

Preface

I wrote the first edition of *Fundamentals of Space Medicine* in 2003, when the *Columbia* tragedy grounded the space shuttle for nearly 3 years. My friend Doug Hamilton, a flight surgeon at the NASA Johnson Space Center who knew personally some of the *Columbia* crewmembers, had written a touching preface, dedicating this book to the memory of space travelers who give their lives for the advancement of space life sciences in general and space medicine in particular.

Today, I am writing the second edition of *Fundamentals of Space Medicine* just as the space shuttle will soon complete its last two space missions. By the middle of 2011, the shuttle fleet will be grounded forever, and a page in the history of space exploration will be turned. For the foreseeable future, the only vehicles allowing access of humans to space will be the Russian *Soyuz* and the Chinese *Shenzhou*. Russian, European, and Japanese automatic cargo vehicles will also dock with the International Space Station (ISS) to bring resources for the crew, equipment, fuel, and to return trash.

Fortunately, new spacecraft are in development, boosted by the commercial space and space tourism opportunities. The *Orion* and other new space vehicles developed by commercial companies for the National Aeronautics & Space Administration (NASA) in the United States will hopefully soon provide human access to the ISS. On a different scale, the commercial version of *SpaceShipTwo* is scheduled to fly by next year and will carry loads of paying passengers on suborbital flights up to 100 km in altitude, the official frontier of space. Much needs to be learned on the adaptation of the human body to the first minutes of microgravity, which was never fully investigated on board *Soyuz* and the space shuttle. So the advent of suborbital flight might prove an interesting opportunity for space medicine as well.

The International Space Station is now in its tenth year of existence, with a permanent crew of 6 people and 13 world-class laboratories equipped for state-of-the-art research in life sciences, material sciences, Earth observations, and space science. During the past decade, many experiments and observations were conducted in orbit in the area of space biology, physiology, and medicine, which have complemented the results previously obtained on the *Mir* and *Skylab* missions. The equipment and procedures used in orbit have become more and more accurate and refined, bringing new insights into the mechanisms of body adaptation to the conditions of spaceflight. Ground-based simulations of these effects, as well as studies in analog environments on Earth, have also provided useful models and new research questions. The main results of these experiments are included in this new edition, together with the results of the latest biosatellite missions and ground-based studies in analog environments on Earth.

Why this title, *Fundamentals of Space Medicine*? Space medicine and space physiology are often viewed as two aspects of space life sciences, with the former being more operational, and the latter being more investigational. Space medicine tries to solve medical problems encountered during space missions. These problems include some adaptive changes to the environment (microgravity, radiation, temperature, and

pressure) as well as some non-pathologic changes that become maladaptive on return to Earth (e.g., bone loss). Space physiology tries to characterize bodily responses to space, especially microgravity. It provides the necessary knowledge, hence the “fundamentals,” required for an efficient space medicine.

Space physiology and medicine is as old as the first flight of humans in a hot air balloon, when the symptoms of hypoxia were first discovered (at the expense of one pilot’s life). The interest in this field of research kept growing along with the space program and the opportunities it provided for more and more humans to fly in space on board capsules, shuttles, space stations, and soon suborbital spaceplanes. The future of human spaceflight will inevitably lead to human missions to Mars. These missions will be of long duration (30+ months) in isolated and somewhat confined habitats, with the crew experiencing several transitions in levels of gravity (1–0 g, 0–0.38 g, 0.38–0 g, and 0–1 g), dangerous radiation, and the challenges of landing and living on their own on another planet.

In *The Fundamentals of Space Medicine* Second Edition, special emphasis has been placed on the challenges, tasks, and research questions that must be addressed before safely sending humans to explore Mars. The greatest test for space medicine will be the projected nearly 3-year round-trip to Mars, whereas our current knowledge on humans in space does now not exceed 14 months and for only one individual, and the cumulative time in space by all astronauts and cosmonauts as of today is comparable to the lifetime of one single individual. The Achilles’ heel of the Mars mission may be some adverse reactions of the human body, such as bone loss, decreased motor and sensory capabilities, or simply psychological issues. A chain is as strong as its weakest link. Possible ways to prevent problems and countermeasures are discussed throughout the book.

This book reflects *what we do know* in space life sciences at the beginning of the twenty-first century. It also points to the missing data, i.e., *what we don’t know* and *what we should know* before committing to increased access for humans in space, including space commercial participants, by contrast with the professional astronauts, and for longer duration exploratory missions.

The format of the book is intended to facilitate its use by professors, undergraduate or graduate students, space life scientists, and space enthusiasts. It reviews step by step the changes in the major body functions during spaceflight, from the cellular level to the behavioral and cognitive levels. To better appreciate these changes, each chapter starts with a brief review of the basic principles of these human physiological functions on Earth:

- Chapter 1 begins with an introduction to the environmental challenges that spaceflight poses to the human body, and continues with a short history of space life sciences research.
- Chapter 2 reviews the effects of microgravity and radiation at the cellular level on bacteria, animals, plants, and humans, including the issues of reproduction and development.
- The following chapters each review the effects of spaceflight on the major human body functions: Chapter 3: Neuro-sensory function (the brain in space); Chapter 4: Cardio-vascular function (the heart in space); Chapter 5: Musculo-skeletal function

(the muscle and bone in space); Chapter 6: Psychological issues (the mind in space).

- However, every system or process must ultimately be viewed in the context of the entire body. The consequences of the aforementioned changes at a function level on the health and well being of the astronauts are therefore described in the Chapter 7: Operational Space Medicine.
- Chapter 8 focuses on the technical aspects related to life support systems, including radiation shielding, and the challenges for a closed, environmental system for exploration missions.
- Chapter 9 concludes this review with some tips from the author on how to proceed with proposing and planning a space experiment that uses humans as test subjects, given the available resources and constraints of current space missions.

Each chapter corresponds to one core lecture of the Space Life Sciences Department of the International Space University Space Studies Program. These lectures were developed with the help of many people from all over the world in a collegial and collaborative environment. In particular, the sections related to the medical effects of spaceflight are a contribution of my old friend and “partner in crime” at ISU, Doug “Hami” Hamilton. Some of the updates that are included in this revision have been taken nearly verbatim from books that I have published since the first edition of this book came out.

As a neurophysiologist actively participating in space research since 1982, with experiments manifested on *Salyut*, *Mir*, the space shuttle, and the International Space Station, I know what it takes to collect data during relatively simple space experiments, and then try to make sense of the sparse, often contradictory, results in a scientific paper. This book provides a summary of the main results, observations, and trends described in the literature. I apologize to the authors of the scientific publications if all of their interpretations are not included. The detailed descriptions of this research and the findings can be found in the studies listed in the bibliography. A list of other books on space life sciences is also provided.

Some space-related physiological changes and their underlying mechanisms and interpretations are sometimes described in the text in greater detail than what is required for a plenary academic lecture. For the courses I teach at ISU I have prepared PowerPoint presentations corresponding to each of the chapters in this book. These presentations include key concepts in bullet-form illustrated by recent relevant photographs and video clips. PDF versions of these presentations as well as the video clips are included on the website Springer Extras.

The first edition of this book has been translated into Chinese (see front cover in Figure 1). Should there be sufficient demand, no doubt the publisher of this book would be interested in producing other translated versions.

Finally, thanks to Angie Bukley for editing this book and being there for me.



Figure 1 The Front Cover of the Chinese Version of Fundamentals of Space Medicine (First Edition).

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Clément, G.

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