RADIATION EFFECTS ON THE NERVOUS SYSTEM

One of the most important developments in radiobiology in recent years has been a change in the concept of the ability of the nervous system to withstand the effects of ionizing radiation. Until recently it had been generally believed that the tissue of the nervous system was especially resistant to radiation and that any kind of damage to it could occur only at extremely high radiation doses. Over the past few years, however, there has been increasing evidence to show that the nervous system responds to even small doses of radiation and that this response may often be associated with some form of radiation damage.

A reference to this change was made by the IAEA Director General, Mr. Sterling Cole, in his opening remarks at a Symposium on the Effects of Ionizing Radiation on the Nervous System held by the Agency in Vienna from 5 to 9 June 1961. He recalled that Dr. Peter Alexander, the well-known British radiobiologist, had written to the Agency: "I was asked recently if brain functions, in particular with regard to finer judgments, are liable to be affected by doses of the order of 50 - 100 roentgens since in severe accidents selected personnel may have to expose themselves to such levels. Until recently I would not have hesitated to dismiss the possibility that someone experiencing such a dose might not be able to exercise his full judgment, but in view of more recent work the subject is now wide open."

Much of this work was described and discussed at the Vienna symposium which was attended by leading experts in this field from 20 Member States of the Agency. The importance of the findings reported at the meeting in the establishment of safety codes for atomic operations was particularly emphasized by Mr. Cole. The meeting, he pointed out, gave an opportunity to examine "whether new facts in this field will alter our ideas on health and safety measures".

Nervous Reactions to Radiation

Experiments to determine the sensitivity of the nervous system to radiation have revealed a number of interesting facts. As was pointed out by Professor Otto Hug in an article in the April 1959 issue of this Bulletin, it has been demonstrated that many invertebrates react with reflex motions to astonishingly small radiation doses. For example, snails retract their feelers and clams shut their shells. Among insects, it has been observed that ants behave wildly in an attempt to flee rapidly from an irradiated area into a "radiation-proof shelter". In the course of observations on humans, it has been seen that even small radiation doses produce nervous over-excitability, changes in the normal reflex responses, and disturbances of the electrical currents of the brain which are measurable with an electro-encephalograph.

IAEA has sponsored some research in this field, and under a contract awarded by the Agency, investigations have been conducted at the Pharmacological Institute of Vienna University into the effects of small radiation doses on cells, particularly on those of the nervous system. A great deal of research work on radiation effects on the nervous system has been done in some of the scientifically advanced countries, and the symposium in Vienna last June provided an occasion for a detailed review of the results.

Several papers were presented at the first session of the symposium on radiation effects on the peripheral nervous system, i.e. the large network of nerves which connect the central nervous system, the co-ordinating machinery, with organs which receive sensory stimulii and those which act in response to these stimulii. (In other words, these nerves carry messages to or from the central nervous system.) Apart from papers describing individual studies, R. Brinkman, from the Netherlands, presented a survey paper on the effect of radiation on nerve receptors.

Central Nervous System

Discussion of the radiation effects on the central nervous system was divided into four sections: electrophysiological changes, higher nervous functions and behavioral studies, changes in developing embryo, and biochemical and histochemical changes. In a paper on changes in the electrical currents of the brain following irradiation of brain tumors, C. H. Hakansson and M. Lindgren, from Sweden, pointed out that while the tissue of the central nervous system is highly resistant to radiation, functional disorders are often noticed in the early treatment of brain tumours by x-rays, which seem to indicate that the central nervous system is able to respond to small doses of radiation. They discussed the nature of these changes as reflected on electro-encephalograms. Some other scientists reported on experiments made on the brain and spinal cord of cats and rabbits.

Observations reported by Thomas J. Haley (USA) showed that doses as low as 200 r or 400 r total-body irradiation of cats with x-rays produce definite and specific changes in brain electrical activity appearing within an early period when no signs of neurological damage or radiation injury are present. With chronic irradiation, however, these changes occur along with clear signs of radiation damage. W. Lynn Brown and A. A. McDowell, also from the

USA, presented findings concerning behavioral changes (such as distractibility and narrowing of attention) in monkeys exposed to nuclear radiations both in the laboratory and at the Nevada Test Site.

A paper by G. Z. Abdullin (USSR) described a study of the comparative radiosensitivity of different parts of the brain in terms of changes in their functions. According to this study, ionizing radiations operate selectively on different parts of nerve formations; also, they cause considerable changes in all sections of the brain observed. A survey paper on the effects of radiation on the vegetative nervous system was presented by A. V. Lebedinsky, also from the USSR.

New experimental data were presented by R. Rugh (USA) regarding the extreme radiosensitivity of the embryonic brain.

Response or Damage?

W. O. Caster (USA) pointed out that the role of the central nervous system in the causation of radiation damage had been the source of some confusion; while some scientists considered it to be among the most radio-resistant portions of the body, others regarded it as the most sensitive to ionizing radiation. The fact is, as Dr. Caster explained, that direct, visible and permanent damage to the central nervous system can be observed only under the effect of a very high radiation dose, but even at the lowest doses there is strong evidence that the central nervous system is involved. After a detailed technical analysis of observations, he showed, inter alia, that at an LD-50 radiation dose (i.e. a dose which would be lethal in 50 per cent of cases), there are definite chemical and functional changes in the brain. This and other effects suggest that "regardless of the aspect of radiation damage which one is investigating, it is necessary to keep in mind the possible role of the central nervous system in the production of the changes being observed".

Referring to the fact that even at very small dose levels, the central nervous system may be involved in some way without being observably damaged, Dr. Caster posed the question whether one should differentiate between "radiation damage" and a "radiation response" in the central nervous system. There is a large difference between the sound that can be detected by the ear and that which will permanently damage the ear. Similarly, the changes in the reflex action and other changes that can be observed in animals at doses of a fraction of a roentgen unit may represent a "response" and may not be properly regarded as damage. At very high dose levels, say 10 000 r and above, irreversible damage can of course be observed. But even the response to very small doses, without representing identifiable damage to the central nervous system itself, may be associated with some other manifestation of radiation damage. "In truth", said Dr. Caster, "it may turn out that a central nervous system response is an important underlying factor in the causation of many of the common manifestations of radiation damage."

The possible action mechanisms of radiation effects on the nervous system were discussed in two papers at the last session of the symposium.

In all, 35 papers were presented and discussed at the meeting. The different sessions were presided over by nine prominent scientists: A. Zuppinger (Switzerland), O. Hug (Federal Republic of Germany), D. Rosen (UK), C.S. Bachofer (USA), J. Lefebvre (France), R. Brinkman (Netherlands), T. J. Haley (USA), A. V. Lebedinsky (USSR), and W. Haymaker (USA).