6.1 Introduction

Radiation biology in space is multifaceted. It comprises the measurement of radiation field parameters, study of interaction processes with materials of biological interest (including the development of special equipment suitable for flight conditions) as well as the investigation of radiation–related phenomena in biological systems, extending from molecules to the whole body. Investigations span many orders of magnitude in spatial dimensions and time, and require the cooperation of many disciplines. This is all equally true for Earth-bound radiation biology, of course, but investigations in space pose special problems related to the specific properties of the radiation field which cannot be found on the ground and can only be poorly simulated. An additional factor to be taken into account is the possible interaction with flight–related conditions, of which microgravity is the most prominent one, that can only be studied in a sensible way during space missions. Results obtained will not only be of value for space radiobiology as a subdiscipline but may also shed light on fundamental processes important for the whole field. Radiation constitutes the most important hazard for humans during long–term space flights, particularly those outside the Earth’s magnetic field (Adams 1992). Radiation protection is therefore mandatory to safeguard the well–being of astronauts and to limit the occurrence of later damage, like cancer. Passive shielding is practical only to a certain extent, both because of obvious mass limits and physical reasons related to the very high energies of the particles in galactic cosmic radiation (GCR). In spite of very many investigations, the understanding of heavy particle radiation biology, which constitutes the necessary prerequisite for a rational approach to hazard estimation, is still rather rudimentary.

Not all of the questions which remain can be tackled in space, and it is not even advisable to do so since the experiments are difficult to control and high cost would be involved. Rather, there has to be a careful balance and coordination between ground studies and flight experiments, and the latter should concentrate on specific questions. It has to be pointed out here, and this cannot be overstated, that there is no value in transporting into space sophisticated equipment and complex systems which are difficult to handle even in a ground–based laboratory in the hope of obtaining good ‘scientific’ results. This does not only apply to radiobiology, of course, but especially in
this field one finds the tendency, even among peer groups, to recommend support only for studies with mammalian systems because of their obvious relevance to humans even though this does not properly take into account that experimental conditions are very difficult to control even in a well-equipped space laboratory. Measurements in space do not have value in themselves; they have to be scrutinized critically in exactly the same way as observations made on Earth. Since flight investigations can be repeated rarely, if at all, the methods used should be simple. The importance of appropriate controls, and a sufficient number of them, can hardly be exaggerated. Many studies, particularly the early ones, do not meet these criteria and this is certainly one reason why they do not find their way into refereed journals, a circumstance which has sometimes given life science research in space an attribute of 'esoteric science'.

Radiation protection in space is not only an issue for manned missions; it is also a concern for electronic equipment. Electronic circuit structures are nowadays so small that they are comparable to the dimensions of chromosomes and biomolecules. Approaches to the study of their damage are quite similar, both experimentally and theoretically, and these seemingly very distant fields appear now to converge and may be able to gain substantially from each other.

This short introduction sets the scene for this Chapter. In the first part the measurement of radiation field parameters and related problems will be discussed. Effects in biological systems constitute the next section, and the chapter will conclude with particular radiation protection issues. Although results from space observations are at the centre of interest, supporting ground experiments will also be discussed.

6.2 The space radiation field

6.2.1 Observations in space

In general terms, the space environment presents radiation conditions which cannot be found anywhere else. It is not uniform, however, but depends on parameters like altitude, geographical latitude (in low earth orbits) and the activity of the sun. Table 1 gives a schematic summary of the types of radiations, some of their properties and where they are found.

6.2.1.1 Galactic cosmic rays (GCR)

Heavy charged particles as important components of cosmic radiation were discovered as early as 1912 by Hess which earned him a Nobel prize (Hess 1912). Their origin is still not known. With the availability of satellites more