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DISCUSSION OF DR. SWANSON'S TALK

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Soon after discovery of the heavy nuclear component of primary cosmic rays by the Minnesota group, a small group of scientists became interested in the possible effects of these radiations in space flight, noting that the effects may very well be different from those due to conventional radiations. The heavy primaries have much greater ionization interaction with matter than the so-called penetrating and soft components of cosmic rays. In the first high altitude measurements it appeared that the rate of the particles arriving at the earth from space is quite small, most of them have high energy, and it was reasoned that in short flights to high altitude the cosmic rays present very little hazard.

Almost each year during the last decade new facts were discovered about primary cosmic radiation. Today we know that in the interplanetary space cosmic ray effects show astonishing variation as far as quality of particles, location and time variation are concerned.

Today we have not yet formed a completely clear quantitative picture of all the radiations in space and their exact dosage. We do know, however, that there are several classes of radiations present. An abbreviated list might read as follows: infrared, visible and ultraviolet light, ex-rays, electrons, high energy protons and alpha particles, neutrons heavy ions, meaning carbon, nitrogen and other even heavier nuclei up to atomic number of 29. Mesons and "strange" particles appear as the primary rays interact with matter. The first four radiations mentioned come mainly from the sun, and shielding against them is feasible. Several groups of investigators measured the flux of heavy nuclei, particularly pertinent data were obtained by Yagoda[1]. Nothwithstanding the efforts made in balloon flights, rockets and satellites to date (January, 1959), the energy distribution and complete frequency distribution of the heavy ions is not as yet known: the earth's magnetic field would not allow penetration of the lower energy particles near the surface of the earth except near the magnetic poles. Yet biologically these particles

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present an interesting and possibly important challenge to radiobiologists. They ionize more heavily than the radiations usually available at ground level, and their inelastic collisions with atomic nuclei result in emission of many particles forming nuclear "stars." For particles of the same velocity the ionization of heavy ions of atomic number Z increases as Z^2.

Whereas extrapolation of the average cosmic ray intensity to outer space, even counting on the heavy particles, only yields a 24 hour daily dose near the "permissible level" set by the ICRP,[2] great temporal and spatial variations of cosmic ray dose rate have been detected.

It has been shown for example that during certain solar flares the primary proton and heavy particle flux is very significantly increased for brief periods. During these events the heavy ion flux, particularly at energy lower than 1 Bev per nucleon, can deliver significant doses of radiation.[3] At the same time x-rays emanating from sun spots also increase significantly.

Relationships exist pointing to a correlation of cosmic ray intensity with the eleven year solar cycle, during which the sunspot numbers undergo variations. Most of these variations imply magnetic interactions between solar fields, fields due to ionized plasma, and the earth's magnetic field. Since the effects of the earth's field are mostly shielding, we can expect greater variations and intensities outside the earth's magnetic field.

The discovery of a double radiation belt by Van Allen and his associates near the earth has increased the presence of radiation hazard in the vicinity of the earth.

At certain altitudes above the magnetic equator the dose rate appears to be as much as 3 to 5 r per hour due to electrons and probably protons and other nuclei.

In view of the complex distribution of radiations and their variations, one cannot give a single general answer to the cosmic ray problem. It would appear that staying below the radiation belt the first space flyers in flights lasting a few days would be exposed to dose values near tolerance levels and thus be reasonably safe. Prior to venturing into space for extended periods of time, biophysicists and radiobiologists should undertake definite and detailed studies. Generally speaking, these studies should be directed into several areas as follows:

1. Physical measurement of the detailed spatial and temporal distribution of cosmic rays, of each different component and with respect to energy distribution.

2. Development of dose-monitoring instruments for overall dose rate and for separating components of different ionization density. Because of variations, such instruments may be needed on human satellite flights and on flight for the purpose of testing radiobiological effects.
3. The primary rays should be duplicated in accelerators at ground level and the dose effect relationships studied in detail for radiation where this has not as yet been done.
4. Even after knowledge of the entire composition and dosimetry of cosmic radiation in space, it seems to be interest to fly some biological test objects in exploratory experiments in satellites. These would serve not only to verify and substantiate the dose measurements and biological predictions but may also open interesting new avenue where interaction of different environmental conditions occur. For example, one may ask the question how radiation effect and gravity-free state interact.
5. On the moon and on the surface of other planets the radiation environment is probably quite different from that on the earth. Thus if life is found in some part of the solar system, it must exist under these radically different conditions, and its evolution depended on possibly different sets of conditions than our own. It is well for us then to initiate studies into the problem of life in the presence of certain radiations, e.g. intense ultraviolet light. Similar problems arise if we wish to test the theory that living cells, perhaps dry spores may have drifted in the universe from one solar system to another. Radiation may well be a limiting factor for such propagation of life.

Cosmic radiation problems viewed in the above groups present a challenge which may result in better understanding of certain problems of evolution and radiobiology.

It is of interest to note that independently from space flight considerations, the author and his colleagues have for some years been interested in biological effects due to heavy nuclei. At one of the accelerators in Berkeley, the HILAC (heavy ion linear accelerator) for almost two years radiobiological studies were carried out with various materials on the effects of heavy ions up to neon particles with 10 positive charges. These particles have only 10 Mev Kinetic energy per nucleon, but they are present in intensities 10^7 or 10^8 times that of the cosmic rays. (A similar machine has been completed at Yale University.) Already a certain amount of data are available due to the efforts of Dr. Tor Brustad[4], Dr. Don Fluke[5] and others on the radiation sensitivity of unicellular organisms, phage and certain enzyme molecules. Work has also started in exploring the effects on tissues accessible to the particles, which can only penetrate a few hundred microns. It is clear from the initial efforts that for most organisms the heavy ions (per particle) are much more effective in producing killing effects than light ions. We do not yet know what the efficiency is in producing mutations and other subtle changes.

The actual heavy cosmic rays are much more penetrating than the accelerated heavy ions, and if we wish to study certain biological effects e.g. carcinogenesis in animals, it might be necessary to accelerate some of the heavy particles to perhaps 1 Bev per nucleon. If this is done, our knowledge with respect to their biological effects could be greatly increased.

For observation of most of the biological effects of cosmic radiation it would seem advisable to recover the specimens or to fly along with them in a satellite.

It is possible that heavy ion bombardment will result in novel syndromes of radiation, centered around relatively few injured regions, where particularly heavy particles hit in high concentrations; if such regions of the body have particular importance, (e.g. essential hypothalamic nuclei or germ cells), the effects on them, though local, could have definite significance on certain physiological functions.

In certain regions of space, e.g. in the Van Allen belt, it may be necessary to employ shielding to protect a human; it seems certain that shielding will not be effective against the most penetrating components of primary rays. Thus a radiation component many times higher than cosmic ray radiation at ground level will always be present: we should make attempts to learn as much as possible about it.

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