cept with the previous step, the emphasis being clearly on the decisions and results, not on the path to the results.

However, in a tight time schedule, as in this project, parallel efforts are necessary, which often produce pressures for decisions and trade-offs between various efforts. These undoubtedly occurred in the class but do not appear in the report.

In describing an immense project in 115 pp., this book does not go into sufficient detail or depth to aid in teaching any of the fields touched upon. A text on Systems Engineering based on the MIT experience could be quite useful, but it should cover items such as:

1) The mechanics of teaching a Systems Engineering course. The Preface to this book lists 21 students and 8 faculty. How much time do the students devote to the course? How much faculty effort is required? What are the room space requirements? What are the costs for lecturers, report preparation and distribution, secretarial services, etc.?

2) Information on class organization, student leadership, methods of interacting, etc.

3) Utilization of time. How much of the 15 weeks is spent in assembling information, preliminary design, evaluation, and final design? Are these times the same for each of the student groups?

4) Problem areas, such as late decisions, absence of decisions, meeting of deadlines, lack of data, quality of leadership, etc.

5) The interactions between phases of the work during design.

6) Any special optimizing or scheduling techniques, used in the design phase.

Such points are absent from the book, for it was not prepared as an expository of the MIT method of teaching Systems Engineering. A professor using this book in teaching, either for developing an approach or for the subject matter, would have to be well versed in his field to pick out and use the pertinent points. If he is this knowledgeable initially, the book becomes a case study and of lesser value in teaching the basic subject.

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CAUTION—TRITIUM AT WORK

Title Biological Effects of Transmutation and Decay of Incorporated Radioisotopes

Publisher International Atomic Energy Agency, Vienna, 1968

Pages 244

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Reviewer Bernard Strauss

A radioisotope incorporated by an organism may produce damage either as a result of the radiation emitted or as a result of the transmutation which is a concomitant of the decay event. In a certain proportion of decay events, the transmuted atom is ejected from the molecule in which it occurs, or, if the recoil energy is insufficient, the atom remains in place leaving a molecule with changed structure. For example, in the $^{32}P \rightarrow {}^{32}S$ transmutation the newly formed S atom may be forcibly ejected from the molecule in which its parent phosphorus occurred. Even if the newly formed S remains in place, the molecule may disintegrate due to the instability of the chemical binding in which S replaces P. Transmutation-induced damage is greatest when atoms involved in bivalent linkages decay; destruction of a phosphorus atom in a nucleic acid chain results in chain breakage. On the other hand, the transmutation from ^{3}H to ^{3}He produces only minor structural damage but leaves a positively charged molecule.

The decay of incorporated isotopes can also result in radiation damage. If an isotope emits an energetic beta particle, such radiation damage will occur at some distance from the site of the decay. However, the energy from a weak beta particle is absorbed close to the site of the radioactive decay. As pointed out in this volume by Oliver, the maximum dose rate for tritium decay occurs within a sphere of 6 μm radius which is comparable to the size of the mammalian cell nucleus. The site at which tritium decay occurs is therefore important.

There are then two possible sources of damage due to an incorporated radioisotope, radiation and transmutation. The problem is whether these can be distinguished, i.e., whether a biological effect accompanying radioactive decay is due to the radiation accompanying disintegration or to the transmutation that occurs at each decay event.

This volume is the report of a panel called to discuss these questions and held in Vienna, October 9-13, 1967 under the auspices of the International Atomic Energy Agency. The foreword to the volume defines the aim of the discussions: To investigate the modes and mechanisms of action associated with transmutation and radiation decay events; to achieve a clearer picture of the present status of such studies; and to "go some way towards defining the hazards of using labelled compounds in human beings and standards for setting body-burden levels."

Fourteen contributions are published along with the discussion that follows each paper. These include discussions on the effects of incorporated ^{32}P, ^{3}H, and ^{14}C in bacteria and bacteriophage by Apelgot, Drobnik, Koch, and Person, in yeast by Moustacchi, in Drosophila by Kieft, Oftedal, and Kaplan, in mammalian cells by Cleaver and Oliver, and in chick embryos labeled with ^{32}P by Szabo and his collaborators. The volume contains a short general review by Feinendegan and concludes with three papers on radiation chemistry by Adams, Kacena, and Getoff. There is a final section of general conclusions.

These conclusions should be briefly summarized since they are the major result of the meeting: the lethal effect of tritium decay is due

to irradiation and there is no evidence for a contribution from transmutation. The site of tritium decays within a cell is important, due to the short range of the beta particle; killing efficiency is highest when tritium decays occur in DNA. Cell killing by ^{32}P is mainly due to transmutation in DNA; killing by ^{14}C in DNA is also mainly due to transmutation. Transmutation of ^{32}P causes mutation in bacteria, fungi, and Drosophila. Tritium transmutation can result in mutation as evidenced by the greater mutagenic efficiency of 5-^{3}H cytosine decay as compared with 6-^{3}H cytosine decay in phage and bacterial DNA. The Panel concluded: "Although no special effects of transmutation are raised here, it is felt that the administration of ^{3}H-labelled material to humans should be avoided or at least be restricted to patients with only a short life expectancy."

The volume consists of a series of individual research reports. It is saddening to realize how little connection there is between the research in radiation chemistry and that in radiobiology. The radiobiologists are interested in the effects of isotope decay in nucleic acids and in organisms; the radiochemists work on simple chemical substances and can, at best, only make informed guesses about the behavior of more complex systems. This means that the interpretation of the radiobiological effects must be approached from a purely empirical viewpoint. In 1958 I felt it unlikely that ^{14}C transmutation could be detected; this report contains evidence showing that ^{14}C transmutation effects in DNA are a major cause of lethality. No tritium transmutation effect should be expected; Person demonstrates a difference in the mutagenic effectiveness of uracil-5 ^{3}H and uracil-6 ^{3}H indicating that the position of a decaying atom within a single molecule can be important, i.e., that there is a transmutation effect. With the exception of the extensive use of ^{32}P transmutation for the study of molecular biology, transmutation is still a problem rather than a technique. Happily one barrier to the distinction between transmutation and radiation effects has now been removed. The problem of energy deposition by low-energy electrons in absorbing material has been solved in several model systems and is discussed in this volume by Person, by Oliver, and by Koch. This solution of the dosimetry problem makes it possible to tell whether an effect can be accounted for as a result of radiation.

Many of these papers are of personal interest to me, and the conclusions of the Panel are of importance and of general interest. The meeting seems to have been profitable, and the inclusion of so much discussion gives the illusion of participation as well as indicating the response of the audience to the work. However, it is not certain that the publication of this particular collection of papers is the proper way of disseminating the results of the meeting, especially since most of the data are published elsewhere. The panel discussion was clearly a most useful device for focusing the attention of investigators in different areas on this one problem, but it may be that the results of such meetings would best be disseminated as a general review in monograph form which included a critique of the meeting. Still, it is true that the volume, and especially the printed discussion, is particularly helpful to those of us working in the area but who were unable to attend.

I conclude from the detailed contributions that we cannot answer two fundamental questions presented to the Panel: How can one predict the fate of individual large molecules with a component radioisotope which has just disintegrated? and, How may one partition the effect of radioisotope decay between transmutation and radiation damage based on the properties of the isotope and the molecule into which it is incorporated? Regardless of such ignorance, however, we are more certain than ever that tritium, taken internally and deposited in the DNA, kills cells and is one of the most dangerous of isotopes.

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BOOK ANNOUNCEMENTS

Although the following books will not be reviewed, they may be of interest to some of our readers:

Thorium Fuel Cycle, Raymond G. Wymer, Coordinator, CONF-660524, U.S. Atomic Energy Commission, 1968, ix + 839 pages, $3.00

Teleoperators and Human Augmentation, Edwin G. Johnsen and William R. Corliss, NASA SP-5047, 1967, viii + 265 pages, $1.00

Direct Energy Conversion, S. L. Soo, Prentice-Hall, 1968, xiii + 333 pages, $12.50