Preface

Space and Biology – this combination of terms is not very common in science despite the fact that biological phenomena in the unique environment of weightlessness have been analysed from the early days of space flight up to now. The exploration of Space required investigations in an area beyond the experience of man living on Earth: the border presented by the long-established environment of gravity had to be crossed, and, as in the rising era of steam trains when people were questioning the ability to survive in these high-speed vessels, one could not imagine the impact of zero gravity and Space radiation on any organism during space flight.

After more than 40 years of Space research we have a better understanding now about life in weightlessness. The authors of Chapters 4 and 8 summarize the unique results in plant root physiology and in cells of the immune system collected in their experiments over a period of 12–30 years. This wide timeframe indicates a typical fact of Space research: the frequency of experiments is very low, not days or weeks as in typical ground investigations but rather months or years due to the rare flight opportunities, the complex preparation and the many controls, all of them also having an impact on the costs of experimentation in Space. The transfer of an experimental idea from the common ground-based laboratory to the Space environment is usually combined with many tests to prove that the situation in orbit is comparable to that on the ground. Potential failures and side effects are described in Chapter 1, where the basic terms are also defined, especially the term "microgravity", which is very often used by the science community of gravitational and Space biology to describe the near weightless environment in an orbiting spacecraft. From the perspective of a Project Scientist, however, who was responsible on behalf of the Space Agency for a complete experiment from proposal until the final hand-over of the Space-flown samples to the investigator, these reviews allow one to look upon the subjects of investigation from a different angle – the big picture!

We share this perspective with our readers not only from the historical point of view, although right now experiments in Space biology are entering a new era with the International Space Station (ISS), after the retirement soon of the Space Shuttle as the main carrier for numerous experiment facilities. Most experiment platforms are accumulated now on the ISS, with a few others on satellites. The logistics and the experiment protocols are different on the ISS – more complex,

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on the one hand, but larger exposure to near weightlessness and Space radiation is possible on the other hand. These expectations will influence future research and our authors reflect these aspects in their conclusions and outlooks.

The other topic of this book is related to "Life on Earth". It was our aim to demonstrate that experiments in Space are not a solitary research field but are bound into a wide spectrum from ground-based fundamental research to application-oriented medical research. Chapters 2–4 discuss in detail the mechanisms affecting the orientation of plants in the gravitational environment. The progress achieved in this part of plant physiology was not possible without the experiments under reduced gravity in low Earth orbits. The reaction chain between the gravity stimulus and the cell-internal response can be described much better now with recent discoveries achieved in Space experiments – many pieces of the mosaic have been collected and implemented, either by falsifying a previous hypothesis (e.g. Chapter 4, Section 4.2.2) or by adding new evidence from facts previously unknown due to the permanent interference of gravity in ground-based experiments.

Human health research has also gained by space flight: Chapters 5–8 analyse investigations in the field of connective tissues, bone metabolism and immune system.

The widely spread bone loss or osteopenia by ageing or by disease, osteoporosis, is accelerated tremendously in weightlessness and is, therefore, a research objective not only in astronauts but also in cellular models, in which the primary reactions and the potential cure of bone loss can be investigated. Removal of the gravitational force is a perfect way for short-term experimentation with cell cultures, allowing deep insight in the primary processes of tissue formation (Chapter 5), bone formation (Chapters 6 and 7) and immune cell response (Chapter 8) *in vitro*. Whilst it seems obvious that the reduction of mechanical loading leads to bone loss (like on Earth during prolonged bed rest), it is not at all evident that cells of our immune system respond to gravity, which has been present during their entire evolution on Earth. Chapter 8 analyses this mysterious phenomenon that was already observed on astronauts in the very early days of human space flight.

Chapters 9 and 10 concentrate on the other feature of space flight: Space radiation and its impact on organisms and isolated cellular systems. Chapter 9 describes one kind of technological approach for radiation research in Space and on ground, focussing on radiation damage of the DNA in single cells. Chapter 10 extends this aspect of radiation research to general questions, ranging from evolution to the habitability of Mars.

We hope that the reader gets a good overview of past and current achievements in this comprehensive description of biological research in Space. Since most of the Space experiments described in the following chapters were performed in facilities of the European Space Agency (ESA), the Introduction summarises typical mission scenarios and describes ESA's experiment platforms for biological research in Space.

Enno Brinckmann
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