

Science and Prediction.

"PROPHECY", we are told, "is the most gratuitous of all forms of error", and long-distance forecasts have a way of going wrong, even when apparently firmly based upon all the available knowledge of the time. Thus, Sir William Crookes predicted a world shortage of wheat for the present age, when in fact (owing to the unexpected success of science in fixing atmospheric nitrogen and making new fertilisers) there is an embarrassing surplus. The real justification for making such forecasts is not that they are likely to be realised; but that they throw light upon the state of contemporary science, and may indicate where it requires supplementing. This may be exemplified from the address of Sir Arthur Eddington presented in the present supplement.

Before analysing Sir Arthur's basis of predictions concerning the end of the world, we may briefly consider earlier discussions of this topic. At one time, such speculations had a theological basis, and often predicted a very unequal distribution of temperature, which in some regions would be excessively high. In the nineteenth century, these were replaced by considerations concerning the loss of heat by the earth and the sun. The earth was apparently cooling so rapidly as to leave insufficient time for biological evolution, and in a comparatively short time (from the evolutionary point of view) both earth and sun seemed doomed to experience a temperature which would be uniform and excessively low. However, the date of this predicted catastrophe had to be put forward about a billion and a half years when radioactivity was discovered, for it revealed immense quantities of stored-up atomic energy which could be changed into heat. Another postponement was necessitated by the discovery of the convertibility of mass and radiation. This gave the sun an enormously increased lifetime. A period at least a hundred times more remote than before was offered by the astronomer's suggestion that in the interior of heavy atoms an electron may combine with a proton and release energy by their mutual annihilation. But all this merely put off the evil day when a dying earth should at last fall into a dying sun and the whole universe, ever contracting, finally collapse in a single heap. Sir Arthur Eddington, taking as his basis the second law of thermodynamics and recent developments of the cosmological theory of relativity, adopts the prediction as to the ultimate uniformity and lowness of temperature, but declares the universe to be expanding instead of contracting. Possibly it will

become a ball of radiation which doubles its size every 1500 million years, growing ever more and more attenuated.

Let us consider the evidence for the physical laws underlying these predictions. The cosmological theory of relativity may be considered as having arisen from the attempt to make the boundary conditions, as well as the differential equations expressing physical laws, independent of the choice of co-ordinates. Einstein in 1917 accomplished this by the drastic method of abolishing the boundary, and postulating a universe which was finite though unbounded (the analogue of the finite but unbounded surface of a sphere). An alternative theory was given by de Sitter; but, as was pointed out by Sir Arthur Eddington, neither of these theories could be accepted as corresponding to physical realities. One contained matter but no motion, and the other motion but no matter. No further progress was made for about ten years, when Lemaître obtained a new solution of the relativity equations. This corresponded to an expanding universe, and it was afterwards shown that Einstein's and de Sitter's theories were limiting cases of this, one at the beginning of the motion and the other at the end, probably both unattainable. The strong point of Lemaître's theory is that it offers an explanation of the observed redness of the spectra of many nebulae, which is generally taken to mean that they are moving away from us at enormous speeds. But it must not be forgotten that other explanations of this redness are possible. Lemaître's cosmological theory holds the field for the present, but it is far from being thoroughly tested.

The second law of thermodynamics is on a different footing. Nothing seems better established than that it is impossible for a self-acting system, unaided by an external agency, to convey heat from one body to another at a higher temperature. Yet even here doubt may be felt as to whether this is without exception. Millikan tells us that the intensely cold regions in the depths of interstellar space are the source of a very penetrating radiation, known as the cosmic rays. These seem to be due to the building up of the more complex elements out of hydrogen. In other words, the processes of disintegration and decay which are taking place elsewhere appear to be reversed here. Let us not be too sure that the universe is like a watch that is always running down; there may be a rewinding. The process of creation may not yet be finished.

H. T. H. PIAGGIO.