if all the ordinary causes of premature death were eliminated, this would increase the average duration of life by not more than thirteen years. On the other hand, he shows that the children of long-lived parents have an expectation of life which is twenty years greater than that of the average individual.

It is evident, then, that if longevity is our goal it is not medical science we must look to but eugenics, and I doubt whether the question is one with which we are concerned. The sorrow of the world is not the eternal sleep that comes to every one at the end of his allotted span of years, when man rests from his labours. It is the pain, mental and physical, associated with sickness and disability, or the cutting off of a man by disease in the prime of life, when he should have had many years of work before him. To us falls the task of alleviating and preventing this sorrow. In our childhood most of us learnt that suffering and death came into the world through sin. Now, when

as physicians we stand on the other side of good and evil, we know that the sin for which man is continuously paying the penalty is not necessarily failure to comply with some one or other of the rough tribal adjustments to the environment, which we call morality, but is always and in every case ignorance or disregard of the immutable working of the forces of Nature, which is being continually revealed to us by scientific investigation.

In spite of the marvellous increase in knowledge, to some aspects of which I have directed your attention, suffering is still widespread amongst us. Only by following out the injunction of our great predecessor—to search out and study the secrets of Nature by way of experiment—can we hope to attain to a comprehension of “the wisdom of the body and of the understanding of the heart,” and thereby to the mastery of disease and pain which will enable us to relieve the burden of mankind.

The Equation of Van der Waals.¹

By J. H. JEANS, Sec. R.S.

VAN DER WAALS' equation

$$\left(p + \frac{a}{v^2}\right)(v - b) = aT$$

expresses the result of supposing a molecule to be endowed with two distinct physical properties—finite size, giving rise to the term b , and cohesive force, giving rise to the term a/v^2 . The physical meaning of the equation is best exhibited by drawing diagrams of isothermals of the familiar type. Representing different gases there will be different diagrams corresponding to different values of a and b . It is, however, readily shown that one diagram of this type can be made to represent all values of a and b , and so the isothermals of all gases, by suitable expansions and contractions of its horizontal and vertical scales. On removing the scale from any single diagram we have a universal diagram which represents the p, v, T relation for all gases, but without specifying the scale. The circumstance that such a diagram is possible is equivalent to the so-called “Law of Corresponding States”; this is now seen to be a mathematical consequence of Van der Waals having confined himself to a two-constant specification of molecular structure.

Thus the accuracy, or the reverse, of the law of corresponding states provides a test of the sufficiency of Van der Waals' two-constant specification of a molecule. In actual fact the law is not very closely obeyed; the deviations show distinct correlation with atomicity, and so suggest that the two-constant specification is not altogether adequate—a full treatment must take account of differences of atomicity (or physical shape) as well as of differences of size and cohesive power.

Van der Waals explained his cohesive power by the supposition that all matter possesses inherent powers of attraction for all other matter. Gravitational attraction is numerically far too small to come into the question at all, so that it is to the electrical structure

of matter that we must look for the origin of this supposed universal attraction.

If molecules were electrically charged structures, similar molecules would repel one another; as they are electrically neutral, they will repel in some orientations and attract in others, but two molecules meeting at random are as likely to repel as to attract. It is only when the *duration* of molecular encounters is studied that we find an explanation of the preponderance of attraction over repulsion—attractive encounters draw the molecules farther and farther into each other's sphere of influence, and so last longer than repulsive encounters. Comparing the two types of encounters, the “birth rate” is the same for each, but the “expectation of life” is longer for attractive encounters, so that for the encounters in being at a specified instant, there is a preponderance of attractive encounters, and hence a resultant attractive force. This attractive force, however, originates far more in an abstruse theorem of statistical mechanics and far less in an inherent property of matter, than Van der Waals supposed.

If this interpretation is right, the cohesive forces must disappear at very high temperatures and must steadily increase with decreasing temperatures, so that a must be a function of the temperature and not, as Van der Waals supposed, a constant. In point of fact, all attempts to bring Van der Waals' equation into closer agreement with observation begin by making a a function of the temperature. Moreover, a is found to vanish at infinite temperatures in conformity with the suggested explanation.

The second constant b was supposed by Van der Waals to have its origin in the finite sizes of the molecules. If, for example, the hydrogen molecule is regarded as a sphere, its radius as calculated from the observed value of b is found to be 0.64×10^{-8} cm. The same radius can be calculated independently in other ways; the coefficients of viscosity, of conduction of heat and of self-diffusion all agree in yielding the value 0.68×10^{-8} cm. The average of these, 0.66×10^{-8} cm.,

¹ Synopsis of part of the Van der Waals' Memorial Lecture delivered before the Chemical Society on November 8.

would give for the hydrogen atom a volume equal to that of a sphere of radius 0.53×10^{-8} cm. But the normal hydrogen atom, as is now known from the researches of Bohr, consists of two electric charges, describing a circular orbit, one about the other, of radius precisely equal to 0.53×10^{-8} cm. As regards collisions with other molecules, this invertebrate structure, consisting of two point-charges with no material connexion between them, appears to reserve for itself a three-dimensional spherical volume with as much precision as though it were a sphere of infinite hardness.

The explanation of this infinite hardness is to be found in the intangible fetters of the quantum dynamics. The nature of these fetters is not in the least understood, but it is believed that they are such that no force in creation can cause the electron of the hydrogen atom to describe a smaller orbit than the normal orbit of radius 0.53×10^{-8} cm. If it is further supposed that this orbit is free to assume all orientations in space we

begin to understand why it is legitimate, for kinetic theory purposes, to treat the hydrogen atom as an infinitely hard sphere of radius 0.53×10^{-8} cm. The quantum theory brings us back, in a sense, to the infinitely hard spherical atoms of Lucretius, and the radius of these spherical atoms can now be calculated with precision from the quantum theory; their infinite hardness is beautifully exemplified in the experiments of Franck and Hertz.

It is thus seen that the *a* and *b* of Van der Waals admit of exact interpretation in terms of the physical conceptions of to-day. His *b* arises from what we may call the quantum forces—the perfectly unyielding restraints which bind the electrons of an atom down to definite orbits—while his *a* arises from the ordinary electric field of force. It is the *b* of Van der Waals which saves us from immediate annihilation, through positive and negative charges rushing together to their mutual destruction, just as it is his *a* which saves us from rapid disintegration.

The Nerves of Plants.¹

By Prof. HENRY H. DIXON, F.R.S.

THE general similarity of the distribution of the fibro-vascular bundles in plants and that of the nerves in animals was early noticed. These structures in plants were in consequence often called nerves. However, anatomists and physiologists alike have long held the view that the likeness is merely superficial, and is not based on any real physiological or anatomical resemblance.

In plants—as in animals—the receptive and responsive regions are often quite distinct from one another, and may be widely separated. What becomes of the stimulus between the two, and how is it transmitted? Remarkable experiments during the last ten years have given the answers to these questions.

First may be summarised, in a few words, Ricca's work on the sensitive plant, *Mimosa*. The phenomena of transmission of stimuli in this plant are as striking as they are well known. The stimulus is propagated through its organs at velocities variously estimated at 10-20 mm. per sec. This speed is fast among plants, but very slow when compared with the velocity of transmission of stimuli along animal nerves.

Two views were suggested to account for this propagation. The first referred the passage of the stimuli to those excessively fine strands of protoplasm which, penetrating the walls of the living cells, place the protoplasts of adjacent cells in communication with one another. This view was a product of a period obsessed with the physiological importance of these then recently discovered protoplasmic fibrillæ, which, in all probability, have only a developmental significance. These fibrillæ composed of living matter were supposed to convey stimuli just as the living processes of the nerve cells do in the animal body.

This view was soon rendered untenable when it was shown that stimuli are effectively transmitted even after the protoplasm of the cells of the transmitting organs was killed by the application of heat.

To meet this new growth of knowledge Haberlandt developed his theory, that the stimuli are transmitted in *Mimosa* in the form of a pulse in the water filling certain elongated tubular cells situated in the bast of the bundles. At the best this was an unsatisfactory theory. For this method would require a much higher velocity of transmission than is observed, and it was wellnigh impossible to imagine how the turgor requisite to transmit this pulse could be maintained after the protoplasts of these tubes had been rendered permeable by heat.

In 1914 Ricca gave the *coup de grâce* to the pulse theory. He showed that the stimulus is transmitted through a strand of *Mimosa* wood from which all the bast, including the tubes of supposed transmitting function, had been removed for a considerable length. By a series of beautiful experiments Ricca showed that the wood, as Dutrochet long ago believed, transmits the stimulus, and that it does this even when all its living elements are eliminated. Further, he demonstrated that the mechanism of the transport is the transpiration current. This carries in its stream a substance, or hormone, originating from the receptive cells, to the cells of the reactive region and so evokes their response. Ricca's work also disposes of a more recent view that the stimulus is transmitted as an electrical disturbance in the bast.

Almost at the same time as Ricca was disposing of the older views regarding the transmission of stimuli in *Mimosa*, Boysen-Jensen was carrying out experiments on the phototropic reactions of seedlings, which were bound to have a profound effect on the received views regarding the propagation of stimuli.

When the tip of a grass-seedling is illuminated on one side a stimulus is transmitted from the receptive region downwards in the seedling and evokes a curvature in the shaded part. Boysen-Jensen found that this stimulus was transmitted downwards even when the protoplasmic continuity of the cells of the receptive apex with those of the responsive region was severed by complete section.

¹ Synopsis of a lecture delivered before the Royal Dublin Society on November 9.