COLLAPSE OF DETERMINISM

AT the thirty-first meeting of the Indian Science Congress, which met in Delhi in January 1944, the Congress president, Prof. S. N. Bose, discussed "The Classical Determinism and the Quantum Theory", showing how "physicists have gained knowledge but lost their faith". This was supplemented in the Section of Mathematics and Statistics by B. M. Sen, president of that Section, in his address entitled "The Fundamental Equations of Quantum Mechanics". It is difficult to do justice to this without mathematical symbols, so the following article will be based mainly on Prof. Bose's more general treatment.

Classical physics may be said to have begun with Newton. His laws of motion and theory of gravitation gave an explanation of planetary motion which was so satisfactory that it seemed to provide an infallible means of predicting the motion of the solar system. Laplace went so far as to assert that if a sufficiently vast intellect knew the mass, position and velocity of every particle of the universe at any one instant, and the forces acting on them, then "nothing would be uncertain for him; the future as well as the past would be present to his eyes".

It was difficult to fit the phenomena of light into this scheme, since the discovery of interference had shown that light moves like waves rather than like particles. But Maxwell overcame this difficulty by developing Faraday's ideas about the ether. Newton's absolute space was no longer to be regarded as empty, but as a medium possessing energy and momentum, capable of being strained and transmitting waves. This theory was later extended to explain also X-rays, radio signals, and the γ-rays emitted by radium. Maxwell's electromagnetic theory was extended by Lorentz into a theory of electrons. The modifications in the Newtonian scheme had left it stronger than before. Almost everywhere was seen the reign of exact laws. It was true that in thermodynamics physicists had to make shift with laws that applied only to large aggregates, but no one doubted that these were derivable by averaging from exact equations which were too numerous to be conveniently considered individually. The derivation of these averages contained the term probability or chance, but it was always pointed out that really there was no such thing, and that every occurrence could be predicted if all the circumstances were known. It was characteristic of the eighteenth century, the 'age of reason', that Voltaire should assert that "Chance is a word void of sense: nothing can exist without a cause", and Linnæus that "Nature does not proceed by jumps".

These beliefs were rudely shaken by the quantum theory. In 1900 Planck, puzzled by the phenomena of heat radiation, made the revolutionary suggestion that the emission of energy is discontinuous. Soon afterwards Einstein made a similar suggestion about the photo-electric effect. Bohr explained the spectra of hydrogen and other atoms by postulating that an electron must pass discontinuously from one orbit to another. These postulates were empirical, put forward so as to lead up to the results of experiment. They succeeded in this, but at the cost of abandoning the established laws of mechanics and electrodynamics. What seemed a greater break with tradition was called for by the theory of relativity, but in fact this theory does not reject causality. It is true that it denies the existence of absolute time and absolute space, but it sets up a new set of absolute laws in space-time which are independent of all axes of reference. Einstein's success in explaining the slight discrepancy in the motion of the planet Mercury, and in predicting the apparent displacement of stars during a solar eclipse, struck the imagination of the public, but really it is quantum theory that clashes fundamentally with classical physics.

At one time there were hopes of a reconciliation through Schrödinger's wave mechanics, but it turned out that the waves in question are only mathematical fictions. They are excellent as a means of calculation, as they can be treated by the familiar methods of differential equations instead of by the unfamiliar matrices of Heisenberg or Dirac's algebra of observables. However, all three methods are equivalent, and all lead to the same startling conclusion, Heisenberg's Principle of Uncertainty. This shows that if we measure the position and momentum of a stream of electrons, the more accurately we determine the position the less accurately can we determine the momentum, and conversely. Some think that this merely expresses the obvious truth that every experiment interferes to some extent with the phenomena we attempt to measure. Others go further, and interpret the principle to mean that we cannot predict the motion of a single particle exactly, owing to the slight variation of the forces on it caused by atomic structure, although we can obtain statistical laws which hold for the average motion of a large number of particles. But a third interpretation goes so far as to claim that the existence of causality is disproved. Von Neumann claims to have demonstrated that the results of the quantum theory cannot be obtained by averaging any exact causal laws.

Some philosopher-physicists welcome these conclusions, as giving us a hope of escape from the tyranny of an iron law of causation, and assuring freewill to mankind as well as to electrons! However, the majority of physicists regard causality as essential to science, and are hoping to establish a unified theory that will once again reunite all our knowledge into exact causal laws. While the matter is still unsettled, we should do well not to insist on imposing our preconceived ideas upon Nature, but let them evolve and adjust themselves to our growing, if somewhat unmanageable, knowledge of reality.

H. T. H. PIAGGIO.

THYROXINE: ITS BIOSYNTHESIS AND ITS IMMUNO-CHEMISTRY*

THE suggestion that thyroxine might be formed in Nature from tyrosine through the stage of diiodotyrosine was made at an early stage of the elucidation of the chemistry of thyroxine, and was made more probable when the constitution of the latter was finally determined. Over a number of years several pieces of evidence, all indirect in character, were brought forward in support of this biogenetic hypothesis, which thus came to be generally accepted.

Recently two lines of direct evidence have become available which seem to place the matter beyond doubt. In the first place, the transformation of diiodotyrosine into thyroxine has been effected by purely chemical methods of a character which make

* Abstract of the Croonian Lecture of the Royal Society delivered by Dr. C. R. Harington, F.R.S., on July 13.

it possible to formulate a theory of the chemistry of the process involved. Secondly, by the application of modern biochemical technique, the actual synthesis of thyroxine from diiodotyrosine has been demonstrated in surviving thyroid tissue *in vitro*. The latter type of experiment incidentally offers an opportunity for the analytical study of the action of substances such as thiourea, which inhibit thyroid activity supposedly by interfering with the biosynthesis of the hormone.

Accepting the mechanism of biosynthesis of thyroxine as being satisfactorily established, we are left with two outstanding problems. Is thyroxine itself the actual circulating thyroid hormone, and, if so, by what mechanism does it exercise its effect in the periphery ? To the second of these questions no answer can yet be given. Evidence regarding the first is conflicting, and in the attempt to obtain a definitive answer an approach has been made along a new line which raises matters of some general interest. The method is based on the theory, deduced from the known facts of immunological chemistry, that an antigen of which the determinant group is a physiologically active substance should give rise to an antiserum capable of inhibiting the characteristic activity of this substance. Application of this idea to the problem of thyroxine involved the development of a new technique for building up artificial antigenic complexes. Such a complex containing thyroxine as the determinant group has proved to be able to give rise to an antiserum which can inhibit the physiological action both of a protein containing thyroxine, such as thyroglobulin, and of thyroxine itself. The latter observation, together with extension of the experimental method to an entirely different compound, favours the hypothesis that thyroxine itself is in fact the actual circulating thyroid hormone.

INCIDENCE OF RICKETS IN GREAT BRITAIN

DURING the six weeks from mid-January to the end of February 1943 the British Pædiatric Association carried out a combined clinical and radiological investigation into the frequency of rickets in twenty-three areas of Britain and Ireland*. Out of a total of 5,283 children aged 3–18 months, 106 only were reported to show radiological evidence of rickets. Dr. Percy Stocks, who analysed the returns, concluded that the incidence of rickets, diagnosed radiologically, was 2·5 per cent before six months, 4 per cent during the first year and negligible after the first year. The incidence was highest in Ireland and lowest in South England. In Watford and St. Albans no case was detected even by clinical methods. There is no evidence of any increase in the incidence or severity of rickets during the War. In some of the cities of north England, older children with deformities due to severe rickets may still be seen, whereas the cases found in this investigation were slight and free from any gross deformity. It may be inferred that severe rickets was more common a few years ago.

Two points stand out. First, the number of cases diagnosed by clinical methods was nearly ten times the number diagnosed radiologically. Even the three radiologists who examined the films differed in their interpretations. Obviously, we do not yet know what constitutes evidence of slight rickets. But this disagreement is itself evidence of the mildness of the disease, for there is no mistaking severe rickets.

Secondly, 85·5 per cent of the babies that were considered to have rickets on X-ray evidence had had some form of treatment with vitamin D. On this point the report is disappointing. Examiners were supposed to find out what preparation was used, when dosage began, and the daily dose given ; but analysis in terms of the duration of vitamin D prophylaxis and the dosage was not attempted, and the nature of the preparations used is not mentioned in the report. It is little use saying that "scientific evidence has clearly shown that adequate vitamin D administered in an adequate dosage and in a suitable form will prevent rickets", and that "a common cause of rickets is the popular cod liver oil-and-malt", without inquiry into the reasons why 77 out of 4,317 babies who were given vitamin D got rickets. The fashion of handing over the results of an investigation for mechanical analysis by a statistician who may not appreciate the importance of the problems that may be involved has its disadvantages.

* Reports on Pub. Health and Medical Subjects, No. 92. "The Incidence of Rickets in War-time". Pp. 36. (London : H.M. Stationery Office.) 9*d*. net.

MODERN ASPECTS OF INORGANIC CHEMISTRY

THE presidential address by Prof. R. C. Ray to the Chemistry Section of the Indian Science Congress at Delhi dealt with some aspects of modern inorganic chemistry. After mentioning that research in inorganic chemistry had declined towards the close of the nineteenth century, mainly because of the very rapid development of organic chemistry and the rise of physical chemistry, he pointed out that there are very many new aspects of the subject now being developed.

Prof. Ray went on to describe some interesting developments. Compounds of the inert gases with water, boron fluoride and phenol have been obtained, and compounds with metals such as mercury, and iodine, sulphur and phosphorus are described. A subject which has been fully studied, particularly by Stock, Wiberg, Bauer and others, is the chemistry of the hydrides of boron and related compounds, which are also of great interest in relation to the electronic theory of valency. In this field, Indian workers have made important contributions, particularly Prof. Ray and his pupils, who have also worked on the chemistry of co-ordination compounds, glass and hydrides of metals such as nickel.

Nickel forms two hydrides, NiH and NiH_2, and cobalt forms analogous compounds, the heats of formation being comparable with those of the salt-like hydrides of the alkali and alkaline earth metals. The heats of formation of hydrides of some rare-earth metals, zirconium, tantalum and titanium, generally regarded as interstitial compounds, are also of the same order, this suggesting that there can be little difference in the nature of the chemical bond in such substances as zirconium hydride and barium hydride, with nearly equal heats of formation.

Prof. Ray considers that there has probably never been a time when the prospects of inorganic chemistry were so promising as they are to-day, when new methods in physics, physical chemistry and organic chemistry are available.