[*The Observer*]

THE NEW WORLD OF SPACE AND TIME

BY SIR OLIVER LODGE

THE term 'dimension' is used in a technical scientific sense, as well as in its ordinary vague significance as a sort of equivalent for 'size.' That last is quite alien from the technical meaning. By the 'dimensions' of a physical quantity we mean the way in which the fundamental units of mass length and time enter into the specification of that quantity. Thus the dimensions of velocity are length divided by time — the ratio of distance traveled to time taken. Speed can be expressed in miles per hour or feet per second or kilometres per annum, or in any units whatever so long as they involve the ratio of length to time. Units are arbitrary, some are handier than others, in that they simplify mere arithmetic; but their selection is unessential. Dimensions are not arbitrary, and are selected by nature. You can express a length in centimetres or inches or millions of miles, and it shall be the same length — it may be the distance of the sun or the width of a table. What you cannot do is to express a length in acres or quarts; the attempt would be nonsense. Size of unit is merely a matter of convenience; it is the dimensions or nature of the unit that is essential. You can express the national debt in farthings, if you like, but you cannot express it in yards.

This, which is so obvious in simple cases, is liable to be forgotten or ignored in more complex ones; people worry about the units instead of attending to dimensions. Any unit will do, so long as it is defined and specified, provided it is of the right dimension. The volume of a sphere is inexpressible in linear feet. A force cannot be expressed as a mass. The intensity of gravity must needs be of the dimension of acceleration — the ratio of a velocity to a time. Popularly it may be handy to speak of the force of a ton, but you really mean not the ton of matter itself but its weight, the force with which the earth pulls it. The intensity of gravity is necessarily involved in any complete specification of weight. The dimensions of force are mass multiplied by length and divided by time squared. Anything less complex than that is inaccurate and incomplete — a shorthand convention or slang, not an absolute measure — like a draper's 'six eleven three.'

What then is meant by the dimensions of space? Space signifies room to move about. The conception is derived from our muscular sense, just as the conception of force is derived. If an exertion of our muscles only results in statical pressure, we know that we are exerting force. If we exert our muscles and find our limbs free and unimpeded, we know they are moving through space. And we have an idea of how fast they are moving, by our sensations too. The exertion of walking a mile or running a hundred yards gives us an idea both of distance and of speed, and so incidentally introduces the conception of time as derived from the two primary sensations of motion and speed.

We can move in three directions —

to and fro, right and left, up and down. No more. Hence, by experiment and observation, space is found to have three dimensions. Any volume can, therefore, be expressed in cubic inches, or cubic miles, or pints, or gallons, or anything convenient for some practical purpose. You can travel in a north and south line, and in an east and west line, and you can climb up or down; or, of course, you can combine these motions in any fashion you please. A solid object has length, breadth, and thickness. These it must have, and it cannot have more. Existing space, as revealed to us by our senses, has three dimensions. It may be called cubical, because it has the same dimension as a cube or any other solid.

But is the evidence of our senses conclusive as to reality? By no means. They are capable of informing us that so much exists; they do not enable us to deny that more exists. For instance, they tell us of the presence of matter, they do not tell us of the presence of ether. Yet we have valid reason for knowing that the ether is just as substantial as matter, only it does not make itself felt. Though, by the way, it does in truth indirectly affect the eye, else we might have known nothing about it. There are probably many kinds of existence of which we do know nothing. Our senses are very far from revealing everything that exists; they themselves rose in the struggle for existence, not for the purpose of scrutinizing and philosophizing on the Universe. Our minds must do that. And our minds enable us, or seem to enable some of us, to imagine more dimensions — not, indeed, of actual space, but of an ideal, enlarged, more comprehensive 'something' which for lack of another word we are accustomed to call super-space or space of more than three dimensions. Mathematicians have been known to deal in nine dimensions, and to deduce valid results (I am thinking of the late Professor Sylvester and his British Association address at Exeter). It is not for us ordinary mortals to say them nay.

We can at least emulate them in imagining *less* than three dimensions, as Dr. Abbott among others did in his well-known and popular *Flat-land*. A superficial creature inhabiting a surface, say, a soap film, through which a clean wet wire is being poked, would only be aware of the section of the wire actually in his limited two-dimensional space. If the wire is crooked or spiral or oddly shaped, and is steadily pushed through the film, the observed section will move about in the film, and the superficial inhabitant will interpret the phenomenon in terms of two-dimensional motion and time. He will know nothing of the rest of the wire, and will have no suspicion that what he is observing is really the result of a motion of a solid object in a third dimension of space. He would know nothing of solidity or thickness. He is not wrong as far as he goes, he describes motion in his own plane truly, but his conception of real existence is incomplete.

Many a quadruped is practically limited to a two-dimensional existence in a sense — the surface of the earth. Cows and pigs enclosed in a high wall or fence are empounded; they cannot get out. A gap in the fence is needed to liberate them. But a bird in the same predicament would experience no difficulty at all. A prison made of floor walls and roof is a complete enclosure for human beings; but a fourth dimensional being, thus empounded, would escape in what to him would be an obvious manner.

The fourth dimension, supplementary to length, breadth, and thickness — what Dr. Abbott called 'throughth' — is, strictly speaking, inconceivable to

us, but that may be only due to the limitation of our senses and dearth of experience.

It is safest not to dogmatize, either way, concerning the possibilities of inconceivable dimensions. And if it ever happens that miracles are performed or observed such as we cannot account for — the extraction of an object from a sealed globe, for instance — we may some day possibly have to extend our categories and admit that there may be not only a possibility but actually some kind of reality in the existence of more dimensions than we know. It is a question whether we are approaching some such idea now. But it is still only a question.

Meanwhile, analytically, mathematicians find it easy to deal with as many dimensions as they please. They have long written down x y and z as the three coördinates which specify the position of a point. Everyone knows that two of these three coördinates, x and y, are sufficient to specify a point in a plane or a place on a map — latitude and longitude in fact. Two will do for any surface or apparent surface, like the sky. They suffice to point a telescope, they partly suffice to aim a gun. But in the latter case 'range' has to be considered too; and if we want to specify the real position of a star, we must know its distance as well as its direction; and, strangely enough, we can observe motion in the line of sight, that is, a rate of variation in the third dimension. Latitude, longitude, and altitude might specify the top of a mountain, or locate a treasure sunk in the sea.

But suppose we were specifying the position of a balloon or a comet. The three lengths just mentioned would only give us the position at a single instant. A second later it has moved. How are we to specify its position continually? Only by a curve — an orbit — combined with a statement about speed. We must introduce the idea of time. The coördinates x y z are not enough — a fourth t is necessary. Given a relation between all four — an equation between x y z and t — and we have a complete specification of the motion of a heavenly body; its orbit is known. Its position at any time can be assigned. Or, if lost, it could be refound from the equation.

But then, someone may object, time is not a fourth dimension of space, it is a different thing altogether.

Yes, it is, as far as our three-dimensional space is concerned. But not so in a hyper-space of four dimensions. In that inconceivable kind of space what we call time would be a steady variation of the fourth coördinate; like the pushing of the wire through the film. A fourth-dimensional being would see the whole phenomenon occurring, which we interpret as the stream of time. He would see the part that had gone through the film (as it were) and the part that was about to go through. Knowing our limitations, he might surmise that we should call the one the past, and the other the future; and that only the instantaneous section of which we were aware could be called the present. But it would be all 'present' to him; he would see as a simultaneity what we see as a succession. Yet he would know *why* we saw it as a succession in time, and would not deny that time was a reality.

Some rough notion of a simultaneity perceived as a succession is obtainable by considering a steadily moving traveler, on, say, the Nile. He sees the landscapes arrive, and disappear, and he might fancifully liken this progression to the past, the present, and the future. He might even seriously speak of the inexorable stream of time — provided he was born on the boat and could not change its drift.

Undoubtedly, the mathematician can work out and express the history of a solar system or of an atomic universe — amenable to the reign of mechanical force, *vis a tergo*, and determinate necessity — in terms of four dimensions.

And one of these dimensions will be what is called 'imaginary' with respect to the other three. When discussing motion in a straight line, anything off that line is an imaginary region, and its position is indicated by an imaginary quantity, some multiple of the square root of minus one.

So also when working (as we daily do) in three dimensions, a fourth dimension must involve a $\sqrt{-1}$ coefficient to distinguish it from the others. And so it is in all the theories — Einstein-Minkowski's among others. In Minkowski's recent theory this fourth coördinate definitely takes the shape of an imaginary velocity, $ct\sqrt{-1}$, a motion of something unknown through a fourth dimension — an imaginary motion with the velocity of light — interacting with our ordinary space; just like my rod and film analogy.

These imaginary quantities, when properly dealt with, introduce no confusion; they are helpful; and in the end, when interpretation into practical consequences is wanted, they always drop out. They are powerful intermediate weapons — auxiliaries — like the scaffolding which enables us to build a house or a bridge, and which is removed when the structure is finished. Removed they must be, if we are going to be satisfied with space of three dimensions; otherwise they may be retained, and the imaginary quantity regarded as in some sense real.

Let it not be regarded as certain, however, that the existence of a fourth dimension is necessarily bound up with Einstein's theory. It is a convenient way of mathematically expressing that theory, but I judge that it can be expressed by a suitable complication of our measurements of time and space without necessarily involving time as an aspect of a fourth dimension. Einstein's theory essentially depends on a changing system of coördinates, and on the hypothesis that whatever queer coördinates we choose the result will be the same. Four variables are undoubtedly involved; but so they are in any system of dynamics. Only usually we discriminate between space and time, and we deal with forces and inertia.

Ingenuity is required to dispense with inertia and to treat force as a property of space. Whether it turn out valuable ingenuity, in the long run, time will show. Meanwhile the new method is justifying itself by results; and if a warped space is a reality, more than three dimensions must somehow exist.

I have just said that equations in four variables fully express the working of an inorganic universe (the idea is known to philosophers as 'Laplace's Calculator'); but what about the actions and movements of live things — of human beings or of a common fly? Can those motions be thoroughly and fully expressed in terms of four or any number of dimensions? In other words: Is the future all settled beforehand, and only waiting to be 'pushed through' into our three-dimensional ken? Is there no element of contingency? No free will? I am talking geometry, not theology, and it would be a stupid mistake to pretend to decide questions of high reality by aid of mere groping analogies and mathematical analysis. Parenthetically, however, and for myself, I would say that I believe in a subordinate element of contingency; that the happenings of the future are partially decided by voluntary actions in the present; that the future, though already in some

way existent or inferable, is dependent on what has gone before, and is not an inexorable, dull, completely pre-arranged mechanical necessity, that has to go through the solemn farce of obtruding itself on our perception —'the hollow form of taking place.' A universe so constituted would lack interest and be un-Divine. The idea could hardly have been formulated save as a concession to human faculties, which have found a perennial difficulty in reconciling the two apparently incompatible things, Free-will and Fore-knowledge.

There are many other puzzles which we are unable completely to resolve at present. Let us not discard facts of conscious experience because of some theoretical difficulty in understanding them.

Reference to such subjects in this connection may be pardoned, simply and solely as a caution against drawing conclusions from what it may be possible for mathematicians to do, and what it is possible for our limited imagination to conceive. The full truth of reality is not to be limited by our notions, nor can it be ascertained in any such sidelong fashion. Suffice it to say that whether we use three coördinates and a separate conception of time, or whether we use four coördinates *ab initio* — so as to involve time as the human aspect of one of the dimensions of a super-space — is mainly at present a matter of convenience. If one method gives us more power, if the complexities of the atomic and electric and ethereal universe are made more tractable by our ingeniously artificial machinery of calculation — then that machinery is justified. The fact that we can in any way deal with more than three dimensions of space seems to render it rather possible that more dimensions exist. It is not likely that our conceptions — if they be clear conceptions — shall transcend reality. The Universe may be infinite in an infinite number of ways, and the little that we as yet know of it only makes us greedy to know more.

All in good time. The human race has not been in existence very long; it began its scientific studies very recently (our schools have hardly begun them yet); it is still scraping on the surface of things, the three-dimensional surface of things; some time may yet elapse before it succeeds in digging down effectively into what may be the deeper reality of a fourth dimension.

TALK OF EUROPE

A BRITISH firm once contracted to deliver a piece of machinery in Tokio, but because of some unavoidable delay, was unable to live up to its contract. Fearing lest the Japanese consignees should make efforts to collect the money indemnity due them for non-delivery, the Japanese agent of the British firm, sent to the home office a suggestion for avoiding payment. Mr. E—— is the English agent of the same firm also stationed in Japan.

'Regarding the matter of escaping penalty for non-delivery of machine, there is a way to creep round same by diplomat. We must make a statement of big strike occur in our factory (of course big untrue). Please address my firm in enclosed form of letter and believe this will avoid penalty of case. As Mr. E—— is a most religious and competent man and also heavily upright and godly it fears me that useless apply for his signature. Please attach name by Yokohama office making forge, but no cause to fear prison happening as this is often operated by other merchants of highest integrity.

'It is highest unfortunate Mr. E—— so godlike and excessive awkward for business purpose. I think much better add little serpentlike wisdom to upright manhood and so found a good busness edifice.'

In these few sentences lies all the wisdom of the East applied to all the wisdom of the West.

O LITTLE boy who threw a stone
At Socrates, and hit Euphron;
Who, wounded in the lower calf,
Went home and beat his better half;

Who ran into the street and cried,
While, passing on the other side,
A poet made a couplet, bright
But cynical, upon the sight;

Which tiniest of pleasantries
Came safely down the centuries,
Almost undamaged by the way
(Though Tragedies have gone astray),

And exercises brains that loom
In the Museum Reading Room;
Or poses as an epigram
For purposes of an exam.

And that it was that floored me, sure
(And really it is most obscure):
Ploughed! And, observe, from far B.C.
That furrow pointed straight for Me!

So, while I vainly try to guess
Why the twin portals of Success
(As all authorities insist)
Are Particle and Aorist;

And note in all my kinsmen's eyes
Every emotion but surprise,
I write, lest you should censure me,
This devious apostrophe:

O boy (as I remarked before),
Had you but stayed within the door,
Or had you been a better shot,
Or chosen another sage to pot,

I'd not been in this horrid fix;
And, therefore, from beyond the Styx,
Consider well the curious chain
Of circumstance that links us twain:

And how that stone you can't replace
Careers in Time as once in Space —
A devastating Comet: who
Will be the next it bangs into?

And all you boys of later days,
So rash in various sorts of ways,
Remember trouble's on the wing
Whenever you do anything.

R. B.

HAS an artist ever existed who has seen his ideal turned into a commercial success without its being in some way debased? It is hard to think of one, and hardest of all to imagine a pure artistic ideal surviving in the atmosphere of the modern theatre. But this is what Reinhardt's admirers and