but no similitude with the full-scale phenomenon was claimed.

Mr. R. L. Maltby (United Kingdom) based his presentation on one of five papers which have been prepared for an AGARDOgraph on flow-visualization, and which describes the methods used in British low-speed wind tunnels. In addition to the usual 'smokes', mention was made of the use of soap bubbles. Condensation trails can form a natural method of visualizing the leading-edge vortices from swept wings when the vorticity is of sufficient strength to produce the condensation.

Moving from methods suitable for use in low-speed tunnels to those for high-speed flow visualization, J. L. Solignac (France) described interferometric apparatus used at the Office National d'Etudes et de Recherches Aéronautiques. One of these employed split-beam interferometry, whereas the other, which was developed there, was a schlieren-interferometer system using polarized light. As compared with the ordinary schlieren system, the latter method was claimed to have the advantages of simplicity as well as of the ability to make quantitative measurements.

C. SCRUTON

PRIMARY AND INITIAL EFFECTS OF IONIZING RADIATIONS

PROF. G. M. FRANK organized in Moscow during October 18-22, on behalf of the Academy of Sciences of the U.S.S.R., an international symposium which was sponsored by Unesco and the International Atomic Energy Agency. Half the thirty participants came from countries other than the U.S.S.R. As the contributions ranged widely and encompassed several disciplines, the classification under the headings chosen for this report must be somewhat arbitrary.

Interference with Intracellular Structures

The concept that the initial radiochemical reaction leading to the death of a cell is brought about by interference with the intracellular organization of the cell found support from many of the participants. In the first of the scientific papers, P. Alexander (London) reviewed the chemical data concerning damage to proteins and nucleic acids by ionizing radiation, and concluded that reactions of this kind, although they occur in cells, as do many others, did not meet the requirements for the radiochemical events that initiate cell death. He suggested the phospholipids of the intracellular membranes as a more probable site. Since one of the most frequent and earliest biochemical lesions following irradiation is an increase in enzymatic activity, it had been proposed by Bacq and Alexander (enzyme-release hypothesis) that radiation interferes with the structures within the cell that are responsible for its essential compartmentalization. G. M. Frank (Moscow) provided a striking demonstration of an increase in metabolism within an hour of irradiation by showing that the time taken for oxygen-levels in the brain to return to normal after a short period of inhalation of pure oxygen was less in an irradiated animal. The same technique also revealed that radiation immediately interferes with the homeostatic maintenance of oxygen-levels in tissues.

L. A. Stocken (Oxford) and M. Errera (Brussels) described their experiments on the immediate effect of X-rays on the metabolism of the nuclei of rat thymocytes. Stocken concluded that low doses produce local disorganization of the nucleus, which alters binding sites, and he outlined his current research programme directed to discovering the factors that maintain the nucleus in an organized state. Changes in the structure and behaviour of cytoplasmic fine structures within minutes of irradiation were seen by M. N. Meissel (Moscow) using fluorescent vital staining and by A. Shabadash

(Moscow) with histochemical techniques. O. Hug (Munich) reported that smooth muscle was unexpectedly radiosensitive, and contracted with a dose of a few hundred röntgens so long as this was given at a sufficiently high dose-rate. He interpreted this effect as a temporary change in permeability of the nerve (or muscle) membrane.

A. M. Kuzin (Moscow) observed mitotic inhibition in the tip of the bean root (*Vicia faba*) although only a leaf had been irradiated. An antimitotic substance could be extracted from irradiated leaves and on purification was shown to be a soluble oxidation product of a polyphenol (a quinonoid substance). Evidence was found in support of the view that the active substances were formed as the result of the release (activation?) of enzyme peroxidases from cytoplasmic organelles.

A. J. Passynsky (Moscow) was led by general kinetic considerations to the view that death of a cell by radiation was due to interference with the orderly sequence of biochemical events due to damage to the interphases at which they occur. Experiments in a model system illustrated the breakdown of membranes by 20,000 r. of X-rays. Particles of an enzyme were coated with a layer, approximately 100 Å. thick, of ribonucleic acid and then suspended in a solution of substrate. Enzymatic activity was accelerated on irradiation because the permeability of the ribonucleic acid film was increased. N. N. Doemin (Moscow) carried out a very detailed study of the effect of radiation on the lipids and lipoproteins in different sub-cellular fractions (microsomes, mitochondria); surprising differences were observed in different organs of the rats, though in every case early lesions among lipids were observed.

B. N. Tarusoff (Moscow) has found that the concentration of lipid peroxides in tissues of mice increases with time after irradiation, which initiates the oxidation chain. A correlation was seen between the peroxide-level and the time of death of the animal, and Tarusoff supports the view advanced some years ago by J. St. L. Philpot that toxic peroxides contribute to radiation death in mammals.

Genetic techniques using 'sexual' transfer between biochemically deficient mutants were used by H. Marcovich (Paris) to show that the killing of *E. coli* (that is, the loss of ability of the cells to proliferate indefinitely and form colonies) could not be attributed to a dominant lethal mutation. K. Tobias (Berkeley), on the other hand, argued that killing of yeast and the very complex relationship between ploidy and radiosensitivity could be adequately explained as the

combined action of dominant and recessive lethal mutations.

A comprehensive mathematical formulation of the processes leading to cell death was presented by A. V. Lebedinsky (Moscow), who considered the simultaneous occurrence of repairable interference with metabolism and irreversible blocking of mitosis.

Modification of Radiation Damage

Death of a cell, rate of mitosis, chromosome damage, mutation production can be altered by a variety of post-irradiation treatments in unicellular organisms and some plant materials. N. I. Shapiro (Moscow) has now found that chromosomal damage in Ehrlich mouse ascites cells irradiated *in vitro* and then injected back into the animal can be substantially reduced if the cells are suspended in a medium containing arginine for 1 hr. after irradiation. A. Hollaender (Oak Ridge) reported that genetic damage in *Paramecium* could only be repaired if the post-irradiation treatment was begun before chromosome duplication had occurred. Shapiro's data could bear a similar interpretation. Powerful synergism in the amount of chromosome damage was found at Oak Ridge if a dose of X-rays was followed by ultra-violet irradiation within a comparatively short time. F. Herčík (Brno) demonstrated that the treatments that result in the recovery of *Paramecium* also lead to recovery of the phage-synthesizing capacity of *E. coli* in spite of the fact that doses of the order of 5×10^5 r. are needed to inhibit this synthetic process. Another Czech scientist, J. Soška, finds that the regeneration of bone-marrow *in vivo* is significantly increased by the administration of cytidylic and thymidylic acid, but not by purine nucleotides. Interference by radiation with deoxyribonucleic acid synthesis of bone-marrow cells *in vitro* is reduced by the addition of triphosphates to the medium.

The reduction of the killing action of X-rays for mammalian cells in tissue culture by fractionation had been interpreted as evidence that post-irradiation restoration processes occur normally. On repeating these experiments with α -rays from polonium, J. W. Barendsen (Netherlands) could find no evidence for recovery, suggesting an important qualitative difference between densely and sparsely ionizing radiations.

Radiation response can also be modified by treatments that have to be given before and during irradiation. L. H. Gray (London) provided further evidence that the radiosensitizing action of oxygen cannot be attributed to early post-irradiation metabolic processes, but that it must be connected with the immediate radiochemical events. The phenomenon is, however, far from simple, and B. N. Tarusoff (Moscow) has shown that there is an optimum oxygen concentration for sensitization in the case of yeast cells. If the amount of oxygen in the atmosphere exceeds 80 per cent the cells become less radiosensitive. This observation is interpreted as support for the view that a branched, oxidative chain-reaction is involved in the initiation of radiation damage.

The mechanism of radiation protective agents received much discussion. Z. M. Bacq (Liège) stressed that the almost universal protective action of cysteamine arose from the fact that this substance could protect by at least three different physico-chemical mechanisms: radical capture, energy trans-

fer and 'repair' by transferring a hydrogen atom to an organic radical. There was no reason for believing that in biological systems the same chemical mechanism was involved in every case. In mammalian systems radical capture or 'repair' seemed the most probable and the suggestion that cysteamine protected mammals by producing anoxia had to be rejected. This view was strongly supported by the extremely detailed investigations of E. Y. Grayevsky (Moscow). His group showed that the protective action of hypothermia, neurotropic substances and substances combining with haemoglobin, but not of cysteamine, was directly attributable to a fall in oxygen tension in the radiosensitive tissues to less than half the normal value. L. H. Gray (London) showed that the protection of cell suspensions *in vitro* by aliphatic alcohols was also not related to the oxygen effect. Evidence that protection against the mutagenic action of X-rays is independent of protection against death of the cells was presented by A. Hollaender (Oak Ridge). 10^4 r. kills no cells of *Aspergillus terreus*, but the number of mutations produced by doses of this order is greatly reduced by cysteamine.

P. Alexander (London) interpreted his results on radiosensitization as showing that substances which are normally present in the cell can act as intracellular protective agents. Blocking of sulphhydryl groups of lymphoma cells by iodoacetate was responsible for the radiosensitization of these cells by this substance. The great variation in the radiosensitivity of micro-organisms may in part at least be due to the presence of particularly effective intracellular protective substances; for example, carotenoid pigments.

Radiosensitivity of Biological Macromolecules

E. C. Pollard (Yale) described the use of radiation as an analytical method for determining the size and shape of functional units within cells. He deduced that the organelle responsible for protein synthesis was a unit having the weight of a microsomal particle, but with highly asymmetric shape. This quite unexpected finding receives striking support in recent electron microscopic studies on sections of frozen dried cells which have suggested to some workers that the microsomal particles can assume a sheet-like character. L. H. Gray (London) interpreted death of a bacterial cell as a single-hit target event, since he finds the dose-response curve to be accurately exponential over a vast range. On the other hand, J. W. Barendsen (Netherlands) finds that a target type interpretation cannot be applied to mammalian cells since the log (survivor) v. X-ray dose-curve never becomes truly linear and increases continually in steepness. K. Tobias (Berkeley) presented data showing that the determination of 'target sizes' was impossible even for isolated pure proteins, as there was interaction between particles.

L. A. Blumenfeld (Moscow) gave a detailed review of what can be learnt from the electron spin resonance patterns of irradiated proteins and nucleic acids and provided further evidence for his own well-known theories on the presence of conduction bands in native proteins. The use of electron spin resonance for discovering the nature of the initial lesion is very limited, as almost all cell constituents give rise on irradiation to radicals. All these radicals are seen by electron spin resonance, although many of them have

no part in the biological effects. E. L. Powers (Argonne, U.S.A.) used the electron spin resonance method to good effect to confirm the presence of a number of different types of trapped free radicals which remain in the dry spore after irradiation. He observed that post-irradiation treatments with hydrogen sulphide and nitric oxide reduced the number of spores rendered non-viable, while exposure to oxygen enhanced damage. Electron spin resonance measurements indicated that these effects were due

to reaction with trapped radicals. In swollen systems, such as vegetative cells, radicals have only a very short lifetime, and to be detected a 'flash radiolysis' technique has to be used. L. H. Gray described some results obtained in this way. Mrs. B. Holmes (Cambridge) described experiments of J. S. Mitchell which revealed the existence in irradiated mammalian tissues of relatively long-lived excited molecules that emit ultra-violet light after irradiation.

PETER ALEXANDER

COKE RESEARCH

NOT all annual reports of technical, or even non-technical, activities provide an absorbing story of events of interest to others than the specialist. The sixteenth annual report of the British Coke Research Association, however, is noteworthy for a new feature in the form of a very clearly expressed appendix, in which an attempt is made to clarify the objectives of the programme of research*. Any likely developments that may point to the future importance of coal should be of interest to many engineers and technologists, and indeed to quite a number of laymen engaged in pursuits perhaps of greater philosophical calm. Particularly so must be the situation at the present time, when one hears so much of the potentialities of oil and nuclear fuels, and when hoping that the price of coal was tending to find a stable keel, one is startled by new economic storms. In a refreshing and lucid manner the research objectives of an important industry on which the future of steel and coal must depend to a substantial measure are set out in a manner that brings conviction of the care and thought given to their preparation.

The interested reader will learn that 40 per cent of the research effort of the British Coke Research Association is devoted to the improvement in quality and yield of metallurgical coke, and that a further 28 per cent is devoted to work designed to throw light on phenomena and factors that govern the efficiency of use of all types of coke.

The modern blast furnace requires a coke of consistent quality in respect of its physical and chemical properties. The Coke Research Centre at Wingerworth has its small experimental ovens and the industrial scale 10-ton oven in which the various factors may be worked out to enable the optimum conditions to be arrived at for the carbonization of a 'standard' coal. At the same time, attention is devoted to the yields and nature of the by-products from the point of view of the efficiency and economy of the coke-oven process in general.

In the scientific work on coke the more advanced techniques of physical science such as X-ray diffraction have long been used. The latest techniques, that are now finding a place in the elucidation of a workable understanding of the structure of carbon and the texture of coke, are concerned with magnetic susceptibility and microwave absorption. Perhaps the lessons of the value of the more abstruse techniques necessary in fundamental investigations are not lost in these days on the comprehension of the

layman, even if the mysteries of the techniques themselves seem to provide rather heavy going. In the present instance the ultimate answer may well be the means of production of cokes, capable of superior performance in use, from supplies of coal of unexpected suitability.

In the programme of research two other broad fields of interest are considered: first, the magnitude and complexity of the coke oven effluent and atmospheric pollution problems; and secondly, new methods of making blast furnace coke. In the former, the problem becomes an issue common with many other industries, and it is thus only a part of a larger national issue being considered by the Department of Scientific and Industrial Research. In the latter the matter is at the design-study stage where the fundamental requirements of the problem have to be analysed, the estimates of the chances and conditions of success determined, and some practical course of research devised.

The report of the achievements of the year covers not only the work on the new full-scale test plant but also that of the fundamental and applied studies laboratories at Wingerworth, and the progress achieved by work in the universities, notably at King's College, Newcastle upon Tyne. In this last case the technique of electron resonance absorption has been used to follow in the course of coke formation the development of reactive centres, described as 'free radicals'. They are formed in coke at temperatures up to 800° C., and play a part in the fixation of sulphur as organic sulphur in coke. At the University of Leeds work on the flow of heat in the coke oven during carbonization has been prosecuted with the application of a digital computer. This work constitutes a further proof of the potentialities of the use in this manner of the unsteady heat conduction equation in the solution of practical problems.

Also of specific interest to scientist and technologist alike is the correlation found, almost to a surprising degree, between the results of the performance in carbonization from a 5-cwt., a 10-ton oven, and even a commercial battery. Practical trials on cupolas have settled the question of the effect of coke size in iron melting, and have shown that a 3-1 in. coke size may be used successfully in hot-blast cupolas.

A very wise decision has been not to allocate 15 per cent of the effort of the Association to any strictly defined objective. For is there not force in the argument that on the border of the unknown there is needed the keener search? Alike, as in diagnosis, the less definite the symptoms the greater the need for the sensitive touch!

* British Coke Research Association. Sixteenth Annual Report for the year 1959. Pp. 40. (Chesterfield: British Coke Research Association, 1960.)