SCIENCE, MATTER, AND IMMORTALITY

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To

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M.Sc., F.R.S., D.Sc., LL.D.

MAN OF SCIENCE, THINKER, AND TEACHER

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CORRIGENDA

Page 85, line 17, *for* "as a cannon" *read* "as a cannon-ball."
" 85, " 25, *for* "energy" *read* "velocity."
" 98, " 25, *for* "carbon" *read* "hydrogen."
" 144, " 4, *for* "estimate" *read* "provisional estimate."
" 147, " 13, *for* "inorganic" *read* "organic."
" 191, " 15, *for* "brain" *read* "rough anatomy of the brain."

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CHAPTER I

THE FABRIC OF MATTER—THE ATOMIC THEORY IN ITS FIRST BEGINNINGS

PROBABLY the coarsely convoluted brain within a Neanderthal skull had no very definite and clear-cut sense of personal identity, nor of the modern distinctions between mind and matter—between the living and the dead. Ideas of personal identity, definitions of the living and the dead, are really very complex mental operations, and "Nature's insurgent son," chipping his flinty eolith at the side of a glacier, took much more interest in mammoths and woolly rhinoceroses than in questions of physics or metaphysics. For thousands and thousands of years, getting food and begetting progeny were man's chief concerns ; and he had so little idea of the nexus between body and mind, and of the criteria of life and death, that the dawn, and the night, and stars, and the sea, and all moving objects were to him living and thinking beings. For thousands and thousands of years, man was a most *practical* creature.

Then suddenly in certain corners of the globe his brain acquired new cells, or new creases, and he began to think in quite new ways, and to wonder where he was, and what he was, and why he was. Such an awakening took place about twenty-five centuries ago in a little country called Greece (then including Ionia in Asia Minor). Why did the brain develop ; why did thought flare up there and then ? It was not a case of gradual growth, due to selection and survival of the fittest. Brains had then no particular survival-value, and certainly in respect of brains there could be no very stringent selective process. To what, then, was this awakening due ? The question is difficult to answer ; but it is suggestive that the brain-wave culminated where East meets West, and just about the time the Egyptian ports were opened to the Greeks, and when there was great activity in Greek commerce, and correspondingly active intercourse with all parts of the world. On the shores and isles of Greece met and married fair-haired barbarians from the North, land-measuring Egyptians, star-gazing Babylonians, sea-going Phœnicians—on this little ragged piece of land, with its adjacent islands, met and married Europeans, Asiatics, Africans. Probably never before in the history of the world had there been such a clash of ideas, such an intermarrying of nations ; and surely it is permissible, and in accordance both with the laws of biology and ethics, to suppose that such international promiscuity would result at once in mental quickening and in moral deterioration ; and this supposition would explain at once the suddenness of the intellectual ascent and the quickness of the decadence. Mongrels have often brains and vitality, and are rich in remarkable variations, but in accordance with the laws of heredity they do not breed true. We see something of the same kind in towns like Chicago and New York—great intellectual activity, combined with moral deterioration, and qualities that appear in one generation to disappear in the next.

We suggest, then, that the great fertility of the Greek mind at this period was due chiefly to race admixture. It was simply an instance of natural eugenics—a case of germinal variations resulting in a crop of geniuses.

Yet the awakening was not *quite* so sudden as it might seem. The Greek brain was ready for the quickening : the Greek language and Greek mythology presuppose an intellect already highly developed. And it must be remembered, too, that the Egyptians and Babylonians were richly endowed peoples who had already some considerable knowledge of geometry and astronomy.

Anyhow, whatever the cause, in Greece, twenty-five centuries ago, there arose geniuses with brains as big, and active, and speculative, with an intellectual appetency as keen, as the world has ever known. With wide-open eyes they gazed around them, and saw, and wondered. No longer were there mammoths, and woolly rhinoceroses to slay; and they had not only brains, but leisure to use them.

All the old civilisations—Babylonia, Egypt, Peru—arose, as was natural, where climatic conditions were favourable; and these Greek thinkers, born in a beautiful land, with a beautiful climate, had "shelter to grow ripe and leisure to grow wise." The old explanations of things would not fit their larger horizons: the old categories would not contain their larger facts: the old gods failed to satisfy their new appetite for truth. They gazed around: the islands gleamed in the blue ocean, they saw men with brawny limbs, and women with rounded bosoms, and in their souls was born a sense of beauty, so that they carved wonderful statues and made great poems; and lo! there appeared a Homer, or a Phidias, or a Euripides, or a Sophocles. They gazed around: and they saw above them the moon and stars ; they saw behind them Birth, and before them Death ; and realising the mystery of existence, they propounded new creeds and philosophies, and lo ! there appeared a Plato, or a Socrates, or a Democritus, or a Heraclitus.

It was simply a case of harp and hand. For 150,000 years the brain had been there ; for 150,000 years the stars and the seas had been waiting to play upon it, but only now was the instrument ready for the musician. Palæolithic Man had no doubt his art, for bisons and reindeer, and mammoths, carved on antlers and tusks, have often been found ; but yet Palæolithic Man did not, could not, produce a Plato or a Phidias. The Greek brain of 600 B.C. was something quite new in the world.

The modern man goes to his business day after day, and in many respects his brain is very much alert and alive ; but he is usually quite incurious of the stars ; he knows enough about them to satisfy his feeble curiosity, and he feels that the mechanism of the world is no concern of his. Not so the Greek philosopher. To him the world was new, and strange, and full of problems, and he was afire with divine curiosity.

One of the earliest problems that engaged the awakened Greek mind was the nature of the *objective*—of that changing something we call *matter*, which forms the material universe. At the very first, perhaps, man conceived the material merely as the sensuous ; and having not yet reached "that invention of the human intellect, spoliated and passive matter," he drew no distinction between substance and its properties, or between the objective and subjective ; but by and by arose the conception of matter as a duality of substance and properties,—of matter as something outside the mind. Whether this later conception be correct and final, or acceptable to the most highly developed intellects, we cannot here discuss ; but it is a conception now well-nigh universal, and it was the conception of matter current in the golden centuries of Greek philosophy.

What, then, was this *matter*, a thing outside and separate from the mind, that composed stones, and trees, and stars, and men ? What was the world ? Had it existed from all time ? Or was it made ? No longer satisfied with beautiful myths, the great thinkers tried to construct new cosmogonies. Thales, for instance, inspired no doubt by Egyptian philosophy, derived all things from *water.* His pupil Anaximander, with more mystical tendencies, maintained that the material cause and first element of things was the *Infinite.* Theophrastus in his *Opinions* writes : "Anaximander of Miletus, son of Praxiades, a fellow-citizen and associate of

Thales, said that the material cause and first element of things was the Infinite, he being the first to introduce this name for the material cause. He says it is neither water nor any other of what are now called the elements, but a substance different from them, which is infinite, from which arise all the heavens and the world within them." This is an interesting anticipation of the modern theory of an "Urstoff" or primordial element.

Diogenes of Apollonia (not the Cynic) and Anaximenes of Miletus considered *air* the origin of all things—a doctrine that influenced physiology down even till the time of Harvey. Theophrastus gives Diogenes' theory as follows : "He, too, says that the primordial substance of the Universe is Air, infinite and eternal, from which, by rarefaction, condensation, and change of state, everything else arises."

Heraclitus, again, found in *fire*, and Pythagoras in *number*, the source of all things ; while Empedocles propounded the view that all things were made of *fire*, *air*, *earth*, and *water*—a view that persisted till comparatively recent times.

These views may seem very foolish now, but they are not so foolish as they seem, and they were often based on very subtle, sound, and suggestive philosophical reasoning. That *number* could be the source of the world may seem absurd ; but in this twentieth century, the labours of mathematicians have reduced matter and the laws of matter to little more than mathematical equations. That *fire* could be the source of all things may also seem absurd, yet we must not forget that it is just from fire—from the fiery nebula—that modern science has derived the solar system ; that the relationship between heat and energy is one of the great mysteries of science. Moreover, if we follow the reasoning of Heraclitus, we find it astonishingly strong and acute. His views are given thus by Edward Clodd (*Pioneers of Evolution*) : "Flux or movement, says Heraclitus, is the all-pervading law of things, and in opposition of forces, by which things are kept going, there is underlying harmony. Still on the quest after primary substance, whose manifestations are so various, he found it in *fire*, since 'the quantity of it in a flame burning steadily appears to remain the same ; the flame seems to be what we call a thing.' And yet the substance of it is continually changing. It is always passing away in smoke, and its place is always being taken by fresh matter from the fuel that feeds it. This is just what we want. If we regard the world as an everliving fire—this order which is the same in all things, and which no-one of gods or men has made—we can understand how fire is always becoming all things, while all things are always returning to it." This is surely acute, subtle, and suggestive.

Let us hear how Diogenes makes out his case for air.

"My view," he says, "is, to sum it up briefly, that all things are differentiations of the same thing, and are the same thing. And this is obvious, for if the things which are now in the world—earth, and water, and air, and fire, and the other things which we see existing in this world—if any of these things, I say, were different from any other, different, that is, by having a substance peculiar to itself, and if it were not the same thing that is often changed and differentiated, then things could not in any way mix with one another, nor could they do one another good or harm. Neither could a plant grow out of the earth, nor any plant or animal come into being, unless things were composed in such a way as to be the same. But all these things arise from the same thing; they are differentiated, and take different forms at different times, and return again to the same thing. But this, too, appears to me to be obvious, that it is both great, and mighty, and eternal, and undying, and of great knowledge. For it would not be possible for it to be divided as it is without intelligence, so as to keep the measures of all things, of winter and summer, and day and night, of rains, and winds, and fair weather. And anyone who cares to reflect will find that everything else is disposed in the best possible manner."

This also is surely acute, subtle, and suggestive, and sets forth a very logical case for a *prima materia*. Not only the question of the origin of matter engaged the Greek mind, but also the question of its nature, and especially the question of its continuity.

The question of the continuity of matter may seem, at first sight, a question purely philosophic and dialectic ; yet it has most important practical issues, and on its solution depended almost all modern scientific achievement.

The obvious answer to the question is, that matter is homogeneous and continuous, and not discrete and particulate in its ultimate constitution ; for the eye sees no ultimate particles and granules, and the mind conceives of matter as infinitely and indefinitely divisible, and deems all its finer divisions as equally artificial. Yet, strange to say, Greek Philosophy leant, on the whole, towards the theory that matter was built up of minute invisible indivisible particles with empty spaces between, and in most of the doctrines of matter of the early Greek philosophers there was implied some sort of atomic theory.

"When Anaximander," says Gomperz, "explained the changes in the form of his primary matter by condensation and rarefaction, when he taught that its fundamental form proceeded intact from each successive variation, the thought must plainly have dawned on him that minute imperceptible particles were there at work, now coming closer together, and now departing from one another. Again, when Heraclitus proclaimed his doctrine of the ceaseless transformation of things, and declared the uninjured existence of an individual object to be a mere delusion brought about by the constant accession of fresh particles in the place of those that had been severed, he was obviously assuming the presence of invisible particles of matter as well as of their invisible movements. And finally, when Anaxagoras complained of the 'weakness' of our senses, when he combined in every corporeal structure an infinite number of 'seeds' or of the minutest primary particles, and made the appearance of the structure depend on the predominance of one sort of those particles, he was stating, in unambiguous words, the very doctrine which inference alone enables us to attribute to his two predecessors."

The atomic theory was, however, only implied by these philosophers, and it was left to Leucippus and Democritus explicitly to formulate it. Aristotle states: "Democritus and Leucippus say that all things are composed of indivisible bodies, and that they are infinite both in number and in their forms, and that the differences between things are due to the elements of which they are composed, and to the position and arrangement of these elements."

Theophrastus, in his opinions, gives Leucippus' views rather more fully: "He assumed innumerable and ever-moving elements, namely, the atoms. And he made their forms infinite in number, since there was no reason why they should be of one kind rather than another, and because he saw that there was unceasing becoming and change in things. He held further that *what is*, is no more real than *what is not*, and that both are alike causes of the things that come into being; for he laid down that the substance of the atoms was compact and full, and he called them *what is*, while they moved in the void which he called *what is not*, but affirmed to be just as real as *what is*." How like this is the modern view of ether and its vibrations!

Leucippus was probably the originator of the atomic theory, but only these fragmentary accounts of sayings of his are extant, and the theory is usually associated with the name of Democritus, who propounded his views at considerable length. His fundamental propositions are given by Mendeleef as follows:—

"(1) Nothing can proceed from nothing, nothing that exists (and hence matter) can disappear or be destroyed, and every change consists only of a combination or separation.

"(2) Nothing is accidental; there is a reason and necessity for everything.

"(3) All except atoms and vacua is reason, and not existence.

"(4) The atoms, which are infinite in number and form, constitute the visible universe by their motion, impact, and consequent revolving motion.

"(5) The variety of objects depends only on a difference in the number, form, and order of the atoms of which they are formed, and not upon a qualitative difference of their atoms, which only act upon each by pressure and impact.

"(6) The spirit, like fire, consists of minute, spherical, smooth, and very mobile and all-penetrating atoms, whose motion forms the phenomenon of life."

Much the most important of these propositions are the fourth and fifth. Though quite empiric and intuitive, they yet were a forecast of the principles and hypotheses on which modern science is based, and they have influenced scientific thought for over two thousand years, and have become only more firmly established and more illuminating with the progress of scientific discovery and the development of scientific method. Only, indeed, in quite recent years has their full philosophic meaning been demonstrated. They amount, in fact, to an enunciation of the truth that science is only now reaching—that differences in matter are due not to different primordial elements, but to differences of shape, and position, and movement, and number, in elements essentially identical.

"Atomism," says Gomperz, "may be superseded; the theory of cognition in its progress has already weakened the distinction between primary and secondary qualities; but the attempt to correlate all qualitative differences with differences of size, and shape, and situation is destined to survive all changes of opinion and thought. The exact knowledge of nature rests entirely on this attempt to reduce qualities to quantities, or, to speak more precisely, to establish fixed relations between the two."

Two thousand years later the great Galileo had the same great intuition, and wrote: "I do not believe that anything else is required than magnitudes, shapes, quantities, and slow movements or swift, to produce in us tastes, smells, sounds"; while, later, Huyghens assumed that bodies were made of homogeneous matter, "in which no qualities were distinguished, but only magnitudes, shapes, and movements."

And now, in modern days, as we have said, as we shall see, this same hypothesis is the very pivot of modern science. "Corporeal movements"—

to quote Gomperz again—"as an element that can be quantitatively determined, are the 'Open Sesame' that has unlocked countless secrets in the system of nature, and that will unlock countless more." "If," says Huxley, "there is one thing clear about the progress of modern science, it is the tendency to reduce all scientific problems, except those that are purely mathematical, to problems in molecular physics—that is to say, to attractions, repulsions, motions and co-ordinations of the ultimate particles of matter."

Democritus not only laid down these broad and fruitful propositions, he also worked out his theory in detail with great ingenuity, and anticipated some of the ideas of modern chemistry. Thus he pictured groups of atoms, and imagined them fixed together by links, and hooks and eyes, and mortises, and dovetailings. He also drew a distinction between atoms that were sociable and readily linked together, and those that were unsociable and did not easily combine, or—as we should say in modern terminology—between elements inert and elements chemically active. He even had an idea that some atoms had one point of attachment and others several, and may almost be said to have suggested modern stereo-chemistry.

After Democritus came Empedocles (the philosopher of Mount Etna), in his golden girdle and crown, who suggested that the motions, the combinations and separations, of the atoms were determined by the love and strife, even as we still talk, of affinities ; and who went so far as to conceive that there was a struggle for existence among primitive organisms, with a survival of the fittest. Most interesting is his picture of the unfit forms that perished. "It (Love) made many heads spring up without necks, and arms wandered bare and bereft of shoulders. Eyes strayed up and down in want of foreheads. . . . Many creatures with faces and breasts looking in different directions were born ; some offspring of oxen with faces of men, while others, again, arose as offspring of men with heads of oxen."

But most interesting of all to us is this theory of immortality based on the indestructibility of the atoms : "And I shall tell thee another thing. There is no coming into being of aught that perishes, nor any end for it in baneful death ; but only mingling and separation of what has been mingled.

"Coming into being is but a name given to these by men. . . . But when the elements have been mingled in the fashion of a man, and come to the light of day, either in the fashion of the race of wild beasts, or plants, or birds, then men say that these came into being ; and when they are separated, they call that, as is the custom, woful death. I, too, follow the custom, and call it so myself. . . . Fools!—for they have no far-reaching thoughts who deem that what before was not comes into being, or that aught can perish or be utterly destroyed, for it cannot be that aught can arise from what in no way is, and it is impossible and unheard of that what is should perish; for it will always be, wherever one may keep putting it. . . . A man who is wise in such matters would never surmise in his heart that so long as mortals live what men choose to call their life, they are, and suffer good and ill; while before they were formed, and after they have been dissolved, they are, it seems, nothing at all."

Surely these are words of wisdom!

Epicurus may also be mentioned as one of the Atomic School. He taught that there was an infinite number of atoms falling perpendicularly down an infinite space. Some of these atoms, he suggested, deviated from a straight path, and stuck together and formed the world.

But the ancient apostle *par excellence* of the atoms was Epicurus' disciple, the great Roman poet Lucretius, who made a most scientific use of his imagination, and propounded the atomic theory "in harmonious and beautiful verse, swayed by a fervour that is akin to religious emotion."

To Lucretius we must give a separate chapter.

CHAPTER II

LUCRETIUS

Lucretius lived in the decadent days of Cæsar and Cicero, when Rome stood between two worlds, "one dead, the other powerless to be born." No longer did thinkers believe in the old gods. Cicero, though hoping in immortality, was an agnostic. Cæsar, even when Pontifex Maximus, dared to assert, in the consecrated Temple of Concord, that the nations were ruled by the caprice of fortune—*Fortuna cujus libido gentibus moderatur*. The unlettered mob, who did still in some sort believe, were dupes of the priests, slaves of superstition, and an easy prey to exorcisers, diviners, soothsayers. Corrupt in her creeds, Rome was equally corrupt in her morals. Agriculture was neglected; civil war devastated the land; vice was rampant; brutality was a commonplace, and six thousand slaves on crosses on the road to Capua were signs of the times to every passer-by.

"Sitting aloof, holding no form of creed, but contemplating all," Lucretius surveyed the painful panorama of life. He saw that the pride of Roman imperialism was false and foolish : he saw that wealth and power were as dust under the feet of Death.

"All that nature demands is freedom from care and fear ; but neither wealth nor power will deliver thee from these, nor yet from sickness . . . . What avails it all unless, then, thou findest that superstitious fears are scared away, and fly panic-stricken from thy mind. Nor does it avail thee ought to see thy fleet swarm forth, and spread far and wide over the sea, unless then the fear of death leaves thy breast untenanted and free from care."

How, then, Lucretius asked, are men to escape from fear and care ? In the gods he could find no hope. If gods there were, they were cruel and careless to allow such a world—to allow vice and disease, and these six thousand slaves rotting on the crosses. Far better no gods than such gods, he maintained ; far better believe that the world was the creation of blind atoms, than the plaything of capricious deities. And so he tried to prove that man was at the mercy of lawful atoms, and not of lawless powers, and that death ended all. It was a pessimistic creed, and yet his genius gave it some sort of beauty and nobility, and, as John Masson (*Lucretius, Epicurean and Poet*) remarks: "There was more true faith in Lucretius's denial of a Divine Providence at such an era than there is in the self-complacent creed of many a modern optimist with whom, if things go well with himself, all is well, and this world the best that can be." To free men from superstition, and cant, and fear, is the next best thing to leading them to a fair faith. How great the emancipation, it is difficult now to realise; for it is difficult to realise how completely most men of that day were under the dominion of superstitions of every kind, and how much the limbs of truth were hampered by the fetters of fear. To look facts in the face, and to have the courage to study the nature of things, was a great step on the way to wisdom.

Hundreds of years before Lucretius, there had, as we have seen, been atomists; and Lucretius, in working out his atomic philosophy, chose as his master Epicurus, whom he praises as the first man to withstand religion openly. Indeed, it is probable that Lucretius merely gave a luminous and logical exposition of the doctrines adumbrated by Epicurus. "Thee I follow, thou glory of the Greek race," says Lucretius, "and now fix my steps firmly in thy footprints and tread in them." However that may be, the fact remains that

Lucretius has given us the most consistent and systematic atomic theory of ancient times, and it will repay us to look at its main features.

Plunging at once *in medias res*, the poet explains the purpose of his poem. "I will unfold the atoms whence Nature forms, and increases, and feeds all things that are, and into which she dissolves them again after their destruction."

The sun, the moon, he says, are moved not by the caprices of the gods, but by natural inevitable mechanical laws, and, indeed, by natural inevitable mechanical laws all things are made and moved. "It is absolutely decreed," he asserts, "what each thing can do, and what it cannot do, according to the conditions of Nature."

> "Unde refert nobis victor quid possit oriri
> Quid nequeat, finita potestas denique cuique
> Quanam sit ratione atque alte terminus haerens.
> Quare religio pedibus subjecta vicissim
> Opteritur, nos exaequat victoria coelo."

He holds that the universe consists of atoms and a void ; and, given atoms and a void, he is prepared to show how the universe came into being. He argues that matter is built up of atoms, and that the atoms are impenetrable, indivisible, and indestructible—"solida pollentia simplicitate." If destructible, he says, there would not be the uniformity in objects which now obtains ; for as the atoms become chipped and broken and worn, the objects they formed would alter, "nor could the generations so often reproduce, each after its kind, the nature, habits, ways of life, and motions of the parents."

It is interesting to find that, many centuries later, Newton employed almost exactly the same reasoning. "While the same particles continue entire, they may compose bodies of one and the same texture in all ages; but should they wear away or break in pieces, the nature of things depending on them would be changed. Water and earth composed of old worn-out particles would not be of the same nature and texture now with water and earth composed of entire particles in the beginning. And, therefore, that Nature may be lasting, the changes of corporeal things are to be placed only in various separations, and new associations, and motions of these permanent particles."

Lucretius supposes, further, that atoms vary in size, shape, and weight, but that the varieties are *finite* in number. If not finite, he points out, some would be infinitely large; and further, there would be an infinite variety of things, and fresh things would be always forming. Though he had probably no conception of the ultra-microscopic dimensions of the atom of modern chemists, he yet pictured the average atoms as invisibly small; and again, though he had no conception of the modern philosophical division of qualities into primary and secondary, he denied to the atoms all secondary qualities, such as colour, warmth, scent. The sensible secondary qualities of objects, however, he imagined to depend on the shape and size of the atoms, and on the way in which they are fixed together. Thus light is formed of very, very small atoms—so small that they can pass through horn. Liquids are usually formed of round, smooth atoms. Things which are hard or tough, like diamonds, are formed of atoms tightly hooked together, or united together by many branches. A thunderbolt is formed of particles especially minute and ready to move! The mind is composed of very tiny smooth round atoms. All the atoms are very hard, so that they are not crunched even by the teeth of death.

> "Nam quid in oppressu valido durabit eorum,
> Ut mortem effugiat, leti sub dentibus ipsis?"

Perhaps the most extraordinary thing about the Lucretian atomic theory is the manner in which it anticipated the modern theory of molecular motion. To the ordinary unscientific eye, matter, even if conceived as particulate, seems to consist of coherent and motionless particles. Yet Lucretius taught that the particles of matter were not coherent

—"Nam certe non inter se stipata cohaeret materies" —but discrete and in constant movement. Even in iron and stone, and such hard substances, his eye could see the atoms throb and seethe. Surely such scientific imagination and such prescience were most remarkable! More remarkable still, Lucretius actually anticipated the modern scientific and philosophic theory which reduces all material phenomena to motion, or to mass and motion. "It matters much," he insists, "with what others and in what position the same atoms are severally held in union, and what motion they mutually give and receive."

The objection that matter *seems* stationary is seen by Lucretius to have no great weight. "One thing," he says, "you need not marvel at: why, seeing that the first beginnings of things (atoms) are all in motion, still the sun appears to stand in perfect rest"; and he points out that experience is full of similar contradictions: that a flock of sheep playing about on a distant slope appears to be "a white spot standing on a green hill," and that a gleaming army seen afar may seem only a bright patch.

His theory of chemical combination was also sound. "There are certain bodies (*i.e.* atoms) possessed of such a nature that if they have haply produced fire, the same may, after a few have been taken away and a few added on, and their order and motion changed, produce air; and all other things may in this way interchange with one another." Illustrating this by the case of the letters of the alphabet, he explains: "It matters much with what other letters and in what order the several letters are placed. If all the letters are not entirely alike, still by far the greatest part are; but the words which they compose differ through the position of these letters. Thus in material things as well: when the clashings, motions, arrangement, position, and shapes of matter change about, the things must change too."

The weakest point about the atomic theory of Lucretius is its failure to account for the concourse and combination of the atoms. According to theory, the atoms rain straight down through the void. Raining straight down, they would never clash, and meet, and combine; so Lucretius has to postulate that they occasionally swerve from a straight line, and so collide. "This point of the subject we desire you to apprehend, that when atoms are borne straight downwards through the void by their own weights, at quite uncertain times and uncertain places they push themselves a little from their course, only just so much that you can call it a change of inclination. If they were not wont to swerve thus, they would fall down like drops of rain through the deep void, and no clashing could have been begotten, nor any collision produced among the first beginnings: thus Nature never would have produced anything." It has been pointed out that a force almost infinitesimally small, acting at right angles on a falling body, would suffice to deflect it from its perpendicular course, and that in the case of a rain of infinite atoms the swerving of a single atom would be sufficient to initiate an infinite series of collisions. Yet even the swerving of a single atom requires a *cause*; and in order to account for the deflection of atoms, Lucretius supposes each endowed with a sort of embryonic *free-will.* This supposition both accounts for the deflection of the atoms and gives an atomic explanation of the origin of the free-will in man in which the Epicureans firmly believed. Yet even granting free-will in atoms, resulting in deflection and collisions, what then? Could a series of atomic collisions produce the universe and all that therein is; would it not, as Plutarch objected, produce "no incorporation or coalition, but only percussions and repercussions"—only "a confusion and combat of atoms"? Given sufficient time, says Lucretius, and the atoms will eventually combine into the forms of matter we know. "Truly not by design nor by sage consideration have the first beginnings of things (atoms) stationed themselves each in their proper places, nor have they made agreement what motions they should each assume. Not so in truth ; the cause is, that they are many in number, and have shifted, in changes many, all the universe over. They have been driven together and tormented by constant shocks from all eternity. After trying in this way motions and unions of every kind, they fall at length into the arrangements out of which this world of ours has been formed, and by which, too, it has been preserved in being through many cycles when once it has been thrown into the fitting motions." Again, "this world has been made by Nature just as the seeds of things have chanced to clash, entirely of their own accord, after being driven together in many ways without purpose, without foresight, without result, and at last such seeds have filtered through as, when suddenly thrown together, might become the germs of great things of earth, sea, heaven, and of the race of living things." At first no substance could be seen like our substances, "but a kind of strange storm and medley made of atoms of every kind, whose lack of harmony caused a conflict and disordered their interplaces, passages, connections, weights, blows, clashings, motions, because, by reason of their unlike forms and different shapes, they could not all remain thus joined together, nor unite in harmonious motions."

Thus we see that Lucretius explained the first forms of matter much as Clifford explained the first living molecule, saying they were "produced by a coincidence and preserved by natural selection."

But Lucretius realises that something more is still wanted—not merely free-will of sorts to cause collision, and not merely natural selection of the combinations so produced, but also preferential affinities between atoms, which he denotes by the term *concilium*.

Finally, Lucretius adumbrated the law of conservation of energy. "Nor was the store of matter ever more dense or ever separated by larger intervals than now; for nothing is either added to it or lost from it. Wherefore, in whatsoever motion the bodies of the first-beginnings now move, in the same way they moved in time gone by, and in like manner they will always be borne along hereafter. . . . No force can alter the sum of things; for there is no *Beyond* into which either any kind of matter can escape out of the universe, or out of which a new force can arise and burst in and change all the nature of things and disturb its motions."

Such, then, in brief, was the Atomic Theory of Epicurus and Lucretius. Such, then, were the first theories of matter. They were crude, wild, and empiric, yet not without both scientific and philosophic value. In order fully to understand them, we must divest our minds of preconceptions, and must approach the problems with the same scientific equipment and with the same young curiosity as these ancient philosophers. It is difficult to do : we see the world with the eyes of the twentieth century ; we see it through telescopes and microscopes. Yet, difficult though it be, it is worth doing. To realise the world as it *seemed* two thousand years ago is to widen our horizon by twenty centuries ; and it is as necessary for culture to understand ancient views of matter as ancient views of God. Indeed, the sun of Truth can be rightly viewed only by means of the parallax obtained at the extremes of Time.

CHAPTER III

THE GROWTH OF THE MODERN MECHANIC CONCEPTION OF MATTER

THERE is nothing more interesting in the history of human thought than the endeavours of the human mind to get to the bottom of the mystery of matter. Some of these endeavours we have already discussed in tracing the beginnings of the atomic theory; but the mystery is many-sided; and in order fully to understand modern views of matter, we shall now require to look at their growth through the centuries. We cannot see any beliefs in their true character and context unless our horizon includes their embryology and infancy.

We shall now try, briefly, to trace the evolution of the conception of matter as something active and energetic.

As we have said, the conception of matter as something passive and dead was not pristine and aboriginal, and at what time it arose it is difficult to say. Probably the conception of inorganic matter as dead grew *pari passu* with the idea of a spiritual principle of life in organic moving matter; and this idea, again, must be almost as old as the observation that breath was necessary to maintain the activities of animals. The distinction between animate and inanimate matter must be at least as old as the conception of breath as spirit, or even as the raw material of spirit.

Even as the psycho-physiological doctrine of the manufacture of spirit from breath was developed by Plato and by the early physiologists, its corollary, dead matter, must have coincidently established its place in the creed of thinking men; but it must be recognised that there is nothing inevitable in the distinction between dead and living matter; and that, except for the doctrine of *soul*, there is really not much reason why a star should be considered deader than a tree. Passive and spoliated matter is, as Bacon said, "an invention of the human intellect." A star moves, a star shines: a star acts upon mind by its light. And, in early days, as we have before suggested, no clear distinction between dead and living was drawn; and the stars, and the seas, and all great aggregates of inorganic nature were considered as living bodies. Hence, no doubt, Tithonus, Ceres, Neptune, and all the mythical personages of the Greek and Latin religions. All along—even in the days of philosophy and physiology—there seems to have been some repugnance in the human mind to the doctrine of *dead* matter ; and all along, the mystery of matter, and especially its formative power, seems to have compelled many ancient thinkers to endow it or associate it with some sort of life, or soul, or sensibility.

Plato had a World-Soul to mould matter into archetypal forms. Anaxagoras had his *Nous.* Empedocles moved his atoms by Love and Hate ; and Lucretius, as we said, found it necessary to endow his atoms with a species of *free-will*, in order to account for their swerving motion, and with *concilium*, in order to account for their chemical affinities. Anaxagoras was cast into prison for asserting that the sun and moon were made of earth and stone ; and we find that even Aristotle considered the stars to be passionless beings, worthy of worship, and that Zeno and Strato deemed the world a living being.

Moreover, though the distinction between the living organic and the dead inorganic world, once drawn, became gradually, century by century, more hard and fast, and ultimately so firmly rooted as to be almost ineradicable, yet it never quite satisfied the human mind ; and at all times there was a counter-tendency to take a more imaginative view of so-called *dead* matter. Thus we find Moses Maemonides, as late as the twelfth century, writing as follows : "Know that this universe in its entirety is nothing else but one individual being ; that is to say, the outermost heavenly sphere, together with all included therein, is, as regards individuality, beyond all question, a single being, like Said and Omar. The variety of its substances —I mean the substances of that sphere and of all its component parts—is like the variety of the substances of a human being ; just as Said is one individual, consisting of various solid substances, such as flesh, bones, sinews, various humours, various spiritual elements."

The more men thought, the more men knew, the more mysterious appeared the properties of *dead* matter ; and the more philosophers and scientists strove to simplify and explain it, the more it seemed necessary to endow it again with life and motion, or to dematerialise it in some way. Look at the philosophical theories of the last few hundreds of years ! Have not they all recognised the dynamical character of matter ? Have not most of them attached to matter some psychical significance, or put matter under some psychical control, or found in matter some inner mystery beyond bodily vision ? Giordano Bruno, that brave monk who was burned alive in the sixteenth century, felt it necessary to conceive of matter as made of Monads—ultimate spherical points, regarded as possessing both spiritual and material characteristics. Van Helmont, in the next century, preached the same doctrine. Leibnitz, too, had his Monads of matter ; and though their activity was regulated by "pre-established harmony," yet he gave them "appetition," and talked of "petites perceptions," which combined and increased into "apperceptions," and thus gave a continuity to all souls, "from the soul of a pebble to that of an angel." Matter, to Leibnitz, was alive in every atom. "Whence it appears that in the smallest particle of matter there is a world of creatures, living beings, animals, entelechies, souls." "Each portion of matter may be conceived as a garden full of plants, and like a pond full of fishes." "Thus there is nothing sterile and nothing dead in the universe."

The exact significance of Leibnitz's terms "appetition" and "perception" it is not easy to discover. Professor Latta puts it thus : "As representative or symbolic of the whole, the part in Leibnitz's terminology has *Perception*, while in so far as in the part the potential whole tends to realise itself, the part is said to have Appetition." Whatever the exact meaning of the term, the fact remains that Leibnitz gave matter some rudiment of sensibility.

This tendency, however, to revert to a soul of matter, never overcame the other tendency to consider matter dead, and to explain it on mechanical principles; and the most important feature of Leibnitz's philosophy was its theory of the mechanical nature of physical processes—a theory that has become more and more dominant in science ever since. "Everything in nature," he said, "is effected mechanically." Let us give one instance of his mechanical theory. "Thus the organic body," he writes, "of each living being is a kind of divine machine, or natural automaton which infinitely surpasses all artificial automata. For a machine made by the skill of man is not a machine in each of its parts. For instance, the tooth of a brass wheel has parts and fragments, which for us are not artificial products, and which do not have the special characteristics of the machine, for they give no indication of the machine; whereas the machines of nature, namely, living bodies, are still machines in their smallest parts *ad infinitum*. It is this that constitutes the difference between nature and art, that is to say, between the divine art and ours."

A still greater apostle of the mechanic was Descartes. To him matter meant merely the extended in space; and from extension and motion he was prepared to construct the universe. "The nature," he says, "of matter or of body, considered generally, does not consist in a thing being hard, or heavy, or coloured, but only in its being extended in length, breadth, or depth." "All variations of matter, or all diversities of its forms, depend," he affirms, "on motion"; and "the matter which exists in the world is everywhere one and the same." Here we have the idea of motion in matter becoming prominent.

Coming on to the eighteenth century, we find Boscovitch bringing forward his famous theory that matter has no extension, and consists simply of mathematical points endowed with attractive and repulsive forces.

In the nineteenth century, Schopenhauer was representative of an idealistic counter-tendency, and analysed matter into *Will* and *Idea*, thus giving it a purely immaterial foundation. He expresses his theorem in various ways. "Pure matter . . . . is causality itself thought objectively, consequently in space, and therefore filling it. Accordingly, the whole being of matter consists in acting. Only thus does it occupy space and last in time. It is through and through pure causality." "For what is material is that which *acts* (the actual) in general, and regarded apart from the specific nature of its action. Hence also matter, merely as such, is not an object of perception, but only of thought, and thus is really an abstraction." "Matter is causality itself bound up with space and time, hence objectified, *i.e.* conceived as that which fills space." "Accordingly matter is that whereby the *will* which constitutes the inner nature of things becomes capable of being apprehended, perceptible, visible. In this sense, then, matter is simply the visibility of the will, or the bond between the world as will and the world as idea." "The essence of matter is acting; it is acting itself in the abstract; thus acting in general apart from all difference of the kind of action; it is through and through causality. On this account it is itself, as regards its existence, not subject to the law of causality, and thus has neither come into being nor passes away, for otherwise the law of causality would be applied to itself. Since, now, causality is known to us *a priori*, the conception of matter as the indestructible basis of all that exists can so far take its place in the knowledge we possess *a priori*, inasmuch as it is only the realisation of an *a priori* form of our knowledge. For as soon as we see anything that acts or is causally efficient, it presents itself *eo ipso* as material; and conversely, anything material presents itself as necessarily active or causally efficient. They are, in fact, interchangeable conceptions. Therefore the word actual is used as synonymous with material."

We quote Schopenhauer at such length because, as we shall see later, he reached a metaphysical conception of matter which is being daily corroborated by scientific discovery.

Towards the end of the nineteenth century the scientific view of matter became again less metaphysical and more atomical and mechanical. In 1874 Tyndall, in his famous Belfast Address, stated that he could discern "in matter which we, in our ignorance, and notwithstanding our professed reverence for its Creator, have hitherto covered with opprobrium, the promise and potency of every form and quality of life"; and it was almost universally held that all the manifestations of matter, including life, were merely the result of ordinary mechanical law. Matter was considered as a wonderful and potent piece of machinery. More and more, too, the idea gained strength that the qualities of matter were not due to fundamental differences in atoms, but to different motions of atoms really qualitatively alike. "Chemistry," wrote Professor Wundt in 1875, "still attributes the varying qualities of matter to an original difference in atomic quality. But now the whole tendency of atomic physics is to derive all the properties of matter from the movements of the atoms. The atoms themselves remain necessarily as elements lacking all qualities."

"It is conceivable," wrote Thomas Graham, "that the various kinds of matter now recognised as different elementary substances may possess one and the same ultimate or atomic molecule existing in different conditions of movement." "The tendency of physico-chemical science," said Huxley, "is clearly towards the reduction of the problem of the world of the infinitely little, as it already has reduced those of the infinitely great, to questions of mechanics."

Berthelot, the great French chemist, also desired "ramener la chimie tout entière . . . . aux même principes mécanique qui régissent déjà les diverse branches de la physique."

Mendeléef, in his *Principles of Chemistry*, asserts : "In the present condition of science, either the atomic or dynamical hypothesis is inevitably obliged to admit the existence of an invisible, imperceptible motion in matter, without which it is impossible to understand either light, heat, or gaseous pressure, or any of the mechanical, physical, or chemical phenomena. The ancients saw vital motion in animals only, but to us the smallest particle of matter endowed with *vis viva* or energy, in some degree or other, is incomprehensible without self-existent motion."

The mechanical theory, as it grew, naturally left little room for any psychical motive power, or for any metaphysical conception of matter ; but yet even the most advanced of the mechanic school could not quite explain things on purely mechanical principles, and were obliged betimes to admit "Mens agitat molem et magno se corpore miscet." Thus we find Haeckel writing, quite after the style of Anaximenes or Schopenhauer, "matter and æther are not dead, and moved only by extrinsic force, but they are endowed with sensation and will; they experience an inclination for condensation, and dislike for strain; they strive after the one, and struggle against the other." And W. K. Clifford, who had a theory that matter was caused by bends, twists, and wrinkles in space, and would cease to be if these were smoothed out, writes: "A moving molecule of inorganic matter does not possess mind or consciousness, but it possesses a small piece of mind-stuff. When molecules are so combined together as to form the film on the under side of a jellyfish, the elements of mind-stuff are so combined as to form the faint beginnings of Sentience." Even Tyndall declares, "The very molecules appear inspired with the desire for union and growth."

Thus, up to the time of the vacuum-tube, scientific opinion had drifted to and fro between the mechanic conception of matter as mass and motion, and the more or less metaphysical conception which found it necessary to endow matter with something like rudimentary mind, or to analyse it into a conceptual figment. In the main, however, opinion developed along mechanic, atomic lines; and in the following chapter we will deal with the nature of the atom as conceived by the modern atomic school.

CHAPTER IV

ATOMS AND MOLECULES

PERHAPS no other inchoate conception had ever such vitality as the atomic theory. Crude and empiric though it were in its first beginnings, it yet persisted through the centuries, waiting for Dalton to complete what Democritus had begun.

Dalton it was who, a hundred years ago, gave to the atom a crown of "indivisible supremacy." Dalton it was who made the atom a fact—a fact to be admitted, and a fact to be used. Dalton it was who brought down the atom from the clouds to the laboratory and the factory. The atoms of the Greeks, even the atoms of Lucretius, were vague and elusive; the atoms of Dalton were as undeniable as the bricks in a wall—were indeed "the foundation-stones of the universe." Higgins, Richter, and one or two others hinted the atom, but Dalton led it forth into the light of day; and since then "its properties and faculties, its attractions, repulsions, motions, and co-ordinations," have been the chief concern of science.

Dalton showed that the constant and definite proportions in which the elements combined could be best explained by assuming that the elements consisted of certain indivisible ultimate particles which had various definite weights ; and this hypothesis unified, and simplified, and correlated so many facts, that it has become the fundamental fulcrum of practical science, and the physicist may believe "that though he cannot handle or see them, the atoms and molecules are as real as the ice-crystals in the cirrus clouds that he cannot reach—as real as the unseen members of a meteoric swarm whose death-glow is lost in the sunshine, or which sweep past us unentangled in the night"—that the atoms are in fact "not merely helps to puzzled mathematicians, but physical realities."

The discoveries to which the atomic theory has led are legion ; and it has led not merely to discoveries, but to creations ; for by its means chemists have created substances which had never appeared in the universe before.

Let us try, now, to illustrate the modern conception of the atom. If we take a drop of mercury and divide and subdivide it indefinitely, we get mercury, and only mercury. If we had skill, we might divide it into a particle so small as to be quite invisible to the most potent microscope, yet it would still be a particle of mercury. Eventually, if we continued dividing, we would reach a particle which could be no further divided ; and even this final particle would still be mercury. Substances of this kind, which can be divided and divided without change of character down to a final indivisible, invisible particle (as contrasted with a substance like water or salt, which can be divided into different constituent substances), are known as *elements*, and the ultimate indivisible particles are known as *atoms*. Further, the atoms of different elements have been shown to have different weights, known as their *atomic* weights. The lightest atom is the atom of the gas, known as hydrogen, and with it the weight of all other atoms is compared. Thus the atom of sulphur, which is twelve times as heavy as an atom of hydrogen, is said to have an atomic weight of 12.

The process of reasoning by which we reach these facts need not be detailed here. Suffice it to say that the facts are fully established, and that there are known to be about eighty elements, each with atoms of a particular atomic weight.

Atoms have a strong aversion to single life ; in fact they never remain single, and are always found in twos or threes, or occasionally in hundreds or thousands, joined together in complexes known as *molecules*.

Now, what sort of thing are these atoms and molecules? How big are they? The smallest object that can be seen by the naked human eye is $\frac{1}{250}$ inch in diameter. A good microscope reveals objects $\frac{1}{50,000}$ inch in diameter; and the smallest object that, even theoretically, a perfect microscope could show must measure at least $\frac{1}{146,000}$ inch in diameter. Yet these magnitudes are colossal compared with the size of an atom, even compared with the size of the conglomerations of atoms, known as *molecules*.

The average diameter of the molecule of an element was estimated by the late Lord Kelvin and by Professor O. E. Meyer as about two-tenths of a micro-micron, *i.e.* about $\frac{1}{125,000,000}$ of an inch.

Professor J. J. Thomson has calculated that in a cubic centimetre of gas at atmospheric pressure (*i.e.* in as much gas as might be held in a little box $\frac{2}{5}$ inch square) there are about 20,000000,000000,000000 molecules; and, of course, in the same volume of a liquid or solid, the molecules, being more closely packed, are even more numerous. If closely packed, about 2,000000,000000,000000,000000 could be contained in a little box an inch square. Even such a minute object as a blood corpuscle contains, according to Wismann, about 3,625,000,000 large molecules ; and it is calculated that no living germ can contain fewer than 100,000,000 large molecules. So light are molecules, too, that it requires 1,000000,000000,000000 molecules to affect a delicate balance.

Figures such as these convey very little to the mind, and efforts are often made to express the multitude and minimissitude of molecules in some comprehensible way. Thus Sir Oliver Lodge explains that "a portion of substance consisting of a billion (a million million) atoms is only barely visible with the highest power of a microscope ; and a speck or granule, in order to be visible to the naked eye, like a grain of "lycopodium-dust, must be a million times bigger still." Kelvin, again, tries to give an idea of the smallness of the atom by an estimate that if a drop of water were magnified up to the size of the earth, the atoms would be larger than pellets of shot, and smaller than cricket-balls. Others have pointed out that we know dimensions small enough to be comparable to molecules—that the thinnest part of a soap-bubble is only about twenty or thirty molecules thick, and that gold-leaf and films of oil may be prepared only about seven or even fewer molecules thick. It might also be safely asserted that a molecule on the point of a needle would be like a midge on the summit of the Matterhorn; and that the molecules in a tear would exceed the population of the world.

All these illustrations are interesting; but the most imaginative picture of the smallness of molecules we know is that given by Sir William Crookes in his essay on *Radiant Matter.* He points out that a vacuum bulb (the glass bulb used in the production of X-rays) holds a quadrillion molecules, and that even when apparently exhausted it still contains a trillion. What trillion and quadrillion mean he explains: "To suggest some idea of this vast number, I take the exhausted bulb and perforate it by a spark from the induction coil. The spark produces a hole of microscopic fineness, yet sufficient to allow molecules to penetrate and to destroy the vacuum. The inrush of air impinges against the vanes and sets them rotating after the manner of a windmill. Let us suppose the molecules to be of such a size that at every second of time a hundred millions could enter. How long, think you, would it take for this small vessel to get full of air? An hour? A day? A year? A century? Nay, almost an eternity! A time so enormous that imagination itself cannot grasp the reality. Supposing this glass bulb, indued with indestructibility, had been pierced at the birth of the solar system ; supposing it to have been present when the earth was without form and void ; supposing it to have borne witness to all the stupendous changes during the full cycles of geologic time, to have seen the first living creature appear and the last man disappear ; supposing it to survive until the fulfilment of the mathematician's prediction that the sun, the source of energy, four million centuries from its formation, will ultimately become a burnt-out cinder—supposing all this, at the rate of filling I have described—one hundred million molecules a second—this little bulb even then would scarcely have admitted its full quadrillion of molecules.

"And what will you say if I tell you that all these molecules, this quadrillion of molecules, will enter through the microscopic hole before you leave this room. The hole being unaltered in size, the number of molecules undiminished, this apparent paradox can only be explained by again supposing the size of the molecules to be diminished almost infinitely—so that instead of entering at the rate of one hundred million every second, they troop in at the rate of something like three hundred trillions a second."

Since matter is made up of such millions of minute particles, its atoms, when disparted, are capable of populating comparatively enormous areas. Thus, as Carl Synder (*New Conceptions of Science*) points out: "a single grain of indigo, the weight, say, of a small pin, gives a distinct coloration to a ton of water. In order to produce this reaction, the indigo must have been divided up into enough parts to be present in large numbers in every drop of water; it must have been broken up into millions and millions of parts."

Even more remarkable is the ubiquitous emigrations of the molecules of the substance known as fluorescein. Fluorescein added to water causes the water to fluoresce, and a single grain will cause fluorescence in a hundred tons of water.

Now, these minute atoms and molecules are not passive, inert things; they are in constant movement. The molecules of the air of the room in which I sit are darting hither and thither with incredible speed. The nitrogen molecules are dashing about at a rate of nearly a quarter a mile a second, the oxygen molecules are rather slower, and the heavier carbonic acid molecules are slower still. If hydrogen be present, its molecules outstrip all the rest, for it darts at the rate of more than a mile a second. It is a case, however, of the more haste the less speed, for the molecules constantly collide, so constantly indeed that a molecule of hydrogen can proceed only $\frac{1}{250.000}$ of an inch without collision, *i.e.* collides about 16,000,000,000 times a second; while if it be heated, its progress is still more rapid and more interrupted. Some of the lighter gases of the air fly with such velocity that they succeed in escaping from the atmosphere altogether. And the molecules of gases not only constantly fly about, they are also in a state of constant vibration ; and it has been calculated that a molecule of hydrogen vibrates four hundred and fifty million million times a second, representing a distance in to-and-fro movement of about one mile.

We have instanced the molecules of air, which is of course a gas, but the molecules of liquids and solids are equally restless. The paper on which I write is really seething like a sea. Carl Synder says that "a drop of water would resemble a thick swarm of bees pounding against each other in their flight with tremendous force. Even the crystalline diamond would seem like pyramids of billiard-balls, hung wide apart by invisible springs, and gyrating intensely." "We ought," says Le Bon, "to picture to ourselves any body whatever, such as a block of steel or a rigid fragment of rock, as being composed of isolated elements in motion, but never in contact."

Clifford gives a very picturesque and vivid account of the varied behaviour of molecules in gases, liquids, and solids. In the case of gases, he says the molecules "do not fly far in one direction, but any particular molecule, after going over an incredibly short distance—the measure of which has been made—meets another, not exactly plump, but a little on one side, so that they behave to one another somewhat in the same way as two people do who are dancing Sir Roger de Coverley : they join hands, swing round, and then fly away in different directions." "In the case of a liquid, it is believed that the state of things is quite different. We said that in the gas the molecules are moved in straight lines, and that it is only during a small portion of their movement that they are deflected by the other molecules ; but in a liquid we may say that the molecules go about as if they were dancing the grand chain in the Lancers. Every molecule, after parting company with one, finds another, and so is constantly going about in a curved path, and never sent quite clear away from the sphere of action of the surrounding molecules. In the case of a solid, quite a different thing takes place. In a solid, every molecule has a place which it keeps ; that is to say, it is not at rest any more than a molecule of a liquid or a gas, but it has a certain mean position which it is always vibrating about and keeping fairly near to, and it is kept from losing that position by the action of the surrounding molecules."

Dalton's definition of a solid body is of interest. He defines it thus: "A solid body is one the particles of which are in a state of equilibrium betwixt two great powers, attraction and repulsion, but in such a manner that no change can be made in their distances without considerable force. If an approximation of the particles is attempted, then the heat resists it; if a separation, then the attraction resists it."

It is a little difficult to believe that the molecules of hard substances are in constant motion, but even in the hardest substances the motion takes place. Sir Roberts Austen placed pieces of lead and gold in contact at atmospheric temperatures, and found after four years that the gold had travelled into the lead to such an extent that appreciable quantities of the gold were detected at more than five millimetres from the common surface.

If the molecules are far apart we have a gas; if nearer together, a liquid; if still nearer together, a solid. By means of heat we can cause a separation of molecules, and thus can convert a solid into a liquid, a liquid into a gas. By means of cold, again, we can convert a gas into a liquid, a liquid into a solid; and the contraction of the molecules may be assisted by pressure. By means of combined cold and pressure, Sir James Dewar succeeded in crushing together the molecules of air into a liquid —liquid air. By means of heating water we obtain steam; by cooling steam we obtain water.

The difference between the molecular distances in the case of a liquid and gas may be very great; thus water vapour occupies hundreds of times the space occupied by the same weight of water. It is the violent separation of the water molecules in steam that makes steam such a tremendous energy. The infinitesimal water molecules charging about, hustling and colliding, trying to get away from each other, lift a colossal piston; then, catching a chill, lose all energy, and fall in a heap like dew. It is strange to think how molecules of water, scourged apart by heat, carry men over continents and seas; and how molecules of petrol, driven apart by a tiny spark, whizz the throbbing motor car along the dusty road. It is strange also to think how molecules of dynamite, separated or broken, may leap apart with force sufficient to destroy a city, and how a few grains of the molecules of the active substance of tetanus might kill every man in London. Roscoe states that if we could convert the whole of the heat which can be obtained from a pound of coal into mechanical energy it would suffice to pitch the coal two thousand miles high. Infinitesimally small as atoms and molecules are, they yet are capable of tremendous violence and have tremendous destructive force—a force, it must be remembered, which is always there, though not in disruptive form.

But the most wonderful thing about atoms and molecules is not their power of destroying, but their power of creating. They themselves choose their partners, and their partnerships have made the world as we know it.

With gross matter man can work miracles. He can mix colours on a palette and spread them on canvas and make a Sistine Madonna. He can put blocks of marble together and make a Milan Cathedral. Of the *macroscopic* he is undisputed lord.

But the *microscopic* elements of matter are only partially in the control of man: they create without his *fiat*, and their simplest improvisations far surpass his most elaborate compositions. Where is the loom that can weave a lily-leaf? "Consider the lilies of the field how they grow, they toil not, neither do they spin, and yet I say unto you that even Solomon in all his glory was not arrayed like one of these."

Even the most materialistic and unemotional scientist talks about atomic *affinities*. And no wonder! The atoms and molecules, by their aggregation and arrangement, by their weddings and partnerships, make everything. We put a packet of molecules, known as a seed, into the ground, and they attract other molecules from the air and soil—molecules of carbonic acid, and lime, and potassium, and so on, and lo! a lily, or a pine tree. Without mistake they carry out their complicated architecture, though there is more machinery in each molecular brick than in a chronometer, and more molecular bricks in each leaflet than in a cathedral.

All living things are built of cells, and cells have a particularly complicated molecular structure. It has been computed that a liver-cell contains 300,000000,000000 atoms, of varying size and quality, grouped together in almost infinite variety, into 64,000,000,000 molecules. There is more going on there than in the busiest factory in the world. It has also been computed that the head of a sperm-cell $\frac{1}{20}$ of a millimetre in diameter contains 2,500,000,000 molecules, each composed of several atoms; that in a germ-cell there are 1,728,000000,000000 molecules, composed of 8,640,000,000000,000000 atoms. And all these molecules are marrying, and dancing, and vibrating, and building up some living thing! It is prodigious!

It must be noted that molecules move not only in space, but that they also expand and contract like a beating heart. It is this throbbing or vibrating that causes light. It is the throbbing of the hot molecules in the sun that causes the ether waves which we know as light and heat; and we get some idea of the rapidity of the throbbing when we remember that the ether-ripples beat on the eye at the rate of from 450 to 750 million millions per second.

A very interesting fact may be mentioned in connection with this. It has been found that molecules of different elements throb in different ways, and thus produce different light waves, which, when analysed by a spectroscope (an instrument that spreads out and separates waves of light on the principle of a prism), give definite characteristic colours.

Each substance has its own "spectrum," or alternations of light and shade; and we can discover what any substance is simply by heating it so as to agitate its molecules, and then analysing, by a spectroscope, the ripples of light caused by the throbbing molecules. In this way we may be said to be able to tell any substance by *feeling its pulse*, or by listening to its heart, and the spectroscope may be compared to a stethoscope. But a spectroscope is far more wonderful than a stethoscope; it is more delicate, and it reaches farther. Sir Henry Roscoe, in his *Elementary Chemistry*, states that a portion of sodium salt less than $\frac{1}{180,000,000}$ part of a grain, and that a portion of lithium $\frac{1}{6,000,000}$ part of a grain, can be detected. Not only so, but it matters not at all how far off the throbbing heart of the molecule may be. However far off, the spectroscope can record and read and interpret the ether waves produced by the throbbing molecules. The molecules—the tiny fierce molecules—throbbing in the sun 92,000,000 of miles away, have been made to write their name in ripples; and we know now that in the sun are hydrogen, sodium, iron, copper, magnesium, zinc, calcium, and about thirty other elements. Stranger still, the spectroscope discovered in the sun an element then unknown on earth, which the discoverers called *helium*; and some years later this very element was discovered in a mineral called clevite; and, a few years later still, it was found (as we shall relate in another chapter) in very interesting association with the new metal radium. And we can find out not only the constitution of our own sun, but the constitution of alien suns millions of millions of miles away—all told by the throbbing molecules! Nor is this all; it is possible by the same means, through consideration of certain details, to measure the velocity and masses of double stars. Well may Sir Robert Ball ask: "Could anything show more wonderfully how the different branches of science have become interwoven than the fact, that by looking at a beam of light through a prism we have been able to *weigh* the star from which the light has come?"

Some people find it difficult to understand how matter can be particulate and yet continuous—how it can be in motion and yet appear at rest. There is no real difficulty in the conception. Each molecule moves so fast that it is a host in itself and seems ubiquitous. We have a recollection of a small army that put a large army to flight by scattering itself, and by making such a tumult that it seemed a mighty host. And that is what happens in the case of the molecules; their activity is so intense that they seem to be everywhere at once, and give the impression of solidity and stolidity. In just the same way, the air driven before an avalanche may wipe a village away as we might blow a fly off our hand. In just the same way, falling stars are smashed on the atmosphere as on an avil. In just the same way, a column of water "only 2 centimetres in diameter, falling through a tube of the height of 500 metres, cannot be broken into by a violent blow from a sabre. The arm is stopped as if by a wall when it arrives at the surface of the liquid. Professor Bernard Brunhes, who witnessed this experiment, is persuaded that if the velocity of the liquid column were sufficient, a cannon-ball would not go through it. A layer of water a few centimetres thick, animated by a sufficient velocity, would be as impenetrable to shells as the steel plates of an ironclad." On the same principle, a piece of tallow candle can be shot through an inch plank, and a rapidly revolving soft disc of iron will cut through the hardest steel. On the same principle, too, if soft leaf be laid on a piece of iron, if then gun-cotton be placed upon the leaf and exploded, an impress of the leaf will be left on the iron.

Atoms and molecules have been weighed ; they have been proved to dance, they have been persuaded to wed, and yet their shape is still unknown. The atoms were pictured by Democritus as various in shape, with hooks and handles ; they were pictured by Descartes as tourbillons, and by Kelvin as vortices in the ether ; but no eye has ever seen atoms, and even theory cannot quite depict them.

CHAPTER V

ELECTRONS

From earliest times a belief in the indestructibility and indivisibility of the atom was a cardinal article in the creed of the atomic school. The atoms of Democritus were indestructible and indivisible. Lucretius held that "the principles of matter, the elements of the great whole, are solid and eternal: no foreign action can change them. The atom is the smallest body in nature . . . . it represents the last term of the division." In more modern times the same doctrine prevailed. Newton wrote: "It seems probable to me that God in the beginning formed matter in solid, massy, hard, impenetrable particles, of such sizes and figures, and with such other properties, and in such proportions to space, as most conduced to the end for which he formed them; and that these primitive particles, being solids, are incomparably harder than any porous bodies compounded of them, even so very hard as never to wear or to break in pieces, no ordinary power being able to divide what God himself made in the first creation." Sir John Herschell was of the same opinion, and stated that the atoms bore "the stamp of the manufactured article." Dalton held that "we might as well attempt to introduce a new element into the solar system as to create or destroy a particle of hydrogen." More emphatic still, Clerk-Maxwell, in a lecture at Bradford in 1873, declared: "Natural causes, as we know, are at work which tend to modify, if they do not at length destroy, all the arrangements and dimensions of the earth and the whole solar system. But though in the course of ages catastrophes have occurred and may yet occur in the heavens, though ancient systems may be dissolved, and new systems evolved out of their ruins, the molecules out of which these systems are built—the foundation-stones of the material universe—remain unbroken and unworn."

That was the creed of the atomists, and it grew stronger as chemical knowledge increased.

No wonder the belief in the "indivisible supremacy" of the atoms was so firmly held. Chemists crushed substances, dissolved them in acids, changed them from gas to liquid, from liquid to solid, forced them into unnatural combinations, tore them asunder from each other with explosive violence, and still the atoms remained intact and undamaged. When, in the combination of the two gases hydrogen and oxygen, the fluid water is formed, it almost seems that the atoms of the gases are lost and gone for ever; but by a simple process the water can be decomposed, and the atoms come forth again quite unchanged and as dry as a bone. In a clear lotion of perchloride of mercury, the silvery mercury atoms seem completely abolished, but they are in the clear fluid all the same, giving it weight and certain mercurial characters; and by suitable means they can easily be produced again. There does not seem to be much black carbon in the bottle of aerated water, and yet it can be demonstrated by ordinary chemical analysis.

Everything, in fact, seemed to prove the indestructibility of Dalton's atoms, and of material substance. "Do with it what we please," wrote Professors Stewart and Tait, "we cannot make our senses indicate to us an increase or diminution in a given quantity of what we call matter. We find it so far amenable to our control that we can alter its arrangement, form, density, state of aggregation, temperature, etc.; nay, by so approximating it to other matter as to produce a chemical combination, we may entirely transform its appearance and properties—*all but one*, its mass or quantity is completely beyond our control. Measure it by what process we please, by the 'muscular sense,' by weight, anyhow, there it is, altogether independent of us, laughing our efforts to scorn."

It must be noted that there were really originally two atomic creeds. Both schools believed in indestructible atoms, but one believed in atoms *all alike*, and the other believed in a variety of atoms.

The latter school, supported by the apparently invulnerable evidence of Dalton, eventually won the day; but nevertheless the Daltonian conclusions did not satisfy all thinkers. Side by side with the unwavering faith of such scientists as Clerk-Maxwell there was a strong spirit of scepticism. The idea of eighty or so elemental substances was repugnant to a certain intuition in the human mind which demands a single primæval "urstoff." The instinct to unify—to trace back heterogeneity to homogeneity, to be economical with causes—is one of the strongest of intellectual instincts: we see it active from Democritus to Kelvin. Even as the intellect refuses to believe in numerous gods, so it refuses to believe in primary complexity, and affirms that the complex must originally have been simple. *This*, most of the old Greeks realised. The atoms of Leucippus, and Democritus, and Lucretius were all of the same material—"solida pollentia simplicitate"—and differed merely in their architectural features or kinetic properties. The *Water* of Thales, the Infinite of Anaximander, the Fire of Heraclitus were all inspired by this instinctive craving to trace diversity back to unity. Other schools, too, besides the atomist schools, were led by the same instinct to premise a *materia prima*—a simple first substance, from which all other substances were derived. Aristotle had his πρωτη ὕλή (raw stuff) and his ἐσχάτη ὕλη (finished stuff). Diogenes of Apollonia had a surprisingly clear grasp of a *materia prima*. His opinions we have already quoted. Among the philosophers of the Middle Ages the doctrine still survived. Moses Maimonides (1135), the great Jewish philosopher, gives the views of the Jewish school of philosophy as follows: "Also the body of the heaven, the body of the angels, the body of the Divine Throne—such as it is assumed to be—the body of anything creeping on the earth, and the body of any plant, have one and the same substance; they only differ in the peculiarity of the accidents, and in nothing else; the substance of all things is made up of equal atoms." Among the alchemists the same idea of an urstoff was ever dominant. Though they still clung to the Earth, Fire, Air, and Water of Empedocles, yet they believed that these elements had a common ancestor—a *materia prima*, almost abstract in its character—and that substances could be transmuted. Albertus Magnus taught that the birth of one element was in some way the result of the corruption and death of another. The great Roger Bacon taught that there was an immaterial essence of matter or "yle" (a word obviously derived from Aristotle's ὕλη). In his *De Arte Chymiae* he lays down the law as follows: "Elementa sunt quatuor, ignis, aqua, aer, terra, modi id est proprietates, sunt quatuor, calor frigiditas, siccitas et humiditas, at yle est res in qua non est calor nec siccitas, nec humiditas et non est corpus. Et elementa sunt facta de yle et unumquodque elementorum convertitur in naturam alterius elementi et omnis res in quamlibet."

Boyle, in his *Sceptical Chymist*, shows that he had a very shrewd conception of a *prima materia*. "Now," he writes, "if it be true, as 'tis probable, that compound bodies differ from one another in nothing but various textures, resulting from the magnitude, shape, motion, and arrangement of their small parts, it will not be irrational to conceive that one and the same particle of universal matter may by various alterations and contextures be brought to deserve the name sometimes of a sulphureous (gaseous), a terrestrial, or aqueous body." Geber taught that nature could transmute metals, although man could not. Descartes, though not an atomist, declared that "the matter which exists in the world is everywhere one and the same"—"materia itaque in toto universo una et eadem existit." "I do not believe," affirmed Galileo, "that anything else is required than magnitudes, shapes, quantities, and slow movements or swift to produce in us tastes, smells, sounds." Huyghens supposed bodies formed of homogeneous matter in which no qualities were distinguished, but only different magnitudes, shapes, and movements.

Perhaps the most prescient of all was the great chemist Faraday, who, in 1816, when only twenty-four years old, wrote as follows: "I may now notice a curious progression in physical properties accompanying changes of form, and which is perhaps sufficient to induce in the inventive and sanguine philosopher a considerable degree of belief in the association of the radiant form with the others in the set of changes I have mentioned. As we ascend from the solid to the fluid and gaseous state, physical properties diminish in number and variety, each state losing some of those which belonged to the preceding state. When solids are converted into fluids, all the variations of hardness and softness are necessarily lost. Crystalline and other shapes are destroyed. Opacity and colour frequently give way to a colourless transparency, and a general mobility of particles is conferred.

"Passing onward to the gaseous state, still more of the evident characters of bodies are annihilated. The immense differences in their weight almost disappear; the remains of difference in colour that were left are lost. Transparency becomes universal, and they are all elastic. They now form but one set of substances, and the varieties of density, hardness, opacity, colour, elasticity, and form, which render the number of solids and fluids almost indefinite, are now supplied by a few slight variations in weight and some unimportant shades of colour.

"To those, therefore, who admit the radiant form of matter, no difficulty exists in the simplicity of the properties it possesses, but rather an argument in their favour. Those persons show you a regular resignation of properties in the matter we can appreciate as the matter ascends in the scale of form, and they would be surprised if that effect were to cease at the gaseous state. They point out the greater exertions which Nature makes at each step of the change, and think that, consistently, it ought to be greatest in the passage from the gaseous to the radiant form.

"If we conceive a change as far beyond vaporisation as that is above fluidity, and then take into account also the proportional increased extent of alteration as the changes rise, we shall perhaps, if we form any conception at all, not fall far short of Radiant Matter ; and as in the last conversion many qualities were lost, so here also many more would disappear."

This seems to me one of the most wonderful forecasts ever made, and within fifty years proof of its correctness began to appear.

In 1865 Plücker and Hittorf discovered that certain elementary substances, when subjected to great heat, furnished spectra simpler than and quite unlike the spectra obtained at ordinary temperatures ; and it was soon found, moreover, that similar abnormal spectra were furnished by elements in the chromosphere of the sun and in the stars. Now, since the spectrum of an element certainly depends on its fundamental constitution, it follows that a radical change in the spectrum of an element certainly indicates a radical change in the element itself ; and thus a fair presumption was established that, under certain conditions, matter may undergo a constitutional alteration, and pass from the gaseous into a more primitive or radiant state. Prout and Lockyer maintained that this more primitive matter consisted of *dissociated atoms*, and was the *materia prima* so long sought.

In 1872 Herbert Spencer affirmed: "the properties of the different elements result from differences of arrangement, arising by the compounding and recompounding of ultimate homogeneous units."

Still, science as a whole suspended judgment; and the state of scientific opinion in 1873 may be well shown by a quotation from Professor F. W. Clarke of Cincinnati, who in that year wrote as follows: "We do not know but that the evolution of one element from another may be possible, under circumstances over which we have as yet no mastery; indeed, such a view would have many points of probability about it. Although unsupported, it is quite strongly suggested by evidence. The demonstrated unity of force leads us, by analogy, to expect a similar unity of matter; and the many strange and hitherto unexplained relations between the elements tend to encourage our expectations. These elements which seem to-day so diverse in character, may be, after all, one in essence. This idea is philosophically strong, but waits for experimental evidence to support it. At present it can neither be discarded as false nor accepted as true. But what an addition the proof of such a doctrine would bring to the philosophy of evolution! . . . It is plain that the nebular hypothesis would be doubled in importance and our views of the universe greatly expanded if it could be shown that an evolution of complex from simple forms of matter accompanied the development of planets from the nebulæ. Evolution could look for no grander triumph."

At that point, indeed, the doctrine of unity of matter could neither be discarded as false nor accepted as true.

A few years later, however, Sir William Crookes brought forward convincing evidence of Radiant Matter—of matter neither solid, nor liquid, nor gaseous, but apparently in the fourth state which Faraday had foreseen. This was the first step towards the demonstration of a *materia prima*.

It came about thus. Hittorf had been investigating the result of passing an electric current through a glass bulb almost exhausted of air, and Sir William Crookes continued the same experiments. We have already explained that the molecules of the air dart about with tremendous rapidity; but that, owing to collisions with each other—thousands of millions in a second—their progress is very interrupted. When, however, a bulb is exhausted of air, the remaining particles have much more room to rush about, and do not jostle each other so much.

By ingenious technique, Sir William Crookes succeeded in producing a more complete vacuum than had ever been produced before; and on studying the behaviour of the flying particles in the vacuum, he came to the conclusion that they had properties not possessed by ordinary matter. Here are his words: "In these highly exhausted vessels, the molecules of the gaseous residue are able to dart across the tube with comparatively few collisions, and, radiating from the pole with enormous velocity, they assume properties so novel and so characteristic as to entirely justify the application of the term borrowed from Faraday, that of *Radiant Matter*. . . ." "In studying this Fourth state of Matter, we seem at length to have within our grasp, and obedient to our control, the little indivisible particles which with good warrant are supposed to constitute the physical basis of the universe. We have seen that in some of its properties Radiant Matter is as material as this table, whilst in other properties it almost assumes the character of Radiant Energy. We have actually touched the borderland where Matter and Force seem to merge into one another, the shadowy realm between the known and the unknown, which for me has always had peculiar temptations."

Lenard, J. J. Thomson, and others made a special study of the flying particles, and their special characteristics are now well established. They are deflected in a magnetic field; they can penetrate thin plates of metal; they can affect photographic plates ; they can discharge insulated electrical bodies ; they have a definite momentum, and they carry a fixed electric charge. Finally, they are exactly *the same in size and character whatever the nature of the gas in the vacuum and whatever the metal used for the electrodes*, and *they have an apparent mass of only about* $\frac{1}{1000}$ *of the hydrogen atom.* Since the particles are projected from the negative electrode or "cathode," they are often called "cathode" rays.

In 1895 Röntgen's discovery of the X-rays attracted still more attention to the phenomena of vacuum tubes ; and in 1896 the famous French savant, Henri Becquerel, undertook a series of experiments with the object of investigating the relationship between the phosphorescence of vacuum tubes under the influence of "cathode" rays, and the phosphorescence of various substances under the influence of light or pressure.

In the course of his experiments Becquerel made the striking discovery that salts of uranium have the power of *spontaneously* emitting invisible radiations, which affect photographic paper, which pass through metals and other substances opaque to ordinary light, and which discharge electrified bodies. Obviously these radiations were closely akin to the cathode rays produced in a vacuum tube.

In 1898 Monsieur and Madame Curie noticed that pitch-blende, an ore of uranium, had more power of emitting radiations—more *radio-activity*, as it is called—than had the salts of uranium ; and after infinite pains they succeeded in obtaining from the ore the substance named *radium*, which is about two million times as radio-active as uranium. The radio-activity of radium was carefully and ingeniously investigated, and it was found that the radiations consisted of rays of three kinds : (1) Alpha (α) rays, so-called, consisting of particles about twice the size of a hydrogen atom, charged with positive electricity, and projected at the rate of about 20,000 miles a second ; (2) Beta (β) rays, so-called, identical with the "cathode" rays of a vacuum tube, and consisting of particles about $\frac{1}{1000}$ the size of a hydrogen atom, charged with negative electricity, and projected at the rate of 75,000 to 150,000 miles a second ; (3) Gama (γ) rays, so-called, which resemble the X-rays used in X-ray photography, and which have the power of penetrating matter generally considered opaque, *e.g.* lead, iron.

Besides uranium and radium, three other markedly radio-active substances, thorium, polonium, and actinium, have been discovered.

Thus, within a hundred years of Faraday's great prophecy, the existence of radiant matter, consisting of particles much finer than the smallest atom, was proved.

It seems also to be proved that the radiations are due to the breaking up of atoms, and that radium and other radio-active substances are undergoing spontaneous decomposition. It seems also possible that *all* matter can be broken up into identical particles by means of heat, electricity, sunlight, etc., and that all over the universe the atoms are slowly decaying.

It is now commonly regarded as an established fact that atoms are made up of infinitesimally small corpuscles, and that, no matter what the kind of atom, the particles are always exactly the same in material and size. A diamond, a daisy, a star, a man are all made of the same *urstoff.*

"All things the world that fill,
Of but one stuff are spun."

In the ancient, wild, hot, fire-mist days, all the primordial particles were free: it was a case of "liberty, equality, fraternity"—the first, last, and only case; but as the fire-mist cooled, the corpuscles felt that it was not good to be alone, and so they grouped themselves in the little systems known as atoms, and these, again, formed associations called molecules, and the molecules, again, formed gases, and liquids, and solids—the great corporations we know as suns and stars. In the hottest stars, such as *Zeta Puppis*, *Gamma Argus*, *Algol Sirius*, *Arcturus*, *Epsilon Orionis*, certain atoms are seen by the spectroscope to be even now in a dissociated, dissolute condition; and the cooler the stars the more numerous the elements.

It is very difficult to believe that a thin, light gas like hydrogen, and a heavy liquid metal like mercury, and a solid substance like a diamond, are all made of precisely the same primordial substance, but so it is. The particles are probably precisely the same in every instance; and the difference in the atom is merely a question of the number, arrangement, and movement of the corpuscles. After all, there is nothing more incredible in this than in many miracles we see performed every day. We see two gases, hydrogen and oxygen, made into water; we see solid, heavy metals, like lead, and silver, and gold, vanish into clear liquid.

An atom, then, as now conceived, is not a solid, stolid thing—not merely a conglomeration of dead dust—not merely a dust-heap. The atom of hydrogen contains a thousand "β" corpuscles: the atom of mercury a hundred thousand; and every one of the corpuscles is "intensely, wondrously alive," and gyrates and rotates like a dancing dervish. But "dancing dervish" is a simile unworthy of the occasion. One of the ancient philosophers considered man an epitome of the universe, and talked of him as a microcosm; and the atom is in very truth a microcosm, or at least a miniature solar system. Probably in the centre of the atom there is a corpuscle like a sun, and round this central sun the other corpuscles whirl. The velocity with which the corpuscles gyrate and rotate is enormous, and the power developed correspondingly colossal. When the forces within the atom are in equilibrium they are known only as apparently passive matter; but when this equilibrium is disturbed, and when the corpuscles become dissociated, as occurs in radium, then the intra-atomic energy becomes more apparent.

The case of radium is especially interesting. It has a large, and therefore presumably unstable, atom; and the α particles it emits seem identical with helium (an element which was discovered in the sun before it was discovered upon earth), while the residue of the radium atom left after the emission of sundry α, β, and γ rays seems identical with lead. Thus helium and lead are products of the decomposition of a larger atom, the atom of radium; and thus, again, we have a verification of the dream of the alchemists with regard to the transmutation of elements, and a verification, too, of the doctrine of Albertus Magnus, that the birth of one element is in some way due to the corruption and death of another. Could anything be more amazing? Not only the disruption of an atom, but its transformation into other atoms !

It may be remarked that various unstable residues are formed before the stable residue, lead ; and that the breaking down of the radium is so slow that it takes more than fourteen hundred years to convert half of any given quantity of radium into lead.

Another very remarkable fact has been recently discovered with regard to the transmutation of radium. It has been found that when the radium emanation (one of the intermediate products of radium) is dissolved in water, not helium, but another gas, *neon*, is formed ; and that when the emanation is dissolved in a copper solution, still a third gas, *argon*, is formed.

It would seem, accordingly, that not only are atoms evolved, but that various atoms are formed, of which only the fittest survive, and that the atom evolved depends to some extent on environment.

CHAPTER VI

MORE ABOUT ELECTRONS

Let us now consider in more detail the character and behaviour of the β particles (commonly called "electrons" or "corpuscles"), which seem to be the final product of the disruption of atoms, and the *prima materia* of matter.

Whether they are found in a vacuum tube, whether emitted from radium, whether ejected by glowing carbon—whatever, in fact, their origin—the electrons always carry the same charge of negative electricity; they always fly with incredible speed; and they have always an apparent mass of about $\frac{1}{1000}$ of a hydrogen atom. We have already shown how infinitesmal atoms are, yet a corpuscle compared to an atom is as a comma to a cathedral.

The relationship between corpuscle and atom has been illustrated thus: "If we imagine an ordinary church to be an atom of hydrogen, the corpuscles constituting it will be represented by about one thousand grains of sand, each of the size of a period, dashing in all directions inside, and rotating with inconceivable velocity, and filling the whole interior of the church with their tumultuous motion." Again: "If an electron be represented by a sphere an inch in diameter, the diameter of an atom of matter on the same scale is a mile and a half. . . ." "An atom is not a large thing; but if it is composed of electrons, the spaces between them are enormous compared with their size—as great relatively as are the spaces between the planets in the solar system."

According to this new conception of the atom, it is a miniature solar system, with a certain number of negative corpuscles rotating and gyrating like planets round a nucleus, or within a sphere of positive electricity. These negative corpuscles move in definite orbits round the central nucleus or within the sphere, and also spin with tremendous velocity round their own axes; and the stability of the atom depends on an equilibrium of forces. Each element has an atom with a particular number of corpuscles proceeding in definite orbits.

The hydrogen atom is generally supposed to have a thousand corpuscles, and some of the larger atoms may have two hundred thousand or more. "We ought therefore," writes Le Bon, "to picture to ourselves any body whatever, such as a block of steel or a rigid fragment of rock, as being composed of isolated elements in motion, but never in contact. The atoms, of which each molecule is formed, themselves contain thousands of elements, which describe, round one or more centres, curves as regular as those of celestial bodies."

Lord Kelvin supposed a radio-active atom might be composed of "concentric layers of positive and negative electricity, disposed in such a way that its external action is nil, and that nevertheless the force emanated from the centre may be repellent for certain values when the electron is within it."

Sir Oliver Lodge says: "The electron has been shown to possess in kind, though not in degree, the fundamental properties of the original atom of which it had formed a part; and it becomes a reasonable hypothesis to surmise that the whole of the atom may be built up of positive and negative electrons interleaved together, and of nothing else, an active or charged ion having one electron in excess or defect, but the neutral atom having an exact number of pairs."

The atomic sidereal systems are more or less stable; the larger systems, such as radium, thorium, polonium, which contain thousands of corpuscles, are naturally less stable than the smaller systems with fewer corpuscles. Radium, indeed, has been aptly compared by Sir Oliver Lodge to a contracting nebula. "Roughly," he says, "the process may be likened in some respects to the condensation and contraction of a nebula. The particles constituting a whirling nebula fall together until the centrifugal force of the peripheral portions exceeds the gravitative pull of the central mass, and then they are shrunk off and left behind, afterwards agglomerating into a planet, while the residue goes on shrinking and evolving fresh bodies and generating heat. A nebula is not hot, but it has an immense store of potential energy, some of which it can turn into heat, and so form a hot central nucleus or sun. A radium atom is not hot; but it, too, has a great store of potential energy, immense in proportion to its mass, for it is controlled by electrical, not by gravitational forces; and just as the falling together of the solar material generates heats, so that a shrinkage of a few yards per century can account for all its tremendous emission, so it has been calculated that the collapsing of the electrical constituents of a radium atom by so little as one per cent. of their distance apart can supply the whole of the energy of the observed radiation—large though that is—for something like thirty thousand years."

This is a most interesting comparison, and numerous other astronomical comparisons may be made. Thus it has been found possible to perturb the orbits of the corpuscles in atoms.

"Electrons in orbital motion," says Sir Oliver Lodge, "have been shown to constitute the mechanism by which atoms are able to radiate light; and a great mass of semi-astronomical facts concerning these orbits and their perturbations have been obtained by immersing the source of light in a strong magnetic field, and observing the minute but very definite changes of spectra thereby produced."

So far has scientific imagination ventured that models have been made to illustrate the architecture of an atom, and even the laws that govern the number of the corpuscles in their several solar systems. Professor Mayer thrust magnetised needles through pieces of cork and floated them so that their negative poles projected above the water. The negative poles, in accordance with the laws of electricity, repel each other, just as the corpuscles charged with negative electricity must do. In order, however, to complete the atom, the positive electricity must be represented, and Professor Mayer represented it by suspending over the needles the positive pole of a magnet. The needles thus repelled by each other and attracted by the magnet give a fair picture of atomic conditions; and by studying such arrangements and by mathematical calculations, Professor J. J. Thomson and others have succeeded in showing how corpuscles must group themselves in different atoms, and have proved that the corpuscles in the atom probably revolve in their orbits, either in concentric rings or in concentric shells. In the same way it has been shown that the relationship between atomic weight and other atomic characters is a dynamical necessity, and also that the abstraction of a single corpuscle may break down the whole atom.

The illustration of the floating needles, however, is not quite correct, since the equilibrium of the atomic corpuscles depends largely on their velocity, even as the equilibrium of a top depends on the rate at which it is spinning. On this more complex conception, we may think of an atom as a sphere of positive electricity, enclosing a number of negatively electrified corpuscles, maintained in a condition of equilibrium by forces of attraction, and repulsion, and kinetic energy ; and a radio-active substance may be defined as one wherein the velocity of the constituent particles of its atoms has fallen so low that equilibrium has been destroyed, and disruption and rearrangement of the corpuscles is in process. In the case of every atom, the velocity of the atomic corpuscles must decrease as energy is radiated away, and ultimately a time must come when every atom will break up and show the phenomenon of radio-activity. But the atoms are more stable even than solar systems, and will maintain equilibrium for millions of millions of centuries.

It is difficult to believe that bodies as small as corpuscles can make the apparent *plenum* of an atom, which is as large in comparison with them as a cathedral in comparison with a comma ; yet when we remember that the infinitesimal corpuscles are moving in their infinitesimal orbits at such a pace that they would reach the moon in a second or two, their apparent ubiquity is explained. It is simply a case of kinematographic continuity. Granted that the corpuscles move with such speed, an atom may well appear single and solid. A single grain of dust flying about with such velocity within a church would make it as impenetrable as a rock of granite.

It is not even necessary that the atoms should be hard. More and more modern science leans to the strange idea that hardness is simply softness in motion. "It is probable," says a French scientist, "that matter owes its rigidity only to the rapidity of the rotary motion of its elements, and that if this movement stopped it would instantaneously vanish into ether without leaving a trace behind. Gaseous vortices animated by a rapidity of rotation of the order of that of the cathode rays would in all probability become as hard as steel."

The question may be asked—What reason have we to believe in this amazing agility of corpuscles? The belief is founded on just such a basis as our belief in the movement of the earth and planets. The belief explains and unifies various facts which without it are inexplicable and incoherent. Especially does it explain the extraordinary facts of radio-activity, and the tremendous energy displayed by the corpuscles. How could the corpuscles start from "scratch," so to speak, with a velocity of 20,000 to 150,000 miles a second? It is inconceivable. But if we consider that the corpuscles have been spinning with tremendous velocity in definite orbits, it is easy to understand how orbital might be converted into tangential velocity. "To explain the phenomena of radiation it is *necessary*," says W. C. D. Whetham, "to suppose that the electrified corpuscles—the electrons—are in rapid orbital and oscillatory motion within the atom; that, for example, the electrons whirl round their orbits as the planets swing round the sun."

Certainly the energy and velocity of the atomic dust requires *some* explanation. Infinitesimal particles flying off from decaying atoms may seem very insignificant things, but they are tokens of an energy so great as to be almost incredible. When an atom dissociates, the corpuscles are shot forth with a velocity that, according to the calculations of Le Bon, could be equalled by a bullet only if it had one million three hundred and forty thousand barrels of gunpowder behind it. Le Bon further calculates that corpuscles could flash from the earth to the moon in four seconds (a cannon-ball would take five days), and that there is enough intra-atomic energy in a copper one-centime piece "to work a goods train along a horizontal line equal in length to a little over four times and a quarter the circumference of the earth,"—as much energy, that is to say, as would be produced by about three million kilogrammes of coal, costing about seventy thousand francs. Sir Oliver Lodge, in his usual picturesque way, says that electrons are as much faster than a cannon-ball as a cannon is faster than a snail, and that they are a hundred times faster than the fastest flying star.

J. J. Thomson gives another picture of intra-atomic force by estimating that a few grains weight of hydrogen has within it sufficient force to raise a million tons to a height of more than three hundred feet.

Rutherford estimates the energy of the α particles of thorium at six hundred million times that of a rifle-ball.

Max Abraham calculates that one gramme

weight of corpuscles contains energy equal to 80,000,000,000 horse-power per second. A gramme of radium in a little more than a year gives out enough heat to raise the temperature of 900,000 grammes of water by 1° C.; and Professor R. K. Duncan declares that "the heat evolved by the radium emanation is over three million five hundred thousand times greater than that let loose by any known chemical reaction." And Whetham calculates that it may possibly be ten million times greater.

Measured by its electrical potency, the intra-atomic energy is equally prodigious; one gramme of hydrogen contains an electric charge of 96,000 coulombs—enough to charge the whole surface of the globe to a potential of 6000 volts, and Le Bon computes that the best static machines would have to work unceasingly "for a little over thirty years to give the quantity of electricity contained within the atoms of one gramme of hydrogen."

Such concentration of energy is almost incredible; but energy is mainly a question of velocity: a gramme or fifteen grains of matter, says Sir William Crookes, moving with the speed of light, would have energy enough to lift the British navy to the top of Ben Nevis; and, as Le Bon points out, the head of a pin spinning with sufficient speed might have a mechanical power equal to several thousands of locomotives. The speed of the corpuscles is so tremendous that, despite their smallness, they are able to develop tremendous energy.

Now, such energy cannot be generated *de novo* from nothing ; and there seems no way of explaining it unless we believe that the corpuscles in the intact atom are not at rest, but in a state of whirling equilibrium. The energy developed when gunpowder explodes is just the same energy which holds the atoms and molecules of the powder together ; the energy developed by the exploding atom is just the same energy that held it together into a miniature solar system, with a central sun and spinning planets. The force that holds together the corpuscles—the intra-atomic energy—is enormously much greater than the force that holds atoms and molecules together, and its disruptive power is accordingly correspondingly greater.

We may picture the situation in a simple way by imagining molecules, atoms, corpuscles pulled together by bands of elastic. The bands of elastic between the atoms are stronger than those between the molecules, and the bands of elastic between the corpuscles stronger than those between the atoms. Consequently, when the elastic band between the corpuscles is severed they fly apart with greater force than do molecules or atoms when the bands between these are severed. Undoubtedly a great deal of the potential energy of the electrons is due to their electric charge. We have already pointed out the numbers of coulombs in a gramme of hydrogen, and it has been calculated by Le Cornu that "if it were possible to concentrate a charge of one coulomb on a very small sphere, and to bring it within one centimetre of another sphere likewise having a charge of one coulomb, the force created by this repulsion would equal about nine billions of kilogrammes — *i.e.* one thousand million of horse-power—per second."

We are not yet able to utilise intra-atomic energy to any extent. The intra-atomic energy made manifest in radium is only very, very slowly developed—so slowly that it takes centuries to evolve. Could we disrupt only a few grains of matter instantaneously we should be able to acquire enormous energy. With a teaspoonful of salt we might destroy a city, and we could keep in a thimble enough concentrated fuel to take many Mauretanias across the Atlantic. Nay, we might be able to make a plaything of the moon and to harness the stars. It is merely a question of conversion, of redirection, of liberation of energy. The energy is already there, holding the electrons together, and impelling that at a terrific speed in infinitesimal orbits. We can widen the orbits by means of heat, and thus obtain the energy of a gas; we can perturb the orbits by means of magnetism; and the day will come, perhaps, when we shall be able to turn the whole enormous rotational energy of the electrons into useful translational form.

"The scholar," says Le Bon, "who discovers the way to liberate economically the forces which matter contains will almost instantaneously change the face of the world. If an unlimited supply of energy were gratuitously placed at the disposal of man, he would no longer have to procure it at the cost of arduous labour. The poor would then be on a level with the rich, and there would be an end of social questions."

CHAPTER VII

ELECTRONS AND THE AURORA BOREALIS

THE theory of the part probably played by electrons in the production of the phenomenon known as the *aurora borealis* is one of the most interesting of scientific hypotheses. Regarded in the light of this theory, the aurora borealis may be considered a beautiful demonstration on a large scale of the unity of natural law—indeed, it may be deemed the magnificent luminous signature of the sun to the balance-sheet of the laboratory.

According to latest scientific theory, the explanation of the aurora borealis is as follows :—

The spectrum of the aurora borealis shows that it is largely produced by the vibrating molecules of argon, krypton, xenon, neon, and other rare gases of the air, which, for reasons into which we need not now enter, are likely to collect in the upper layers of the atmosphere. By putting these gases in a Crookes tube and passing an electric current through them we can produce a very good imitation aurora borealis on a small scale, with beautiful rosy and green tints, due to the gases called "neon" and "krypton." The presumption is therefore very strong that the aurora borealis is caused by electric discharges—discharges of electrons through the upper layers of the atmosphere. But where do the electrons come from? It has been proved that all hot bodies, and especially glowing carbon, give off electrons. Now, the sun is a hot body, and its photosphere contains enormous quantities of glowing carbon. Accordingly—the hypothesis is as plausible as it is audacious—the electrons probably come ninety-three million miles from the sun. At the rate they travel—twenty miles or so a second—it won't take them long.

But ninety-three million miles is a considerable way to come, and one may well ask for some particulars of the journey. Electrons, or minute particles containing negative electricity, are certainly emitted by the sun, but would they not be drawn back again by gravitation and by the sun's positive electricity? Under ordinary circumstances the positive electricity and gravitation would hold the negative particles; but there is another factor to be reckoned with, namely, the mechanical pressure of light. That light *has* mechanical pressure was proved mathematically by Clerk-Maxwell in 1873, and experimentally by Peter Lebedew in 1901. The pressure is small: the light pressure on the whole earth is only 70,000 tons, but even a slight pressure would be sufficient to repel these small electrons. We have, thus, gravity and positive electricity attracting the electrons, and light pressure repelling them. In the case of such small bodies, which are almost all surface, it is certain that the light pressure would be stronger than gravitation, and the only question is—Would it be strong enough to overcome the attractive force of the positive electricity? To this final question there can be but one answer: that undoubtedly at times, when the sun blazes up and the sun-spots enlarge, the light pressure is sufficient to destroy the equilibrium between the negative and positive electricity, and to hurl the electrons across the ninety-three million miles between the sun and the earth. Long before the relationship was understood it was noted that there was "an almost perfect parallelism" between the intensity of auroral phenomena and the abundance of sun-spots, and that any flare-up of the sun was followed by splendid auroras. When the electrons reach the magnetic field of the earth (the earth is, of course, a magnet), they are conducted by the magnetic lines of force, in a series of spirals, toward the poles, and on their way through the outer atmosphere they electrify the molecules of the gases neon, argon, etc., and cause them to phosphoresce and produce the light known as the aurora borealis.

In brief, the aurora borealis is due to the bombardment of the rarefied gases of the outer atmosphere by electrons ejected by the sun, and borne across space by light pressure.

The theory is surely beautiful. We believed that the light gases were probably at the top of the atmosphere, but no one had ever been there to see, and lo! we find that the sun pelts them with electrons across ninety-three million miles of space, and compels them to sign their names through Lockyer's spectroscope. We had reason to believe that electrons were emitted by the sun; we had reason, from Clerk-Maxwell's calculations, and from Peter Lebedew's experiments, to believe that the electrons of the sun would be carried across space by the pressure of light; but we had no proofs of the correctness of our beliefs, and lo! we find in the red and green of the Northern Lights proofs almost indubitable. Again, we had every reason to believe that the earth is a great magnet, with lines of force curving through space; but what proof of it have we here when we see the electrons arranged by its lines of force, even as iron filings are arranged according to the lines of force of an ordinary little magnet!

It is a small universe after all when the aurora borealis and the phosphorescence in a vacuum tube are akin ; and when the toy magnet of the child and the great world spinning through space exercise attractive powers different only in degree.

It is a strange world when we think that the *prima materia* which mankind had so vainly sought had all the time been battering away at the boundaries of the atmosphere !

Finally, we may mention that Arrhenius makes the audacious suggestion that the life upon our globe was brought to it from interstellar space by this corpuscular rain.

"Yet all these were when no Man did them know,
Yet have from wisest Ages hidden beene,
And later Times thinges more unknowne shall show ;
Why, then, should witless Man so much misweene
That nothing is but that which he hath seene ?"

CHAPTER VIII

MATTER AND ITS DEMATERIALISATION

We have told in previous chapters how the atoms, formerly thought so impenetrable and indestructible, are soft and breakable, and really consist of whirling particles. We have told how certain atoms in the process of breaking down become transformed into other atoms (*e.g.* radium into helium and lead), and how, thus, the dream of the alchemists has come true. We have described, further, the enormous velocity of the β corpuscles and the heat and power they can develop. We have shown that, no matter what the kind of atom, the electrons are always the same in mass and general character, and that, therefore, they must form the *urstoff*, the *prima materia*, the *protyle* of all kinds of atoms—whether oxygen or gold. All these are astounding and amazing facts, but there is a story stranger still to tell. It seems that the electrons, the splinters of the atoms, are not radiant matter, are not a "fourth form of matter," are not matter at all; for their whole mass and inertia—really the only material property they retain—can be explained as the result of an electrical charge in motion. Matter in solid form, "*en masse*," has weight, shape, colour, temperature, and other material properties. In liquid form, its material properties are fewer. In gaseous form, its material properties are fewer still; and finally, these atomic fragments, called "corpuscles" or "electrons," have no material properties at all, and seem simply disembodied electrical charges. Thus the prophecy of Faraday, that there must be a fourth form of matter, has been more than fulfilled. The dust of atoms is seemingly not matter at all. They may *have been* matter; but, as isolated particles, they seem to have lost material qualities. It is very extraordinary, it is almost incredible, that this should be so! Yet so it is: there seems no way out of it.

The most characteristic and essential property of matter is its mass or inertia—its power to resist change of motion—as is seen in turning a grindstone, for instance; but the mass and inertia of the electrons seems almost certainly to be nothing but the mass or inertia of the electric charge.

In his work on Radio-active Transformations, Professor Rutherford, one of the most distinguished investigators of radio-activity, puts the situation thus: "By comparison of theory with experiment, it was found that the mass of the electron was purely electrical in origin, and that there was no necessity to assume that the charge was distributed over a material nucleus. We thus arrive at the remarkable conclusion that the particles of the cathode stream (*i.e.* the negative corpuscles or electrons) and the β particles of radium are not matter at all in the ordinary sense, but disembodied electrical charges, whose motion confers on them the properties of ordinary mass."

"It is probable," writes Whetham, "that the whole of the observed mass of the corpuscle is in reality an effect due to the electro-magnetic inertia of its electric charge. Representing the atoms of ordinary matter as made up of corpuscles, and identifying the corpuscles with electrons, or isolated electric charge units, it becomes possible to explain their mass by the electro-magnetic properties of a moving charge."

This may be considered equivalent to the assertion that all mass is electrical in essence; and Professor R. K. Duncan, in his book *The New Knowledge*, asserts: "we are therefore entitled to believe, if we like, that the *whole* mass of the corpuscle arises from its electric charge. But the corpuscle we deem to be the constituent of an atom is itself the constituent of a molecule, and a molecule is the constituent of a mass of matter, such as a table or chair. Hence, on this view, the inertia of any material body, or the mass of it measured by the inertia, is due simply to electrical charges in motion."

Professor J. J. Thomson declares: "In fact, all mass is mass of the ether; all momentum, momentum of the ether; and all kinetic energy, kinetic energy of the ether."

Accordingly, matter is merely electricity in motion. When we sit on a chair we are sitting on little whirling systems of electricity; when we eat our dinner we are munching molecules of electricity; and when the notorious Count Mattei sold his little phials of coloured water and called them green and blue electricity, he was telling the truth, though he probably did not know it.

We may, however, here point out that the identification of electrons with electricity does not necessarily mean the identification of matter "*en masse*" with electricity. It may be that matter is transformed by the mere fact of division, and that electrons and electricity are not identical with matter "*en masse*," but are simply products or by-products of its disruption. Thus carbon and oxygen are not identical with water, but products of its disruption. Certainly, when negative and positive electricity join, electricity as electrical force seems to vanish; and if it appear in matter in the form of vibrations, giving rise to sound and colour, etc., who shall venture to call it still electricity?

Still, leaving aside the question of the electrical character of matter "*en masse*," the fact remains that by various means it can be broken up into what are called electric charges.

The cursory and desultory survey of scientific and philosophic theories in Chapter III. will show that, from all time, both science and philosophy had been inclined to regard motion as essential to the explanation of the phenomena of matter; and that, therefore, the analysis of matter into electrical charges in motion came as no surprise, and was quite in accordance with the anticipations of hypothesis. The discovery could easily be made to fit Boscovitch's points of force, for instance, or even Kelvin's vortex-rings of Leibnitz's monads; and though it finally destroyed the conception of matter as passive and inert, that was merely slaying the slain.

Nor had the discovery been unforeseen. In 1875 W. K. Clifford declared: "Now there is great reason to believe that every material atom carries upon it a small electric current, *if it does not wholly consist of this current.*" Again: "The position is this. We know with great probability that wherever there is an atom there is a small electric current. Very many of the properties of atoms are explained by means of this current: we have vague hopes that all the rest will be likewise explained." Ten years later Karl Pearson went a step further. "I have no objection," he asserted, "to calling the moving things matter; but we must bear in mind that the moving things may be the last things in the world which accord with the popular conception of matter; they may even be its negation. What if the ultimate atom upon which we build up the substantial realities of the external world be an absolute vacuum? Or what if matter be only non-matter in motion? I do not say that the moving thing is of this kind, because nobody as yet knows what it really is, but let us endeavour to imagine something of the kind."

In 1890 Preston wrote: "The present tendency of physical science is to regard all the phenomena of Nature, and even matter itself, as manifestations of energy stored in the ether." Nay, as far back as 1708, Newton had hinted that matter was ethereal in nature. "Perhaps," he suggested, "the whole frame of nature may be nothing but various contextures of some certain ethereal spirits and vapours condensed, as it were, by precipitation, and, after condensation, wrought into various forms, at first by the immediate hand of the Creator, and ever after by the power of Nature." (And what is this, again, but the "rarefactions" and "condensations" of Anaximenes and Diogenes?)

New or old, the proposition had new and startling implications. For if matter consist merely of electricity in motion, or if it may be decomposed into electrical charges, then it is surely on the brink of destruction; for who shall say, who can believe, that an electric charge, which is nothing more than a perturbation of the ether, is eternal? Of course, the same force which perturbed the ether once may perturb it again, and even now new electrons and new strange atoms may be in process of formation; but the electrons—the ether ripples—into which matter dissociates will almost certainly die away into the nothingness of ethereal calm.

> "The cloud-capped towers, the gorgeous palaces,
> The solemn temples, the great globe itself,
> And all which it inherit shall dissolve,
> And like this unsubstantial pageant faded
> *Leave not a rack behind.*"

"There is no reason," said W. K. Clifford long ago, "why vibratory motion of the ether should not be transformed into other kinds of ethereal motion; in fact, there is no reason why it should not go to the making of atoms" ; but, on the other hand, when once the equilibrium of the intricate ether whirls which make an atom is destroyed—when once it is simplified into electric atoms—it can never be restored again, and the ultimate ripples of ether will surely die away. Le Bon puts the matter very clearly : "These vibrations of the ether, ever the companions of the electric atoms, most likely represent the form under which these vanish by the radiation of all their energy. The electric particle, with an individuality of its own, of a defined and constant magnitude, would thus constitute the last stage but one of the disappearance of matter. The last of all would be represented by the vibrations of the ether, vibrations which possess no more durable individuality than do the waves formed in water when a stone is thrown into it, and which soon disappear.

"How can the electric atoms proceeding from the dematerialisation of matter preserve their individuality and transform themselves into vibrations of the ether ?

"All modern research leads us to consider these particles as constituted by whirls, analogous to gyroscopes, formed in the bosom of the ether and connected with their lines of force. The question, therefore, reduces itself to this : How can a vortex formed in a fluid disappear into this fluid by causing vibrations in it?

"Stated in this form, the solution of the problem presents no serious difficulties. It can be easily seen, in fact, how a vortex generated at the expense of a liquid can, when its equilibrium is disturbed, vanish by radiating away the energy it contains under the form of vibrations of the medium in which it is plunged. In this way, for example, a waterspout formed by a whirl of liquid loses its individuality and disappears in the ocean.

"It is, no doubt, the same with the vibrations of the ether. They represent the last stage of the dematerialisation of matter, the one preceding its final disappearance. After these ephemeral vibrations, the ether returns to its repose and matter has definitely disappeared. It has returned to the primitive ether from which hundreds and millions of ages and forces unknown to us caused it to emerge, as it emerged in the far-off ages when the first traces of our universe were outlined on chaos."

The great mathematician Larmor has reached the same conclusion by mathematical processes, and declares that the atom is a whirl in the ether rotating with tremendous velocity. "The material molecule," he writes, "is entirely formed of ether, and of nothing else."

In terms of ether, says W. C. D. Whetham, "Matter is a persistent strain-form flitting through a universal sea of ether." And according to Sir Oliver Lodge, an electron "is only a peculiarity or singularity of some kind in the ether which is of perfectly uniform density everywhere. What we sense as matter is an aggregate or grouping of an enormous number of such units."

Such, then, is the belief of modern science with regard to the nature of matter—a temporary whirl or strain in the ether. But what is ether? To a consideration of that question we will devote the next chapter.

CHAPTER IX

THE ETHER

It may well be asked, "What is the ether, and why is the ether?" Yet no questions are more difficult to answer. The ether seems at once everything and nothing; it is so pervasive that it fills infinitude, and it is so evasive that Lord Salisbury once said that it was nothing more than the nominative case of the verb to undulate. It is essentially *that which undulates*; and according to the nature of the undulations it appears in our consciousness as the phenomena light, heat, electricity. These phenomena appear to have periodicity in space and time, like waves in a fluid; and therefore it has been assumed that they are waves of *something*, and this something is called ether, and is given various properties to account for the particular behaviour of its undulations. Of late years ether has also been used to account for gravitation, on hydrodynamical principles. But scientists have found a good deal of difficulty in making ether do all it is supposed to do without endowing it with contradictory properties.

Still, it is a *working* hypothesis of great value; and all the greatest physicists of the day use it to unify and explain physical facts, and to many it appears to have a more real existence than matter itself. If it verily be the *medium* of light, and heat, and electricity, and gravitation, its importance cannot be overestimated. Without it—on this hypothesis—we should be in a dark, dead world; nay, there would be no world at all; for matter, if there be matter apart from it, would be dissipated into infinite space.

How did the hypothesis originate? Someone remarked that it was "made in England"; and Sir Oliver Lodge supplements the remark with the suggestion that it was largely constructed in the Royal Institution. No doubt the idea had floated about for many centuries; but it was Newton and Hooke who gave it force and fixity, and brought it "through the Horn Gate of dreamland into the region of reality."

Newton had shown that throughout the whole universe all particles of matter attracted each other in accordance with a fixed law. The earth attracts the falling apple; the sun attracts the earth; and so on *ad infinitum* across the millions and millions of miles of empty space. Now the question naturally arose, *could* matter attract matter across space unless there was some substance between connecting them? Newton thought it could not. In his famous third letter to Bentley he wrote: "It is inconceivable that inanimate brute matter should, without the mediation of something else which is not material, operate upon and affect other matter without mutual contact, as it must do if gravitation, in the sense of Epicurus, be essential and inherent in it. And this is the reason why I desired you would not ascribe innate gravity to me. *That gravity should be innate, inherent and essential to matter, so that one body may act upon another at a distance through a vacuum without the mediation of anything else by and through which their action may be conveyed from one to another, is so great an absurdity that I believe no man who has in philosophic matters a competent faculty of thinking can ever fall into it.*"

The impossibility, then, of conceiving "actio in distans," of believing that one body can act on another body at a distance without material mediation, gave origin to the hypothesis of ether. Philosophically, the basis of the hypothesis might be contested. When Carlyle was asked to assent to the principle that a body cannot act where it is not, he answered: "With all my heart; but, pray, where is it?" And it may be quite well argued, in accordance with Leibnitz's axiom "quod non agit non existit," that a body *is where it acts.*

Even more than gravitation, the undulatory characteristics of light have seemed to require an undulating medium with wonderful elastic properties; and Clerk-Maxwell, in an address on "Action at a Distance," gives a very picturesque description of the ether as light-bearer: "The vast interplanetary and interstellar regions will no longer be regarded as waste places in the Universe, which the Creator has not seen fit to fill with the symbols of the manifold order of his kingdom. We shall find them to be already full of this wonderful medium; so full that no human power can remove it from the smallest portion of space, or produce the slightest flaw in its infinite continuity. It extends unbroken from star to star; and when a molecule of hydrogen vibrates in the Dog-star, the medium receives the impulses of these vibrations, and after carrying them in its immense bosom for several years, delivers them in due course, regular order, and full tale into the spectroscope of Mr Huggins at Tulse Hill."

If the ether is to be the medium of gravitation and light, it must extend through space to the smallest star; if it is to be the medium which brings the smallest particles of matter *into touch*, it must also permeate all matter; and, of course, if the electronic theory of matter be correct, it not merely penetrates matter, but is matter.

The properties of ether are, of course, wholly inferential ; and, as we said before, mathematicians have found it very difficult to make these consistent *inter se*. It was at first conceived as a fluid, but it is certainly not a fluid, nor a solid, nor a gas, nor radiant matter ; and different physicists picture it in different ways. Maxwell supposed it to be formed of tiny spheres, rapidly rotating. Mendeleef reached the conclusion that it is an inert gas with an atomic weight a million times less than hydrogen, and with a velocity of 2250 kilometres per second. Others, again, have pictured it as a homogeneous elastic jelly ; others have suggested that it may be "fibrous, like a bundle of hay." Professor Osborne Reynolds, a well-known mathematician, who has worked at the subject for years, claims that "there is one, and only one, purely mechanical system capable of accounting for all the physical evidence, as we know it, of the universe. The system is neither more nor less than an arrangement of indefinite extent, of uniform spherical grains, generally in normal piling so close that the grains cannot change their neighbours although continually in relative motion with each other, the grains being of changeless shape and size." The grains he requires for his ether are infinitesimally small—smaller even than electrons; and the pressure in the medium is tremendous—about 10,000 tons per square centimetre. According to this theory, matter is simply areas of diminished density in the ether, which is something very like the direct opposite of the ordinary ideas of matter and ether.

Dr Larmor, again, thinks that the ether is "a rotationally elastic medium," and is pervaded by "a structure of tangled or interlaced vortex filaments which might resist deformation by forming a stable configuration."

It is evident, accordingly, that there is much difference of opinion with regard to the constitution of the ether. With regard to its general characters there is less doubt. There are certain characters it *must* have. The light undulations in it are so small that there are 40,000 to 69,000 in one inch, yet light travels at the rate of 186,000 miles a second, which means that for the smaller waves the ether must vibrate about 5,900,000000,000000 times in a second, or far more times in a second than there are individual letters in all the books in the British Museum. Any medium which can do this must be extraordinarily elastic and dense. Sir Oliver Lodge says that the ether is "so dense that matter by comparison is like gossamer, or a filmy imperceptible mist, or a milky way." And yet it is imponderable, and it permits the planets to pass through it without friction. Personally, we must admit such a medium is beyond the wildest stretch of our imagination ; and when Sir Oliver Lodge mentions that the intrinsic energy of the constitution of the ether is so incredibly, portentously great that every cubic millimetre of space possesses what, if it were matter, would be a mass of a thousand tons, and energy equivalent to the output of a million-horse-power station for forty million years, we are not inclined to contest his calculations.

We can well believe that the atomic miniature solar systems are only strains in this marvellous medium ; and even, as Sir Oliver Lodge and Clerk-Maxwell suggest, that it may "constitute the organism of beings exercising functions of life as high or higher than ours are at present."

CHAPTER X

COSMOGONIES

"Where wast thou when I laid the foundations of the earth? declare, if thou hast understanding. Who hath laid the measures thereof, if thou knowest? or who hath stretched the line upon it? Whereupon are the foundations thereof fastened? or who laid the corner stone thereof; when the morning stars sang together, and all the sons of God shouted for joy?"

The mind of man is curious, not only concerning the nature and origin of matter *quà* matter, but also concerning the nature and origin of the world, *quà* world, on which he lives. Very soon, then, he began to ask what was this solid, stolid earth, standing steady amid the stars; and very curious were some of his primitive theories. A Hindu theory, for instance, held that the earth was borne by a gigantic elephant which stood on an immense tortoise, and was borne over a shoreless sea of milk as boundless as infinity. A

Brahmin legend, again, taught that the earth floated like a full-blown lotus on the surface of mighty water. "The two peninsulas of the Ganges and the other Asiatic countries are the expanded flower, the isles scattered over the ocean are the half-open buds, distant lands are the softly-spreading leaves. The Ghauts and the Neil-gherries are the stamens of the immense flower, while in the centre culminates the lofty Himalayas, the sacred pistil, in which are organised the seeds of the world. Man, like the tiny insect which sees infinity in a rose, builds his imperceptible cities near the honey-cup of the flower, and sometimes spreads his wings to glide over the sea, from the corolla of the Indies to that of Ornuez and Socotra. The stalk of the plant disappears in the depth of the ocean, and descending from abyss to abyss, at last buries itself in the very heart of Brahma."—(*The Earth*, Reclus.)

We need not recapitulate here more of these primitive cosmologies: they were based on imagination, not on reason, and have no genetic relation with the later and more scientific attempts to solve the riddle of the universe. On such fanciful cosmology only fanciful cosmogonies could be founded. Not till astronomy became a science—not, at least, till men realised that the world did not end at the Pillars of Hercules, but that it was a globe whirling round the sun—had thinkers sufficient straw to make bricks.

The Adipones and Esquimaux, we are told, "refuse to trouble themselves with questions of origins, on the ground that the hard facts of life leave no ground for otiose discussions"; and it is not surprising to find that astronomy flourished chiefly in Egypt and Chaldæa, where the skies were clear and the fields fertile, and the facts of life less hard. Yet even in Egypt and Chaldæa astronomy was cultivated chiefly for practical purposes—in order to read fate in the stars, or to know when the Nile might be expected to overflow—and any cosmological applications were chiefly an afterthought.

In the Middle Ages, astronomy made considerable progress in Europe. In 1536 Copernicus propounded his heliocentric theory. Not long afterwards, Bruno published his work on the Plurality of Worlds, in which he taught that every star might be a sun, with planets revolving round it. In 1622 Kepler published his work *Epitome of the Copernican Astronomy*. In 1632 Galileo published his work, *The System of the World*, and in 1686 Newton published his *Principia*.

But progress in astronomy was not necessarily progress in cosmogony. For cosmogonies the time was not yet ripe. Bruno was burnt at the stake for his speculations, and Galileo almost shared the same fate; and though Kepler formulated a theory that the sun exercised a magnetic influence, and that the planets were made to revolve by a whirling medium, and Descartes brought forward his theory of "tourbillons" or vortices, which was afterwards borrowed by Swedenborg, not till the time of Kant can there be said to have been a really successful attempt to construct a cosmogony.

With Kant the science of cosmogony may be said to have started.

Kant was a follower of Democritus and Epicurus, and he tried to construct the cosmos, or at least the solar system, from the motion of atoms and molecules; but he had Kepler's and Newton's laws to guide him, and he brought to the task much more mechanical and astronomical knowledge than were possessed by the two Greek philosophers. He postulated merely atoms, gravitation, and molecular repulsion, and with these he attempted to make the solar system. Under the influence of gravitation and molecular repulsion, the atoms would rush towards the centre and clash with each other, and, according to his views, the collisions and jostlings would cause the whole mass to revolve, and the revolution, again, would throw off by centrifugal force the planets which had formed peripherally by fortuitous accretion of clashing atoms.

Kant's mechanics were at fault in various respects. Particles falling centrally by gravitative attraction would never cause rotatory movement; and if rotatory movement did occur, and if the planets formed by accretion were thrown off, they would rotate in exactly the opposite direction to that in which the planets do rotate. These flaws are fatal to his theory, but it was a brilliant attempt at cosmogony.

Equally brilliant and more correct was Kant's discovery of the cosmogonical fact that the tidal friction between the earth and the moon must retard the motion both of the moon and of the earth.

It is interesting to know that Kant was inspired in his brilliant speculations by a summary in a Hamburg paper of a "New Theory of the Universe" by one Thomas Wright, son of a Durham carpenter.

In 1796 Pierre Simon Laplace brought forward his famous nebular hypothesis of a fire-mist which once stretched from the centre of the sun to at least as far as the outermost planet of our system, and which, as it cooled and contracted, threw off the planets as nebulous equatorial rings (such as are still seen in Saturn's Belt), which rings, again, eventually coalesced into globular masses and formed planets. According to a well-known law of mechanics—the law of conservation of moment of momentum—the spinning body must spin faster as it contracts, and thus at intervals, enough centrifugal force would be acquired to shed an equatorial ring. The first ring would be thrown off where Neptune spins in its outer orbit, the next would account for Uranus, the next for Saturn, and so on. By assuming the mist coherent so as to spin "*en masse*," Laplace was able to arrange that the planets would spin on their axis in the *right* direction, not in the wrong direction, as Kant's planets must have done. Unlike Kant, too, he did not try to account for the initial rotation, but wisely postulated it.

It was a beautiful and plausible hypothesis, beautiful in its simplicity, plausible in its explanation, and to this day it has held the imagination of mankind. What bolder and braver vision could one have than the vision of this fiery mist rotating in space and flinging off from its fringes the flaming planets and the molten world! What could be more fascinating than the picture of the beginning of the world as a belt round the waist of the whirling sun!

But unfortunately the hypothesis is not mechanically sound. If the sun and the planets were dispersed into space so as to fill an area bounded by Neptune's orbit, they would form a gas so attenuated that all coherence would be out of the question.

Not only, accordingly, would centrifugal force fail to give the planets the right spin, but it would fail to form planets at all. Miss Agnes M. Clerke, in *Modern Cosmogonies*, puts the matter very clearly : "We know perfectly that a rotating globe of matter, thousands of times less compact than air, would intermittently disintegrate at the surface with the progress of acceleration. The disturbance and restoration of equilibrium would be virtually simultaneous. There would be no accumulation of internal stress, and consequently no definitely separated epochs of instability. At the first solicitation, at the first instant that centrifugal velocity gained the upper hand over gravity, nebulous wisps would have become detached, and their detachment would have gone on without pause. Space would have been strewn with the débris of condensing nebula, and there should have resulted a vast cloud of cosmic dust, not a majestic array of revolving spheres."

Moreover, by the "law of areas" the rate of rotation of the fire-mist must have been extremely slow when it occupied the enormous area measured by Neptune's orbit, so that really gravitation would have more than counterbalanced centrifugal force, until the whole mass had shrunk to the size of the orbit of Mercury. Further, the several planets do not move at relative rates proportionate to the rate of rotation of the fire-mist at the time of their origin, and this, according to the laws of mechanics, they ought to do. And there are many other facts that have almost completely overthrown belief in the nebular hypothesis as formulated by Laplace, nor have any means been found to patch it up into a consistent and credible theory, though notable attempts have been made by Roche, Kirkwood, Faye, and other physicists.

Further attempts have been made by M. du Ligondès, Sir Robert Ball, Arrhenius, Chamberlin, Moulton, Lockyer and others to formulate a consistent hypothesis, but none of these have been entirely successful.

The tendency of the more recent hypotheses has been to start with a nebula of low temperature, and, in accordance with thermo-dynamic principles, to derive any necessary heat from the contraction of the nebular constituents under the influence of gravitation.

Perhaps the most famous of modern theories is the meteoric hypothesis, first proposed by Chadli as far back as 1794, and resuscitated and developed by R. A. Procter in 1870 and by Sir Norman Lockyer in 1887.

It is a well-known fact that the earth, as she spins through space, is picking up millions of meteorites ; and the meteoric hypothesis supposes that the solar system was formed in bygone ages by the accretion of meteoric swarms, and that the nebulæ at present seen in the heavens are meteoric swarms, which are growing into stars and planets. "A meteoric swarm," says Miss Agnes Clerke, "may be defined as a rudely globular aggregation of small cosmical masses revolving, under the influence of their mutual attraction, round their common centre of gravity." They would circulate in all planes and would constantly collide, with the result that certain of them would be brought to a standstill and would condense as a central nucleus, which, owing to the heat produced by gravitation and collision, would be in a liquid or gaseous state, whilst others, compelled by collision and elimination into orbits with the same direction, would revolve as satellites round the central mass. The formation of planets would seem to require original inequalities in the density of the swarm ; but once their nuclei were formed, they might easily increase in size by a process of accretion, for they would attract, as does the earth, meteoric material.

According to this form of the theory, the outer planets would be the larger, because they would attract most material, while the inner ones would be smaller, because the sun would, so to speak, take the bread out of their mouths. According to this form of the theory, the planets would be heated by collision and contraction and by the impact of meteoric particles.

The theory, however, takes many forms. Sir Norman Lockyer supposed that the meteoric stones banging about in an atmosphere of hydrogen would be volatilised by the heat of their mutual impacts, and would eventually form such a gaseous mass as Laplace postulated. Professor Darwin, on the other hand, prefers to hold that the meteoric particles behave under impact like colossal molecules, and thus are not volatilised, but give rise to "fluid pressure."

One of the most striking of recent hypotheses has been brought forward by Professor J. H. Jeans. He postulates a hot spherical nebula of gas or meteorites which revolves slowly. Such a nebula, he points out, would cool unequally, since the outer portion would cool more quickly than the central, and this inequality of temperature, together with the increasing velocity of rotation consequent upon the contraction due to cooling, would produce instability of the nebula and cause it to take a *pear-shaped* form. Eventually, he suggests, the pear-shaped end would be flung off and form a planet or satellite. The impact of a meteorite, or the attraction of some other body, would favour the separation of the pear-shaped end, and might cause the obliquity so often found in the orbits of planets. The formation of a pear-shape and the separation of its pointed end might be frequently repeated.

Chamberlin and Moulton have another theory still, and suppose that the planets have been formed by the accretion of meteorites moving in various elliptical orbits.

So many different opinions are a proof that the meteoric hypothesis is still in an inchoate and unsatisfactory condition.

The spectroscope is rather against the meteoric hypothesis, since it finds in the nebulæ no metallic elements such as compose meteorites, but principally an unknown gas named "nebulium," whose spectroscopic signature is a green line.

CHAPTER XI

NEBULÆ

Of late years the nebulæ have been studied with particular care; and though their dynamics are not yet fully understood, and though, as we have said, no nebular hypothesis is quite satisfactory and consistent, yet "there is good reason to believe that they are really the material out of which stars are made, and that in their forms, aggregations, and condensations we can trace the very process of evolution of stars and suns."

Nebulæ are nearly all invisible to the naked eye. Seen through the telescope, they appear like faint luminous clouds, but, unlike clouds, they do not change their shape, and they are many millions of miles away, and of tremendous size. The smallest nebulæ we know are much larger than the sun, while some of the largest are so huge as to stagger imagination. "The earth," says Sir Robert Ball, "sweeps around the sun in a mighty path, whose diameter is not less than 185,400,000 miles.

Let us imagine a sphere so mighty that the circle would form just a girdle round its equator, and let this gigantic globe be the measure wherewith to compare the bulk of the vast nebula of Orion. It can be demonstrated that a million of these mighty globes rolled into one would not equal the great nebula in bulk, though how much greater than this the nebula may really be we have no means of ascertaining." And yet such a nebula is little more than a shred of the great nebular system of the Milky Way, from which probably it sprung.

Some of the nebulæ consist entirely of gases; others seem to consist entirely of clusters of minute stellar points; others, again, of gases and stars. The spectrum of a gaseous nebula is composed of seven bright lines: three of these indicate hydrogen; the other four lines correspond with no gas we yet know. The spectrum of a *stellar* nebula is the ordinary continuous band of colour crossed with dark lines, and such a nebula, accordingly, is often known as white nebula. There are scores of gaseous nebulæ, but the white number tens of thousands.

It is generally thought that the gaseous nebulæ are the earlier stages of the white, and that the general tendency of nebulæ is to end in star-clusters; but this is not certain, and the relationship between the gases and the stars has yet to be decided.

In shape, nebulæ vary : some are more or less spherical ; some annular ; but the greater majority are spiral, often with two spiral arms, and usually with stars following the curves of the spiral. The cause of the shape of nebulæ, and especially the cause of the spiral formation, is a question that has been much debated. Arrhenius holds that the nebulæ are the result of collisions, and that the shape depends on the character of the collision. When direct face to face, an elliptic or more or less spherical nebula would be produced ; while what may be called a *half-ball-cannon* collision would result in a rotating spiral nebula with two arms—a shape frequently seen. "At the collision, matter will have been ejected from both these celestial bodies, at right angles to the relative directions of their motions, in two powerful torrents, which would be situated in the plane in which the two bodies were approaching each other."

The double arm seen in most well-developed spiral nebulæ is explained in a somewhat similar way by Chamberlin. He holds that such nebulæ are formed, not by actual collision, but by tidal disruption. When two bodies in space, of stellar size, pass within a certain distance of each other, the smaller is apt to be not only tidally deformed and elongated by the larger, but strained to such an extent that it bursts into fragments. The fragments of the elongated rotating mass will necessarily take on a whirling or spiral motion, and "when the explosive eruption occurs the two protuberances or elongations of the body will fly apart, and having also a rapid rotatory movement, the resulting spiral will necessarily be a double one."

The mere formation of a spiral is easy to account for. Almost any collision, says A. R. Wallace, between unequal masses of diffused matter would, in the absence of any massive central body round which they would be forced to revolve, lead to spiral motions.

Sir Robert Ball explains the spiral thus. On ordinary mechanic principles, any globular collection of promiscuously revolving particles will tend to flatten down into a disc, with particles all revolving in one direction; and since the central mass would revolve more rapidly, the general circulation of the particles would come to have a spiral direction.

But it is not sufficient to account for the spiral, we must also account for its two-armed structure, and these can only be "the outcome of long-continued, oppositely-directed eruptions."

The manner in which the nebulæ are converted into stars (if so converted) is, of course, quite unknown ; but if such conversion take place, it probably takes place in some such way as is surmised by the various nebular hypotheses.

When we come to the post-natal character of stars we are on surer but still rather speculative ground.

The spectroscope shows that stars have varying degrees of heat, and that, according to the heat, the chemical constitution of the star varies. The hottest stars (which, upon one nebular hypothesis, may be supposed to be stars new-born from the nebula) are known as "gaseous" stars ; these give a very long spectrum, and consist almost entirely of hydrogen and helium and some unknown gases. A group of stars less hot, known as metallic stars, give a spectrum of medium length, which shows that they contain, besides gases, certain metals, *e.g.* calcium or magnesium, in a semi-dissociated form. And a third group of stars less hot still have a short spectrum, which shows fewer gases, and metals now in the condition in which they exist at the comparatively low temperature of the electric arc. (It should be explained, perhaps, that many elements, when exposed to great heat, give spectra varying with the degree of heat. Thus iron has a flame spectrum, an arc spectrum, and a spark spectrum, all distinct.)

Since heat causes the dissociation of elements—really partial disintegration into electrons—we find in the hotter stars the fewer metals, and only in the cooler stars elements as numerous as in our world.

So far all is plain sailing ; but when we come to try to find the relationship of the hotter and cooler stars to each other, and to the nebulæ from which they were presumably evolved, we find many difficulties and many differences of opinion.

We may consider, with Sir Norman Lockyer, that nebulæ begin as clouds of cold meteoric stones, which gradually gain heat as the stones clash together, until they are converted into gases, and then gradually cool again by radiation until they are as dead as the moon. On this hypothesis, which begins with cold and ends with cold, the cooler stars are either newly-born or senile, and the hottest stars are in the prime of life. Sir Norman Lockyer claims to be able to tell by spectroscopic appearances whether a metallic star is beginning or ending its career.

On the other hand, if we accept a hypothesis which postulates a hot gaseous nebula, then the hotter and more gaseous the star the younger it is.

None of the hypotheses, however, so far, have taken into account the electron theory of matter.

Since the electron is the ultimate and simplest element of matter, it is probable that all forms and congeries of matter commenced as electrons, and that the elementary architecture of the cosmos was conditioned, not by heat, but by the properties and capacities of electrons — properties and capacities of which we know very little. In the light of the electronic theory of matter, a nebula may be considered simply as a storm in the ether, giving rise to vortices which take atomic shape, and form, in the first place, simpler atoms such as hydrogen and helium, and afterwards, under the stress of conflicting forces, the larger and more complicated metallic elements. The atoms so formed would, like atoms in a vacuum tube, be rendered incandescent and hot by the impact of free electrons ; and under the action of gravitation, the heavier would sink to the centre with the further production of heat. In view of the fact that atoms are dissociated by heat, the synthesis of atoms from electrons would take place at a low temperature, and the heat certainly found in stars and planets, at certain stages of their career, would be the result of gravitation, and of the interplay of electrons and atoms. It seems to us that the key of cosmogony is to be found in the micro-cosmogony of the atom. Until we can understand how the corpuscles of the atoms are sent spinning with such terrific speed and force in their little orbits, it is useless to speculate how the atoms themselves are built into stars and worlds. Cosmogony is a function of the ether: its first phenomenon is an electric charge; its second phenomenon is the conjunction of electric charges in certain orbits to form atoms; and only its third phenomenon, the impact and conjunction of atoms with the production of these vibrations, we know as heat. Ether has no heat; electrons have no heat: heat is atomic vibration.

It is quite possible that meteoric stones might make a star, as watch-wheels might make a watch; but we want to know how the stones were formed in the first instance. Meteoric stones need explanation quite as much as watch-wheels, and it is as necessary to account for the rotation of electrons as for the rotation of planets.

In fine, our knowledge of nebulæ is very nebulous, and more in the region of poetry and imagination than in the region of the mathematical sciences; and if we are to explain the cosmos, we must begin with the ultimate structural energies of matter.

"We can, however," says Miss Clerke, "gather one sufficiently definite piece of information regarding the history of the cosmos. All the inmates of the heavens, stellar and nebular, represent quite evidently the débris of a primitive rotating spheroid. Its equator is still marked by the galactic annulus (*i.e.* the ring of the Milky Way), its poles by a double canopy of white nebulæ. The gyrating movement which it once possessed as a whole doubtless survives in its parts, but ages must elapse before the fundamental sidereal drift can be elicited."

With all due deference to Miss Clerke, the information is *not* "sufficiently definite," but still the idea is surely magnificent enough to be true.

One thing *is* certain, that space is full of millions and millions of shining suns, wherever they came from and however they were evolved, and that there are millions and millions more of dead, dark stars we cannot see. One is apt to forget the dead, dark stars ; but they far outnumber those that shine—so much so that Sir Robert Ball says that luminous stars are but the glowworms and fireflies of the universe as compared with the myriads of other animals.

CHAPTER XII

THE EARTH

If the enormous nebulæ of space are but specks of foam on the mighty ocean of the ether, our world is less than a bubble of the foam. And yet the world is large enough for us, and in some respects it is an epitome of the Cosmos. We have scoured space for millions, and millions, and millions of miles, yet, if we except one or two unknown nebular gases, we have found no atom that is unrepresented in the Earth. The law of gravitation is exemplified as well by the Earth's orbit as by the orbit of the most colossal star, and no doubt the general process of cosmogony is seen as well in the Earth's development as in the evolution of some gigantic nebula. Anyhow, the Earth is to us the most interesting of all the spheres, and we have found out a good deal about it since the days when it was supposed to be upborne by an elephant on a tortoise, and since the days when it was believed by the Greeks and Romans to end at the Pillars of Hercules.

For centuries the world was considered flat; for centuries it was considered the hub of the universe, and crystal spheres and other machinery were invented to carry the Sun and the planets round it. It was only natural; and the first men who allowed their reason to give the lie to their senses and to their common-sense, and to assert that the Earth spun on its axis like a top and whirled round the Sun, must have had almost incredible mental force and courage.

Even after the heliocentric idea had been promulgated, even after Pythagoras and Archimedes and Ptolemy had adumbrated the truth, conservative mankind still clung to its old belief, and not for many hundreds of years did the heliocentric doctrine become the belief of thinking men. Not till Copernicus, in 1543, published his famous work, in which he taught that the Earth spun on its axis and revolved round the Sun—not till then had the doctrine any grip on the mind of man. Even then it had to fight for its existence. Lord Bacon would have none of it, and to the Church it was anathema. On March 5th, 1616, the Church decreed: "And whereas it hath also come to the knowledge of the said Holy Congregation that the false Pythagorean doctrine of the mobility of the earth and the immobility of the sun, entirely opposed to Holy writ, which is taught by Nicholas Copernicus, is now published abroad and received by many : In order that this opinion may not further spread, to the damage of Catholic truth, it is ordered that this and all other books teaching the like doctrine be suspended, and by this decree they are all respectively suspended, forbidden, and condemned."

Later, as is well known, Galileo Galilei was compelled to recant and curse his abominable heretical doctrine that the Earth moved ; and even as late as 1751 the great naturalist Buffon had to publicly declare : "I abandon everything in my book respecting the formation of the earth, and generally everything which may be contrary to the narrative of Moses."

In this twentieth century, however, the movement of the Earth and its position among the other planets is a matter of common knowledge.

We will now give a brief sketch of what is at this time known or believed about the Earth. The Earth is now known to be one of a group of planets which spin on their axes and revolve round the Sun, and which are named collectively the *Solar System*. All the planets of the system revolve more or less in the same plane, and there is little doubt that millions of years ago they were once mingled in a nebula, and were evolved according to some one of the nebular hypotheses we have already described. The principal members of the solar system are Mercury, Mars, the Earth, Venus, Jupiter, Saturn, Uranus, and Neptune. The innermost planet is Mercury and the outermost Neptune, and the others come in succession in the order in which we have named them, the Earth accordingly spinning round the Sun between Mars and Venus.

The Earth is about 8000 miles in diameter : it is larger than Mercury and Mars, and about the same size as Venus ; but compared with the outer four planets it is only a pigmy, and compared with the Sun it is a midge to a football. Jupiter is more than a thousand times, and the Sun more than a million times the size of the Earth ; and we may mention, *en passant*, that there are many stars in space much larger than our Sun. The Earth cannot, therefore, claim to be very big, and is hardly big enough to be the hub of the universe. But it has a good deal of pace ; it not only spins on its axis, but it yearly runs 583,000,000 miles round the Sun, at the rate of eighteen miles a second—that is to say it moves almost a hundred times as fast as a bullet from a rifle, and more than a thousand times as fast as an express train. That is certainly a good pace, yet Mercury and

Venus both outstrip it ; and though Neptune does not go nearly so fast, it describes an orbit twenty-seven or twenty-eight times as long.

A remarkable thing about the solar system is its isolation in space. "Our solar system," says Sir Robert Ball, "forms a little island group, situated at almost incomprehensible distances from the stars. The solar system is isolated from its neighbours just as a rock a few yards square in the middle of the Atlantic would be isolated from the coasts of Europe and America."

Yet the solar system is not fixed like a rock : the Sun and its retinue of planets are constantly moving through space to a certain point in the constellation of Hercules. Every two days it is about a million miles nearer this point, and at the present rate of progress we shall reach the constellation of Hercules in about a million years.

So much for the Earth in its social relations ; we will now consider for a moment its individual characters and its life history. When was it born ? What has it done since birth ? How old is it ? How was it shapen ? What is to become of it ?

The manner of its birth we have already considered ; but *when* was it born ? We do not now believe that it was born in the year 4004 B.C., but the date of its birth we do not know.

Certainly it had a separate existence millions of years ago. It has been calculated by Professor G. H. Darwin that it is at least fifty-six million years since the Earth bore her only child, the Moon.

At the time the Earth bore the Moon it was a molten mass, probably pear-shaped, for reasons we have already explained, and surging with great tidal waves produced by the attraction of the Sun; and the theory is that eventually the tugging of the Sun tore away a great piece of molten metal twenty-seven miles in depth, which since then has rotated round the Earth as the Moon. The Earth was spinning at a tremendous pace then, six or twelve times as fast as now; and since the Moon revolved round it every three or four hours, and was only ten or twenty thousand miles away, the tides in the molten masses of the Earth and Moon must have been very great.

Soon after bearing the Moon, the Earth acquired a solid crust, which must at first have had a temperature of 1200° C. At this stage all the water now on the face of the Earth may have existed as a deep, dense atmosphere of a steam, which must have exercised great pressure on the thin crust of the Earth, and may have helped with the Moon to form the beds for the coming oceans. When the temperature of the crust fell to 370° C.

the steam would begin to condense, and soon the surface of the world would show lakes and seas of hot water. Dr Osmond Fisher has suggested that the bed of the Pacific Ocean is the scar left where the Moon was torn off.

All this time the Earth must have been the scene of continual cataclysms. Think of the molten mass seething and surging as it spun! How often must its incipient crust have been cracked and broken by the volcanoes below, by the tugging of the Moon and Sun above, by the tidal waves of the turbulent ocean of steam! Think, later on, of the hot rain, of the wild steaming seas, of the continual earthquakes in the contracting, crumpling, unstable crust! It must have been a pandemonium!

Réclus (*The Earth*) gives the following vigorous description of the beginnings of ocean and atmosphere: "When the temperature was lowered sufficiently to enable them to pass from a gaseous to a liquid state, metals and other substances would fall down in a fiery rain on the terrestrial lava. Next, the steam, confined entirely to the higher regions of the gaseous mass, would be condensed into an immense layer of clouds, incessantly furrowed by lightning. Drops of water, the commencement of the atmospheric ocean, would begin to fall down towards the ground, but only to volatilise on their way and again ascend. Finally, these little drops reached the surface of the terrestrial scoria, the temperature of the water much exceeding 100°, owing to the enormous pressure exercised by the heavy air of these ages; and the first pool, the rudiment of a great sea, was collected in some fissure of the lava. This pool was constantly increased by fresh falls of water, and ultimately surrounded nearly the whole of the terrestrial crust with a liquid covering; but at the same time it brought with it fresh elements for the constitution of future continents. The numerous substances which the water held in solution formed various combinations with the metals and solids of its bed; the currents and tempests which agitated it destroyed its shores, only to form new ones; the sediment deposited at the bottom of the water commenced the series of rock and strata which follow one another above the primitive crust.

"Henceforward the igneous planet was externally clothed with a triple covering, solid, liquid, gaseous; it might therefore become the theatre of life."

Yet still the moulding of the planet by fire, and water, and ice, went steadily on, and sedimentary rocks fifty miles deep seem to prove that the sea has been at work for over twenty-six million years, probably very much more—some have estimated it at a thousand million.

And now the Earth has attained to a placid, rotund respectability, it has driven the Moon 264,000 miles away; its waters are cool, its crust is solid, it takes twenty-four hours to turn round, and only occasional little earthquakes and volcanoes serve to remind it that it has had a past. Yet still its heart is hot, and the crust between us and cauldrons of molten metal is only about fifty miles thick—not thicker, in proportion, than the skin of an apple.

It is usually assumed that the sea was at one time in the form of an atmosphere around the world, and that when it condensed the present atmosphere was left behind; but to the writer both assumptions seem rather rash. The nitrogen of the atmosphere may quite well be considered a by-product left over from the chemical combinations of molten mass of the world; but how about oxygen, carbonic acid, and water? How did they escape occlusion in the cooling slag of the Earth's crust, or how did they fail to enter into chemical combination with the rocks of the Earth? How did these gases escape from the heavy, dense vapours and rains of iron? How was water formed in such quantities? Do we find water or vapour in the other young atmospheres, *e.g.* of white nebulæ? These and many other questions seem to require answer before we can rest satisfied with the ordinary theory of the production of the atmosphere. To us it seems much more likely that the water and carbonic acid were a gradual product of volcanic action, and that a great part of the oxygen was later in origin, and was formed by the chemical action of plant-life.

Wherever there are volcanoes, hydrogen is ejected and steam is formed; and it is at least suggestive to find that the great seas are ringed with volcanoes. No doubt, too, the ocean-beds, where the crust of the Earth would be thinner, were also sites of volcanic eruption; and such a multitude of volcanoes in full action for a few million years could easily account for most of the water in the sea. It is very likely that in the early days of the Earth volcanoes were much more plentiful and active than now. We find in the Moon twenty thousand or thirty thousand extinct volcanoes (some with craters 15,000 feet high), and it is quite possible that at one time the Earth had volcanoes as numerous and vigorous. It is true that the usual theory supposes that the steam of volcanoes is caused by a leakage from the sea into the hot crust of the Earth; but considering the pressure and heat of the crust, such leakage is surely unlikely.

The ejection of carbonic acid by volcanoes is a phenomenon still better known, and even from springs and from the craters of dead volcanoes considerable amounts of carbonic acid are given off. The Grotto of Dogs at Solfatara is well known ; and there is a valley in Java named the Valley of Death because of the amount of carbonic acid which arises in a certain deep bosky hollow. The carbonic acid issues so copiously that tigers, deer, and wild-boar are frequently suffocated. In Western America there is a similar dell called Death Golch, where grizzly bears, elk, squirrels, and other animals frequently perish. On the shores of the Laacher See there is a spot equally perilous. And no doubt all over the world carbonic acid is excreted in large quantities. Even mineral springs represent a large output. Dr Phipson calculated that a small chalybeate spring near Naubau, in the principality of Waldeck, discharged about half a hundredweight in twenty-four hours, and there are thousands of such springs.

There can be no difficulty at all, then, in believing that a large part of the atmosphere and of the ocean was not residual but excretory in origin, and there can be little doubt at all that in the Carboniferous period the atmosphere was much richer in carbonic acid, and that the carbonic acid acted like the glass of a hothouse and increased the Sun's heat.

The thickness of the Earth's crust is supposed to be only about fifty miles, yet the tension of the globe is so great that the whole mass is more rigid than steel. The nature and condition of the material within the crust is unknown, but it is certainly intensely hot. Not only have we volcanoes to prove this, but experiments with borings show that the temperature of the Earth increases about 1° F. for each 70 or 80 feet we penetrate it. This fact would make us suppose that the centre is fluid, but there are other facts that make such fluidity doubtful. We do not really know what would happen to hot matter at the enormous pressure existing in the centre of the Earth, and it is quite possible that at such pressures even intensely hot matter might remain solid, and melt only with reduction of the pressure.

Sartorius von Waltershausen and Hopkins think that there "are no actual central fires, but only internal seas of red-hot molten matter scattered about in various parts of the inside of our planet, situated not far from the surface of the Earth, and separated from one another by masses of solid strata."

Attempts have often been made to estimate the age of the Earth by the amount of heat it has lost, but the discovery of radium in the crust of the Earth has quite destroyed the value of these calculations, and Lord Kelvin's estimate that it is only about twenty million years since the solidification of the Earth is no longer accepted.

The discovery of radium has also greatly altered the prospects of the Earth's life. The Earth must depend for life on the heat of the Sun ; and on looking into the question of the Sun's expenditure of heat, physicists found it difficult to understand how it had radiated heat so long, and came to the conclusion that it could not continue to do so much longer. It was calculated that even if it consisted of pure carbon it would burn out in four thousand years. Mayer suggested that swarms of meteorites rushing into the Sun might have helped to maintain the heat of the Sun in the past, and might help to maintain it in the future ; but further consideration of this theory showed that it could not be correct, and that even if it were, an incredibly huge supply of meteorites would be necessary, for even if the Earth itself ran into the Sun, the Sun's life would not be greatly lengthened. Helmholtz made a more satisfactory suggestion, namely, that the Sun's heat was augmented by the continual contraction of its mass ; but even so, it would have little heating power at the end of seventeen million years, and could not have been effectual for more than ten million years back. Now, geologists required at least twenty-six million, and possibly as much as a thousand million, years to account for the sedimentary strata. Accordingly, there must have been some other source of heat, and this other source of heat is now believed to be explosive compounds or atoms in the Sun, which explode with a force comparable to the energy of decomposition of radium. "We may therefore imagine," says Arrhenius, "the interior of the Sun charged with compounds which, brought to the surface of the Sun, would dissociate with an enormous evolution of heat and an enormous increase of volume. These compounds have to be regarded as the most powerful blasting agents, in comparison with which dynamite and gun-cotton would appear like toys. . . . It thus becomes conceivable that the solar energy—instead of holding out for four thousand years, as it would if it depended upon the combustion of a solar sphere made out of carbon—will last for something like four thousand million years. Perhaps we may further extend this period to several billions." Even in four thousand million years a good deal may happen.

As soon as the Earth obtained a suitable crust, a suitable atmosphere, and a suitable temperature, animal and vegetable life became possible; probably both soon appeared. The beginning of organic life on the Earth is usually dated about forty million years ago. The first forms of life were low marine forms—foraminifera, amœbæ, sponges, and such-like, and only a hundred thousand, or at most three hundred thousand, years ago man appeared. Between the appearance of foraminifera and the appearance of man many strange creatures lived. For about six million years the ichthyosaurus, dinosaurus, plesiosaurus, and such-like monstrosities flourished; and even within the last three hundred thousand years mammoths and woolly rhinoceroses trotted about Europe.

The development of organic life is the most wonderful feature of the Earth. Probably on none of the other planets of our system are there trees and flowers, and birds and beasts. Even the Moon, daughter of the Earth, has no organic life. So many are the conditions required for organic life, as we know it, that some hold that only on the world does animal and vegetable life exist, and it is quite possible that that is so. Still, when we think of the millions and millions of planets in space, and when we remember that they have been made by the same processes as the Earth, out of the same atoms, it is strange if none of them have been given conditions so similar to the conditions of the world as to result in similar organic life. Even if the conditions are far from identical, yet they may favour some kind of conscious or unconscious molecular growth and activity comparable to the animals and plants of the world.

On a question so speculative there are naturally different opinions.

"Supposing," wrote Tyndall, "a planet carved from the Sun, set spinning round an axis and revolving round the Sun at a distance from him equal to that of our Earth, would one of the consequences of its refrigeration be the development of inorganic forms? I lean to the affirmative."

Dr H. H. Turner, Professor of Astronomy in the University of Oxford, stated in a lecture at the Royal Institute: To the question, Are the planets inhabited? his answer would be that, in the absence of evidence, he did not know, but that he felt pretty sure they were, because they were so like the Earth in so many particulars that they might be supposed to be like it in this one.

M. Camille Flammarion wrote in *Knowledge*: "Yes, life is universal and eternal, for time is one of its factors. Yesterday the Moon, to-day the Earth, to-morrow Jupiter. In space there are both cradles and tombs."

On the other hand, Dr A. Russell Wallace, who has made a special study of the question, is strongly of the opinion that it would be almost impossible for such a consilience of factors favourable to life as are formed on the Earth to be repeated on any other planet. He says, in his work, *Man's Place in the Universe* : " The combinations of causes which lead to this result (life) are so varied, and in several cases dependent on such exceptional peculiarities of physical constitution, that it seems in the highest degree improbable that they can *all* be found again combined either in the solar system or even in the stellar universe" ; and he points out that the various factors that render life possible are interrelated in a very complicated and delicate way.

CHAPTER XIII

LIFE

WHAT is life? That is the question of questions. Is life a form of energy quite distinct from those forms of energy we see in chemical mixtures, in heat, and electricity, or is it simply a particular manifestation of these energies? Is the distinction between the living and the dead a real or only an apparent difference?

In early times, as we have seen, the distinction was not nearly so firmly drawn, and in all times there has been an instinct to attribute to matter some sort of life or sensation. The atoms of Lucretius had "free-will"; the monads of Leibnitz had perception and apperception. To Schopenhauer matter was *will* made perceptible and visible. Haeckel endowed his atoms with sensation and will, and W. K. Clifford considered them bits of mind-stuff.

What are the meaning of the distinctions drawn between the living and the dead, and of this instinct, nevertheless, which attributes life to dead matter? What has the modern atomist to say? What light have recent discoveries thrown on the question?

Certainly no one believes in "that invention of the human intellect, passive and spoliated matter." Certainly, matter is as active as an ant-hill; but how about life? But has matter in all its shapes some amount of these particular activities which we have been accustomed to attribute only to its special forms —plants and animals? And can it from atomic energy produce these functions we have been accustomed to call *vital*, and to consider superadded?

In the first place, *is* there such a gulf between the organic and the inorganic, between the living and the dead, and *are* any atoms dead? Can any atoms be considered dead which contain such prodigious, almost infinite, energy? Can atoms be considered dead when each atom is a solar system, whose members move with almost the velocity of light, and are capable of penetrating some inches of steel? To call them *dead* seems a misuse of language. Is not their activity the very essence of life?

When the atoms were considered dense, inert particles, it was difficult to see how even they could *originate* life; but now that we know that a door-nail is not altogether dead, but, in a sense at least, very much alive, there is little difficulty in believing that atomic and vital energies are akin—there is little difficulty in believing that the functions of life may be produced by the energies of the common or garden atom.

Archimedes, more than two thousand years ago, said, "Give me matter and I will build the world."

Newton, with true prophetic prescience, wrote in his *Principia*: "Would that the rest of the phenomena of nature could be deduced by a like kind of reasoning from mechanical principles, for many circumstances lead me to suspect that all these phenomena may depend upon certain forces, in virtue of which the particles of bodies, by causes not yet known, are mutually impelled against one another, and cohere into regular figures, and repel and recede from each other."

So thought Archimedes and Newton, and shall we who have seen the beating heart of the atom have less faith?

Let us look into the matter. What is life? No definition is entirely satisfactory. Herbert Spencer's definition "Life is the continuous adjustment of internal relations to external relations" is one of the best. Taking this definition, it may be said that the molecules of dead matter, so called, do not react to external stimuli, and that there is thus a great gulf between living and dead matter.

But the molecules of dead matter *do* react to stimuli. Many so-called dead substances are as sensitive to touch as the human skin, and as mobile as the human muscles. We measure heat and cold by the movements of the molecules of mercury and alcohol ; and though we may not be able to see the movement of a more solid metal under slight changes of temperature, *e par si muove*. "The sensitiveness of matter is such that a variation in temperature of one millionth of a degree suffices to modify its electric resistance in a fashion appreciable by experiment." And metals are sensitive not only to changes of temperature, but also to electric changes. If a steel wire be touched with the tip of a finger, its molecules are altered by an electric current ; and if the faintest ray of light fall upon a delicate platinum wire known as a *bolometer*, a change is at once produced in the molecular structure of the wire. Even such a complex vital phenomena as the electrical response of the retina to light can be reproduced in an artificial metallic retina, while in wireless telegraphy the response of steel filings to Hertzian electric waves started hundreds of miles away surely indicates a sensitiveness which no living sense-organ can surpass.

Matter must thus be admitted to be "endowed with an unconscious sensibility which cannot be approached by the conscious sensibility of any living being."

Not only so, but metals may be poisoned, or fatigued, or depressed, or stimulated, just like living organisms. A scientist, who has specially investigated the subject, has shown that sodium carbonate has a stimulating action and potassium bromide a depressant action on certain metals; and he has also shown that the electrical excitability of metals may be diminished by such poisons as veratrine, and abolished by such poisons as oxalic acid, and that fatigue in metals runs the same course as fatigue in living tissues. In fact, there is a complete parallelism between the phenomena of response in the organic and inorganic.

"Living response is found to be only a repetition of responses seen in the inorganic. . . . Nowhere in the entire range of these response phenomena—inclusive as that is of metals, plants, and animals—do we detect any breach of continuity . . . . there is no necessity for the assumption of vital force . . . . these things are determined, not by the play of an unknowable and arbitrary vital force, but by the working of laws that know no change, acting equally and uniformly throughout the organic and the inorganic worlds."

And we find in dead matter many other qualities and characters suggestive of life.

Take crystals, for instance. They have definite characteristic forms, and if they are broken they have power to repair themselves. Moreover, it has been shown that crystals show a cycle of growth, and evolve like living tissues. At first they have a cellular-like structure, then they become fibrous, and finally clear and crystalline. More wonderful still, it is found in some instances that crystals will not form in a solution unless a formed crystal be added to the fluid, to act, so to speak, as a parent of the new crystals.

Not even *ferments* serve to differentiate the living from the dead. Ferments are extraordinary albuminous substances formed by living bodies which have the power of breaking up compound substances without themselves undergoing any apparent change. The ferment *amylopsin*, for instance, formed in the sweetbread gland, has the power of breaking up starch, and the ferment *pepsin* formed in the glands of the stomach has the power of breaking up proteids. Even in this province of ferments, dead matter competes and compares.

The molecular structure of matter is, as we have said, really very mobile. The same element may appear either in a liquid, or a gaseous, or a solid form ; water may be either steam, or water, or ice, or snow ; carbon may be either a lump of charcoal or a diamond. A metal may assume, among other forms, an anomalous form known as colloidal. By dipping the metallic poles of an induction coil in distilled water and passing sparks between them, the water becomes coloured and acquires special properties due to the presence of the particular metal in what is called its *colloid* state. A colloid metal cannot be seen, and its properties in nowise resemble those of the metal in its ordinary state, but partake much more of the nature of ferments formed by living organisms. Thus colloid platinum decomposes oxygenated water, as do certain ferments of the blood, and transforms alcohol into acetic acid, as does the mycoderma aceti. Colloidal iridium, again, decomposes formiate of lime into carbonate of lime, carbonic acid, and hydrogen, as do certain bacteria. More curious still, bodies which, like prussic acid, iodine, etc., poison acid, iodine, etc., poison organic ferments, "paralyse or destroy in the same manner the action of colloidal metals." The colloidal ferments, in fact, may be chloroformed or poisoned just like living germs.

And the atoms not only have such vital qualities, they even, as we have seen, *evolve*, and evolve (as Democritus and Lucretius maintained) apparently in accordance with the law of the survival of the fittest. We have seen how radium has been caught in the act of breaking down and changing into other elements, and this is nothing less than an instance in the inorganic world of the extinction of the unfit. The corpuscles, the ultimate particles of matter, have tried the combination *radium*; the combination proves unstable, and the atom changes form till a form helium appears, which is fitted to survive. Other atoms are found to be in the same state of unstable experimental evolution; and one, *thorium*, is found to pass through half-a-dozen forms before it reaches a form fitted to survive. No doubt there are as many extinct atoms as extinct animals; and the eighty or so elements now existent have been produced by the ordinary evolutionary law of the survival of the fittest. Nay, more; Professor J. J. Thomson has lately shown that it is possible to modify the evolution of an unstable atom by varying its environment, so that the atom, like the animal, is a product of heredity, variation, and environment, and can, like domestic animals, be artificially bred.

We cannot, therefore, find any division between the functions of the so-called living and the so-called dead.

As long ago as 1849 Mulder, in his *Chemistry of Vegetable and Animal Physiology*, declared: "If anyone fancies that it is more easy to conceive of the production of a crystal than of a texture composed of fibres, globules, and cells, that is, of any organ—of the origin of a precipitate than of a primary fibre—of the state in which crystallised sugar exists in solution than of the rudiments of organs in the embryo—he egregiously errs."

"I try," says Professor William Keith Brooks, of the Johns Hopkins University, "to treat all living things, plants as well as animals, as if they may have some part of a sensitive life like my own, although I know nothing about the presence or absence of sense in most living things, and am no more prepared to make a negative than a positive statement. While it is nonsense to regard trees and rocks and lakes as endowed with mind, it is nonsense because we know nothing about it, and not because it is untrue; for it is no less nonsense to assert that stones are unconscious than to assert that they are conscious."

"The chemical processes of life," says Carl Synder, "are no whit more mysterious than the chemical processes which produce salt, or sugar, or glass, or result in the burning of coal in the grate." "To-day," says Jacques Loeb, "everybody who is familiar with the field of chemical biology acknowledges the fact that the chemistry of living matter is not specifically different from the chemistry of the laboratory. . . . A measurement of the quantity of CO formed and the amount of heat produced gives approximately identical results in the case of a burning candle and a living guinea-pig."

"The magnet," says Haeckel, "that attracts iron filings, the powder that explodes, the steam that drives the locomotive are living inorganics; they act by living force as much as does the sensitive mimosa when it contracts its leaves at touch, or the venerable amphioxus that buries itself in the sand of the sea, or man when he thinks."

CHAPTER XIV

THE ORIGIN OF LIFE—"NATURA NON FECIT SALTUM"

It cannot, thus, be held that between living beings and dead matter there is a great gulf fixed. Both are made of the same *urstoff*; both are responsive to external stimuli, and both participate in activities commonly called vital.

Still, between the living and the dead there *is* a difference. Plants and animals reproduce their kind; plants and animals assimilate, *i.e.* change other substances into the substances of their tissues; and this is the case even in the very lowest forms of vegetable and animal life. There is another difference too—a difference of the greatest importance—plants and animals, in the twinkling of an eye, and under a stimulus apparently completely inadequate, completely change their chemical and mechanical characters and become, as we say, *dead*, while the chemical and mechanical properties of the inorganic know no such cataclysms.

And the question is—Can matter with these vital qualities be produced, by ordinary molecular and atomic laws, from ordinary so-called dead atoms; or are these special qualities of life, qualities quite beyond the potentialities of atoms and molecules and the laws of matter?

In view of the corpuscular, atomic, and functional relationships we have already shown—in view of the enormous intra-atomic energy—in view of the continuity of nature—there is surely a strong presumption that life in its plant and animal manifestations was produced by a process of gradual evolution from the inorganic, under the influence of the ordinary laws of matter; but have we any proofs of the evolution? Where and when did life begin, and how? What molecules were the first to reproduce their like, and to exist in a constant state of breaking down and building up? If life *can* be produced by the dead organic or inorganic, *is* it *still* evolved, or was it evolved only under conditions no longer present?

These are difficult questions, and science has not quite succeeded in answering any of them.

The question whether life can be evolved at the present day, under present cosmic conditions, from dead matter, has been a question of debate for thousands of years.

Thales, the first Greek philosopher, thought that life originated in water. Anaximander thought that mud, "the moist element," as it was evaporated by the sun, was the source of organic life. Aristotle, in the true Aristotelian manner, affirmed that "every dry body becoming moist, and every moist body becoming dry, engenders animals."

All down the centuries, a belief in the spontaneous generation of life persisted in a gross, sometimes in a subtle, form.

In the sixteenth century the belief assumed wild forms. A learned Italian Jesuit, Philippe Buonanni, for instance, taught that when certain timber wood rotted in the sea it produced worms; which, again, produced butterflies; which, again, produced birds. And Van Helmont, a very eminent physicist, gives the following recipe for producing scorpions:—

"Scoop out a hole in a brick. Put into it some sweet basil, crushed. Lay a second brick upon the first so that the hole may be perfectly covered. Expose the two bricks to the sun, and at the end of a few days the smell of the sweet basil, acting as a ferment, will change the herb into real scorpions."

In the eighteenth century, after Redi had shown that maggots were not developed in meat unless flies were allowed to deposit their eggs in the tissues, the belief in spontaneous generation began to be shaken, and was held in a more qualified form. Buffon, for instance, held that there were certain primitive and incorruptible particles common to animals and to vegetables which could mould themselves into various organic forms. When death occurred these particles became free, and, "ever active, they worked the putrefied matter, appropriating to themselves some raw particles, and forming, by their reunion, a multitude of little organised bodies, of which some, like earthworms and fungi, seem to be fair-sized animals or vegetables, but of which others, in almost infinite numbers, can be seen only through a microscope." And something like this was the common belief of the time.

In the middle decades of the nineteenth century the controversy over the question of the origin of life became acute ; and finally, after many battles, the authority and brilliant experimental genius of Pasteur convinced almost the whole scientific world that life, nowadays at least, never arises save from preceding life. In 1864 Pasteur, lecturing at the Sorbonne before a large and distinguished audience, spoke the following dramatic words :—

"And therefore, gentlemen, I could point to that liquid and say to you, 'I have taken my drop of water from the immensity of creation, and I have taken it full of the elements suited for the development of inferior beings. And I wait, I watch, I question it, begging it to recommence for me the beautiful spectacle of the first creation. But it is dumb, dumb ever since these experiments were begun several years ago ; it is dumb because I have kept from it the only thing man cannot produce from the germs which float in the air—from *Life* ; for life is a germ, and a germ life.' Never will the doctrine of spontaneous generation recover from the mortal blow of this simple experiment."

Such was the weight of Pasteur's authority that from that day to this very few have ventured to suggest that life still can and does arise from dead matter. Darwin, Huxley, Tyndall, Spencer all believed that life must at one time have originated from dead matter—that it was the product of "the free play of the forces of atoms and molecules," but under conditions which are no longer existent, and which cannot be reproduced ; and most thinkers of recent years have held the same opinion.

Still the question is not settled, and there may be said to be still three theories in the field :—

(1) That life has originated, and *still does originate*, from dead matter.

(2) That life did, æons ago, originate from dead matter, but that it *no longer can do so.*

(3) That life was brought to the world from another planet.

The great exponent of the first theory, that life has originated and still does originate from dead matter, is Dr Bastian, who has been working for thirty years at the problem of the origin of life. Dr Bastian claims that life may originate in organic and even in inorganic fluids without antecedent life. His experiments with inorganic saline solutions are particularly interesting. He used solutions of sodium silicate, ammonium phosphate, dilute phosphoric acid, with distilled water, or of sodium silicate, and liquor of pernitrate of iron, with distilled water. He heated these saline solutions in hermetically sealed tubes to over 250° F., and yet thereafter found that numerous organisms, bacteria, yeast-cells, etc., appeared in the tubes. In his book, *The Evolution of Life*, he says :—

"But, as we have seen, such bodies, as well as vibriones, cocci, streptococci, torulæ, and other germs of fungi, have appeared within our experimental vessels when they have been heated for from ten to twenty minutes to temperatures ranging from 115° to 130° C. (239° to 266° F.). These organisms which we have seen to be living —which developed and multiplied—must, therefore, have been evolved *de novo*. What other answer is it possible to give ?"

No one can read Dr Bastian's works carefully and impartially without being struck by the logical and scientific strength of his arguments, and it is very astonishing that results so remarkable, obtained by a worker at once a scientist and a thinker, should have attracted so little attention. When Butler Burke, a few years ago, declared that living organisms were produced in soup by the action of radium, his statement caused quite a sensation, and yet Dr Bastian's results, which are equally startling, have passed almost unnoticed. Yet, till his results have been put to the test of independent experiment, the question must be considered open, and we are quite at liberty to believe, if we choose, that the spontaneous production of life from inorganic materials "may be taking place on the earth without cease, let us say, under the tremendous pressures existent at the bottom of the sea, or in warm springs of peculiar chemical content," and that "in forty or fifty years a Berthellot or a Fischer may be producing endless varieties as readily as they do new chemical varieties of sugar now."

The theory that life did originate, æons ago, from dead matter, but can no longer do so, is the theory now held by most scientists. How or when they do not pretend to say, more than that when the world cooled down sufficiently to make life possible, certain atoms of carbon, hydrogen, oxygen, and nitrogen leapt together, and, in the conjunction, acquired the special energies and activities that we call life. In the early days, when the atoms clashed together, when the enormous intra-atomic energy was unfettered and unconfined, there is no saying what may have happened. "If," says Huxley, "it were given to me to look beyond the abyss of geologically recorded time to the still more remote period when the earth was passing through physical and chemical conditions, which it can no more see again than a man can recall his infancy, I should expect to be a witness of the evolution of living protoplasm from non-living matter." "Who," asks Tyndall, "will set limits to the possible play of molecules in a cooling planet?" Doubtless, physical conditions were very different then, when the world was cooling; and it is quite possible to hold that life originated then, and ceased to originate when the conditions altered. Spencer held it likely that life began "at a time when the heat of the earth's surface was falling through those ranges of temperature at which the higher organic compounds are unstable"; and he, Huxley, Darwin, and Tyndall all considered themselves "justified in supposing that natural causes are now no longer able independently to initiate this living matter, or protoplasm, as it is termed." Dr Saleeby considers this supposition of former more favourable conditions not only unjustifiable, but unwarrantable. "Now it happens to be true," he says, "that every difference between past and present conditions which physics and geology and chemistry can assert tends to the probability that if spontaneous generation is impossible now, it must have been a hundredfold more impossible a hundred million years ago. Yet, for some three decades, the great majority of biologists have been content to believe that spontaneous generation is impossible now, even though land, and sea, and sky are packed with organic matter under the very conditions which obviously favour life, as the all but omnipresence of life abundant to-day demonstrates, but that spontaneous generation was possible in the past when, by the hypothesis, there was no organic matter present at all, and when life had to arise in the union and architecture of such simple substances as inorganic carbonates."

This criticism seems fair, and yet life undoubtedly did arise from the inorganic; and if it *did*, and if it does not do so now, there *must* have been some favourable condition present then which is not present now, and of which we know nothing. It is quite true that we sterilise by heat, but it is also true that we incubate by heat; and what the chemical effects may be of a heat of 6000° C. or so we do not know, further than that it would cause a certain amount of corpuscular disintegration, and that some compounds, *e.g.* compounds of nitrogen and oxygen, both constituents of living tissues, are formed at very high temperatures.

It is not difficult to regard heat as *vis a tergo*, and to believe that, at a certain stage in the chemical combinations that took place *pari passu* with the cooling of the molten mass of the world, nitrogen, oxygen, hydrogen, and carbon leapt together, according to the ordinary laws of chemical affinity, into new combinations, with new far away mechanical consequences. We see every day the so-called dead atoms of our food put into new partnerships in our hearts and livers, and performing there functions quite different from those they performed in the meat and bread.

The atoms, however, were not supplied by meat or bread in the beginning, they were all in inorganic form ; and it may be asked where the atoms and molecules came from which went to the making of protoplasm. There seems some reason to believe that they were in solution in the warm water of the circumpolar seas.

It is an interesting and suggestive fact that the salts in solution in the blood are almost identical with the salts of sea-water. As long ago as 1802

Lamarck wrote: "In the waters of the ancient world and at the present time very small masses of mucilaginous matter were collected. Under the influence of light, certain elements, caloric and electric, entered these little bodies. These corpuscles became capable of taking in and exhaling gases, vital movement began, and thus an elemental plant or animal sprang into existence."

As long ago as 1809 Oken speculated that every organic thing had risen out of sea-slime. "Every organic thing," he wrote, "has risen out of slime, and is nothing but slime in different forms. This organic slime originated in the sea, from inorganic matter in the course of planetary evolution. The origin of life 'generatio originaria' occurred upon the shores where water, air, and earth were joined." Again: "All life is from the sea; the whole sea is alive. Love rose out of the sea-foam . . . ." "Man also is the offspring of some warm and gentle seashore, and probably rose in India, where the first peaks appeared above the water. A certain mingling of water, of blood-warmth, and of atmosphere must have conjoined for his production, and this may have happened only once and at one spot."

Bastian claims, as we have said, to have found living germs produced in various inorganic solutions simply by a synthesis of the necessary atoms.

And there is nothing inherently improbable in this. Living molecules can certainly feed on inorganic salts, and by inorganic salts can be repaired; and the same worsted that can darn a stocking can make one.

It is usually assumed that the first life must have been vegetable life, because only plants can assimilate nitrogen and carbon in inorganic form; but plants can assimilate only after they are made, and by virtue of their *make*, so that the difficulty of the first formation of living matter is not diminished by calling it vegetable. The first combination of nitrogen, oxygen, carbon, and hydrogen, able to build itself up again as it broke down, was probably able to obtain its carbon without the aid of that *very complex substance* called chlorophyll. It is probable, too, that first molecules were not grouped in the structural complexity now seen in cells, but in much simpler formation.

That, then, is the second theory, which may be held, of course, in conjunction with the third.

The third and last theory, that life was brought to the world from another planet—from "the moss-grown ruins of another world"—suggested by Sales, Guyon de Montlivault, H. E. Richter, and Ferdinand Cohn, was propounded in particular by two great men, Lord Kelvin and von Helmholtz. The theory suggested that meteors had been the messengers of life—that germs of life had been brought to earth tucked away in the interstices of meteoric stones. At first the objection was made that any living germs in the pores of the meteor would be destroyed by the great heat generated as the meteor flashed through the earth's atmosphere, but the objection is not valid, since it has been found that only the surface of the meteor is fused, and that its interior is comparatively cool. Granted that life began at an earlier date on another planet, granted that meteors are fragments of planets, it is quite possible that life was brought to earth in the womb of a meteor. But even if we accept this theory of the origin of life, we only shift the problem to another planet.

Kelvin held that "Dead matter cannot become living without coming under the influence of matter previously alive. This seems to me as sure a teaching of science as the law of gravitation." Since, then, it was quite evident that life had at one time been unknown on the world, it followed that it could never have appeared unless created by a miracle or imported. Kelvin chose the alternative of importation, and, in a presidential address to the British Association in Edinburgh in 1871, he declared his creed thus :—

"When two great masses come into collision in space, it is certain that a large part of each is melted; but it seems also quite certain that in many cases a large quantity of débris must be shot forth in all directions, much of which may have experienced no greater violence than individual pieces of rock experience in a landslip or in blasting by gunpowder. Should the time when this earth comes into collision with another body, comparable in dimensions to itself, be when it is still clothed as at present with vegetation, many great and small fragments carrying seed, and living plants, and animals would undoubtedly be scattered through space. Hence, and because we all confidently believe that there are at present, and have been from time immemorial, many worlds of life besides our own, we must regard it as probable in the highest degree that there are countless seed-bearing meteoric stones moving about in space. If at the present instant no life existed upon this earth, one such stone falling upon it might, by what we blindly call *natural* causes, lead to its becoming covered with vegetation."

Arrhenius has suggested a modification of this meteoric theory. He suggests that living particles, the molecular combinations that exhibit the phenomena of life, are drifting about everywhere in space, under the pressure of solar radiation. He supposes that such light germs of life would be carried by the winds of a fertile planet of any solar system to the upper strata of its atmosphere, where they would meet with electrons (the same electrons which, as we have seen, cause the aurora borealis), and be charged with sufficient electricity to cause their repulsion into the realms of space. In space they would be driven by solar radiation towards the outer planets, or, meeting with streams of larger particles going towards the sun, might alight on an inner planet. (It is evident that if there are cosmic particles of life, they might easily be caught up by meteors, and thus Kelvin's and Arrhenius' theories are quite compatible.)

The objections to this theory, as Arrhenius himself sees, are many. In the first place, the germs would have to face the intense cold and desiccating dryness of space and the unimpeded ultra-violet solar rays; and even if they did happen to hit a planet, the chances are a million to one that it would not be a suitable planet or a suitable time—"never the place and the time and the loved one altogether." "It may take one million or several million years," Arrhenius admits, "from the age at which a planet could possibly begin to sustain life to the time when the first seed falls upon it and germinates, and when organic life is thus originated." But he explains: "This period is of little significance in comparison with the time during which life will afterwards flourish on the planet." Yes, but another comparison still must be made. The time on which life can flourish on a planet is very insignificant compared with the æons when it cannot—a mere momentary episode in its thermal history. Every germ, accordingly, which reaches an unsuitable planet or a suitable planet at an unsuitable time would be lost, and in time, by the law of averages (even taking no account of the germs which must perish in space), space would be depleted of germs. Nor could space be resown from fertile planets, since the germs would presumably evolve, and become more and more unfit to face such a journey as, say, the journey from our solar system to its nearest neighbour, Alpha Centauri.

But even admitting Arrhenius' or Kelvin's theories workable, they are unsatisfactory; for, in the first place, it is almost impossible for the mind to believe that the tremendously complex and intricate structure of living tissues composed of various changeable atoms, and indeed whose very essence is change, have existed, floating about in space, from all time, waiting for worlds to be ready to develop them. Further, it seems to us that a world in such *intimate* and *intricate correspondence* with a molecular complex as to be able to develop it from an amœba into a man would surely, in all probability, be able to make the comparatively simple beginning for itself.

It is much more likely that the molecular combinations of primitive plants and animals began by the ordinary chemical conjunction of atoms, under special conditions, to form special ferment-like combinations. Why any combination of carbon, hydrogen, oxygen, and nitrogen should have power of assimilative increase we cannot say ; but such increase is only a more elaborate instance of the accretion we see in inorganic substances, and of such interchange of atoms as we see in a flame.

CHAPTER XV

THE PHYSICAL BASIS OF LIFE

WHENEVER we find matter which assimilates and multiplies, we find it consists of a substance with a certain more or less definite chemical constitution, and this physical basis which shows the so-called vital functions is called *protoplasm.* Cows and cabbages, microbes and men, midges and mammoths are all made of this substance, and they all are able to multiply, and all are able to assimilate their food, or to weave the food atoms into this same substance. The atoms that make the machinery of life are only four—carbon, hydrogen, oxygen, and nitrogen. Usually in association with these we find also sulphur, phosphorus, iron, calcium, sodium, and a few other elements, but only the quartet carbon, hydrogen, oxygen, and nitrogen are *necessary* to make the compound which is able to unweave itself, as Penelope unwove her web, and then to build itself up again just the same from the atoms of quite dissimilar-looking substances. A man brings guano from some South American island and puts it beside the molecules of a rose, and the molecules of the rose take atoms from the guano and weave them into the warp and woof of petals, and stamens, and roots. A man burns up several pounds of his tissues by violent exercise, and he puts some cheese or some potatoes into contact with certain molecules in his stomach—the molecules of the so-called digestive glands—and the stomach molecules pull the molecules of the cheese or potatoes to pieces and rebuild them into protoplasm—into compounds containing carbon, hydrogen, oxygen, and nitrogen, in certain definite proportions.

Let us look for a moment at the atoms comprising the molecule of protoplasm. Oxygen, nitrogen, and hydrogen are all gases at ordinary temperatures. Carbon, again, is a solid at ordinary temperatures, and only at very extraordinary temperatures, a gas: it occurs in such different forms as graphite, charcoal, diamond, and in combination with oxygen it forms the colourless gas, carbonic acid gas. Carbon also has an extraordinary faculty of linking a number of atoms together and forming large molecules. Thus the carbon compound, stearine, has a molecule consisting of no fewer than one hundred and eighty-three atoms.

Oxygen is a most sociable element and weds on every opportunity, the wedding being often celebrated by visible flame, *e.g.* ordinary combustion. Nitrogen is what is known as an inert gas and weds only under compunction. It is also a constituent of gunpowder, dynamite, and most explosives. Hydrogen is a gas so light and active that the earth is unable to retain it, and it flies away into space. In combination with oxygen, hydrogen forms water.

Protoplasm is thus seen to consist of three remarkable gases and a remarkable solid. It is very strange to consider that there are about eighty elements, and that four, and only four, are essential to life. One would think that silicon, or gold, or silver might do as well as carbon, but they are quite useless ; without carbon, life cannot be. Why should these four elements have such a remarkable career ? We cannot tell ; but we can guess at least that the power possessed by carbon of linking atoms together may be useful ; that the explosive tendencies of nitrogen may give protoplasm its mobility, and that the chemical activity of oxygen must be serviceable. Whatever the reason, these four elements are the bearers of life.

Where do they come from ? They are found everywhere. The ocean, as we have seen, is oxygen and hydrogen combined. A considerable proportion of the air and of the crust of the earth is oxygen. Carbonic acid gas is belched by volcanoes and expired by plants, and bubbles in many mineral springs. There are thousands of tons of nitrogen in the air. Accordingly, the elements of life are plentiful and ready to hand.

The abundance and availability of the atoms that go to make protoplasm is a matter of much importance, which has been usually quite overlooked. Suppose gold *had* been an element necessary for the manufacture of protoplasm, where should we be? Suppose carbon had been utilisable only in its diamond form, how extensive would the fauna and the flora of the globe be? The universality and abundance of life is a matter of the universality and abundance of the elements that enter into its physical basis, and it is very remarkable that the seething turmoil of the cauldron of the molten world should have resulted in the emergence and emancipation of the very elements which protoplasm requires. It is very amazing that the steam of the stewpan, that the residual atmosphere, and that the breath of volcanoes should go to the making of microbes and men. By what calculation were the atoms so arranged as to have such a miracle-working remainder—such a magic scum, such a fairy film? Who can say!

We have looked for a moment at the atoms which compose protoplasm. Let us look now for a moment at the molecules they make. A molecule of water contains two atoms of hydrogen and one of oxygen ; a molecule of sulphuric acid contains two atoms of hydrogen, one of sulphur, and four of oxygen ; but a molecule of protoplasm is much larger than these, and contains no less than eight or nine hundred atoms, each of these, again, according to modern physics, being a veritable miniature solar system. The individual atoms, as we have seen, have no very remarkable properties, and in certain conjunctions and combinations they seem as stagnant as a stone ; yet conjoined and interwoven in the massive molecule of the protoplasm, and grouped together into the structures known as cells, they have the wonderful properties known as *vital functions*.

An individual molecule of protoplasm has probably as little *vital function* as the individual atoms of which it is composed : the physical basis of life is a contexture of molecules—a tissue of molecules, not massed together anyhow, but arranged in a complicated manner so as to show special structural features—a nucleus, etc.—when viewed through the microscope. The size of these molecular units of life varies ; but it has been calculated that the smallest cell known must contain at least 100,000,000 large molecules. A liver cell contains about 4,000,000,000 molecules ; and Professor McKendrick states that "it is reasonable from existing data to suppose that the germinal vesicle might contain a million of millions of organic molecules." Whatever the size of the cell, however, it has always structural and functional differentiation, and the powers of contractibility, assimilation, and reproduction. Reproduction is one of the most mysterious of the so-called vital functions. Every cell at some period of its life has the power of reproducing its like by a process of budding or division, and the so-called *germ-cells* of the multicellular organisms have the power when fertilised of initiating a process of growth and division which ends in the production of an individual composed of groups of coherent cells differing in appearance and in function.

Besides their special powers of assimilation, contraction, and reproduction, cells have great chemical energy. "In the infinitesimal liver cells," says Carl Snyder, "at least ten or twelve distinct ferments have been found manufacturing various kinds of sugars, and acids, and urea, and bile, and colour-stuffs ; they take up various poisons and render them harmless, bind up the acids with diverse substances to form others more complex, and in the meantime must see that they themselves get a proper supply of food and water and oxygen, and that all these are churned up in a state proper to assimilation.

"What is true of the liver seems equally true of all the other glands and organs of the body—the kidneys, the spleen, the pancreas—and for each of them there may be a dozen or more distinct ferments, each with a special and appointed work to do."

The physical basis of life, therefore, as we know it, is structurally, kinetically, and chemically a very complex thing. But still, be it recognised, its complexity in nowise contradicts its genetic or kinetic relations with the inorganic, since we have seen that even inorganic molecules have an intricate constitution and a complex mechanism.

Certainly the material of matter, dead or living, organic or inorganic, whether we regard it as electrons or atoms, is the same, and the motion is probably in every case of the same orbital character; and if we are evolutionists, there is nothing in our analysis of living matter to hinder us from believing "that the whole world, living or not living, is the result of the mutual interaction, according to definite laws, of the forces possessed by the molecules of which the primitive nebulosity of the universe was composed." To conceive of forces acting for millions and millions of years, and capable, by intricate and devious courses, of eventually evolving an organic molecule, and the combinations of molecules that make men and trees —to conceive of forces which, once set agoing in the nebula, could and must end in living beings, "so that a sufficient intelligence could from a knowledge of that vapour have predicted, say, the state of the fauna of Britain in 1869 with as much certainty as one can say what will happen to the breath in a cold winter day"—to conceive of forces working through vapour, and molten metal, and rocks, and volcanoes, to flora and fauna, may be difficult, but there is nothing in the nature of the material or in the complexity of the ultimate result to make the conception impossible.

CHAPTER XVI

THE ORGANIC EVOLUTION OF MAN

GRANTED that the organic was duly evolved from the inorganic, and that a cell such as we know now came sooner or later into being, what line did evolution take next?

Most biologists assume that the first organic matter was a cell—either a bit of green protoplasm or an amœba—and even those who see a hiatus between the organic and inorganic usually find evolution in the organic, once the organic is started, comparatively plain sailing.

From the first protoplasmic mass—so runs the modern biological creed—grew the two great stems, animals and plants, and these were divided and subdivided into branches by variation and selection until one twig is a mushroom and another twig a rose; until one twig is a starfish and another twig a man.

The organic evolution of man is undoubtedly one of the most interesting problems of science.

Biology affirms that man began millions and millions of years ago as a microscopic particle of protoplasm ; and that through variations in this and in its descendants, and through a selection of these variations by environment, etc., man was produced.

That is, according to biology, man's general organic pedigree, but we naturally wish to know something more about our family tree.

According to Haeckel, man's family tree is as follows : firstly a bit of green protoplasm ; then an amœba (a bit of protoplasm with power to move about) ; then, by a process of gradual development, a worm of sorts ; then a fish without skull, jaws, or limbs ; then an ordinary fish ; and so on, through mammals, marsupials, lemurs, Western apes, Eastern apes, speechless ape-men—

> "The gibbering shape obscene
> That was and was not man"—

to man himself. Thus we have rather a mixed and fishy ancestry, and include among our ancestors worms and kangaroos—or at least opossums.

"It is certain," says Haeckel, "that man has descended from some extinct mammal ; and we should just as certainly class this in the order of apes if we had it before us. It is equally certain that this primitive ape descended in turn from an unknown lemur, and this from an extinct marsupial."

But it must be remembered, he warns us, that no exact counterpart of the particular ape, lemur, and marsupial now exists.

Our more distant ancestors and relatives we can afford to ignore, but our nearer kin have family resemblances that tell their own tale. Man certainly belongs to that great division of animals known as vertebrates, and to that class of vertebrates known as mammals ; in other words, he has a backbone, or at least ought to have, and his young are suckled, or at least ought to be. By means of his backbone he may claim kinship even with an alligator, and through his mammary glands he is "very like a whale." And if, despite backbone and breast-glands, he would fain repudiate his kin, he will find corroboration in all his bones; and when, in current slang, he says "Give me your flapper," he will find on investigation that he has spoken a true word in jest, and that fin, and wing, and arm are variations of the same structure.

Bone by bone, muscle by muscle, cell by cell, he will discover confirmation of his organic pedigree. He will find in the inner corner of his eye a small semilunar fold, the remnant of the third inner eyelid found in sharks and some other vertebrates. He will find under his skin, in certain parts, layers of muscles which some of the lower animals employ to shake flies off their skin. He will find in the dangerous little death-trap known as the "appendix" a relic of an organ which was useful to his vegetarian ancestors. He will find attached to his spine the remnant of a tail, and occasionally the tail is something more than rudimentary, and may be nearly a foot in length. Granville Harrison removed from a child such a tail, which moved briskly when the child cried or was excited, and was drawn up when at rest. Even the arrangement of the hairs of his body will "give him away."

And biologists have not been content with such evidence in the *man*: they have found evidence even more startling in the *ovum* and the *embryo*. They point out that man is not only descended from a little bit of protoplasm, but that the ovum from which he is developed is just such a little bit of protoplasm. They point out, further, the very remarkable, the astounding fact that the embryo in course of its development recapitulates part of the biography of the race, that—to use the technical expression—"Ontogeny is a recapitulation of phylogeny." This fact is stated by Haeckel as follows:—

"The series of forms through which the individual organism passes during its development from the ovum to the complete bodily structure is a brief, condensed repetition of the long series of forms which the animal ancestors of the said organism, or the ancestral forms of the species, have passed through from the earliest period of organic life down to the present day."

"On the strength of the biogenetic law," says Weissman, "it could also be predicted that man, in whom it is well known there are twelve pairs of ribs, would in his earliest youth possess a thirteenth pair, for the lower mammals have more numerous ribs, and even our nearest relatives, the anthropoid apes, the gorilla and chimpanzee, have a thirteenth rib, though a very small one, and the siamang has even a fourteenth. This prediction has been verified by the examination of young human embryos, in which a small thirteenth rib is present, though it rapidly disappears."

This seems hardly credible, yet so it seems to be. We see in the embryo of man the gills of a fish and the tail of a monkey; and at a certain stage of development we cannot distinguish between the embryo of a man, a lizard, or a fish. As the embryo grows, however, it develops distinctive features, and at birth it is indubitably human, and with little likeness to any of the animal kingdom except the apes. But the ape, man must confess as cousin.

At what date the ape became man it is difficult to say. For at least three hundred thousand years man has manufactured flint instruments, and for at least that period man has had a body distinctively human. Nevertheless all biologists agree that at some remote period "Natural selection began to favour that increase in the size of the brain of a large and not very powerful semi-erect ape which eventuated, after some hundreds of thousands of years, in the breeding out of a being with a relatively enormous brain-case, a skilful hand, and an inveterate tendency to throw stones, flourish sticks, protect himself in caves, and in general to defeat aggression and satisfy his natural appetites by the use of his wits rather than by strength alone—in which, however, he was not deficient. Probably this creature had nearly the full size of brain and every other physical character of modern man, although he had not as yet stumbled upon the art of making fire by friction, nor converted his conventional grunts and groans, his screams, laughter, and interjections, into a language corresponding to (and thenceforth developing) his power of thought."[1]

It is the "relatively enormous brain-case" that differentiates a man from an ape; otherwise, as Huxley affirmed, "whatever systems of the organs

[1] Ray Lankester, *The Kingdom of Man.*

we take, the comparison of their modifications in the series of apes leads to the same result: that the anatomical differences that separate man from the gorilla and chimpanzee are not so great as those that separate the gorilla from the lower apes." When we compare the skeleton of a man with the skeleton of the so-called anthropoid apes we find a startling similarity. Except for the length of the arms and the size of the hands, the skeleton of the gibbon might pass for the skeleton of a man. In every instance, however, the brain-case is a differentiating feature; and even if we take the least type of human skull at present known and the highest type of ape-skull known, between the two there is great disparity.

Still, our brain-cases will not save us, for transitional forms of skull between monkey and man *have* been discovered. The most famous of these transitional skulls is the fossil skull discovered by a military surgeon in Java. This skull is supposed to have belonged to an erect ape-man—the kind of creature from which man is believed by most biologists to be directly descended.

It must be understood that man is not supposed to be descended directly from any of the anthropoid apes at present existent: he and the anthropoid apes are merely cousins; he and they are supposed to be branches of a common stem; and the skull in the stem form is supposed to have had such a formation and capacity as this Javanese fossil skull. If the theory of the biologists be correct, the gibbon, the orang, the chimpanzee, the gorilla, and man can all regard this skull as the skull of a near relation.

But, after all, brain-cases are not so important as brains, and perhaps in brains we may find a denial of our ape ancestry.

Alas ! our brains are also the brains of an ape. The brains of the anthropoid apes exactly resemble the brains of a man. They have the same fissures, the same convolutions, the same lobes, and, so far as can be determined, the same functional areas. There is nothing in the brain of a Shakespeare that cannot be found in the brain of a baboon. Professor Huxley states :—

" As to the convolutions, the brains of the apes exhibit every stage of progress from the almost smooth brain of the marmoset to the orang and chimpanzee, which fall but little below man. And it is most remarkable that as soon as all the principal sulci (fissures) appear, the pattern according to which they are arranged is identical with that of the corresponding sulci of man . . . . So far as cerebral structure goes, therefore, it is clear that man differs less from the chimpanzee and orang than these do even from the monkeys, and that the difference between the brain of the chimpanzee and of the man is almost insignificant when compared with that between the chimpanzee brain and that of a lemur."

"I confess," says Agassiz, "I could not say in what the mental faculties of a child differ from those of a young chimpanzee."

Science therefore affirms that man is descended from a little particle of protoplasm, and that the orang, the gibbon, the chimpanzee, and the gorilla are his cousins.

> "There was an ape in the days that were earlier,
> Centuries passed and his hair became curlier,
> Centuries more to his thumb gave a twist,
> Then he was man and a Positivist."

CHAPTER XVII

SOME THOUGHTS ON THE EVOLUTIONARY THEORY OF THE ORIGIN OF MAN FROM MATTER

No conception in the vast universe of thought can have more intellectual and imaginative value than the evolutionary hypothesis. It is so colossal in its scope that it dwarfs the sun, yet so meticulous in its regard that it aligns the infinite with the infinitesimal. It calls a cloud of witnesses from all ages and from all spheres. Its scroll is space, its alphabet the orbits of the stars, its syllables the solar system. It exalts and it debases: it surmises man's beginnings in a fire-mist, and surprises his endings in a monkey. In its cosmic premises it is superb, in its biological conclusions humiliating. Yet it is always magnificent. What could be more magnificent than the vision of the condensation of the suns and the blossoming of the planets? Can we not imagine the hot earth spinning, and glowing, and hissing, and steaming? With what wonder must we watch the first crude crawling life in the warm silt of the circumpolar seas, and the gradual apparition of reptiles and roses! With what amazement must we decipher in the embryo of man the bold signatures of man's ancestry!

The conception is so colossal as to be almost incredible, yet so correlated and so corroborated as to be almost irresistible.

Yet though the conception is so wonderful and so wide, it is rejected by many and feared by many as a base and unprofitable creed. To certain timid minds there is something profane in the idea of the evolution of matter. Yet where is the profanity? Where is the cause of fear? Why, the theory is not even new; it is as old as philosophy. Many an old Greek philosopher cried, "Give me matter and I will make the world." Thales realised that everything was always becoming something else, and found the beginning of all things in water. Heraclitus also discerned the evolution of things, and chose fire as the origin of the world. Anaximander taught that there was "one eternal indestructible substance out of which everything arises, and into which everything once more returns," and that "things arose by separation from a universal mixture of all" (quite Spencer's definition of evolution as the production of heterogeneity from homogeneity), and he even guessed that man began in muddy water as a fish. What would he have thought had he seen the gills in the human embryo! Still more precisely, and with an apparent prescience of the modern doctrine of corpuscles, Anaxagoras declared: "Together were all things infinite in number and smallness; nothing was distinguishable. Before they were sorted, while all was together, there was no quality noticeable." The Arabic and Jewish philosophers of the Middle Ages—Avempace, Abubacer, Maimonides—also believed in the evolution of the organic from the inorganic.

And we find that the bravest minds of more modern times discerned and preached the divinity of matter. The brave Bruno, who was burned at the stake for asserting the horrible heresy that the earth went round the sun, declared that matter was not "that mere empty capacity which philosophers have pictured her to be, but the universal mother who brings forth all things as the fruit of her own womb." And Newton, penetrating more deeply into the mystery of matter, saw the possibilities of the atom, and wrote in his *Principia*:—

"Many circumstances lead me to suspect that all the phenomena (of Nature) may depend upon certain forces, in virtue of which the particles of bodies, by causes not yet known, are mutually repelled against one another, and cohere into regular figures, and recede from each other, which forces being unknown, philosophers have as yet explored nature in vain."

So Bruno and Newton; and what they have held, why fear we to believe? We shall not be burnt nowadays if we use our reason; and we need not take alarm at the term "materialist" in the mawkish mouths of the unimaginative.

We may be "dust of a weary satellite of a dying sun," but when we know the seething secret of the dust—when we know the infinite force it conceals—when we know that each atom is a miniature solar system, with a central sun and revolving planets—then surely, without profanity, we may recognise that matter is mother of man, and mother, even, of the soul of man.

Matter is the miracle of miracles, the most mystical of all things mystical.

Now, is this not thaumaturgy? We put the solar systems called hydrogen beside the solar systems known as oxygen, and we send a spark through them, and the planets of the two systems combine their two mazy orbits; and behold, where these were two gases is now the wonderful fluid we call water. Oxygen, which is the father of flame, has become the flame-extinguisher, or, as Samuel Laing picturesquely puts it, "In his nature war-paint oxygen is a furious savage; with a hydrogen atom in each hand he is a polished gentleman." However we put it, it is a miracle; and from whatever standpoint we regard an atom, an atom is a wonder-worker.

As we have mentioned, a single atom may have some hundreds of thousands of corpuscles spinning and gyrating—flashing round their orbits at the rate of thousands of miles a second—while in the immense molecules of living protoplasm there must be millions of such solar systems. Dr C. W. Saleeby compares the molecule of hæmoglobin (the colouring matter of the blood) to a star-cluster such as the Pleiades—each sun in the cluster with thousands of satellites. If there is to be any material basis of life at all, could there be a more magnificent and mysterious mechanism? *Little wonder that God can make souls when his clay is star-clusters!*

Verily, we lose no sense of awe, no sense of reverence, when we conceive of man as a product of the atoms, and when we perceive in matter "the promise and the potency of all terrestrial life." Nay, see; the atoms dance and throb in the very beard and bones of Death, and in the presence of such infinite, incorrigible energy our faith in immortality is surely strengthened. What matter rigid jaw and stiffened fingers? The *energy* that once made the living soul is still prodigious in the disintegrating atoms. Can we believe that the intricate, complicated, infinite energy that bound solar systems into a thinking brain can become as nought? Even in a corpse "the intense atom glows," and in eternal energy there is surely promise of immortality.

And if, in face of these considerations, there still be some who think matter a mean and mortal mother, we may point out that nothing more spiritual than matter can be conceived; for science has followed where great philosophic thinkers long ago led, and has come to the conclusion that matter is really energy and nothing more—the Energy, if we will, of the Spirit in whom we live and move and have our being—the Power

> "Which wields the world with never wearied love,
> Sustains it from beneath and kindles it above."

The corpuscles of the atom have been proved to be nothing but electricity; and electricity, like light and heat, is nothing but waves of ether. Matter, which seems so heavy and gross, is only waves of ether. And what is ether? What are these ripples known as heat, light, electricity, matter? Ether is nothing save force; it is no more solid than a symbol, no heavier than an hypothesis. We assume something as a medium for the propagation of waves, even as we formerly assumed a substance in which the properties of matter inhered ; but this *something* is immaterial. According to theory, it is imponderable, and yet more rigid than steel ; and though more rigid than steel, the planets pass through it without friction. We cannot weigh ether, we cannot see it, we cannot conceive it ; and when we analyse matter into ether waves we dematerialise it ; we prove that the tactile, and visual, and muscular, and other sensations which give rise to the phenomena matter are products of force, and that when the force is altered or abolished the phenomenon is altered or abolished too.

Immaterial energy may seem inconceivable, but nevertheless it is a scientific fact, and it seems inconceivable, simply because the forces with which we are most familiar are forces in *material form*, and because we have believed, despite Berkeley, that the properties of matter are *substantial*—that there is something besides the sensations it implies, something in which the properties inhere. But matter is only an *idea*, caused by tactile, and visual, and muscular sensations produced by force. It is not something called matter or the substance of matter that makes us see black or white, or feel heat or cold ; on the contrary, it is these associated subjective sensations that cause the idea "matter," and these sensations, again, are caused by force, and may be altered by altering the direction or velocity of the forces.

This is nothing new. Long ago the great thinkers concluded that the properties of matter, weight, colour, temperature, etc. had no existence apart from the thinking mind, and all that new scientific discovery has done is to give scientific proof of this philosophic thesis, and to show that the hypothetical "substance" of matter has no existence. It has shown this by analysing matter into ether waves, *i.e.* into imponderable forces. It has shown this by showing that all the qualities of so-called matter are the product, in the mind, of forms of immaterial force — that matter is nothing apart from force, and changes in all its characters as the force changes its form. Water, steam, ice are not different forms of one substance, but interchangeable forms of energy. Every quality of every kind of matter—its colour, its temperature, even its weight—may be removed by varying, by ordinary physical processes, the directions, and velocity, and quantity of so-called inter-atomic and intra-atomic energy. When the metal gold combines with the metal chlorine to form a colourless liquid, where are the *substances*? It is nonsense to say that the gold is still there, that the chlorine is still there; they are *not* there; they vanished when the forces which constituted them—which produced their mental apparition—were altered and dissociated, and a quite new "matter" has arisen from the redisposition of force.

Matter, then, is force, and nothing but force—nothing but mental effects of a certain kind, produced by forces which are neither visible nor ponderable. All the whirling worlds, all the dancing atoms, are merely our subjective projections of various forms of force impinging upon us.

Matter may be quite well pictured as vacuity bounded by force. "Immaterial as the ether seems to be," wrote Karl Pearson, "we might even suggest the possibility that an atom is "a small portion of space in which there is no ether, or, in other words, void of anything, even the immaterial ether. A theory which supposes the boundaries of these voids to be endowed with a certain amount of energy will indeed account for some of the phenomena of gravitation and cohesion. I only refer to this theory as showing how delusive may be the popular conceptions of matter ; what we term the atom, the ultimate basis of matter, may be the negation of all that is currently called material."

And if we be asked what is meant by force, the spiritual position brightens. Force, in its ultimate analysis, is *conscious motion* resulting in new conscious experience. We raise a finger and press it on the eye : the *conscious movement* is followed by a sensation in the eye, and we say we have applied force. The two factors, conscious movement and a new conscious phenomenon, are essential to the concept force. When we talk of blind, unconscious force, we are guilty of a contradiction in terms; force necessarily connotes conscious movement. We cannot empty the idea of force of its psychical significance. The term and the idea are derived from our own conscious action. The moment we identify matter with force, we identify it with Conscious Will and Conscious Being. There is no way out of it. What was formerly called the substance of matter is now known to be Force; and the Force is recognised to be the Soul or Will of God.

"I consider," says Schopenhauer, "every natural force as a will [*i.e. conscious* will]. Will is essentially identical with all the forces which act in Nature, the various manifestations of which belong to the species of which Will is the genus. It is the direct consciousness which we have of Will which alone conducts us to the indirect Knowledge of the other forces."

"In that peculiar mental sensation," says Sir John Herschell, "clear to the apprehension of everyone who has ever performed a voluntary act, which is present at the instant when the determination to do a thing is carried out into the act of doing it (a sensation which, in default of a term more specifically appropriated to it, we may call that of *effort*), we have a consciousness of immediate and personal causation which cannot be disputed or ignored ; and when we see the same kind of an act performed by another, we never hesitate in assuming for him that consciousness which we recognise in ourselves . . . . in every such change [change occurring in material substance] we recognise the action of *Force*. And in the only case in which we are admitted into any personal knowledge of the origin of force, we find it connected (possibly by intermediate links, untraceable by our faculties, but yet indisputably *connected*) with volition, and by inevitable consequence with *motive*, with *intellect*, and with all those attributes of mind in which personality consists."

The grip of the atoms is the grip of the great Hand of God. Matter is not "an unintelligible turbulence in an inconceivable ether," it is the manifestation in force of the Universal Spirit

> "Whose dwelling is the light of setting suns,
> And the round ocean, and the living air,
> And the blue sky, and in the mind of man."

"The ether means, perhaps," says Fourier, "the all-embracing, all-connecting soul of the Universe."

This may seem mysticism, but every scientific thinker must become a mystic. As the great spiritual teacher Huxley averred: "The honest and rigorous following up of the argument which leads us to materialism *inevitably carries us beyond it.*"

The ultimates of science must be interpreted in terms of philosophy, and the whole revelation and gospel of matter may be summed up thus: All the phenomena of matter are ideas, and the ideas in aggregate produce the idea "Causal Force," which, again, gives rise both to the idea and emotion, God, even as sensation heat in excess gives rise to the sensation pain.

But it may be said, this force is not eternal. The grip of God relaxes; the atom decays; the force becomes ripples; the ripples die away into motionless ether, which is cosmic death.

"The vibrations of ether," according to Le Bon, "represent the last stage of the dematerialisation of matter, the one preceding its final disappearance. After these ephemeral vibrations the ether returns to its repose, and matter has definitely disappeared. It has returned to the primitive ether . . . . as it emerged in the far-off ages when the first traces of our universe were outlined on the chaos."

To return to the primitive ether is just, as we have seen, a way of saying the force ceases. But *does* force ever cease? We have no reason to believe so. Complete cessation of *force* is incredible. Force is not abolished, it is merely redistributed. God does not die; He is "the same yesterday, and to-day, and for ever." Behind the force is the Conscious Will, but even its manifestations in the phenomena of matter seem eternal.

Let us see what the mighty mind of Herbert Spencer thought on the subject. In a magnificent passage he says :—

"This rhythm of evolution and dissolution, completing itself during short periods in small aggregates, and in the vast aggregates distributed through space completing itself in periods which are immeasurable by human thought, is, so far as we can see, universal and eternal, each alternating phase of the process predominating, now in this region of space and now in that, as local conditions determine. All these phenomena, from their great features even to their minutest details, are natural results of the persistence of force under the forms of matter and motion. Given these as distributed through space, and their quantities being unchangeable either by increase or decrease, there inevitably result the continuous redistribution distinguishable as evolution and dissolution, as well as those special traits above enumerated. *That which persists, unchanging in quantity, but ever changing in form, under these sensible appearances which the universe presents* *to us, transcends human conception, is an unknown and unknowable power which we are obliged to recognise as without limit in space, and without beginning or end in time.*"

Evolution and dissolution are merely the systole and diastole of the Heart of God.

And we——?

We are the tides, fast and slow,
  Bitter and sweet;
We are the tides that come and go,
  Ebb and flow,
  Throb and beat,
In the Godhead's every vein,
  Hands and feet
  And body and brain.

The creed may be Pantheism: what creed dare be other than Pantheistic? "If I ascend up into heaven, Thou art there; if I make my bed in hell, behold, Thou art there. If I take the wings of the morning, and dwell in the uttermost parts of the sea; even there shall Thy hand lead me, and Thy right hand shall hold me." And Pantheism may be as personal as love, and as full of emotional value as the Universe it dematerialises and spiritualises.

"Mortals," said Xenophanes of Colophon, "think that the gods are born as they are, and have senses, and a voice and body like their own. So the Ethiopians make their gods black and snubnosed; the Thracians give theirs red hair and blue eyes."

But to Science "there is one God, the greatest among gods and men, unlike mortals both in mind and body."

The God of Science speaks in the thunder and smiles in the sunshine. He is so great that the stars eddy round his feet not ankle-high, yet so loving that He makes roses and sunsets for the human heart.

. . . . .

All ideas give rise to this final, integrating, emotional idea—God. Nor is the God an unknown God. If the force of Nature were seen as oil-engines or watches, our reason would give birth to a God like a man with engineering and mechanical talents. But the God that Science knows is not born of the reason, but is a direct product of the Consciousness, and coloured with all the emotional value of the universe which causes the Idea. Even as certain forces result in the concept matter, so the result of all the forces which constitute conscious life result in the concept God. The *substance* of the Schoolmen, the noumenon, the *Ding an sich* of the German Philosophers, the *points of force* of Boscovitch, the ether of the modern physicist, can also be conceived as Power, and conceived emotionally as a conscious Power, as the Power that makes Beauty and Love—what can it lead to but to that great causal concept, God?

No instinct is stronger than the instinct to attribute cause; and matter is simply a causal concept, produced by forces which act on us and give rise to sensation. Matter, as Schopenhauer saw, is "pure causality," merely the *Cause* of the *actual*; and when we consider the *One Cause* of *all* consciousness we reach the conception, God.

Self-consciousness, so-called, thus becomes God-consciousness, or Sense of God; and the more vivid and varied the phenomena of consciousness, the more intense and alive the great connecting *Idea*, *God*.

In the lower consciousnesses of animals no idea "matter" is produced by the associated qualities, hard or soft, white or black, cold or hot, etc.; matter, as an idea, belongs to the higher functions of the mind. And so, in lesser consciousnesses of man, the idea matter does not connote conscious force, and does not lead to the idea, God. But as the brain develops, men will more and more find the divine emerge from the material. "By the aid of philosophy, by the aid of poetry," writes Sir Oliver Lodge, "a great deal can be accomplished. Mind and matter may be then no longer two but one; this material universe may then become the living garment of God; gross matter may be regarded as a mere inference, a mode of apprehending an idealistic cosmic reality, in which we live and move and have our being; the whole of existence can become infused and suffused with immanent Deity."

The greatest achievement of modern science has been its analysis of matter into force—its proof that when the qualities of matter, colour, heat, weight, which are admitted to be subjective, are removed, there is nothing left save the immaterial activating cause which the mind demands, and which must be at least as multipotent as the multiplicity of its products. Schelling declares: "It is merely a delusion of the imagination that after man has stripped an object of all its predicates, yet something, he knows not what, remains behind." Nothing remains behind except the idea *cause*, and this idea is exactly of the same nature as the idea of a fellow-being's personality.

The great Berkeley taught this long ago. "If," he writes, "we follow the light of reason, we shall, from the constant uniform method of our sensations, collect the goodness and wisdom of the Spirit who excites them in our minds; but this is all that I can see reasonably concluded from thence. To me, I say, it is evident that the being of a

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Spirit infinitely wise, and good, and powerful is abundantly sufficient to explain all the appearances of nature ; but as for inert *senseless matter*, nothing that I perceive has the least connection with it, or leads to thoughts of it." . . . . "It is plain, philosophers amuse themselves in vain when they inquire for any natural efficient cause distinct from a *mind* or *spirit*." . . . . "Thus it is plain we do not see a man—if by *man* is meant that which lives, moves, perceives, and thinks as we do—but only such a certain collection of ideas as direct us to think there is a distinct principle of thought and motion like to ourselves, accompanying and represented by it. And after the same manner we see God : all the difference is that whereas some one finite and narrow assemblage of ideas denotes a particular human mind whithersoever we direct our view, we do at all times and in all places perceive by sense, being a sign or effect of the power of God ; as is our perception of these very motions which are produced by men."

Spinoza, too, realised that the eternal substance of all things was God, and that the seen, and felt, and imagined universe merely presents us with an infinite number of finite aspects of the infinite whole. In each case he considered the cause to be the eternal energy of the whole being. "It is possible," he wrote, "for the mind to secure that all the affections of the body or the images of things shall be referred to the idea of God."

And what is all this but Plato's: "You judge that I have a reasonable soul because you perceive order in my words and actions. Judge, then, by a parity of reasoning, from your observation of the order and regularity of this world, that it is activated by a soul supremely intelligent"—what is it all but the still older doctrine of Upanishad of the Veda, "Hae omnes creaturae in totum ego sum, and praeter me aliud ens non est"?

The deep-rooted instinct to find unity in multiplicity, and identity in diversity, is nothing more than the instinct groping for the idea of God. The tendency to ascribe mind or will to matter is nothing more than the discernment of intelligent purpose in the mechanics of the universe.

Looked at even in its more popular aspect as an objective entity, or as objective entities, still matter demands mind and force to account for its behaviour. If a table turn without visible cause, the superstitious exclaim "Lo, a spirit!" And when the table is shown to be turning in every atom—when every molecule is shown to be thronged with spinning corpuscles that put table-turning quite in the shade—how are we to disbelieve in spirit then? It is idle to say that motion is as natural as rest: the mind refuses to believe that the complex series of motions that make and maintain a table or a brain are independent of conscious instigation and conscious guidance. If a face should grow out of clay without any visible hand moulding it, we would say it must have been moulded by spiritual power ; and when, in the womb, atoms of carbon, and hydrogen, and oxygen, and nitrogen run together in such a way that, as Huxley says, "we are forcibly reminded of a modeller in clay," surely we must recognise a conscious purposive hand. Tyndall talks of "the exquisite sense of the beautiful displayed by nature in the formation of a common block of ice."

"All these operations" (of the atoms), says Le Bon, "so precise, so admirably adapted to one purpose, are directed by forces of which we have no conception, which act exactly as if they possessed a power of clairvoyance very superior to reason. What they accomplish every moment of our existence is far above what can be realised by the most advanced science."

If an amœba suddenly grew into a man, what a miracle it would seem ! And when the microscopic ovum becomes an infant it is surely a miracle quite as wonderful, and we are surely constrained to believe in a conscious directive force.

It is often assumed that the atomic theory has divested nature of its mystery, and has reduced natural and evolutionary processes to the level of ordinary mechanics. But this is not so. The atomic theory doubles the mystery and the wonder of life. Any artist might mould a bird or beast of clay, but where is the artist who could make so much as a little finger-nail or a single eyelash out of the dancing molecules? And yet continually this miracle is wrought. The molecules I take for dinner, the molecules I unconsciously breathe, will find their way to the little finger-nail or eyelash, and will take there their appointed places; indeed, by molecular mobilisation, the whole body is built up from the ovum.

Let us consider even such a minor wonder as a hen's egg. In the egg are quadrillions of molecules, arranged as the white and the yolk. In this shape they maintain their molecular integrity and molecular motion for some time, but let some tiny germ of putrefaction enter the egg and they go all to pieces. On the other hand, let the egg be subjected to gentle warmth, *i.e.* let certain waves of ether beat upon the molecules and a few atoms of oxygen have access to them, and lo and behold! these millions and millions of molecules change their structure and change their position, and become the tissues and organs, the beak and heart, and eyes and feathers of a bird. The arrangements, the collocations, the permutations and combinations of these millions of atoms and molecules must be infinite ; yet every single one must go to its right place, for eventually every one is used, and rightly used, and the very same atoms which made the soft, structureless egg are now built up into a bird. Were one to take every letter in Shakespeare's works and jumble them together and shut them into an eggshell, and were one to find that when subjected to a gentle heat the letters arranged themselves into Plays and Sonnets, the result would not be in the least more wonderful than the formation of a chick. Consider what precise proportions of the atoms must have been contained in the egg to finish the finest tip of the finest feather. Consider that there were in the original egg atoms of carbon, and hydrogen, and oxygen, and nitrogen, and iron, and calcium, and sulphur, and phosphorus, and sodium, and potassium, and that all these had to go to their places in new combinations, with no more guidance than the heat from a hen's bosom. Consider even the grosser complexity of a chick—a complexity simple compared with the molecular combinations—its veins, and arteries, and nerves, and retinæ, and ears, and bones—and how all of these had to be accurately estimated and preordained in atoms. Consider these things, and we will see that the atomic theory has merely deepened the mystery of life.

Suppose some mathematical and chemical genius were able to collect *somehow* the atoms required to make a chick (just the same atoms that we find in lucifer matches, and bread, and butter, and soap, and such-like things), suppose he were to combine them into the white and yolk of an egg, is it conceivable that he should give these millions and millions of molecules and atoms such special unstable equilibrium, such kinetic potentiality, that when filliped by heat they should rearrange themselves into the intricacies of blood, and bone, and heart, and lungs? Would it be possible for the exact number of A's, and B's, and C's, and commas, and hyphens, necessary for a book, to be gathered together into an egg before the book was even conceived? Perhaps? But would it be possible to give the individual letters such dynamical properties that on the application of heat they should dance together into words, and sentences, and paragraphs? It is inconceivable! Yet each blood-cell is as purposive as a word, each pause of the heart as significant as a comma, each affinity of a molecule as full of meaning as a hyphen, each nerve-cell as correlated as a sentence.

And think: these atoms in the egg have been gathered together in a few hours, and have come from all quarters of the earth. Not so long ago the oxygen may have come on the wings of the wind from the leaf of a lily, the hydrogen from the teardrop of a maiden, the carbon from a factory chimney, the nitrogen from the plains of Chili, the sulphur from Mount Pelée, and the iron from a meteorite. And behold, there they all are collected together by red rivers of blood into an eggshell, ready to make a chicken! Think, too; the atoms are not merely fastened together, but fastened together with a certain definite fixity, and by their meetings and partings give rise to the special phenomena of life. Verily, "all the king's horses and all the king's men couldn't put Humpty Dumpty together again."

What makes the atoms come together into such form? Heat? But how could heat, which is simply an agitation of the ether by vibrating atoms, effect such a miracle? What makes oxygen behave as oxygen, and carbon as carbon, all the universe over? These atoms, as we said, had never met before till they met in the hen's ovary, and yet, like a disciplined army, they go through the most complicated manœuvres without a mistake. And once together, they act together in the most marvellous way to keep intact the form they have taken. The neck bends, the beak opens, the throat swallows, the gizzard crushes, the heart beats, and molar and molecular activities work hand in hand.

So much for a hen's egg; but even more wonderful is the growth of the ovum in Placentals when the molecules are selected hour after hour, day after day, from the placental blood-stream.

It is marvellous that all these atoms should be collected in the ovum; it is marvellous that a little heat should cause them to form such molecular combinations, with such wonderful molar and molecular activities; but it is more marvellous still if we consider (as we must if we accept the modern evolutionary hypothesis) that the ovum of a man, the ovum of a hen, and all other ovums there may be, are ovums from the mighty loins of a fire-mist, just as certainly and inevitably as an apple is the fruit of an apple tree. "All our philosophy," said Tyndall, "all our poetry, all our science, all our art—Plato, Shakespeare, Newton, and Raphael—are potential in the fires of sun." The orbits of the electrons in every drop of ink on this page were predetermined in the nebula.

When we consider the complexity of an atom, and the myriads of permutations and combinations through which every atom has passed on its journey through space and time to the brain of a man, we realise that only the hand of Purpose could have ever brought it safely there. The evolution of the molecules in an eggshell, wonderful though such evolution may be, is only a moment in their evolutionary career, and the *vis a tergo* began as far back as the nebula, millions and millions of years ago, and will impel them yet for millions and millions of years to come.

It is sometimes suggested that chemists will in time be able to make protoplasm in their laboratories. It is quite possible that protoplasm may be produced ; but the chemist who produces it will be no more the maker of the protoplasm than the man who winds up a watch is a watch-maker, or the man who sows an acorn is an oak-maker, or than the man who feeds his brain is a brain-maker, or than Bastian is a microbe-maker. All that chemists will ever be able to do will be to set certain molecules at work to collect others. But, as in chess, it is the opening moves that count ; and they may never be able to find the openings, which in the case of Nature were nebulæ.

CHAPTER XVIII

WHAT HAS EVOLUTION IN STORE?

GRANTED that the world, as we know it, is an evolutionary product, can we see what evolution has still in store?

The moon is dead, just a piece of slag in a sling, but the world is still alive; and if modern physicists are right, it has still millions of years to live. What is likely to become of it and us, under conditions more or less like those at present prevailing?

The crust of the earth will alter; continents and seas may change places; but our earth is pretty safe from collisions, and from freezings and fryings, and will probably lead a sober and orderly life for many million years. But what will happen to its flora and fauna? If, in the past, man grew from an amœba, what may amœbas still produce? If man has already climbed so high, how much further will he yet climb?

According to the doctrine of evolution as commonly held, development is the result of germinal variation and selection. No offspring exactly resembles its parents, and germinal variations which favour in the struggle for existence will survive, and thus the type may change. The theory that variations due to use and disuse, or otherwise *acquired*, are inheritable, and may lead to racial variation, is not now held, and only germinal variations—variations due to peculiarities in the germ-plasm—are considered to be inheritable, and to have evolutionary influence.

In considering, then, what the future will bring forth, we have to consider what germinal variations may occur, and which of these are likely to have *survival-value*. Such a consideration is really beyond us. We cannot tell what variations are likely to arise, and we can tell only very roughly how they would be likely to fare. Who could guess that an amœba would evolve into a man; and what wonderful possibilities may not birds, and beetles, and seals, and simians yet hold? Regarded as an evolutionary product, man owes his pre-eminence chiefly to favourable variations in the muscles of his thumb and backbone, and in the brain-cells in his third left frontal convolution. An erect position set his forelimbs free; apposition of his thumb and forefinger gave him new manual dexterity; and the new cells in his brain gave him power of speech and of abstract thought. Who would have imagined that such apparently trivial variations would have had such momentous consequences? And who can say what variations may yet arise to overthrow the dynasty of man? Perchance some new branch of the ape family may oust man from his kingdom. What possibilities of favourable variation multitudes of animals may yet contain we cannot guess.

When, however, we confine our prophecies to man we are more likely to prophesy rightly. We know what germinal variations usually occur, and we know something of their survival-value. And from a study of man's evolution in the past, and of his present environments and variations, we can see how he is likely to evolve in the next epochs.

Within geological periods, man has gradually arisen to an erect attitude, and he now stands straight, under the stars. Here, in this respect—in this respect so important to the human race—evolution has apparently finished. The hand also seems a perfect instrument, and one can imagine no marked variation of any organ or part which would have any marked survival-value. Man's physical adaptation to his physical environment seems in many respects almost perfected. Better than any other animal he is able to endure extremes of heat and cold. More easily also than any other animal can he change his habitat, his food, his clothing, according to his needs; and this power he possesses of choosing and arranging his environment prevents environment from freely choosing and arranging and varying him.

Further, the multitudinous and interrelated nature of his adaptations render improbable the perpetuation of any single corporeal variation, and make for the stability of the species. The chief factors in modern life of much evolutionary force are microbes and marriage: microbes, as a selector of obscure variations; marriage, both as a producer and selector of variations. These two factors it is which will make the man of the future, and their selection probably will not much affect the present physical type of man.

Let us look first at microbes.

Nature, as we have seen, has brought man's body so far into correspondence with its environment that it is difficult to see how it can be much further evolved; but in one respect it is certainly still lacking — it has little or no power to resist certain microbes of disease; and probably during the next few thousand years breeds of men will be evolved, by the weeding out of the vulnerable, which will be immune to certain microbic diseases. Already such a process of immunisation by selection has commenced. We find, for instance, among civilised men much more resistance to tuberculosis that is found among savage races, and, again, we find more immunity to malaria among races that have been for long exposed to it. Why such selection should favour men rather that microbes has not been explained. The microbes, which multiply with enormous rapidity, must also undergo a process of stringent selection, and one would think that, century by century, they would become more vigorous and vicious, but this seems not to be the case. The reason probably is that the microbes have not the faculty of variation in so high a degree as the cells of man; and it is probably just for that reason they have remained microbes, and have not become monkeys or something. It is interesting to think that the final selection of men regarded as physical organisms is being made by these blind, cruel cohorts of death which seem to regard nothing save cellular chemistry, and which may pass by the vicious and the foolish and slay the good and wise. Did not the bacillus of tuberculosis slay Spinoza, and Keats, and Chopin, and R. L. Stevenson; and how many famous men have died of pneumonia or typhoid? It seems a process of selection about as sensible as might be made by spinning a coin, and yet no doubt Nature knows what she is about, and perhaps immunity is correlated with most valuable qualities of character *in esse* or *in posse*. Nature seemed very wanton when she engulfed the great primæval forests, but she was looking some hundreds and thousands of years ahead, and preparing coal to drive the "Mauretania" across the Atlantic. Nature never errs in the long-run. She made man from a shred of the Milky Way, and she may be trusted to look after the creature she has made.

A similar selection is being made by alcohol; it has killed off most of the Red Indians, and also a pretty fair percentage of Englishmen.

When Nature has finished with man's body it will be exempt from most, if not from all, the diseases flesh is at present heir to, but the muscle and bone and nerve changes are not likely to be great. We have no reason to believe that man's body has much further capacity for variation, and less reason still to believe that any muscular or bone or nerve variations would have much survival-value.

Let us look next at marriage—a much more important evolutionary factor.

The germinal variations, then, which are making mankind are produced by marriage, and can be perpetuated only by marriage; and therefore, if we wish to foresee the future of mankind, we must give special regard to the marriage both in its productive and selective aspects. If we can see how people are marrying, we can see what posterity is likely to be.

Marriage at present, as an evolutionary factor in civilised countries, is instigated by two broad motives—love and money. In a broad way, the former motive is eugenic and the latter dysgenic, so far, at least, as physical qualities are concerned. For love in most cases is physical attraction, and implies, on the average, health; and selects, on the average, the physically fit; whereas money guarantees only money, and implies that physical attraction has had only a very subordinate place in the transaction.

But the situation is not quite so simple as that; we must consider the effect of the two motives on the offspring. The offspring of the love-marriage will probably have love, and the offspring of the money-marriage money; and even granting that the offspring of the former marriage are the finer men and women, will not the offspring of the latter marriage, with all the advantages of money, be the likelier to survive in the struggle for existence and to perpetuate their kind, and will not the very same qualities that made money make them also succeed in life? If this be so, then granting that money-marriages and love-marriages are about equal in number, the general effect might seem dysgenic under modern conditions of society, since no amount of natural advantages will remedy the disadvantages of poverty, and since the very advantages money can bestow will result in the survival and marriage of an excess of unfits. But happily this is not so; the force that brought us from the fire-mist will not abort us now in the womb of wealth. The same lack of courage, and love, and wisdom that makes men and women slave for money and marry for money will make them bad fathers and mothers, and in the majority of instances will mean that their children, brought up in an ignoble and selfish atmosphere, will lack the moral stamina to survive through many generations. Indeed, it is notorious how many rich men's sons "go to the dogs" even in the first generation. Further, heirs and heiresses are very often the final representatives of a dying stock, and they rarely have large families.

Given, then, equal numbers of love-marriages and money-marriages, the likelihood is that the seed of the former will possess the earth.

Even in face of the present preponderance of money-marriages there is no need for alarm; the worship of Mammon is merely a passing stupidity, due partially to social and economic conditions that cannot last; and evolution is certainly not likely to be much hampered and hindered by any temporary cessation or retrogression due to this cause, and may even have a wise purpose in it.

We may assume, then, that selection by money is not likely to continue long, nor to exercise any permanent effects on the race. On what lines, then, is matrimonial selection likely to proceed?

Evolution in man will probably proceed in future chiefly on mental and moral lines. "The cosmic evolution of Nature," wrote Kant, "is continued in the historic development of humanity, and completed in the moral perfection of the individual." Already evolution has started the second chapter of man's development: no longer is she chiefly concerned with his body, but with his mind; and the Eugenic Society, which has started to improve the human breed, is perhaps both too late and too previous. It is too late to do *much* for man's body, and too soon to do much for his higher nature. Too *soon*, we say, for his higher nature; for whither nature would lead him, and to what goal he should aspire, he hardly yet knows.

Love has been the lever wherewith evolution has raised mankind, and, so far, has acted chiefly through the physical attraction of the fit; but now, love is assuming new characters and man seems to be entering on a new course of development. Is it not the case that in the more highly developed nations love is growing to mean something more than mere physical attraction? Is there not a mental and spiritual affinity that sometimes irresistibly impels lovers into marriages which may be physically imperfect, and even reprehensible? In the more modern world man's work becomes less and less muscular, more and more mental, and his environment less and less material, more and more spiritual; and who can say where this will lead, or where it *should* lead, and who will undertake to rule the appetencies of minds and souls? Let us check by all means marriages that will result in physical and mental misery; but let us be careful not too easily to admit impediments to the marriage of true minds. We were not put into the world merely to propagate, merely to give nature material to evolve muscle and bone. Surely the formation of individual and racial character is the final goal of evolution; and perchance the marriage of a Robert Browning and an invalid poetess is of more value to the world, and to the world to come, than the marriage of a Hebe and Hercules, resulting in twenty stupid and sturdy children.

The drawing together of male and female has been the mainspring of evolution: it has produced the germinal physical variations that natural environment in the widest sense has perpetuated or rejected. Now, variations for selection are likely to be mental, moral, and spiritual, and selection will be almost entirely sexual selection. So if we find now that the drawing together of man and woman is often a matter of subtle mental and spiritual need and affinity rather than the attraction of physical fitness, we must recognise that nature has now almost finished with the body, and is now beginning the crown of her whole work—the evolution of the soul—and we must not too readily interfere. It may be said that, given good, strong bodies, the mind will evolve. That is untrue. Mind has its own breeds, and strains, and crosses, and we know little of their interactions. How subtly character and character represented in the germ plasm may affect each other! What remarkable variations they may bring forth!

So convinced am I of the eternal value of mind as compared with body, of the marriage of souls as compared with the mere propagation of healthy animals, that I say, if a man and woman *love* each other, and are drawn towards each other by the cravings of character, let no impediments be too readily admitted. Again, in the words of Kant: "The cosmic evolution of Nature is continued in the historic development of humanity, and completed in the moral perfection of the individual." Love is the crown and consummation of all things —the great purpose that throbbed in the fire-mist, and worked through amœba and monkey to man.

Nature is much wiser than we are apt to believe. When an ape with a curious thumb married an ape with a similar deformity, the whole ape community were no doubt scandalised, and talked of preventive legislation and so forth ; and yet, look what the thumb has meant. When man and woman nowadays are blind to all the beauty of love, and marry for financial reasons, the wiser of us with hearts and heads are shocked ; and yet perhaps nature is using lust-for-gold to kill off morally unsound stock. And when Angelina marries Edwin for reasons which no mortal can discover, there is no doubt nature has reasons, and good reasons too.

The physical basis of mind and character is so complex and so obscure that it is almost impossible to foresee what will be the character of the offspring of any two parents, and quite impossible to improve the race by serial increments of desirable traits. Who imagines that by carefully assorted marriage or by any method of stirpiculture he could produce a Newton, or a Kelvin, or a Shakespeare, or a Tennyson, or a Cæsar, or a Heraclitus ! What may be a virtue, too, in the parents may become a vice in the offspring. Prudence may reappear as timidity, courage as recklessness, love as lust. There are only thin partitions, after all, between a virtue and a vice. Moreover, even if character could be bred as speed is bred in horses, who shall say what character it is best to produce? The best is the fittest for its environment; and while the character of a Kitchener may do very well in Khartoum, it might not do so well in the City Temple; and while the character of a bishop may look very well in gaiters, it might not look so well in gold-braided uniform. Again, ideals of character vary with race: the Celtic and Anglo-Saxon ideals are very different,—each no doubt, like other things, the result of germinal variation and of natural selection.

On the whole, then, it will be best to leave the evolution of character in the hands of sex.

But can we not perceive in a general way what type of character is likely to be evolved—what type of character has survival-value? Only very vaguely. The mutual choice of male and female has evolved the animal world, but hitherto it has worked mainly through physical attraction; *character*, as a *dominant* determinant, is a comparatively new factor; and the material with which it has to work is so infinitely various and variable that it is almost impossible to discover either the rules that regulate the choice or the result of the selection. In most cases the choice seems purely personal, and the result fortuitous.

Still, in a very general way, we can see that the elements that enter, whether consciously or unconsciously, into sexual selection are twofold, and vary in the sexes. In a very general way we can foresee, too, that the woman of the future is likely to choose the man for strength of mind, even as she formerly chose him for strength of body; and the man to choose the woman for beauty of mind, even as he formerly chose her for beauty of body. Indeed, in many cases now the attraction of money is, on the one side, the attraction of strength; and, on the other hand, the attraction of beauty; for, on the one hand, the woman attributes to the man the power which exists only in his money, and, on the other hand, the man attributes to the woman the beauty due really to her golden setting. Both illusions originate in stupidity, and they often end in the Divorce Court.

It may be objected that the terms "strength" and "beauty" are rather vague; but it is impossible to define features of character otherwise than vaguely, and the terms probably indicate definitely enough what may be called the negative and positive electricities of sexual attraction in the future. A man who has intellectual grip and wide mental horizons—a man who does good work with his mind and who has a virile outlook on the universe—will be more likely to mate (in future centuries at least) than will a man who has merely a successful business or a coronet. A woman who has a beautiful womanly mind will be more attractive to men than any strong-minded advocate of woman's rights. And probably mating on such principles of selection will result in a general elevation of the mental and moral qualities of the race, and in an increase of its capacity for happiness, till man a million years hence will be to man of the present day as man of the present day is to a monkey.

The progeny of marriage determined merely or chiefly by physical qualities of strength and beauty cannot survive under modern conditions. We have in the aristocracy of England an example of such unfitness to survive. The aristocracy have beauty and physique, and probably physical energy superior to the beauty and physique and energy of the middle and lower classes, but they have not the qualities of mind fit to survive in modern environment; and though their doom may be averted for a time by the dollars of American heiresses, yet unless the dollars also bring new brains, the aristocracy, as a race, are doomed to die out.

The future is certain to be a future of brains, and probably of brains leavened with imaginative and emotional qualities, and with the great quality *love*.

In the past, the environment that evolved man was wild beasts, then intertribal and international wars. In future it will be chiefly character in its relationship to marriage ; and since women are in the majority, it will be *chiefly* man's sexual predilections with respect of womanly character that will determine the race. Where sexual selection is in abeyance—where, for instance, the community is small, or where matrimony is due merely to housekeeping considerations, or where the men outnumber the women—racial degeneration frequently follows. The larger the proportion of unmarried women, the more stringent the selection and the more rapid the evolution.

The difficulty in foreseeing the intellectual and social future of the race is greatly increased by the fact that many unforeseen psychical variations may arise, and by the fact that even actual variations are not always at once manifest. The mental and moral difference between man and man is very much greater than any physical difference, and may be infinitely deepened by a very small physical variation. The bodily difference between a Hottentot and a Tennyson is small, the difference in character and intellect very great. Moreover, the mental difference is probably much greater than it appears. We know that a few cells in the third left frontal convolution give man his great gift of speech ; we know that a slight difference in physical conditions during sleep causes an enormous difference in the mental functions ; we know that a few drops of morphia in the blood completely alters a man's character ; and knowing these things, it is impossible to doubt that the difference (which undoubtedly subsisted) in the number and arrangement of the brain-cells in different individuals must mean very great differences in their mental processes, and in their apprehension of the so-called objective world. A considerable percentage of the population are colour-blind, and it is probable that perception of some of the colours has been acquired in comparatively recent years.

Henry James, the great American psychologist, says : "The Object which the numerous inpouring currents of the baby bring to his consciousness is one big, blooming, buzzing Confusion. That confusion is the baby's universe. . . ." And there can be no doubt that there are many big babies in the world, and that most of us are babies compared with great minds. It is probably hardly an exaggeration to say that there is not *one* world, but as many worlds as there are minds.

The difference, then, between man and man and woman and woman is very great, and there is great scope for selective evolution, and great possibility for further differentiation. It is possible, almost likely, that in a few more thousands of years we shall not only be able to make and break atoms at will, but that we shall have new faculties and senses—perhaps an electric sense, for instance. It may be noted that the world, as we know it, seems purely a matter of waves. As the writer of *Confessio Medici* remarks: "The tint of walls, the pattern of the carpet, the warmth of the fire, the sound of my voice, the fragrance of your smoking, the sight of your faces—all are waves of which I know nothing, agitating an invisible something of which I know less than nothing." And yet the waves that make the world—the waves of ether and the waves of air—are very few in number, and there are many other waves—the ultra-violet and infra-red, for instance—of which we know nothing. Surely there is at least some likelihood that our octaves of sight and sound may be extended. There seems little doubt that even the insects and flowers have senses and faculties that we do not yet possess.

One fact seems to the writer particularly suggestive. Perhaps the most characteristic physical features of man are his prominent frontal lobes. These lobes are always considered the seat of the higher mental faculties, and yet there seems no doubt that various parts of these are still quite functionless and unused. Cases have been known where large parts of the lobes have been lost without the least effect on the patient's body or mind. In a Lumleian lecture, Dr Baddeley quotes the case of a boy who lost a portion of his brain through a fissure in his skull caused by violent injury, and who was so little affected that he earnestly requested that the part of his brains might be sent to his schoolmaster, who had often asserted that he had no brains.

The *Anthropological Review* also gives the following instances of brain injury without corresponding mental injury. "A young man at Ghent lost by a pistol-shot two teacupsful of brain, and more at subsequent dressings. He lived for two years with his intellect vastly improved, having been before of limited intelligence."

Paroisse (*Opuscules de Chirurgie*, Paris, 1806) received, after the battle of Landrecies, in the hospital at Soissons, twenty-two wounded soldiers. In all of them a considerable portion of the cranium, integuments, and brain had been cleanly cut off in battle by sharp swords. All of them marched, with their wounds, thirty-five leagues, about five leagues a day, to the hospital. Ten of these soldiers, in whom the loss of bone, integument, and brain was less, recovered completely within six or seven weeks. The remaining twelve were carried off in about three weeks. In none of these were the intellectual faculties much disturbed.

Many other similar instances might be cited. It is therefore certain that a considerable part of the brain is not essential either to thought or to organic life, and it is quite legitimate to infer that these parts are rudimentary and in process of evolution, and that the day will come (as it has come in the case of other rudimentary structures) when they will play an important part in the conscious life of the individual. Perhaps, then, ether-waves, of which we have now no cognisance, may be more to us than even waves of light and sound. Perhaps we shall discover space peopled with intangible presences. Perhaps we shall be able to communicate thought direct from brain to brain. Seeing what the brain already can do, seeing how few cells may give origin to most wonderful faculties, we have a right to be sanguine about the possibilities of the future. To the brain all things are possible, for it is the instrument of God, played upon by an infinite variety of forces, and giving rise, according to its constitution, to very different tunes. The same forces which, acting upon a sane brain, produce a rose in the consciousness, may, acting upon an insane brain, produce a demon ; and what they may produce in the brain of a bettle, or a cat, or dog, who can say ?

Certainly what is a rose to us is something very different through different eyes and in different brains.

To sum up, then, the future evolution of man will be, on the objective side, evolution of brain, and on the subjective side, evolution of character ; and this evolution will be guided and conditioned not by the exigencies of physical environment so much as by sexual selection of mental and spiritual variations. The evolution will probably result in an accentuation of those qualities commonly distinguished as womanly and manly, by the development of mental powers, and possibly by the acquisition of quite new faculties ; and it is quite possible that ultimately races of men may be produced as divergent in mental and moral characteristics as man and monkey.

CHAPTER XIX

IS SERIAL ORGANIC EVOLUTION PROVEN ?

So far, we have dealt with evolution as a *chose jugée* ; but now let us ask the question, "Is organic evolution of species really proven ?" Must we accept such evolution up a series as a fact in science and philosophy ?

Evolution is *not proven*. The question is still open. It has not been *really proved* that we came from a fire-mist, and that we are cousins of the monkey ; and organic evolution is merely a great, plausible, and unifying hypothesis.

That different species have structural and functional similarities, and that different species vary within wide limits, is quite certain ; but that all the species of animals and plants in the world have risen from a primitive piece of protoplasm is very doubtful ; and if they have so risen, it is also very doubtful if they can have arisen by a *selection of more or less tentative variations*, by one or all of the various agencies suggested. So far as we can see, all species of animals vary only a certain distance from their mean, and tend always to recur to the average type. But granting even much wider variations, it is almost impossible to conceive of any selective processes, though acting for millions of years, adequate to evolve a man from an amœba.

It seems to us that we must confine selective evolution to the variations within a species, and the establishment of the variations most fitted to survive, and must conceive of serial evolution from amœba to man as an inevitable process of development as accurate and unerring as the growth of an acorn into an oak. The acorn does not try experiments ; it does not first attempt to be a honeysuckle, and then a turnip ; it is not transmogrified by the influence of environment ; in every case it becomes an oak. And so with the first hypothetical protoplasm : it probably did not try this and that variation ; it probably varied along certain preordained lines, just as a growing finger or tooth does, and became reptile, fish, marsupial, ape, man. It is quite easy to understand how each species may have been modified by the selective action of environment (including sexual selection) on its variations ; but it is very difficult indeed, as we have said, to conceive of variations great enough, and of selective action stringent enough, to account for the tremendous differences between, say, a starfish and a man. It may be easy to conceive of the translation of two similar species—to picture the circumstances that might make an ape into a man; but if variations at present tend to swing to and fro about a mean, and if we cannot conceive of variations and selective action sufficient to translate species into species *all along* the supposed genealogical line, we cannot accept selective evolution as a whole. It must be realised that it is a very different thing to believe that one species may turn into another species, and that hundreds of species, by a process of variation and selection, may be consecutively transformed along the arborescent line from amœba to man. Each succeeding transformation becomes more and more mathematically improbable, since, species by species, the number of possible variations involved in the evolution increases, and, species by species, some new variation in the selective process must be invented. Say that the chances are ten to one against an amœba being converted into a starfish; they are about a million to one against its conversion into a codfish, and so on in increasing ratio.

Granting infinite germinal variations, we have yet to find machinery sufficient to select the right ones, and such machinery we have not found. The selective agencies that have been suggested might prune an oak certainly, but would never shape a single leaf of it.

If we are to make selection the determinant of species, and believe that, save for selection, variation could never have produced the species, we have to assume selective influences at least as subtle and as sensitive as a sculptor's hands, and variations almost infinite in number. And if we are consistent, we must carry this principle back to the fire-mist, and believe that the orbit of every electron and the permanent position of every atom in the earth was the result of numerous *tentative* combinations, with a survival of the fittest. We must believe that the position of every atom and every cell in an oak tree was the result of *selective* addition and superposition. We must believe that every egg was an experiment; and when we remember that every egg has to produce not only an organism, but an organism with the capacity of repeating itself, the odds against the adequacy of variation and selection seem hopelessly great.

There is nothing new about the idea of evolution; it is at least as old as Empedocles, probably much older; and Aristotle stated the position almost as it is to-day when he wrote: "Yet it may be said that they (the teeth) were not made for this purpose, but that this purposive arrangement came about by chance; and the same reasoning is applied to other parts of the body in which existence for some purpose is apparent. And it is argued that where all things happened as if they were made for some purpose, being aptly united by chance they were preserved, but such as were not aptly made, these were lost, and still perish according to what Empedocles says concerning the bull-species with human heads. This, therefore, and similar reasoning, may lead some to doubt on this subject.

"It is, however, impossible that these parts should arise in this manner, for these parts, and everything which is produced in Nature, are either always or for the most part thus (adaptively) produced, and this is not the case with anything which is produced by fortune or chance, even as it does not appear to be fortune or chance that it frequently rains in winter. . . ." "Similarly, it may be argued that there should be an accidental generation of the germs of things ; but he who asserts this subverts Nature herself, for Nature produces these things which, being continually moved by a certain principle contained in themselves, arrive at a certain end."

There is the whole point : *Does* Nature produce these things which, *being continually moved by a certain principle contained in themselves*, *arrive at a certain end* ; or does the end depend on the selection by environment of variations offered for selection ?

In view of the character of evolution—in view of the extraordinarily complex nature of its final products—we find it difficult to believe that variation offered many alternatives to selection, or that selection had much to do with the essential characters of the species evolved, and certainly we find it almost impossible to believe that all the species from amœba to man were produced by environment acting upon variation.

Why, after all, should there be such a desire to trace all organisms, animal and vegetable, to a *single* organic prototype? Go back to the beginning! When the corpuscles ran together they *probably* formed *various* atoms; when the atoms ran together into inorganic molecules, the molecules were *varied* in their composition and potentialities; and there seems little reason to believe that Nature showed more lack of imagination and versatility when she proceeded to produce organic life.

The assumption made by almost all biologists, that the first form of life resembled the simplest form of life now known (*i.e.* was a minute mass of naked protoplasm, capable of assimilation, growth, and reproduction), and that by the interplay of varition and environment there sprang from this all the flora and fauna of the world, is so audacious as to capture at once the reason and the imagination; but, we ask again, is the assumption sound, and have we any right to assume that any prototype mass of protoplasm could contain such infinite capacity for variation as is implied by all the species of plants and animals now existent ; and admitting such infinite capacity, can we conceive of such prolonged and extreme difference of environment as would produce the differentiation now prevailing ?

If there were in such an elementary particle of protoplasm such infinite possibility of variation—if environment has been so hard at work selecting and perfecting these variations—how is it that at the present day, after millions of years, we find elementary particles of protoplasm still quite unaltered from their hypothetical primordial condition ? How is it that the amœbæ in the blood, subjected as they are to an environment as variable as the blood, still remain amœbæ and nothing more ? How is it that the pathological microbes, which, by reason of their enormous progeny and of their constant struggle for existence, ought to exhibit great variations, remain true to a type apparently primæval ?

Here is an amœba ! Here is a man ! Can any sane thinker affirm that one amœba has been stationary for millions of years, while the other has become fish, monkey, man ? If this have actually occurred, then there must have been enormous molecular differences from the first ; and to call both molecular combinations "amœbæ" would be a misuse of nomenclature.

Ray Lankester admits: "We have no reason to suppose that the offspring of the beetle could in the course of any number of generations present variations on which selection could operate so as to eventually produce a mammalian vertebrate; or that, in fact, the general result of the process of selection of favourable variations in the past has not been *ab initio* limited by the definite and restricted possibilities characteristic of the living substance of the parental organisms of each divergent line or branch of the pedigree."

Good! but why begin at beetles? Why not go a step farther back and say that we have no reason to suppose that the offspring of the *amœba* could in the course of any number of generations present variations on which selection could operate so as to eventually produce a mammalian vertebrate? Why not also admit that we have no reason to suppose that the twins of an amœba could present such different variations and be exposed to such different environments that in the course of a million years one should become a beetle and the other a man?

It is all very well to limit the possibilities of each branch of the biological tree by the possibilities of its progenitor, but how about the *stem*?

Did one piece of *stem* protoplasm contain the possibilities of all the branches? And why did the branches which all sprang from a parent stem, and which were all under the laws of heredity, come to vary to such an extraordinary extent? If we are to assume a primordial progenitor of all life, we must attribute to it such potentialities that it seems superfluous to call in Selection to correct its mistakes. Unless, indeed, in the first cell it foresaw the last; unless each variation was on the way to *something*, evolution from a bit of protoplasm into all the *physiologically competent* vegetables and animals of the world could not have occurred. There must have been such a formative spirit as Plato supposed torturing "the unwilling dross that checked its flight into beasts and birds"; or the developing beings must have been "continually moved by a certain principle contained in themselves." We cannot otherwise account for so many births and so few abortions. As Aristotle pointed out, it is not a few things that show apparent purposive adaption, "for these parts and *everything* which is produced in Nature are either always or for the most part purposively produced."

We cannot believe that so many living things were successfully produced by evolution unless the general process was inevitable, and independent of the accidents of environment.

John Gerard puts the matter well thus : "It is not simply because iron is hammered and filed that a railway-engine is produced ; nor is it sufficient that a block of marble be chipped with mallet and chisel in order to obtain a statue of Apollo. Unless some influence comes in to direct the forces in such cases to their respective results, the results will never by any possibility be secured. And in the processes of Nature such direction or determination must be exercised in particulars inconceivably intricate, to which the works of man furnish no parallel."

"If a tree," writes Mr Croll, "is to be formed, the lines of least resistance must all be determined and adjusted in relation to the objective idea of the tree ; of the root, of the branches, of the leaves, of the bud, of the fruit, and of every part of the tree. But this is not all : the tree is built up molecule by molecule, each of which requires a special determination, and beyond all this we have the structureless protoplasm [protoplasm is not structureless], which must be differentiated according to the objective idea of the whole. What produces this marvellous adjustment of means to ends ?"

And Mr Croll insists, in another passage : "The determinations which take place in nature occur not at random, but according to a plan—an objective idea. Thus the question is not simply what causes a body to take some direction, but what causes it to take, among the infinite number of possible directions, the proper direction in relation to the idea. In the formation of, say, the leaf of a tree, no two molecules move in identically the same direction, or take identically the same path. But each molecule must move in relation to the objective idea of the leaf, or no leaf would be formed. The grand question therefore is: What is it that selects from among the infinite number of possible directions the proper one in relation to the idea?"

"And this sort of thing is going on in every blossom, and leaf, and blade of grass, in every hair and every feather, over the surface of the earth."

Mr Croll, in the passages quoted, deals of course with the tree and leaf as completed by evolution, and as produced from a seed; but the determinations of the molecule as seen in the productions of the tree with its leaves from a seed are, according to theory, simply the summation of evolutionary additions; and, in view of the multitude and intricacy of the determinations, it cannot be believed that evolution reached them by any painful process of experimentation, and it must be believed that Nature knew where she was going.

In fine, whatever view we take of evolution, we cannot give *much* shaping or directive value to the selective influence of environment. Moreover, all the latest researches into heredity have tended to reduce the shaping value of environment, by showing that only germinal variations are inheritable. Up to quite recent date it was believed that acquired differences might be inherited, and thus aid in the moulding of species, but now it is almost universally held that only germinal characteristics are transmitted to offspring. Germinal variations, again, can only be selected by sexual selection or by death.

The more we examine the matter, the more certain it seems that evolution of species owed as little to environment as any pictures painted by an artist, or any statues carved by a sculptor. And this being so, is it necessary or advantageous to consider evolution as a *slow* process, requiring long ages?

We have said that all life is usually supposed to have sprung from one prototype. But nothing is gained by this assumption, and it is not probable. The common stem of all life was the cooling world, but it is surely likely that, at various points on its surface, various protoplasmic combinations with different potentialities of variation arose, and that from these were evolved most of the present-day species. A mere likeness between species, not even embryonic resemblances, does not necessarily mean serial genetic relationship. The assumption —which is a quite legitimate assumption—that life began at various parts of the world in varying forms, greatly simplifies the process of evolution.

But personally we are prepared to go a step further, and to say that it is quite possible that many existent species from amœba to man *began* in some form very much like their present form, and have varied since their birth only within very narrow limits. It is quite possible, since we find that existent species *do* vary only within narrow limits. It is quite possible, since it is as easy to conceive the evolution of self-contained species as to conceive the translation of species to species by any process of evolution. Organic evolution was brought forward to *explain* the origin of species; but it itself can only be explained by assuming a formative force working consistently down the centuries, aided hardly at all by the suggested means of selection; and it is quite as easy to imagine that this force acted quickly as slowly—indeed, it is more easy to imagine it acting straightway, since every day we see such action in the formation of an egg, and in the development from the egg of the individual. To bring man from an amœba in some hundreds of thousands of years is no less a miracle than to bring him from an ovum in a few months. And, after all, the difference between an amœba and a man, considered dynamically, is not so great if we regard them in their atomic aspect. The real difficulty is the origin of the first protoplasm ; and if we beg the first amœba, we may almost as well beg the first monkey and man. If we can educe an amœba from a fire-mist, it seems to me there is little we cannot educe ; and to put a few more organisms between the inorganic and, say, a worm, does not make the worm's eduction any simpler.

The imagination may bogle at the idea of the origin of the first worm or the first cœlenterate from the dust of the ground—from inorganic molecules ; but the imagination that is able to picture the origin of an amœba from a fire-mist, of an oak from an acorn, of a lily from a seed in the soil, of a man from a seed in the womb, has no right to decline to imagine a worm born from the sea-slime.

Even the story in the first chapter of Genesis is almost as plausible as the usual evolutionary hypothesis of the origin of species. Whichever way we turn we meet miracles ; we are beset with them—there is no escape.

Whatever force made the first molecular combinations of organic life must have been so strange and prodigious that all things must have been possible to it.

As Tyndall admits: "The whole process of evolution is the manifestation of a power absolutely inscrutable to the intellect of man. As little in our day as in the days of Job can man by searching find this Power out. Considered fundamentally, then, it is by the operation of an insoluble mystery that life on earth is evolved, species differentiated, and mind unfolded from their prepotent elements in the immeasurable past."

In fine, God made the world; and all our explanations—all our attempts to get behind the first mystery of creation and the continual miracles of birth—are as vain as our attempts to solve the mystery of matter. *Ignoramus* and *Ignorabimus*!

But this we know, that *form* including colour has some special significance and is a mystery—an emotional mystery of its own. We feel that form and colour are more than mere form and colour; we feel that the shaping of things has some divine significance. We *feel* that the *idea* preceded the form and is the Final Cause; that form is not a matter of mere mechanic variation, that there is "a mysterious architectonic principle, which has not yet been detected," which we may call, if we will, the Imagination of God. When Tennyson looked into a stream and saw it swarming with strange water-creatures, he wondered at the imagination of the Almighty; and it is not difficult to imagine that in the imagination of the Almighty we all come into being. "In the beginning was the *Word*," says the old Chaldæan cosmogony; but "In the Beginning was the *Thought*" might be truer still. As some German poet sings:

"Die Rose die allhier dem irdisch Auge siehet
Die hat von Anbeginn in Gott also geblühet."

The emotion *Beauty* is produced by certain lines and colours, and never do we seem more in sympathy with the Divine Mind than when it moves us. Beauty is perhaps a Final Cause of organic Evolution, and Watson has perhaps reached higher truths than Darwin when he sings:—

"Beauty the Vision whereunto
In joy, with pantings, from afar
Thro' sound and odour, form and hue,
And mind and clay, and worm and star,
Now touching goal, now backward hurled,
Toils the indomitable world."

CHAPTER XX

SCIENCE AND MIND

According to Science, the brain is the organ of the mind.

We have grown so accustomed to think of the brain as the organ of the mind that it is difficult to realise that any other opinion could ever have been held. Yet in the Bible the word "brain" is never used, and thoughts and emotions are attributed to quite other organs. Thus in the Psalms we read: "His reins instruct him in the night seasons," and "The Lord trieth the heart and the kidneys."

Among the early Greek thinkers there was a difference of opinion. Plato and Alcmæon taught that the brain was the seat of the mind. Aristotle, again, taught that the brain was merely a sponge to cool the heart.

Not till experimental physiology was practised at Alexandria was the position of the brain as the centre of mind established, and not till the time of Galen was the doctrine of intellectual and sensory functions of the brain generally accepted.

Now, of course, the doctrine is such a commonplace that the term "brains" is often used as a synonym for mind.

But what is the brain? From one standpoint it is ninety or ninety-five per cent. water and essentially highly phosphorised fats in a weak salt solution; from another standpoint it consists of some hundred of millions of cells connected with each other, and with all the tissues of the body, by means of nerve-fibres; from still another standpoint, it consists of a mass of molecules particularly responsive to vibrations of the ether and air. When it is removed from the skull it is found to have certain furrows and fissures running in definite directions, and dividing it into lobes and convolutions, and the lobes and convolutions correspond, in the main, with those of the higher apes. There are about three pounds weight of brain in man, but the lower animals have comparatively small brains; yet "whether it be the brain-cell of a glowworm or one trembling with the harmonies of *Tristan und Isolde*, the stuff it is made of is much the same"; it is merely a specialised form of protoplasm, containing considerable quantities of phosphorus.

Physiologically considered, the molecular vibrations which are the concomitants of sensation and thought are situated in the nerve-cells spread over the surface of the brain, forming a layer known as the "grey layer." When these cells are destroyed, thought and sensation and voluntary movement are abolished. Certain areas of grey matter are concerned specially with movements, others with hearing, others with thinking. Thus, if a certain group of cells in the posterior part of the third left frontal convolution is destroyed, power of speech is lost. Thinking powers seem to be located chiefly if not entirely in the frontal lobes (those behind the brow), but the special faculties, mathematical, philosophical, etc., have not been located—indeed it is doubtful if there be such a thing as *separate* faculties, and the "bumps" of the phrenologists have no sort of relation to the faculties they are said to represent.

In a general way it may be said that good frontal development is usually associated with mental power ; but between the total weight of the brain and mental ability there is no constant connection. Idiots have sometimes very large brains and clever men sometimes small ones, and the following tables will show how little connection there is between weight or size and ability.

Average human brain 1400 *cubic centimetres.*

Dr Dollinger	1207	Agassiz .	1512
Harley . .	1238	Thackeray .	1644
Gambetta .	1294	Schiller . .	1781
Liebig . .	1352	Cuvier . .	1829
Bischoff .	1452	Tourguenieff .	2012
Broca . .	1485	Byron . .	2238
Gauss . .	1492		

(From *New Conceptions of Science*, Synder.)

Average human brain 49·5 *oz.*

Abercrombie .	64·7	Whewell .	51·2
Lord Campbell	56·7	Grote . .	52
Webster .	55·5	Tiedmann .	47·4
Chalmers .	54·8	Hausemann .	45·4
De Morny .	54·0	Helmholtz .	45

(From *Journal of Anatomy and Physiology.*)

Karl Pearson and Dr Raymond Pearl, after analysing the weights of 2100 adult male and 1034 adult female brains of Swedes, Bavarians, Hessians, Bohemians, and English, reported in the *Journal of the Biometrical Society*: "There is no evidence that brain weight is sensibly correlated with intellectual ability. Of the five races investigated by the biometricians, the English have the smallest mean brain weight. The mean of the adult Englishmen is 27 grams less than the Bavarian mean, 65 grams less than the Swedish mean, and 120 grams less than the Bohemian mean."

It must be remembered that only a small fraction of brain is intellectual in function, and it is probable that mental ability depends more on the architectural or textural arrangement of the cells and their special molecular activity than upon their total bulk and weight.

The brain, then, is in some way and in some sense the organ of thought ; thought is in some way and in some sense dependent on its structural integrity and functional activity ; and yet it is impossible to find the causal connection, and it may well be doubted whether the relationship is causal at all. How can movements or conditions of material atoms, or, if you will, of ethereal vortices, produce sensation and conscious thought ; and why should the production be limited to the special molecular combinations of the cells of the brain ? Waves of ether of a certain length break on the retina of the eye and cause its molecules to vibrate in new ways, and the molecular disturbance spreads up the optical nerve to certain brain-cells and *we* have consciousness of red. But *why* have *we* consciousness of red ? The waves have no colour, the molecular agitations have no colour ; why, then, do *we see* red ? By altering the length of the wave, again, we can alter the colour ; but what has length to do with colour ? Colour is not fast, or slow, or long, or short. So with sound.

Certain waves of air beat upon the drum of the ear and in certain brain-cells produce a sensation of sound, varying with the rapidity, amplitude, etc. of the waves ; but the waves *qua* waves are quite silent, and the vibration of the cells of hearing is silent, and there is no evident connection between the size or rate of waves of air and the consciousness of sound. How is it ?

Tyndall, in his famous Belfast Address, imagines Bishop Butler arguing thus : "I can follow the waves of sound until their tremors reach the water of the labyrinth and set the otoliths and Corte's fibres in motion ; I can also visualise the waves of ether as they cross the eye and hit the retina. Nay, more ; I am able to pursue to the central organ the motion thus imparted at the periphery, and to see in idea the very molecules of the brain thrown into tremors. My insight is not baffled by these physical processes. What baffles and bewilders me is the notion that from these physical tremors things so utterly incongruous with them as sensation, thought, emotion can be derived. You may say or think that this issue of consciousness from the clash of atoms is not more incongruous than the flash of light from the union of oxygen and hydrogen, but I beg to say that it is. For such incongruity as the flash possesses is that which I now force upon your attention. The 'flash' is an affair of consciousness, the (?) objective counterpart of which is a vibration. It is a flash only by your interpretation. *You* are the cause of the apparent incongruity, and *you* are the thing that puzzles me."

If the cells of the brain are the source of thought, how do they produce it? We can hardly be satisfied with the explanation of Karl Vogt and Cabanis that the brain secretes thought just as the liver secretes bile.

All scientific explanation amounts to identification of the unfamiliar with the familiar. Thus we explain the moon's motion by identifying it with the motion of a falling stone; we explain the heat of the body by identifying it with the heat of ordinary exudation; and we explain the aurora borealis by identifying its colours with the colours produced in a Crooke's tube by electrical discharges through gases.

But what identity can we detect between molecular motion and thought? "Are you likely," asks Tyndall, "to extract Homer out of the rattling of dice, or the Differential Calculus out of the clash of billiard-balls?"

And, from another point of view, what *is* molecular motion? Molecular motion is itself thought, and exists only in thought; it is really an abstract idea—a concept, as much as height or whiteness ; it is simply an abstraction of certain properties or qualities we suppose or assume to be present in all matter. We find that material objects differ in colour and shape, and we strip them of all points of unlikeness, and find that there remains a point in which they all agree, *i.e.* particles in motion ; and we talk as if the particles in motion had an objective existence : they have not ; they are merely an hypostatised concept—a *summum genus*. Sir William Hamilton defines a concept as "the cognition of general character, point or points in which a plurality of objects coincide" ; and molecular motion is just such a concept. To try to explain thought or conception by a concept is obviously absurd.

Suppose we put aside the abstract idea, motion. Suppose we allow the particular molecules *concrete* existence ; suppose we make each of them, not a hypothetical dynamic basis of matter, but material, with the ordinary tangible and visible qualities of matter (which, of course, is quite contrary to the ordinary conception of matter as motion) ; suppose we are able to magnify or modify the molecules till they become apparent to the sight and touch—I do not think that will help us to understand the causal connection between the particles and the thought ; for the particles are merely the sum of their qualities, and every quality is a subjective experience, and exists merely in and as thought. If the molecular particles are grey, the greyness is surely in the perceiving mind ; if hard or soft, the hardness or softness is surely in the perceiving mind. And we surely cannot attempt to explain thought merely by a reference to some of its contents. A brain-cell, and all its properties and motions, is simply a part of the consciousness we seek to explain. As Stallo (*Concepts of Modern Physics*) well puts it : " However much, and in whatever sense, it may be contended that the intellect and its object are both real and distinct entities, it cannot for a moment be denied that the object of which the intellect has cognisance is a synthesis of objective and subjective elements, and is thus primarily, in the very act of its apprehension and to the full extent of its cognisable existence, affected by the determinations of the cognising faculty."

From whatever point of view we approach the question we are met with mystery. " We can," says Tyndall, " form a coherent picture of the physical processes—the stirring of the brain, the thrilling of the nerves, the discharging of the muscles, and all the subsequent motions of the organism. But we can present to our minds no picture of the process whereby consciousness emerges, either as a necessary link or as an accidental by-product of this series of actions."

All we do know is that thought is in some way dependent on the brain, and that the dependence is not of that kind usually known as *causal*.

Could we understand the relationship of brain and mind, we might understand the whole mystery of existence.

CHAPTER XXI

SCIENCE AND DEATH

We do not understand life, neither can we understand death; but it seems certain that, regarding matter from a mechanical standpoint, we cannot draw such a hard and fast line as for some centuries we were wont to draw. As we have shown in previous chapters, to talk of dead, inert, passive matter is nonsense. Dead matter so-called is an enormous reservoir of energy.

We can find no better definition of life, as contrasted with death,—and we offer the definition most diffidently,—than combinations of molecules which are constantly breaking down and as constantly being renewed, which, despite such flux, retain constantly the same general chemical composition, and which always show molar as well as molecular motion, resulting in locomotion and reproduction. What we call *death* is a change in the combination, resulting in abolition of molar movement and decomposition of the molecular aggregate. In the case of conscious animals, the change is supposed to be followed by permanent loss of consciousness.

Now, what is the cause of the change? Is death some mysterious force, or is it just the forces we see ordinarily at work among atoms and molecules? The decomposition it causes is of exactly the same class as any other chemical decomposition, and follows similar laws. Chemically speaking, it is a breaking down of large, complex, unstable molecules into simpler molecules, such as water and ammonia. What takes place after death—after abolition of molar movement—is simply a series of ordinary chemical processes, which can be hastened or retarded by ordinary chemical methods.

But what is it that *initiates* these new actions? Merely some mechanical or chemical interference with the ordinary molar or molecular movements commonly called vital. We may mechanically prevent the entrance of oxygen to the tissues; and the protoplasm, debarred from its ordinary exchange of atoms, will undergo the molecular rearrangement we know as "rigor mortis"—an arrangement that no longer gives and takes, but gradually, under the chemical influence of the air or of putrefactive germs, breaks down. We may put a bare bodkin into the so-called "vital knot" at the base of the brain, and by disturbing the ordinary molecular vibrations of the cells of the "respiratory centre" prevent the propagation to the respiratory muscles of those molecular waves which cause respiratory movements, and thus, again, by depriving the protoplasm of oxygen, cause permanent molecular changes in it, incompatible with the processes known as *vital*, which it had previously shown.

Life in living tissue is like nothing perhaps so much as a candle-flame. In the candle-flame the molecules are composed and decomposed, yet the candle-flame keeps always the same shape; but let us change the environment of these dancing, partner-changing molecules—let us conduct away their heat by means of some copper wire, or let us deprive the flame of oxygen—and *out* goes the candle.

Protoplasm is only a slow flame, easily extinguished. It is easy to understand how a little thing—a needle, a few grains of poison—may destroy a large organism when we remember how intricately correlated it is in its minutest parts. Break but a single thread in the warp and woof of life and the whole wonderful web, with its pictures and patterns, all comes asunder. Take but a single brick out of the great house of life and it falls into ruin. The construction of the wonderful organisms of vegetables and animals is a miracle and mystery, but their death is merely a chemical or mechanical commonplace.

To man, death means pre-eminently loss of consciousness. Consciousness, we have seen, is in some way connected with brain. When a man sleeps, when molecular and molar motion are diminished, and when the brain, supplied with less blood and less oxygen, has less chemical activity, consciousness is dulled. So in illness or old age, when the brain is starved, consciousness usually becomes less acute ; and finally, death is usually preceded by impairment or loss of consciousness, and seems always to mean unconsciousness, with loss of power of molar motion, and chemical change. The dead man hears not, sees not, feels not, and moves not ; and the consciousness—the mind that thought and discerned—seems quite abolished.

All this seems to imply that thought and consciousness are a transient chemical phenomenon, and that they cannot exist apart from certain molecular structure and action. That seems to be the clear logical implication of the facts. Disturbance of the chemistry of the cells of brain causes disturbance of the consciousness in varying degrees, and destruction of the chemical structure of the cells destruction of consciousness. We cannot expect the same molecular edifices ever to be built again : the atoms are scattered far and wide :

> "Imperial Cæsar, dead and turned to clay,
> Might stop a hole to keep the wind away,"

or might be dew in the heart of a rose, or carbonic acid gas in a bottle of soda-water. There can be no remobilising of the molecules that made a man. They were carefully extracted from the nebula, they were carefully stored in the mother's ovary, they were carefully gathered from the mother's blood, they were carefully and wondrously built up into the magic machinery of the body; but once they are disarranged, and rearranged, and jumbled together, and torn apart, they can never go together again. There is no power known which can remake the digested or decayed egg, or rebuild the structure it evolved when once that structure is destroyed.

If, then, consciousness depends on a certain motion and disposition of molecules, death, with its rigor mortis, and its corruption and decay, is the end of consciousness for ever. Can science give us no hope of conscious life beyond death? Even up to the very moment when the heart stops and the jaws stiffen, the mind may be quite clear and the senses most acute; and men who have been mistaken for dead, or who have been considered completely unconscious, have reported, on recovery, that they were quite conscious all the time. In cases of drowning, too, it is well known that just before unconsciousness the brain often works with extraordinary rapidity. Is it not possible that even the *post-mortem* molecular arrangements may mean some kind of consciousness? Is it possible that, all in a moment, by a mere rearrangement of minute molecules, the tremendous, almost infinite universe of a clear, strong mind can be annulled?

Science can give no hope either of a resurrection of the body or of a bodiless consciousness. The very most science can say (and, so far as I know, she has not said it) is simply that it is possible that consciousness may exist for a little time after apparent death. It is indeed scientifically possible, almost scientifically probable, that the tremendous molecular perturbation in the cells of the brain may mean a period of intense consciousness of some sort. It is scientifically possible that the brain-cells die last, and that the molecular messages from the dying muscles may be translated into some beautiful mental picture. These things are scientifically possible, but it is scientifically impossible that after disruption of the molecules of the brain-cell consciousness can still persist. Science believes that consciousness depends on certain molecular machinery, and it can no more believe that consciousness can exist after the machinery is broken than it can believe that a watch can go without works.

That is the verdict of science; and yet our mind declines to believe it, and it appeals to philosophy.

Can philosophy give no hope? Philosophy can. Philosophy admits that from one point of view—the point of view of science—the mind is dependent on the integrity of the brain, and that logically there seems no way out of it; but still there is a philosophic way out of it—the way we have indicated in the previous chapter.

The cells of the brain—the cells upon which consciousness seems so certainly to depend, as can be shown by many experiments—are nevertheless only items of consciousness. Every quality they possess simply exists by virtue of the consciousness which *seems* to depend upon them: they have certainly no separate existence outside the consciousness. How, then, can they be the source of consciousness? Science says certain cells are the cells of sight and see; but it is quite conceivable that a man might be trepanned, and might by means of mirrors and microscopes see these very cells which are supposed to be the seat of sight. How can that be? How can the cells get outside themselves and see themselves? They cannot! It is absurd! Therefore sight cannot depend on them. But, says Science, and says truly, "if you destroyed these cells you could not see." "Likewise," retorts Philosophy, "if you destroyed the eye you would not see; but you do not say, therefore, that the *eye* sees."

The eye *seems* to see, and the man in the street says he sees with his eyes ; but Science asserts that sight is further back, and believes that it is in certain brain-cells. "*Further back still*," says Philosophy, since these cells which are supposed to see can themselves be seen, and consist, after all, only of a bundle of subjective sensations.

Such a mess and a muddle Science and Philosophy make of it between them ; yet out of the mess and the muddle of contradictions certainly springs the *hope* of immortality ; for we at least discern quite plainly that the whole thing is a great, inexplicable mystery, and that the logic of science is too superficial to solve the problem of consciousness and immortality. The question is at least left open—Science herself must admit that her methods are not infallible ; and if the question is left open, then Faith, and Love, and Beauty settle it in a moment, and we know that beyond this strange thing called death there is immortal life.

Death should be to men a beautiful hope, and not a fear. It *cannot* be the end. The scientific logic that would say so is easily refuted by philosophy, and philosophy can easily go further ; it can show that when we talk of *beginnings* and *ends* of consciousness we talk nonsense. Birth and death are only finite terms, useful enough for the finite judgments required in everyday life ; but used with respect to consciousness, they are meaningless. The question is not even fit to be discussed. Beginning and end may be used with regard to parts of consciousness : this pen has a beginning and an end ; this chapter has a beginning and an end : but with regard to consciousness *as a whole*, it cannot be used. Unless we can get outside consciousness, which we cannot, and look on it as something separate from ourselves, which we cannot, we cannot legitimately speak of consciousness as having a beginning and end, either in space or time. What is *time*, forsooth ?—it is merely a form of thought imposed by the limitations of the intellect. An infinite mind has "no time, neither shadow of a turning." Time depends on consecutive mental fields ; but with an infinite field there would be neither past, present, nor future ; for past, present, and future would be consentaneous.

What is time ? Why, the stars we see now may have been extinguished thousands of years ago.

We cannot talk about the beginning and end of consciousness ; and the mental tendency that makes us do so simply because certain facts seem to show it, is false and mistaken, as the tendency makes us still think of the sun going round the earth.

The sun certainly seems to go round the earth, and we certainly find it almost impossible to conceive of the earth turning on its axis, and still talk and think of the rising and setting of the sun ; but still we know that the earth really does go round the sun.

So, with the birth and death of a man, consciousness does most certainly seem to begin and end—to be born and cease ; and yet, nevertheless, a larger view assures us that this must be a delusion ; and, in spite of the protest of methods of reasoning that are justified by their results in the affairs of everyday life, we are bound to believe the broader, deeper view, and to trust the larger hope. The earth goes round the sun ; there is no matter apart from consciousness ; and *there is really no death.*

Those who face the facts will reach a firm faith, and will meet death with wonder and without fear, believing that it is the portal of a fuller consciousness.

Yet to many life is good as it is, and in all a love of life is implanted as a first condition of survival; and it may be asked, has science done anything and can science do anything to prolong life as we know it ?

Science has prolonged human life and is still prolonging life in many ways. We have explained that death is a destructive interference with certain modes of molecular machinery. The interference may be either mechanical, as when a man falls on his head or cuts his throat ; or chemical, as when he swallows prussic acid or typhoid bacilli, or an excess of alcohol. With accidental mechanical interference with the machinery of life science is only indirectly concerned, but chemical interference is her special province, and she battles this under such titles as pharmacy, pathology, and medicine. Science, within the last sixty years, has found a host of poisonous microscopic vegetables that grow in the human tissues and chemically interfere with the chemical processes of life, and science has not only found these vegetables but has found ways and means of avoiding or destroying them and their poisons. We cannot here enter into the big subject of bacteriological medicine, but we may just recall here how science has found an antitoxin able to neutralise the poison of diphtheria, and has thus saved thousands of children's lives.

Not only thus, but in many other ways, such as by providing fresh air or advocating wise feeding, or by killing rats and mosquitoes, science has also checked the chemical assaults of death, and has lengthened the average life of civilised man.

Still, even when such recognised attacks of death are all baffled—still, what are called old age and natural death are inevitable, and cannot be long postponed by any known means.

Metchnikov is of the opinion that old age is in most cases due chiefly to poisons secreted by microbes in the intestine, and he suggests that these microbes may be kept in check by the microbes of sour milk. He points out that the Bulgarians, who consume large quantities of milk, usually live to an old age.

However that may be, there can be little doubt that the average length of life of the human race is likely to increase, both because length of life is a variation with survival-value (*i.e.* it gives offspring of long-surviving parents, who have a better constitutional and environmental chance of surviving), and because surgical and medical art and better conditions of living all tend to prolong life.

It is probable also that life will not only grow longer but happier ; that old age will become the happiest time of life, and that the foolish fear of death will be replaced by a wondering desire for the "undiscovered country."

Many fear death not because of the mystery of it, not because of the terrors with which a blasphemous theology has tried to invest it, but simply because of the pain of it. But in most cases death is as painless as sleep, and in many cases death is like a beatitude, full of peace and beauty. Even when the breath is panting and the pulse flagging, the conscious mind may be filled with visions of joy. Many die with a smile on their lips. And what though there be pain and struggle, shall we not face it, so long as conscious will is left in us, in the spirit of Browning, when he wrote his "Prospice":

"Fear death?—to feel the fog in my throat,
The mist in my face,
When the snows begin, and the blasts denote
I am nearing the place,
The power of the night, the press of the storm,
The post of the foe;
Where he stands, the Arch Fear in a visible form,
Yet the strong man must go:
For the journey is done and the summit attained,
And the barriers fall,
Though a battle's to fight ere the guerdon be gained,
The reward of it all.
I was ever a fighter, so—one fight more,
The best and the last!
I would hate that death bandaged my eyes, and forebore,
And bade me creep past.
No! let me taste the whole of it, fare like my peers
The heroes of old,
Bear the brunt, in a minute pay glad life's arrears
Of pain, darkness and cold.
For sudden the worst turns the best to the brave,
The black minute's at end,
And the elements' rage, the fiend-voices that rave,
Shall dwindle, shall blend,
Shall change, shall become first a peace out of pain,
Then a light, then thy breast,
O thou soul of my soul! I shall clasp thee again,
And with God be the rest!"

CHAPTER XXII

SCIENCE AND CHRISTIAN SCIENCE

"PRIMUS in orbe deos fecit timor" surmised Petronius; and the primæval gods of primæval fear were capricious and emotional deities, dispensing thunderbolts and smiles much as the fancy took them. In a world ruled by divine caprice, all superstitions throve; augurs and sibyls drove as prosperous a trade as any Piccadilly palmist, and love philtres had as large a sale as any modern liver-pill. But the wiser men soon grew tired of an incoherent universe, and Epicurus and the atomic school, rising in rebellion, endeavoured to reduce to atoms the drunken and dissolute gods. That was the birth of science; and the work of science for nearly two and a half millenniums may be epitomised as the atomisation of the gods. How far science has failed, and how far it has succeeded, the preceding chapters will show. But science has not only destroyed; it has constructed. It has destroyed the old capricious gods, but it has constructed of the atoms a God in whom there is no variableness, neither shadow of turning. It has destroyed the gods of fear, but has revealed the God of Law—a God who promises and fulfils; who says do this, and I shall do that; who says that what a man sows that shall he also reap; who says "sow tares and ye shall reap them, sow flesh and ye shall reap corruption." This is the God of Science: a God who hears no prayer but labour, and whose answer to prayer is the reward of labour according to His laws—a God whose words are deeds, and whose deeds are not capricious, but as coherent as a star. God's past deeds say that a certain comet will return at a certain time. It flashes out millions of miles into the invisible; generations live and die as it speeds its way through space. But in God's own time it will return.

In 1682 the astronomer Halley saw a comet, and from the laws of the deeds of God he learned that it would return in 1758. It was a long contract to make with law, and before his prophecy was fulfilled Halley died; but the promises of God are always kept, and on Christmas Day 1758 the comet duly appeared. Through similar faith in the truth of God's deeds, we know that the same comet is returning even as I write, and may flash into view at any moment; through similar faith we know that Venus will make a transit across the sun in 2004. Not only in large things—in comets, and planets, and suns—is law faithful and just; but even in infinitesimal things it never fails us. We know that if we add a certain amount of oxygen to a certain amount of hydrogen we can get a certain amount of water, and we get *exactly* that amount. We may buy oil from an oil-merchant under guarantee, and we may find that it fulfils its guarantee or that it does not; but the guarantee of law never fails. Law guarantees that hydrogen will always act in certain ways; it may come from a volcano on the Andes, it may come from the pores of a meteorite; but it will perform its appointed functions with an exactitude beyond all exactitude of man-made laws. Even the atoms of hydrogen ninety-three million miles away in the sun are found to throb in exactly the same rhythm as the hydrogen obtained from a grain of Dead-Sea salt. The millions and millions of atoms have each their own rôle, and play it always in exactly the same fashion.

Every proposition of science may be regarded as a formulation of the promises of God, and every successful application of the proposition as a practical proof that the promises are true. Thus the proposition that oxygen is the agent of combustion is proved every time we burn magnesium in oxygen gas. The steam-engine, the motor-car, the clothes we wear, the food we eat, the poisons we eschew, the diseases of which we die, are all repeated proofs of the constancy of law, of the faithfulness of the deeds of God.

However science may conceive of cause and effect, whether in terms of matter, or in terms of force, or in terms of Deity, the fact remains that for two or three thousand years all the great thinkers of the world have found laws in the universe, and have spent their best powers in understanding and applying them. However science may interpret the uniformity of law in things great and small—in moons and microbes, in suns and cells—still the fact remains that science preaches and teaches uniformity of law with no uncertain sound, and that on uniformity of law are based the equanimity and progress of modern civilisation.

And lo and behold ! at the end of the nineteenth century there appears in America a woman called Mrs Eddy, who coolly proceeds to subvert both science and philosophy. An illiterate woman, with a history of hysteria, with no knowledge either of science or of philosophy, with no mental training of any kind, with no particular intellectual capacity, she writes a book which every accredited scientific and philosophic expert in the world knows to be pretentious nonsense, and yet such are the credulity and ignorance of mankind that she has made not only a large fortune but also thousands of converts.

What exactly Mrs Eddy means it is impossible to discover, since most of her statements mean nothing, and since those which mean anything are self-contradictory. Still, the fundamental article of her creed—the article which is the fulcrum of her influence—seems to be, that there can be no disease and no pain because God is good, and that therefore disease and pain are due to the sinful imagination of the sufferers or of mankind. The reasoning is, of course, logically, philosophically, and ethically unsound, and probably Mrs Eddy and her neurotic worshippers do not know the difficulties of the terms they use so glibly ; but still it may be interesting to glance at the broad relationship of this pseudo-creed to the creed of science.

Science says that disease is due to certain structural or functional abnormalities caused by material agencies. When a man breaks his leg, Science says that the incident is of the same nature as the breaking of any other bone, *e.g.* breaking of a bone of beef by a butcher, or the breaking of a child's leg by a surgeon to straighten the bone. Christian Science, on the other hand, professes to believe that the fracture of a man's leg is not real—that in fact the bone is not broken, and cannot be broken, because God is good. Again, Science says that typhoid fever is due to tiny germs whose vital chemistry disturbs the vital chemistry of man ; and to Science the germs are as real as the man, and the digestion of a man by a germ is quite as real as the digestion of a man by a cannibal. But Christian Science asserts that the germ is imaginary, and that fever, and no doubt the rise in the thermometer, are imaginary, and that the disease has no real existence. Again, Science says that the burning of a man's hand is just as real as the burning of King Alfred's cakes, or the frying of bacon; while Christian Science declares that the burn and pain are only imaginary. Yet, again, Science declares that poison acts, just as food acts, by means of molecular and chemical affinities, and that the narcotic action of opium is just as real as the nourishing action of red herrings; while Christian Science asserts that poisons do not poison; and I believe that a novel by a well-known novelist (may he be forgiven!) represents that a Christian Scientist swallows a fatal dose of poison without bad effect.

Truth is known by its consiliences and consistencies, and such views as these of Christian Science which we have noted obviously lead to a multitude of contradictions before they proceed two feet. If the fracture of a bone is merely imaginary, why not try the skull of a Christian Scientist beneath a steam-hammer? If germs are only imaginary, why not inject a few pyogenic organisms into Mrs Eddy's jugular vein? If germs are only imaginary, why not garden weeds, and tigers too? If a burn is only imaginary, why not sit on a bonfire at once? If poisons do not poison, why not flavour milk with prussic acid?

Indeed, the views of Christian Science are so absurd that failure to see their absurdity certainly implies mental deficiency, and we cannot here undertake to try to enlighten the mentally deficient. It would be easy to show to the ordinary sane man the practical dangers of Christian Scientist teaching, which have already been painfully and tragically demonstrated in the police courts; it would be easy to show to the healthy-minded man that the denial of pain and disease empties the world of half its nobility and heroism; it would be easy to prove that the statements of cures made by Christian Science are wholly untrustworthy, and that most Christian Scientists belong to stock neurotic and mentally unstable; but such demonstration must be superfluous, for no clear-headed man is at all likely to be duped by Christian Science, and the muddle-headed who are duped are incapable of reasoning.

What we wish to do here is not to demonstrate the folly of the most cowardly and vulgar religion ever preached, but merely to point out the very interesting fact that the mind able to believe such muddy inconsistencies is really a case of reversion to the primitive savage mind. For hundreds of years the human mind has been evolving a type able to appreciate and able to use the machinery of law—able to imagine the unseen, and able to discern real identity in apparent diversity. Century after century the stronger minds of men have fought upwards from a tangled wilderness of inconsistencies to a knowledge of consistent law—to the knowledge that "it is absolutely decreed what each thing can do and what it cannot do, according to the conditions of Nature," and that "each thing has its properties fixed and its deepest boundary-mark." To the primitive mind, on the other hand, nature is incoherent, inconsequent, and capricious; and incoherent, inconsequent, and capricious is nature as seen by the Christian Scientist. The Christian Scientist cooks his dinner over a fire, yet if he happens to cook his finger the latter cookery is merely a wicked imagination. The resemblance between his finger and a beefsteak is beyond him. The Christian Scientist believes that lions and fleas and midges can bite and digest people, but the idea that microbes can bite and digest people is quite beyond his grasp, and is to him a wicked imagination. His world is a world at the mercy of the caprice of the individual, and he cannot grasp its larger relationships. He has no scientific imagination; he has no philosophic insight; he has indeed the primitive mind of a savage. A broad generalisation merely bewilders him, as it might bewilder a child. One may point out to him that the tubercle bacillus is as much a plant as a dock, and as real as the weeds in his garden. He cannot grasp that ; he sees things merely in their superficial aspect. One may point out to him that to deny the action of a poison is to deny chemical action of all sorts, and that it is impossible to pick out one kind of chemical action and to call it unreal and imaginary. He cannot see that ; he is no more able to see it than a savage or a child. He denies law when he chooses, or when he is unable to comprehend it ; and he breaks the warp and woof of the web of the universe at his own sweet will. It is partly amusing and partly tragic.

And yet Nature is not mocked. If the Christian Scientist deny law and tamper with truth, law and truth will have their revenge : the tubercle bacillus will gnaw away lips and nostrils ; the diseased heart will suddenly insist on the truth by ceasing to beat ; the septic joint will sow death in the blood; the starved and stunted character will become undeniably decrepid.

Mrs Eddy may claim that she can cure pain and disease, and that these have no real existence—but the stars laugh at her, and every sunrise ridicules her pretentious folly.

CHAPTER XXIII

THE PLACE OF SCIENCE

In one of his purple passages Robert Louis Stevenson declares : "Science writes of the world with the cold finger of a starfish ; it is all true, but what is it when compared to the reality of which it discourses ? where hearts beat high in April, and death strikes, and hills totter in the earthquake, and there is glamour over all the objects of sight, and a thrill in all noises of the ear, and Romance herself has made her dwelling among men. So we come back to the old myth, and hear the goat-footed piper making the music which is itself the charm and terror of things ; and when a glen invites our visiting footsteps, fancy that Pan leads us thither with a gracious tremolo ; or when our hearts quail at the thunder of the cataract, tell ourselves that he has stamped his hoof in the nigh thicket."

But Stevenson is surely wrong. Science writes not with the cold finger of a starfish, but with the radiant finger of a star. She deals not merely with truth but with beauty, and in her eyes "seven snow-drops sister the Pleiades," and a grain of dust is big with the mystery of the whole Cosmos. Science—the discovery, acceptation, and utilisation of the Consistent—has not only saved man from fear and impotence, has not only given man peace and power ; it has also opened to him wide, wonderful, and mysterious horizons.

What is there narrow and cold in the scientific conception of matter, of man, of the universe? Is it not rather a thrilling picture—the shred of a nebula woven into a world, and the world, with its wonderful burden, reeling round the sun, between Venus and Mars! Does not the idea of the atom as a microcosm appeal to the imagination?

To maintain that science is purely utilitarian and material—to try to fetter her within the horizons of a coleopterist—is to have a complete misconception of her dominion and destiny. All related knowledge is the province of science; and if she be at all wise and deep-seeing science, she walks through her domains hand in hand with poetry and philosophy.

Why, then, should Robert Louis Stevenson attribute to science the cold finger of a starfish? Simply because science has perils for her votaries. Her province is so large, her problems so multitudinous, her details so imperative, that many find even the field of a microscope sufficient for their curiosity. Again, her deeds are so practical that many forget their divine applications, and her facts are so definite that many miss their infinite relationships. Hence many scientists become one-sided, narrow, cold, and dogmatic.

Even the great Darwin suffered from a too great devotion to his special department of science. In his autobiography he writes : "I have said that in one respect my mind has changed during the last twenty or thirty years. Up to the age of thirty, or beyond it, poetry of many kinds, such as the works of Milton, Gray, Byron, Wordsworth, Coleridge, and Shelley, gave me great pleasure, and even as a schoolboy I took intense delight in Shakespeare, especially in the historical plays. I have also said that formerly pictures gave me considerable, and music very great, delight. But now for many years I cannot endure to read a line of poetry ; I have tried lately to read Shakespeare, and found it so intolerably dull that it nauseated me. I have also almost lost my taste for pictures or music. . . . My mind seems to have become a kind of machine for grinding general laws out of large collections of facts, but why this should have caused the atrophy of that part of the brain alone on which the higher tastes depend I cannot conceive. A man with a mind more highly organised or better constituted than mine would not, I suppose, have thus suffered; and if I had to live my life again, I would have made a rule to read some poetry and listen to some poetry at least once every week, for perhaps the parts of my brain now atrophied would thus have been kept active through use. The loss of these tastes is a loss of happiness, and may possibly be injurious to the intellect, and more probably to the moral character, by enfeebling the emotional part of our nature."

There can be no doubt at all that an exclusive devotion to any branch of science which deals exclusively with limited areas of objective relationships does damage, derange, and desiccate the higher emotional faculties, and that the term "dry-as-dust," so commonly applied to scientific men, is not without its justification. Objective science, starting from the false if convenient assumption of objective existence, sees life only from certain standpoints and certain sides; and though it may make pills or aeroplanes, it cannot of itself make creeds; and if it is to be a power in life outside the workshop and laboratory, it must seek assistance from its elder sisters, poetry and philosophy. A very limited acquaintance with philosophy would have saved Carl Vogt, for instance, from such an absurd assertion as that the brain secretes thought even as the liver secretes bile.

Science is great and wonderful only when she discovers her limitations, and sees behind the barriers, the mystery of the infinite. Let Science analyse a red rose into whirling colourless atoms, let her analyse sight and hearing into a dance of molecules, let her analyse marble into a seething sea, and let her show, if she will, that by such analyses she can build up a consistent scheme of the universe, and weigh the sun, and harness Niagara, and vanquish disease. But let Science nevertheless recognise that, starting from the false postulate of the separate objective existence of matter, her extreme results, however convenient and consistent, are not absolutely true. Let her recognise that her scheme is nothing more than a convenient working hypothesis, and that she is no nearer the truth when she analyses a rose into whirling atoms than a wind when it analyses it into whirling petals. Let her, indeed, recognise that the red rose is more real and more true than the dancing hypothesis, to whatsoever practical results the hypothesis may lead, and that the world, as we see and feel it, is more real and more true than the phantasmal things she invents and supposes in order to harmonise and co-ordinate its facts. It is probably more true to say that this paper is white and still than that it is colourless and whirling, since it is the former properties that help to make the concept, paper. It is probably more true to say that *I* see and that *I* think than to say that cells in the brain see and think. I am writing in the British Museum, under the great dome, with its dado of books; and the scientific statement that the vision of the dome and books is an agitation of molecules in my brain seems to me either false or meaningless—the ultimate "reductio ad absurdum" of the primary postulate of science (*i.e.* that the objective has separate existence).

Let it be granted that by assuming that the eye sees, and that brain-cells think, and that the earth goes round the sun, we can draw many useful practical inferences; still, the assumptions are only convenient symbolism, and as far away from real truth as the mathematical symbol *x* may be from the star it may represent.

The most materialistic of philosophers must admit that all objects are *subject-objects*, and that the ultimate atoms of science—*pace* Tyndall—are simply and purely conceptual; and both admissions involve that the conclusions of science are only provisional. True Science grants and recognises all this.

The great achievement of modern science seems to me not so much its mechanical inventions as its *rapprochement* to philosophy and religion—a *rapprochement* necessitated by its own progress and by its recognition of its own limitations. It has discovered that the objective is merely force; it has abolished the barrier between mind and matter; and where it ends, philosophy and religion may begin.

The working hypotheses of science beginning in an unsound postulate have ended in mystery, and symbolism, and contradiction; and now science must frankly, and gladly, and tolerantly surrender ultimate questions of beginnings and endings to Religion and Philosophy. If Religion finds a working hypothesis in a God—the Alpha and Omega, the Beginning and the End—Science will not, cannot, say her "Nay." The hypothesis of a God of Love is just as warrantable as her hypothesis of electrons, and perhaps *works* better. Where Science can find only force, Religion and Philosophy can find Will; and even crude and anthropomorphic views of God must be given value, as *working* hypotheses, on a level with such scientific *working* hypotheses as the mighty atom and the ether waves.

In all departments of practical life Science is supreme. She builds bridges; she constructs dams; she cultivates germs and potatoes; she mends men's bones and boots, she heals his diseases; and anyone who denies the value of her postulates and laws in such connections will suffer as suffer the Christian Scientists. But further—and this is the point too apt to be ignored and forgotten—she has opened new vistas to the imagination : she has shown that the little twinkling stars are really suns ; she has shown how worlds are made ; she has given to man the marvellous hypothesis of evolution, and has opened up tremendous horizons before and after. As soon as man learns to take an imaginative view of the slow results of Science, Science will take a place in his daily life that will increase tenfold — even apart from its practical advantages—the joy and the interest of living. We must get out of the dust of dry detail on to the heights of great generalisations and conceptions. We must let Science *capture the imagination.*

Why should the moon be only a yellow disc of varying shape to most men ? Does it not have more meaning and beauty when we imagine its origin torn from the molten world, when we can see in it not "the man in the moon," but the mighty craters of dead volcanoes ? Does it not stand out better from the sky when we see in the curved line of its crescent or gibbous phase sign that it is a globe, and not a merely flat disc ? Does not Mars have more interest when we imagine the sun shining on its red sands, and living creatures wandering along the green banks of its canals ? Does not the earth seem a more marvellous dwelling-place when we consider its past history, when we try to realise it spinning in its axis and rushing through space towards the constellation of Hercules ? Does not the heart of man seem more wonderful when we understand something of its mechanism ?

Nor is Science fascinating merely in what it has shown and done : more fascinating still are its hopes and aspirations, and prophecies and questions. What is to happen in future ? What is man to become ? Will disease be finally extirpated ? Is the philanthropic effort to keep the diseased alive wise and far-sighted, or foolish and short-sighted ? Will man ever be able to create life out of inorganic molecules ?

From whatever point regarded, science has both practical importance and theoretical interest ; and it is sad that it should be so unjustly neglected by the man in the street, and so unjustly maligned by the man in the pulpit.

When, at the last meeting of the British Association, subjects of the most fascinating interest were discussed, the newspaper placards advertised only cricket matches and breach of promise cases. During the last few years Science has made the most marvellous discoveries — discoveries more marvellous than any romance, more kindling to the imagination than any poem, and yet the great majority of people know and care nothing about them. "The ordinary run of men," says Sir Oliver Lodge, "live among phenomena of which they care nothing and know less. They see bodies fall to the earth, they hear sounds, they kindle fires, they see the heavens roll above them, but of the causes and inner workings of the whole they are ignorant, and with their ignorance they are content." Why is this? Is it not strange?

We cannot all be practical scientists, but we can all take an interest in scientific problems and achievements, and in their imaginative references; and there is no interest in the world more living and lasting. "Science," says Renan, "will always remain the gratification of the noblest craving of our nature curiosity; it will always supply man with the sole means of improving his lot."

It is time that men knew that Science does not write with the cold finger of a starfish; it is time that men realised that true science is not a mere compilation of dead facts; it is time that men understood that Science is flamboyant and alive.

The religious have shunned Science because its premises lead logically to irreligious conclusions—to the belief that mind is a transient function of a perishable brain—to the belief that the earth is only a bubble in the ocean of space and time. But Science *now gives up her dogmatism*—birth and death, the beginnings and endings of things, the nature of matter, and many other things, are beyond her—and she finds herself a mighty mystic in the midst of a mightier mystery.

A certain type of mind, again, is out of sympathy with the great generalisations of science, and prefers a more simple and childlike view. This is, perhaps, a wise and good *preference* :—"What matter to me if their star is a world? mine has opened its heart to me, therefore I love it." "Except ye become as little children ye will in no wise inherit the kingdom of God" is one of the wisest of all wise sayings. The eyes that interpret the moon, and the stars, and flowers, and men, and beasts, in simple terms of form, and colour, and character, are perhaps the happiest and wisest eyes. The soul that lives without thought of the past, without thought of the morrow—the soul that symbolises infinite power simply as a God-man—is perhaps the wisest and happiest, after all; and perhaps the conveniences and weapons of modern scientific civilisation have been bought at the expense of things more excellent. After all, no analytic knowledge of a rose or a star can surpass the rose itself or the star itself. After all, life and death remain mysteries, and the chief things necessary for happiness are food, and raiment, and love. After all, civilisation is artificial, and science, as we have seen, is largely symbolic artifice. After all, the happy girl in an environment of faith, and beauty, and love, praying to her Saint, is perhaps wiser and happier than the careworn scientist bowed under a burden of wisdom, amid the ruins of an ancient creed. Perhaps the out-of-door man, brown, robust, and empty-headed, is wiser and happier than the great philosopher "sicklied o'er with the pale cast of thought." What is it all but words, and what are words compared with the sweetness and bitterness of life itself? Better let a man give all his time to selling groceries if he win thereby the means of winning love, and a home, and children, than give all his time to the problems of life and fail to live.

For such views there is much to be said; but they are not necessarily wholly antagonistic to the scientific spirit, and they may live and thrive side by side with the views of science. A man may both admire the constellations with the eyes of a child and with the eyes of an astronomer; a man may both rest on a chair and enjoy the scientific conception of it as an infinity of infinitesimal solar systems. A man may both believe in inevitable law and yet believe in God. A man may both understand the scientific view of brain-cells and yet have a simple faith in immortality. Moreover, it seems to us that faith, reached over the stormy seas and rugged mountains of philosophy and science, is firmer, deeper, higher, more beautiful than the faith of a child. We must become as little children through fighting and adventuring like men.

Conceived aright, science must always lead to belief in the unseen and to hope of immortality ; but Science must learn to recognise her own limitations—must learn to recognise that her logic is not conclusive when her postulates are dubious—and that she can only become a ruler of men's souls and a brightener of men's lives if she takes Poetry and Philosophy by the hand, and dwells with them in the temple of Beauty and Reverence.

> "Let knowledge grow from more to more,
> Yet more of reverence in us dwell,
> That Mind and Soul according well
> May make one music as before."

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