THINKING IN MILLIONS

J. B. S. HALDANE

HOW can we think about the unthinkable? It is quite simple, according to Mr. Haldane, because there really is no unthinkable. There is nothing appalling in the immense figures of the astronomer or the infinitesimal measurements of the chemist. They are both perfectly understandable and entirely workable. The trouble is that we do not approach them in the right way. No one can take a bath or use a map without dealing in millions,—yet we do both successfully. Why be aghast at millions?

"LE silence éternel de ces espaces infinis m'effraie" said Pascal as he looked at the stars and between them, and his somewhat irrational terror has gone echoing down all the centuries since. It is fashionable to find the distance of even the nearest fixed stars inconceivable and to make no attempt to grapple with the number of atoms in one's thumbnail. This habit of mind makes it quite unnecessarily hard for the plain man to understand the main results of modern science, many of which are quite straightforward, but happen to involve rather large numbers. For Pascal's attitude is neither scientific nor religious. "I shall soon be above that fellow," said Sir Thomas More, as he took his last look at the sun before his execution, and the modern astronomer views the sun as a rather small but quite fairly typical star in a particular cluster.

There is no reason to suppose that interstellar space is infinite. Very probably the whole of space is finite, and certainly the distances of all the visible heavenly bodies are within the range of the human mind. Infinity is the prerogative of mind rather than matter. We can reason about it, but we certainly cannot and do not observe it. As for the silence of interstellar space, one cannot live in it and hence cannot discover whether it is silent or not. But if one were shut up in a steel box in it, like Jules Verne's travelers to the moon, one would probably hear fairly frequently (at least in the neighborhood of a star) the sound made by a minute dust particle, moving at enormous speed, hitting one's abode.

The average man complains that he cannot imagine the eighteen million million miles which is the unit in modern astronomy when once we leave the solar system, and is called a "parsec" because the apparent parallax of a star at this distance is a second. In other words, the earth's orbit from a parsec away would sub-

tend an angle of two seconds, or look as large as a halfpenny at three thousand yards distance. Of course one cannot imagine a parsec. But one can think of it, and think of it clearly.

For every educated person learns a process which is really of extraordinary difficulty and involves a stupendous change of scale. That process is map-reading. In ordinary life our practical unit is about a centimetre, or two-fifths of an inch. Rather few of the measurements of everyday life exceed this in accuracy. Now suppose we look at a map of the world on a globe measuring sixteen inches round the equator. We are using a model on a scale of one in a hundred million (10^8), and the average man learns to understand its meaning and draw practical information from it. An Englishman hears that his son is going to New Zealand and has only to look at the globe to see that his letters will take longer to arrive than those from his other son in Newfoundland. But although we are at home on this particular scale of one thousand kilometres (or about six hundred miles) to a centimetre, as regards the earth, the average person has not yet grasped the fact that on the same scale the sun is a mile off and as large as a church.

Our grandchildren will have learnt to do the opposite mental trick, namely, to be familiar with models on a scale of a hundred million to one. On this scale the atoms of the common elements are represented as less than an inch across, and molecules of fairly complex organic substances as a foot or so long. The electrons in these atoms and the nuclei round which they are believed to circulate would still be too small to be visible, but we could mark out their orbits, just as we can represent railway lines on a map, though only by exaggerating their width. It is doubtful whether a much greater magnification would serve any real purpose. When we come to deal with the events inside the atom the attempt to represent them in space and time breaks down, or at any rate the properties of space and time in very small quantities are so unlike those of common-sense space and time that models are of rather slight value. On the other hand, models of chemical molecules deduced from X-ray analysis of crystals are most reliable guides and are opening up a new era of chemistry.

Let us now take a second step in the opposite direction and try to construct a model such that in it the globe will be as much reduced as the earth was in representing it as the globe. That is

to say, our model is to be on a scale of one in ten thousand million million (10^{16}). This would really show us very little, for not only the earth but its orbit round the sun would be invisibly small, and even the orbit of Neptune would be comfortably contained on a pin's head, which would also represent the size of the largest known star. Unfortunately, however, even on this scale the nearest fixed star would be about four yards away, and only about twenty would be within twenty yards. Light would creep about a yard a year, or much more slowly than a snail, but quicker than the growth of many plants!

But a third step in the same direction would probably be illegitimate. If we tried once more to reduce our scale a hundred million times, the farthest known star cluster would be represented only a tenth of an inch away from the sun, and probably all the known heavenly bodies could be shown within a football. And perhaps that football would contain the whole universe. For the extended theory of relativity seems to lead inevitably to the view that the universe is finite, and that progress in any direction would ultimately lead back to the starting point. In fact an attempt to make a model on this scale might produce results as misleading as those obtained when by Mercator's projection we try to represent the surface of the earth on a single plane. For a model representing the neighboring stars we should do better to reduce by one thousand only, which would bring several of them within an inch, whilst many at least of the spiral nebulae would be within five miles.

We have seen, then, that we can usefully think of models up to a hundred million times life-size, and down to a scale of about a ten million million millionth. Beyond those limits space does not have the properties demanded of it by common sense, and visual imagination does not help us. We are compelled to plunge into the mathematics of the quantum theory at the small end, of relativity at the big end. But long before that is necessary, people are frightened off the attempt to think, — apparently by the word "million". This is because it is generally applied to large aggregations like a million dollars or a million years, which we cannot easily imagine, though as a matter of fact a quite ordinary room would hold a hundred million dollars, provided its floor did not give. But we ought to get the million habit by remembering that

we wash ourselves daily in a bath containing about ten million drops of water, walk ten million millimetres a day, earn several million centimes per year, and very likely own a million cents.

It is a pity that outside India no opportunities are presented of seeing a million men and women, for crowds of this size only occur on Hindu religious pilgrimages, and very impressive they are. A crowd of three million may sometimes be seen at the Kumbh Mela, a twelve-yearly festival which, if I remember, will next be held at Allahabad in 1930. I cordially recommend attendance to anyone unable to imagine a million. Incidentally, I am informed that participation gets one off several million reincarnations.

In science we soon get accustomed to those large numbers. The astronomer switches over merrily enough from measuring stellar distances in kiloparsecs, which take light three thousand years to travel, to determining its wave-length correct to a fraction of an Ångstrom unit which is a hundred-millionth of a centimetre. And there is a certain thrill when the final result of a calculation which has involved hundreds of millions comes out at one or two, when up till the last moment it might apparently have been anything from a million to a millionth, and thus leads to a simple theory. I am thinking, for example, of Professor Eddington's famous calculation as to why stars are no heavier (for none are known as much as a hundred times heavier than the sun).

Starting from the data of atomic physics, he calculated the internal temperatures of the stars, and since radiation exerts a push on matter emitting, absorbing, or reflecting it, he was able to discover what proportion of the weight of a star of given mass was supported by its own radiation. Thus through a wilderness of millions we arrive at a rational explanation of why all stars have about the same weight. Again Gorter and Grendel and Fricke have just shown by quite independent methods that the oily film surrounding a red blood-corpuscle is two molecules thick. Both used numbers including the five thousand million corpuscles in a cubic centimetre and the six thousand million million million atoms in a gram of hydrogen; but the final answer was "two" in the one case, and "one or two" in the other. It is the success of such calculations that makes it impossible for a scientifically trained person not to believe in the numbers on which they are based.

DICK MAPLETOFT'S CHRISTMAS

JOHN DRINKWATER

'LL be a ghost come Christmas,"
Dick Mapletoft he said,
"By Christmas Day in the morning
I doubt I shall be dead."
But Christmas came and found him,
In velveteen and cord,
Bright as a young saint chanting
His service to the Lord.

For overnight his burden
Of years had been put by.
And now at three and eighty
He was too young to die;
Too young to heed the labors
His traveling feet had trod,
For he had seen a marvel,
And heard the voice of God.

Good ale was at the Seven Stars,
As well you may believe;
Among his mates Methuselah
Was Dick on Christmas Eve;
He drank a pint, he drank a quart,
Until the logs burnt low,
Then for his home upon the hill
He made across the snow.

The snow was deep upon the path,
And he would sometimes turn
To see the glowing window-panes
With ebbing lustre burn;