N94-13766

GENETIC EFFECTS OF HZE AND COSMIC RADIATION
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Background and Outline of the Experiment

Space radiation like cosmic rays originates both from distant sources in the universe and from the Sun. A fraction of such cosmic rays reaches the surface of the Earth. Fortunately, all the organisms on the Earth are well protected from cosmic rays by the thick layer of atmosphere, as well as by the Earth's magnetic field deflects low-energy cosmic particles falling on the Earth. But, if we go into space these protectors against cosmic rays are no longer available, and the dose (amount) of space radiation will increase several hundred-fold over what we routinely encounter on Earth. Nevertheless, the radiation dose in space is still too small to cause any serious effects on astronauts, so the risk of space radiation has been neglected so far.

Our knowledge obtained with experimental animals has indicated that low or medium doses of radiation cause two major delayed effects of radiation, namely, induction of cancers among exposed animals and induction of mutations among descendants of exposed animals. Genetic properties of each individual, such as ABO blood type and hair color in humans, are determined by each specific gene located on the chromosomes in the cell nucleus. These properties usually do not change at all and are transmitted through many generations from parents to children and also from a parent cell to daughter cells within the same body. However, on very rare occasions, radiation or toxic chemicals produce an alteration of a gene, resulting in the acquisition of a new property among descendant individuals or cells, the property different from their parents. Such a change in genetic property is called "mutation." In fact, in 1927, Dr. H. J. Mueller of the University of Texas first discovered that x-ray irradiation can induce mutations in Drosophila, a small fruit fly widely used for study of genetics. For this outstanding discovery, he was awarded the Nobel Prize in 1946. It is also known that human cancers arise from mutations that occur in "proto-oncogenes" in cells constituting a human body. Of course, such cancerous mutations which occur in a cell of a certain organ, like the lung, liver and stomach of a particular person will not be transmitted to a child. This type of "non-heritable mutation across generations" is called "somatic mutation," and it appears as a change observable with a portion of cells in a body.

As mentioned above, the effects of space radiation on astronauts, such as high-charge and high-energy particles (HZE) and other cosmic radiation, are believed to be very small, at least during the short-term flight by the space shuttle. However, in theory, even those small doses of radiation will certainly elevate the frequency of mutations, including specific somatic mutations leading to cancer induction. Although the possible increase in cancer incidence due to space flight may be practically negligible, we should have the knowledge of "theoretical mutation risk" caused by space radiation.

The purpose of our experiment is to detect mutations in Drosophila possibly induced by space radiation during the SL-J mission, so that we will be able to obtain basic information about " the genetic (mutational) risk of space radiation" which can be used to estimate human risk of cancer induction by space flight. As an example of somatic mutation, we will analyze morphological changes in hair growing on the surface of the wing of an adult fly. A piece of wing consists of about 30 thousand wing cells and in the wild type Drosophila a long single piece of hair is growing on the surface of each wing cell. When Drosophila is exposed to radiation at its early stage of development, such as embryonic stage or larval (maggot) stage, some mutations will appear in the wing hair of the adult fly with a certain low frequency, depending on the radiation dose. Among the mutations, the most frequent one is a change in the number of hairs per cell, that is, usually three or more hairs are coming out from a single wing cell.

In the actual SL-J flight, we will install thousands of Drosophila larvae (maggots) into the Space Shuttle Discovery and expose them to space radiation during the 7-day mission. Immediately after the re-entry to the ground, these larvae are expected to develop (emerge) into adult flies. Then the wings will be fixed by ethylalcohol and permanent samples will be prepared. Finally, we will analyze the wing samples microscopically in order to detect mutations.

Future Prospect Derived from Experimental Results

As mentioned in the previous section, the total radiation dose during the SL-J mission may be very small, probably the same order of dose which we usually receive after a single exposure to medical x-rays for health screening, such as chest x-rays. Therefore, we do not have to worry about any effect on crew members of such low dose of radiation during the space shuttle flight.

However, during the late 1990's Space Station Freedom will usher in a new era of space programs. The Space Station Freedom is planned to make an orbital flight with an altitude of

460 km, a much higher altitude than the space shuttle program. In addition, it is projected that the crew members of the Station may be replaced every 6 months. With these flight conditions, the approximate possible radiation dose accumulated for 6 months may be in the range of 10 to 20 rem (0.1 to 0.2 Sv). This value seems to be quite large. It is true that there are still considerable debates as to whether or not such a dose range of radiation (10 to 20 rem) would cause appreciable health effects in humans. Yet it is also clear that necessary precautions must be taken to minimize radiation dose inside the spacecraft in order to protect crew members (or general public who will expand into space in the distant future) from unnecessary exposure to radiation.

The results of this experiment may provide basic, important information which will enable us to calculate "the necessary radiation shielding of the spacecraft to ensure crew safety."