Bateman's[19] corpuscular theory of the structure of the electromagnetic field is not out of harmony with this view, and, moreover, his hypothesis has the distinct advantage of accounting for wave-motion as a special case, thus apparently pointing to a method of avoiding those difficulties with interference and diffraction that usually affect corpuscular theories. If we accept the rather preferable "solid angle" hypothesis instead of a less restricted type of non-uniform radiation (such, for instance, as the "specked" wavefront[20]), it is not certain just what difficulties might arise in regard to the ultimate trend of planetary temperatures. But certainly the great majority of recorded sidereal phenomena would be unaffected, whether the "solid angle" interpretation is adopted or merely one which requires that radiation should be much restricted outside the solid angle.

In addition to the possibility of accounting immediately for the large discrepancy in the duration of solar and stellar radiation, there would be other decided advantages in a hypothesis of this kind.

First, we should no longer be confronted with the tragic and almost incomprehensible "waste" of stellar energy. On the ordinary continuity theory, all the sun's radiation, except the one-millionth of 1 per cent. that falls upon planets or known stars,[21] penetrates indefinitely far beyond the regions where now we observe material bodies; and we recognise no reasonable mechanism for its recovery or rematerialisation.

Secondly, we should not have to call upon some unknown source of energy to account for the simplest problems of stellar radiation; the otherwise happy accordances now existing between astronomical observation and gravitational theories of gaseous bodies would emerge from the shadow of this great doubt.

Thirdly, among others of less obvious connection, the following outstanding stellar phenomena might find partial or complete explanation:—(*a*) The remarkable decrease of redness with brightness for the giant stars in globular clusters[22]; (*b*) the relation of spectral type to brightness for both giant and dwarf visual binaries; and (*c*) the low density of the reddish companions in eclipsing variable star systems. In all these cases it would be a matter of the ratio of the angle occupied by neighbouring bodies to the total solid angle.

To summarise:—As commonly interpreted, the Helmholtz-Kelvin contraction, and other but less important known stores of energy, can have maintained solar radiation for less than twenty million years. On the other hand, it is equally definite that the sun has radiated at its present rate for much more than a thousand million years; in support of strong geological evidence of a long time-scale, various astrophysical results may now be adduced, mainly from observations and interpretations of star clusters and variables. The very pronounced disagreement might be explained either if sources of energy now unrecognised could be discovered in the sun and stars, or if the necessity of modification of the physical theories could be demonstrated. "The search for an additional store of energy is not at all encouraging,"[23] since gravitational, chemical, radio-active, or other electrical sources appear unavailing. If we assume that the radiation from isolated sources, such as sidereal bodies, is not uniformly propagated in all directions,[24] we may find the solution not only to the dilemma of the ages of stars, but perhaps also to other astrophysical phenomena; and, conversely, the removal of this serious discrepancy may be proposed as an argument for a corpuscular theory of radiation, in which the direction of other bodies from a radiant source is an important factor.

HARLOW SHAPLEY.

Mount Wilson Solar Observatory, Pasadena, California, December 14, 1918.

19 Proc. Nat. Acad. Sci., vol. iv., p. 140 (1918); the *Messenger of Mathematics*, N.S., vol. xlvii., p. 161 (1918); *Phil. Mag.*, vol. xxxiv., p. 405 (1917). The more extended statement of the theory will appear in the Proceedings of the London Mathematical Society.

20 Sir J. J. Thomson, Proc. Cambr. Phil. Soc., vol. xiv., p. 419 (1907). Cf. Jeans, "Report on Radiation and the Quantum-Theory" (London, 1914), pp. 81, 85 ff.

21 The angle subtended by the large nebulæ much exceeds that of stars and planets, but it is very unlikely that the nebulæ represent a continuous distribution of matter.

22 Mt. Wilson Communications, Nos. 19 and 34 (1916), and elsewhere.

23 Eddington, NATURE, vol. xcix., p. 445 (1917)

24 [December 28.] Father Rodés has pointed out to me that Poincaré, in a discussion of the impossibility of regarding the sun as a cooling body entirely without power of renewing its heat ("Hypothèses Cosmogoniques," p. 192), refers to the "solid angle" hypothesis, rejecting it, however, for the reason (which in the present problem does not now appear sufficient) that "at the moment when energy leaves the sun it obviously cannot foretell whether or not it will encounter a planet." Poincaré did not consider the discrepancy very serious between geology and the contraction theory, apparently believing that radio-activity would be competent to make up whatever defic of energy might exist.

RESEARCH AND UNIVERSITY EDUCATION.

IN his opening presidential address this session to the Royal Society of Edinburgh on "The Endowment of Scientific and Industrial Research" (Proc. Roy. Soc. Edinburgh, 1919, vol. xxxix., No. 1), Dr. John Horne discusses the report of the Committee of the Privy Council for Scientific and Industrial Research for 1917–18, and the findings of Sir J. J. Thomson's committee on the position of natural science in the educational system of Great Britain, and then turns his attention nearer home to the results of the Carnegie Trust's research scheme in furnishing trained research workers. He alludes especially to the chemistry department of St. Andrews, which has secured more research scholars and fellows under this scheme than any other educational centre in Scotland. Its favourable position in this respect is ascribed to the smallness of the number of students, to specially commodious and well-equipped laboratories, to a private research endowment which secures complete freedom of action to the head of the department and has rendered it unnecessary for him ever to approach the University Court for help, to a special field of investigation—the chemistry of sugars—capable of providing unlimited subjects for the training not only of the organic, but also of the physical and bio-chemist, and, lastly, to the initiative of the professor in finding industrial positions for the trained workers—it is to be hoped, at a salary that interests the income-tax commissioner. In the larger Scottish universities the science departments struggle under the disadvantages of inadequate laboratories, crowded class-rooms, and overworked and underpaid staffs. One hears, in fact, of nothing now but the duplication of the notoriously large medical classes, and even of the double daily lectures being given by the same lecturer. The Carnegie Trustees are asked seriously to consider whether the funds provided for scientific study and investigation cannot be increased very largely.

It is interesting to find thus officially recognised a few of the more elementary conditions for the fostering of research. The conclusion that one of the main reasons for the success of the St. Andrews chemical research school is due to the *smallness* of the number of students should give at least a moment's pause to those who are urging on the movement for the expansion of the universities, and demanding that they should undertake more and more the routine instruction of the community. There is no surer way of killing research than to leave it, as it usually has been left, to take what is over in a rapidly growing democratic university, after every other need has first been canvassed. If we are, as is probable, to have greatly enlarged universities everywhere, and greatly increased Government grants for this purpose, in the name of common sense let some definite and inalienable part of these grants be put in the hands of persons who know what scientific research is.

The St. Andrews research school of chemistry is a brilliant exception just because this has been the case. A private individual, Prof. Purdie, the present professor's predecessor, founded it, built the laboratory, and provided the endowment out of his own private generosity, and left it in the hands of his successors. He knew what research was, and he has been able to effect more for research in Scotland than the million of Mr. Carnegie, in the hands of his trustees. So little did the latter understand the needs of scientific research, or how to promote it before the war, that they spent on their whole research scheme less than one-half *what they saved* out of the revenue of the fund given them primarily for this purpose.

F. S.

PROF. E. C. PICKERING, For.Mem.R.S.

BY the death of Prof. Edward Charles Pickering, astronomy has lost a great leader, whose stimulating influence and remarkable gifts for organisation have contributed in an extraordinary degree to the advancement of our knowledge of the stellar universe. Born at Boston in 1846, Pickering was educated at the Boston Latin School and at the Lawrence Scientific School, Harvard. At the early age of twenty-one he was appointed Thayer professor of physics at the Massachusetts Institute of Technology, where he is said to have established the first physical laboratory in the United States. In 1876 he succeeded Winlock as professor of practical astronomy and director of the Astronomical Observatory of Harvard College, and continued in this position to the time of his death, which occurred on February 3.

Pickering's work in astronomy has been especially remarkable for the numerous enterprises of great magnitude which he initiated, and for the energetic manner in which he carried his schemes to successful completion. Thanks to the generous encouragement given to scientific workers in America, the resources of the Harvard Observatory were in some measure commensurate with Pickering's great conceptions. Beginning with the erection of the 15-in. refractor in 1847, by public subscription, the resources of the observatory have since been so augmented by subscriptions, gifts, and bequests that the annual income from invested funds during recent years has provided for the employment of a staff of no fewer than forty persons. Through the Boyden bequest, in 1887, Pickering was charged with the establishment of an observatory at a high elevation, under favourable climatic conditions; and with admirable foresight as to the needs of modern astronomy, he seized the opportunity of locating the new observatory south of the equator. The station selected was at Arequipa, in Peru, at an elevation of 6080 ft., and all important researches undertaken at Harvard College have since been made to include stars in all parts of the sky, from the North to the South Pole. Another important benefaction, which largely influenced the activity of Pickering, was the Henry Draper memorial, by which Mrs. Draper made liberal provision for the continuation of the researches on the spectra and other physical properties of the stars which had been carried on by her husband, and interrupted by his death.

While precise measurements of position have not been neglected, the policy of the Harvard Observatory, from the beginning, has been the development of the physical side of astronomy, and it was doubtless very congenial to Pickering to find himself in a position to devote his energies mainly to photometry, photography, and spectroscopy. His earliest work at the observatory was the reduction of Argelander's observations of variable stars, calling for extensive photometric measurements of the brightness of the stars which had been utilised for purposes of comparison. Photometric work in general later became a leading feature of his programme of observations. For these investigations he devised the meridian photometer, with which, under favourable conditions, stars could be observed at the rate of one a minute, with an average deviation not generally exceeding one-tenth of a magnitude.

Under Pickering's guidance, and largely through his own untiring personal observations, a photometric survey of the entire heavens, involving observations to the number of more than two millions, has been made and published. The "Revised Harvard Photometry," forming vol. l. of the Annals of the observatory, and giving the magnitudes and spectra of 9110 stars, mainly of magnitude 6·50 and brighter, has thus become an indispensable source of reference in many departments of astronomical research. A later volume of the Annals (vol. liv.) extends the observations to 36,682 stars fainter than magnitude 6·50. This again has been supplemented by numerous publications on photographic photometry, including the results of investigations undertaken for the establishment of a standard scale of photographic magnitudes. These extensive researches are the chief basis of modern standard magnitudes, and have been of immense value to observers of variable stars, as well as to those occupied with stellar statistics.

The great advantages of photographic methods of observation were early realised by Pickering,