The chapter on the discharge of torpedoes is necessarily disappointing, as the author is unable to disclose information of a confidential nature.

The most interesting chapter is that which deals with the different stabilities on which the successful navigation depends. There can be no stability of buoyancy when totally immersed; the vessel either rises to the surface, or if it is ever so little heavier than the surrounding water it descends with ever-increasing velocity as the shell becomes compressed until the bottom is reached. When, however, the ship is moving longitudinally, the horizontal rudders determine the rise or fall. The author has no word of commendation for the method of rising or sinking by means of vertical screws.

After discussing shortly the interesting question of lateral stability when floating and when immersed, the author proceeds to the explanation of the effect of the position of the horizontal rudder on the good behaviour of the ship when diving. It seems that the old contest between rear and front steering wheels in tricycles has its counterpart here, and that the front steering, as in the other case, leads to more steady and certain results. The stability of direction depends upon there being plenty of length with fine lines aft. We are told that the submarine of the French Navy, after a run under water of several miles, can come to the surface again on exactly the same course as that which was followed at first.

A series of chapters on motors—steam, electric, petrol—and on tactics bring the author to his conclusion, which shows that he and the French Navy are in grim earnest, and that in his opinion so powerful and insidious a weapon will make naval warfare too terrible to be tolerated any longer. However confident the author may be, and whatever the truth may be, there is in this country much scepticism as to the power of the submarine, as will be gathered from an excellent article in the current number of *Whitaker*, p. 694. C. V. B.

THE DYNAMICAL FOUNDATIONS OF THERMODYNAMICS.

Elementary Principles in Statistical Mechanics. By J. Willard Gibbs, Ph.D., LL.D. Pp. xviii + 207. (New York: Charles Scribner's Sons; London: Arnold, 1902.) Price 10*s.* 6*d.* net.

WHERE a branch of science has been approached exclusively from the deductive side or exclusively from the experimental side, it is far easier to form a correct estimate of our state of knowledge in it than is the case where experimental and deductive methods have been continuously worked side by side. The study of rational dynamics has afforded excellent mental training for those who have made the greatest marks in the world as physicists, notwithstanding the fact that the conclusions arrived at in rational dynamics are in direct contradiction to ordinary experience. Thus it is impossible to verify experimentally that the times taken by *particles* to slide down *perfectly smooth* chords of a vertical circle are equal, and the phenomena of Nature are far too complicated to allow of an experimental test of the velocity with which a boy would have to throw a cricket ball *in vacuo* in order to give it a horizontal range of 200 yards. In the study of thermodynamics, on the other hand, where the experimental has preceded the deductive treatment, as has been the case ever since Joule discovered the so-called mechanical equivalent of heat, much confusion and failure to appreciate correctly our state of knowledge have necessarily resulted, and the only way of evolving order out of chaos is to formulate a theory on a purely deductive basis founded on certain hypotheses. The interest of the theory from a physical standpoint will then depend in the agreement or want of agreement between the conclusions of the theory and the results of observation.

In his study of the equilibrium of heterogeneous systems, Prof. Willard Gibbs, starting from the deductive side, gained a point of vantage which has proved of the greatest possible value to the experimental physical chemist. In his present work the same author is to a large extent following in the footsteps of Boltzmann, Watson and other writers, but at the same time he is imparting a great amount of his own originality, both in form and in treatment, to their work. It is impossible to read this volume without feeling that Prof. Gibbs has been to a great extent imbued with the same spirit which led Dr. Watson to produce the second edition of his excellent treatise on the "Kinetic Theory of Gases." This is a valuable feature, for it would be difficult to produce in a small compass a better introduction to the purely deductive study of the kinetic theory than has been given us by Dr. Watson. But Prof. Gibbs has gone further, and has not only discussed the subject at somewhat greater length, but by clothing the investigation in new language, under the title of "Statistical Dynamics," has presented it in a form in which it can be studied quite independently of any molecular hypothesis as a purely mathematical deduction from the fundamental principles of dynamics.

The study of statistical dynamics is based on the consideration, not of a single body or system, but of a very large number of such systems, and such a collection Prof. Gibbs calls an *ensemble*; moreover, in the course of the work it is found necessary to distinguish between *grands ensembles* and *petits ensembles*. The principle underlying the whole investigation is the well-known determinantal relation (corresponding to § 8 of Watson's book) connecting the initial and final values of the multiple differentials of the coordinates and momenta of an *ensemble*. The precise meaning of this relation has always been exceedingly difficult to grasp. It surely adds considerably to our clear understanding of the property to have it now enunciated as the "principle of conservation of extension in phase." A slightly modified form of enunciation gives the principles of conservation of density in phase, and of probability of phase. A further property is that extension in phase is an invariant in that it is independent of the choice of coordinates.

The most interesting distribution of the coordinates and momenta of an *ensemble* is that determined by a probability coefficient of the form $e^{-h\mathrm{E}}$ which is commonly known as the Boltzmann-Maxwell distribution. Prof. Gibbs calls this the *canonical* distribution, and the limiting case of $h=0$ where the coefficient of probability is unity is called the *micro-canonical* distribution. The discussion of certain maximum and minimum properties leads to considerations of the changes which take place in an *ensemble* of system both when left to itself and when subjected to external influence, also of the results obtained by bringing two canonically distributed *ensembles* within influence of each other. The general conclusion is that there exist in statistical mechanics processes strictly analogous to many of those occurring in thermodynamics. Thus equations may be formulated closely resembling those which represent the irreversible heat-changes between two bodies of unequal temperature. When it comes to choosing a pair of conjugate variables to represent temperature and entropy, it is found that these are not uniquely determined, but that several systems are possible, a fact previously brought out, indeed, by von Helmholtz in his "Statics of Monocyclic Systems."

The last chapter deals with *ensembles* analogous to mixtures of different kinds of molecules, and these the author calls *grands ensembles*. They differ from the *petits ensembles* previously considered in the fact that they contain particles or systems of different kinds which may be present in different numbers.

Prof. Gibbs's work is not very easy to read, and it hardly seems appropriate to apply the title "elementary" to it; but the difficulties are no doubt inherent in the subject. It does much to elucidate the conditions under which a body composed of molecules obeying the equations of rational dynamics presents to beings of comparative dimensions similar to those of the human race attributes which may be summed up in the single word "temperature."

G. H. BRYAN.

AN ATTEMPT AT ORIGINALITY IN THE TEACHING OF ZOOLOGY.

A Course in Invertebrate Zoology. By Henry Sherring Pratt, Ph.D. Pp. xii + 210. (Boston, U.S.A., and London: Ginn and Co., the Athenæum Press, 1902.)

DR. PRATT'S book, defined on its title-page as a guide to the dissection and comparative study of invertebrate animals, is the latest of the many novelties which aim at effecting an improvement on the world-famous Huxleyean system, to which acknowledgment is made. The author sets out with the intention of enabling the student to study the larger groups as a whole, instead of detached types of different groups, as he claims is now generally done. In order to achieve this end, he deals in 174 pp. with no fewer than thirty-four representative animals, and the headlines of some of his chapters even bear the names of two alternative genera, for which a single description is made to suffice. Although this gives an average of little more than five pages for each animal, it must be admitted that, so far as they go, the descriptions and instructions, of necessity of a very elementary form, are lucid and correct.

Without going into further detail concerning the body of the book, it may be said that the essence of its novelty lies rather in the appendix and its associated classificatory scheme. This leads off with a copy of Claus's 1887 system, in which, as an all-conspicuous feature, the Sponges were classed as Cœlenterates, the Enteropneusta as Echinoderms. Then follows a short, but withal a useful, historical sketch of the growth of classificatory systems, from Cuvier to Hatschek, whose scheme of 1888 is given in tabular form, with a succeeding list of "short definitions" which are supposed to be *en suite*, and of which it is remarked that while not exhaustive they "are intended but simply to characterise the various groups in the fewest possible words." The first great subdivision is into subkingdoms (Protozoa and Metazoa), divisions follow, then types, classes, and orders. When, however, on comparison, one finds that while the table provides for five types (Spongiaria, Cnidaria, Trochozoa, Echinodermata, and Chordata), the three first-named are for the definitions numbered in order, and the two last-named are numbered five and six, one is led to seek for number four. The search is vain, since table and definitions do not agree. Most of the descriptions, moreover, in their would-be conciseness, are inadequate. And when with this it is said that, under type Trochozoa, defined as "Metagastrozoans whose common descent and relationship are shown by their possession in some form of a trochophore larva or of an embryonic form allied to it," there are included as subtypes Vermes, Articulata, and Mollusca, further comment becomes unnecessary, except to give it as our opinion that whatever the future of the zoological training of the young, it will not develop on these lines.

The above analysis might be extended with even humorous results; but whatever the good points the book may possess, failure appears to us certain in the attempt to do too much. The would-be new departure is foreign to the best traditions of the Huxleyean system. In the later development of this, the thorough mastery of type-structure has come to be regarded as an alphabet, by which the student learns to read, and the broadest possible survey of the structural limitations of the several groups of which the types are members, as a reading lesson to follow, under the special guidance of the teacher.

OUR BOOK SHELF.

Slide Rule Notes. By Lieut.-Colonel H. C. Dunlop, R.F.A., Professor of Artillery at the Ordnance College, and C. S. Jackson, M.A. (Barrister-at-Law), Instructor in Mathematics R.M. Academy, late Scholar Trinity College, Cambridge. Pp. 66. (London: Simpkin, Marshall, Hamilton, Kent and Co., Ltd., 1901.)

THE slide rule is one of those things which can be less readily explained in writing than verbally. A few words explaining the principle so as to develop the slide rule sense is all that is required to put anyone of reasonable quickness in the way of becoming an adept. On the other hand, the full exposition of the logarithmic theory of the mode of setting for each class of operation, which is essential where the art is to be taught from a book, makes the thing seem so complicated and difficult to remember, that many who would find no difficulty in being taught by the first method might well give it up in despair at the very outset when taught only by the second method. However, it is not given to everyone to be able to find an adept with a power of exposition, and so the book becomes a necessity.