lowed by a train of sparks much like a spent rocket, but originated too high to have been one. From our position we could not see if it reached the water. While it seemed to be only two or three miles away, I realized that such appearances are deceptive. There was no sound accompanying the fall audible from where we stood.

WILLIAM L. BRYANT

PARK MUSEUM

QUOTATIONS

THE NATIONAL MUSEUM OF AUSTRALIAN ZOOLOGY

IN 1924 the Federal Parliament of Australia, knowing the fact that the unique native fauna of the commonwealth was fast disappearing, and recognizing its importance to medical science, founded the National Museum of Australian Zoology. It was a wise and statesmanlike act, the full effect of which is only now beginning to be seen. Dr. Colin Mackenzie was appointed director, with the title of professor of comparative anatomy. It was a museum with a difference. In the previous year Professor Mackenzie had presented to the commonwealth his specimens of living native animals, together with the buildings and fencing on the Research Reservation at Healesville. He had given also his collection of macroscopic and microscopic specimens, numbering many thousands; and these now form the basis of the museum collection. Each specimen has a direct application to some medical or surgical problem. Nothing quite like the collection of normal histological preparations from reptiles, monotremes and marsupials, with which human or other mammalian tissue can be compared, exists anywhere in the world, and we are glad to know that illustrated atlases describing the collection are being prepared for publication—a huge enterprise which has been begun not a day too soon. Early in 1923, when commenting on the announcement that the commonwealth government had passed an act to establish a Museum of Australian Zoology, we observed that there was clearly an obligation on Australia to preserve a full series of specimens, since the whole indigenous fauna of Australia seemed only too likely to follow Tasmanian man to extinction. The commonwealth legislature has now gone rather further than we hoped, for it has not only allotted a site for the National Museum of Australian Zoology at Canberra, the new capital of Australia, but the Federal Capital Commission has provided a site for a zoological park or reservation, in which will be kept living specimens of Australian and Tasmanian native animals in their natural state. The area of the site for the museum, laboratories and lecture theater is about five and a half acres, in a magnificent situation on Action Hill, facing Parliament House. The research reservation or zoological park, containing about eighty acres, is on a peninsula bounded on two sides by the river Molonglo. The report of the Parliamentary Standing Committee on Public Works, dealing with the construction of buildings, has now been published, authorizing for this purpose a sum approximating £100,000. The report has received the unanimous approval of the Federal Parliament, and the buildings, representing what is really the first stage in the establishment of the National University of Australia, will be begun immediately. When the buildings are completed every facility will be offered to workers—not only Australian, but also from other countries—wishing to study comparative anatomy and its application to modern medical and surgical practice. The museum is now at Melbourne, but is to be moved to Canberra next year. To its original contents many important additions have recently been made, including the collection of specimens valued at £25,000 belonging to Dr. George Horne, of Melbourne, dealing with the Stone Age men of Australia, and also a collection of aboriginal skulls made by Dr. Arthur Nankivell, of Kerang. The museum also possesses the Froggatt entomological collection, and that of Mr. Murray Black dealing with the aborigines of South-East Victoria. The completely fossilized prehistoric Cohuna skull, together with many other specimens of anthropological value, belong to the museum. The federal government of Australia is to be congratulated on its decision to establish a center for the advancement of comparative anatomy, which admittedly is the foundation of all the medical sciences. We may venture to express the hope that the lead now given by Professor Colin Mackenzie will encourage wealthy Australians to display a similar national spirit, and by liberal endowments help on the necessary research work in the interests of humanity.—*The British Medical Journal.*

SCIENTIFIC BOOKS

The Internal Constitution of the Stars. By A. S. EDDINGTON, M.A., F.R.S., Cambridge; at the University Press, 1926. 407 pp., 5 figures.

THE fundamental problem in astrophysics may be regarded as the construction of models which, obeying the well-established laws of theoretical physics, describe the observed intrinsic properties of the stars. Thus there are stellar models which describe the formation of the observed spectra in reversing layer and chromosphere, models which describe the formation of binary stars by fission and the behavior of cepheid variables and finally models which lead to relations between the mass, radius, luminosity and effective temperature of a star. Such stellar models, both as regards their field of usefulness in scientific thought as well as their frequent incompatibility with one another, are closely analogous to the various atomic models designed to describe the properties of matter. In astronomy, as well as in atomic physics, the value of a given model depends upon the range of facts *quantitatively* described, upon its powers of prediction and upon the small number of special postulates built into the model.

It is now some ten years since the appearance of Eddington's first paper on the interior of a star. The general theory therein developed and the model adopted furnished a successful description of the stars as then known. The development by Kramers, from the correspondence principle, of an expression for the mass coefficient of absorption permitted Eddington in 1924 greatly to improve his model and to predict the mass-luminosity relation. This prediction and its verification have profoundly modified astronomical conceptions of stellar evolution. At the same time, Eddington's theory has reacted upon modern atomic physics and has inspired numerous important investigations on the physics of matter at high temperatures, notably the work of Eggert (which led to Saha's important theory) and the recent investigations of R. H. Fowler. Astronomers and physicists both, then, will welcome the present volume in which Eddington gives a systematic development of the whole theory.

The general treatment may be outlined in the following manner: Given a mass of gas under its own gravitational attraction, the internal distribution of density, pressure and temperature may be derived from the equation of state of the gas and the requirements of mechanical and thermal equilibrium. The condition of mechanical equilibrium requires that the total pressure (gas pressure + radiation pressure) at any internal point balances the weight of the overlying layers, and is expressed by the well-known differential equation of hydrostatics. The condition of thermal equilibrium requires that the flow of heat does not disturb the internal distribution of temperature, but to formulate the differential equation it is necessary to know the mode of heat transfer. Schwarzschild has shown that this transfer in the outer layers of the sun is by radiation rather than convection, and Eddington has shown that convection currents can in fact be only maintained at the expense of their own mechanical energy and so must die out. Granting that heat transfer is by radiation, the well-known differential equation of radiative equilibrium may be derived from elementary considerations, and this equation, Eddington has shown, is accurate to a high order of approximation.

To integrate these differential equations, it is now necessary to make certain assumptions, or in other words to adopt a definite stellar model. Eddington assumes that the star consists of a perfect gas of constant molecular weight in which the product $\eta\ k$ is invariable throughout the interior. Here η is the ratio of the average liberation of energy per gram within any sphere of radius r to the average liberation of energy per gram in the whole star, and k is the mass-coefficient of absorption. On this model and without difficult quadratures it is possible to arrive at two important results—firstly, that the ratio of radiation pressure to gas pressure throughout the star is constant and a function of the stellar mass; and, secondly, that *for stars of the same mass the luminosity varies inversely as* $\eta\ k$. A detailed solution by quadratures, integrating from within outwards, as carried through first by Emden, gives the internal distribution of density, pressure and temperature, but involves as an unknown constant the mean molecular weight. The mean molecular weight of course depends upon the degree of ionization in the interior, which in turn depends upon the temperature and pressure. A solution by trial and error indicates a molecular weight of 2.1 which is adopted for subsequent work. Accordingly when the model star is of the same mass and radius as our sun, its central density turns out to be 76 gms. per cu. cm. and its central temperature forty million degrees. Finally, Kramers' law of absorption is introduced, and this, by virtue of the constant proportionality throughout the model of the density to the cube of the temperature, reduces to the form that the absorption coefficient varies inversely as the square root of the temperature. Introducing this result into the relation italicized above, the mass luminosity relation is reached—

$$\log\text{(Luminosity)} = \frac{7}{5}\log\ \text{(Mass)}$$
$$+\frac{3}{2}\log\frac{\text{radiation pressure}}{\text{total pressure}}+\frac{4}{5}\log\text{(Surface temperature)}$$
$$+\text{Constant.}$$

absorption law), and this is fixed from the mass, luminosity and effective temperature of a single star (Capella). It is then found that all thirty-seven stars of known mass and luminosity, both giants and dwarfs, lie on Eddington's mass-luminosity curve

Of the several quantitative predictions furnished by Eddington's model, none is more striking or more general than this relation that the luminosity of a star, apart from a small factor depending upon the surface temperature, is a single-valued function of its mass. The relation contains but one disposable constant (the proportionality constant of Kramers' with an average residual of the order of half a magnitude. It is at first sight paradoxical that a "perfect gas" model should accurately predict the luminosity of dwarf stars with a mean density as high as that of copper. The paradox is, however, removed if Eddington's model be regarded as giving an acceptable picture of the actual interior of a star. In that event we must regard the stellar interior as being highly ionized so that the stellar "molecules" (free electrons and atoms ionized down to the K shell) have but one millionth the volume of terrestrial molecules. The equation of state for a perfect gas will therefore be applicable in the actual stellar interior at mean densities comparable with that of platinum. Moreover, we may qualitatively predict the possible existence of stars with mean densities for in excess of terrestrial experience—a prediction recently verified by the "white dwarfs" of which one, the companion of Sirius, has a mean density of sixty-one thousand grams per cubic centimeter. Quantitatively and qualitatively a veritable triumph for the Eddington model!

The model, as so far detailed, predicts that for stars of the same mass any surface temperature or spectral type is equally probable. The facts are, however, that the stars fall into a Russell diagram which must now be described as a reversed figure Z consisting of three branches—the giant, main sequence and white dwarf branch. Along the main sequence, which contains by far the greatest number of stars, there is a very definite relation between spectral type, on the one hand, and mass, or equivalent luminosity, on the other. Eddington's model will only obey a relation of this kind if the liberation of energy per gram rapidly decreases from star to star down the main sequence. We are, therefore, forced to postulate an unknown source of energy, and one of the most interesting and stimulating chapters in the book under review is concerned with a very full discussion of the nature of this source and the cause of its variation. A survey of the possible sources, from the viewpoint of the time-scale demanded by both geologists and astronomers, indicates that some form of subatomic energy is required. The difficulty on Eddington's model, however, is that the temperatures which stimulate and control this subatomic source are absurdly low. It would seem as if the only subatomic source compatible both with contemporary physics and Eddington's model is C. T. R. Wilson's "runaway electron," a not very encouraging prospect. A question of interest to the astronomer is whether the source or sources form a large fraction of the mass of the star. It is only in this event that any important evolution, which can only result from a loss of mass, is possible in the life history of the star. Quite apart from any stellar model, and accepting the mass-luminosity law as a purely empirical relation, Trumpler's recent observations of the coexistence in open, and presumably old, clusters of massive stars of types B, F, G, coeval with ordinary dwarfs of types F and G, seem to preclude the possibility of such evolution in these clusters. Eddington says, "it seems almost necessary to throw over the idea of any important advance in evolution in the life-time of the clusters, and it then becomes a question whether there is any point in retaining the idea for stars in general"—a statement which should commend itself to the conservative astronomer.

The general plan of the book, which discusses these and many other problems, is firstly to lay the foundations of thermodynamics and the quantum theory and then to proceed step by step in, roughly speaking, an historical order, through the whole theory. In this way are discussed in successive chapters Emden's quadratures of the differential equations for various polytropes, the derivation of the equation of radiative equilibrium, the solution of the equations with a detailed justification of the various assumptions included in the model, the mass-luminosity law and the problem of Cepheid and other variable stars. Chapter IX deals with the coefficient of opacity, and here Eddington's model encounters its second principal difficulty, the other difficulty, of course, having to do with sources of energy. Kramers' theory gives the following expression for the mass coefficient of absorption:

$$\log(K) = \log(\text{Density}) - \log(\text{Molecular Weight}) - \frac{7}{2}\log(\text{Temperature}) + \text{Constant}.$$

The numerical value of the constant is predicted by theory and satisfactorily verified by laboratory experiments with X-rays. This is the same constant, however, which was disposable in Eddington's model, and for which an astronomical value was obtained. The astronomical value exceeds the theoretical one, verified by terrestrial experiment, by a factor of ten. Eddington's thorough discussion of the whole problem reveals no adequate explanation of this discrepancy. Subsequent chapters discuss ionization and diffusion in the star, sources of energy, models for the outside of the star (largely due to Milne) and finally diffuse matter in space. Special mention should be made of the treatment of diffusion and von Zeipel's general theorem on a rotating star. If these theories which are applicable to all models can be successfully defended they rule out of court models, such as those recently proposed by Jeans, in which there is a concentration towards the stellar center of the heavier elements.

The book is written with Eddington's characteristic clarity and abounds in happy and stimulating allusions. It can not fail to suggest to every serious reader numerous subjects for further observational and theoretical investigation. In future editions the value of the book would be enhanced for the reviewer, and possibly also for other observational astronomers of slender mathematical attainments, by the interpolation of a chapter between III and IV giving a brief and as nearly as possible self-contained mathematical development of the whole theory. Reference could then be made forward from this chapter to the subsequent chapters, which would retain much their present form, for a detailed discussion of the various assumptions, for the quadrature of the differential equations, for the discussion of the opacity law and so on. I do not believe that such an interpolation would seriously interfere with the logical treatment of the theory, and it is conceivable that it might eliminate some of the many cross references, forwards and backwards, which are essential with the present arrangement.

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ARTIFICIAL TRANSMUTATION OF THE GENE

MOST modern geneticists will agree that gene mutations form the chief basis of organic evolution, and therefore of most of the complexities of living things. Unfortunately for the geneticists, however, the study of these mutations, and, through them, of the genes themselves, has heretofore been very seriously hampered by the extreme infrequency of their occurrence under ordinary conditions, and by the general unsuccessfulness of attempts to modify decidedly, and in a sure and detectable way, this sluggish "natural" mutation rate. Modification of the innate nature of organisms, for more directly utilitarian purposes, has of course been subject to these same restrictions, and the practical breeder has hence been compelled to remain content with the mere making of recombinations of the material already at hand, providentially supplemented, on rare and isolated occasions, by an unexpected mutational windfall. To these circumstances are due the wide-spread desire on the part of biologists to gain some measure of control over the hereditary changes within the genes.

It has been repeatedly reported that germinal changes, presumably mutational, could be induced by X or radium rays, but, as in the case of the similar published claims involving other agents (alcohol, lead, antibodies, etc.), the work has been done in such a way that the meaning of the data, as analyzed from a modern genetic standpoint, has been highly disputatious at best; moreover, what were apparently the clearest cases have given negative or contrary results on repetition. Nevertheless, on theoretical grounds, it has appeared to the present writer that radiations of short wave length should be especially promising for the production of mutational changes, and for this and other reasons a series of experiments concerned with this problem has been undertaken during the past year on the fruit fly, *Drosophila melanogaster*, in an attempt to provide critical data. The well-known favorableness of this species for genetic study, and the special methods evolved during the writer's eight years' intensive work on its mutation rate (including the work on temperature, to be referred to later), have finally made possible the finding of some decisive effects, consequent upon the application of X-rays. The effects here referred to are truly mutational, and not to be confused with the well-known effects of X-rays upon the distribution of the chromatin, expressed by non-disjunction, non-inherited crossover modifications, etc. In the present condensed digest of the work, only the broad facts and conclusions therefrom, and some of the problems raised, can be presented, without any details of the genetic methods employed, or of the individual results obtained.

It has been found quite conclusively that treatment of the sperm with relatively heavy doses of X-rays induces the occurrence of true "gene mutations" in a high proportion of the treated germ cells. Several hundred mutants have been obtained in this way in a short time and considerably more than a hundred of the mutant genes have been followed through three, four or more generations. They are (nearly all of them, at any rate) stable in their inheritance, and most of them behave in the manner typical of the Mendelian chromosomal mutant genes found in organisms generally. The nature of the crosses was such as to be much more favorable for the detection of mutations in the X-chromosomes than in the other chromosomes, so that most of the mutant genes dealt with were sex-linked; there was, however, ample proof that mutations were occurring similarly throughout the chromatin. When the heaviest treatment was given to the sperm, about a seventh of the offspring that hatched from them and bred contained individually detectable mutations in their treated X-chromosome. Since the X forms about one fourth of the haploid chromatin, then, if we assume an equal rate of mutation in all the chromosomes (per unit of their length), it follows that almost "every other one" of the sperm cells capable of producing a fertile adult contained an "individually detectable" mutation in some chromosome or other. Thousands of untreated parent flies were bred as controls in the same way as the treated