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## Neutron Therapy of Cancer

There have been six recent reports on the application of neutrons to cancer therapy; they report on the biochemical and biophysical aspects of fast-neutron therapy, neutron-capture and neutron-conversion therapy with intermediate-range neutrons, the chemistry and physics of nuclides for neutron-capture therapy, the localization of dyes and azoproteins in tumors, and a computer program for neutron-gamma radiobiology. The series is highly comprehensive and reflects a significant advance in this area of research.

Three applications of neutrons to the problem of cancer therapy have been proposed: fast-neutron, neutron-capture, and neutron-conversion therapy. The latter two involve biochemical as well as biophysical problems. Workers on the biochemical and biophysical aspects have attempted to provide effective chemical agents by localization and distribution studies of various compounds in normal and tumor-bearing animals. Studies have been implemented by synthesis of unavailable compounds, and by development of analytical techniques applicable to determination of the nuclides of interest:  ${}^6\text{Li}$ ,  ${}^{10}\text{B}$ , and  ${}^{235}\text{U}$ . Attempts have been made also to ascertain the biological effectiveness of the intermediate-energy neutrons, proposed for therapeutic use, by straightforward studies of lethality in mice induced by monoenergetic neutrons in the range between 0.01 and 1.0 Mev.

The article on neutron-capture and neutron-conversion therapy with intermediate-range neutrons reports an examination of the parameters of systems involving intermediate-range neutrons. From theoretic studies it had been determined that beams of neutrons of intermediate energy (0.3–300 keV) would be more effective than thermal or epithermal neutrons in

destroying the neoplasm and leaving the normal tissue unharmed.

Boron-10 and  ${}^{235}\text{U}$  are determined to be the most promising nuclides for capture therapy. The chemical and physical characteristics of nuclides most pertinent to neutron-capture therapy have been studied and reported. The problem of poor neutron penetration of the tumor tissue had been solved by application of narrow beams of intermediate-energy neutrons, but problems of adequate localization and dose distribution required further study.

For effective neutron-capture therapy, it was necessary to know whether a massive dose of labeled protein would localize in a tumor; that is, a dose large enough to yield concentrations (in a tumor) of at least  $3.5 \times 10^{-3} M$  of the nuclide undergoing neutron capture. Thus the localization of dyes and azoproteins in spontaneous or induced (but not implanted) tumors was studied. *p*-Aminophenyl arsonic acid was used as the protein carrier in the localization studies.

Many problems arise in theoretical and experimental neutron-gamma radiobiology that are difficult to handle by simple approximations, by transport theory, or even by experimental methods. Good computational methods were needed as adjuncts to experiment, not only to provide guides for good experimental design, but also to permit extrapolation from experimental results into regions difficult to examine experimentally. A newly devised computer program, based on the Monte Carlo method, permits great flexibility in problem and yields highly detailed information even at the microscopic level.

Also reported is investigatory development of a radiobiologically useful source of monoenergetic neutrons free of contaminating radiations and sufficiently

(continued overleaf)

flexible to afford rapid irradiation of typical biological objects at neutron energies from epithermal to 2 Mev.

**Reference:**

N. A. Frigerio, J. Shaw, H. N. Nellans, "Neutron therapy of cancer: Biochemical and biophysical aspects," in *ANL-7409* (Argonne National Laboratory, 1967); N. A. Frigerio, "Neutron capture and conversion therapy with intermediate-range neutrons," and "The chemistry and physics of nuclides for neutron capture therapy," in *ANL-7136* (Argonne National Laboratory, 1965); ——— and J. Shaw, "The localization of dyes and azoproteins in tumors," in *ANL-7136*; N. A. Frigerio and H. Branson, "BIM-130: A computer program for neutron-gamma radiobiology," in *ANL-7409* (Argonne National Laboratory, 1967); N. A. Frigerio, D. L. Jordan, R. D. Hudnut, "Development of monoenergetic neutron sources for radiobiology," in *ANL-6971* (Argonne National Laboratory, 1964).

**Notes:**

1. This information may interest all concerned with cancer or heart afflictions.
2. Inquiries may be directed to:  
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**Patent status:**

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