Student information sheet
Grades 6-9

SPACE TRAVEL AND THE EFFECTS OF WEIGHTLESSNESS ON THE HUMAN BODY

The human body is an extraordinary but, also, an astonishingly complex machine. Like other living organisms, the human body has evolved by adapting to Earth's gravitational field, and the biological structure and mechanisms of the body have developed to suit normal Earth gravity.

What is gravity?

The phenomenon of gravity is created by the interaction between two bodies. The force of gravity increases as the size of the two bodies increases and/or the distance between them decreases.

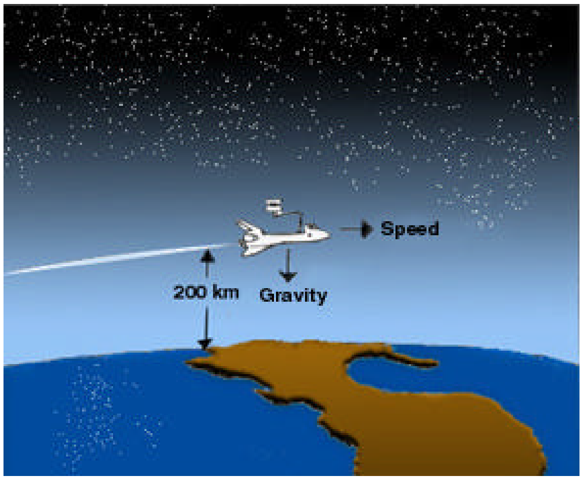
The gravitational force that acts on human beings at the Earth's surface is the result of the interaction between Earth and the human body. As Earth is more massive, it pulls the body toward the centre of the Earth. This is gravity. Do you think your weight would be the same if you were on another planet of the solar system? Mass (m) is the total amount of matter in an object, while weight (W) is the product of the acceleration due to gravity (g) and the mass. The mathematical formula is as follows:

$$W = m * g$$

On Earth, gravity equals 1. This figure began as an arbitrary, egocentric one (with the Earth as the benchmark for the rest of the universe). Strangely enough, this makes for the same figure, on Earth, for quantity of matter and weight. Such is not the case on other planets, which have different gravitational fields. Thus, on the Moon, gravity is six times weaker than on Earth. So an astronaut would weigh a sixth as much on the lunar surface. The Moon's gravity is six times less than the Earth's gravity.

When in Earth orbit, the astronaut's body is still acted on by gravity, but much more weakly because of the distance. In addition, the speed acquired by the spacecraft to send the astronaut into space partially counteracts the gravitational force that continues to act on the spacecraft. This is the law of inertia. Thus, gravity disappears and the astronaut's body becomes weightless.

Canadian Space Agency Agence spatiale canadienne



"Weightless" means that there is no *sensation* of weight. The term ***zero gravity*** is also used, but to avoid promising too much scientists have adopted the term ***microgravity,*** because the effects of Earth's gravitational force, and other forces, are not completely cancelled out.

Why do we float in space?

An astronaut is in ***free fall*** when orbiting Earth. The reason the astronaut floats inside the spacecraft is that he or she is falling at the same speed as it is.

The phenomenon of floating caused by free fall can also take place on Earth. Consider the example of a person in an elevator that suddenly breaks free and falls from the 30th floor of a building. The person inside, who would be falling at the same speed as the elevator, would float inside.

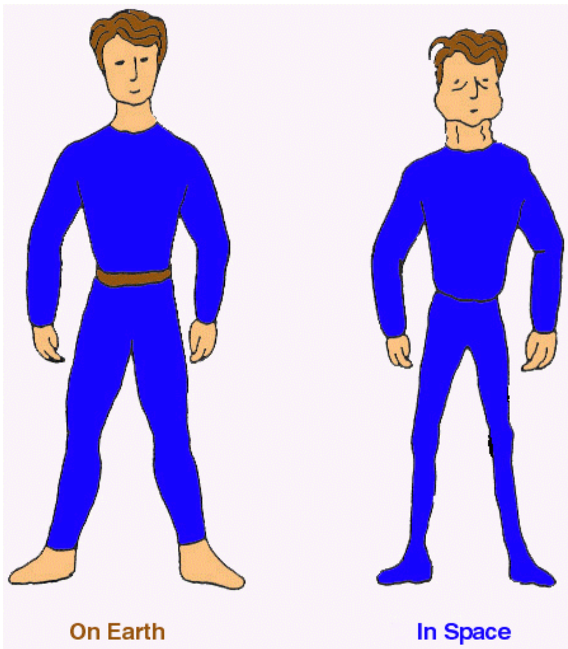
Naturally our astronaut does not fall to Earth, despite being in free fall, because the speed imparted to the spacecraft keeps it in orbit.

Both phenomena, microgravity and floating, have an impact on an astronaut's body in space. Space research has given us a better understanding of the physical and chemical properties of matter. This broad field of research is known as "*microgravity science*." The effects of gravity on our bodies and the biological mechanisms involved in adapting to weightlessness are studied under real microgravity conditions. Research on astronauts has shown that body function is disturbed in microgravity. Space agencies are therefore continuing their research in hope of eventually reducing or eliminating some of these undesirable physical effects that appear during a stay in space. Results of this research will make prolonged space missions safer, at a time when construction of the international space station is just getting under way, and may one day allow human beings to go on to Mars.

Canadian Space Agency astronaut Chris Hadfield experiences the physiological effects and the freedom of weightlessness

Influence on blood circulation

One of the most visible effects of a space mission is no doubt the "*puffy-face", "bird-leg"* look that astronauts get.

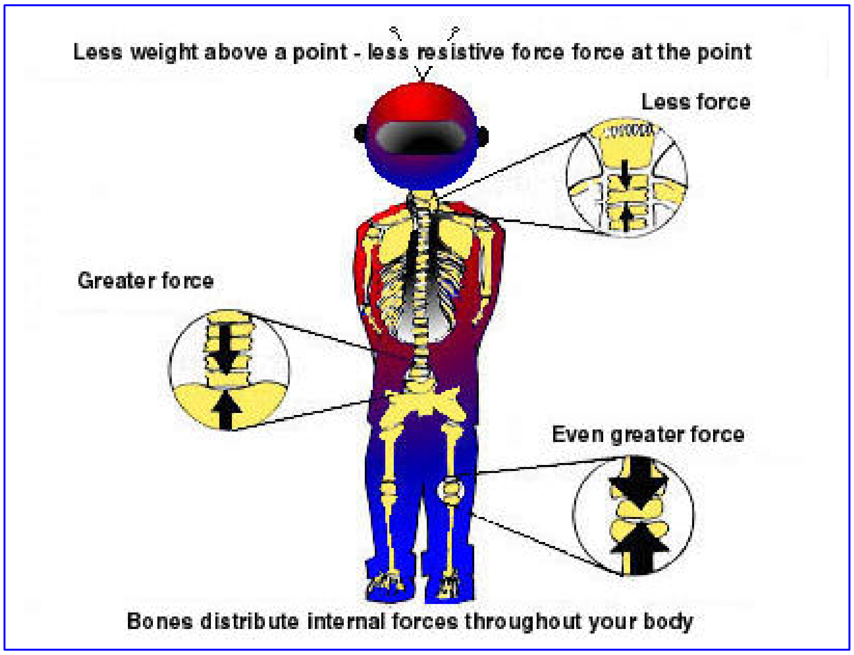


On Earth, the heart is programmed to distribute blood evenly throughout the body. The heart must do more work to supply the upper body, because blood is naturally drawn downward by the force of gravity. The lower limbs do not have this problem, as the blood coming to them is gravity-assisted.

In space, bodily fluids no longer flow back down naturally by gravity. The heart is still programmed the way it was on Earth. So, under the pressure of the heart and the veins and arteries, the blood rushes to the person's torso and head, and they then experience *"puffy face syndrome*." The veins of the neck and face stand out more than usual; the eyes become red and swollen. This effect is often accompanied by nasal congestion and sometimes even headaches. Astronaut's legs also grow thinner, because instead of dropping effortlessly down to the lower limbs, the blood has to be pumped there by the heart.

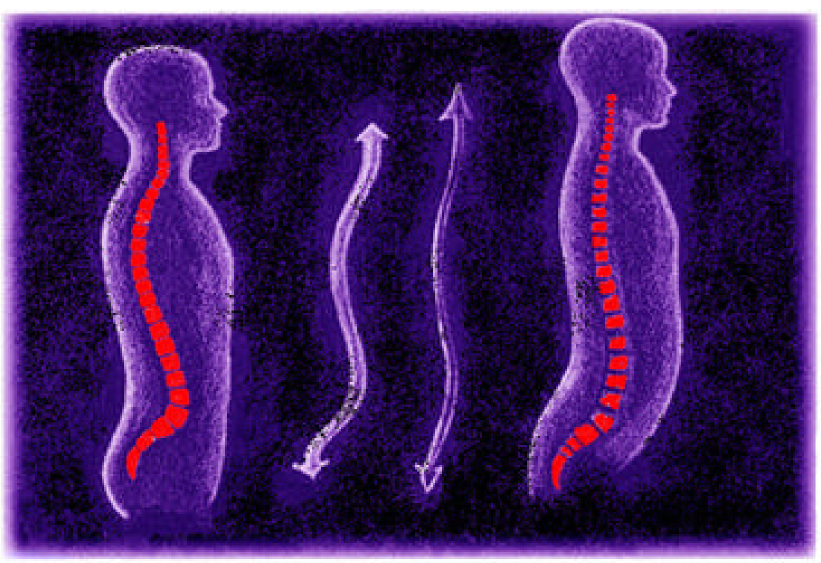
Particularly because of physiological changes such as these, astronauts suffer from space sickness or space adaptation syndrome (the space version of what we call motion sickness on Earth). About 40% of those who have gone into space have had dizziness or nausea. Both generally wear off after 2 or 3 days, as soon as the astronaut's body has had time to adapt.

Influence on the bone and muscle structure



In space, the musculoskeletal system continuously deteriorates. The muscles, in particular the leg muscles, which are underused, become flabby and lose tone and mass. The astronauts are then subject to *muscular atrophy*. The bones, too, become weaker because of a loss of minerals (calcium, potassium and sodium). This bone degradation can reduce bone in the lower limbs by up to 10%.

Astronauts try to mitigate these changes by taking medication and, especially, by exercising as often as possible.

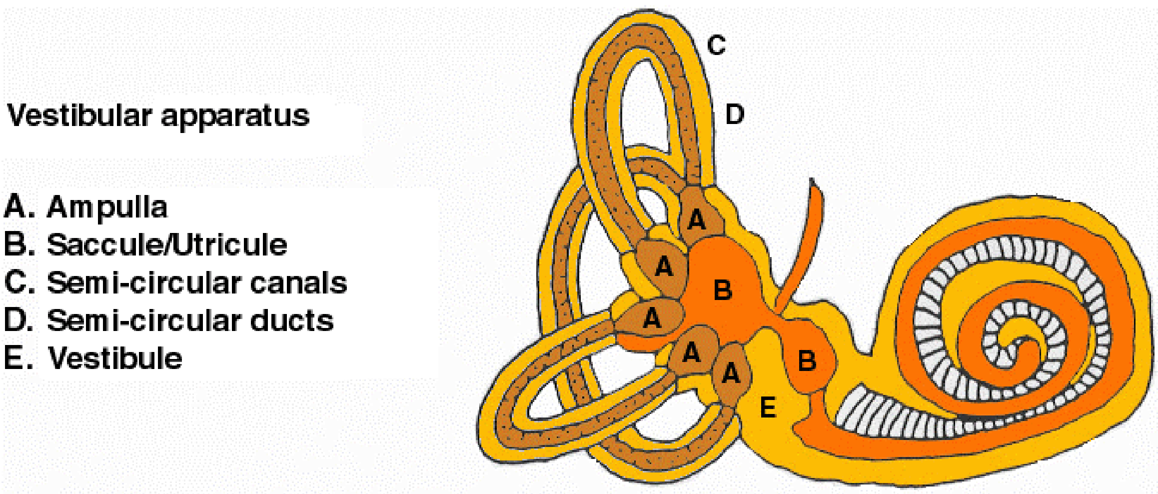


During space flight, the vertebrae separate slightly from one another and the spine lengthens for more than seven centimeters due to weightlessness.

Did you know that your body gets taller in space? Because the spine is no longer compressed by the force of gravity, the vertebrae separate slightly from one another and the person's body lengthens. Astronauts often have backaches, which, it is thought, are caused by relaxation of the muscles and ligaments of the back. Back on Earth, the force of gravity will influence the astronaut's spine, which will return to its normal size.

Influence on balance and the sense of orientation

Balance and orientation are also disturbed, for in space the body lacks its normal points of reference. Whatever medium the human body finds itself in, the brain receives information from its environment through the eyes (the *visual cues*), the muscles and tendons (the *proprioceptive apparatus*) and a set of sensors that detect liquid movement and are located in the semicircular canals of the inner ear (the *vestibular apparatus*).



Even after the astronaut leaves Earth, his or her brain continues to believe that its points of reference are terrestrial ones. Thus, because the information being received is chaotic, the astronaut has trouble adapting to this new microgravity environment. He or she is disoriented because the sensors of the inner ear and the muscular apparatus cannot orient themselves in zero g. The only useful information reaching the astronaut's brain is through the eyes.

Definitions to remember

Physiological effects of space flight: Effects of space travel on the human body: space sickness, disorientation, migration of organic fluids to the upper body, bone deterioration, muscular atrophy, lengthening of the spine, backaches, etc.

Gravity: Result of the gravitational forces exerted by a heavenly body on some other body.

Mass: Quantity of matter in a body.

Weight: Heaviness of an object owing to the force of gravity.

Zero gravity (or weightlessness): State of a body such that the set of gravitational and inertial forces to which it is subject have a zero resultant.

Microgravity: State of a body such that the set of forces of gravitational origin to which it is subject to have a very small resultant compared to Earth-normal gravity.

Space sickness (or space adaptation syndrome): Set of physical symptoms manifested in space by human beings and other living beings.

Disorientation: Malaise caused by a sensation of loss of balance and direction.

Vestibular apparatus: One of the physiological systems which, with the visual and proprioceptive systems, is responsible for our balance and sense of orientation.

Bibliography

This bibliography is intended to be instructive but is not exhaustive. All these documents may be consulted (and, in the case of videos, reproduced) at the Canadian Space Resource Centres.

Books in English

How do you go to the Bathroom in Space?, William R. Pogue, Tom Doherty Associates, 1991.

The Astronauts: - Canada's Voyageurs in Space, Lydia Dotto, Stoddart, 1993.

Books in French

Habiter dans l'espace : De Gemini aux cités du futur, Éditions Hatier, Paris 1992.

Ils voulaient la Lune : Alan Shepard, Deke Slayton, Éditions J'ai lu, Paris 1995.

L'exploration de l'espace : Voyage à travers l'univers, Éditions Time Life, 1990.

Mission Mir : Journal de bord, Jean-Loup Chrétien, Éditions Michel Lafont, Paris 1998.

Videos

- *Living in Space:* Shuttle Life in the World of Weightlessness
- *Living in Space:* Lift-off to Learning
- *NASA Biology:* On Earth and in Space (episodes 1 to 14)
- *The Musculoskeletal System in Space:* The Biology and Space Exploration Series