Microgravity & The Human Body

Since the beginning of human spaceflight more than forty years ago, scientists have desired to understand the effects of spaceflight on the human body. These studies have provided invaluable information related to long-duration spaceflight and also the aging process in humans. Many new materials have been developed as a result of the space programs around the world.

The majority of this report is devoted to the effects of micro-gravity and the human body, with the rest focusing on the materials developed as the result of spaceflight and their origins.

Pre-1980 Studies

The first microgravity studies were conducted during Mercury 3, the first U.S. manned spaceflight in history. Its goal was to test the effects of spaceflight on the human body.

In the end, it likely tested an astronaut's endurance ability as much as it did his physical ability to withstand the effects of spaceflight. During Mercury 3, astronaut Alan Shepherd waited more than six hours inside his phone-booth-sized capsule before launch.

The flight went flawlessly, with a force of 11 times the force of gravity being felt during reentry. This is enough to black out and possibly kill a normal person, but in his full pressure suit, Shepherd very much survived the flight.

During the Gemini and Apollo years, vital signs were observed on most of the astronauts that went into space. Rarely was any mission's focus on life sciences, but rather, mechanical checkouts were the prime focus, the secondary focus being politics.

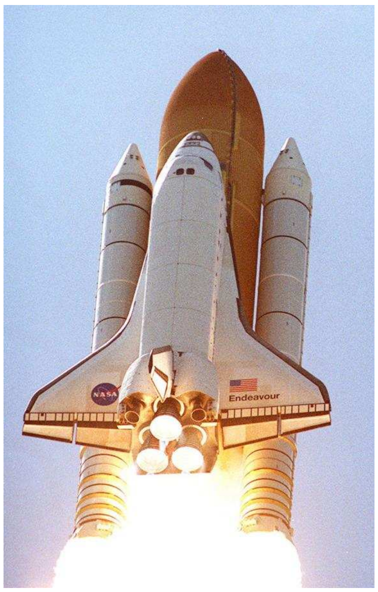

Skylab *(1974)*

The first step taken toward life sciences studies was the construction and launch of Skylab in 1973. Three crews were subsequently sent to Skylab in the next 9 months. Little information was found about the actual studies, but it is assumed that they much resembled the early Shuttle/Spacelab missions.

The Shuttle Era

The birth of the Space Shuttle was a giant leap forward for the United States, making life science studies much more affordable than they were previously. Of the 112 Shuttle missions to date, the prime goal of 23 of the missions was life science related. Most of these 23 missions included Spacelab, a European-built module which was placed in the Shuttle's cargo bay and was designed solely for the purpose of providing an environment for conducting life-science experiments. The most recent life science mission (and the last Spacelab mission) was STS-95, on which John Glenn returned to space. STS-107 is sponsored by SPACEHAB, an American space research company.

The effects of spaceflight parallel the effects of aging in many ways. When astronauts are in space for long periods of time, they lose bone and muscle mass, as do people when they get older. The biggest difference in the two is that most astronauts do not lost bone or muscle mass permanently and usually recover in a short amount of time. Long-duration astronauts' bone loss is much more pronounced, and depending on the age of the astronaut, can be somewhat permanent. It can take much longer to recover bone mass after a long-duration spaceflight.



Space Shuttle Endeavour *(2000)*

The skeletal system likely changes more than any human system while in space. The most immediate effect is the loss of bone mass, which starts immediately after being exposed to microgravity. Calcium in the bones is discharged into the blood, eventually to be filtered out by the kidneys. If left unchecked, osteoporosis can set in within a few months. To combat this, astronauts exercise daily with treadmills and bicycles. This does not stop bone loss, but it drastically reduces the amount of bone loss which occurs during spaceflight missions.

The circulatory system experiences some changes as well while an astronaut is in space. Experiments conducted aboard STS-9 (the first Spacelab mission) showed that the red blood cell count of the astronauts decreased, on average, 9% during the week-long mission. The blood plasma decreased 6% in the same time period, but quickly returned to its normal level following the mission. White blood cell count, on the other hand, did not change, though subsequent spaceflights observed a marginal decrease. In summary, the total amount of blood loss was 10%, but it returned to normal within ten days of landing.

Water is also shifted around considerably while an astronaut is in space. Due to the lack of gravity, the fluids in the body move from the legs to the torso area, causing the astronaut's upper body to appear swollen and the legs to appear very skinny. Much of this fluid is removed from the body by natural means. On the STS-40 mission, a 4% decrease in the amount of water in the astronauts was observed, as was a 22% decrease in the amount of plasma.

One rather peculiar change that occurs during spaceflight is the change of an astronaut's sense of taste. While in space, they lose their sense of taste, making normally appetizing foods appear nearly tasteless. To compensate for this, most astronauts usually pick foods which are more spicy than they would on earth. Don't get the mild, go with the hot!

Cosmic radiation is a large concern for long-duration astronauts and an even larger issue for a potential expedition to Mars than it has been in the past. Although radiation is somewhat higher on orbit, the extreme upper atmosphere shields spacecraft (and their occupants) from otherwise harmful radiation, hence the existence of the ionosphere. Recently, a primary astronaut on the International Space Station's Expedition 6 crew asked to be removed from the flight due to radiation concerns for unknown reasons. In any case, radiation is monitored closely, as it poses a high risk to astronauts if they receive too much.

Plant experiments have also been flown aboard the Shuttle, the first of such missions being STS-3 in 1982. STS-3 consisted of eighteen oat and ten mung bean seedlings, which germinated several hours prior to launch. Post-mission analysis revealed that the roots of the plants on the mission were 6% smaller than those in a control group on the ground. Amazingly enough, twenty-four of the plants flown on the mission had roots that grew upward, apparently trying to find some sense of up and down! The number of divisions in the plants was considerably smaller in the flight group than was in the control group, decreasing by 90% on the oat seedlings and 50% on the mung beans.

Many animals have been flown on Shuttle missions in addition to plants. STS-51B, for example, featured two squirrel monkeys and twenty-four rats, half of them being adults, half of them being twelve-week-old juveniles. Four rats were equipped with telemetry transmitters.

Neither monkey ate as much in orbit as they did on the ground. Adaptation was very different for both monkeys, as one did so very quickly; the other did not, and did not consume any food for the first four days on orbit.

The rats flown on the mission drank more water, but ate less food while on orbit. The effects on the bodies of the rats were similar to that of humans: bone mass was reduced, the immune system was weakened, and the metabolism was altered significantly. The rats were subjected to little stress during the mission.

Space Station Alpha

Although the Shuttle is a great resource for conducting scientific experiments, it cannot fly missions longer than 28 days, though the longest missions to date have been 16 days.

Freedom, the original U.S. space station design, was originally commissioned by Ronald Regan in 1988 as a U.S.-only project. Later, Bill Clinton commissioned the help of Russia to aid in the construction process. The plans were revised and work started. However, the road was not easy, stretching budgetary constraints on both ends. In the end, several pieces to the station, and more recently, Russia has stated that it will not be able to supply Soyuz emergency return capsules to the Station for the length of its contract, which expires in 2006.

The International Space Station, Alpha *(2002)*

The key to the International Space Station is the duration of its missions. As of December 31, 2002, the longest mission was over 190 days, breaking a U.S. record. With long-duration missions to the International Space Station, experiments can have a chance to develop over several months, even several years in some cases.

A major problem plaguing astronauts on long-duration missions is bone loss and the associated side-effects. When calcium is removed from the bones, it is usually filtered out of the body through the kidneys and removed by natural means. This poses a health risk because some of the calcium can build up in the kidneys, causing kidney stones. An experiment on the International Space Station at the present time is being used to evaluate kidney stone prevention treatment, and hopefully be applied to patients on Earth.

The International Space Station program is so new and few experiments have been evaluated, so little data is available about the experiments currently being flown. Studies are in work to see if plants are a viable way to produce oxygen aboard the station, the main downside being that they consume water.

Material Development

With spaceflight comes the need for new materials, both for the construction of spacecraft and to provide a habitable environment for astronauts to live in for, in some cases, months at a time. Because of this need, many new materials have been developed. This section takes a look at the benefits of the materials developed from the space program.

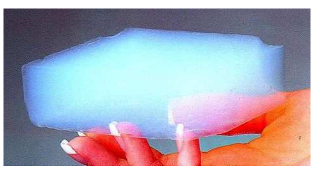
Several elements are essential in building a habitable spacecraft. A spacecraft must be able to provide life support to its occupants, shield them from the hazards of space, put them into orbit safely, and bring them back to Earth.

Every manned spacecraft has a pressurized cabin, similar to that in an airliner, albeit much stronger. The cabin's shell is usually made of a strong metal to withstand the pressure differential between the inside air and the outside (which is something to the tune of 14 PSI). It is inside this cabin where the astronauts live for the duration of their mission. A breathable atmosphere is usally provided through compressed oxygen and nitrogen in the spacecraft. Water and electricity are provided through fuel cells, which burn liquid oxygen and hydrogen at a slow rate to produce electricity and water.

Atlantis *(1997)*

The thermal insulation products developed have quite remarkable properties. The thermal tiles used on the belly of the Space Shuttle, for example, absorb heat so well that they can be taken out of a 3000-degree kiln and be held in a bare hand without being so much as a little warm to the touch. It comes as little surprise that the main component of these tiles is carbon.

Of great interest to scientists is Aerogel, known for its remarkable insulation qualities (its insulation qualities are 39 times greater than fiberglass). No less remarkable are its physical properties. It is similar in composition to glass, though it is extremely porous. It could likely see value as a home insulator in the future, however, nobody has succeeded in completely removing the bluish tint, which would be essential to its use in windows.



Aerogel

Hints of Shuttle and Shuttle-based technology have also made their way into aircraft design and the fly-by-wire systems integral to nearly all large aircraft today. The Shuttle was a pioneer in computer-based flight management; it was essential to the safety of each flight. Cockpit designs have also been heavily influenced by Shuttle research.

The medical industry has received its fair share of breakthroughs thanks to technology developed during the Shuttle program. An excellent case study of this comes from the HED foundation. Several people in the United States who cannot tolerate exposure to UV rays have received UV suits developed originally by NASA, and following the suits' success, the HED foundation.

Space exploration can be a valuable tool for research which could ultimately lead to new materials being developed which could save many lives and a lot of money in the future, for example, windows paned with Aerogel. Many stones have yet to be turned, however, and only time will tell what they bring.

Because of the nature of this project, this report is only able to outline the developments of the space program. The bibliographical sources contain much more information about the topics discussed here.

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Photo Credits

Page 1: *Skylab* (1974). Description: *Skylab* above the Earth as seen during Skylab 4 mission. Source: NASA.

Page 2: Space Shuttle *Endeavour* (2000). Description: A perfect liftoff of Space Shuttle *Endeavour* on mission STS-100. Source: NASA.

Page 4: The International Space Station, *Alpha* (2002). Description: The International Space Station following the undocking of *Endeavour* on mission STS-113. Source: NASA.

Page 5: *Atlantis* (1997). Description: Through a fish-eye lens, *Atlantis* is seen moments from touchdown to conclude mission STS-84. Pictured is the underside of *Atlantis*, showing the thermal tiles which protect the orbiter from the extreme heat of reentry into Earth's atmosphere. Source: Kennedy Space Center.

Page 5: Aerogel. Description: This Aerogel was manufactured for an unmanned research mission by NASA's Jet Propulsion Laboratory. Composed of 99.8% free space, it will be used to capture comet particles for scientific study.