STEADY-STATE THEORY

The mathematics of cancer

Disease induced by radiation can appear either immediately or after long delay. The immediate type comes from a massive dose of radiation to the whole body and has physiological effects similar to those of a massive burn. The delayed variety usually involves some form of cancer. An example is a group of women who had been employed during the 1920's painting radium on watch dials: At the time they did the work they appeared healthy; 20 years later all were dead of bone cancer.

For the last 20 years dogs at the University of Utah in Salt Lake City have been irradiated with radium. Comparing what happened to the dogs with things that happen to nonirradiated people as they grow older has led Betsy Stover and Dr. Henry Eyring to formulate a mathematical theory of mutation and death connecting the aging process and the onset of cancer. Dr. Eyring reported the work at last week's meeting of the American Chemical Society in Chicago.

At the time they reached maturity, about a year and a half to two years after birth, the dogs were given doses of radium or chemically similar radioactive elements. After 11 years the dogs began to die of bone cancer. Four years later all were dead.

Radium acts chemically like calcium: It is deposited in the bones. The radioactivity lasts for years. Thus, in the dogs and in the women, radiation was continually delivered to the bone cells for many years. Yet cancers did not develop until a decade or more had passed.

Nonirradiated populations seem to have a similar connection between time and the development of cancer. Cancer appears most in older people.

When radiation penetrates a cell, it dissociates the water in the cell into hydrogen ions, hydroxyl ions and hydrated electrons. All of these are chemically highly reactive. They enter chemical reactions with the chromosomes of the cell and break the chromosomes, destroying some of the information carried by them. The destroyed information may range over any part of the genetic message, but sometimes it is that which controls the replication of the cell, says Dr. Eyring. In that case uncontrolled replication of mutated cells may begin, and one of the 100 or 200 known varieties of cancer is on its way.

Cancer does not set in every time a chromosome is broken in the appropriate way. However, its chances of doing so increase as the dog or the person grows older. The body has the ability to repair the chromosome damage, but the stresses of living erode it.

This circumstance leads Dr. Eyring and Mrs. Stover to suggest that the situation is what in chemistry is called a steady-state reaction. That is, in general, a process that builds up a particular compound is going on at the same time as one that destroys it. If the two are in balance a steady amount of the compound will be present. If the balance is tipped to one side or the other, the compound will increase or decrease.

In the dogs' case, radiation was breaking chromosomes and the body was repairing them. Mathematical equations were derived that took into account the number of cells in danger of starting a cancer at any given time, the body's ability to repair the damage and the decline of that ability with age. The equations predict the probability of death or survival, but not the fates of individuals. "Chemistry always happens by chance," says Dr. Eyring. "It hits one molecule but not another."

American Chemical Society

Eyring: Balancing damage and repair.

Dr. Eyring believes these same equations will work for human populations, and for other carcinogens than radiation. Since people are continually ingesting a large variety of substances that break chromosomes, the theory gives cancer a certain grim inevitability. To old people Dr. Eyring says: "If you don't die of other degenerative diseases, just wait and you'll get cancer. It's coming. The best insurance against dying of cancer is to get run over by a car."

From studies like these, however, there is some hope of effective chemical prevention. Some substances apparently enhance the body's ability to repair chromosome damage. If research on them succeeds, they could be introduced to keep the balance on the side of repair. They might prove effective both in preventing cancer and slowing the aging process, Dr. Eyring says. □

VARIETY AND VISCERA

Fish protein progress

Earlier this year, the fate of fish protein concentrate (FPC) was uncertain (SN: 1/24, p. 91). Although the substance promised to be a major cheap source of protein for underdeveloped nations, as well as for hungry people in the United States, legal and technological problems had bogged down progress in its development.

The Agency for International Development, for example, had rejected FPC manufactured by Alpine Marine Protein Industries, Inc., because Alpine's product did not meet the 100 percent protein efficiency ratio (based on the protein efficiency of casein) required by the Food and Drug Administration. In addition, FDA had imposed other limitations, such as refusing to allow fish other than hake to be used.

Since then, there has been progress. Although AID and Alpine have mutually agreed to terminate their earlier contract, Alpine continues to have faith in its product. It recently began a marketing program in the United States, legal under present law if the product is sold in individual packages of less than one pound.

In the meantime, FDA has relaxed its requirements on fish species; now menhaden and herring of the genus *Clupea* (including the common Atlantic and Pacific herring) may also be included. But FDA clearances are still a major roadblock to the Bureau of Commercial Fisheries' FPC program. FDA requires that when the viscera of fish are included in the final product, extensive toxicological data must be submitted to preclude any possibility that toxic materials from organisms eaten by the fish would be included in the protein concentrate.

"This is primarily a problem of time," says Roland Finch of the bureau's National Center for Fish Protein Concentrate. "It requires a great deal of work in the library, reading biologists' accounts of the diets of the fish."

However, this problem may be bypassed if a process being developed in Sweden turns out to be successful. Astra Nutrition Corp., in combination with several other firms, has a small experimental plant at Bua, Sweden, which eviscerates and debones fish before they are converted to FPC. Presumably, says Finch, FDA might not require the extensive toxicological data if viscera are removed.

The interesting thing about the Swedish process is its projected cost. The company estimates FPC might be produced at a selling price of 49 cents a pound. (Alpine's contract with AID would have given the company 42 cents a pound.) At this price, the FPC would