the preparations for war. The present time is exceptional in the wide divergence of opinion on the subject. In earlier periods men of science found themselves in no dilemma. In general, either they were not asked to put their knowledge to military use, or, if asked, they did so unquestioningly. The increasing importance of applied science in warfare is now, we see, assisting the virtual conscription of scientific knowledge for military purposes; and the resultant increase in the horrors of war, together with the growing realization of war's futility and wastefulness, has caused new heart-searchings among scientific workers.

Lord Rayleigh confines himself in the main to pointing out that science can not be blamed for the horrors of war. Those inventions which have made modern warfare more horrible, including mustard gas and incendiary bombs, are almost without exception applications of old scientific discoveries, made with no military objective. As he rightly concludes, science is the outcome of the urge to explore the unknown, and its results can not be divided into sheep and goats. Science is of its nature ethically neutral; what good or evil use is made of its discoveries depends on society at large. The problem remains, however, as to the conduct of individual men of science in putting their knowledge at the service of the war machine. Opinions are bound to differ on this subject. The view accepted by most scientists seems to be that this is a matter of individual conscience just as much as readiness to serve in any other direct or indirect military capacity. It is true that the man of science has greater potentialities for good or evil as a technical adviser than as a private or even as a colonel: but this does not alter the nature of the problem.

There is finally the question whether we can do anything in the matter. Lord Rayleigh is frankly sceptical, but allows a modest ray of hope in the proposal to establish a division of the association for the study of the social relations of science. So far as there are likely to be immediate results, scepticism is undoubtedly justified. But in the long run perhaps a more hopeful view may be taken. The scientific study of human nature, especially in its social aspect, is only in its infancy. As Dr. Glover forcibly pointed out a few years back, the causes of war are at least as much psychological as economic. Repression and frustration in early life engender unconscious cruelty whose natural outlet is violence, and mass suggestibility, under the influence of propaganda, generates an irresistible mass hysteria, a neurosis of society. Theoretically, at least, it is possible to plan a system of education which would allow the natural impulses to be expressed instead of repressed, thus removing the dangerous because unconscious mainspring of violence, and making it possible to harness the deep psychological forces to construction instead of destruction; and one which, instead of fostering suggestibility and material respect for authority as such, would encourage critical reflection and a healthy distrust of propaganda. A society educated thus would be a new kind of society, of its very nature much less inclined to make war than ours. Admittedly this is remote; but is it more remote than was our electric age from the age of Galvani or of Ampère, or even of Faraday? To apply scientific method to the study and control of human nature, new techniques and a new approach are necessary; but there is no reason to suppose that it can not be done, and many reasons for supposing that in doing so lies the world's chief hope of emerging from chaos and frustration.—*The Times, London.*

SCIENTIFIC BOOKS

QUANTUM MECHANICS

The Fundamental Principles of Quantum Mechanics. With Elementary Applications. By EDWIN C. KEMBLE. McGraw-Hill, New York and London, 1937. xviii + 611 pp. $6.00.

THE classical or Hamiltonian dynamics arose from celestial mechanics, especially the study of the motion of the solar system under gravitation. It provided a consistent mathematical system of equations representing these motions very accurately. Exact solutions of these equations can only be obtained in simple cases; and it is still doubtful over how long a period of time the approximate solutions can be applied. There are still unsolved mathematical difficulties involved in the long time solution of the problem of three bodies. Classical electrodynamics arose from physical experiment. It provided a consistent system of equations representing the action of electric and magnetic forces on matter in bulk regarded as generally continuous. It was applied to give a consistent theory of radiation moving with the velocity of light in empty space. Classical statistical mechanics applied classical dynamics to the motion of chemical molecules. There were three principal but not exclusive methods of attempting to surmount the mathematical difficulties; that associated especially with Maxwell, assuming "continuity of path"; that especially due to Boltzmann, using collisions and the H-theorem; and that of Gibbs, using from the beginning an "ensemble" of states taken by the assemblies of molecules with various probabilities. These methods arrived at essentially the same result; that isolated closed systems and systems contained in thermostats would approach a statistical equilibrium in which the general laws of thermodynamics would hold; but they gave, for instance, specific heats disagreeing with observation. "Continuity of path" has only recently been justified by the work of T. M. Cherry, Birkhoff and J. v. Neumann.

With the discovery of the electron came the attempt to apply electrodynamics to the motion of single electrons and statistical mechanics to the motion of assemblies of electrons; leading to the well-known interconnected disagreements with observation in the thermodynamics of radiation and in the processes of emission and absorption of radiation. The attempt to describe the electron itself in terms of its field alone also led to an impasse. Some of these difficulties were met by the introduction of the quantum theory by Planck and Bohr, first in *ad hoc* assumptions about the processes of emission and absorption of radiation and the possible intermediate states of atoms. The methods of statistical mechanics were extended especially by Planck and by Darwin and Fowler. Various theoretical results were verified by observation and new difficulties arose. These led to a new discussion of the nature of our knowledge of atoms by Bohr and Heisenberg and to the introduction by Heisenberg and Dirac of matrix and operator mechanics; and to that of wave mechanics by De Broglie and Schrödinger. It was said even before matrix or wave mechanics were developed that, while the theory of relativity on the one hand dealt with physical problems in which the quantum of action could be regarded as negligibly small, but the time taken by light to pass from one part of the system to another was taken into account, the quantum theory on the other hand dealt with physical problems in which the latter could be neglected, but not the former.

Now the development of quantum mechanics has led to a formulation which seems to be logically complete when the time of passage of light can be neglected. It provides a consistent set of mathematical equations to represent the observable properties of atomic systems. There are no outstanding discrepancies between conclusions drawn from this theory within its range of validity, and observation; while many new phenomena, such as electron diffraction, have been given no other explanation. The observable properties of atoms are generally to some extent of a statistical nature, and the connection between the solutions of the equations and observation requires careful discussion; while the quantum statistical mechanics for assemblies of atoms requires the special foundation provided by J. v. Neumann. Just as in classical dynamics, when three or more bodies are involved, the equations are not exactly soluble, and there still remain mathematical difficulties in their treatment. Indeed, very little certain is known about the solution of the mathematical problem that must be solved to deal with the continuous spectrum in the many body problem. Moreover, in statistical mechanics difficulties like those of classical statistical mechanics remain. Quantum mechanics has been extended to take account of the finite time of propagation of light only in a somewhat tentative way and "quantum electrodynamics," if it is on the right track at all, is far even from providing a consistent set of mathematical equations; while no description of an electron in terms of its field alone has yet proved satisfactory.

Professor Kemble's "Fundamental Principles of Quantum Mechanics" is, in my opinion, an important work likely to be useful both as a reference book for mathematical methods to the research worker and as a text-book for the graduate student of theoretical physics. It covers generally the ground of non-relativistic quantum-mechanics, which, as stated above, now forms as logically complete and consistent a system as classical dynamics. The manner in which these mathematical equations describe the observable properties of atomic systems are explained, and the most part of the mathematical methods that have been employed to solve the equations are discussed in detail; the foundations are laid for the quantum treatment of statistical mechanics and of the structure of many electron atoms. I think this book is especially good in its clear explanation of the mathematics used in quantum theory and in its accurate statement of the limitations of that mathematics.

In the first two chapters wave mechanics in the Schrödinger form is built up from classical mechanics and selected observational results using the analogy of the relation of physical to geometrical optics, and the statistical interpretation of wave mechanics is explained, finishing up with the uncertainty principle. In the next four chapters a large number of mathematical methods for exact and approximate solution of the wave equation are considered. One-dimensional problems, separable problems in several dimensions, the continuous spectrum, and finally "The Existence and Properties of Solutions of the Many-particle Schrödinger Eigenvalue-Eigenfunction Problem" are dealt with in succession. This part of the book is especially excellent in pointing out how far the mathematics really goes and what is uncertain and unproved; it contains much material that is not to be found collected together, if at all, elsewhere; and forms the exact mathematical background of the theory.

The next three chapters introduce the general theory of operators representing dynamical variables; their properties; and the theory of their measurement. To this part a quotation from the preface applies most directly. "A feature of the present volume on the physical and philosophical side is its consistent emphasis on the operational point of view and on the fundamental importance of Gibbsian assemblages of independent systems in the physical interpretation of the mathematical formalism." While the reviewer is in complete agreement with the second part of this statement, he does not agree so well with the first part. While it is valuable to know how far operational treatment is possible, one must start somewhere; and in many connections an alternative emphasis, stressing, with Norman Campbell, the theory-fact scheme of treatment of measurement, and allowing such ideas at least as probabilities of unmeasured positions in the theory, seems to be much more convenient, especially as, as Professor Kemble admits, in dealing with probability the operational theory presents difficulties, while an hypothesis-fact picture, such as that of Harold Jeffreys or such as the reviewer believes could be made with the aid of the "likelihoods" of R. A. Fisher, seems much simpler. But these are very much matters of opinion, and the difference may be mainly about words.

The next two chapters, ten and eleven, deal with matrix theory and perturbations not involving the time, including a discussion of the variational method. The following chapter is entitled "Quantum Statistical-Mechanics and the Einstein Transition Probabilities." The first part endeavors, in very small compass, to lay the foundations of statistical mechanics, using the methods of J. v. Neumann and directing the arguments towards a proof that, roughly speaking, as in classical mechanics, an assembly of molecules will tend to a state of statistical equilibrium—in classical mechanics such a proof makes use of the H-theorem or of continuity of path; so in quantum theory, a pure state of such an assembly will after some time be indistinguishable from a Gibbsian mixture. The reviewer finds this argument very difficult reading and has not satisfied himself that the steps all follow, though he feels sure that an argument can be carried through on these lines. He hopes that in some future edition this part of the book may be considerably expanded. He thinks that a discussion of the extension of Gibbs's own arguments, making use of maximum and minimum properties of canonical ensembles, to quantum theory, such as given by Delbrück and Molière, would find a place at this point; though perhaps that would be going further into statistical mechanics than the author intends. This statistical theory is then used to give a mathematically well-grounded first approximation treatment of absorption and stimulated emission of radiation.

The last two chapters contain discussions of electron spin and approximate relativistic theory and a rather detailed discussion of the problem of atomic structure, in which the assumptions and approximations made are carefully stated. The book concludes with appendices on particular mathematical points and name and subject indexes. It is well printed and this reviewer has discovered very few misprints. That, p. xviii, Condon and Shortley's "The Theory of Atomic Spectra" is attributed to "Oxford" instead of "Cambridge" may perhaps be noted.

L. H. THOMAS

MENDENHALL LABORATORY OF PHYSICS,
THE OHIO STATE UNIVERSITY

SPECIAL ARTICLES

ROD-CONE DARK ADAPTATION AND VITAMIN A

THE association of vitamin A with the visual cycle has by now been firmly established not only indirectly by the occurrence of nightblindness with vitamin A lack,[1] but by the direct chemical identification in the retina of vitamin A and the carotenoid retinene.[2] Because of the presence of nightblindness and of the relation of retinene to visual purple, this association has generally been attributed to the retinal rods, since they mediate vision at low illuminations and contain visual purple.

However, the behavior of the rods and cones is so alike in many visual functions[3] that the association of vitamin A with cone vision also seemed quite probable. This has now been demonstrated by Haig, Hecht and Patek's recent study[4] of the dark adaptation of persons with cirrhosis of the liver. Such individuals are less sensitive to light than normal people, and the loss of sensibility occurs both in cone vision and in rod vision. With substantial additions of vitamin A to the diet, the subjects improve in visual function and become normal. The essential point is that the two retinal systems behave in a parallel manner during the various stages of vitamin A therapy, indicating that vitamin A is just as essential for the restoration of cone visual function as for rod visual function.

In cirrhosis, the flow of vitamin A from food to eye is disturbed by the failure of liver function. One starts with an abnormal visual condition, and by the

[1] L. S. Fridericia and E. Holm, *Am. Jour. Physiol.*, 73: 63, 1925; K. Tansley, *Jour. Physiol.*, 71: 442, 1931.

[2] G. Wald, *Jour. Gen. Physiol.*, 18: 905, 1935, and 19: 351, 1935.

[3] S. Hecht, *Physiol. Rev.*, 17: 239, 1937; "La Base Chimique et Structurale de la Vision," Hermann and Co., Paris, 1938, 97 pp.

[4] C. Haig, S. Hecht and A. J. Patek, SCIENCE, 87: 534–536, 1938.