occasional lethal effect of the rays. If the cells which have been killed are to be regarded merely as one type of variant, the calculation is unaffected. However, in the experiments with the intense X-rays a large fraction of the cells experienced several ionisations. This would be likely to increase relatively the number of cells destroyed, a view for which there seems to be some experimental evidence (for example, the work of Wood, quoted by Crowther, *NATURE*, **118**, 86; 1926). Any allowance made for this effect would increase the calculated number of variants produced by natural radiation.

We may, therefore, conclude that the number of variants caused per year in the tobacco plant by natural radiation is greater than two per thousand. The number of variants in the normal plants actually found per year in a prolonged study of this plant is estimated as lying between two and four per thousand. It seems, therefore, not altogether extravagant to assume that such variations as actually occur in Nature are due largely to the radioactivity of the environment. It becomes an extremely interesting task to ascertain whether, in those places where an exceptional accumulation of radioactive material occurs, any unusual variability of fauna and flora is to be observed.

AXEL R. OLSON.
GILBERT N. LEWIS.

Department of Chemistry,
University of California, Berkeley, California.

What becomes of Stellar Radiation?

ON the occasion of Dr. Jeans's magnificent lecture (*NATURE*, Mar. 24, pp. 463-470) Sir Oliver Lodge (*ibid.*, p. 462) asked: "What becomes of the radiation which the stars are continually pouring into space? . . . No one has yet been able to hazard even a plausible guess as to where it goes or is destined to go in a possible finite space." Formerly we should have been obliged to assume that it vanished into infinite space. Einstein's theory of relativity has, however, entirely changed this point of view, and to-day space must be regarded as finite. If a straight line starts from a star it does not go straight to infinity, but returns to the original source. I beg to conjecture or suggest that the radiation from a star may behave like the straight line and be brought back to its origin again, after having travelled around the universe.

According to Dr. Jeans, *light* would require for this return 100,000 million (10^{11}) years. As the stars are much older, some 10^{13} years (Jeans), a great part of their *radiation* might have been brought back to them, or to other stars in its way, which will again provide other stars with their energy, so that the energy which they have lost would be partly renewed in this way. The stars might be regarded as a kind of *perpetuum mobile*—to some degree, like a mill on the river. Thus the lives of the stars would be prolonged.

BOHUSLAV BRAUNER.

Bohemian Academy, Prague,
Mar. 27.

It is, I think, generally recognised that light can travel round and round an Einstein universe in the way described by Prof. Brauner. Alternative universes have of course been imagined in which this cannot happen; that of de Sitter, for example, expands so rapidly that light can never get back to its starting point.

If light goes round and round, a certain fraction must inevitably re-enter the stars, but the faintness of the night sky seems to show that the fraction must be very small; if it were nearly unity we should see

a star in every direction in space, and the sky would be a uniform blaze of light. The sun occupies about a hundred-thousandth part of the half-sky, so that if even one part in 100,000 of their light fell back into the stars, the night would be half as bright as the day. Or, if the radiation were transformed into heat on its journey, the heat received from the night sky would be equal to that received from the sun. The actual fraction, then, must be very minute.

Personally, I do not feel the difficulties of Sir Oliver Lodge and Prof. Brauner as to the ultimate fate of stellar radiation. Hubble estimates the average density of matter in space to be 1.5×10^{-31} , so that the total annihilation of all the matter in the universe would produce an energy-density of 1.35×10^{-10} ergs per c.c., which would only raise the temperature of space from 0° abs. to 11.5° abs. The total annihilation of all matter outside the solar system would only raise the temperature of the earth's surface by 0.00018 of a degree centigrade, so that the radiation of ten thousand dead universes may be eternally wandering round space without our suspecting it. Space is so vast by comparison with the matter it contains, that discussing the ultimate fate of radiation seems rather like discussing the ultimate fate of a few lumps of sugar dropped into the Atlantic.

It is particularly hard to see how stray stellar radiation could create new matter. The creation of a single electron and proton, or of a hydrogen atom, requires a quantum of energy 0.0015 erg. Quanta of this energy do not begin to appear until a temperature of the order of 7,500,000,000 degrees is approached. Then, and not until then, there begins a free (reversible) transformation of energy between its two forms of matter and radiation. The statistics of such a process have been discussed by Stern (*Zeits. f. Elektrochem.*, **31**, 448; 1925; and *Zeits. f. phys. Chem.*, **120**, 60; 1926) and Jordan (*Zeits. f. Phys.*, **41**, 711; 1927), but in view of the foregoing figures the interest would seem to be academic rather than astronomical. A simple calculation shows that if the present universe were left to itself long enough for its total energy to distribute itself in thermodynamical equilibrium between atoms and radiation, the expectation of the total number of non-permanent atoms in the final steady state would be of the order of $e^{-mc^2/RT}$, or $10^{-420,000,000,000}$. The reciprocal of this, raised to a power equal to the total number of non-permanent atoms in the present universe, may be interpreted as the odds (relative to our present knowledge) in favour of the universe being a special creation and not a mere fortuitous concurrence of atoms and radiation.

Apart from all calculation, the widely desired cyclic universe in which just as much matter is created as destroyed, would seem to be a universe already dead. Its entropy must be a maximum, otherwise the system could and would increase its entropy by irreversibly disturbing the balance between creation and destruction of matter. With universes, as with humanity, the only possible life is progress to the grave.

J. H. JEANS.

The Branchial Gland of the Cephalopoda: a Possible Endocrine Organ.

Up to the present day, no definite endocrine organs have been discovered in any invertebrates, though some evidence of adrenalin production in annelids has been obtained by Gaskell,^{1 2} and of an internal secretion of the testis in turbellarians by Vandel.^{3 4}

¹ *Phil. Trans. Roy. Soc.*, B, **205**; 1914.

² *J. Gen. Physiol.*, **2**; 1919.

³ *C. R. Acad. Sci.*, **170**; 1920.

⁴ *Bull. Biol. Fr. Belg.*, **55**; 1922.