiment, armed with a six-shooter repeating rifle, takes his stand between two soldiers of the first regiment armed with single-barrelled rifles, the effective fire will be increased in the ratio of 8 to 2. And this is precisely what is meant by the statement that the pressure of two gases in the same space is the sum of the separate pressures of each. It is clearly established that the pressure of a gas on a containing surface is caused by the bombarding to which it is subjected from the impacts of an almost infinite number of these almost infinitely small atoms, which, when let loose from the mutual attractions which hold them together in the solid and fluid state, dart about in all directions, colliding with one another and rebounding, like a set of little billiard-balls gone mad, and producing a certain average resultant of momentum outwards which is called pressure.

Another simile may help us to conceive how the indivisibility of atoms is inferred from the fact that they only combine in definite proportions. Suppose a number of gentlemen and ladies promenading promiscuously in a room. The band strikes up a waltz, and they at once proceed to group themselves in couples rotating with rhythmical motion in definite orbits. Clearly, if there are more ladies than gentlemen, some of them will be left without partners. So, if instead of a waltz it were a threesome reel, in which each gentleman led out two ladies, there must be exactly twice as many ladies as gentlemen for all to join in the dance. But if a gentleman could be cut up into fractional parts, and each fraction developed into a dancing gentleman, as primitive cells split up and produce fresh cells, it would not matter how many ladies there were, as each could be provided with a partner. Now this is strictly analogous to what occurs in chemical combination. Water is formed by each gentleman atom of oxygen taking out a lady atom of hydrogen in each hand, and the sets thus formed commence to dance threesome reels in definite time and measure, any surplus oxygen or hydrogen atoms being left out in the cold. Wonderful as it may appear, science enables us not only to say of these inconceivably minute atoms

that they have a real existence, but to count and weigh them. This fact has been accomplished by mathematical calculations based on laws which have been ascertained by a long series of experiments on the constitution of gases.

It is found that all substances, when in the form of gas, conform to three laws:

1. Their volume is inversely proportional to the pressure to which they are subjected.
2. Their volume is directly proportional to the temperature.
3. At the same pressure and temperature all gases have the same number of molecules in the same volume.

From the last law it is obvious that if equal volumes of two gases are of different weight, the cause must be that the molecules of the one are heavier than those of the other. This enables us to express the weight of the molecule of any other gas in some multiple of the unit afforded by the weight of the molecule of the lightest gas, which is hydrogen. Thus, the density of watery vapour being nine times that of hydrogen, we infer that the molecule of water weighs nine times as much as the molecule of hydrogen, and that of oxygen being eight times greater, we infer that the oxygen molecule is eight times heavier than that of hydrogen.

These weights are checked by the other law which has been stated, that chemical combination between different substances always takes place in certain definite proportions. Thus, whenever in a chemical process the original substances or the product are or might exist in the state of gas, it is always found that the definite proportions observed in the chemical process are either the proportions of the densities of the respective gases or some simple multiple of these proportions. Thus, the weight of hydrogen being 2, which combines with a weight of oxygen equal to 16 to form a weight of watery vapour equal to 18, the density of the latter is to that of hydrogen as 9 to 1, *i.e.*, as 18 to 2.

But to get to the bottom of the matter we must go a step further, and as we have decomposed substances into molecules, we must take the molecules themselves to pieces and see what they are made of. The molecule is the ultimate particle into which any substance can be divided retaining its own peculiar qualities. A molecule of water is as truly water as a drop

or a tumblerful. But when chemical decomposition takes place, instead of the molecule of water we have molecules of two entirely different substances, oxygen and hydrogen. Nothing can well be more unlike than the product water and the component parts of which it is made up. Water is a fluid, oxygen a gas; water extinguishes fire, oxygen creates it. Water is a harmless drink, oxygen the base of the most corrosive acids. It is evident that the water-molecule is a composite, and that its qualities depend, not on the essential qualities of the atoms which have combined to make it, but on the manner of the combination, and the new modes of action into which these atoms have been forced. In his native war-paint oxygen is a furious savage; with a hydrogen atom in each hand he is a polished gentleman.

Our theory, therefore, leads beyond molecules to atoms, and we have to consider these particles of a still smaller order than molecules, as the ultimate indivisible units of matter of which we have been in search. And even these we must conceive of as corks, as it were, floating in an ocean of ether, causing waves in it by their own proper movements, and agitated by all the successive waves which vibrate through this ether-ocean in the form of light and heat.

Working on these data, a variety of refined mathematical calculations made by Clausius, Clerk Maxwell, Sir W. Thomson (now Lord Kelvin), and other eminent mathematicians, have given us approximate figures for the actual size, weight, and velocities of atoms and molecules. The results are truly marvellous. A millimetre is the one-thousandth part of a metre, or roughly one twenty-fifth of an inch. The magnitudes with which we have to deal are all of an order where the standard of measurement is expressed by the millionth part of a millimetre. The volume of a molecule of air is only a small fraction of that of a cube whose side would be the millionth of a millimetre. A cubic centimetre, or say a cube whose side is between one-third and one-half of an inch, contains 21,000,000,000,000,000,000 molecules. The number of impacts received by each molecule of air during one second will be 4,700 millions. The distance traversed between each impact averages 95 millionths of a millimetre.

It may assist in forming some concep-

tion of these almost infinitely small magnitudes, to quote an illustration given by Sir W. Thomson as the result of mathematical calculation. Suppose a drop of water were magnified so as to appear of the size of the earth or with a diameter of 8,000 miles, the atoms of which it is composed, magnified on the same scale, would appear of a size intermediate between that of a rifle-bullet and of a cricket-ball.

These figures show that space and magnitude extend beyond the standards of ordinary human sense, such as miles, feet, and inches, as far downwards into the region of the infinitely small as they do upwards into that of the infinitely great.

And throughout the whole of this enormous range law prevails. The same law of gravity gives weight to molecules and atoms, makes an apple fall to the ground, and causes double stars to revolve round their centre of gravity in elliptic orbits. The law of polarity which converts iron-filings into small magnets under the influence of a permanent magnet or electric current, animates the smallest atom. Atoms arrange themselves into molecules, and molecules into crystals, very much as magnetised iron-filings arrange themselves into regular curves. And the great law seems to prevail universally throughout the material, as it does also throughout the moral world, that you cannot have a North without a South Pole, a positive without a negative, a right without a wrong; and that error consists mainly in what the poet calls "the falsehood of extremes"—that is, in allowing the attraction of one pole, or of one opinion, so to absorb us as to take no account of its opposite.

The universality of law has received wonderful confirmation of late years from the discovery made by the spectroscope that the sun, the planets, and the remotest stars are all composed of matter identical with that into which chemical analysis has resolved the constituent matter of the earth. This has been proved in the following way:

If a beam of light is admitted into a darkened room through a small hole or narrow slit, and a triangular piece of glass, called a prism, is interposed in its path, the image thrown on a screen is a rainbow-tinted streak, intersected by numerous fine dark lines, which is called a spectrum. If, instead of solar light, light

from other luminous sources is similarly treated, it is found that all elementary substances have their peculiar spectra. Light from solid or liquid substances gives a continuous spectrum, light from gases or glowing vapours gives a spectrum of bright lines separated from each other, but always in definite positions according to the nature of the substance. The next great step in the discovery was that these bright lines become dark lines when a light of greater intensity, coming from a solid nucleus, is transmitted through an atmosphere of such gases or vapours. We can thus photograph the spectrum of glowing hydrogen, sodium, iron, or other substances, and placing it below a photograph of a solar or stellar spectrum, see if any of the dark lines of the latter are coincident in position with the bright lines of the former. If they are, we may be certain that these substances actually exist in the sun or star. It is, in fact, just the same thing as if we had been able to bring down a jar-full of the solar or stellar matter and analyse it in our laboratories.

It is difficult to convey any adequate description of these grand discoveries made by the new science of spectroscopy without referring to special works on the subject; but it may be possible to give some general idea of the principles on which they are based.

As has been shown, light consists of waves propagated through ether. These waves are started by the vibrations of the ultimate particles of matter, which, whether in the simplest form of atoms, in the more complex form of molecules, or in the still more complex form of compound molecules, have their own peculiar and distinct vibrations. These vibrations are increased, diminished, or otherwise modified by variations of heat and by the collisions which occur between the particles from their own proper motions. If we take the simplest case, that of matter in the form of a gas or vapour composed of single atoms, at a temperature just sufficient to become luminous and at a pressure small enough to keep the atoms widely apart, the vibrations are all of one sort, viz., that peculiar to the elementary substance to which they belong, and one set of waves only is propagated by them through the ether. The spectrum, therefore, of such a gas is a single line of light, in the definite position which is due to its

refrangibility, i.e., to the velocity of the particular wave of light which the particular vibration of those particular atoms is able to propagate.

When pressure is increased so that the particles are brought closer together, their vibrations made more energetic and their collisions more frequent, more waves, and waves of different qualities are started, and more lines appear in the spectrum and the lines widen out, until at length when the gas becomes very dense, some of the lines overlap and an approach is made towards a continuous spectrum. Finally, when the particles are brought so near together that the substance assumes a fluid or solid state, the number of wave-producing vibrations becomes so great that a complete system of different light-waves is propagated, and the lines of the spectrum are multiplied until they coalesce and form a continuous band of rainbow-tinted light. If the particles of the gas, instead of being single atoms, are more complex, as molecules or compound molecules, the vibrations are more complex and the different resulting light-waves more numerous, so that the lines in the spectrum are more numerous, and in some cases they coalesce so as to form shaded bands, or what are called fluted lines, instead of simple lines.

Moreover, whatever light-waves are originated by the vibrations of the particles of gas are absorbed into those vibrations and extinguished, if they originate from the vibrations of some more energetic particles of another substance outside of it, whose light-waves, travelling along the ether, pass through the gas, and are thus shown as dark lines in the spectrum of the other source of light.

We can now understand how the assertion is justified that we can analyse the composition of the sun and stars as certainly as if we had a jar full of their substance to analyse in our laboratory. The first glance at a spectrum tells us whether the luminous source is solid, fluid, or gaseous. If its spectrum is continuous it is solid or fluid; we know this for certain, but can tell nothing more. But if it consists of bright lines, we know that it comes direct from matter in the form of luminous gas, and knowing from experiments in the laboratory the exact colours and situations of the lines formed by the different elements of which earthly

matter is composed, we can see whether the lines in the spectra of heavenly matter do or do not correspond with any of them. If bright lines correspond we are sure that the substances correspond, both as to their elementary atoms and their condition as glowing gas. If dark lines in the spectrum of the heavenly body correspond with bright lines in that of a known earthly substance, we are certain that the substances are the same and in the same state of gas, but that the solar or stellar spectrum proceeds from an intensely heated interior solid or fluid nucleus, whose waves have passed through an outer envelope or atmosphere of this gas.

Applying these principles, although the science is still in its infancy and many interesting discoveries remain to be made, this grand discovery has become an axiomatic fact—Matter is alike everywhere. The light of stars up to the extreme boundary of the visible universe is composed mainly of glowing hydrogen, the same identical hydrogen as we get by decomposing water by a voltaic battery.

Of the 76 elementary substances enumerated by chemists, 36 are known certainly to exist in the sun's atmosphere. The elements whose presence is proved comprise many of those which are most common in the composition of the earth, as hydrogen, carbon, iron (represented by about 2,000 lines in the solar spectrum), lead, calcium, aluminium, magnesium, sodium, potassium, etc.; and if others, such as oxygen, nitrogen, and chlorine have not yet been found, the explanation is that when a mixture of the incandescent vapours of the metals and metalloids (or non-metallic elementary substances, to which class both oxygen and nitrogen belong), or their compounds, is examined with the spectroscope, the spectra of the metalloids always yield before that of the metals. Hence the absence of the lines of oxygen and other metalloids, carbon and silicon excepted, among the vast crowd of lines in the solar spectrum. Then, too, in extreme states of rarefaction of the sun's absorbing layer, the absorption of the oxygen is too small to be sensible to us. The main fact is firmly established that matter is the same throughout all space, from the minutest atom to the remotest star.

Thus far we have been treating of matter only, and of force and motion but

incidentally. These, however, are equally essential components of the phenomena of the universe. What is force? In the last analysis it is the unknown cause which we assume for motion, or the term in which we sum up whatever produces or tends to produce it. The idea of force, like so many other of our ideas, is taken from our own sensations. If we lift a weight or bend a bow, we are conscious of doing so by an effort. Something which we call will produces a motion in the molecules of the brain, which is transmitted by the nerves to the muscles, where it liberates a certain amount of energy stored up by the chemical composition and decomposition of the atoms of food which we consume. This contracts the muscle, and the force of its contraction, transmitted by a system of pulleys and levers to the hand, lifts the weight. If we let go the weight it falls, and the force which lifted it reappears in the force with which it strikes the ground. If we do not let go the weight but place it on a support at the height to which we have raised it, it does not fall, no motion ensues, but the lifting force remains stored-up in a tendency to motion, and can be made to reappear as motion at any time by withdrawing the support, when the weight will fall. It is evident, therefore, that force may exist in two forms, either as actually causing motion, or as causing a tendency to motion.

In this generalised form it has been agreed to call it energy, as less liable to be obscured by the ordinary impressions attached to the word force, which are mainly derived from experiences of actual motion cognizable by the senses. We speak, therefore, of energy as of something which is the basis or *primum mobile* of all motion or tendency to motion, whether it be in the grosser forms of gravity and mechanical work, or in the subtler forms of molecular and atomic motions causing the phenomena of heat, light, electricity, magnetism, and chemical action. This energy may exist either in the form of actual motion, when it is called energy of motion, or in that of tendency to motion, when it is called energy of position. Thus the bent bow has energy of position which, when the string is let go, is at once converted into energy of motion in the flight of the arrow.

Respecting this energy modern science has arrived at this grand generalisation,

FORCE.

that it is one and the same in all its different manifestations, and can neither be created nor destroyed, so that all these varied manifestations are mere transformations of the same primitive energy from one form to another. This is what is meant by the principle of the "Conservation of Energy."

It was arrived at in this way. Speaking roughly, it has long been known that heat could generate mechanical power, as seen in the steam-engine; and conversely that mechanical power could generate heat, as is seen when a sailor, in a chill north-easter, claps his arms together on his breast to warm himself. But it was reserved for Dr. Joule to give this fact the scientific precision of a natural law, by actually measuring the amount of heat that was added to a given weight of water by a given expenditure of mechanical power, and conversely the amount of mechanical work that could be got from a given expenditure of heat.

A vast number of carefully-conducted experiments have led to the conclusion that if a kilogramme be allowed to fall through 424 metres and its motion be then suddenly stopped, sufficient heat will be generated to raise the temperature of one kilogramme of water by 1° Centigrade; and conversely this amount of heat would be sufficient to raise one kilogramme to a height of 424 metres.

If, therefore, we take as our unit of work that of raising one kilogramme one metre, and as our unit of heat that necessary to raise one kilogramme of water 1° Centigrade, we may express the proportion of heat to work by saying that one unit of heat is equal to 424 units of work; or, as it is sometimes expressed, that the number 424 is the mechanical equivalent of heat.

But the question may be asked, what does this mean, how can mechanical work be really transformed into heat or *vice versa*? The answer is, the energy which was supplied by chemical action to the muscles of the man or horse, or to the water converted into steam by combustion of coal, which originated the mechanical work, was first transformed into its equivalent amount of mechanical energy of motion, and then, when that motion was arrested, was transformed into heat, which is simply the same energy transformed into increased molecular motion.

If we wish to carry our inquiry a step further back and ask where the original energy came from which has undergone these transformations, the answer must be, mainly from the sun. The sun's rays, acting on the chlorophyll or green matter of the plants of the coal era, tore asunder the atoms of carbon and oxygen which formed the carbonic acid in the atmosphere, and locked up a store of energy in the form of carbon in the coal which is burned to produce the steam. In like manner it stored-up the energy in the form of carbon in the vegetable products which, either directly, or indirectly after having passed through the body of some animal, supplied the food, whose slow combustion in the man or horse supplied the energy which did the work.

But where did the energy come from which the sun has been pouring forth for countless ages in the form of light and heat, and of which our earth only intercepts the minutest portion? This is a mystery not yet completely solved, but one real cause we can see, which has certainly operated and perhaps been the only one, viz., the mechanical energy of the condensation by gravity of the atoms which originally formed the nebulous matter out of which the sun was made. If we ask, how came the atoms into existence endowed with this marvellous energy, we have reached the furthest bounds of human knowledge, and can only reply in the words of the poet: "Behind the veil, behind the veil."

We can only form metaphysical conceptions, or I might rather call them the vaguest guesses. One is, that they were created and endowed with their elementary properties by an all-wise and all-powerful Creator. This is Theism.

Another, that thought is the only reality, and that all the phenomena of the universe are thoughts or ideas of one universal, all-pervading Mind. This is Pantheism.

Or again, we may frankly acknowledge that the real essence and origin of things are "behind the veil," and not knowable or even conceivable by any faculties with which the human mind is endowed in its present state of existence. This is Agnosticism.

There is another conception, of which we may certainly say that it is not tenable—that is Atheism. For it is the spirit that denies without warrant for

denial, and pronounces a verdict which is arrived at without evidence.

But these speculations lead us into the misty regions where, like Milton's fallen angels, "we find no end in wandering mazes lost." Let us return to the solid ground of fact, on which alone the human mind can stand firmly, and, like Antæus, gather fresh vigour every time it touches it for further efforts to enlarge the boundaries of knowledge and extend the domain of Cosmos over Chaos.

The transformation of energy which we have seen to exist in the case of mechanical work and heat, is not confined to those two cases only, but is a universal law applicable to all actions and arrangements of matter which involve motions of atoms, molecules, or masses, and therefore imply the existence of energy. In heat we have had an example of energy exerted in molecular motion and molecular separation. In chemical action we have energy exerted in the separation of atoms, severing them from old combinations and mutual attractions, and bringing them within the sphere of new ones. In electricity, and magnetism, which is another form of electricity, we have energy of position which manifests itself in electrical separation, by which matter becomes charged with two opposite energies, positive and negative, which accumulate at separate poles, or on separate surfaces, with an amount of tension which may be reconverted into the original amount of energy of motion when the spark, passing between them, restores their electrical equilibrium. Of this we have an example in the ordinary electrical machine, where the original energy comes from the mechanical force which turns the handle, and is given back when the electric spark brings things back to their original state.

We have also energy of motion, when instead of electrical separation and tension we have a flow or current of electricity producing the effect of the electric spark in a slow, quiet, and continuous manner. Thus, in the voltaic battery, the free energy created by the difference of chemical action of an acid on plates of different metals, is transformed into a current which charges two poles with opposite electricities, and when the poles are brought together and the circuit is closed, flows through it in

a continuous current. This current is an energetic agent which produces various effects. It deflects the magnetic needle, as is seen in the electric telegraph. It creates magnetism, as is seen when the poles of the battery are connected by a wire wrapped round and round a cylinder of soft iron, so as to make the current circulate at right angles to the axis formed by the cylinder. In fact, all magnetism may be considered as the summing up at the two opposite extremities or poles of an axis, of the effects of electric currents circulating round it; as, for instance, the earth is a great magnet because currents caused by the action of the sun circulate round it nearly parallel to the equator. Electric currents further show their energy by attracting and repelling one another, those flowing in the same direction attracting, and those in opposite directions repelling, the same effect showing itself in magnets, which are in substance collections of circular currents flowing from right to left or left to right according as they are positive or negative. Again, currents produce an effect by inducing currents in other bodies placed near them, very much as the vibrations of a tuning-fork induce vibrations and bring out a corresponding note from the strings of a piano or violin ready to sound it. When a coil of wire is connected with a battery and a current passes through it, if it is brought near to another isolated coil it induces a current in an opposite direction, which, when it recedes from it, is changed into a current in the same direction.

These principles are illustrated by the ordinary dynamo, by which the energy of mechanical work exerted in making magnets revolve in presence of currents, and by various devices accumulating electric energy, is made available either for doing other mechanical work, such as driving a wheel, or for doing molecular or atomic work by producing heat and light.

Another transformation of the energy of electric currents is into heat, light, or chemical action. If the two poles of a battery are connected by a thin platinum wire it will be heated to redness in a few seconds, the friction or resistance to the current in passing through the limited section of the thin wire producing great heat. If the wire is thicker heat

will equally be produced, but more slowly.

If the poles of the battery are made of carbon, or some substance the particles of which remain solid during intense heat, when they are brought nearly together the current will be completed by an arc of intensely brilliant light, and the carbon will slowly burn away. This is the electric light so commonly used when great illuminating power is wanted.

Again, the electric current may employ its energy in effecting chemical action. If the poles of a battery, instead of being brought together, are plunged into a vessel of water, decomposition will begin. Oxygen will rise in small bubbles at the positive pole, and hydrogen at the negative. If these two gases are collected together in the same vessel, and an electric current, in the intense and momentary form of a spark, passed through them, they will combine with explosion into the exact amount of water which was decomposed in their formation.

Everywhere, therefore, we find the same law of universal application. Energy, like matter, cannot be created or destroyed, but only transformed. It is therefore, in one sense, eternal. But there is another point of view from which this has to be regarded.

Mechanical work, as we have seen, can always be converted into heat, and heat can, under certain conditions, be reconverted into mechanical work; but not under all conditions. The heat must pass from something at a higher temperature into something at a lower. If the condenser of a steam-engine were always at the same temperature as the boiler, we should get no work out of it. It is easy to understand how this is the case if we figure to ourselves a river running down into a lake. If the stream is dammed up at two different levels, each dam, as long as there is water in it, will turn a mill-wheel. But if all the water runs down into the lake and, owing to a dry season, there is no fresh supply, the wheels will stop and we can get no more work done. So with heat, if it all runs down to one uniform temperature it can no longer be made available to do work. In the case of the river, fresh water is supplied at the higher levels, by the sun's energy raising it by evaporation from the seas to

the clouds, from which it is deposited as rain or snow. But in the case of heat there is no such self-restoring process, and the tendency is always towards its dissipation; or in other words, towards a more uniform distribution of heat throughout all existing matter. The process is very slow; the original fund of high-temperature heat is enormous, and as long as matter goes on condensing fresh supplies of heat are, so to speak, squeezed out of it.

Still there is a limit to condensation, while there is no limit to the tendency of heat to diffuse itself from hotter to colder matter until all temperatures are equalized. The energy is not destroyed; it is still there in the same average amount of total heat, though no longer differentiated into greater and lesser heats, and therefore no longer available for life, motion, or any other form of transformation. This seems to be the case with the moon, which, being so much smaller, has sooner equalised its heat with surrounding space, and is apparently a burnt-out and dried-up cinder without air or water. And this, as far as we can see, must be the ultimate fate of all planets, suns, and solar systems. Fortunately the process is extremely slow, for even our small earth has enjoyed air, water, sunshine, and all the present conditions necessary for life for the whole geological period, certainly from the Silurian epoch downwards, if not earlier, which cannot well be less than 100 millions of years, and may be much more. Still time, even if reckoned by hundreds of millions of years, is not eternity; and as, looking through the telescope at nebulae which appear to be condensing about central nuclei, we perchance dimly discern a beginning, so, looking at the moon and reasoning from established principles as to the dissipation of heat, we can dimly discern an end. What we really can see is that throughout the whole of this enormous range of space and time law prevails; that, given the original atoms and energies with their original qualities, everything else follows in a regular and inevitable succession; and that the whole material universe is a clock, so perfectly constructed from the beginning as to require no outside interference during the time it has to run to keep it going with absolute correctness.

*And yet, seeing all this,
it is possible to be an
agnostic?*

CHAPTER IV

LIFE.

Essence of Life—Simplest Form, Protoplasm—Monera and Protista—Animal and Vegetable Life—Spontaneous Generation—Development of Species from Primitive Cells—Supernatural Theory—Zoological Provinces—Separate Creations—Law or Miracle—Darwinian Theory—Struggle for Life—Survival of the Fittest—Development and Design—The Hand—Proof required to establish Darwin's Theory as a Law—Species—Hybrids—Man subject to Law.

THE universe is divided into two worlds—the inorganic, or world of dead matter; and the organic, or world of life. What is life? In its essence it is a state of matter in which the particles are in a continued state of flux, and the individual existence depends, not on the same particles remaining in the same definite shape, but on the permanence of a definite mould or form through which fresh particles are continually entering, forming new combinations and passing away. It may assist in forming a conception of this if we imagine ourselves to be looking at a mountain the top of which is enveloped in a driving mist. The mountain is dead matter, the particles of which continue fixed in the rocks. But the cloud-form which envelops it is a mould into which fresh particles of vapour are continually entering and becoming visible on the windward side, and passing away and disappearing to leeward. If we add to this the conception that the particles do not, as in the case of the cloud, simply enter in and pass away without change, but are digested, that is, undergo chemical changes by which they are partly assimilated and worked-up into component parts of the mould, and partly thrown off in new combinations, we shall arrive at something which is not far off the ultimate idea of what constitutes living matter, in its simplest form of the protoplasm, or speck of jelly-like substance, which is shown to be the primitive basis or raw material of all the more complex forms both of vegetable and animal life. Digestion, therefore, is the primary attribute. A crystal grows from *without*, by taking on fresh particles and building them up in regular layers according to fixed laws, just as the pyramids of Egypt

were built up by layer upon layer of squared stones upon surfaces formed of regular figures, and inclined to each other at determinate angles.

The living plant or animal grows from within by taking supplies of fresh matter into its inner laboratory, where it is worked up into a variety of complex products needed for the existence and reproduction of life. After supplying these, the residue is given back in various forms to the inorganic world, and the final residue of all is given back by death, which is the ultimate end of all life.

The simplest form of life, in which it first emerges from the inorganic into the organic world, consists of protoplasm, or, as it has been called, the physical basis of life. Protoplasm is a colourless semi-fluid or jelly-like substance, which consists of albuminoid matter, or in other words, of a heterogeneous carbon-compound of very complex chemical composition. It exists in every living cell, and performs the functions of nutrition and reproduction, as well as of sensation and motion. In its simplest form, that of the microscopic monera or protista, the lowest of living beings, we find an apparently homogeneous structureless piece of protoplasm, without any differentiation of parts. The monera are simple living globules of jelly, without even a nucleus or any sort of organ, and yet they perform all the essential functions of life without any different parts being told off for particular functions. Every particle or molecule is of the same chemical composition and a facsimile of the whole body, as in the case of a crystal. They are, therefore, the first step from the inorganic into the organic world, and if spontaneous generation takes place anywhere, it is in the passage of the chemical elements from the simple and stable combinations of the former into the complex and plastic combinations of the latter.

The next step upwards is to the cell in which the protoplasm is enclosed in a skin or membrane of modified protoplasm, and a nucleus, or denser spot, is developed in the enclosed mass. This is the primary element from which all the more complicated forms of life are built-up. Each cell seems to have an independent life of its own, and a faculty of reproduction by splitting into fresh cells similar to itself, which multiply in geometrical progression, assimilating the elements of their

substance from the inorganic world so rapidly as to provide the requisite raw material for higher structures.

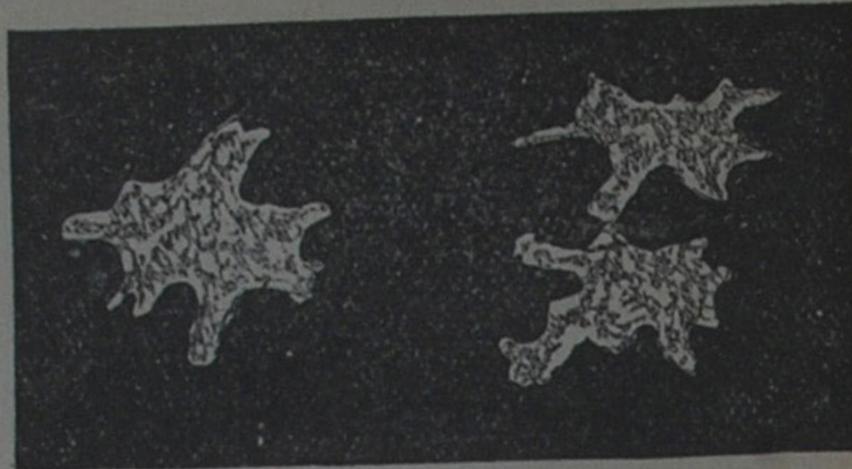
The first organised living forms are extremely minute, and can only be recognised by powerful microscopes. A filtered infusion of hay, allowed to stand for two days, will swarm with living things, a number of which do not exceed $\frac{1}{40000}$ th of an inch in diameter. Minute as these animalcula are, they are thoroughly alive. They dart about and digest; the smallest speck of jelly-like substance shoots out branches or processes to seize food, and if these come in collision with other substances they withdraw them. They exist in countless myriads, and perform a very important part in the economy of nature. They are the scavengers of the universe, and remove the remains of living matter after death, which would otherwise accumulate until they choked-up the earth. This they do by the process of putrefaction, which is due mainly to the multiplication of little rod-like creatures known as bacteria, which work up the once living, now dead, matter into fresh elements, again fitted to play their part in the inorganic and organic worlds.

One of the simplest of these forms is the amœba, which is nothing but a naked little lump of cell-matter, or plasma, containing a nucleus; and yet this little speck of jelly moves freely, it shoots out tongues or processes and gradually draws itself up to them with a sort of wave-like motion; it eats and grows, and in growing reproduces itself by contracting in the middle and splitting up into two independent amœbæ.

The germs of these various animalcula swarm in the air, and carry seeds of infection wherever they find a soil fitted to receive them; and thus assist the survival of the fittest in the struggle of life, by eliminating weak and unhealthy individuals and species. Thus when the potato, the vine, or the silkworm has had its constitution enfeebled by prolonged artificial culture, there are germs always ready to revenge the violation of natural laws, and bring the survivors back to a more heathy condition. In like manner the germs of cholera, typhoid, and scarlet fever, enforce the observance of sanitary principles.

In this simple form the lowest forms of life are not yet sufficiently differentiated

to enable us to distinguish clearly between animal and vegetable, and they have been called by some naturalists Protista, while



AMCEBA.

AMCEBA dividing into two.

others designate them as Protozoa or Protophyta, according as they show more resemblance to one or the other form of life. But it is often so doubtful that in looking at the same organism through a microscope, Huxley was inclined to consider it as a plant, while Tyndall exclaimed that he could as soon believe that a sheep was a vegetable.

In the next stage upwards, however, life subdivides itself into two great kingdoms, that of the vegetable and of the animal world. Alike in their general definition as contrasted with inorganic matter, and in their common origin from an embryo cell, which divides and subdivides until cell-aggregates are formed, from which the living form is built up by a process of evolution, the plant differs from the animal in this: that the former feeds directly on inorganic matter, while the latter can only feed on it indirectly, after it has been manufactured by the plant into vegetable substance.

This is universally true, for if we dine on beef, we dine practically on the grass which the ox ate; that is, on the carbon, oxygen, hydrogen, and other simple elements which the grass, under the stimulus of light and sunshine, manufactured into complex compounds; and which the ox again, by a second process, manufactured from these compounds into others still more complex, and more easily assimilated by us in the process of digestion. But in no case can we dine, as the plant does, on the simple elements, and thrive on a diet of air and water, with a small admixture of nitrate of ammonia, and of phosphates, sulphates and chlorides, of a few primitive metals. Vegetable life.

therefore, is the producer, and animal life the consumer, of the organic world.

Practically the plant derives most of its substance from the carbonic acid gas in the atmosphere, which green leaves under the stimulus of light and heat have the faculty of decomposing, and abstract the carbon giving out the oxygen; while the animal, by a reverse process, burns up the compounds manufactured by the plant, principally out of this carbon, by the oxygen obtained from the air by the process of respiration, exhaling the surplus carbon in the form of carbonic acid gas.

The balancing effect of these two processes may be seen in any aquarium, where animals and vegetables live together in water which is kept pure, while it would become stagnant and poisonous in a few hours, if one of the two forms of life were removed. All that the animal requires therefore for its existence—materials with which to build up its frame and supply waste; heat with which to maintain its circulating fluids and other substances at a proper temperature; motive power or energy to enable it to move, feel, and, in the case of the higher animals, to think—are all proceeds of the slow combustion of materials derived from the vegetable world in the oxygen breathed from the air, just as the work done by a steam-engine is the product of a similar combustion, or chemical combination of the oxygen of the air with the coal shovelled into the fire-box. These distinctions, however, between animals and vegetables are not quite absolute, for, even in the more highly-organised forms of life, there is a border-land where some plants seem to perform the functions of animals, as in those which catch and consume flies and eat and digest pieces of raw meat.

Those who wish to pursue this interesting subject further will do well to read the Chapter on Living Matter in Huxley's "Physiography," where they will find it more fully explained, with the inimitable clearness which characterises all the writings of an author who was at the same time one of the first scientific authorities and one of the greatest masters of English prose. But my present object is not to write a scientific treatise, but shortly to sum up the ascertained results of modern science, with a view to their bearings on modern thought; and from

this point of view the immediate question is, how far unbroken sequence, which has been shown to prevail universally throughout space, time, and inorganic matter, can be shown to prevail equally throughout the world of life.

Up to a certain point this admits of positive proof. It is as certain that all individual life, from the most elementary protoplasm up to the highest organism, Man, originates in a minute or embryo cell, as it is that oxygen and hydrogen combined in certain proportions make water. But if we try to go back one step further, behind the cell, we are stopped. In the inorganic world we can reason our way beyond the microscopic matter to the molecule, and from the molecule to the atom, and are only arrested when we come to the ultimate form of matter, and of energy, out of which the universe is built up. But, in the case of life, we are stopped two steps short of this, and cannot tell how the cell containing the germ of life is built up out of the simpler elements.

Many attempts have been made to bridge over this gulf, and to show how life may originate in chemical compounds, but hitherto without success. Experiments have been made which, for a time, seemed to show that spontaneous generation was a scientific fact, *i.e.*, that the lowest forms of life, such as bacteria and amœbæ, really did originate in infusions containing no germs of life; but they have been met by counter experiments confirming Harvey's *dictum*, "Omne vivum ex ovo," or, all life comes from an egg, *i.e.*, from antecedent germs of life, and the verdict of the best authorities, such as Pasteur, Tyndall, and Huxley is, that spontaneous generation has been "defeated along the whole line." This verdict is perhaps too unqualified, for it appears that, on the assumption with which both sides started, all organic life was destroyed by exposure to a heat of 212°, or the boiling-point of water, the advocates of spontaneous generation had the best of it, as low forms of life did appear in infusions which had been exposed to this heat, and then hermetically sealed, so as to prevent any germs from entering. But it was replied that, as a hard pea takes more boiling than a soft one, it might very well be that heat sufficient to destroy life in any moist organism of sufficient size to be seen by the microscope,

might not destroy the germinating power of ultra-microscopic germs in a very dry state. And this position seems to have been confirmed by various experiments, showing that such ultra-microscopic germs really do exist, and are given forth in the last life stage of the bacteria which cause putrefaction; and that if they are absent or destroyed by repeated applications of heat, infusions will keep sweet for ever in optically pure air.

Above all, the germ theory has received confirmation from the brilliant practical results to which it has led in the hands of Pasteur, enabling him to detect, and to a great extent eradicate, the causes which had led to the oidium of the vine and the pebrine of the silkworm, thereby saving millions to the industries of France. The germ theory has also led to important results in medical science, and is pointing towards the possibility of combating the most fatal diseases by processes analogous to that by which vaccination has almost freed the human race from the scourge of small-pox.

On the whole, therefore, we must be content to accept a verdict of "Not proven" in the case of spontaneous generation, and admit that as regards the first origin of life, science fails us, and that there is at present no known law that will account for it.

Should spontaneous generation ever be proved to be a fact, it will doubtless be in creating living protoplasm from inorganic elements at its earliest stage, before it has been differentiated even into the primitive form of a nucleated cell or that of an amœba. This is what the doctrine of evolution would lead us to expect, for it would be in contradiction to it to suppose that the starting-point could be interpolated at any stage subsequent to the lowest. It may be also that this step could only be made under conditions of heat, pressure, and otherwise, which existed in the earlier stage of the earth's existence, but have longed since passed away.

This, however, is only a small part of the difficulty we have to encounter in reducing life to law.

These primeval embryo cells, like as they are in appearance, contain within them the germs of an almost infinite diversity of evolutions, each running its separate course distinct from the others.

The world of life is not one and uniform, but consists of a vast variety of different species, from the speck of protoplasm up to the forest tree, and from the humble amœba up to man, each one, at any rate within long intervals of time, breeding true and keeping to its own separate and peculiar path along the line of evolution.

The first germ, or nucleated cell, of a bacterium develops into other bacteria and nothing else, that of a coral into corals, of an oak into oaks, of an elephant into elephants, of a man into man. In the latter case we can trace the embryo in its various stages of growth through forms having a certain analogy to those of the fish, the reptile, and the lower mammals, until it finally takes that of the human infant. But we have no experience of a fish, a frog, or a dog, born of human parents, or of any of the lower animals ever producing anything resembling a man.

How can this be explained? Naturally the first attempt at explanation was by miracle. At a time when everything was explained by miracle, when all unusual occurrences were attributed to supernatural agency, and men lived in an atmosphere of providential interferences, witchcraft, magic, and all sorts of divine and diabolic agencies, nothing seemed easier than to say that the beasts of the field, the birds of the air, and the fishes of the sea, are all distinct after their kind, because God created them so.

But as the supernatural faded away and disappeared in other departments where it had so long reigned supreme, and science began to classify, arrange, and accumulate facts as they really are, it became more and more difficult, or rather impossible, to accept this simple explanation. The very first step destroyed the validity of all the traditional myths which described the origin of life from one simultaneous act of creation at a single centre. The earth is divided into separate zoological provinces, each with its own peculiar animal and vegetable world. The kangaroo, for instance, is found in Australia and there only. By no possibility could the aboriginal kangaroo have jumped at one bound from Mount Ararat to Australia, leaving no trace of his passage in any intermediate district. This isolation of life in separate provinces applies so rigidly, that we may

sum it up by saying generally that there are no forms of life common to two provinces unless where migration is possible, or has been possible in past geological periods.

In islands at a distance from continents, we find common forms of marine life, for the sea affords a means of communication; and often common forms of bird, insect, and vegetable life, where they may have been wafted by the winds; but forms which neither in the adult nor germ state could swim or fly, or be transported by something which did swim or fly, are invariably wanting. New Zealand affords a most conspicuous instance of this. Here is a large country with a soil and climate exceptionally well adapted to support a large amount of animal life of the higher orders, and yet, with the exception of two species of bats, it had absolutely no mammal before they were introduced by man, the dog being probably introduced by the Maoris. If special creations took place to replenish the earth as soon as any portion of its surface becomes fit to sustain it, why were there no animals in New Zealand? Or, in the Andaman Islands, in the Gulf of Bengal, which are as large as Ireland, covered with luxuriant vegetation, and within 300 miles of the coast of Asia, where similar jungles swarm with elephants, tigers, deer, and all the varied forms of mammalian life, there are no mammalia except a pigmy black savage and a pigmy black pig, the latter probably introduced by man.

The sharpness of the division between zoological provinces is well illustrated by that drawn by the Straits of Lombok, where a channel, not twenty miles wide, separates the fauna of Asia and Australia so completely that there are no species of land animals, and only a few of birds and insects, common to the two sides of a channel not so wide as the Straits of Dover.

There is no possibility of accounting for this, except by supposing that the deep water fissure of the Straits of Lombok has existed from remote geological periods, and barred the migration southwards of those Asiatic animals, which, as long as they found dry land, migrated northwards and westwards till they were stopped by the Polar and Atlantic Oceans. This difficulty of requiring special creations for separate

provinces is enormously enhanced if we look beyond the existing condition of things, and trace back the geological record. We must suppose separate creations for all the separate provinces of the separate successive formations from the Silurian upwards. And the more we investigate the conditions of life either under existing circumstances or in those of past geological epochs, the more are we driven to enormously multiply the number of separate creations which would be necessary to account for the diversity of species. We find life shading off into an infinite variety of almost imperceptible gradations from the highest organism, man, to the lowest, or speck of protoplasm, and we can draw no hard and fast line and say, up to this point life originated by natural processes, and beyond it we must have recourse to miracle. Either all life or none is a product of evolution acting by defined law, and the affirmation of law is the negation of miracle.

Every day brings us an account of some new discovery linking forms of life nearer together and bridging over intervals thought to be impassable. The discovery of insectivorous plants, which also devour and digest pieces of raw meat, has added to the difficulty which has been long felt, particularly in the humbler forms of life, of drawing any clear line of demarcation between the animal and vegetable worlds.

Microscopic research brings to light fresh facts confounding our fixed ideas as to the permanence of particular modes of reproducing life, and showing that the same organism may run through various metamorphoses in the course of its life-cycle, during some of which it may be sexual and in others asexual, *i.e.*, it may reproduce itself alternately by the co-operation of two beings of opposite sex, and by fissure or budding from one being only which is of no sex.

These, and a multitude of other similar facts, complicate enormously the problems of life and its developments, whether we attempt to solve it by calling in aid a perpetual series of innumerable miraculous interpositions, or by appealing to ordinary known laws of Nature.

Is the latter solution possible, and can the organic world be reduced, as the inorganic world has been with all its

mysteries and the infinities of space, time, and matter, from chaos into cosmos, and shown to depend on permanent and harmonious laws? Is the world of life, like that of matter, a clock, so perfectly constructed from the first that it goes without winding up or regulating? or is it a clock which would never have started going, or having started would soon cease to go, if the hand of the watch-maker were not constantly interfering with it? This is the question which the celebrated Darwinian theory attempts to answer, of which I now proceed to give a short general outline.

The varieties among domestic animals are obvious to every one. The race-horse is a very different creature from the dray-horse; the short-horned ox from the Guernsey cow; the greyhound from the Skye terrier. How has this come to pass? Evidently by man's intervention, causing long-continued selection in breeding for certain objects. The English race-horse is the product of mating animals distinguished for speed for some fifteen or twenty generations. The greyhound is a similar dog-product by breeding for a longer period with the same object; as the Skye terrier is of selection in order to get a dog which can follow a fox into a cairn of rocks and fight him when he gets there. In all these cases it is evident that the final result was not attained at once, but by taking advantage of small accidental variations and accumulating them from one generation to another by the principle of heredity, which makes offspring reproduce the qualities of their parents.

The most precise and scientific experiments on this power of integrating, or summing up, a progressive series of differentials, or minute differences, between successive generations, are those conducted by Darwin on pigeons. He has shown conclusively that all the races of domestic pigeons, of which there are two or three hundred, are derived from one common ancestor, the wild or blue rock pigeon, and that the pigeon-fancier can always obtain fresh varieties in a few generations by careful interbreeding. Of the existing varieties many now differ widely from one another, both in size, appearance, and even in anatomical structure, so that if they were now discovered for the first time in a fossil state or in a new country, they would

assuredly be classed by naturalists as separate species.

This is the work of man; is there anything similar to it going on in Nature? Yes, says Darwin, there is a tendency in all life, and especially in the lower forms of life, to reproduce itself vastly quicker than the supply of food and the existence of other life can allow, and the balance of existence is only preserved by the wholesale waste of individuals in what may be called the "struggle for life." In this struggle, which goes on incessantly and on the largest scale, the slightest advantage must tell in the long run, and on the average, in selecting the few who are to survive, and such slight advantages must tend to accumulate from one generation to another under the law of heredity. The cumulative power of selection exercised by man in the breeding of races is therefore necessarily exercised in Nature by the struggle for life, and in the course of time, by the cumulation of advantages originally slight, small and fluctuating variations are hardened into large and permanent ones, and new species are formed.

Darwin illustrates this principle of the "struggle for life" with a vast variety of instances, showing how the balance of animal and vegetable life may be preserved or destroyed in the most unexpected manner. For instance, the fertilisation of red clover is effected by humble-bees, and depends on their number; the number of bees in a given district depends mainly on the number of field-mice which destroy their combs and nests; the number of mice depends on the number of cats; and thus the presence or absence of a carnivorous animal may decide the question whether a particular sort of flora shall prevail over others or be extirpated.

The countless profusion with which any one species, unchecked by its natural foes, may multiply in a given district, is illustrated by the potato disease, which in a few days invades whole countries; and by the rabbit plague in Australia and New Zealand, where, in less than twenty years, the descendants of a few imported pairs have rendered whole provinces useless for sheep pasture, and stoats are now being imported to restore the balance of life. The tendency in species to produce varieties which by selection may become exaggerated and fixed, is illus-

trated by the case of the Ancon herd of sheep. A ram lamb was born in Massachusetts in 1791, which had short crooked legs and a long back like a turnspit dog. Being unable to jump over fences like the ordinary sheep, it was thought to possess certain advantages to the farmer, and the breed was established by artificial selection in pairing this ram with its descendants who possessed the same peculiarities. The introduction of the Merino superseded the Ancon by giving a tame sheep not given to jump fences, with a better fleece, and so the breed was not continued, but it is certain that it might have been established as a permanent variety differing from the ordinary sheep as much as the turnspit or Skye terrier differs from the ordinary dog. The tendency of Nature to variation is apparent in the fact that of the many hundred millions of human beings living on the earth, no two are precisely alike, and varieties often appear, as in giants and dwarfs, six-fingered or toed children, hairy and other families, which might doubtless be fixed and perpetuated by artificial or natural selection, until they became strongly marked and permanent.

It is evident that if the theory of development is true it excludes the old theory of design, or rather, it thrusts it back in the organic, as it has been thrust back in the inorganic, world, to the first atoms or origins which were made so perfect as to carry within them all subsequent phenomena by necessary evolution. Design and development lead to the same result, that of producing organs adapted for the work they have to do, but they lead to it in totally different ways. Development works from the less to the more perfect, and from the simpler to the more complicated, by incessant changes, small in themselves, but constantly accumulating in the required direction. Design supposes that organisms were created specially on a predetermined plan, very much as the sewing-machine or self-binding reaper were constructed by their inventors.

Until quite recently all adaptations of means to ends were considered as evidences of design. A series of treatises, for which prizes were left by a late Duke of Bridgewater, was published some thirty years ago, to illustrate this theme. Among these one by Sir Charles Bell on the Hand attracted a good deal of attention. It was

shown what an admirable machine the human hand is for the various purposes for which it is used, and the inference was drawn that it must have been created so by a designer who adapted means to ends in much the same way as is done by a human inventor. But more complete knowledge has dispelled this idea, and shown that the design, if there be any, must be placed very much farther back, and is in fact involved in the primitive germ from which all vertebrate life certainly, and probably all life, animal or vegetable, has been slowly developed.

The human hand is in effect the last stage of a development of the vertebrate type, or type of life in which a series of jointed vertebræ form a backbone, which protects a spinal cord containing the nervous centres, gives points of attachment for the muscles, and forms an axis of support for the looser tissues. Certain of these vertebræ throw out bony spines or rays; at first, by a sort of simple process of vegetable growth, which formed the fins of fishes; then some of these rays dropped off and others coalesced into more complex forms, which made the rudimentary limbs of reptiles; and finally, the continued process of development fashioned them into the more perfect limbs of birds and mammals. In this last stage a vast variety of combinations was developed. Sometimes the bones of the extremities spread out, so as to form long fingers supporting the feathered wings of birds and the membranous wings of bats; sometimes they coalesced into the solid limbs supporting the bodies of large animals, as in the case of the horse; and finally, at the end of the series, they formed that marvellous instrument, the hand, as it appears in the allied genera of monkeys, apes, and man.

Any theory of secondary design and special miraculous creation must evidently account for all the intermediate forms as well as for the final result. We must suppose not one but many thousands of special creations, at a vast variety of places and over a vast extent of time; we must take into account not the successes only, but the failures, where organs appear in a rudimentary form which are perfectly useless, or in some cases even injurious, to the creature in which they are found. For instance, in the case of the so-called wingless birds,

like the dodo of the Mauritius, and the apteryx of New Zealand, which were found in oceanic islands, evolution accounts readily for the atrophy or want of development of organs which were not wanted where the birds had no natural enemies and found their food on the ground; but why should they have been created with rudimentary wings, useless while they remained isolated, and insufficient to prevent their extermination as soon as man, or any other natural enemy, reached the islands where they had lived secure?

If we are apt to adopt the theory of design and special creation, we must be prepared to take Burns's poetical fancy as a scientific truth, and believe that Nature had to try its "prentice hand," and grope its way through repeated trials and failures from the less to the more perfect. Again, the theory of special creation must account not only for the higher organs and forms of life, but for the lower forms also. Are the bacteria, amœbæ, and other forms of life which the microscope shows in a drop of water all instances of a miraculous creation? And still more hard to believe, is this the origin of the whole parasitic world of life which is attached to and infests each its own peculiar form of higher life? Is the human tape-worm a product of design, or that wonderful parasite the trichina, which oscillates between man and the pig, being capable of being born only in the muscles of the one, and of living only in the intestines of the other?

These are the sort of difficulties which have led the scientific world, I may say universally, to abandon the idea of separate special creations, and to substitute for it that which has been proved to be true of the whole inorganic world of stars, suns, planets, and all forms of matter; the idea of an original creation (whatever creation may mean and behind which we cannot go) of ultimate atoms or germs, so perfect that they carried within them all the phenomena of the universe by a necessary process of evolution.

This is the idea to which the Darwinian theory leads up, by showing natural causes in operation which must inevitably tend to originate and to accumulate slight varieties, until they become large in amount and permanent, thus developing new races within old species, new species within old families, new families

within old types, and new and complex types from old and simple ones.

The theory is up to a certain point undoubtedly true, and beyond that point in the highest degree probable, but scientific caution obliges us to add that it is still to a considerable extent a "theory," and not a "law." That is, it is not like the law of gravity, a demonstrated certainty throughout the whole universe, but a provisional law which accounts for a great number of undoubted facts, and supplies a framework into which all other similar facts, as at present ascertained, appear to fit with a probability not approached by any other theory, and which is enhanced by every fresh discovery made, and by the analogy of what we know to be the laws which regulate the whole inorganic world.

To enable us to talk of the "Darwinian law," and not of the "Darwinian theory," we require two demonstrations:

1. That living matter really can originate from inorganic matter.
2. That new species really can be formed from previously existing species.

As regards the first, we have seen that the efforts of science have hitherto failed to produce an instance of spontaneous generation, and all we can say is that it is probable that such instances have occurred in earlier ages of our planet, under conditions of light, heat, chemical action, and electricity, different from anything we can now reproduce in our laboratories. This, however, falls short of demonstration and for the present we must be content to leave the origin of life as one of the mysteries not yet brought within the domain of law.

As regards the second point, we are farther advanced towards the possibility of proof. But here also we are met by two difficulties. If we appeal to historical evidence, we are met by the fact that a much greater time than is embraced by any historical record is almost necessarily required for the dying out of any old species and introduction of any new one, by natural selection. And if we appeal to fossil remains we are met by the imperfection of the geological record. As to this, it must be remembered that only a very small portion of the earth's surface has been explored, and of this a very small portion consists of ancient land surfaces or fresh water formations, where alone we can expect to meet with traces

of the higher forms of animal life. And even these have been so imperfectly explored, that where we now meet with thousands and tens of thousands of undoubted human remains in the shape of rudely-fashioned stone tools and weapons lying almost under our feet, it is only within the last thirty years that their existence has even been suspected. Cuvier, the greatest authority of the last generation, laid it down as an incontrovertible fact that neither men nor monkeys had existed in the fossil state, or in anything more ancient than the most superficial and recent deposits. We have now at least twenty specimens of fossil monkeys, from one locality alone of the Miocene period, that of Pikermi, near Athens, and many thousands of human remains, contemporary with extinct animals of the Quaternary period, if not earlier. We must be content, therefore, with approximate solutions pointing up to but not absolutely demonstrating the truth.

What is a species? Speaking generally it is an assemblage of individuals who maintain a separate family type by breeding freely among themselves, and refusing to breed with other species. There can be no doubt that this represents what, at the first view and for a limited range of time, is in accordance with actual facts. The animal and vegetable worlds are practically mapped-out into distinct species, and do not present the mass of confusion which would result from indiscriminate cross-breeding. It is clear also that this state of things has lasted for a considerable time, for the paintings on Egyptian tombs and monuments carry us back more than 4,000 years, and show us the most strongly marked varieties of the human race, such as the Semitic, the Egyptian, and the Negro, existing just as they do at the present day. They show us also such extreme varieties of the dog species as the greyhound and the turnspit, then in existence; and the skeletons of animals such as the ox, cat, and crocodile, which have been preserved as mummies, show no appreciable difference from those of their modern descendants.

When we come to look closely, however, into the matter, our faith in this absolute rule of the entire independence of species is greatly modified. In the lower grades of life we see everywhere species shading off into one another by insensible grada-

tions, and every extension of our knowledge, both of the existing animal, vegetable, and microscopic worlds, and of those of past geological periods, multiplies instances of intermediate forms, differing from one another far less than do many of the individual varieties of recognised species. In the case of sponges, for instance, the latest conclusion of scientific research is this: that if you rely on minute distinctions as constituting distinct species, there are at least 300 species of one family of sponges, while if you disregard slight differences, which graduate into one another, and are found partly in one and partly in another variety, you must designate them all as forming only one species. Even in higher grades, as species are multiplied, it becomes more and more difficult to say where one ends and the other begins. Take the familiar instance of the grouse and ptarmigan. The red grouse is believed to be peculiar to the British Islands, while the ptarmigan is a very widely spread inhabitant of Arctic regions and high mountains. Which is more probable—that the grouse was specially created in the British Islands, apparently for the final cause of bringing sessions of Parliament to wind-up business in August, or that, as the rigour of the Glacial period abated, and heather began to grow, certain ptarmigan by degrees modified their habits and took to feeding on heather tops instead of lichens, and by so doing gradually became larger birds and assumed the colour best adapted for protection in their new habitation? In point of fact, grouse showing traces of this descent in smaller size and much whiter plumage are still to be met with. It would be easy to multiply instances, but this consideration seems conclusive.

If we reject the Darwinian theory and adopt that of independent species descended from a specially created ancestor or pair of ancestors, we are driven by each discovery of intermediate or slightly modified forms, into the assumption of more and more special acts of creation, until the number breaks down under its own weight, and belief becomes impossible.

For instance, in the Madeira Islands alone, 134 species of air-breathing land-snails have been discovered by naturalists, of which twenty-one only are found in Africa or Europe, and 113 are peculiar to

this small group of islands, where they are mostly confined to narrow districts and single valleys. Are we to suppose that each of these 113 species was separately created? Is it not almost certain that they are the modified descendants of the twenty-one species which had found their way there in a former geological period, when Madeira was united to Africa and Spain?

There remains only the argument from the fertility of species *inter se* and their refusal to breed with other species. This also, when closely examined, appears to be a *prima facie* deduction, rather than an absolute law. Different species do, in fact, often breed together, as is seen in the familiar instance of the horse and ass. It is true that in this case the mule is sterile and no new race is established. But this rule is not universal, and quite recently one new hybrid race, that of the leporine, or hare-rabbit, has been created, which is perfectly fertile. The progeny of dog and wolf has also been proved to be perfectly fertile during the four generations for which the experiment was continued. In the case of cultivated plants and domestic animals, there can be little doubt that new races, which breed true and are perfectly fertile, have been created within recent times from distinct wild species. The Esquimaux dog is so like the Arctic wolf that there can be little doubt he is either a direct descendant, or that both are descendants from a common stock. The same is true of the jackal and some breeds of dogs in the East and Africa, and other races of dogs are closely akin to foxes. But all dogs breed freely together, and can with difficulty be mated with the wild species which they so closely resemble. The modern Swiss cattle are pronounced by Rutimeyer to show undoubted marks of descent from three distinct species of fossil oxen, the *Bos primigenius*, *Bos longifrons* and *Bos frontosus*.

There is now¹ in the Zoological Gardens, in Regent's Park, a hybrid cow, whose sire was an American bison and its mother a hybrid between a zebu and a gayal. This animal is perfectly fertile, and has bred again to the bison; but what is singular is, that this hybrid resembles much more an ordinary domes-

tic English cow than it does any of its progenitors. It is totally unlike the bison, both in appearance and disposition, and except in having a projecting ridge over the withers, it might be mistaken for a coarse, bony, common cow. If a hybrid bull had been born of the same type, and mated with this hybrid cow, there is little doubt that a new race might have been established, extremely different from its ancestors.

In fact, nearly all the domesticated animals have the essential characters of new races. We cannot point to wild progenitors existing in any part of the world from which they are descended, and when they run wild they do not revert to any common ancestral form.

In the vegetable world instances of fertile hybrids are still more abundant, and the introduction and establishment of new varieties is a matter of very-day occurrence.

Now, whatever artificial selection can do in a short time, natural selection can certainly do in a longer time, and nothing short of absolute proof of the impossibility of species coming into existence by natural laws should induce us to fall back on the supernatural theory, with all its enormous difficulties of an innumerable multitude of special creations, most of them obviously imperfect and tentative—or rather, useless and senseless on any supposition except that of a necessary and progressive evolution. In fact, if it were not for its bearing on the nature and origin of man, few would be found to maintain the theory of miraculous creations, or to doubt that the world of life is regulated by fixed laws as well as the world of matter. But whatever touches man touches us closely, and brings into play a host of cherished aspirations and beliefs, which are too powerful to be displaced readily by calm, scientific reasoning. Shall man, who, we are told, was created in God's image and only "a little lower than the angels," be degraded into relationship with the brutes, and shown to be only the last development of an animal type which, in the case of apes and monkeys, approaches singularly near to him in physical structure? Are the saints and heroes whom we revere, and the beautiful women whom we admire, descended, not from an all-glorious Adam and all-lovely Eve, as

¹ 1888.

portrayed in Milton's "Paradise Lost," but from Palæolithic savages, more rude and bestial than the lowest tribe of Bushmen or Australians? Is the account of man's creation and fall in the Hebrew Scriptures as pure a myth as that of Noah's ark, or of Deucalion and Pyrrha?

The only answer to these questions is that truth is truth, and fact is fact, and that it is always better to act and to believe in conformity with truth and fact, than to indulge in illusions. There are many things in Nature which jar on our feelings and seem harsh and disagreeable, but yet are hard facts, which we have to recognise and make the best of. Childhood does not pass into manhood without exchanging much that is innocent and attractive for much that is stern and prosaic. Death, with its prodigal waste of immature life, its sudden extinction of mature life in the plenitude of its powers, its heart-rending separations from loved objects, is a most disagreeable fact. But it would not improve matters to keep grown-up lads in nurseries for fear of their meeting with accidents, or of becoming hardened by contact with the world. Progress, not happiness, is the law of the world; and to improve himself and others by constant struggles upwards is the true destiny of man.

In working out this destiny the fearless recognition of truth is essential. Facts are the spokes of the ladder by which we climb from earth to heaven, and any individual, nation, or religion, which, from laziness or prejudice, refuses to recognise fresh facts, has ceased to climb and will end by falling asleep and dropping to a lower level.

"Prove everything, hold fast that which is true," is the maxim which has raised mankind from savagery to civilisation, and which we must be prepared to act upon at all hazards and at all sacrifices, if we wish to retain that civilisation unimpaired and to extend it further.

CHAPTER V

ANTIQUITY OF MAN

Belief in Man's Recent Origin—Boucher de Perthes' Discoveries—Confirmed by Prestwich—Nature of Implements—Celts, Scrapers, and Flakes—Human Remains in River Drifts—Great Antiquity—Implements from Drift at Bournemouth—Bone Caves—Kent's Cavern—Victoria, Creswell, and other Caves—Caves of France and Belgium—Ages of Cave Bear, Mammoth, and Reindeer—Artistic Race—Drawings of Mammoth, etc.—Human Types—Neanderthal—Attempts to fix Dates—History—Spy, Trinil—Bronze Age—Neolithic—Danish Kitchen-middens—Swiss Lake-Dwellings—Glacial Period—Traces of Ice—Causes of Glaciers—Croll's Theory—Gulf Stream—Dates of Glacial Period—Rise and Submergence of Land—Tertiary Man—Eocene Period—Miocene—Evidence for Pliocene and Miocene Man—Conclusions as to Antiquity.

GREAT as the effect has been of the wonderful discoveries of modern science of which I have attempted to give a general view in the preceding chapters, there remains one which has had the greatest effect of all in changing the whole current of modern thought, viz., the discovery of the enormous antiquity of man upon earth, and his slow progress upwards from the rudest savagery to intelligence, morality, and civilisation. It is needless to point out in what flagrant and direct opposition this stands to the theory that man is of recent miraculous creation, and that he was originally endowed with a glorious nature and high faculties, which were partially forfeited by an act of disobedience. It is important, therefore, to understand clearly the evidence upon which rests a conclusion so startling and unexpected as that which traces the origin of man back into the remote periods of geological time.

It had been long known that a stone period preceded the use of metals. Flint arrow-heads, stone axes, knives, and chisels, rude pottery, and other human remains lie scattered almost everywhere, on or near the existing surface, and are found in the sepulchral mounds and monuments which abound in all countries until they are destroyed by the pro-

gress of agriculture. These are certainly ancient, for their origin was so completely forgotten that the stone hatchets or celts (from the Latin *celtis*, or chisel) were universally believed to be thunderbolts which had fallen from heaven. But there was no proof that they were very ancient, they were always found at or near the present surface, and if animal remains were associated with them, they were those of the dog, ox, sheep, red deer, and other wild and domestic species now found in the same district. Historical record was not supposed to extend beyond the 4,000 or 5,000 years assigned to it by Bible chronology, and it was thought that this might be sufficient to account for all the changes which had occurred since man first became an inhabitant of the earth. Above all, the negative evidence was relied on, that geologists had explored far and wide, and although they had found fossil remains which enabled them to restore the characteristic fauna of so many different formations, they had found no trace of man or his works anywhere below the present surface. This seemed so conclusive that Cuvier, the greatest authority of the day, pronounced an emphatic verdict that man had not existed contemporaneously with any of the extinct animals, and probably not for more than 5,000 or 6,000 years. Here, then, appeared to be an edifice based on scientific fact, in which geologists and theologians could dwell together comfortably, and the weight of their united authority was sufficient to silence all objections, and ignore or explain away the instances which occasionally cropped up, of human remains found in situations implying greater antiquity.

Suddenly, I may almost say in a single day, this edifice collapsed like a house of cards, and the fact became apparent that the duration of human life on the earth must be measured by periods of tens, if not of hundreds of thousands of years.

It happened thus: A retired French physician, Monsieur Boucher de Perthes, residing at Abbeville, in the valley of the Somme, had a hobby for antiquarianism as decided as that of Monkbarns himself. Abbeville afforded him a capital collecting-ground for the indulgence of his tastes, as the sluggish Somme flows through a series of peat mosses, which are extensively worked

for fuel, and afford many remains of the Gallo-Roman and pre-Roman or Celtic period. Higher up, on the slopes of the low hills which bound the wide valley, are numerous beds of gravel, sand, and brick-earth, which are also extensively worked for road and building materials. In these pits remains of the mammoth, rhinoceros, and other extinct animals are frequently found, and the workmen had noticed occasionally certain curiously-shaped flints, to which they gave the name of "langues du chat," or cats' tongues. Some of these were taken to Monsieur Boucher de Perthes as curiosities for his museum, and he at once recognised them as showing marks of human workmanship. This put him on the track, and in the year 1841 he himself discovered, *in situ*, in a seam of sand containing remains of the mammoth, a flint rudely but unmistakably fashioned by human hands into a cutting instrument. During the next few years a large quantity of gravel was removed to form the Champ de Mars at Abbeville, and many of these celts or hatchets were found. In 1847, M. Boucher de Perthes published his "Antiquités Celtiques et Antédiluviennes," giving an account of these discoveries, but no one would listen to him. The united authority of theologians and geologists opposed an infallible veto on the reception of such ideas, and it must be admitted that M. Boucher de Perthes himself did his best to discredit his own discoveries by associating them with visionary speculations about successive deluges and creations of pre-Adamite men. At length Dr. Falconer, the well-known palæontologist, who had brought to light so many wonderful fossil remains from the Sewalik hills in India, happened to be passing through Abbeville and visited M. Boucher de Perthes' collection. He was so much struck by what he saw that on arriving in London he spoke to Mr. Prestwich, the first living authority on the Tertiary and Quaternary strata, and Mr. (now Sir John) Evans, whose authority was equally great on everything relating to the stone implements found in such numbers in the more recent or Neolithic period. He urged them to go to Abbeville and examine for themselves whether there was anything in these alleged discoveries. They did so, and the result was that on their

return to England Mr. Prestwich read a paper to the Royal Society on the 19th May, 1859, which conclusively and forever established the fact that flint implements of unmistakable human workmanship had been found, associated with the remains of extinct species, in beds of the Quaternary period deposited at a time when the Somme ran at a level more than 100 feet higher than at present, and

have been found from Western Europe to Tibet; in Africa, and Central Australia; in fact wherever they have been looked for, except in northern countries which were buried under ice during the Glacial period. The earliest known authentic witness to man's presence in Britain are some rudely-worked flints which were found, mingled with bones of huge extinct animals, at a great depth in brick-earth at



FLINT HACHE,
From Moulin Quignon, Abbeville.
(Half the actual size.)



FLINT HACHE,
From St. Acheul, Valley of the Somme.
(Half the actual size.)

(From Lubbock's "Prehistoric Times.")

was only beginning to excavate its valley.

The spell once broken, evidence poured in from all quarters, and although twenty-five years¹ only have elapsed since Mr. Prestwich's paper was read, the number of stone and other implements worked by man, deposited in museums, is already counted by tens of thousands, and they

¹ Written in 1884.

Hoxne, in Suffolk. Some idea of the immense number of these rude implements may be formed from the fact that the valley system of one small river, the Little Ouse, which rises near Thetford and flows into the Wash after a course of twenty-five miles, has within little more than ten years yielded about 7,000 specimens.

They have been found in great abundance also in the valley gravels of the