graphic film by use of these techniques that permits a determination of a 3-mr. γ -ray exposure with a precision of ± 0.2 mr.

A very promising approach to the problem of determining human exposure to low-level ionizing radiation has evolved out of the recent development of thermoluminescent materials for personnel dosimetry. Commercially available dosimeter systems using lithium fluoride²³ and calcium fluoride²⁴ are claimed to provide measurable responses at the 10-mr. and 5-mr. level of γ -ray exposure, respectively, with approximately ± 20 per cent accuracy (*S.D.*). These limits may eventually be somewhat lowered and the precision improved with refinements in read-out techniques. Cullen²⁵ has recently utilized 156 lithium fluoride dosimeters for a population exposure investigation in a high background area in Brazil, with 50 mg of the material placed in religious medals to be worn for a three-month period. This exposure time provided a total γ -dose of several hundred milliroentgens, well above the minimum now routinely detectable. In general, thermoluminescent dosimeters have the significant advantages of small size and relatively low unit cost, and may prove to be a useful tool for future population investigations. The Health and Safety Laboratory is at present engaged in evaluating the available thermoluminescent dosimeter systems for their applicability to the routine measurement of human exposure to environmental radiation, and field tests along the lines of the New England survey are planned when sufficiently promising dosimeter systems are developed.

These recent advances in direct personnel dosimetry, particularly in the extension of the sensitivity limits to ever lower γ -dose levels, render the detailed examination of human exposure to environmental radiation on a routine basis increasingly feasible, even in the extremely low-level radiation fields that are characteristic of the normal environment. But the reliability and reproducibility of the readings of the various types of dosimeter in terms of absolute dose under the stresses of actual field use remain to be thoroughly explored. The New England survey results seem to indicate the adequacy of *in situ* measurements in establishing a radiation profile over extensive areas, a profile that when sufficiently uncomplicated may be properly interpreted in terms of population exposure to environmental radiation. These results also emphasize some of the problems associated with adequately calibrating the response of personnel dosimeters under field conditions. It appears that the use of highly accurate ionization-chamber and spectrometric techniques for *in situ* measurements will be required in the near future for all population studies of the type described

here, if only to provide a standard by which the adequacy of the new techniques for direct human exposure measurements can be determined (for example, ref. 20). Eventually, it is anticipated that the logistically difficult *in situ* approach will be completely superseded by direct measurements of radiation incident on representative individuals in their daily rounds.

We thank our colleague, H. L. Beck, as well as several Health and Safety Laboratory summer students, including J. Grebowski, H. Grotch and I. Hammerman, for their assistance with the outdoor survey. A. Spiegall carried out the indoor measurements. Many helpful discussions have been held with Dr. A. Segall of the Harvard School of Public Health, who co-ordinated the various parts of the New England survey and who kindly supplied the dosimeter results. We also thank J. E. McLaughlin, director, Radiation Physics Division, Health and Safety Laboratory, for his advice and support.

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OBITUARY

Prof. G. N. Watson, F.R.S.

PROF. G. N. WATSON, who died at his home in Leamington Spa on February 2, 1965, was born at Westward Ho! in 1886. He was educated at St. Paul's School, London, and Trinity College, Cambridge; he was Senior Wrangler in 1907, and was awarded a Smith's Prize in 1909. He was a Fellow of Trinity College from 1910 until 1916. After a short period at University College, London, he was appointed Mason professor of mathematics in the University of Birmingham in 1918, and he remained there until his retirement in 1951. He was an honorary LL.D. of Edinburgh, and an honorary Sc.D. of Dublin. He was awarded the Sylvester Medal of the Royal Society in 1946, and the De Morgan Medal of the London Mathematical Society in 1947. He leaves a widow and one son.

Prof. Watson played a prominent part in the London Mathematical Society, serving on the Council for more than twenty-five years, and taking the onerous position

of honorary secretary from 1919 until 1933. He was president of the Society during 1933-35.

Prof. Watson was part author of *Modern Analysis*, and author of the *Theory of Bessel Functions*, a book still in daily use among those who have to work with Bessel functions. In referring to this book, one cannot do better than quote the words spoken of it by the late Prof. Titchmarsh in presenting the De Morgan Medal. "I well remember the excitement and admiration with which I plunged into this great work, from which I have never really emerged. Here, one felt, was mathematics really happening before one's eyes. The theorems proved were obviously of the highest interest, and yet it was a book in which one did not have to rack one's brains to discover what the author could possibly mean. The older English mathematical books were full of mystery and wonder. With Prof. Watson we reach the period when the mystery is dispelled, though the wonder remains."

Although Watson was probably more widely known for his books, he produced a very large number of original papers on such topics as asymptotic expansions, Bessel functions, singular moduli, and problems arising out of the work of Ramanujan. He had a remarkable power of solving special problems. Much of his work was suggested by physical problems; but he was not really interested in the physical applications, being concerned only with the mathematical aspects of a problem.

While it is impossible in a short notice to deal adequately with Watson's original work, there are two papers of his which may, perhaps, be singled out for mention. One is that on 'general transforms', or, as they are sometimes known, Watson transforms. It has long been familiar that, under suitable conditions on $f(x)$, the relation:

$$g(x) = \int_0^\infty k(xy) f(y) dy \quad (1)$$

implies that:

$$f(x) = \int_0^\infty k(xy) g(y) dy \quad (2)$$

when $k(u)$ is either of the functions $\sqrt{(2/\pi)} \cos u$, $\sqrt{(2/\pi)} \sin u$. This raises the question of determining the most general function $k(u)$ (satisfying appropriate restrictions) for which the same result holds. The problem was investigated independently in two papers, both published in 1933, one by Watson, and the other by Hardy and Titchmarsh. The two papers are complementary rather than overlapping. Without going into details, one can say roughly that Hardy and Titchmarsh required (1), (2) to hold in the sense of ordinary convergence, or some simple summability method, and therefore had to impose rather severe restrictions on the functions considered; whereas Watson required only that (1), (2) should hold in

some more general sense, and was therefore able to obtain results under much weaker restrictions.

One of Watson's last papers was on periodic sigma functions. The sigma function $\sigma(z)$ is defined by:

$$\frac{d^2 \log \sigma(z)}{dz^2} = -p(z)$$

where $p(z)$ is the Weierstrassian elliptic function; the two arbitrary constants implicit in this definition are fixed by specifying the behaviour of $\sigma(z)$ near the origin. The function $\sigma(z)$ differs from $p(z)$ in not being doubly periodic; in place of the relations:

$$p(z+2\omega_1) = p(z+2\omega_2) = p(z)$$

(where $2\omega_1, 2\omega_2$ is a pair of primitive periods), we have:

$$\sigma(z+2\omega_1) = -e^{2\eta_1(z+\omega_1)} \sigma(z);$$

$$\sigma(z+2\omega_2) = -e^{2\eta_2(z+\omega_2)} \sigma(z);$$

where η_1, η_2 are constants depending on ω_1, ω_2 . Elliptic and related functions had been so extensively investigated that one would not have imagined that any major problem connected with them remained to be considered. It was, however, left for Watson to point out that, while $\sigma(z)$ cannot be doubly periodic, it may be singly periodic. It is clear that this will happen if $\eta_1 = 0$, the period then being $4\omega_1$; Watson showed that any case in which $\sigma(z)$ is singly periodic can be reduced to this case by a suitable choice of the primitive periods. This is fairly easy; a much harder problem is that of determining in what cases (if any) the relation $\eta_1 = 0$ is, in fact, satisfied. Watson showed that $\eta_1 = 0$ if, and only if, the ratio ω_2/ω_1 takes one of an enumerably infinite set of values; and he investigated this set of values in some detail.

On his retirement, Watson expressed his intention of preparing a new and enlarged edition of *Modern Analysis*. It appears that this was never completed; and the world of mathematics is the poorer. B. KUTTNER

NEWS and VIEWS

U.S. National Academy of Sciences : Foreign Associates

THE following have been elected foreign associates of the U.S. National Academy of Sciences:

Prof. J. Brachet, professor and director of the Laboratoire de Morphologie Animale, Université Libre de Bruxelles. Prof. Brachet's work has been concerned with the distribution of two types of nucleic acid (DNA and RNA) in the cell and with interactions between the nuclear material of the cell and the surrounding cytoplasm.

Dr. J. M. Harrison, deputy to the Deputy Minister of Mines and Technical Surveys, Ottawa, Canada, and former director, Geological Survey of Canada. Dr. Harrison has made notable contributions to the understanding of the geology of the Canadian shield, particularly in working out the relation of ore deposits to complex Precambrian structures.

Prof. W. R. Hawthorne, Hopkinson and Imperial Chemical Industries professor of applied thermodynamics, University of Cambridge. Prof. Hawthorne's major contributions have been in connexion with aircraft propulsion, particularly in the development of turbo-type engines and related fundamentals of fluid mechanics and combustion.

Dr. P. B. Medawar, director, National Institute for Medical Research, Medical Research Council, Great Britain. Dr. Medawar's work has been concerned with tissue transplantation, including the demonstration of the phenomenon of acquired immunological tolerance in experimental animals for which he was awarded the 1960 Nobel Prize for Physiology and Medicine.

Prof. Jean Leray, professor, Collège de France, Paris. To further the field of partial differential equations, Prof. Leray has delved deeply into algebraic topology and related fields, introducing new concepts and methods which have been a major factor in revolutionizing parts of homotopy theory, algebraic geometry, and modern analysis.

Dr. Sin-Itiro Tomonaga, president of the Science Council of Japan. Dr. Tomonaga has been a leader in the active and productive development of the field of theoretical physics in Japan and, in addition to his own research on nuclear forces, quantum field theory, cosmic rays, and many-body problems, has played an important part in the over-all development of Japanese science and education.

New Members

Prof. R. A. Alberty, professor of chemistry, University of Wisconsin; Dr. J. G. Baker, research associate, Harvard College Observatory, and consultant in optical physics; Prof. R. H. Bing, professor of mathematics, University of Wisconsin; Prof. D. H. Blackwell, professor of statistics, University of California, Berkeley; Prof. G. H. Büchi, professor of organic chemistry, Massachusetts Institute of Technology; Dr. J. W. Chamberlain, associate director, Space Division, Kitt Peak National Observatory; Prof. Erwin Chargaff, professor of biochemistry, Columbia University College of Physicians and Surgeons; Prof. R. F. Christy, professor of physics, California Institute of Technology; Prof. V. G. Dethier, professor of zoology and psychology, and associate, Neurological Institute,