(a) To calibrate the experimental equipment, a solution of phosphorus-32 of known concentration was frozen into a block of ice of approximately the same size and shape as a rat and counted under identical conditions. This procedure is legitimate inasmuch as the maximum energy of the electrons from phosphorus-32 is equal to that of the positrons from oxygen-15, and the annihilation radiation from the latter is negligible. In this way we estimate that after an exposure of 30 min. in a beam of 0·6 r./min. produced at 21 MeV., the activated oxygen is disintegrating at a rate of 35 disintegrations per second per c.c. of tissue; that is, $N_\infty = 35$.

(b) Assuming the distribution of energy in the *Bremsstrahlung* spectrum to be that calculated by Heitler[4] for heavy elements, and knowing the energy flux per röntgen at energies up to 30 MeV.[5], we can calculate by graphical integration the fraction of the total ionization due to quanta above a given threshold. By reversing the process, it is then possible to calculate the total energy flux in ergs/cm.² sec. above the threshold, and so the number of quanta.

We find in this way that the number of quanta having energies greater than 16·3 MeV., the threshold for oxygen, in our beam of 0·6 r./min. is

$$n = 1{\cdot}37 \times 10^5 \text{ quanta/cm.}^2 \text{ sec.}$$

If we base our argument upon an experimental determination of energy distribution in the spectrum[6], we find $n = 1{\cdot}27 \times 10^5$.

Assuming that 70 per cent by weight of tissue is oxygen, $\rho = 0{\cdot}70$ gm./c.c., and inserting $L = 6{\cdot}06 \times 10^{23}$ and $M = 16{\cdot}0$ we calculate, using the Heitler data,

$$\sigma = 0{\cdot}9 \times 10^{-26} \text{ cm.}^2 \text{ for a } (\gamma, n) \text{ reaction in oxygen-16.}$$

By precisely analogous arguments, but allowing for the lower efficiency of counting of the lower-energy particles from carbon, we find

$$\sigma = 5 \times 10^{-26} \text{ cm.}^2 \text{ for a } (\gamma, n) \text{ reaction in carbon-12.}$$

It is clear that these are mean cross-sections at 21 MeV. for the quanta above the respective thresholds, and are of the order of magnitude estimated for other (γ, n) reactions.

Biological Significance

We may calculate from these data the rates of absorption of energy in tissue (a) directly from the X-ray beam, and (b) by virtue of the disintegrations. One röntgen delivered to 1 gm. of tissue corresponds to an energy absorption of 93 ergs. At a dosage-rate of 0·6 r./min., the rate of energy absorption is, therefore, 0·93 ergs/gm. sec.

The rate of absorption of energy due to the disintegrations from oxygen, assuming a mean energy per disintegration of 0·7 MeV., is $0{\cdot}4 \times 10^{-4}$ ergs/c.c. sec.

Even allowing for carbon disintegration, we see that the rate of absorption of energy during irradiation due to the activation is only of the order of 0·01 per cent of that due to the more usual mechanisms of absorption, namely, electron recoil and pair production. Unless, therefore, there are unknown strong short-lived reactions and high 'resonances', it is unlikely that the production of radioactive isotopes in the tissues investigated by us would contribute materially to the biological effects of high-energy X-rays in them. By analogous argument it is unlikely that short-lived materials remaining at the end of irradiation will contribute appreciably to the total energy absorption.

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BIOLOGICAL ASPECTS OF RIVER POLLUTION

BIOLOGICAL aspects of river pollution were discussed at a joint session of Sections D (Zoology) and K (Botany) of the British Association on September 5. Dr. B. A. Southgate, in introducing the subject, described briefly the varied types of domestic and industrial wastes discharged to surface waters. In industrial districts the sewage treated at municipal sewage-disposal works often contains a high proportion of waste liquors from manufacturing processes. Some constituents of these are incompletely removed during treatment of the sewage. For example, effluent from a works treating sewage containing gas liquor usually contains small quantities of thiocyanate and polyhydric phenols.

The extent to which surface waters in Great Britain are polluted varies very greatly from one district to another. In some rivers the effect of the pollution on the flora and fauna is mainly that caused by the addition of nutrient substances; on the other hand, some rivers, and many estuaries, receive such large quantities of organic matter and poisonous substances that only a few species of the more resistant organisms can survive. The effects of polluting substances in streams depend markedly on the temperature. Increase in temperature increases the rate of oxidation of organic matter by bacterial action and reduces the concentration of oxygen in solution in the water; in very polluted streams conditions may become wholly anaerobic in hot weather. The toxicity of some poisonous substances—for example, cyanide—is increased by a rise in temperature and also by a reduction in the oxygen tension in the water, which is itself reduced by a rise in temperature.

Mr. F. T. K. Pentelow discussed the effects of metallic poisons and of oxidizable organic matter on the fauna of streams. A striking instance of poisoning by copper salts occurred in the River Dove, where waste waters from the pickling of copper are discharged into a tributary. Immediately below the point of discharge the concentration was about one part of copper per million; at a point thirty miles downstream this had been reduced only to about 0·1 p.p.m. Above the tributary 178 invertebrate animals, belonging to thirty species, were collected from unit area of the river bed. A short distance below the confluence the numbers in a corresponding area were seventeen animals of two species; eight miles downstream there were twenty-one animals of six species; and thirty miles below the discharge there were 108 animals of ten species. In the reaches affected by the pollution the species present were the same as those in the unpolluted river; this appears to be typical of pollution by metallic poisons.

The effects of pollution by oxidizable organic matter are usually quite different. Immediately below the point of discharge, and before decomposition has begun, the effect on the distribution of the flora and fauna (including fish) may be very small. Lower down the stream, where decomposition is proceeding actively, with a lowering of the oxygen tension and deposition of sludge, the normal fauna is replaced by a typical community consisting of 'sewage fungus', Tubificidæ, and larvæ of Chironomidæ of the *plumosus* type. Farther downstream Chironomidæ of other groups and leeches—particularly *Herpobdella octoculata*—appear. At this stage sewage fungus disappears and with it the black deposit of sludge on the river bed. The numbers of Chironomidæ and Tubificidæ then decline, and *Asellus* becomes a characteristic member of the fauna. The next stage, farther still downstream, is usually marked by the appearance of pulmonate molluscs, after which the animals of the community normal to the unpolluted river replace those of the polluted stretch. At this stage fish are usually found.

Prof. W. H. Pearsall pointed out that, from the botanical aspect, investigations of river pollution have been concerned mainly with attempts to employ different plants as indicators of the stages of organic pollution and of subsequent oxidation. He illustrated the sensitivity of these tests by referring to the effects of small concentrations of organic matter on the algal population of a stream. The products of oxidation of organic matter in flowing water, mainly carbonates, nitrates and phosphates, have a great effect on the luxuriance of plant growths and thus lead to accumulation of organic muds, even though the polluting liquids themselves may lack visible turbidity. The animal population is also affected by the presence of these muds and the anaerobic conditions they may introduce.

The principal botanical problem associated with such pollution is, however, connected with the large quantities of compounds of nitrogen and phosphorus discharged to surface waters in sewage effluents and their loss to the national economy. Methods by which these materials can be recovered and used in agriculture are thus very important. One possibility would be to pass the effluent through shallow lakes containing such plants as *Elodea*, which would grow very rapidly under these conditions and which might be harvested and used as a green manure. Another possible method of utilization might be to pass the sewage effluent through water meadows containing such plants as *Sparganium* or *Glyceria*, which could be grazed by stock or possibly harvested and used for making silage.

Mr. H. Jones described the pollution of the rivers of North Cardiganshire—particularly the River Rheidol—by compounds of lead and zinc leached from spoil banks of mines. The active polluting substances are lead sulphate and zinc sulphate, which are formed by oxidation of the sulphides at the surface of the spoil banks. In the drainage area of the Rheidol, mining on a large scale ceased in 1922; the river at that time was almost barren, containing only small numbers of Algæ and Bryophytes, with occasional insect larvæ and Crustacea. By the summer of 1923, however, the river contained representatives of all the usual groups of aquatic animals with the exception of Mollusca and fishes; at this time *Callitriche verna* and *Ranunculus aquatilis* appeared in the river. Although mining has generally ceased, pollution still occurs, however, during periods of flood. Intensive work has been undertaken at University College, Aberystwyth, to investigate methods by which the river could be restored to its natural condition. It was shown by E. W. Jones that addition of calcium carbonate and superphosphate in comparatively large amounts to soil impregnated with the metals greatly improved the growth of vegetation by reducing the concentration of available lead and zinc below the toxic level. Trees of several species were successfully grown in the affected areas, the two most resistant of those tried being birch and pine. Best results were obtained when trees about six feet high were transplanted, and when they were planted in pockets of uncontaminated soil. During recent years there has been a remarkable improvement in the condition of the River Rheidol, which has now been extensively re-colonized by aquatic plants, particularly *Callitriche intermedia* and *Glyceria fluitans*. Migratory trout and salmon are now found in the river, and freshwater trout have been successfully introduced.

INDUCTION OF MUTATIONS

At the recent Newcastle meeting of the British Association, the Botany and Zoology Sections jointly held a symposium on the artificial induction of mutations. Dr. P. T. Thomas (Aberystwyth) reviewed the work on the induction of cytoplasmic changes by the action of chemical agents. He pointed out that when such changes are induced in lower organisms, as in yeasts, they often appear to be relatively stable, indicating that the cytoplasm in these organisms is incompletely subordinated to the control of the nucleus. In higher organisms, on the other hand, cytoplasmic changes are of limited duration (*Dauermodifikation*), although they may last through several sexual generations.

Two important conditions must apparently be satisfied in order to induce cytoplasmic changes, particularly in higher organisms. (1) The external agents must act for a relatively long time, because, unlike the nuclear genes, the genetically important cytoplasmic determinants are thought to be in a chemical equilibrium. (2) The influence of the nucleus on the cytoplasm must be at the minimum —a condition which can be attained by keeping the nucleus arrested in its mechanically active phase, while at the same time allowing cytoplasmic synthesis to proceed.

Dr. J. M. Thoday (Sheffield) discussed the influence of oxygen on radiation-induced chromosome structural change and indicated the advances that have been made towards elucidating the sequence of events involved in the formation of chromosome structural changes initiated by ionizing radiations. While these advances have been largely concerned with the later phases of the sequence, he thought it possible that the discovery of the influence of oxygen might lead to knowledge of some of the active chemical substances involved in the earliest phases. This would help to bring radiation work into line with that being done on chemical mutagens.

Dr. Thoday then outlined the target theory of radiation breakage, and presented results, obtained with *Vicia faba*, to demonstrate that the target theory stands up to some of the criticisms that have been levelled against it. However, the target theory can only account for the variation in yield of aberrations