chemistry, physiology, pharmacology, pathology, entomology, industrial and forensic medicine and food technology. The aim of *Essays in Toxicology*, of which this is the first volume, is to provide a publication which is scientifically accurate and at the same time sufficiently general to be read with profit by the "non-toxicologist". This is an ambitious aim in a world of increasing specialization, but the four essays in this volume illustrate the wide range of what may be regarded as toxicology. The titles of the four essays in this volume illustrate this point. They are "Poisons as tools in studying the nervous system", "Teratology", "The significance of methemoglobinemia in toxicology" and "Lead poisoning. An old problem in a new dimension".

The first essay, by R. D. O'Brien, occupies a third of the book and is an account of how poisons are used to study various forms of nervous transmission, namely axonic, excitatory synaptic and inhibitory synaptic transmission. The essay is an excellent introduction to nerve physiology with a brief account of the history and chemistry of each of the poisons used. It describes how natural and synthetic poisons have been used to study and differentiate the various forms of nerve transmission, the natural tetrodotoxin and synthetic DDT for axonic transmission, the plant poisons atropine, physostigmine, and the like, and the synthetic carbamate and organophosphate insecticides for excitatory synaptic transmission, and strychnine and picrotoxin for inhibitory synaptic transmission. The author suggests that whilst these poisons have served and will serve as tools for the nerve physiologist, they also represent one of the very few available starting points for biochemical work in this field in which our knowledge of biochemical mechanisms is as yet poor apart from the work on GABA (γ-aminobutyric acid), a transmitter substance in invertebrates. This could be regarded as an essay on nerve physiology rather than toxicology, but it illustrates admirably how the information from other sciences can be used to explain certain toxic actions.

The second essay, on teratology, by R. S. McCutcheon, is relatively short but with an extensive and useful bibliography. Although abnormal development and foetal malformations have been studied for more than a century, the author regards teratology as a new science stimulated by the thalidomide episode. The widespread occurrence of thalidomide malformations has led to the need for careful assessment of new and old drugs from the point of view of their action upon the foetus. The terms such as embryo and foetus and conceptus are defined, then the essay covers briefly placental physiology and the part of nutrition, genetic factors, drugs and infectious diseases in teratogenesis. The chief emphasis is on the need for increased basic and analytical research in teratology to replace much of the empirical animal work being done.

The third essay, on aspects of methaemoglobinaemia, by Roger P. Smith, discusses the concept of using a toxic response as a therapeutic measure, namely the generation of methaemoglobin by sodium nitrite in cyanide and sulphide poisoning. The other points which are interestingly discussed are toxic methaemoglobinaemia and its treatment and the contradictory reports concerning the effect of methylene blue in cyanide and carbon monoxide poisoning.

In the fourth essay, on lead poisoning, by P. B. Hammond, attention is drawn to the general problem of environmental pollution, lead being taken as an example. The author surveys lead poisoning in infants, industry and domesticated and wild animals, the metabolism of lead and the mechanism of its toxicity especially through the inhibition of haem synthesis. The new dimension mentioned in the title is that of foresight regarding general environmental pollution. In the case of lead, the author shows that, in the United States in 1966, 1,277,000 tons of lead were consumed, 573,000 tons were recovered, leaving 704,000 tons in the environment. About 20 per cent of the US lead consumption is in the form of the petrol additive, tetraethyl lead (TEL), and 70–80 per cent of the TEL used is released into the atmosphere to be inhaled or deposited on vegetation, soil and water.

These essays show the wide scope of toxicology, which is really a combination of many sciences. The "non-toxicologist" should therefore have no great difficulty in assimilating their content.

R. T. WILLIAMS

Obituaries

Professor Max Born

THE account that follows is a translation of the main part of a memorial address by Professor Werner Heisenberg. The address was given on January 12 at a meeting in Göttingen, where Max Born had died a week before at the age of 87.

Göttingen was Born's true scientific home. By the time he was 22, he was reading mathematics under Felix Klein and David Hilbert; he was introduced by Minkowski to problems in the electrodynamics of moving bodies, and it was here that he heard of the very beginnings of Einstein's theory of relativity and Einstein's light-quantum hypothesis, both of which made a very deep impression on him. Born's own thesis brought him into contact with questions of the elastic oscillations of rigid bodies, and in 1912, together with Theodore von Karman, he published his first scientific work of great significance; this dealt with the oscillations of crystal lattices. At that time the concept of a crystal as a regular ordering of atoms in a three dimensional lattice was generally accepted in principle; but it became a true physical statement only when it was possible to obtain concrete measurable results from the concept of a lattice. Born and von Karman applied the lattice model to the specific heat of the crystals at low temperatures for which Einstein had given a preliminary, although not entirely satisfactory, explanation in terms of Planck's quantum theory. Born and von Karman were able to demonstrate that the specific heat could be expressed even better if instead of considering the individual atoms as vibrating oscillators (as Einstein did), one considers the fundamental oscillations of the crystal lattice as the carriers of the oscillation-quanta. Henceforth much attention was to be paid to the lattice-structure of the crystal. In the same year, X-ray diffraction in crystals was discovered, providing a tool to throw light on the interior of crystals and to test the speculations of theoreticians. In the years that followed, Born continued to publish research on the lattice theory of crystals and assigned to his students doctoral theses connected with this sphere of problems. As late as 1954, when he was 72, he wrote in collaboration with a Chinese colleague a definitive report on this subject.

In 1915, Born was invited to Berlin as professor-extraordinary, where he entered into close association with Planck and Einstein. The four years in Berlin founded, first and foremost, the close friendship of Max Born and his wife Hedwig with Albert Einstein, which endured with undiminished cordiality until Einstein's death in 1955. A great part of Born's scientific deliberations was set down in his extensive correspondence with Einstein. After a brief period as professor in the University of Frankfurt, Born succeeded in 1921 to the professorship of theoretical physics at the University of Göttingen, and he was successful in obtaining at the same time the position of experimental physicist at Göttingen for his friend James Franck. Thus began the decisive new chapter in the history of the Mathematical Scientific Faculty at Göttingen. Up to this time, Göttingen had been a stronghold of mathematics; the tradition of Gauss, Riemann and Weber was consolidated by Felix Klein and Hilbert. And now, through Born and Franck, Göttingen also became a focus of atomic physics. Through his close cooperation with Franck, Born's interest was turned towards quantum theory, which he already knew very well from his contacts with Planck but which had originally repelled him somewhat by its obscurity, since he was so steeped in mathematical precision. With Niels Bohr's invitation to Göttingen in the summer of 1922 there began for Born a period of great activity on Bohr's theory of atomic structure, which found its expression in numerous lectures, seminars and colloquia.

Max Born proved to be an excellent teacher. Very soon he had attracted to his institute a number of gifted young theoreticians from various countries whom he inspired to take part in the study of the difficult problems of quantum theory. Together with Copenhagen, where Niels Bohr founded the new atomic theory, and Munich, where Sommerfeld with his work on atomic structure and spectral lines had founded a school for the new atomic science, Göttingen became a centre of the emerging discipline.

When I look back and compare the two schools of Munich and Göttingen where I was educated, and the teachers Sommerfeld and Born who headed them, I would say that Born bound his young colleagues to him first and foremost by making them still more sceptical of the contemporary state of the Bohr–Sommerfeld theory of atomic structure, and by awakening in his students the conviction that the most important work still remained to be done. In Munich there was still a widely held opinion that the atom could be approached by the old Newtonian mechanics provided that it was supplemented by the quantum conditions as formulated by Planck, Bohr and Sommerfeld. We at Göttingen had already more or less lost faith in this approach as a result of Bohr's lectures at Göttingen in 1922, and in his seminars Born expounded systematically his conviction that ultimately the problem was not one of working out complicated models of atoms and molecules, but rather of creating an entirely new mechanics. In spite of that fact—or rather, because of it—he required his students and colleagues to make a thorough study of the mathematical methods of the older mechanics and to consider them in seminars and discussions. For he rightly expected that only from a mastery of the older mechanics in all its details could there be awakened a consciousness of the scope which could perhaps be found for a new formulation of mechanics.

The seminars often took place in the evenings in a very small circle in the living room of the Borns' villa in an atmosphere of personal contact to which Frau Born, too, made a not inconsiderable contribution. I recall that at the time when I took part in these seminars, the participants very often included Pauli, Fermi, Hund, Jordan, the later Frau Goppert-Mayer and Delbrück. At that time most of them were still young students and only a few of them were over 25 years old. It was only later that they became known as co-founders of a new science, but it was here that they received their training for their future roles.

While speaking of personal contact, it should be mentioned that Born's home provided a good deal of social life for the young people, in which music played a great part. Born often played sonatas with Einstein, and as there were two grand pianos in Born's living room, I was occasionally able to play Mozart or Bach concertos with him. In the discussions at Born's seminars the ground was certainly prepared for the new atomic physics. As early as 1924 the word quantum mechanics was among those concepts which were obvious subjects of study. Born succeeded in producing among his young collaborators a sense of enthusiasm which meant that in the refectory or in the ski-lifts of the Harz mountains, quantum mechanics and the theory of astronomical perturbation were discussed far more than the notable events of the day.

If Born's school is to be compared with Bohr's school in Copenhagen, it should perhaps be said in favour of the Göttingen school that Born had a stronger conviction than Bohr that ultimately there must be a quantum mechanics that is closed and strictly formulated mathematically, and that quantum theory could not long remain in a state of contradiction between Newtonian mechanics, quantum conditions and the light quantum hypothesis. For Bohr, who had picked up the pragmatic tradition from his studies in England, this idea was not of such compelling importance as it was for Born with his mathematical training.

In 1925 and 1926, as a result of the joint work of Born's school, the final form of the new atomic theory was evolved. From his exceptional mathematical knowledge, Born was able to provide the methods of modern linear algebra, matrix calculus and theory of mappings for the representation of the new-found physical relationships. In the spring of 1926, when Schrödinger published his first researches in wave mechanics and proved the mathematical equivalence of quantum mechanics and wave mechanics, Born showed that the Schrödinger waves should be interpreted statistically so that their intensity is taken as a measure of the probability of finding a particle at a given point. The statistical character of natural law was for a long time the great stumbling-block to acceptance of the new theory; even Born and Einstein themselves could not agree on this, although their long-standing friendship was not, of course, affected. Later developments, however, proved that Born's views were the right ones.

In the years that followed, Born, together with his younger colleagues and students, applied the new quantum mechanics to problems of atomic structure, molecular physics and solid state physics. During this period a number of people destined to become the leading minds in physics, including Heitler, Fock, Oppenheimer, Teller, Weisskopf, Wigner and von Weizsäcker, belonged to the Göttingen circle. The intensive work they achieved is too far-reaching in its implications to be discussed here. The University of Göttingen at that time contributed far more to the prestige of German science abroad than most other German universities.

In the spring of 1933, the work came to a sudden halt with the devastation inflicted by the Nazis on Göttingen and all the other German universities. Born and Franck had to leave Göttingen. First of all, Born obtained a lectureship in Cambridge—the Stokes lectureship in applied mathematics, a position far lower than he had held in Göttingen. In 1936 he was offered the Tait professorship in natural philosophy at Edinburgh, and here he remained until his retirement in 1953. In Edinburgh too, Born gathered colleagues and students around him for a combined assault on physics. A series of works appeared on the statistical mechanics of condensed systems, the theory of fluids and associated problems. But the great activity of the Göttingen years could not be repeated in the Scottish university city, if only because in the meantime the interest of many physicists had turned to other problems. Nuclear physics was now the chief point of discussion. But Born did not take part in these developments. The possibility of the technical application of nuclear physics and the use of atomic energy became, at the end of the thirties, with Otto Hahn's discovery of uranium fission, the most exciting topic for atomic physicists. Born observed this development with great concern; he was dismayed at the possible consequences of these significant scientific advances and strove to minimize the danger.

Correspondence

X-Ray Stars and Infrared Excess

SIR,—In the course of his article on January 3, your Astronomy Correspondent says that Cowsik and Pal[1] are credited with the observation that " . . . the infrared flux might also be the cause of the X-ray background in the galactic plane which the Leicester group reported in October. . . . "

The fact is that the first article suggesting this mechanism for X-rays is the *Phys. Rev. Lett.*[2] article of the undersigned. Furthermore, when the Leicester results were reported in *Nature*, we published a further article (in *Nature*[3])—which also pre-dated the Cowsik–Pal article—discussing the anisotropy of the X-rays.

Yours faithfully,

ROBERT F. O'CONNELL
SATYA DEV VERMA

Louisiana State University
and Agricultural and Mechanical College,
Baton Rouge,
Louisiana 70803.

[1] Cowsik, R., and Pal, Y., *Phys. Rev. Lett.*, **23**, 1467 (1969).
[2] O'Connell, R. F., and Verma, S. D., *Phys. Rev. Lett.*, **22**, 1443 (1969).
[3] O'Connell, R. F., and Verma, S. D., *Nature*, **224**, 505 (1969).

Diffusion in Embryogenesis

SIR,—As an embryologist who started work during the heyday of "fields" and "gradients", I suppose I ought to be grateful to Dr Francis Crick for allowing me a nostalgic look back at these long-discredited concepts which he has now resurrected—or should I say, canonized—with the double halo of his own reputation and some elegant mathematics (*Nature*, **225**, 420; 1970). There is, however, one point that he appears to overlook: the extreme rarity with which sheer diffusion processes occur in living systems. Twenty years ago my better-informed colleagues told me about active transport and permeases. Ever since then, if materials have diffused in and out of my experimental embryos, I have regarded it as a sign that they are dying or dead. A sheet of frozen-dried tissue, extended between source and sink, might fit Dr Crick's formulae, but—alas—it would not differentiate!

Yours faithfully,

ELIZABETH M. DEUCHAR

The Medical School,
University of Bristol.

British Diary

Monday, February 16

Contention or Polling Techniques for Data-Computer Systems (5.30 p.m. discussion) Institution of Electronic and Radio Engineers. Joint IEE/IERE Computer Group, at the Institution of Electrical Engineers, Savoy Place, London WC2.

Insect Hormones and Insect Control (5 p.m.) Dr K. C. Highnam, Society of Chemical Industry, at 14 Belgrave Square, London SW1.

Recent Advances in Medicine, Surgery and Therapy (6 p.m.) Sir Brian Windeyer, Royal Society of Arts, at John Adam Street, London WC2. (First of three Cantor Lectures. Further lectures on February 23 and March 2).

The Treatment and Disposal of Industrial Effluent (all-day symposium) Institution of Mechanical Engineers, at 1 Birdcage Walk, London SW1.

Tuesday, February 17

Acrylates, Their Production and Use (6 p.m.) Dr H. Willersinn, Society of Chemical Industry, at 14 Belgrave Square, London SW1.

Amplification Reactions and their Applications (4.30 p.m.) Professor R. Belcher, Society for Analytical Chemistry; and the Edinburgh University Chemical Society, in the Chemistry Department, University of Edinburgh, West Mains Road, Edinburgh 9.

Casting of Polyurethanes (2.30 p.m.) Plastics Institute, Processing Discussion Circle, at 11 Hobart Place, London SW1.

Cereal Growing in Britain (10 a.m.) Society of Chemical Industry, Agriculture Group, at 14 Belgrave Square, London SW1.

Discriminators for Broadcast FM Transmission (6.30 p.m.) Mr Hugh Mayo, Institution of Electronic and Radio Engineers, at Brighton College of Technology, Brighton.

Experimental Gallstones (5.30 p.m.) Dr I. A. D. Bouchier, University of London, at the Institute of Child Health, 30 Guilford Street, London WC1. (Twelfth of fifteen lectures on "The Scientific Basis of Medicine".)

Ionisation by Coordination (2.30 p.m.) Professor V. Gutmann (Vienna), University of London, in the New Chemistry Theatre, University College London, Gower Street, London WC1. (Further lecture on February 18).

Ocean Resources—Boom or Bubble? (1.20 p.m.) Professor L. J. Rydill and Dr A. J. Smith, University of London, in the Botany Theatre, University College London, Gower Street, London WC1.

System Identification with special reference to Respiration (5.30 p.m.) Dr I. Priban, Institution of Electrical Engineers; the Institute of Measurement and Control; and the Automatic Control Group of the I.Mech.E., at Savoy Place, London WC2.

The Management of Climatic Resources (5.30 p.m.) Professor T. J. Chandler, in the Chemistry Auditorium, University College London, Gower Street, London WC1.

The Volcano at Santorini and the Destruction of Minoan Crete (5.30 p.m.) Professor D. L. Page, University College London, in the Collegiate Theatre, 15 Gordon Street, London WC1. (Further lectures on February 19 and 24).

Wednesday, February 18

Cybernetics (7.30 p.m.) Dr A. M. Andrew, Institution of Electronic and Radio Engineers, at the University of Reading, Whiteknights Park, Reading.

Development and Marketing of New Chemical Engineering Equipment (2 p.m. symposium) Institution of Chemical Engineers, at the Royal Society, Carlton House Terrace, London SW1.

Factors Limiting the Application of Food Science and Technology in Developing Countries (2 p.m.) UK Coordinating Committee for Food Science and Technology, at the Society of Chemical Industry, 14 Belgrave Square, London SW1.

Gravitation and Geometry (5.30 p.m.) Professor P. C. Vaidya (Gijarat), University of London, at Queen Elizabeth College, Campden Hill Road, London W8.

Mass Communication (6 p.m.) Mr Stanhope Shelton, Royal Society of Arts, at John Adam Street, London WC2.

Microscopical Illustration (1 p.m.) Mr G. L'E. Turner, Royal Institution, History of Science Discussion Group, at 21 Albemarle Street, London W1.

Recent Advances in Radar Anti-Clutter Techniques (5.30 p.m.) Dr W. S. Whitlock, Institution of Electrical Engineers, at Savoy Place, London WC2.

Solute-Solvent Interactions (5.30 p.m.) Professor Viktor Gutmann, University of London, at King's College, Strand, London WC2.

Street Lighting (5.30 p.m. discussion) Institution of Electrical Engineers, at Savoy Place, London WC2.

The Measurement of Ships' Velocity (5 p.m.) Mr B. W. Oakley, Institute of Navigation, at the Royal Institution of Naval Architects, 10 Upper Belgrave Street, London SW1.

The Presentation of Data from a Process Control Computer (7.30 p.m.) Institution of Chemical Engineers, in Room G44 Royal Fort, University of Bristol.

The Professional Engineer as an Industrial Tutor (6 p.m. discussion) Institution of Mechanical Engineers, at 1 Birdcage Walk, London SW1.

The Role of The City University (1.10 p.m.) Sir James Tait, City University, at the Graduate Business Centre, Gresham College, Basinghall Street, London EC2.

Use of Computers in Designing Automatic Process Controllers (6 p.m.) Mr D. J. Norton, Institution of Electronic and Radio Engineers; and the Institution of Electrical Engineers, at the University of Bristol.

Thursday, February 19

Amino-Acids and Peptides in Gut and Kidney (5.30 p.m.) Professor M. D. Milne, University of London, at the Institute of Child Health, 30 Guilford Street, London WC1.