SpringerBriefs in Space Life Sciences

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The extraordinary conditions of space, especially microgravity, are utilized for research in various disciplines of space life sciences. This research that should unravel – above all – the role of gravity for the origin, evolution, and future of life as well as for the development and orientation of organisms up to humans, has only become possible with the advent of (human) spaceflight some 50 years ago. Today, the focus in space life sciences is 1) on the acquisition of knowledge that leads to answers to fundamental scientific questions in gravitational and astrobiology, human physiology and operational medicine as well as 2) on generating applications based upon the results of space experiments and new developments e.g. in non-invasive medical diagnostics for the benefit of humans on Earth. The idea behind this series is to reach not only space experts, but also and above all scientists from various biological, biotechnological and medical fields, who can make use of the results found in space for their own research. SpringerBriefs in Space Life Sciences addresses professors, students and undergraduates in biology, biotechnology and human physiology, medical doctors, and laymen interested in space research.The Series is initiated and supervised by Dr. Günter Ruyters and Dr. Markus Braun from the German Aerospace Center (DLR). Since the German Space Life Sciences Program celebrated its 40th anniversary in 2012, it seemed an appropriate time to start summarizing – with the help of scientific experts from the various areas – the achievements of the program from the point of view of the German Aerospace Center (DLR) especially in its role as German Space Administration that defines and implements the space activities on behalf of the German government.

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Sensory Motor and Behavioral Research in Space

Springer

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Foreword

After the book “Vestibulo-Oculomotor Research in Space” by Andrew Clarke, published in September 2017 in this series, this volume “Sensorimotor Research in Space” is the second one dealing with neurosciences. While Prof. Clarke focused on the central nervous system, especially on the vestibular system of humans and the impacts of changed gravity conditions, the authors of this volume provide a broader view analyzing aspects of posture and locomotion, of spatially oriented behavior as well as of cognitive and psychomotor performance of humans. In addition, and thus in a certain way complementing the volume of A. Clarke, the last chapter deals with the impact of changed gravity conditions on the neurovestibular system in fish.

In the first chapter of this volume, posture control and locomotion of humans on Earth and under changed gravity conditions, i.e., during short- and long-term spaceflight, are compared. It is well documented that the adaptation of astronauts to microgravity as well as to normal gravity conditions after return to Earth after spaceflight occurs rather quickly, which is advantageous in the context of interplanetary space missions involving landing and locomotion in various gravity environments. Moreover, the results of spaceflight experiments obtained are of benefit to people on Earth, especially in the context of clinical bedrest or of understanding the aging process in general. Exercise technologies developed for space have found their way into rehabilitation and clinical care such as partial weight-bearing and suspension technologies. Basic findings from space research on muscle coordination and movement control are of importance as well.

Chapter 2 focuses on spatially oriented behavior. For interacting with the world around, humans need to know where objects are located, how to get there, and how to appropriately exert force on the objects. Spatial perception, spatial navigation, and spatial object manipulation in space and on ground are, therefore, the topics discussed. The author demonstrates that perception and object manipulation are differently influenced by changed gravity conditions—findings that make new training strategies for astronauts necessary with beneficial consequences also for people with age-related navigation deficits.

In Chap. 3, the topic of microgravity-induced changes in sensorimotor processes is taken up again. But here the perspective of the author includes other stressors of spaceflight by looking to more unspecific altered environmental conditions such as living in isolated and confined environments as well as to the noise level that astronauts are exposed to during their missions. The results from spaceflight and accompanying ground research suggest that—in contrast to performance deficits in microgravity—basic cognitive processes, spatial imagery, and object recognition do not seem to be affected much by those stressors.

The fourth and last chapter elucidates the impact of changed gravity conditions on neurovestibular issues in fish. On the one hand, this is a rather peculiar topic in the current volume; on the other hand, however, it nicely complements the previous volume of our series dealing with the vestibular system of humans. Here, the authors present a comprehensive review on the development and behavior of fish as well as on the physiology and morphology of the vestibular system, with special regard to gravity-induced changes. This is not only a wonderful summary of some 40 years of space research in fundamental neurobiology but is also—since attempts are made to analyze the cause and mechanisms of kinetotic behavior in fish—relevant for explaining and possibly avoiding space motion sickness in astronauts and people on Earth.

All in all, the four chapters of this volume—together with the previous volume by Andrew Clarke—provide a broad overview on the impact of changed gravity conditions on the physiology and psychology and partly also on the morphology of the vestibulo-oculomotor and sensorimotor systems especially in humans. Space research in these topics together with the accompanying technology developments is thus shown to be of great benefit not only for the health and well-being of astronauts and cosmonauts during their space missions but also for humans on Earth.

Bonn, Germany Günter Ruyters
August 2017

Preface to the Series

The extraordinary conditions in space, especially microgravity, are utilized today not only for research in the physical and materials sciences—they especially provide a unique tool for research in various areas of the life sciences. The major goal of this research is to uncover the role of gravity with regard to the origin, evolution, and future of life and to the development and orientation of organisms from single cells and protists up to humans. This research only became possible with the advent of manned spaceflight some 50 years ago. With the first experiment having been conducted onboard Apollo 16, the German Space Life Sciences Program celebrated its 40th anniversary in 2012—a fitting occasion for Springer and the DLR (German Aerospace Center) to take stock of the space life sciences achievements made so far.

The DLR is the Federal Republic of Germany's National Aeronautics and Space Research Center. Its extensive research and development activities in aeronautics, space, energy, transport, and security are integrated into national and international cooperative ventures. In addition to its own research, as Germany's space agency the DLR has been charged by the federal government with the task of planning and implementing the German space program. Within the current space program, approved by the German government in November 2010, the overall goal for the life sciences section is to gain scientific knowledge and to reveal new application potentials by means of research under space conditions, especially by utilizing the microgravity environment of the International Space Station ISS.

With regard to the program's implementation, the DLR Space Administration provides the infrastructure and flight opportunities required, contracts the German space industry for the development of innovative research facilities, and provides the necessary research funding for the scientific teams at universities and other research institutes. While so-called small flight opportunities like the drop tower in Bremen, sounding rockets, and parabolic airplane flights are made available within the national program, research on the International Space Station ISS is implemented in the framework of Germany's participation in the ESA Microgravity Program or through bilateral cooperations with other space agencies. Free flyers such as BION or FOTON satellites are used in cooperation with Russia. The recently started utilization of Chinese spacecraft like Shenzhou has further expanded Germany's spectrum of flight opportunities, and discussions about future cooperation on the planned Chinese Space Station are currently under way.

From the very beginning in the 1970s, Germany has been the driving force for human spaceflight as well as for related research in the life and physical sciences in Europe. It was Germany that initiated the development of Spacelab as the European contribution to the American Space Shuttle System, complemented by setting up a sound national program. And today Germany continues to be the major European contributor to the ESA programs for the ISS and its scientific utilization.

For our series, we have approached leading scientists first and foremost in Germany, but also—since science and research are international and cooperative endeavors—in other countries to provide us with their views and their summaries of the accomplishments in the various fields of space life sciences research. By presenting the current SpringerBriefs on muscle and bone physiology, we start the series with an area that is currently attracting much attention—due in no small part to health problems such as muscle atrophy and osteoporosis in our modern aging society. Overall, it is interesting to note that the psychophysiological changes that astronauts experience during their spaceflights closely resemble those of aging people on Earth but progress at a much faster rate. Circulatory and vestibular disorders set in immediately, muscles and bones degenerate within weeks or months, and even the immune system is impaired. Thus, the aging process as well as certain diseases can be studied at an accelerated pace, yielding valuable insights for the benefit of people on Earth as well. Luckily for the astronauts: these problems slowly disappear after their return to Earth, so that their recovery processes can also be investigated, yielding additional valuable information.

Booklets on nutrition and metabolism, on the immune system, on vestibular and neuroscience, on the cardiovascular and respiratory system, and on psychophysiological human performance will follow. This separation of human physiology and space medicine into the various research areas follows a classical division. It will certainly become evident, however, that space medicine research pursues a highly integrative approach, offering an example that should also be followed in terrestrial research. The series will eventually be rounded out by booklets on gravitational and radiation biology.

We are convinced that this series, starting with its first booklet on muscle and bone physiology in space, will find interested readers and will contribute to the goal of convincing the general public that research in space, especially in the life sciences, has been and will continue to be of concrete benefit to people on Earth.

Bonn, Germany
July 2014

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The International Space Station ISS; photo taken by an astronaut from the space shuttle Discovery, March 7, 2011 (NASA)

Extravehicular activity (EVA) of the German ESA astronaut Hans Schlegel working on the European Columbus lab of ISS, February 13, 2008 (NASA)

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