moval of the pelvic and lumbar portion of the sloth specimen referred to and seeing its relation to the human remains, I do not hesitate to pronounce the find as probably the most important prehistory discovery ever made in America.

Through the courtesy of Mr. Conkling, the Los Angeles Museum has been made the repository for all the material recovered. The specimens may now be seen in Los Angeles. The museum has also been given charge of the cavern by its discoverers and will continue the excavation and study of the occurrence.

A number of competent geologists have already examined the deposit and are unanimous in their appreciation of its authoritative, far-reaching significance. While the cavern will not be open to the public, for obvious reasons, during its continued study, qualified investigators will be welcome to examine both the material and the occurrence, but should arrange with the Los Angeles Museum in advance in order that proper facilities can be arranged.

WM. ALANSON BRYAN

LOS ANGELES MUSEUM

SCIENTIFIC BOOKS

Statistical Mechanics. By R. H. FOWLER. 570 pp. Cambridge University Press. 1929. (New York, The Macmillan Company.) 35 shillings.

THE subtitle of this monumental book is "The Theory of the Properties of Matter in Equilibrium," and this is a fairly descriptive characterization of the wide range of phenomena which it covers. Any number of books have been written on the application of modern physics to individual atomic systems, especially on the quantum theory of spectroscopy. There has, however, been a dearth of up-to-date literature on the statistical properties of an assembly of an enormous number of atoms or molecules. Such properties embrace a wealth of phenomena of great interest to the physicist, mathematician, astronomer and chemist. Of course there are standard classical treatments of statistical mechanics, notably those of Gibbs, Boltzmann, Jeans and Ehrenfest, but these use only the pure classical theory. The introduction of the modifications required by modern quantum theory is not merely necessary to secure agreement with experiment, but also is vital for logical consistency, as the negatively infinite potential energy at coincidence of a proton and electron makes the classical Boltzmann distribution formula inapplicable to any real atomic system. Professor Fowler has done wisely to introduce the quantum theory at the very beginning, and to regard classical theory as a limiting case thereof, rather than to adopt the too common procedure of adding on quantum modifications as a nondescript appendage of an otherwise classical treatment. In short, he has done a great service in writing a quantum statistical mechanics more comprehensive than the existing books by Herzfeld, Smekal and Uhlenbeck.

When the reviewer is confronted with the prospect of appraising the 570 large pages of this book, with their 1,607 numbered equations, he feels that he has set himself a Herculean task. His only consolation is how infinitely much more of an ordeal it must have been for Professor Fowler to write the book itself. Even though in the preface Professor Fowler acknowledges the aid of many collaborators, one still is astonished at the accuracy and thoroughness with which he has handled a tremendous diversity of physical, chemical and astronomical phenomena.

After an introductory chapter, the second chapter develops the mathematical scheme which is the backbone of the whole book. This is the derivation of the Maxwell-Boltzmann distribution formula by an ingenious and elegant method which was originally given by Darwin and Fowler in the *Philosophical Magazine* and which should especially interest mathematical readers. In evaluating the sum of factorial products encountered in statistical mechanics, the common procedure is to resort to Stirling's theorem, thereby introducing an approximation whose degree is a bit obscure. Instead, Darwin and Fowler identify this sum with a certain coefficient in a multinomial expansion and evaluate this coefficient as a contour integral by means of the residue theorem of complex variable theory. The integrand is large only in the vicinity of a "col," and so the integral can be evaluated by the method of steepest descents. The average properties of an assembly in the sense of averages over the phase space can thus be calculated. Both as regards physical significance and mathematical rigor, it is far more satisfactory to use such an average property than the "most probable property" so frequently encountered in elementary books on statistical mechanics. In statistics a property which is the most probable has little significance unless it is infinitely the most probable; *i.e.*, what Jeans terms a "normal property." Otherwise it might, loosely speaking, be likened to a weak plurality rather than a dominating majority in an election. To be truly representative, a property must be shown to be normal rather than merely the most probable. Even the average properties are not necessarily the normal ones, and it is only when one calculates the fluctuations, as is done in the next to the final chapter of the book, that one can feel sure they are the same. Professor Fowler uses the term normal property in the sense of a time average property of the system rather than in Jeans' sense of a property which holds in all but an infinitesimal fraction of the phase space. The reviewer inclines towards the Jeans definition, as the two definitions are not the same if nature has some peculiar preference for a diminutive fraction of the phase space, something which statistical mechanics can never rigorously disprove. Even Professor Fowler shows a slight tendency to follow in the path of most writers on statistical mechanics, and dismisses just a bit glibly the passage from mathematical space averages to physical time averages. Following the Darwin-Fowler method, Professor Fowler always uses the micro-canonical or rather surface ensemble instead of the full Gibbs canonical one, and the reviewer agrees entirely with Fowler's statement that this procedure seems physically much the more natural and illuminating, even though the Gibbs method has certain mathematical advantages.

After development of the mathematical framework, the succeeding chapters are devoted to various physical applications: the specific heats of gases, the simple properties of crystals, evaporation and dissociative equilibrium, the relation of the equilibrium theory to classical thermodynamics, Nernst's heat theorem and chemical constants, the dielectric and paramagnetic susceptibilities of gases and the properties of solutions, including the Debye-Hückel theory. There are three very complete chapters on the theory of imperfect gases and interatomic forces, written with the collaboration of J. E. Lennard-Jones, whose fundamental work on the relation of the equations of state of gases and crystals is classic.

Considerable space is given to the application of the equilibrium theory to astronomical problems. In fact, the whole book is the outgrowth of Professor Fowler's receipt of the Adams prize in 1923–1924 for his essay on the physical state of matter at high temperatures. It is well known that the development of a stellar temperature scale by application of the quantum theory of the excitation of spectral lines is one of the important advances of the century in astrophysics. The harder a spectral line is to excite, *i.e.*, the higher the quantum energy levels involved, the hotter a star must be for such lines to appear. Only the hottest stars, for instance, display the lines of ionized helium. This field of work was opened by Saha, but has been greatly enriched by the contributions of Fowler and Milne, who substituted the so-called method of maximum intensities for that of marginal appearances. The escape of molecules from an upper atmosphere is treated much more thoroughly than usual. Stellar interiors are discussed to some extent, but Eddington's theory is omitted to avoid duplication with the latter's book.

The chapters on collision processes, chemical kinetics in gaseous systems and radiative processes should interest physical chemists concerned with uni- and bi-molecular reactions, photochemistry, etc. It is gratifying to have this discussion of mechanisms of interaction, even though they are, strictly speaking, not an immediate part of the statistical theory of equilibrium, which arrives at the final equilibrium concentrations without specializing the mechanism.

The final chapter is on the new statistical mechanics of Fermi-Dirac and Einstein-Bose, and enters more fully into quantum mechanics than elsewhere. The treatments in the preceding chapters have been from a standpoint appropriate to the old quantum theory, and the effect of the new mechanics has been regarded as merely to change the energies of the quantized states. This is legitimate in statistical problems except at such low temperatures or high densities that degeneration effects become important. In the preface, Professor Fowler states that the plan of the book was satisfactory at its inception in 1926, but not at its appearance in 1929, due to the development in the meantime of the new quantum mechanics. In our opinion he is too apologetic, for practically the degeneration is important only in rather abstract radiation theory and especially in the electron theory of the conductivity and related properties of metals. The important advances in the latter theory made by Sommerfeld and others are reviewed in the final chapter. In our opinion, other subjects, in which the degeneration does not appreciably enter, are more easily presented without the Fermi-Dirac or Einstein-Bose complications, and so we do not especially regret that they could not be woven into the earlier chapters. On the other hand, some discussion of the Thomas-Fermi atomic force fields, which involve a curious intermingling of classical theory and the new statistics, would have have been welcome. It is to be clearly understood that although the new statistics are not explicitly introduced in earlier chapters, the results of the new quantum mechanics are throughout utilized in a descriptive way. Hence practically all the book is very up-to-date. This must have necessitated a tremendous amount of revision during the writing or proof-reading. The theories of dielectric constants, paramagnetism and the specific heat of hydrogen are, for instance, profoundly modified and improved by including, as Professor Fowler does, the results of the new quantum mechanics.

In closing we may caution that Professor Fowler's style, though clear and accurate, is not an elementary one. Without conciseness, incorporation of so much material in one volume would have been out of the question. The book is intended presumably as a treatise and compendium for readers having a fairly comprehensive physical and mathematical background rather than as an introductory text. On the other hand, a knowledge of the technique of the new quantum mechanics (matrices, "Eigenwert" theory, etc.) is unnecessary.

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SCIENTIFIC APPARATUS AND LABORATORY METHODS

A METHOD FOR COMPARING THE VALUE OF AMMONIA NITROGEN AND NITRATE NITROGEN[1]

IN a series of experiments, cotton plants[2] were grown in two nutrient solutions of practically identical chemical composition but only different in the sulphate ion concentration and form of nitrogen. One solution contained only ammonia nitrogen as diammonium hydrogen phosphate and ammonium sulphate; the other solution contained only nitrate nitrogen as potassium nitrate, as source of readily available nitrogen. The hydrogen ion concentration was adjusted in each solution to give a maximum yield of dry matter, and the hydrogen ion concentration of the nutrient solutions was then kept constant by mechanical stirring, by aeration and by constant solution renewal. A rate of flow of 1.4 cc per minute per plant was found sufficient for maintaining the hydrogen ion concentration of the solution practically constant around the roots of the cotton plants up to an age of six weeks.[3]

Experiments are now in progress to determine the maximum growth with minimum salt concentration (or osmotic pressure) using the salts given in the solution mentioned in this article.

Johnston and Hoagland maintained a rate of flow of 8 cc per minute per plant when growing tomato plants.[4]

Besides being practically identical in chemical composition, easily buffered by phosphates and nitrogen compounds, and a constant supply of nutrient solution to the roots, these solutions are easily prepared. By simply adding ammonium hydroxide or potassium hydroxide to the monocalcium phosphate in the solution, diammonium hydrogen phosphate and dipotassium hydrogen phosphate[5] are formed.

A mixture of monocalcium phosphate, dicalcium phosphate and dihydrogen potassium phosphate is formed in one case, and monocalcium phosphate, diammonium hydrogen phosphate and dicalcium phosphate in the other. The composition of the solutions in volume-molecular proportions is as follows:

Ammonia Nitrogen Solution		Nitrate Nitrogen Solution	
$Ca(H_2PO_4)_2$	0.0010	$Ca(H_2PO_4)_2$	0.0010
$(NH_4)_2SO_4$	0.00575*	KNO_3	0.0120
NH_4OH	0.0005*	KOH	0.0005**
$MgSO_4$	0.0020	$MgSo_4$	0.0020
K_2SO_4	0.0070	K_2SO_4	0.00075**

* These can be varied according to optimum hydrogen ion concentration.

** Varied to obtain maximum yield of dry matter.

The hydrogen ion concentration of the above solutions was pH 5.8. The osmotic pressure of the above solutions is approximately one atmosphere. Iron as ferrous sulphate was added as needed to keep plants green. By varying the amount of ammonium or potassium hydroxide the hydrogen ion concentration can be varied from pH 3.8 to above a pH of 6.5.

The salts formed by the addition of NH_4OH and KOH given above make these solutions contain:

Ammonia Nitrogen Solution		Nitrate Nitrogen Solution	
$Ca(H_2PO_4)_2$	0.00075 m	$Ca(H_2PO_4)_2$	0.00075 m
$(NH_4)_2HPO_4$	0.00025	K_2HPO_4	0.00025
$CaHPO_4$	0.00025	$CaHPO_4$	0.00025
$(NH_4)_2SO_4$	0.00575	KNO_3	0.01200
$MgSO_4$	0.00200	$MgSO_4$	0.00200
K_2SO_4	0.00700	K_2SO_4	0.00075

The maximum yield obtained from the ammonia-nitrogen solution at various hydrogen ion concentrations was compared with the maximum yield of dry matter of the plants harvested from the solution containing only nitrate nitrogen at various hydrogen ion concentrations. Thus a comparative value was obtained for ammonia nitrogen and nitrate nitrogen.

The following are identical with the above nutrient solutions with respect to the nutrient chemical elements with the exception of the sulphur content and containing mixtures of ammonia nitrogen and nitrate

[1] Published with the approval of the director of the Georgia Experiment Station as paper No. 29, Journal Series.

[2] The results will be reported in another article.

[3] J. W. Shive and A. L. Stahl, "Constant Rates of Continuous Solution Renewal for Plants in Water Cultures," *Bot. Gaz.*, 84: 317–323. 1927.

[4] E. S. Johnston and D. R. Hoagland, "Potassium Required by Tomato Plants," *Soil Sc.*, 27: 89–109. 1929.

[5] D. E. Prianishnikov and M. K. Domontovitch, "The Problem of a Proper Nutrient Medium," *Soil Sc.*, 21: 327–348. 1926.