**Mini-Bioreactors and 'Star Trek' Food Replicators**

**Marcel Egl, Head of the Swiss based 'Space Biotechnology Group' of the ETH Zurich talks about biotechnology research in space, what it can do for the people on Earth and what astronauts might eat in the future.**

"Biology" and "Space" are not two areas that have an immediate connection. Where is the link?

True, to find a link between them we need to be more specific about the term 'space'. Considering space as an environment in which our planet is embedded. There is a strong link between biology and space. Life on Earth evolved during the last 3.9 billion years in a particular environment providing certain temperatures, an atmosphere, water and other parameters. This terrestrial environment is the result of particular astronomical facts - for example the size of the Sun, the distance between Sun and Earth, the relatively close orbiting Moon that causes tides, and the rotation of the Earth that sets a day and night rhythm. Life adapted to these environmental factors, or one could also say: these factors shape life on our planet. To understand biology on Earth better, we also need to understand how these astronomical facts influence life on our planet.

We have several approaches to how we investigate the influence of space on organisms. One of our main research topics is to study what effect space travel has on daily rhythms of mammals. These rhythms, called 'circadian rhythms' are important in almost all organisms because they are responsible for the internal timing of physiological processes. A particular family of genes - the so-called clock-genes - determine the circadian rhythms. So far, we know that circadian rhythms are altered in space - no surprise really, astronauts witness 16 Sunsets during a standard 24-hour terrestrial day. Our research indicates that the clock-gene expression patterns - the way the genes are actually doing what they are supposed to do - is disturbed in simulated space condition. What we are doing now at the Space Biology Group is trying to find links between the changes of the clock-gene expression patterns and internal physiological rhythms. Traditionally the Space Biology Group of the ETH Zurich also investigates how mammalian cells react to weightlessness. The Space Biology Group started this kind of research about 30 years ago under the lead of its former head Dr. Augusto Cogoli. The first studies were conducted on lymphocytes, blood cells that are vital for our immune system. Our goal is to further investigate the mechanisms of how microgravity affects mammalian cells.

The Space Biology Group also developed different types of space bioreactors, which were used during several space missions. With these reactors, we are able for example to cultivate mammalian cells in space. In collaboration with engineers from the Interstate University of Applied Sciences of Technology Buchs and the University of Applied Sciences Woensdrecht, we are currently developing new types of space reactors enabling us to do more specialised experiments with other cell types in space.

**And now you are reversing this step - bringing life to space to investigate how it reacts. What kind of research is the Space Biology Group doing in space?**

An important result of our research was the discovery that the activation of lymphocytes in humans is reduced in space. This was very unexpected. The results indicate that the immune system of an astronaut who spends a long time in space could be more vulnerable to infections. But beware - it is just an indication. You cannot make valid assumptions about the whole immune system of an astronaut based on single cell experiments. We definitely have to carry out more experiments until we will be able to draw a final conclusion. We also experimented on other cell types and gathered a basis of understanding of how space alters cellular processes. Another highlight of our research activity is certainly the already mentioned space-proven bioreactor. It is very challenging not only for cell biologists but also for engineers to design and build robust as well as reliable mini-bioreactors, which can be operated successfully in space.

**What kind of space research will there be in the future, and will there be benefits for people on Earth?**

Sure, there are benefits derived from space programmes already. Just think about all the technologies, which are natural for us nowadays but were actually developed to a great extent for the Apollo program, such as micro-electronics which are incorporated in pocket calculators, PC’s, cellular phones or freeze-dried food. Even new materials were developed for that programme like Mylar, a synthetic material used for example for sails like the ones...
THOMAS REITER

THE SKINCARE EXPERIMENT IS UPLOADED TO THE ISS DURING AND DISTINCTIVE SHAMPOO THAT WORKS WITHOUT WATER. THEY ALSO NEED SKIN-CARE PRODUCTS THAT DOES NOT ONLY PROVIDE THE MAXIMUM NUTRITIONAL VALUE BUT ALSO DOES NOT ‘GO OFF’ IN THE HARSH SPACE CONDITIONS , THEY NEED PARTICULAR SLEEPING BAGS AS BED-SUBSTITUTES.

ASTRONAUTS HAVE A LOT OF SPECIFIC NEEDS DURING A SPACE MISSION: THEY NEED SPECIAL FOOD THAT DOES NOT ONLY PROVIDE THE MAXIMUM NUTRITIONAL VALUE BUT ALSO DOES NOT ‘GO OFF’ IN THE HARSH SPACE CONDITIONS, THEY NEED PARTICULAR SLEEPING BAGS AS BED-SUBSTITUTES AND DISTINCTIVE SHAMPOO THAT WORKS WITHOUT WATER. THEY ALSO NEED SKIN-CARE PRODUCTS因为 THE HARSH SPACE ENVIRONMENT DRIES THE SKIN OUT. SKIN-CARE IS SO IMPORTANT TO THE WELL-BEING OF AN ASTRONAUT THAT AN EXPERIMENT ON THE ISS IS NOW INVESTIGATING THE EFFECTS OF MICROGRAVITY ON HUMAN SKIN.

However, skin deterioration is one of the major detrimental effects experienced by astronauts in space. The skin being the largest organ of the human body and serving as its protective shield is highly susceptible to harmful environmental influences, such as all of us have painfully experienced with sunburn. Space itself is a tough environment for humans to survive in, and living in space for a long period of time puts lots of strains on the human body - including the skin. Astronauts and cosmonauts living on the International Space Station are constantly exposed to conditions that stress their skin: for instance, the constant draft from the station’s ventilation system takes its toll on the skin by drying it out and making it more susceptible to scratches and irritation. On Earth we experience a phenomenon that shows similar effects on human skin: ageing. Does space have an accelerated effect on the ageing of human skin?

Three German companies have now teamed up to get to the bottom of this problem by conducting the SkinCare experiment on the International Space Station (ISS), namely Degussa, Courage + Khazaka and Skincare supplier ‘Degussa’.

Implemented by ESA’s Commercial Agent for Biotechnology, Health, Food and Nutrition - ISS Lab Ruhr GmbH - in cooperation with ESA, the ‘SkinCare’ experiment is planned to be uploaded to the International Space Station during the Astrolab Mission, the first ESA long duration mission carried out by German ESA astronaut Thomas Reiter. For the first time, the effects of space conditions on human skin will be systematically examined with non-invasive high tech equipment. One goal will be to gather valid scientific data on how skin changes in weightless space conditions. Different parameters of the skin, such as elasticity, hydration, skin surface structure and what scientists call ‘transepidermal water-loss’ - otherwise known as sweating - will be examined. For this, a skin protection product for autonomous production of food will be tested on the European Columbus module, is not too complicated, but should be reasonably fast and affordable for interested companies.

WHAT KIND OF INDUSTRIES DO YOU THINK OF?

There are potentials for biotechnology companies, like our experimental data demonstrated. Cells under microgravity conditions show an interesting behaviour that could be capitalized on. The food industry could also profit from space research. Or you could combine - the space bioreactor used as an independent autonomic system that produces food. The product from this bioreactor could function as an alternative food source for human long-term mission, for instance to Mars.

THIS SOUNDS LIKE AN EARLY VERSION OF FOOD REPLICATOR FROM ‘STAR TREK’.

Almost, and maybe one day we will be able to autonomously produce all the food needed for a space station in orbiting space station, who knows?

Astronauts have a lot of specific needs during a space mission: they need special food that does not only provide the maximum nutritional value but also does not “go off” in the harsh space conditions, they need particular sleeping bags as bed-substitutes and distinctive shampoo that works without water. They also need skin-care products because the harsh space environment dries the skin out. Skin-care is so important to the well-being of an astronaut that an experiment on the ISS is now investigating the effects of microgravity on human skin.
Keeping Astronauts fit

While normally considered to be a unique and exciting experience, free floating in space is potentially damaging for human health. Bone deterioration and muscle loss are common problems of a living in weightlessness for a long period of time, which constitute a serious threat to an astronaut’s health. This is a direct consequence of the lack of gravity: the stress of sustaining the body in the presence of gravity stimulates bone formation and increases bone density, whereas the absence of gravity leads to bone denaturalisation and loss of strength. In the same way, muscular atrophy occurs in space, because the body does not need to fight gravity to move, thus requiring less action and less energy from the muscles. Other negative consequences can be observed on the cardiovascular system. On Earth, the heart must work hard against the force of gravity to pump blood through the body. In space, the heart lessens its pace as a result of the decreased needs. This process of physical deconditioning actually mimics the natural aging condition and can be described as artificially accelerated aging, with the difference that the effects of weightlessness are largely reversible, and astronauts gradually recover as soon as they are back on Earth.

In order to regain their strength quickly and effectively, astronauts need to keep fit and to counteract the adverse effects of microgravity with physical exercise, which is the only means currently known to maintain muscles and bones and to stimulate their recovery. For this reason exercise and fitness are parts of every astronaut’s life before, during and after spaceflight. In space the crew members need to exercise for a few hours a day. Special exercise programmes are prescribed and special equipment is needed, as weightlessness does not allow training with traditional instruments, which rely on the force of gravity. Astronauts can pedal on a bike without tyres, run on a treadmill and use elastic cords, pulleys and ropes to generate resistance and to exert force. Such devices are in some ways similar to those commonly used in fitness centres, but in reality they are considerably smaller and lighter. However, as with many other tools and technologies which were originally created for space and which then resulted in useful applications on Earth, so also have fitness solutions originally developed for space proved to be extremely valuable for improving people’s quality of life.

An example of this is the Swedish-designed Yo-Yo “Flywheel” resistance trainer, developed for astronauts on board the International Space Station to boost muscle performance. The system provides resistance during coupled concentric-eccentric muscle actions, through the inertia of a spinning flywheel assembly, the strap being wound and unwound around the axle of a fixed flywheel. Developed by YoYo Technology AB with support from ESA, NASA and the Swedish National Space Board, the instrument has found successful application in training centres around the world. Another innovative training system has been recently developed by the company Elektronik- & Systementwicklungs-gesellschaft mbH (ESE), in cooperation with ESA and together with the subcontractors Umedicon Chemnitz and Institut für Sportwissenschaften Wien. The ESE Endurance Training System (ETS) is a novel tool which allows optimising the time used to exercise in space and protects the astronauts from over stressing muscles and bones. Other than the Flywheel, which is a strength training device, the ETS is designed for endurance training which primarily has effects on the cardiovascular system. The system allows straining different muscle groups, while a heart rate control is realised and further vital parameters are foreseen for the biofeedback. A built-in software system allows one to program different exercises, and an optical bio-feedback tracks in real time and keeps records of the performance of the subject. Specifically studied for utilisation in space as a countermeasure against the detrimental effects of weightlessness, the ETS could open numerous possibilities of application on Earth, in the areas of medicine, as a rehabilitation device, or in the areas of fitness and sports.

ESA is constantly employing its know how and unique technologies to develop innovative solutions for astronauts which often result in useful application for society, and it is offering its support and its expertise to companies which intend to develop innovative projects or test in the space environment innovative technologies and equipment.

Find out more about how you can join forces with ESA. Contact: issbusiness@esa.int

Companies interested in utilising such equipment to conduct research onboard the ISS, please contact us under this email address: issbusiness@esa.int

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At the Industry Space Days 2006

In order to study its physiological effects and to develop bed rest, confinement, circadian rhythms, etc, in order to improve healthcare. The main activity areas of MEDES are support to space missions, clinical research, health applications and telemedicine. MEDES relies on the scientific, technical and medical expertise of its members (CNES, Toulouse university Hospitals and several universities) to perform these activities. In the space mission area, MEDES is involved in preparing and monitoring astronauts before, during and after space flights. This includes selection and training of astronauts, performing aptitude tests, providing medical support during space flights, as well as ensuring crew rehabilitation and safety. Moreover, MEDES provides support to the user support operation centre CADMOS to prepare physiological experiments which are carried out in space, especially on board the International Space Station. These activities enable MEDES to maintain a good knowledge of the needs of operational space medicine, of the facilities available onboard and of the potential links with medical applications.

MEDES is actively involved in clinical research in the areas of physiology, pharmacology and the evaluation of biomedical devices. These activities rely on a unique European research facility, the Space Clinic, a 1000 m² centre, housed within the Rangueil university hospital in Toulouse. In support to space research, MEDES undertakes experiments which simulate the effects of the Space environment (involving bed rest, confinement, circadian rhythms, etc) in order to study its physiological effects and to develop preventive methods. In this field, MEDES is actively promoting the use of the experimental models developed for space research for the needs of public health and industrial research. In the health applications area, MEDES is actively involved in developing projects with both space and industrial objectives. The space environment causes indeed several physiological disorders which are analogous to health problems (motion sickness and balance disorders, orthostatic intolerance, bone loss…). Understanding the physiological mechanisms responsible for these disorders and developing preventive methods are the key objectives underlying the application of space research to healthcare. For example, with the support of ESA, MEDES is developing within the ERISTO project in partnership with laboratories and industries prevention, diagnosis and treatment methods for osteoporosis. These activities have enabled to develop and validate a new technology measuring bone quality and enabling an early detection of bone loss. MEDES is also participating in several educational projects, aiming to raise awareness among young people of the importance of having a healthy lifestyle.

Moreover, MEDES is contributing to developing satellite applications for healthcare through telemedicine. The main application areas are:

- Remote medical consultation, from isolated locations, mobile sites or from disaster areas
- Epidemiology for the electronic surveillance of epidemics in isolated areas or in crisis situations, as well as using satellite observations to study the environment’s influence on environment-dependent illnesses
- Education and training, in particular through the use of interactive satellite television
- Patient care, through the implementation of projects encouraging patient autonomy

In these fields, MEDES has implemented several sustainable networks for teleconsultation and epidemiological surveillance, and has facilitated the creation of two start up companies.

For further information, go to MEDES web site: www.medes.fr