ESSAY

INTRODUCTION TO THE UNIVERSE

Rabindranath Tagore



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DEDICATION

To Sri Satyendranath Bose, receptacle of my affection

I join this little book to your name. Needless to say, it holds no scientific wealth that could be placed in your hands without embarrassment. Besides, fearing errors born of my trespass upon ground not mine, I feel abashed, and perhaps I have not honoured you at all. With a few authoritative works open before me, I have sifted and winnowed as well as I was able, and some pruning was done. Yet if, moved by the example of my temerity, some man of true learning, at once a lover of letters and a man of science, should descend to this most necessary labour, then this effort of mine will be redeemed.

Those who have begun their schooling should enter, if not the granary of science, at least its courtyard, and from the very start. There is no dishonour in accepting the aid of literature for this first introduction. It was with that duty in mind that I began. But my accountability is owed not to literature alone. It is owed to science also, which forgives not the slightest lapse in the accuracy of fact or the exactness of its telling. Though my capacity is slender, I have been as careful as I could. In truth I wrote from a sense of duty, and that duty was not only to the student but to myself; in the very act of writing I had to go on instructing myself. This discipline of the pupil's temper may, perhaps, prove of use to pupils in their own striving.

I must make my apology to you at some length, for only so can my state of mind regarding this writing become clear to you.

PREFACE

The universe of things has veiled its smallest, made small its greatest, or else withdrawn it into the wings. Whatever can be grasped within the frame of our ordinary powers, it has so arranged, in its own features, and so presented to us. But man, whatever else he may be, is no ordinary creature. He alone has doubted the very evidence of his senses, has protested against it, and has rejoiced whenever he could compel it to yield. In his discipline of passing beyond the bounds of natural power, he has made the distant near and the unseen visible, and has given speech to the incomprehensible. Within the world that shows itself lies a world that does not, and man, entering that depth, ceaselessly unbars the primal mystery of existence. The opportunity and the strength for this discipline are lacking to most of the earth's people. And those wholly cut off from its power and its gifts remain penned in one room on the far frontier of the modern age.

In a great forest, dry leaves fall of themselves beneath the trees, and thereby make the soil fertile. In a country where science is cultivated, fragments of knowledge fall and scatter ceaselessly, and so in the soil of the mind the living grace of scientific fertility stirs awake. For want of this, our minds remain unscientific. This poverty afflicts us not in learning alone; in the field of action too it leaves us unfulfilled.

If a novice such as I attempts even slightly to repair this lack, those who will find it most amusing will be the ranks of novices like myself. But on my side there is a small thing to say. A mother has a tender concern for her child, though she has not a physician's learning. Learning she may borrow; concern she cannot. And the sweetness that this concern awakens in nursing is not a thing to be despised.

That I am no votary of science, it is needless to say. But from boyhood I have been insatiable in tasting its savour. I think I was then nine or ten years old. Now and then, on a Sunday, Sitanath Datta [Ghosh] would come unexpectedly. I know now that his stock of learning was not large, but when he made plain, by examples, one or two very simple principles of science, my mind would open wide. I remember how, when a vessel of water is set on the fire, the water at the bottom grows warm and light and rises, while the cold heavy water above sinks. When he made clear

this cause of the water's heating by means of a few grains of sawdust, the wonder remains with me to this day: that in water without any division, an unceasing difference between above and below may arise. I think that was the first time my mind was made to ponder that what I had accepted without thought, as self-evident, was not so.

Later, when I must have been about twelve (some are colour-blind; I am date-blind, and it is well to confess it), I went with my father to the hills of Dalhousie. After a whole day's journey by hill-litter we would reach the dak-bungalow at dusk. He would have a chair brought out and would sit in the courtyard. Before long, in the clear darkness of the deep blue sky, fenced about by the mountain peaks, the stars seemed to descend and draw near. He would name the stars for me, and the planets. Nor was it naming alone: he would tell me their distances from the sun, the measure of their orbits, the time of their revolutions, and other particulars. Remembering all he told me, I wrote, with an unripe hand, a long essay. I wrote it because I had tasted joy. It was the first serial composition of my life, and its subject was scientific news.

Then I grew older. I had by now acquired wit enough to follow English roughly. Wherever I found easy books on astronomy, I did not cease to read them. Sometimes the road was blocked by mathematical difficulty, and I pressed my mind on over its roughness. From this I gained a lesson: that on the road of our first experience in life we do not understand everything, and yet it cannot be said that our path goes forward only if everything is clearly understood.

Like the parts of land and sea, what we do not understand is far more than what we do, yet we go on and find delight. Even a certain measure of not-understanding urges us forward. When I taught in class, I kept this in mind. Often I have set before young pupils the literature of riper years. I have taken no full account of how much they understood; yet beyond all reckoning they understood, each in his own way, a good deal, and that is by no means an unwholesome diet. This understanding cannot be measured by the examiner's pencil, but it has considerable worth. In my own life, at least, if such chance-gathered things were struck out, much would be lost.

I took to reading the easy books on astronomy. Such books were not then numerous. Sir Robert Ball's large volume gave me the keenest pleasure. In my longing to follow that pleasure I read many books by many writers, Newcomb, Flammarion and others, swallowing them pulp, seed and all. Then, in a bold moment, I took up a set of Huxley's essays on the science of life. Astronomy and biology: these two subjects alone have stirred my mind. It cannot be called sound learning, for there is no firm knot of scholarship in it. But by ceaseless reading a scientific habit of mind grew natural within me. My disrespect for the folly of blind belief has, I hope, preserved me in large measure from the licence of the intellect. And yet what particular loss it has wrought in the realm of poetry, in the palace of imagination, I do not perceive.

Today, in the last season of my years, my mind is held in thrall by the new physics, that scientific doctrine of illusion. What I read then I did not wholly understand, but I read on. Even now I cannot understand all that I read; nor can many a learned specialist.

Those who can draw from science food for the spirit are ascetics. "Sweetmeats are for the rest of mankind": I only taste the savour. There is nothing in that to boast of, but the contented mind calls it yathalabha, whatever chance may bring. This book is the wallet of such gleanings, gathered in the bee's way of begging, from five doors.

I have little learning, and so did not have to labour much to hide the fact. I have laboured rather over language. For a full education in science the technical term is needed, but the technical term belongs to the class of tough fare; it is wholesome once the teeth have come. Remembering this, I have avoided terminology as far as I could and given my mind to plain speech.

One thing you will notice in this book: its little boat, that is, its language, has been made to sail as easily as possible, but I have not thought it my duty to lighten it by drastically reducing the cargo. To deprive out of kindness is not kindness. My view is this: those whose minds are unripe will take what they naturally can, and what they cannot take they will leave of their own accord. But to empty their plate almost wholly of food is no good service. A subject meant to be learned is not to be

surveyed with a gliding eye for mere enjoyment, and skimming cannot be called reading. To give the mind, and to strive, this striving to learn, is itself the companion of delight. The very effort of understanding is a part of education. This experience I draw from what I myself undertook in childhood. At an age when I did not like milk, to cheat my elders I contrived to fill the bowl almost entirely with froth. I see that those who write books for children supply froth in abundance. They forget that knowledge has its delight and also its price, and that if from childhood we are accustomed to cheating the price, we cheat the true title to delight. It is by chewing that the teeth grow strong, and it is by chewing that the full flavour of food is had. I have not forgotten this, as far as I could, in writing this book.

Sriman Pramathanath Sengupta, M.Sc., is your former pupil, and is now teacher of science at the Santiniketan school. At first I laid the burden of writing upon him. Gradually, step by step, most of it fell to me. Had he not begun, I could not have concluded; moreover, on a road unaccustomed, I should not, with an amateur's daring, have ventured to the end, had I not had from him both assurance and help. Retiring to the quiet of Almora, I was able to complete the work. It was a great good fortune to find my beloved friend Boshi Sen, who has read the whole composition with care. That he read it and was pleased is my richest reward.

During my illness, the dear and esteemed Sri Rajshekhar Basu has with great care corrected the proofs and helped me much in the publication of the book. For this I am grateful to him.

Santiniketan
2nd Ashwin, 1344

Rabindranath Tagore

THE WORLD OF THE ATOM

Our living body is born with the power of certain kinds of perception: the sense of seeing, of hearing, of smell, of taste, of touch. These we call sensation, and bound up with them are our likes and dislikes, our joys and sorrows.

The boundaries of these sensations are not very wide. How far, after all, can we see, and how little of sound can we hear! The reach of the other senses is no greater. That is to say, the small store of perceptive power we have brought with us is reckoned merely for keeping our lives going on this earth. Yet something over and above remains in our hands, and by that we can pass beyond the beast's enclosure and arrive at man's.

The star from which this earth was born, whose light sustains its life, is the sun. This sun has drawn a curtain of light about us. Beyond the earth, it will not let us see anything else that the universe contains. But when the day ends and the sun sets, the veil of light is withdrawn, and then, piercing the darkness, countless stars come forth. We understand that the bounds of the universe stretch far beyond the earth. But how far, we cannot grasp by sensation.

Our one bond with that distance is the seeing of the eye. No sound comes from there, for the sense of sound arises from air, and the air lies about the earth like a mantle. It is within the earth that the air wakes sound and sets the waves of sound in motion. Beyond the earth, smell and taste have no meaning at all. Along with the sense of touch we have another, the sense of cold and warmth. With the world beyond the earth this sense, at least at one place, has a real link. From the sun comes sunshine, and from sunshine we receive warmth, and in that warmth is our life. There are stars a hundred thousand times hotter than the sun, but their heat does not reach our sense. Yet the sun cannot be called a stranger to us. Among all the countless stars of this universe, the sun is the nearest of our kin. Still it must be admitted that the sun is distant from the earth, and not a little distant: some ninety-three million miles. We must not start at hearing it. In the universe where we dwell, that distance belongs to the lowest class among the star-worlds. No star is nearer the earth than that.

We are startled by all these distances because this body of water and clay, this earth, is very small. Its longest line, the path of a journey round its equator, is barely twenty-five thousand miles. The further the universe discloses itself, the more plainly we see that, in the ledger of the world's vastness and distances, this figure of twenty-five thousand is utterly negligible. I have said before that the range of our senses is very small. The distance with which we must ordinarily deal is so little! Within that trifling distance are fixed the allotments of our seeing and our going about.

But when the curtain was raised, then the vast universe, making itself very small, revealed itself in a faint glimmer. Otherwise it would never have been known, for we have no eye for seeing things so great. Other living creatures accepted just this much of sight; they were content with whatever was caught within their sense. Man was not. Through the senses he received a mere hint of the thing. But the reach of man's intellect far exceeds that of his senses, and it dares to race against all the courses of the universe. It set out to learn the news of this vast world's vast measure, discarding, as childish rumour, the tales of sensation. Ninety-three million miles we cannot in any way feel, but reason did not admit defeat; it sat down to reckon.

Let us leave the outer universe. Nothing is nearer to us than the earth on which we stand, and yet to see the whole of it at once is beyond our senses. But if we look at a little globe with its map drawn upon it, then we have a small foundation for knowing the whole earth. In volume the globe is but one part in many thousands of the earth. Setting aside all our other senses, only the faint acquaintance of sight is left to us, and as detailed knowledge it is utterly hollow. Since we lack power to see more, we had to be shown it made small.

Every night the universe is shown to us thus diminished, and this too in the globe of the sky above our heads. No sense save sight finds a place in it. A thing so great that the mind is overwhelmed in contemplating it is held before us in this small portion of sky, bounded by the horizon.

To gain some idea of how much it has been made small, we must recall the example of the sun. Of all the great things we know or can conceive, the greatest is naturally this earth, and even this we can see only part by part; a true conception of the whole at once is beyond our sense. Yet the sun is about one million three hundred thousand times larger than the earth. A sun so vast appears to us, at one edge of the sky, like a golden dish. When we learn of all the tumult and upheaval within the sun, and then see, in the early morning, the golden ball rising slowly from behind our mango grove while living creatures and trees grow glad, then I think how we have been beguiled. We have been told, as it were: "For the work of your life you need know no more." Had we not been beguiled, how should we have lived? That sun, in its own vast form, if it came even slightly within our perception, we should be annihilated in a moment. So much for the sun.

There are many, many stars far greater than the sun. We see them as a few sparks of light. The distance across which these stars are scattered is beyond the thought of any shore. How vast is the sky in which the universe has its nest may be reckoned from another side. By our sense of heat, from beyond the earth, there comes a very great piece of news, with very great force: the heat of the sun. This news has come ninety-three million miles. Yet in the sky there are many millions of stars, some of them many times hotter than the sun. By our good fortune their combined heat was so spent upon the way that, in the world-wide conflagration, our sky has not become unbearable. How far is this path, and how vast this sky! To touch the sensation of heat across ninety-three million miles is a trifle by comparison. To sit near the stove in the great kitchen of a sacrificial feast is uncomfortable; but because the fires that burn at ten in the morning in all the kitchens of a city are scattered through the great sky, we can live in the city. The matter of the star-worlds is the same. However fierce the blaze there, the sky that surrounds it is vaster still.

How does news of the stars' existence reach us from this immense distance? The easy answer is: by light. But that light does not sit quiet and let the news dissipate; that light runs, carrying the news on its back like a postman, is one of the great discoveries of science. By running I mean no ordinary running, for no other messenger in the universe runs so. We are creatures of a small earth, and so for ages had no chance to learn of the greatest running in the world. One day it was

caught in the net of the scientists' astonishing calculations: light travels at one hundred and eighty-six thousand miles in a second. Such a speed may be written in figures but cannot be imagined. It is proved by intellect, not felt by experience. To feel such a motion, where in this little earth should we find room enough? Within so small a space we see its motion as no motion at all. Room to test it is found only in the great void. The sun stands in that void at a distance of however many millions of miles, and on the measuring-rod of the astronomical realm that is not very much.

Thus, within so small a distance, upon a relatively small measure, man was able to see the speed of light. The news came that, crossing this void, light travels from the sun to the earth in about eight and a half minutes. That is to say, when the sun stands present to our sight, in truth it has arrived earlier. To announce its arrival, the light, like a messenger, has been delayed some eight minutes. Such a delay is of no particular moment; the news is almost fresh. But the star nearest the solar system, that is, the one we may call our neighbour in the stellar realm, when it declares "Here I am," the light that carries its message has taken some four years; the news we have just received is four years old. Here we might halt, and it would be enough, but there are stars farther away from which light takes many hundreds of thousands of years to come.

Following the news of this travelling of light through the sky, a question arose in science: what is the manner of its motion? That too is a strange matter. The answer found is that its motion is like very subtle waves. Waves of what, one cannot think. Only from the behaviour of light is it roughly known that it is indeed a wave. But to bewilder the mind of man, there appeared at once, with all its evidence, a twin report declaring that light consists of countless particles of fire, minute as shot, falling in unceasing shower. Where these two opposing reports are reconciled, no one can conceive. Stranger still is another contradiction: outside, what occurs is some kind of wave and shower; within, what we receive is neither this nor that, and we call it light. What this means, no scholar has been able to say.

How was such subtle and such vast news obtained of what cannot be thought, what lies beyond sight and hearing? This question may well arise in the mind. There is sure proof, and for the present there is no course but to accept it. Those who have gathered the proof, extraordinary is the austerity of their learning, and exceedingly

hard the path of their researches. Even to test their words for ourselves requires a measure of learning and intellect which many of us lack. To disbelieve, with only a little learning, is to be deceived. The road of proof lies open. If you take up the discipline of walking that road, if you have the strength, then some day discussion of these matters will come easily.

For the present let us understand the waves of light. These waves are not a single stream. Many waves have banded together with it. Some are seen by the eye, many are not. Let it be said here that the light which is not seen by the eye is not, in common speech, called light. But since, whether visible or invisible, this kind of wave-play is the nature of some energy, it is not fitting, in the book of cosmic science, to give them distinct names. The elder brother is renowned, the younger no one knows, yet by family unity both bear the same title; so it is here.

There is one more wave of the light-family which we do not see with the eye, but feel by touch. That is the wave of heat. Its glory in creation is very great. Of these light-kindred things, some are seen, some felt by touch; some we know clearly as light, and at the same time perceive as heat; some can be neither seen nor touched. If the multitude of these waves, manifest and unmanifest, must have one name, it may be called tej, radiance or energy. At the beginning and the end of the creation of the universe, and in its midst, manifest or hidden, is the tremor of this radiance in its many states. Stone or iron, looked at from outside, seems to have no stir within. They seem the very abode of stillness. But it is proved that their atoms, that is, their exceedingly subtle particles, which we have never seen, and out of which they are wholly built, tremble within at all times. When cold, they tremble still; when the trembling grows, then, growing warm, they are caught from outside by our sense. When iron is burned in fire, the atoms of the iron tremble so violently that their excitement can be hidden no longer. Then the wave of trembling strikes the nerves of touch in our body, and the message it sends through them we call heat. In truth, heat strikes us. Light strikes the eye; heat strikes the body.

In childhood, when our master one day showed us a piece of iron put into the fire, how it became first warm, then red, then white and glowing, I remember well how it set me thinking: fire is not some substance which, mingling from outside with iron, can make it change its appearance so. And now I hear that if more heat is

applied this iron will turn to gas. All this is the wonder-working of heat, which has gone on from the beginning of creation until today.

The light of the sun is white. Mingled in this white are seven different colours of light. It is like a skein of silk of seven colours, which, folded up, looks white, and, spread out, shows seven hues. In old days there were chandeliers, but since the electric lamp they have gone out of fashion. On those chandeliers hung three-sided prisms of glass. The property of such a prism is that when sunlight passes through it, the light is broken into seven colours and scattered. Then colour follows colour in order: violet, indigo, blue, green, yellow, orange, and red. These seven colours are seen by the eye, but beyond the two ends of this band are many other smaller and larger waves of radiance that do not come within our ordinary perception. The wave which lies beyond the violet is called ultra-violet light; in plain speech, "light beyond the violet." And the light which has not reached the region of red, lying before it, is called infra-red light, which we may call "below-the-red" light.

Sir William Herschel was a great astronomer. Through a three-sided glass he tested and observed the seven-hued procession of light. Taking a blackened tube for measuring heat, he held it to each colour in turn. Toward the red the heat rose gradually. Passing beyond the red, he carried the tube into the colourless darkness, and even there the warmth would not cease. It was understood that there is yet more light hidden in that darkness, veiled from view. After him came a German chemist, who began his experiments with a photographic plate. On this plate a response was obtained from red to violet, through the seven colours. At last, passing beyond the violet, into the darkness, what the eye cannot catch was caught upon the plate.

It was seen that the heat of light lay toward the red, and its chemical action toward the region beyond the violet. At one time it was thought that these unseen things were the lodgers of the coloured family, fallen into the dark. The farther the search for hidden light advanced, the narrower became the seat of the seven-coloured party. In the surveyor's chain of science, the bounds of light have today passed the realm of the seven-coloured king a hundredfold. Toward infra-red, there appeared the wave on which travels the voice of the sky, which is called the radio message; toward the region beyond the violet there appeared the famed Röntgen light, by

whose help, passing through the covering of the skin, the bones within the body may be seen.

Light tells us not only of the existence of the stars. It tells us also what substances are mingled in them. Man has, as it were, split open the breast of light and drawn this news from it. How it was drawn, let me explain.

When the sun's white light is passed through a three-sided glass, the identity of its seven colours is revealed one after another. When a hard thing like iron is heated until it glows, and its light gradually turns white, then, dividing this white light, the six-fold, seven-fold band is seen, colour beside colour, with no gap between. But when iron is heated till it turns to gas, and its light is broken through that glass, we no longer obtain an unbroken band of colour. There appear separate bright lines, and between them gaps without light. Let us call this mark of coloured light the spectrum, the "script of colours."

In this script it is seen that in the glowing gaseous state the colour-band of each substance is distinct. In salt there is found a primal element named sodium. When heated till it is a gas, its light shows in the spectrum two yellow lines, very close together. No other colour is found. In the spectrum of no substance other than sodium do these two lines fall in exactly that place. Wherever, in the spectrum of a gas, those two lines are seen, we shall know that sodium is surely present.

Yet in the spectrum of the sun's light these two bright yellow lines have vanished, and in their place are two black marks. The scientist says that the light of any heated gaseous thing, passing through a relatively cooler layer of the same gas, is wholly absorbed. Even here the black marks do not arise merely from the lack of light. In truth, the sodium gas in the sun's envelope, which arrests the sun's light, itself scatters light according to its own heat. But since its heat is less than that of the luminous sphere, its light is much dimmer. This dim light, set beside the brilliant light in the spectrum, produces the illusion of black.

By breaking the light of every elemental substance, a chart of its spectrum has been made. By comparing with these differences of spectrum, the difference of

substances may be detected, wherever they be, provided only that they are in the gaseous state.

Of the ninety-two elements of which news has been obtained from the earth, all ought to exist in the sun, for the earth is the sun's own offspring. In the first tests only thirty-six substances were found. What of the rest? This question is being resolved by the Bengali scientist Meghnad Saha. Having found a new path of inquiry, he has caught in the sun several more elements. Following his path, news of almost all of them has been obtained. Even now some, of unknown address, are swallowed by the air of the earth on the way.

All colours together make the light of the sun white; why, then, do we see different colours in different things? The reason is that every thing does not take all colours into itself; some it sends away without a pang. That rejected colour is the gain of our eyes. Thick blotting-paper soaks up a juice, and is of no use to anyone; it is the surplus juice that it does not take which is our due. So it is here. The ruby accepts all the other waves of the sunbeam and gives back the red. By this gift of renunciation the ruby is famous; what it keeps for itself has no fame. Why the ruby does not take red, and why the sapphire is wholly unattached to blue: the answer to this lies hidden in the realm of the atom. Grey hair, which sends back every wave of the sun, is therefore white; black hair returns no wave, that is, no part of light escapes from it, and so it is black.

If all things in the world were to appropriate all the colours of the sun, then that miser's world would appear black; that is, it would not be seen at all. It would be as though the postmaster had shut up the seven postmen who deliver the news. And yet, if nothing took any light at all, all things would be white, and in that monotony all distinction between things would be effaced. It would be as though the letters of all seven postmen were sealed together into a single sheet, and no separate news could be had. To show everything with one and the same countenance is not to show. Neither no-light nor full-light lets us see; we see only in the mingling of broken light.

Entwined with the sunbeam are many waves which come in such small quantity that we cannot feel them. There are also waves that come in abundance, but the

atmosphere of the earth arrests them; otherwise we should be burned to death. The measure of the sun's bounty which we can bear was settled, from the first, with our bodily frame. That is why, beyond it, the traffic of our life's journey is closed.

In the picture of the universe, what strikes our eye most is the world of stars, and the sun, which is also a star. Till now they have held the first place in the mind of man. But what in the present age has most astonished him is the hidden universe within the universe, exceedingly subtle, unseen by the eye, and yet lying at the root of all creation.

Suppose we wish to test a clay house to find out what it is made of at bottom. We shall find particles of dust. When it can be ground no finer, we say that this exceedingly fine dust is the primal material of the clay house. In the same way man once thought: dividing and dividing the substances of the world, when we come to a point so subtle that it cannot be divided further, then that we shall call the primal element, the foundational stuff. In our scriptures it is called paramanu; in the science of Europe it is called the atom. They are so subtle that a hundred million of them laid side by side would measure only one inch.

By ordinary means we cannot divide a grain of dust further, but by scientific pounding man has succeeded in carrying all the substances of the world to a much finer subtlety. At last he has been stopped at ninety-two unmixed substances. The scholars said: by the joining and parting of these, everything in the world is made; their frontier cannot be crossed.

Suppose one part of a clay house is made of pure clay, and another of clay mixed with cow-dung. Then, grinding down the wall, we shall find two kinds of things: pure dust, and dust mixed with powdered dung. In the same way, testing all things in the world, scientists have divided them into two classes; one is called the elements, the other the compounds. In an element there is no admixture, while in a compound there is a union of one or more things. Gold is an element; however finely you divide it by ordinary means, nothing but gold will be found. Water is a compound; divide it, and two elementary gases emerge, one called oxygen, the other hydrogen. While these two gases are separate they have one kind of nature; and the moment they join to become water, they can no longer be recognised.

From their union arises a wholly new nature. This is the condition of every compound: each conceals within itself the identity of its original substances.

However that may be, these very bearers of the title "atom" once won fame as the ultimate constituents of the world; all declared that they would endure no further division. But in the end they too were found divisible. That which was called the atom was broken and broken again, and within it was found the ultra-atom, a marvellous thing, which one hesitates to call a thing at all. Let me explain.

Nowadays the word electricity is very much in vogue: electric lamp, electric torch, electric fan, and I know not what besides. All know that it is a kind of energy. All know, too, that the lightning which flashes from the cloud in the sky is nothing other than electricity. This lightning proclaims electricity to us on earth with the mightiest majesty, in light and in thunder; touching the body, it becomes deadly. The word electricity we shall call in Bengali baidyut.

This electricity is of two kinds. Scientists have named one kind positive, the other negative. Translated, this becomes the "yea-natured" and the "nay-natured." Their dispositions are opposite to each other, and by the mingling of these opposites all that exists has been made. And yet positive has a native antagonism to positive, and negative to negative; their pull is toward the opposite side.

The exceedingly subtle particles of these two kinds of electricity are joined in pairs in the atom. Taking these two parties, every atom is like a planet bound in union with its sun, like a little solar system. As the sun, from the centre of the solar world, whirls the earth upon the rein of attraction, so the positive electric particle, from the centre of the atom, draws the negative particles, and they, like circus horses wearing harness, circle about the positive.

The earth goes round the sun at a distance of ninety-three million miles. In proportion to their size, the distances of the orbits of the ultra-atoms are not much less than this. Even in the infinitesimal space an atom occupies, there are greater and lesser dominions of distance. Earlier I spoke of the immensity of greatness, and of the mutual distances, in the world of stars; but the very small, too, may be called immensely small. As, to mark the boundary of great vastness with figures, one must

write twenty-five zeros after a one, so it is with the smallest vastness: here too an army of figures stands drawn up in a long line.

To illustrate the distance which the ultra-atoms keep as they move about in the exceedingly subtle space of the atom, a famous astronomer has said: take a great station like Howrah Station, remove everything else, and leave only five or six wasps; then it may be compared with the ultra-atoms in the space of the atom. But to hold fast the few restless bodies scattered across this vast void, nearly all the weight and all the power of the atom's central body is at work. Were it not so, the atomic world would fall to pieces, and there would be no existence for the universe built of atoms.

Within matter the molecules lie close to one another by a power of attraction. Yet even in a compact thing like gold, the molecules have gaps between them. I do not wish to state in figures the measure of that extremely subtle gap, for it would pain the mind. The question arises why any gap remains at all, why gas exists, why liquid matter. A question of the same kind is why the earth does not go and cling to the sun, why the whole universe does not cake into one lump. The answer is that, even while accepting the sun's pull, the earth may remain apart by the speed of its running. If its speed were more than enough, it would burst the bond of attraction and fly out into the void; if its speed were to tire, the sun would at once take it to itself. In the same way, the gaps among molecules remain through the speed of their motion, and so hold off the power of the bond.

In gaseous matter the primacy of motion is greater. The molecules in this state run at so great a speed that they have no opportunity to join. Now and then they collide, but in a moment they fly apart. In liquid matter, because the force of molecular attraction is slight, the speed of movement leaves no chance of close contact. In solid matter the force of the bond is relatively strong, and so the company of molecules remains confined in a limited space. Yet it is not that they are therefore still; vibration goes on among them, but the field of their freedom is narrow.

This movement, this trembling among the molecules, is heat. The more the restlessness grows, the more distinctly it is felt as warmth. It would be possible to

bring them wholly to rest if their heat were lowered to 273 degrees centigrade below the zero of the temperature scale.

Now let us turn our eyes to the realm of the atom of hydrogen gas.

There is no gas lighter than this. At the centre of its atom presides a single electric particle, called the proton, and, bound by its attraction, another single particle, called the electron, circles about it. The electricity of the proton is positive; the electricity borne by the electron is negative. The negative electron is nimble and restless; the positive proton is a heavy mass. The weight of the electron is scarcely to be counted; nearly all the weight of the atom is gathered in its central body.

On the whole, all electrons are of the nay-nature, but one kind of electron has been found that is yea-natured, though in weight it equals the electron. These have been named positrons.

Sometimes it has been seen that the atom of a particular hydrogen is twice as heavy as the ordinary. Experiment showed that at its centre, along with the proton, there is a companion. I have said before that the proton is of the yea-nature. On examining this little particle at the centre, it was found to be neutral, neither positive nor negative; it is therefore without electric nature. In weight it equals its companion, the proton, but as the proton attracts the electron, so this cannot attract; nor has it any desire to push the proton away. This particle has been named the neutron. It has been observed that however heavy the atom is made, by weights of another kind, these neutral ones exert no influence upon the electrons. One proton keeps only one electron under its rule. The greater the number of protons at the centre of the atom, the greater the number of electrons they hold in their sway. At the centre of the oxygen atom there are eight protons, and with them eight neutrons, and the number of electrons that circle about it is exactly eight.

Where positive and negative have joined in due proportion and made peace, if by some means the household could be broken up, and a certain number of the negatives driven away, then in that thing the reckoning of electricity would be disturbed, and the positive charge would be in excess. Where man and woman

together have made a harmony of household life, if the woman's influence is taken away by so much, that household becomes by so much dominated by the man. It is the same here.

This word "charge" is always used in connection with electricity. In the things we ordinarily handle, no electric restlessness is seen; they are not charged. That is, they hold the two kinds of electricity in just those amounts which, mingled together, preserve peace. But if in any thing one kind of electricity, refusing to keep the compact, exceeds its proper measure, then the thing is said to be charged with that electricity.

Take a piece of silk and rub it on glass. The result is that, through the rubbing, some electrons leave the glass and pass to the silk. In the glass the negative electricity diminishes and the positive prevails; in the silk the influence of the negative grows, and it is charged with negative electricity. The glass, robbed of its electrons, with its positive charge, longs to draw the silk to itself; and in the silk, crowded with negatives, there falls a pull toward the glass. While glass and silk were in their ordinary state, undisturbed, each was at ease within itself, at peace. In that peace, the existence of electricity in them was not even known. As soon as news of the electrical domestic revolution broke out, the inequality of shares created unrest.

I have spoken of removing, by rubbing, a small quantity of electrons from glass or another thing. If the scientist is asked how great the quantity is, he will give a slight shake of the head and say that, according to the rubbing, it may be four hundred million, five hundred million, six hundred million. In the filament of the electric lamp, when a crowd of electrons presses and jostles along, then it glows. How many electrons pass at once from one end of the wire to the other, what name our mathematics has for that number, I do not know.

However that may be, it is seen that the turbulent restlessness of the ultra-atoms, reconciled in the compact of positive and negative, is held in bond; and therefore there is peace in the universe. The bear-keeper beats his little drum, and to its rhythm the bear dances and performs tricks. If the drummer were not there, and the tamed bear were to snap his chain and follow his own nature, he would wreak havoc in all directions with tooth and claw. In our whole body, and outside the

body, with this tamed terror, to the beat of an invisible drum, the dance and sport of creation goes on. On the stage of creation, two players, mingling their fierce contest, keep the theatre of the moving universe warm.

Some scientists, comparing the atomic world with the solar system, said that around the atom's centre the company of electrons circles in different orbits. Another scholar proved that the electrons, taking a whirling leap, change their place from one orbit to another, and then return to their assigned path.

The picture of the atomic world is cast in the mould of the solar world: a central body bearing positive electricity, and around it the circling of electrons.

There is an obstacle to accepting this view. If the electron moved in a single unchanging path, its energy would gradually be spent, and, step by step narrowing its path, it would at last fall upon the central body, and there would be the utter ruin of the atom.

Now this is the view that has been established: the elliptical path of the electron is not one but many, and the distances of these orbits from the centre are fixed. The nearest path to the centre no electron can cross. The electron appears now in the outer path, now in the inner. Why it appears, and when, suddenly, no fixed law can be found. By absorbing energy the electron leaps from the inner path to the outer, and the measure of this leap depends upon the quantity of energy absorbed. Only when it comes from its outer path into the inner does the electron scatter energy. This released energy we receive as light. So long as it moves in one and the same orbit, the radiation of its energy is stopped. This view is an assumption, for which no cause can be shown. But by accepting this assumption alone can we understand why the atom endures, and why the universe has not vanished.

Behind all these matters lies a theory hard to grasp, and it will be long before it can be understood. For the present it is enough to have heard it.

I have said before that scientists proclaimed with confidence that the ninety-two were the primal elements of the creation of the universe. By the testimony of the

ultra-atoms that claim has today been disproved. Yet the title of honour still remains to them.

There was a time when the fame of the elements lay in this, that their qualities had permanence. However they were broken, nothing altered their nature. In the first chapter of science it was seen that their last division yields a dancing pair of particle-bodies, with electricity of two kinds. Those that bear the name of element keep the peculiarity of their nature by gathering these electric charges in particular numbers. Had it stopped there, the fame of the atom's immutability would have remained. But evidence against it came from their own party. One piece of news was that among the lighter atoms the revolving of the electron about the proton goes on with regularity, but the exceedingly heavy ones, in which the crowd of neutrons and protons is excessive, such as uranium and radium, cannot manage their own treasury; always, at every moment, they are dropping their capital in fragments, growing lighter, passing from one form to another.

Until now, radium, an element, lay hidden within a gross covering. With its discovery the profoundest secret of the atom was caught. The history of its first encounter with the scientists is worth remembering.

When the Röntgen rays were discovered, it was seen that they had the power to pierce gross obstacles. At that time Henri Becquerel was a teacher of science in a municipal school in Paris. He set himself to test whether all self-luminous substances had this power of piercing obstacles. He began his work with a number of such mineral substances. He wrapped them in black paper and laid them on a photographic plate. He saw that, piercing the wrapping, only the mark of the metal uranium appeared. Of all, its atom is the heaviest, and its radioactivity was thus proved.

Uranium is extracted from a mineral called pitchblende. Among Becquerel's pupils was a brilliantly gifted young woman, Madame Curie. Her husband, Pierre Curie, was a professor at a French college. The two together, husband and wife, began to test this pitchblende, and found that its radioactive effect was stronger than that of uranium. In pitchblende there are certain substances at the root of this power,

and in the effort to discover them three new substances came forth: radium, polonium, and actinium.

By experiment, some forty radioactive substances have now been found, nearly all of them new to science.

What astonished most, in those days, was one strange property of this metal. Scattering from within itself particles of light, it transforms itself into various elements, and at last becomes lead. It was like a scientific conjuring trick. That one metal could give rise to another was then first known.

All substances of the kind of radium, whose nature it is to scatter their energy, belong to the party of those who lose their caste. They do nothing but spend the capital of their own energy. In this wastage, the first radiating particle to fall is named alpha, after the first letter of the Greek alphabet. Taking the Bengali alphabet, it may be called ka. It is an atom, of the positive kind. Radium has another scattered particle, named beta, which may be called kha. It is an electron, negatively charged, of terrible swift speed. Yet if a single thin sheet of paper lie in the path of its running, the alpha particle takes a new body: it becomes helium gas. Some further obstacle is needed to halt the beta. In the store of radium there is, besides these two, another ray, named gamma. It is neither atom nor ultra-atom; it is a special ray of light. Its rays can pierce gross matter, as do the Röntgen rays. The behaviour of all these radiating particles is the same in every condition: in the heat of molten iron, or in the cold that turns gas to liquid. Moreover, no one has the power to bring them back and bind them into grains as before.

So long as no harm befalls the central body of the atom, even if two or four electrons are snatched away, the allotment of its electricity may fall somewhat, but the injury is not fatal. But if plunder of the very treasury of that central body became possible, then the atom would change its caste.

Having learned that the atom has no absolute unity of its own, the scientists at first hoped that they, hurling energy as a missile, like gunners, would strike the radium and cause a breach in the atom, to plunder its central capital. But the target is exceedingly minute, and it is not easy to take aim; hurling many clods of energy,

only by chance does one occasionally strike. So, in place of this uncertain method of warfare, preparations are now being made to build immense machines, to produce electricity of extremely powerful force, that may pierce the guard of the atom's central fortress. There stands the guard of mighty champions of strength. Just at the time when an engine that kills a thousand men at once is being devised for the slaughter of hundreds of thousands, just at that time a vast factory of electric showers has been set up to rend the innermost heart of the subtlest substance in the universe.

I have said before that the alpha particle, losing its form, becomes helium gas. This has been put to use in proving the age of the earth. If, in a piece of rock from some mountain, a certain quantity of helium gas is found, then, reckoning the fixed time of this gas's transformation, a horoscope of that mountain's birth can be cast. By this method the age of the earth has been judged.

In weight, the gas which stands immediately above hydrogen has been named helium. This gas is newly known among scientists. It was first caught at a solar eclipse. The sun, beyond the circular boundary of its disc, for hundreds of thousands of miles sends out a very fine cloud-like mantle of vapour, as a waterfall scatters its spray about itself on every side. At the time of an eclipse, the extent of this fiery gas round the sun may be seen through the telescope. The brilliance of this far-flung gas is called in the languages of Europe the corona; in Bengali it might be called the kiritika, the little crown.

Not long ago, in 1937, at the time of a solar eclipse, while testing this crown, scientists saw in the spectrum, toward the blue limit, three unknown white lines. The scholars thought that perhaps some already known substance, under excessive burning, had taken on a new state, and that this was its mark. Or perhaps a new substance had announced itself. Its address has not yet been found.

In the eclipse of 1868 the scientists received a similar shock. From the gaseous envelope of the sun there came a line of some substance then unknown. To this element, newly reported, the name helium was given, that is, "of the sun," for it was thought that this was wholly a gas belonging to the sun alone. At last, after thirty years, the famous chemist Ramsay obtained a trace of this gas in the air of

the earth, in a very small quantity. Then it was settled that on earth this gas is rare. Afterwards it was found that in North America, in the cavern of an oil-well in some field, the gas that is found contains helium in sufficient quantity. Then it became possible to put it to use. Because it is exceedingly light, until then hydrogen gas had been used to give lifting power to airships. But hydrogen is as good for burning as for floating, and this gas has burned many great airships. Helium has no hidden and fierce fury of burning, and yet it is lighter than all gases save hydrogen. So it has come into use to make the flying of airships safe. In medicine, too, its use has begun in certain diseases.

It has been said before that bodies with positive charge and bodies with negative charge draw each other near, but those with charges of the same kind seek to thrust each other away. The nearer they are brought, the fiercer grows the force of their repulsion. In the same way, the nearer opposite charges come to each other, the more the force of their attraction increases. This is why those electrons which dwell near the central body run with greater speed than the more distant, to escape the pull. In the solar system, the nearer the planets are to the sun, the greater is the speed of their running; the far planets have less peril, and go more leisurely.

The diameter of this electron and proton is one fifty-thousandth part of the whole atom. That is to say, in the atom emptiness prevails. If all the atoms of a man's body were pressed together, they would make a body almost invisible, a mere point of matter.

How great is the force of the mutual repulsion of two protons has been reckoned by the chemist Frederick Soddy: if one gram of protons were placed at one pole of the earth, and at the opposite pole another gram, then across that vast distance the force of their thrusting away from one another would be about six hundred maunds. If this is the law, it is hard to understand how more than one proton can cling together in the exceedingly narrow circle of the atom's centre. By this law, hydrogen, whose nucleus has the dominion of a single proton, would be the only thing that could exist; no other substance could endure, and the universe would be made wholly of hydrogen.

Yet uranium metal is seen to carry ninety-two protons and one hundred and forty-six neutrons. It is true that it cannot manage so vast a crowd; from moment to moment it goes on lightening from its central store the burden of electric particles. When its weight has diminished somewhat, it takes the form of radium; when it lessens further, it becomes polonium; and at last, in the form of lead, it finds rest.

Though so much weight has been shed, the doubt remains as to how it finds stability. When the tale of its radiation is ended, after every deduction, there remain in the possession of lead eighty-two protons. With the natural repelling temper of positive electricity, how these protons keep the peace of the atomic world, how they do it, for a long time no good answer was found. Quarrel does not cease outside the centre; within the centre their friendship is unbroken. This is a strange and difficult problem.

By turning this mystery to account, the power of the machines was increased. Against the proton, the target at the centre of the atom, the experimenters launched a host of positive electric particles. With what force the particles struck! Their speed was 6,720 miles in a second. Yet the proton at the centre, preserving its proton-nature, hurled back the assaulting electric army. The force of the electric propulsion was increased. The scientists let loose their blows at 7,700 miles of speed, yet could not make the victim yield. At last, at a speed of 8,200 miles, the opposing force showed signs of softening. Passing the barrier of the power that repels, the power of assault reached the inner fortress of the centre. It was seen that, however near two like-charged particles may come, their mutual thrusting away is hidden within; it is hidden at a nearness of one many-millionth of an inch. Then we must take it that, at that closeness, beyond the power of the protons to push each other away there is some great force, far greater than that, the power of holding them together. That power in the atomic world draws the proton, and likewise draws the neutron; that is, its influence is alike upon what has an electric charge and what has none. This exceedingly powerful force of attraction, dwelling in the atom's centre, keeps the whole universe bound together. The rule which has composed the domestic quarrels within the atom is the very rule by which peace reigns in the universe.

Let us take a comparison from modern history. The peace of the Chinese Republic was destroyed when a number of generals, each greedy for sole dominion, fought one another and laid the country waste. Had there been at the centre of the State a power stronger than these opposing parties, then it would have been easy, in the work of government, to make all of them one, and to keep the power of the State strong and safe. In the atomic State there is that great power above all powers, and so those who by nature do not agree do agree, and the peace of the universe is preserved. From this we see that the peace of the universe is not the peace of a gentle, good-natured temper. A strong union has been made of all the violent. Those who are, each in himself, destroyers of all, are, in union, the bearers of creation.

In the history of the atom, the chapter of radium has a greater value, and therefore I shall tell its story in rather more detail. Radium, like iron and the rest, is a metal. Its atoms are great in weight and in bulk. At last, one day, for what reason no one knows, a radium atom bursts; a part of it flies away. The particles of the alpha rays, streaming from that broken atom, are each made by the union of two protons and two neutrons. That is to say, each is one with the nucleus of the helium atom. The beta ray is merely a stream of electrons. The gamma ray has no particles; it is of the nature of light. Why such breaking-up should happen, the cause has not been found even today. By this small loss, the remainder of the atom no longer stays in its former form of radium; its nature is changed. By taking two electrons to itself, the alpha particle is transformed into helium gas. This bursting cannot be hastened by anything from outside, nor can it be stopped. Whether the state of things around it be cold or hot, whether it mingle with other atoms or not, that is, whatever be the arrangement without, its breaking goes on from within. The average life of radium is about two thousand years, but the atom from which an alpha particle has been thrown out has a life of only some four days. Then from it follow bursts in succession, until at last it arrives at lead.

When the alpha particle begins its course, its speed is about ten thousand miles in a second. But when it must pass through any material substance, even air, after going some two or three inches its motion becomes easy. The alpha ray goes on in a perfectly straight line. How it is able to do so is a matter worth pondering, for the atoms of oxygen and nitrogen in the air are far lighter and smaller than the helium

atom. It is as though along a path of three inches it had to push aside many heavy molecules of air. Yet this is not pushing through a crowd; it is piercing a crowd. By the atom we mean a central body, and the company of electrons circling round it. To pass through the guard of these, the force of tremendous speed is needed, and that force the alpha particle has. It passes through one circle, and into another. Passing through the interior of another atom, it goes on causing loss. Perhaps it strikes out an electron from an atom; perhaps two or three go, and it drops off. Then those electrons wander free of their bonds, but not for long; they pair themselves with other atoms. The atom that has lost an electron gains a positive charge, and the atom that has caught the freed electron gains a negative charge. If they come sufficiently near each other, they again balance the account. When the inequality is done away, the agitation of the electric nature is stilled. Naturally the helium atom has two electrons. But when it issues from radium as an alpha particle, and runs through other matter, it loses its two companions. When the disturbance is over, it makes good its lack from among the running electrons, and returns to its own nature.

On this occasion let me close with one more thing. The electrons, protons and neutrons in the atoms of all substances are one and the same matter. The difference among things lies in their different division and apportionment. The atom that has six positive charges is that of carbon, the atom, that is, of organic substance; that with seven electrons is nitrogen; that with eight is oxygen. Only the hydrogen atom has one electron. And uranium has ninety-two. The difference of kind among atoms lies in the difference in the number of their positive charges. All the diversity of creation moves to the rhythm of number.

When the students of electricity were engaged in their work, suddenly, upsetting their calculations, the existence of an unknown energy was caught. Its radiation was named the cosmic ray, or we might call it the sudden ray. Whence it comes could not be discovered, but it was found everywhere. There is no object, no living creature, upon which its bombardment does not fall. More than that, it strikes the atoms of metals and excites them. Perhaps these rays are aiding the vital energy of living things, or perhaps destroying it; what they do is unknown; that they strike is beyond doubt.

This unceasing shower of cosmic rays, the mystery of its origin remains unknown. But its vast enterprise is known: its spreading across the whole sky, its entry into all substances, in water, on land, in the air. Upon the trail of this great visitor the scientist's spy is already set, and some day its secret dwelling will be discovered.

Some say that cosmic light is light indeed, a hundredfold more powerful than the Röntgen rays, and that therefore it passes easily through thick lead or a thick plate of gold. By the tests of scientists, this much is known: that with this light are electric particles. In those regions of the earth where the magnetic force is greater, these are drawn from their path and gather in the polar regions; so in different parts of the earth the gathering of cosmic rays is seen to be greater or less.

About cosmic rays various theories are still in conflict. Since the new theory of the atom was begun, there has been no end of turmoil of thought and opinion in the world of science; in the arrangement of the universe's primal workshop, it has been impossible to find a firm sign of constancy. If anything can claim fame as eternal, it is only one primal light, which lies at the prelude of all things, and through whose many stages of manifestation has been built up the diversity of this universe.

THE WORLD OF STARS

We have seen, then, the formless electric world that pervades the universe. By the union of its elements, the world of form shines forth in planet and star.

Let me say at the outset that we have no means of knowing the true countenance of the cosmos. Of the substance of the universe, only a very little falls within our sight. Moreover, our eyes, our ears and our sense of touch each have their own peculiarities, and so the things of the world present themselves to us in particular ways and in particular forms. A wave strikes the eye, and we see light. Of waves finer or coarser than this we are blind. What we see is very little, and what we do not see is overwhelmingly more. Nature took no thought that we should become men of science. She fitted our eyes and ears to the business of living on the earth. The human eye performs, in a small measure, the work of both the microscope and the telescope. Had the range of our perception been wider, or its nature different, our world too would have been different.

For the scientist it is indeed different. It is so different that the language in which we carry on our daily business is of little use for describing this world. Each day a language of new signs must be fashioned, of which the common man cannot comprehend a jot or tittle.

Once men decided that the earth sat unmoved at the centre of the universe, and that the sun and stars revolved about her. We cannot blame them. They had only eyes that looked at the earth and saw what the earth shows. Today our sight has been enlarged, and we have fashioned an eye that can look upon the universe. We have had to accept that it is the earth that must run about the sun, whirling in a dervish's dance. The road is long, and takes somewhat more than 365 days. There are planets with longer roads, which take so long to go round that to live through one of their years the span of human life would have to be extended.

In the night sky, among the clusters of stars, there appear here and there patches of smeared light. They are called nebulae. Some of them are vast and diffuse clouds of the lightest gas; others are gatherings of stars. By telescope and camera it has

been learnt that the multitude of stars crowded into these latter nebulae runs to many millions, and that their motions are marvellously swift. Why, then, do the stars, rushing at such speed through the nebular realm, not collide and shatter one another? In seeking an answer, one realises that it is an error to call these star-clusters crowds. There is no jostling among them, no embrace. They wander at immense distances from one another. Sir James Jeans, speaking of the distances between the electrons within an atom, has used a comparison, and he has used a like one for these stellar hosts. In London there is a vast station named Waterloo, which, if I remember rightly, is larger even than Howrah. Sir James says: empty that station of everything, scatter in it only six grains of dust, and the separation of those grains will correspond, in some degree, to the distances between the stars in the sky. However great the number and bulk of the stars, he says, they cannot be compared with the unthinkable emptiness of the heavens.

Scientists suppose that, long before the drama of diversity of form began in creation, there existed only a vast and all-pervading burning vapour. It is the nature of everything hot to go on scattering its heat. Boiling water first rises as vapour; cooling, the vapour gathers into drops of water. Even hard matter, if heated enough, becomes gas. So, in that state of heat, every substance in the universe, light or heavy, was gas. Through crore upon crore of years it has been cooling. As the heat diminished, small fragments condensed out of the gas and fell. Countless particles, joining to form stars, built up the nebulae. In the languages of Europe these are called nebula, plural nebulae. Our sun lies within a nebula of this kind.

On a mountain peak in America a great telescope has been set up, and through it a very large nebula has been seen, in the constellation called Andromeda. Its shape is something like that of a cartwheel, and the wheel is turning. To complete one revolution it takes about twenty million years. Light takes nine hundred thousand years to travel from it to the earth.

The star nearest us, whom we may call the neighbour of our stellar village, cannot be made comprehensible by lines of figures. The distances that may be stated in numbers and roughly grasped by us are confined within the globe of the earth, measured as we travel by rail, motor-car or steamer. Once we pass beyond the earth and cross the borders of the star-settlements, the language of numbers

seems to rave. The arithmetic of astronomy lays its eggs of figures like some many-spawning insect of the earth.

Ordinarily we reckon distance in miles or in krosh, but to do so for the stars makes the burden of figures unbearable. The sun itself is far enough from us, and the hosts of stars lie many hundred thousand times farther. To count their distances in numbers would be like counting thousands upon thousands of gold coins by cowrie-shells. Men have lightened the burden of writing by devising numerical signs; to write a thousand, one does not have to draw a thousand strokes. But even this device proved too small for the measure of the starry realms, and so another unit has come into being: the measure of light's journeying. In a year of 366 days it travels five hundred and eighty-eight thousand crore miles. As the solar year is measured in three hundred and sixty-five days, so the movements of the stars, the limits and boundaries of their realms, are reckoned in years of light's travelling. The diameter of our stellar universe is about one hundred thousand light-years. Beyond it lie many hundreds of thousands more stellar worlds. Among the stars of those remote villages, the light of one has been caught by photograph, and by calculation it lies some five million light-years away. The nearest of our neighbouring stars is twenty-five lakh crore miles distant. From this one may understand in what immensity of emptiness the universe floats. These days I hear that wars arise in the world from want of room. If there were the slightest crowding of space among the stars, the universe would be shattered to pieces in a ruinous collision.

From the age of the seeing eye we passed into the age of the telescope. As the power of the telescope grew, the circumference of our vision in the heavens widened. Where before we had seen a gap, a flock of stars appeared. Yet much remained, as it was bound to remain. Beyond our stellar universe lie worlds whose light is beyond even the telescope's sight. A lamp's flame at a distance of 8,575 miles gives a glimmer so faint that the human eye, striving to catch it by telescope, admits defeat. The telescope brings its news to the eye according to its power; if the eye lacks strength to carry that most attenuated message into the chamber of perception, nothing more can be done. But the light-catching power of the photographic plate is far more enduring than that of the eye. Science awakened this power and set the photograph to cast its net into the remotest sky. A photography was made which can summon to its bar the light that hides its face in

darkness. To the telescope was joined the camera, and to the camera the spectroscope. Lately its power has been rendered still more marvellous. In the sun, many substances burn as gas. When they appear all together, it is impossible to examine them one by one. An American scientist has therefore made a sun-viewing telescope, in which out of all the colours of the burning gases one colour at a time is separated, and by its aid the sun in the special form of each gas has been seen. By choosing to see the sun in the colour of burning calcium alone, or burning hydrogen alone, one learns much of its gaseous conflagration that no other means can reveal.

If white light can be divided, then at one end of its seven-hued band lies red, at the other violet. The light that passes beyond these two limits does not strike our eyes.

The wave-length of deep blue light is one part in a hundred and fifty million of an inch. That is, the distance from the crest of one wave to the crest of the next, in the light of this colour, is so much; in a single inch there lie a hundred and fifty million waves. The waves of red light are about twice as long. When the glowing red light of a heated iron gradually dies and can be seen no more, still other unseen light, of greater wave-length, goes on rising from it in waves. If it could awaken our sight, we should see the cooling iron by that "red-below" light; and in the darkness of a summer evening, when the sun has faded, the earth, scorched by the heat of the season, would be revealed to us in that light.

There is nothing that is wholly dark. Even those things we cannot see have light. Even in the thick black sky beyond the world of stars, rays of many kinds are ceaselessly scattered. By means of the spectroscopic telescope-camera we can now bring these invisible messengers on to the screen of vision and extract from them the secret tidings of their hidden existence.

The light beyond the violet is of less use to astronomers than the light below the red. The reason is that much of the light of these short waves is lost in passing through the earth's air, and so it serves little to bring news from the far worlds. But it brings news from the atomic world. When an atom is excited to a certain degree, it vibrates with white light. As the energy grows, light beyond the violet appears. At last, when the central body of the atom itself is disturbed, there springs from

that violent agitation a wave still shorter, which we call the gamma ray. Man has so increased the power of his instruments that he can make use of rays like the X-ray or the gamma-ray.

What I was about to say is this: with the spectrum-bound telescope-camera, man has brought into the path of vision the remote and invisible realms of the stellar universe. Beyond our own stellar world, far away, the addresses of many more stellar worlds have been found. And not that only: it is also caught in the sight of this instrument that all the stars together are whirling in our stellar sky and in the heavens beyond.

When a mass of luminous gas in the far heavens, which we call a star, advances toward us or recedes, a peculiarity appears in our vision. Were the body still, it would convey to our perception light-waves of a certain length; when it draws near, we receive the impression of a shorter length, and when it goes away, a longer. The waves of light that are short show their colour toward the violet end of the spectrum; those that are long reach the margin of the red. For this reason the spectrum signals, in a different colour, whether a star is coming near or going away. When a railway train, sounding its horn, goes by, its sound strikes the ear higher than before. For the waves the horn sends through the air, as the train draws near, press together and produce in the ear the sense of a higher note. In light, the higher pitch lies toward the violet.

The brilliance of some gaseous nebulae is not from their own light. The stars that crowd within them have kindled them. Elsewhere the atoms of a nebula absorb the light of a star and send it forth again in light of another wave-length.

Another peculiarity of nebulae may be seen. In places they are smeared, as with clouds, with dark patches, and in the thickest crowding of stars there are black gaps. In the researches of the astronomer Barnard, about two hundred such dark regions of the sky have appeared. Barnard supposes them to be clouds of opaque gas which hide the stars behind them. Some are near, some far; some small, some vast.

If we reckon the density of the matter scattered in the sky that follows upon the world of stars, we find it exceedingly small: only half a dozen atoms to each cubic

inch. How small this is may be judged when we recall that even in the emptiness that science creates in the laboratory with its strongest pump, many crores of atoms remain in every cubic inch.

Our own stellar universe is a vast flattened world in whirling motion, filled with many hundreds of crores of stars. In the sky between them lies gas of the most tenuous kind, here extremely rare, there relatively dense, here luminous, there opaque. The sun stands within a star-cloud about one-third of the diameter from the centre of this stellar universe. The greatest crowding of stars is near the centre of the nebula.

The diameter of the star Antares is three hundred and ninety million miles, and that of the sun eight hundred and sixty-four thousand. The sun is reckoned a star of middling size. This sun is a middle-class star of a stellar universe, and there are hundreds of thousands of such worlds. Where the limit of this whole cosmos lies, we do not know.

Our sun, with all his planets, is whirling, and with him are whirling all the stars of this stellar wheel, round a single centre. In this region the speed of the sun's revolution is nearly two hundred miles a second. As mud flies from a turning wheel, the sun, at such a speed, would be flung from the stellar circle; but ten thousand million stars of this wheel draw him back and do not let him pass beyond its bounds.

Readers will surely know of this power of attraction, yet it cannot be omitted from this description of the universe.

Whether true or false, a story is current that the greatest of scientists, Newton, one day saw an apple fall from a tree, and at once the question rose in his mind: why does the fruit fall downward, why does it not rise upward and fly? Many other questions were turning in his mind. By what pull, he thought, does the moon go round the earth, and by what pull does the earth go round the sun? In the matter of the falling apple he perceived that the earth has a power of pulling. It draws everything toward its own interior. If so, why should it release the moon? Surely this power is such that there is nothing, near or far, that it will not pull. The thought spread everywhere. It was understood that not the earth alone, but everything

pulls everything. The greater the quantity of matter in a thing, the greater its force of pulling. And moreover the force varies with distance, more or less. When distance is doubled, the pull falls to a quarter; when quadrupled, it falls to a sixteenth. Were it not so, the pull of the sun would have plundered the earth of everything it owned. In this wrestling-match of pulls, the earth keeps its victory over things near. Some seventy years after Newton's death, another English scientist, Lord Cavendish, in his laboratory, suspended two leaden balls and showed plainly that they pull each other in accordance with the law. Keeping to the reckoning of that law, I too, sitting at this writing-table, am pulling everything: the earth, the moon, the sun, every star that exists in the universe. The ant that has come into the corner of my room in search of food I also pull; and it pulls me from afar. Needless to say it has not greatly troubled me, nor I it. The earth's clutching force has caused many inconveniences. To walk, one must lift the foot. But the earth draws it down; to go far, we tire, and much time is needed. This arrangement of holding down is excellent for trees and plants, but not at all for man. So from birth to death he must go on contending with this pull. Long ago he might have flown in the sky, but the earth will not by any means let him leave the ground. To wrest himself from this pull that never rests, man has made many machines; and so he can cheat the earth a little, but not wholly. Yet we salute this pull when we learn that, were the earth suddenly to slacken it, then with the terrible speed at which she whirls we should be flung from her back, none knows whither. In truth the pull of the earth has been so exactly measured that we can walk, and yet cannot leave her.

In the world that arose from the paired union of opposite electrical particles, two opposing powers are at work throughout all: going and pulling, freedom and bond. On one side is the universe-spanning great race, on the other the universe-spanning great pull. All is moving and all is pulling. What this moving is, and whence it comes, we do not know; what this pulling is, and whence, we do not know. In the science of today the substance of matter has become exceedingly subtle, and the mightiest thing that appears is going and pulling. If going were alone, movement would be utterly straight, along a road that has no end. The pull brings it back and back, into the bounded, and whirls it on its circling path. Between the sun and the planet lie many hundred thousand miles of empty space. Across the void of that distance there goes ceaselessly the force of a bodiless attraction, binding the planets with

an invisible rein and wheeling them round like the horses of a circus. On the other hand, the sun too is whirling by the pull of ten thousand million revolving stars in the wheel of their light. Look at the minutest energy of motion in the universe: there too is the play of the same great rhythm of going and pulling. Compare the distance between sun and planet with the distance between proton and electron in the ultra-atomic world, and it will be found to be, more or less, in the same proportion. The force of attraction carries across that void, and for ever whirls the company of electrons on a fixed path. All things consist of an infinite harmony of motion and restraint. Here it must be said that the pulling between electron and proton is not that of the great attraction; it is the pull of electricity. The pull within the atom is electrical, and the pull outside is the great attraction, as the pull within the walls of a man's house is that of kinship, and the pull outside is that of society.

This theory of the great attraction has been discussed and has come down from the time of Newton. From it there has formed in our minds an idea, that an unseen power pulls and tugs across the space between two bodies.

But there are some difficulties in conceiving this picture. The action of the great attraction takes not the slightest time. I have said before that light takes time to cross the sky. Electrical forces too come playing in waves across space. But despite many experiments, no proof has been found that gravitation moves with any such lapse of time. Its effect is instantaneous. A further marvel is that light and heat obey the barriers in their path, but gravitation does not. Suspend a thing in the sky, and however many barriers be placed between the earth and it, its weight does not lessen. In its working it finds no kinship with any other force.

At last Einstein showed that this is not a force at all. We live in a world of such a nature, in its very structure, that everything must incline toward everything else. Every body has in the space where it lies a certain warp, a bending quality; in gravitation it is this that reveals itself. It is all-pervading and unalterable. Even light must obey this warped law of the universe, and many proofs have been found of it. The picture of pulling was easy to grasp, but of the new geometry by which the inclination of this warped space is reckoned, how few have any command.

Be that as it may, if what English calls gravitation had been named not "the great attraction" but bharabartan, "the turning of weight," the confusion would be at an end.

This stellar universe of ours is like an island in the vast empty sky. From here, at great distances, many other star-islands may be seen. Of these islands, the nearest to us appears near the constellation of Andromeda, looking like a faint and blurred star. The light that strikes our eye from there set out nine hundred thousand years ago. There are other nebulae of coiled and spiral form, farther still. Of the most distant among them it has been reckoned that it lies three hundred million light-years away. The number of these stellar universes, each a gathering of many crores of stars, will not be less than a thousand million.

A strange thing has come to light: except for two or three near ones, all the other stellar universes are steadily receding from our own. The farther they are, the greater their speed. Certain scholars have concluded that the universe, as we know it, made of the sum of these stellar worlds, is swelling ever larger. So, as it swells, the distances between the star-clusters are increasing. At the speed at which they recede, in another thirteen hundred million years their distances from one another will be double what they are now.

That is to say, within the time that has gone to the making of this earth, the stellar universe has swollen to twice its former size.

Nor is this all. According to a school of scientists, along with this world built of masses of matter, the spherical sky itself is expanding. In their view, if one draws a straight line from any point in the sky, it does not go on to infinity, but curves round and at last returns to its starting-point. According to this view, the stellar universes are situated on the sphere of the sky as the living creatures, the trees and plants, are on the sphere of the earth. The swelling of the universe is therefore measured by the expansion of that sky-sphere itself. But it must be remembered that the matter is not settled; the belief that space is infinite and time without limit has not died. On whether even space is a bubble, the doctrine of our own scriptures is that creation moves toward dissolution, and from that dissolution a new creation arises, like the alternation of sleep and waking. From beginningless time the cycles of

creation and dissolution have returned, again and again, like day and night, with neither beginning nor end; this conception is the easiest to hold in the mind.

In the constellation of Perseus there is a bright star named Algol. Its brilliance remains steady for sixty hours. Then, in the space of five hours, its light falls by one-third. Again it begins to grow bright, and after five hours attains full brightness, and that full splendour lasts sixty hours. The cause of this variation is its companion star. As they revolve, now and again there is an eclipse, and the eclipse passes.

There is another class of stars whose light varies not from any outside cause, but by some tide within themselves, now waning, now waxing. For some days the whole star swells, then gradually contracts. Its light is like the throbbing of a pulse. These stars were first found in the constellation Cepheus, and so they are called Cepheids. Since their discovery, a great advantage has been gained in measuring the distances of the stellar universes.

There is yet another company of stars to tell of, which have been named new stars, or novae. Their light suddenly blazes up with extreme swiftness, from many thousandfold to many hundreds of thousandsfold. Afterwards it slowly dims to extreme faintness. Once, taking the sudden appearance of these stars for a new birth, men called them new stars.

Not long ago, near the constellation Lacerta, there blazed up a nova, suddenly dazzling in brightness. Afterwards it cast off four shells of light, one after another. It was seen that the cast-off shells were flying at 2,200 miles a second. This star lies about 2,600 light-years away; that is, the eruption of the star's gases which we have just seen took place six hundred and fifty years before the birth of Christ. What has become of these discarded shells of gas is a matter of conjecture. Are they, breaking their bond, going as renunciates into the great void, or, caught in the star's pull, cooling, do they continue in its allegiance? Considering this flaring up of stars, some scholar has said that perhaps it is in just this way, from the gases thrown off in the explosion of a star, that planets are born; perhaps the sun once, in the manner of such a nova, gave birth to its planetary children from its own separated fragments. If this view be true, it is probable that every ancient star, at some time,

meets the state of explosion and begets a family of planets. Perhaps in the sky there are few childless stars.

The second view is that a wandering star from outside came within the field of another star's attraction and brought about this catastrophe. The origin of the earth, according to this view, will be discussed later.

The stars in our stellar universe are of many kinds. Some give light ten thousand times that of the sun, some a hundred times less. In some the mass of matter is extremely dense, in others it is utterly thin. The surface of one has a temperature of twenty or thirty thousand degrees centigrade, that of another not above three thousand. Some, expanding and contracting again and again, play the tide and ebb of light and heat; some go alone; others go in pairs, and these are a third of the company of stars. The paired stars, caught in the net of mutual attraction, pass their time in the round of revolution. Of the pair, the one of lesser force bears the burden of circling, as the sun and the earth. Poor earth is not without pull, but she cannot much disturb the sun. The ceremony of circling is performed by the earth alone. Where two luminaries are almost equal in force, a point midway between them remains fixed, and the two stars circle round it.

How these paired stars came into being, I hear different opinions. Some say that at the root is brigandage: by the law that might makes right, one star has taken another captive and keeps it as a companion. According to another view, the twin arises from the very body of the parent star. Let me explain. The more a star cools, the more tightly it contracts. As it grows denser, its whirling becomes swifter. In the thrust of that swift motion the outward-flying force grows stronger. When a cart-wheel turns very fast, this outward force gains strength within it, and mud flies from its rim; and if its joints are green, its parts break and fly off. As a star's whirling increases, this outward force grows so great that at last one day it breaks in two. From that time the two parts, as two stars, begin their journey together.

For some pairs a single revolution takes many thousand years. Sometimes it is seen that, circling, one hides the other from our sight and dims its brightness. But there would be no great loss of brilliance if the eclipsing star were not relatively dim. Among stars the differences of brightness are great. There are even stars that have

lost all their light. Stars that began their youth with vast bulk and fierce heat, in the third age have grown cold and squandered their capital of light. In their last state these bankrupt stars remain unknown in the dark.

There is a giant named Betelgeuse, whose red light shows that his years are many. Yet he still glitters. Though he lies far away, his light takes 190 years to reach the earth. The truth is that his bulk is enormous, and within his body he could hold many crores of suns. In the constellation Scorpio stands Antares, nearly twice the size of Betelgeuse. And there are stars that are gaseous indeed, but whose substance is, in weight, far heavier than iron.

The great bodies of the giant stars are great not because their mass is greater, but only because they are so distended. And there are many small stars which are small because their store of gas is packed into a bundle of extreme compression. The density of the sun stands midway between these, somewhat greater than that of water; the average density of the star Capella is like that of our air. But if we reckon the passage from these to the giants, we must remember that the difference is immense. And beyond even this are the red giants of the constellation Orion and of Scorpio, Betelgeuse and Antares. Their density is so exceedingly slight that it cannot even remotely be compared with any substance on earth. It is less than the gas that remains in a vessel pumped as dry as the laboratory can make it.

At the other extreme are the white dwarf stars. Beside their density, iron and platinum are as nothing. Yet they are not solid; they are gaseous and of the sun's own race. In the fierce heat of their inner chambers, the electrons are torn from the bonds of the protons; they are freed from their servitude; and the space that they once filled, each respecting the other's dignity, is diminished; broken atoms ceaselessly dash against one another in disorder. By this shrinking of the atom the star's volume becomes small. And from this lawless disturbance of peace the heat rises beyond its ordinary measure, and the dense gas grows to three thousand times the weight of platinum. So the dwarf stars are small in size but not less in heat, and in the excess of weight they surpass even the great. The star Sirius has a faint companion star. It is small in size, like an ordinary planet, yet in the quantity of its matter it is like the sun. The density of the sun is a little less than one and a half times that of water; the density of Sirius's companion is, on average, fifty

thousand times that of water. If a matchbox were filled with its gas, it would weigh more than fifty maunds. And in the star Perseus, the tiny companion's same quantity of matter would weigh some ten thousand maunds. Again, I hear that certain scientists do not accept this view. When the earth was being newly formed, there was constant contradiction on land and water; where today is a chasm, tomorrow is a mountain; and for some time natural science too has been in this state. How many theories rise and fall, there is no telling.

The stars of our stellar universe, some toward the east, some toward the west, travel by various paths. The sun runs at about two hundred miles a second; there is one giant star whose speed is seven hundred miles a second.

Yet it is a marvel that none among them escapes the dominion of this stellar universe and flies away beyond it. In the great net of one curved attraction, binding many crores of stars, this universe spins like a top. In the universes that lie beyond ours, there too is the same whirling. And in the smallest space of the atomic world, the protons and electrons circle too. The stream of time flows on, bearing the many whirlpools of many luminous worlds. For this reason, in our language, this universe is called jagat, "the moving," and this is its definition: it moves; in moving it is born; to move is its nature.

Looking at the measures of the space and time of the stellar universe, its velocities and distances and the unthinkable fury of its whirlpools of fire, however great our wonder, we must acknowledge that the greatest marvel of all in the universe is this: that man knows them, and, passing beyond the needs of his daily bread, desires to know them. Smaller than the smallest, his body perishable in a moment; present only in the tiniest fragment of time in the history of the universe, occupying a mere atom of place in the vast order of things; and yet he keeps the reckoning of the great and hard-to-measure, and of the subtle that is hard to reach, in this universe that borders upon the infinite. There is no greater marvel in the world than this. Or perhaps, in the vast creation, through endless time, in some other sphere some other mind is taking possession and revealing itself in some other way; I know not. But this man has proved: that the great is not in outward bulk, nor in measure, but in inward fullness.

THE SOLAR SYSTEM

If we consider the bond between the sun and the planets, we find that the paths of the planets' revolutions lie nearly in the plane of the sun's equator. That is one fact. And another: in the direction in which the sun turns about his own axis, the planets also turn and revolve about him. From this we understand that the relation between the sun and the planets is one of birth. Let us consider the story of their origin.

The stars wander at distances of many crores of miles from one another, so that one may say there is no likelihood of their falling upon each other or coming very near. Some suppose that about two billion years ago one such improbable event may have taken place. A vast star came near the sun of that age. By the pull of that star, a tidal wave of fiery vapour surged up, with terrible force, between the sun and the intruding star. At last, in the violence of the pull, certain waves, swelling higher and higher, were torn away. The great star may have taken some of these to itself; the rest, caught in the sun's mighty attraction, began from that time to circle round him. Scattering their heat, they were divided into smaller parts. From those fragments of burning vapour, great and small, the planets were born, and the earth is one of them. Gradually, giving off their heat, they cooled and took the form of planets. By reckoning the distances, numbers and motions of the stars in the sky, it has been found that such a collision may happen only about once in fifty or sixty billion years. If we accept this theory of the origin of planets, we must say that in this universe the creation of stars bearing planetary families is an almost unthinkable event. But if we admit that, as the egg-shaped boundary of the universe swells, the stars are moving ever farther from one another, then we must suppose that in the earlier age, when the sphere of the sky was narrower, collisions between star and star took place continually. It was reasonable to suppose that in those days of the crowded fair of stars, the birth of planets from the broken fragments of many stars was likely. The circumstance in which our sun was struck by another sun, by today's reckoning, was not so improbable in that contracted universe. Some who have not accepted this view say that in a particular stage of a star's development there comes a time when, like a ripe shimul pod, it bursts and flings masses of fiery vapour far on every side with tremendous force. From certain

stars such burning gas has suddenly been seen to issue. There was a small star that, until a few years ago, could never be seen without a good telescope. At one time it grew in brightness almost equal to the brightest stars of the sky. Then in a few months its power slowly waned so far that, as before, it could not be seen without a telescope. It is not unreasonable to suppose that the masses of burning vapour which this star flung on every side, in the brief time of its brightness, slowly cooled and, consolidating, could give birth to planets and moons. If we accept this view, we must say that many crores of stars have passed through this state, and that therefore, like the solar system, many crores of stellar worlds, each with its own planetary company, fill this universe. If even the star nearest the earth has a family of planets, the telescope needed to see them has not yet been made, however great.

Not long ago, a young scholar of Cambridge, Lyttleton, put forward a new view of the creation of the solar system. I have said before that in the sky many twin stars circle each other. In his view our sun too had a twin. While it circled, another wandering luminary came and fell upon this follower, struck it and hurled it far away, and went on its way. As it passed, by the force of their mutual attraction a great stream of burning vapour was drawn out, and into it was mingled the substance of both. The part of this stream of vapour that was caught by the sun's strong pull, and held captive, gave birth to our family of planets. Being small in bulk, they did not delay to cool; as the heat diminished, the fragments of gas became first liquid, and then, growing colder still, the day came when they were to grow hard.

Remember that none of these conjectural views may be counted as established proof.

It must be said that the whole of the sun is gas. All those substances which on earth are hard, earth, metal, stone, are in the sun, in its fierce heat, in the state of gas. The lines of the spectroscope prove it.

Of the very tenuous gaseous envelope of the corona, I have already spoken. The deeper one passes inward through that layer, the denser the gas, and the more fiery the heat. The temperature at the sun's surface is about ten thousand degrees

Fahrenheit; going down, at last one reaches a layer where the gas is so compressed that it is no longer clear. Here the temperature is above fifteen million degrees. At last, at the centre, there will be found a heat of about seventy-two million degrees, where the substance of the sun's body is far denser than solid iron or stone, yet has the nature of gas.

Let me speak of the sun's distance not with figures but with an imaginative illustration. The sensations that occur in our bodies are carried to us by innumerable nerves of touch. These nerves spread through the whole body and meet in the brain. Through them, like the wires of a telegraph, news comes to the brain: we know where an ant has bitten, that the food which touched the tongue is sweet, that the bowl of milk we lifted is hot. Our body is not so vast as the distance from Howrah to Burdwan, and so the news is not long delayed. Yet a little time, a very little, does pass, so little that it is hard to measure. Scholars have measured even that. They have tested and determined that through the body of man a physical event reaches perception at a speed of about a hundred feet a second. Imagine a giant who, stretching out his hand from the earth, could reach the sun. However strong the giant's hand, the moment it touched the sun's surface it would burn. But to learn through the nerves of the loss and agony of the burning would take him nearly one hundred and sixty years. Long before that he would be dead, and never know it.

The diameter of the sun is 864,000 miles. A hundred and ten earths set side by side in a straight line could reach from one end of the sun to the other. The sun's weight is three hundred and thirty thousand times that of the earth, and by the force of so much weight he draws. By this pull the sun holds the earth bound in his grasp, but by the force of her running the earth has preserved her independence.

Imagine a skewer thrust through the exact middle of a round potato, from top to bottom, and the potato turned round the skewer. The turning will be like the earth's revolution once in twenty-four hours. We say that the earth is turning about her axis. The difference between the skewered potato and the earth is that the earth has no such skewer. The axis is no rod at all. The place where the skewer would have been, the imaginary straight line, we call the axis. So with a top: it spins round an imagined vertical line through its middle.

Round her axis the earth takes twenty-four hours to make a turn. The sun too turns round his axis. By what means the time of his turning has been learned, I shall tell. If one looks at the sun in the early morning, when the light does not dazzle the eyes, one may see dark spots upon his face. Sometimes one of these dark spots grows so vast that all the planets and moons together would not equal it. The small spots fade in no long time, but the great ones last two or three weeks. Seen through a telescope they seem to be moving steadily to the right, but in truth it is the sun, carrying them all upon his body, that turns. By following these dark spots the time of the turning has been reckoned, and it is proved that the earth turns in twenty-four hours and the sun in twenty-six days.

The spots on the sun are great whirlpool-hollows in his outer envelope. Through them the heated gas from within comes up in coiling spirals, whirling as it rises. The central part is deep black, and is called the umbra; around it a lesser black fringe is called the penumbra. They seem dark only by comparison with the brilliance about them; if that light could be shut off, their own glow would be seen to be most intense. Of the very great sun-spots, the diameter of the umbra of some is fifty thousand miles from edge to edge; the penumbra, a hundred and fifty thousand miles.

The rise and fall of these spots works upon the earth in many ways, as upon our weather. In a cycle of about eleven years the sun's spots wax and wane. By experiment it has been found that in the trunks of trees the record of these spotted years is written. If the trunk of a large tree is cut, a ring-mark for each year may be seen in it. In some places these rings lie close, in others wide apart. From each ring one can tell how much the tree grew in that year. In the desert-like region of Arizona, in America, Dr. Douglass has observed that in the years when the sun's dark spots appeared more, the ring in the trunk was broader. Counting the marks of five hundred years on the pines of Arizona, he found that from 1650 to 1725 there was a gap in the sign of the sun's spots. At last he enquired at the Greenwich observatory and learned that in those years there were almost no spots on the sun.

Of the abundant light that streams from the sun's body, a very small portion falls upon the planets. The greater part goes out into the void at a hundred and eighty-

six thousand miles a second; it reaches one star in four years, another in thirty thousand, another in nine hundred thousand. We think that the sun is ours alone, and that we have the larger claim upon his gift of light. But only a tiny fraction of so much light touches us. Thereafter the messenger of the sun's light returns to him no more; where it goes, and in what work of the universe it is used, who knows.

One question concerning the luminous worlds has been left: whence comes the unceasing supply of their heat? The search must be made among the atoms.

If by the union of electron and proton an atom of helium were ever to be created, the prodigious energy released in that act would bring upon our earth an annihilating catastrophe. And that is the question of building up. But to destroy matter, a force many times more intense is needed. If proton and electron collide, then, with the most piercing radiation, they will vanish at once. The prodigious energy that is born of this is beyond imagining.

Precisely this is happening in the company of stars. Where the destruction of matter is going on, we may reasonably suppose. According to this theory, the sun is spending daily three hundred and sixty trillion tons of his substance. But the sun's store is so vast that for many hundreds of crores of years such prodigality may continue. Yet if we accept the final reckoning now made of the age of the present universe, the theory of building up fits better than that of breaking down. If we suppose that at one time the sun was a mass of hydrogen, then the energy that must be released in the forming of helium from that hydrogen agrees with our present reckoning.

Therefore scientists have not agreed whether this universe is moving toward destruction, or toward building up, or whether both are occurring together. A few years ago a radiation was discovered, which has been named the cosmic ray; its origin is neither in the earth, nor in the sun, nor even in the world of stars. It is supposed that, from some region of the sky beyond the stars, from the breaking or the building of the universe, it has come forth.

Be that as it may, these contrary signals that come to the scientist's laboratory, messengers of the creation of the universe, may perhaps come to a halt before

some intricate calculation. But we are not scientists. We cannot grasp how the beginning of a reckoning should happen suddenly, whence, or how it should end all at once, and where. A world fully formed, and then suddenly the beginning of time; and with the sudden dissolution of that world, the complete end of time; our understanding cannot find the shore of this. The scientist will say that reason is not in question here, that it is a matter of calculation, and that calculation rests on the course of present events. If in its beginning and its end we see darkness, there is no help for it.

THE WORLD OF PLANETS

What a planet is has already been said. The sun is a star; the earth is a planet, a fragment torn from the sun, cooled, its light gone out. None of the planets has light of its own. Around the sun each of these planets has its own fixed path, in the form of an ellipse, the path of one near the sun, of another far from it. Some take less than a year to circle the sun, others more than a hundred years. However long a planet takes to circle, there is a fixed law for this circling which is never once broken. Every planet of the sun's family, near or far, small or great, must circle from west to east. From this it is understood that the planets were flung from the sun by a shock in the same direction, and so their bent for moving is the same. When one alights from a moving carriage, the body is inclined in the direction in which the carriage was going. If five persons alight, all five lean in that one direction. So, when they sprang from the whirling sun, all the planets received a bent in one direction. From this tendency to move we understand that they are all of one kind, all of one inclination.

Nearest the sun is Mercury, called in English Mercury. It is only thirty-five million miles from the sun, about a third of the distance at which the earth keeps. Some faint blurred markings appear on Mercury, and from watching these it has been understood that only one side of it is turned toward the sun. To go round the sun takes it 88 days, and to turn upon its own axis takes the same. On the path of circling the sun, the earth runs nineteen miles every second; Mercury's speed surpasses this, thirty miles a second. Its road is short and its haste great, and so in a quarter of the earth's time its circling is complete.

The sun is not exactly at the centre of Mercury's path, but a little to one side. Therefore, as it goes round, Mercury sometimes draws relatively near the sun, sometimes goes far.

Being so near the sun, this planet receives very much heat. An instrument has been made to measure extremely small quantities of heat, called in English the thermo-couple. Joining it to the telescope, news of the heat of planets and stars can be learned. According to the reckoning of this instrument, the heat of the side of

Mercury turned toward the sun can melt lead and tin. In this heat the molecules of the air grow so violently restless that Mercury cannot hold them; they leave their country and fly into the void. The molecules of air are fugitive by nature. On earth they dart about at merely two miles a second, and so by her pull the earth can hold them. But if from any cause the heat rose and their speed became seven miles a second, then the earth too could no longer keep her air in obedience.

Among the tasks of the scientists who keep the accounts of the universe, a principal one is to fix the weight of planets and stars. For this the ordinary balance does not serve, and so cunning must be used to obtain the news. Let me explain. Suppose a rolling ball suddenly comes and strikes a traveller, and he is thrown ten cubits away. If one knows the law, how heavy a ball must be, and with what force it must strike, to throw a man so far, then from the measure of those ten cubits the weight of the ball can be worked out. Once, by chance, an opportunity for such a calculation occurred, and the weighing of Mercury became easy. It was a comet that made the opportunity. But before telling of that, I must explain what sort of luminaries comets are.

Dhumaketu, "comet," means "the banner of smoke." The name arises from its appearance: a round head, and behind it trailing a bright long tail. This is commonly its form. The tail is of exceedingly fine vapour, so fine that sometimes the earth has passed through it and we have not felt it. The head is made of meteoric stones. The great scholars of today hold that comets belong to the sun's own train of followers. Some there may be not of the family, who are strangers.

Once a comet's path suffered a mishap. As it passed by the orbit of Mercury, in the tug between it and Mercury its course was thrown into confusion. A derailed train may be pushed back upon its rails, but the time of the timetable has passed. So it was here. When the comet returned, the time fixed for it had been exceeded. The reckoning proceeded from the extent to which Mercury's pull had disturbed the comet. The heavier a body, the greater the force with which it pulls, and from this the weight of Mercury was found. It was seen that twenty-three of Mercury's weights would be needed to equal the weight of the earth.

Next after Mercury on the road comes the course of Venus. It takes her 225 days to go round the sun, that is, her year is seven and a half of our months. How fast she whirls on her axis is a question still in dispute. At one time of the year this planet appears in the western horizon after sunset, and then we call her the evening star; and at another time the same planet rises in the east before the sun, and then we know her as the morning star. But she is no star at all; because she glitters so, she has gained the name among the common people. Her size is a little less than that of the earth. Her path is three million miles nearer the sun than the earth's. Nor is that a small thing. She keeps a fitting distance, yet we cannot learn well what lies within her. This is not because of the sun's fierce light. Mercury is veiled by the sun's light, and Venus by her own dense clouds. Scientists have calculated that the heat of Venus is such that it works no extraordinary change upon water. So we may hope to find there both oceans and clouds.

From what can be conjectured of the upper surface of the clouds, it appears that the oxygen of this planet is very slight. The clear trace of gas found there is carbonic gas. Above the clouds its quantity is many thousands of times greater than that of this gas on earth. On earth the chief use of this gas is to provide food for trees and plants.

In this dense covering of carbonic gas the planet seems wrapped in a blanket. The warmth within cannot come out. So the surface of Venus must be like boiling water, or hotter.

It is strange that no trace of moist vapour has been found on Venus. From what, then, are her dense clouds formed? It may be that in the cold of the upper layers of cloud, water has so condensed that no vapour can be got from it.

This is a matter worth considering carefully. In the first age of the earth's creation, when the molten substances cooled and began to set, moist vapour and carbonic gas arose in great quantity. As the heat diminished further, the moist vapour became water and spread seas over the face of the earth. Then the gases that predominated in the air were inert gases, like nitrogen. Oxygen is of a restless, sociable kind; it is its nature to mingle with other substances and make compounds.

By this means it goes on transforming itself. Nevertheless, how did so great a quantity of pure oxygen endure in the earth's air?

The chief cause was the earth's vegetation. Plants take carbon from the carbonic gas of the air and build their living cells, and release oxygen. Then from the breath of animals and the decay of leaves and creepers, carbonic gas again rises and fills its treasury. On earth, the great chapter of life probably began when there was a little oxygen among the plants of that primal age. As the course of those plants advanced, so in their breath the quantity of oxygen increased; and the carbonic gas diminished.

Therefore it may well be that the state of Venus is like that of the earth in its primal age. Some day, perhaps, in some fissure plants will appear, and, from carbonic gas, will begin to release oxygen. Then in a long age, step by step, will come the turn of living creatures. The state of the moon and Mercury is the exact opposite. There, through the weakness of their pull, the air fit for supporting life was lost in a moment.

In the solar system the seat after Venus is the earth's. When we have finished with the other planets, we shall take the earth's news.

In the line after the earth comes the place of Mars. This reddish planet is, of all other planets, the nearest to the earth. Its size is about one-ninth that of the earth. To go once round the sun takes it 687 days. The path in which it circles the sun is something like an egg; therefore, as it goes round, once it draws near the sun, and again goes far. To turn on its own axis it takes just half an hour more than the earth, and so its day and night are a little longer than ours. The quantity of matter in this planet is a tenth of the earth's, and so its power of attraction is proportionately less.

By the sun's pull, the exact path which Mars ought to follow differs a little from the course it takes. The earth's pull has caused this. By reckoning how far the earth's weight has turned Mars aside, the earth's weight has been fixed, and in this way the sun's distance too was found. For the sun pulls Mars and the earth pulls Mars, and how far away the sun must be, for the two pulls to cancel so as to cause just

this small disturbance of Mars, can be found by calculation. Mars is not a very large planet, and his weight is relatively small, and so, since his pull is not great, there was fear that he would lose his air. But being far enough from the sun, he does not receive so much heat that the molecules of his air might fly off in the warmth. The search for oxygen in the air of Mars has failed; a little may exist. From the red colour of Mars it is supposed that the rocks there have wholly rusted by union with oxygen. And the traces of moist vapour found there are one-twentieth of the moist vapour in the earth's air. The poverty of Mars's air shows that the earth too, little by little, will one day lose her store and come to this state.

Since Mars is farther than the earth from the sun, this planet is much colder. In the day-time, at the equator, it may be somewhat warm, but at night there is without doubt a cold far greater than the cold of frozen ice. Of its polar regions, with their caps of snow, there is nothing to say.

At the poles of this planet the cap of ice waxes and wanes, and sometimes cannot be seen. The changes in form of this melting cap are caught by the instruments of sight. A great part of the surface of the planet is like desert, dry. Only in the summer season do certain portions turn dark green, as if, perhaps, in the days when the ice melts along the courses of water, vegetation springs up.

Among scholars a dispute about Mars has gone on for many days. Once an Italian scientist saw long lines scratched on Mars, and said: surely the inhabitants of this planet have dug canals to bring the melted ice-water from the poles. Again certain scientists said that it was a trick of the eye. Of late man has turned the camera upon the luminous worlds. In the photographs so taken too, dark lines can be seen. But that they are artificial canals, the work of intelligent beings, is wholly conjecture. Yet it is not impossible that living creatures exist on this planet, for there is air and water there.

Two moons circle Mars. One takes thirty hours to complete a revolution, the other seven and a half; that is, within one day and night of Mars the second goes round him nearly three times. They accomplish their circling much more swiftly than our moon.

Seeing so wide an empty space between the orbits of Mars and Jupiter, the scholars grew suspicious and set about searching. At first four very small planets appeared. Then it was found that there were many thousands of fragment-planets crowded there. In flocks they revolve about the sun. Let us call them planetoids; in English they are called asteroids. The first to be seen has been named Ceres, and her diameter is four hundred and twenty-five miles. A planetoid called Eros approaches the earth, in its circling of the sun, nearer than any other planet. They are so small that no special news of their interior can be had. The weight of all of them together is less than a fourth of the earth's; less than that of Mars, for otherwise its pull upon the path of Mars would have created some disorder.

These fragment-planets may be thought the wreck of some once-whole planet. But scholars say that this is not true. It cannot be told for what reason they have not joined together and taken the form of a planet.

In connection with these planetoids another company should be mentioned. They too are very small, they too move in flocks, and along a fixed path they circle the sun; they are the meteors. On the earth their shower goes on unceasingly, and the ash they have mingled with the dust is not small. Were it not for the canopy of air above the earth, we should have no protection from the attack of these tiny enemies.

Meteor falls occur every day and night, more or less. But on certain days of certain months the fall of meteors is more abundant. On the night of the twenty-first of April, on the 9th, 10th and 11th of August, the 12th, 13th and 14th, and on the 27th of November, this meteor-shower is a fireworks worth seeing. Observing the fixity of these dates, scientists have been set to search out the cause.

The matter is this: they have a special path. But unlike the planets they do not travel alone; they are a swarm of locusts of the heavens, bound in companies. Hundreds of thousands go crowded along one road. On certain days of the year the earth goes and falls precisely where they are thickest. The earth's pull they cannot withstand. They rain down in masses. In the earth's dust they become dust. Sometimes large fragments fall, burst, and lay waste on every side. They are the tokens of the ill fortune of comets that have trespassed into the sun's domain and

fallen into peril. It is said also that in the earth's youth, when the heat within her was greater, by volcanic eruption the matter of her interior was flung so high that, escaping her pull, it still wanders about the sun, and when the chance comes the earth draws it back again. On special days it is as though a harir-lut, a scattering of largesse, were made of those meteors. And again, many meteors have been found that came from outside the solar system and were caught by the earth's attraction. Somewhere in the universe perhaps there was a catastrophe, in whose fury masses of matter were shattered and scattered. This company of meteors bears witness to it today.

After these infinitesimal ones, on the next road, appears the great Jupiter, the greatest of the planets.

Before expecting any sure news from Jupiter, two things must be noted: his distance from the sun, and his size. The earth's distance is a little over ninety million miles, and Jupiter's distance is 483 million, that is, more than five times the earth's. The earth receives a certain amount of the sun's heat, and Jupiter receives a twenty-seventh part of it.

Once the astronomers supposed that Jupiter had not cooled as the earth has, and that he had his own store of heat. The restlessness of his atmosphere was thought due to the heat of his own interior. But when the measure of Jupiter's temperature could be reckoned, the planet was found to be exceedingly cold: its temperature is 280 degrees Fahrenheit below the cold of frozen ice. In so extreme a cold there cannot be any moist vapour on Jupiter. From his atmosphere the edges of two gases were found. One is ammonia, the pungent smell of which startles one in sal-ammoniac; the other is marsh-gas, famous for leading wayfarers astray in the fields. Combining many arguments, it is for the present settled that Jupiter's body is solid, of nearly the density of the earth. The rocky core within measures twenty-two thousand miles across; upon it lies a layer of ice sixteen thousand miles deep. Above this mass of ice rises an atmosphere of six thousand miles. Under the pressure of so great a mass of air even hydrogen turns liquid. So on this planet there is, above a hard stratum of ice, a sea of liquid gas; and the upper layers of its atmosphere are of liquid ammonia.

Jupiter is a giant planet; his diameter is about ninety thousand miles, and in volume he is thirteen hundred times the earth.

To go round the sun Jupiter takes nearly twelve years. Being far, his orbit is much greater than the earth's, but his motion too is sufficiently slow. Where the earth goes nineteen miles a second, he goes only eight. But his rotation, his turning about his own axis, is very swift. To spin so vast a body takes him ten hours. Within our one day and one night, his two days and nights are complete, with something over.

Jupiter has a family of nine moons. News of a tenth has been received, but it is not certain. The speed of these moons' circling round Jupiter is much swifter than our moon's. The first four are as large as our own moon. They too have new moon and full moon, and waxing and waning.

The two moons of Jupiter farthest away move in the opposite direction to the others of his company. From this some suppose that they were once two planetoids, caught by the pull of Jupiter.

That light runs at a hundred and eighty-six thousand miles a second was first settled from the eclipses of Jupiter's moons. By calculation, when an eclipse of one of his moons should occur, it is seen to occur each time some while later. The cause is that its light takes a little time to reach our eyes. Light travels with a fixed measure of time; were it not so, the event of the eclipse would be seen at the very moment of its occurrence. By measuring the distance of this moon from the earth, and observing how much the period of the eclipse has been overpassed, the speed of light was first reckoned.

That Jupiter has no light of his own is proved by the eclipses of his nine moons. Consider how an eclipse happens. When, by some arrangement, the sun stands behind, and the planet, shutting out light, stands before the sun, and the moon too stands in the planet's shadow, then the moon, deprived of the sun's light, suffers eclipse. But if the intervening planet had its own light, that light would fall upon the moon, and eclipse could not occur. So too in an eclipse of our own moon: when the earth hides the sun from the moon, the lightless earth can give the moon shade, but cannot give light of her own.

In the line after Jupiter comes Saturn.

This planet is 886 million miles from the sun. In twenty-nine and a half years it completes one circling. Its speed is less even than Jupiter's, only six miles in a second. Except Jupiter, its size is far greater than that of any other planet of the solar system; its diameter is about nine times the earth's. Though nine times the earth's diameter, to turn once on its axis takes less than half the earth's time. So swiftly is it spinning that by the thrust of the speed its shape has become somewhat flattened. Great as its bulk is, its weight is only ninety-five times that of the earth. Being so light, despite its vast volume, its power of pulling is no greater than the earth's. A veil of cloud encircles it, whose shape is seen to change from time to time.

Saturn has nine moons. The largest is in volume greater even than Mercury; it lies about eight hundred thousand miles away, and its circling takes sixteen days.

From the spectrum of Saturn's ring it has been found that the parts of the ring that lie near the planet move much faster than the more distant outer parts. If the ring were a single solid wheel, then by the law of a turning wheel the outer part would move faster. But if Saturn's ring is made of separate pieces, then the part nearer the planet, by the force of attraction, will revolve faster. Besides these hundreds of thousands of fragment-moons, nine great moons circle Saturn in other paths.

How these myriad small fragments came into being in crowds around this planet, I shall relate, as far as the scientists' view goes. No moon can keep its round form under the mighty pull of the planet; in the end it becomes somewhat egg-shaped. At last there comes a time when, unable to bear the pull, the moon breaks in two. These two fragments too begin to break again. By thus breaking and breaking, hundreds of thousands of fragments may come from a single moon. Our own moon too is destined one day for this fate. Scientists say that round every planet there lies an invisible circle, called the limit of danger. When a moon enters it, its body swells out and becomes long like an egg, and then begins to break. At last the fragments circle in a band about the planet. In the opinion of the scientists, the first moon of Jupiter has approached this invisible danger-limit, and a few days hence,

when it enters, it will break into pieces. Like Saturn, round Jupiter will then be formed a shining ring. As to the ring about Saturn, the scholars suppose that long ago one of Saturn's moons, circling, fell within his danger-limit, and that the moon, broken in pieces, still circles about the planet.

The earth's limit of danger lies far outside, and therefore the changes of the moon have not been great. By the earth's pull the moon is slowly drawing near. Then, when she enters the region of that circle, she will be broken in pieces, and the fragments will circle the earth in imitation of Saturn; then will come her Saturn's fate.

The view of Professor Jeffreys of Cambridge is the reverse. He holds that the distance between the earth and the moon goes on increasing. At last the lunar month and the solar month will be equal, and then will begin the turn of drawing near.

Saturn is farther from the sun than Jupiter, and therefore colder still. The outer atmosphere is much like Jupiter's, except that ammonia cannot be found so plentifully, while of marsh-gas there is more than in Jupiter. Though Saturn is far larger in volume than the earth, its weight is not in proportion. Like Jupiter's, its atmosphere should be deep, for there is no way of escape for the air from its pull. Because the quantity of its air is so great, its average weight is so slight compared with its bulk. The diameter of its solid core is 24,000 miles; upon it lie about six thousand miles of ice, and above that, sixteen thousand miles of air.

In the circle after Saturn is Uranus, a newly discovered planet.

Nothing of special note is known of this planet. Its volume is sixty-four times the earth's. At a distance of 1,782 million miles from the sun, at four miles a second, it circles the sun once in eighty-four years. So great is its body, but since it lies so far away, it cannot be seen without a telescope. The substance of which it is made is a little denser than water, and so, though many times larger than the earth, its weight is only fifteen times the earth's. In ten hours and forty-three minutes it turns once upon itself. Four moons in their own courses circle it unceasingly.

Not long after Uranus was discovered, scholars, seeing the irregular motion of Uranus, concluded that this planet was breaking the law of its path through the pull of another planet. Searching and searching, they found that planet. It was named Neptune.

Its distance from the sun is 2,793 million miles; in about 164 years it makes one circuit. Its diameter is about 33,000 miles, somewhat greater than that of Uranus. In the telescope it seems only a small green disc. A moon, at a distance of 222,000 miles, circles it once in five days and twenty-one hours. From the distance of this moon and the volume of the planet it has been reckoned that the substance of Neptune is somewhat heavier than water, and in weight it is nearly equal to Uranus. With what speed it turns about its axis is not yet exactly known.

By the attraction of Neptune the new path in which Uranus ought to have gone was reckoned; yet even after the reckoning it was seen that Uranus does not follow that path exactly. From this it was understood that beyond Neptune there lies, outside the course of this planet, yet another luminary. In 1930 a new planet appeared. It was named Pluto. This planet is so small and so far that even in the telescope it cannot be seen. By means of photographs, its existence has been proved beyond doubt. This is the planet farthest from the sun, and so it receives so little light and heat that we cannot even imagine its condition.

From a distance of 3,960 million miles, in about two hundred and fifty years it circles the sun once.

The temperature of Pluto must be four hundred and forty-six degrees Fahrenheit below that of melting ice. In so great a cold even the most unruly gases turn liquid, and even solid. The gases, carbonic, ammonia, nitrogen and the rest, frozen, must surely have covered the planet in masses of ice. Some suppose that on the farthest border of the sun's realm a number of small planets are scattered, and Pluto is one of them. But no certain proof of this view has been found, nor can it be said whether it ever will be. If a telescope far more powerful than any we have today can lift the curtain of that distance, then the doubt will be resolved.

BHŪLOKA: THE TERRESTRIAL WORLD

Of the other planets we have gathered some scattered tidings concerning their size and motion. But the Earth alone is the one planet whose bodily structure we have come to know almost entire. From the time it passed beyond its gaseous state and its body drew firm and close, the many signs of its history have been inscribed upon its every limb.

Because the topmost layer of the earth had no covering, that portion swiftly cooled and grew hard, while the inner layer went on slowly congealing into solid mass. As the skin upon milk wrinkles as it cools, so the upper layer of the earth wrinkled as it cooled. The slight unevenness that comes to the skin of milk in wrinkling we take no account of. But the unevenness of the wrinkled earth is not so slight that it may be waved aside. The layer beneath had not yet set firm enough to bear the burden of this unevenness. So, lacking good support, the hard upper crust buckled and broke, and began to rise and fall in heights and hollows, and mountains appeared. As the skin of an old man's brow puckers into furrows, so these are the furrows of the earth's skin. Set against the vast depth of the whole earth, these mountains are no more than the wrinkle-marks upon a man's skin.

In the earth of the ancient age, amid the heights and depths of the wrinkling crust, hollows sank in one place and mountains rose in another. The hollows were not yet filled with water, for in the heat of the earth even the water was still vapour. By degrees the ground grew cool and the vapour turned to water. With that water the hollows filled, and the sea came into being.

Much of the earth's water-vapour, then, became liquid. But the chief gases of the air remained gases, for to liquefy them is no easy matter. Had the earth grown cold enough for them to turn liquid, the water would have frozen at such a cold, and the earth from end to end would have lain sheathed in armour of ice. In the middle

measure of warmth and cold, oxygen, nitrogen and the other gaseous substances of the air move freely about, and we live by drawing breath.

The contraction toward the earth's interior has not wholly ceased even now. By the push of that stirring, if somewhere a bed of ground beneath should suddenly give way and shift from below, then the hard covering above breaks and falls upon it with all its weight, and sets the layers of the earth swaying, and an earthquake awakens. Again, in some places, under the pressure of the broken covering, the hot liquid matter below surges upward.

To know the state of the earth's interior we should need to dig deep, but we have not yet bored so far. In search of coal, man has gone down into the soil no more than a mile. From this we have learned only that the farther we descend, the more the heat rises, by a certain fixed measure. The rise is not the same everywhere; it differs from place to place. There was a time when it was commonly held that the land floats upon the molten metal of the earth's heated core. The present opinion is that the earth is solid within. The presence of heat toward the interior can indeed be seen, but the radioactive substances in the earth's strata yield heat enough. The matter of its innermost core is denser than iron. Probably that region is very hot, yet not so hot that the substances there could melt. It is reckoned that the stuff there is iron and nickel, extending over two thousand miles, and that the shell which encloses them is more than two thousand miles thick.

If the whole earth were water, its weight would be far less. The weight of the earth, land and water together, is five and a half times greater than that. The rock of its upper strata is three times denser than water. We must therefore suppose that within lie still heavier substances. It is not merely that their density has grown under the pressure from above; the mass of matter there is by nature heavier.

Of the air that encircles the earth, seventy-eight parts in a hundred are nitrogen and twenty-one parts oxygen. The other gases are very slight. Oxygen is a sociable gas: it unites with iron and brings it to rust, it unites with carbonaceous matter and kindles fire. In such ways the atmosphere is continually drained of it. Meanwhile trees and plants draw from the carbonic acid gas of the air the carbon they need,

and give back the oxygen portion to the air. Were it not so, the earth's air would fill with carbonic acid gas, and man would find no air to breathe.

The air has not greatly changed up to a considerable height. Most of the gases that compose it do not reach much higher. Most probably the air there is a mingling of the two lightest gases, namely helium and hydrogen.

As the density of the air diminishes, it reaches to a great height. Of the meteors that fall upon the earth from outside, most take fire from friction with the earth's air, and many of them first show this burning at a height of 120 miles. We must suppose that above this there is still a considerable body of air, through which they pass before the burning begins.

The sun's light crosses ninety million miles to reach the earth. In passing through the emptiness of the sky that girdles the planets, it has little cause to lose much of its force. With the tremendous energy that it bears to the outermost confines of the atmosphere, it shatters by its impact the atoms of the air there, and they are surely broken and ruined, so that not one remains whole. The layer that the broken atoms form in the highest region of the air has been given the name of the F2 layer.

What is left of the sun's rays after this expenditure attacks the denser air below. There too a layer arises from the breaking of atoms, and it has been named the F1 layer.

Lower still, in denser air, the sun's rays strike and cripple atoms, and yet another layer appears. Its name is the E layer.

Foremost among the agents that break the atoms are the rays that lie beyond the violet. In exhausting their violence upon the higher layers, these rays are in large part spent, and little of them reaches the air below. That is our safeguard. In greater measure we could not endure them.

Besides the sun's rays, many other things come from far, far away to deal invisible blows upon the air. Such are the meteors, of which we have already spoken. They rush through the sky between the planets at ten to a hundred miles in a second. By

friction with the air, heat rises among them, reaching some three to seven thousand degrees Fahrenheit. Thereby the keen arrows of the rays beyond the violet are freed from their quiver; they fall upon the atoms of the air, and burn them, and grind them to powder. There is, besides, another shower of rays, of which we have also spoken: the cosmic rays. In the universe it is they that bear the mightiest force.

In the air of the earth are crores upon crores of particles of oxygen, nitrogen and other gases. They whirl about ceaselessly at extreme speed, and collisions among them never cease. The lighter particles run the faster. The speed of the whole company is far less than the speed of a single molecule straying alone. For that reason, from the boundary of the earth's outer courtyard, stray molecules of hydrogen often slip the earth's pull and dash away into space. But beyond the crowd, the particles of oxygen and nitrogen never attain that impatient speed of flight. Thus in the earth's air they have suffered no impoverishment. Only the hydrogen, which in the earth's youth was the chief of its gaseous wealth, it has lost, little by little, in great part.

Great winged birds float long upon the air merely by spreading their wings, and from this we may judge how much density the air possesses. In truth, like solid and liquid things, the air has weight. From the sky down to the earth the air lies for many miles. Its pressure upon a thing one foot long and one foot wide is about twenty-seven maunds. Upon the body of an ordinary man it falls to over four hundred maunds. Yet we do not feel it. As it presses from above, so it presses from below; and since the air within our bodies pushes back with an equal force against the air's pressure, its burden does not oppress us.

The atmosphere of the earth, by its mantle, holds back much of the sun's heat in the daytime, and by night it checks the fierce cold of the great void. The moon has no mantle of air, and so under the sun's heat she grows hot as boiling water. Yet when the earth casts its shadow upon her at an eclipse, in a moment she turns cold. Had she air, it could have held back the heat. This is not the only lack of the moon. Having no air, she is utterly mute, and there is not the least chance of any sound. For when there is a disturbance, subtle waves of many measures rise in the air, and

these strike their various tremors upon the thin membrane within our ears; and then these waves become sounds of every kind, and answer to us.

There is yet another task of the air. Wherever sunlight meets some obstruction, even in the shadow there is light enough. The air spreads this light abroad. Otherwise there would be light only where the sun fell, and no such thing as shade would remain. Close beside the brilliant light would lie black darkness. Above the tree-tops the noonday sun would rise with a red and angry eye, while beneath them all would be murky black. On the rooftop the fury of noon would blaze, and within the house would be the moonless midnight of midday. It would be vain even to think of lighting a lamp, since on earth all things burn by the aid of oxygen.

In the green leaves of trees dwell minute granules, and among them is a substance called chlorophyll. It is they that store up the sun's light in the various substances of the tree. By their power are made the fruits and grains that are our food, and the wood in the boughs and trunks of trees. In the earth's air there is carbonic acid gas in slight measure. All the carbon in living plants, from which coal is made, is taken from this gas. To man's body this carbonic gas is not only of no use; unless we can cast it out of the body, we perish. But the tree, by the aid of its chlorophyll, mingles this carbonic gas with water, and in grain and fruit makes up the food that it prepares for us; and through that food we can turn the power of the sun's heat to the labours of life. This power we have no ability to take from the sky, but the tree has. From the tree we borrow it. The oxygen-laden vapour that all the creatures of the earth together breathe out is needed for the sustenance of plants. From burning fires, and from the decay of plant and animal bodies, this vapour also goes on spreading into the air. The coal that is burned on earth in factories and in cooking is no small quantity, and from it arise many crores of maunds of carbonic gas. So the air that the tree requires as its fare is supplied, in this manner, from cast-off matter.

The air cannot be called an elemental substance; it is a mixture. Various gases are mingled in it, but they have not blended; they lie together and have not become one. The nitrogen in the air is about four times the oxygen. Were there nitrogen alone, we should die of suffocation. Were there oxygen alone, our vital substance would burn away to nothing. This vital substance burns in some measure and is in

some measure hindered from burning, and only so can we live, standing midway between two excesses.

The whole atmosphere is sodden with water. There is far more water in the air than in the water that lingers in the clouds.

Of the electric layer of the broken atoms in the upper atmosphere I have spoken before. Apart from that, the ordinary air has two layers. The first, which lies nearest the earth, has the scientific name troposphere, and in Bengali we may call it the restless layer. Its height is not more than five to ten miles. Measured against the whole atmosphere, this height is very small, yet within this little space lies nearly ninety parts in a hundred of all the substance of the air. It is therefore far denser than the other layers. Because it clings close against the body of the earth, this layer always feels the touch of the earth's heat. With the waxing and waning of that heat the air rushes to and fro without rest, and so in this layer come storm and rain. In the layer above, the earth's heat cannot raise tempest, and the air there is therefore calm. The learned have named this layer the stratosphere, and in Bengali we shall call it the still layer.

As the earth came forth from the sun in the beginning, so from the vaporous primal earth came forth the moon. Thereafter, through crores of years, the earth cooled and grew hard, and so did the moon.

From a distance of 239,000 miles, in twenty-seven and a third days, the moon circles the earth once. Throughout that circling she keeps only one face turned toward the earth. Her diameter is about 2,160 miles, and her substance is three and a half times heavier than water. Because her distance from the earth is very small compared with that of the other bodies of the heavens, she appears so bright and so great in size. If eighty moons were weighed together, they would equal the earth in weight. Through a telescope it is plainly seen that she is made of hard matter, like the earth. Upon her are great craters and great mountains.

By the earth's pull the moon goes about the earth. To complete one revolution she needs a little less than a month. Her speed on average is no more than half a mile in a second. The earth moves nineteen miles in a second. To turn once upon her

own axis the moon takes exactly a month. Her days and her years pass at one and the same slow and stately pace.

From the moon's weight it has been reckoned that if the speed of any object there were a mile and a half in a second, it could overcome her pull and fly out into space. The moon suffers the sun's heat in excess, and the air over her scorching surface grew exceedingly hot, so she could not hold fast the particles of her atmosphere; they have all gone out. Where there is no pressure of air, water turns to vapour very quickly. As it turned to vapour, the molecules of water, restless with heat, slipped the bonds of the moon and departed. Where there is neither water nor air, we know of no life that can endure. The moon may be called a parched and scorched desert.

Those which we see slip from their places in the night, and call falling stars, are not stars; that need be told to no one today. Those meteoric bodies, drawn by the earth's pull, fall day and night in lakhs upon lakhs upon the earth. Most of them, touched by the friction of the air, take fire and become ash. Those of great size come burning to the ground, burst like bombs, and lay waste whatever lies around.

Upon the moon too this meteor-shower falls without ceasing. There is not air enough to check them and turn them to ash, and so, unhindered, they hammer upon all the moon's body. Their speed is not small, nearly thirty miles in a second, and thus they strike with ruinous force.

The great pits of the moon had their origin in fountains of fire that once burst forth. The molten matter and ash that then poured out have suffered no change through all the ages since, for want of air and water. Because the ash lies spread over her, the sun's light cannot pierce this covering and go far below, nor can the heat beneath rise up.

On the side of the moon where the sun's light falls, the heat is nearly that of boiling water; and where the light falls not, it is so cold that it lies about 250 degrees Fahrenheit below the cold of ice. At a lunar eclipse, when the earth's shadow comes and falls upon the moon, her heat falls in a few minutes by about 346 degrees Fahrenheit.

Because she has no air, and because the covering of ash lies over her, the sun's light cannot enter deep, and the moon holds no stored heat; therefore her heat fades so swiftly. From all these proofs it may be said that the ash of volcanoes has covered nearly all the surface of the moon.

The moon is the earth's near satellite. The force of her pull we perceive directly in the earth's seas, where the tides begin their play; and I have heard that the fevers and rheumatic pains of our bodies also awaken under the force of that pull. Sufferers from rheumatism dread the new moon and the full.

In the earliest age there was no sign of life upon the earth. For some seven or eight hundred million years, energy raged in every shape. Somewhere a volcano hissed forth heated vapour, cast up liquid metal, flung up fountains of scalding water. Shaken from beneath, the ground trembled and split; mountains rose and fell; tracts of land sank away.

When a hundred and fifty crore years had passed since the beginning of the earth, the head-splitting frenzy of that turbulent primal age had largely abated. At such a time the most marvellous of all the events of creation appeared. How, and whence, life came, and thereafter by degrees mind, no trace of its dwelling-place can be found. Before that, in the workshop of creation on the earth, a business of breaking and mending, of pounding and shattering, had gone on with lifeless matter. Its materials were earth and water, iron and stone, and the like, and with them certain gases, oxygen, hydrogen, nitrogen and others. By various mighty shocks these very things were turned upside down and joined together, and the fashioning of rivers, mountains and seas, with all their ceaseless upheaval, went on. At such a time, in the midst of this vast lifelessness, life appeared, and with it mind. With the masses of matter that went before them they have no kinship at all.

As the first beginning of the stars was a nebula, so in the realm of life upon the earth, that which first came to light may be called the nebula of life. It was a formless, scattered life-substance, like thick saliva without division of limbs, and it floated in the faintly warm sea-waters of that age. It has been named protoplasm.

As the star-nebula binds itself into grains in fiery vapour, so in this, through many ages, here and there, lump by lump, began to gather.

One class of these has been named the amoeba. In size it is exceedingly small, to be seen only through the microscope. They may be found in stagnant water. They have no mouth, eye, hand or foot. They wander in search of food. Stretching out a part of the body-mass, they make it do the work of a foot. When food comes near, they draw it in with that foot of the moment. In one part of the body they fashion a digestive organ. Dividing their whole body, they multiply. Another branch of the amoeba appeared, which fashioned a covering about its body, like the snail. In the sea are crores upon crores of their minute bodies. The remains of these bodies, heaped up little by little, have made the chalk hills in places on the earth.

The primal material of the creation of the world is the atom. Those atoms, by laws beyond thought, united into living cells of the utmost minuteness. Each cell is complete and independent. Within each lies a wonderful power by which, taking food from outside, it nourishes itself, casts away what it needs not, and multiplies itself. By this power of multiplication, through decay and through death, the stream of life flows on.

These living cells appeared in the realm of life first of all as solitary things. Thereafter, as they joined together more and more, excellence and variety increased in the living world. As a nebula is the union of crores of stars, so each body is the gathering together of crores of living cells. Through the lines of descent, this world of bodies, making one great current, moves onward through new and ever new forms. We have long discussed the worlds of stars and of the sun. Far more wonderful than these, many times over, is this world of life. When we reflect that it was in the state to which the earth attained, as a small planet, when its wild and fierce energy had been tamed, a state not overly turbulent, that life and its companion, mind, could come into being, we must admit that in the world this is the noblest consummation. There is no proof, and to gain proof is for the present impossible; yet the mind will not consent to believe that in the whole vast universe this state, capable of bearing life and manifesting consciousness, has come about on this earth alone; that in this reckoning the earth is the sole exception to the whole current of the worlds.

EPILOGUE

Once, bearing the most astonishing tidings in the world, there appeared upon the young earth, many crores of years ago, a speck: a living cell, invisible to our eyes. What a history of glory it had brought with it, in secret! From body to body, its creative work of wondrous artistry has gone on without pause through ever new trials. The wit to combine and to refine, to devise and to operate the most intricate mechanisms of the body, where does it lie hidden within them? How, through them, has it made itself active, and gathered ever greater experience? No shore can be found to such thinking. These exceedingly delicate and sensitive living cells, in the course of generations, are joined in fitting ways into the living body, in its various limbs and members. By some impulse within them, I know not how, they make so marvellous a division of the duties of the body's life. The cell that belongs to the organ of digestion has one sort of work, and the cell that belongs to the brain has another, wholly different. Yet the cells are at root the same. By whose command was the apportioning of their difficult labours made, and by what means did the union of their diverse tasks attain the harmony that we call health? The living cell has two chief actions: to procure food from without, and so to live and grow; and to beget a life like its own, and so carry on the line. This intricate striving of self-preservation and race-preservation, from where did it lay its burden upon them at the very outset?

Behind all the events that happen in the lifeless universe lies the ground of the whole material world. Mind knows all these events, and behind this knowing there lies somewhere a universal ground of mind. Stone, iron and gas have within themselves no relation to knowing. Bearing this hard question, at a certain age, life and mind came into the world, carried upon the tiniest living cell.

In the history of creation upon the earth, their advent is beyond imagining. Yet our reason refuses to accept any wholly chance upheaval, unrelated to all else. We may imagine a fundamental unity between the material world and the world of mind, in the all-pervading energy, or luminous substance. After long ages, science discovered that in those gross substances that to the casual eye are without light, the action of light goes on perpetually, in hidden form. The subtle flowering of this

very Great Light is in life, and a subtler flowering still in consciousness and in mind. Since at the beginning of the creation of the universe nothing is found but the Great Light, it may be said that consciousness is its manifestation. From inert matter to living creature, veil after veil lifting, in man the striving to undo the covering of this Great Consciousness is going on. The unfolding of this liberation of consciousness is, I think, the final consummation of creation.

The learned say that the life of the universe is continually dwindling, and this cannot be hidden. Like the body of man, the energy of the body of the world is heat. The law of heat is that as it is spent, its warmth gradually sinks. In the surface layer of the sun, the heat-energy stands at a measure of six thousand degrees centigrade above zero. With some portion of it the winds blow upon the earth, the waters fall, and living creatures move about in the enterprise of life. The store is being spent. One day, when the energy of heat has spread through the great void, who shall draw it back and make it fit to be given form again? One day, when the ever-restless heat-energy of our bodies has become one with all that surrounds it, no one can bring it back to the course of life. Whatever happens in the world, whatever moves, from the crawling of an ant to the course of the stars in the sky, all is set down as an item of expenditure in the ledger of the universe. However far off that time may be, one day, from the treasury of the world's unceasing spending, the capital of its heat will be scattered into the void. On this the men of science, the mathematicians, have reckoned the hour of the death of the world.

This question rises in my mind. For the beginning of the sun, the stars and the other luminaries, I see that the learned fix a number of years. But where in the infinite did the beginning come? In the infinite, an absolute beginning and an absolute end make an incredible argument, which vanishes if we accept what our scriptures say: that in kalpa after kalpa creation arises and dissolves, like sleep and the waking from sleep.

In the movements and positions of the various luminaries of the solar world there lies a vast regularity. The several planets, keeping almost to one plane in their orbits, caught in the eddy of a whirling current, move in one and the same direction and complete their turn in the circuit round the sun. Those who have thought upon the beginning of creation could not accept as accident so great a concurrence of

facts. The theory that could point to a clear cause for this order of the planetary world has won the greatest acceptance. But the reckoning of the measure of rotational speed of the bodies from which the solar system was formed has become a formidable obstacle to making such theories acceptable. Where the arithmetic has fallen into confusion, that theory has had to be rejected. Even the one or two theories that survived so long by keeping the measure of rotational speed nearly right have met new obstacles. Henry Norris Russell, Director of the Observatory of Princeton University in America, has lately made so adverse a criticism of the theory of Jeans and Lyttleton that it seems that within a few days these too must take their leave from the rank of acceptable theories, and their place will be beside the earlier rejected ones.

If the planetary world had been formed by the collision of stars, the drawn-out thread of burning gas would have been so hot that the various parts of this mass of vapour would have been torn asunder. But by scattering its heat exceedingly fast, this thread would have cooled and sought a settled state. Which would prevail, in the tug between these two opposing forces, release and bondage, is what Henry Russell has discussed. From the reckonings of mathematics, obscure to us, it has been roughly demonstrated that every atom of this filament, in the violence of its own energy, would have broken loose and gone out into the great void, and that to gather together and fashion a planetary world would not have been possible for them. The obstacle that he has discussed now strikes at the very root of the prevailing theory of Jeans and Lyttleton, and is about to lay it in the dust.