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0521820529 - Gravity and the Behavior of Unicellular Organisms
Donat-Peter Hader, Ruth Hemmersbach and Michael Lebert
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# Gravity and the Behavior of Unicellular Organisms

Unicellular organisms use gravity as an environmental guide to reach and stay in regions optimal for their growth and reproduction. These single cells play a significant role in food webs, and these factors together make the effects of gravity on unicellular organisms a fascinating and important subject for scientific study. In addition, they present valuable model systems for studying the mechanisms of gravity perception – a topic of increasing interest in these days of experimentation in space. This book reveals how single cells achieve the same sensoric capacity as multicellular organisms, such as plants or animals. It reviews the field, discussing the historical background, ecological significance, and related physiology of unicellular organisms, as well as various experimental techniques and models with which to study them. Those working on the biology of unicellular organisms – as well as in related areas of gravitational and space science – will find this book of value.

Professor Donat-Peter Häder, PhD, holds the Chair in Botany at the Friedrich-Alexander Universität, in Erlangen, Germany. He has worked in gravitational biology and space research for more than 20 years and has been involved in numerous space shuttle, sounding rocket, satellite, and parabolic flight experiments. He is the author and editor of more than a dozen books and has published more than 480 papers in scientific journals.

Ruth Hemmersbach, PhD, is a zoologist and cell biologist in the German Aerospace Center (DLR) and the Rheinische Friedrich–Wilhelms Universität in Bonn, Germany and she has been active in gravity-related research for more than 20 years. She has been principal investigator for several biological experiments under varied gravitational stimulation in microgravity (parabolic flights and space shuttle), functional weightlessness (clinostats), and hypergravity (centrifuges).

Michael Lebert, PhD, is a botanist in the Friedrich–Alexander Universität in Erlangen, Germany, who has been active in gravity-related research and computer science for 10 years. He has been involved as co-investigator in numerous biological experiments in microgravity on airplanes and sounding rockets.

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# List of Abbreviations

| | |
|---|---|
| AAEU | aquatic animal experiment unit |
| A/D | analog to digital |
| AGC | automatic gain control |
| AM | acetoxy methyl ester |
| AOTF | acousto-optical tunable filters |
| BAPTA | 1,2-bis(*o*-aminophenoxy)ethane-*N*,*N*,*N*′,*N*′-tetraacetic acid |
| CCD | charge-coupled device |
| CCIR | Commission Consultative Internationale de Radiodiffusion (video format) |
| CEBAS | Closed Equilibrated Biological Aquatic System |
| CSK | cytoskeleton network |
| DHP | dihydropyridine |
| DLR | Deutsches Zentrum für Luft- und Raumfahrt (German Aerospace Center) |
| EGF | epidermal growth factor |
| EGTA | ethyleneglycol-bis(β-aminoethyl ether)-*N*,*N*,*N*′,*N*′-tetraacetic acid |
| ESA | European Space Agency |
| FC | flagellar current |
| FFM | free-fall machine |
| FLM | fluorescence lifetime measurement |
| IBMX | 3-isobutyl-1-methylxanthine |
| ISS | International Space Station |
| JAMIC | Japan Microgravity Center |
| LED | light-emitting diode |
| LUT | look-up table |
| MAXUS | "Super" TEXUS |
| MASER | Materials Science Experiment Rocket |



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| | |
|---|---|
| MELiSSA | Microecological Life Support System Alternative |
| MIR | Russian space station |
| MscL | mechanosensitive channel large |
| MTR | microtubular rootlet |
| NIZEMI | Niedergeschwindigkeits-Zentrifugenmikroskop (slow rotating centrifuge microscope) |
| NP-EGTA | nitrophenyl-ethyleneglycol-bis(ß-aminoethyl ether)-*N*,*N*,*N*′,*N*′-tetraacetic acid |
| PAB | paraxonemal body |
| PAC | photoactivated adenylyl cyclase |
| PAR | paraxonemal rod |
| PC | photoreceptor current |
| PCR | polymerase chain reaction |
| PFB | paraflagellar body |
| PKC | protein kinase C |
| PYP | photoactive yellow protein |
| SAC | stretch-activated channel |
| STATEX | Statolithen-Experiment (statolith experiment) |
| TEXUS | Technologische Experimente unter Schwerelosigkeit (technological experiments under microgravity) |
| TPMP | triphenyl methyl phosphonium |
| 2D | two-dimensional |
| 3D | three-dimensional |
| UV | ultraviolet radiation |
| VCR | videocassette recorder |
| ZARM | Zentrum für Angewandte Raumfahrttechnologie und Mikrogravitation (Center of Applied Space Technology and Microgravity) |

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# Preface

There comes a point in the career of a scientist when he or she should write a book about his or her subject of interest. Two of us always wondered when and how this was going to happen. Now we know: by pure accident. And, here is one word of advice: You are often warned not to get involved in the book business. Please consider those who are warning you as your best friends; they know what they are talking about. However, one day, we received an e-mail (actually much longer ago than we would have anticipated) asking whether we would be willing to write a book about the effects of gravity on single cells. One of us knew what that meant; he warned us, but we agreed anyway. Finally, all three of us completed the project, and we learned a lot in the process. So, thank you, Peter Barlow and Cambridge University Press for keeping your faith in us.

Those who teach about gravity effects on living systems, including single cells, quickly realize that this weak force seems to have escaped human attention. Although we all had strong fights with gravity, especially during the early phase of our lives, it seems that afterward, we have almost completely forgotten about it. However, for all living organisms in our world, it is the one parameter most steadily encountered. Gravity is so basic for all of us that it is almost hardwired into our interpretation of reality. Gravity is not only related to living organisms; convection and the weather are two other subjects that come to mind when thinking about gravity.

For more than 100 years, scientists have been fascinated to observe the effects of gravity on single, free-swimming cells. The reason is that these little cells have the same capability as humans to tell up from down, but they do it in a single cell. And, even though it may seem to be an eccentric subject to study, this swimming behavior bears a much closer relation to daily life than one might expect. First, it becomes more and more clear that, in terms of biochemistry, single cells detect gravity in much the same way as do higher, more organized, multicellular



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organisms – and that is one of the things we want to show in this book. In addition, single cells are heavily involved in assembly and disassembly (either as consumer or as producer) of organic matter, and by this means are essential for food webs. Finally, photosynthetic cells are important oxygen sources and carbon dioxide sinks – topics coming more strongly to public attention in these times of global warming and climate change.

Lastly, we would like to thank all the people who supported us, including our families, for bearing with us during the process of writing. We would also like to thank Peter Barlow for bringing up the idea of this book. Critical discussions were the source of many new fruitful insights – thanks to I. Block, M. Braun, R. Bräucker, E. Brinckmann, K. Slenzka, and D. Volkmann. Thanks are due to U. Trenz and M. Schuster for helping to prepare the manuscript, M. Häder for the drawing of *Euglena*, E. Ariskina and M. Vainshtein for supplying the image of magnetotactic bacteria, D. Volkmann for supplying the *Lepidium* images, M. Braun for supplying the *Chara* electron microscopic images, I. Block for supplying diagrams of *Physarum*, A. Schatz for supplying the scheme of the clinostat principle, K. Slenzka for supplying the CEBAS diagram, W. Engler for producing the TEXUS image, and W. Foissner for supplying the scanning electron micrograph of *Paramecium*. Finally, we thank the national and international agencies for financial support of the research: German Space Agency (DLR), European Space Agency (ESA), National Agency of Space and Aeronautics (NASA), and the German Ministry of Research and Technology (BMBF).

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How do single cells recognize gravity and apply their perception to their ecological advantage? This book summarizes historical and current approaches to this basic question. Single cells play a significant role in food webs and also present valuable model systems for studying the mechanisms of gravity perception, a topic of increasing interest in these days of experimentation in space. The book is directed to biologists and other life scientists interested in space sciences, cellular evolution, cell motility, signal transduction and ecophysiology. Year: 2005. Edition: 1. Unicellular organisms use gravity as an environmental guide to reach and stay in regions optimal for their growth and reproduction. These single cells play a significant role in food webs, and these factors together make the effects of gravity on unicellular organisms a fascinating and important subject for scientific study. In addition, they present valuable model systems for studying the mechanisms of gravity perception - a topic of increasing interest in these days of experimentation in space.Â  The motile behavior of the unicellular photosynthetic flagellate Euglena gracilis was studied during a two-week mission on the Russian satellite Foton M2. The precision of gravitactic orientation was high before launch and, as expected, the cells were unoriented during microgravity. Unicellular organisms are viewed as the best suitable objects for studying environmental effects, including the field of gravity, on living beings at the cellular level. Investigations of unicellular free-living eukaryotic organisms in gravitational and space biology help resolve both theoretical problems and practical problems associated with the design and development of biological life support systems. This paper presents experimental data about the effect of hypergravity on the structure, function and behavior of unicellular organisms--Tetrahymena pyriformis and Euglena gracilis.

Start by marking â€œGravity and the Behavior of Unicellular Organismsâ€ as Want to Read: Want to Read savingâ€¦ Want to Read. Currently Reading. Read. Gravity and the Behavi by Ruth Hemmersbach. Other editions.Â  Let us know whatâ€™s wrong with this preview of Gravity and the Behavior of Unicellular Organisms by Ruth Hemmersbach. Problem: Itâ€™s the wrong book Itâ€™s the wrong edition Other. The unicellular freshwater flagellate Euglena gracilis shows negative gravitactic behavior. Previous experiments have revealed that the orientation is most likely an active physiological process in which the beating pattern of the flagellum is controlled by gravity and mediated by a change in the calcium concentration inside the cell. In a signal transduction chain, the calcium signal activates a calmodulin, which in turn raises the concentration of cAMP.Â  Gravity is a major clue to select a niche in their environment. Positive gravitaxis leads an organism down into the water column and negative gravitaxis brings it to the surface. In Euglena the precision of gravitaxis is regulated by an internal rhythm entrained by the daily light/dark cycle. The phenomenon that some free-swimming unicellular organisms tend to swim to the top of a tube and gather there â€“ independent of whether the tube is open or closed â€“ has been observed more than 100 years ago. This behavior was termed geotaxis (orientation with respect to the gravity vector of the Earth) â€“ negative geotaxis if the organisms orient upward and positive geotaxis if they swim downward (cf. Section 1.2). Nowadays, this term has been replaced by gravitaxis.