



# DLR\_School\_Lab

Köln

## Cardiovascular physiology

Is weightlessness fatal? In the 1950s, when technology had advanced enough to be able to send living organisms into orbit, scientists were not sure: After all, life evolved under the constant influence of gravity. Test flights with dogs, apes and finally humans showed that most organisms can live under conditions of weightlessness for a prolonged period of time. But how does our body adapt to this new situation?

In weightlessness, our bodily fluids also weigh nothing. Their distribution throughout our body will differ from their distribution on Earth. In this experiment, we will examine the reactions of our cardiovascular system to changes in pressure and fluid dispersal.

A grown-up has around 5 litres of blood. This most important transportation system in our bodies ensures the supply of oxygen to our organs and the removal of CO<sub>2</sub> from our body. Our blood also transports metabolites, vitamins, electrolytes and hormones. Other important functions include immune defense against microorganisms and exogenous substances, as well as the regulation of body temperature. Veins carry more blood than arteries, as venous blood vessels expand slightly.

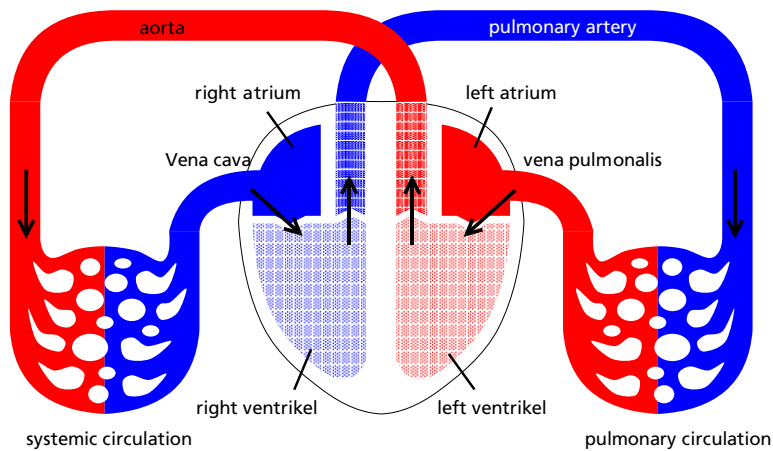


Fig. 1: Simplified blood circulation diagram. Venous blood is carried from the vena cava through the right heart chambers and the pulmonary artery into the lung. From here, it is transported into the left atrium and the left ventricle, where the aorta carries the blood back to the organs.

Our heart has to keep our blood flowing. Four to six litres of blood are transported through our heart per minute. That equals about 8000 litres per day (the contents of roughly 44 large bath tubs).

### Characteristics and regulation of cardiovascular circulation

Our heart rate is governed by a complex system. Special muscle cells in the heart tissue produce a basic rhythm that can be modified by neurotransmitters and the nervous system. The heart's activity and therefore the blood pressure can thus be adapted quickly to suit changing conditions (e.g. sleep, rest, physically and/or mentally demanding situations). By conducting an electrocardiogram (ECG) we are able to examine the contraction of the heart. We will do this during our experiment. Other important measurements include the systolic blood pressure (when the heart contracts) and diastolic blood pressure (when the heart dilates), as well as the heart rate (number of heart beats per minute).

### The baro reflex

Good blood circulation through the brain is vitally important: A sudden drop in blood pressure can result in dizziness, loss of consciousness and critical dysfunctions.

Our heart and the arteries in our necks (arteriores carotes) carry sensors that are sensitive to changes in blood pressure. If the blood pressure decreases, neurotransmitters that increase the heart rate are released immediately (positive chronotropic effect): the heart beats faster, which in turn increases the blood pressure.

A further reaction to the decrease in blood pressure is the contraction of blood vessels that supply peripheral parts of the body. This also leads to an increase in blood pressure. The heart rate decreases, though over time this can lead to cold hands and feet.

The body's reaction to changes in blood pressure is called the baro reflex. It can regulate both increases and decreases in blood pressure. The baro reflex is not only effective in exceptional circumstances, but constantly regulates the blood pressure and can be activated by such a minor situation as a cough or under physical strain. Anyone wanting to

become an astronaut or a jet pilot has to be tested for the baro reflex. Why is that important?

### Acceleration and fluid shift in the body

Our body is accustomed to an apparent gravity of 1g (9.81 m/s<sup>2</sup>): Our heart pumps blood through our bodies and is assisted in this by vein pumps in the legs and by our breathing.

If a jet pilot flies a sharp bend or an astronaut is subjected to extreme changes in velocity during take-off and landing, their blood might weigh up to 30kg instead of the usual 5kg and will be pressed down into the person's legs. Centrifuges are used to test whether the circulation remains stable under such circumstances. You will see a human centrifuge in the DLR\_School\_Lab in Cologne.

In weightlessness, our blood weighs nothing at all. Therefore, more blood than usual is transported upwards into the head. Astronauts suffer from severe headaches in the first few days. Their mucous membranes are swollen and some astronauts complain of limited vision (fig.2 B).

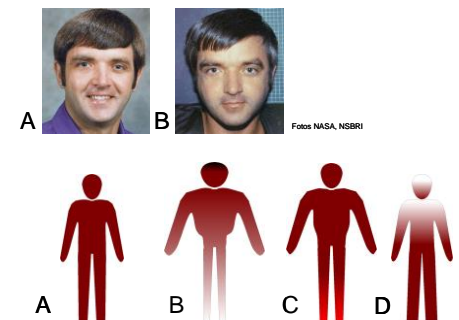


Fig. 2: Distribution of fluids in the body (A) on Earth, (B) in weightlessness, (C) after adaptation to weightlessness, (D) during landing.

The body adapts to the new environment and less blood is pumped into the upper body and the vein pumps work less (C).

When the astronaut returns to Earth, most of his or her blood is pulled towards their legs. This can lead to dizziness and loss of consciousness (D).

## The Valsalva manoeuvre

The Valsalva manoeuvre is a simple test of baro reflex functionality. The test candidate blows into a tube and by doing this, increases the pressure in its ribcage. This results in the compression of the vena cava, meaning that less blood flows towards the heart. The blood pressure decreases and activates the baro reflex. The blood pressure decreases and activates the baro reflex. The experiment simulates situation D in fig. 2.

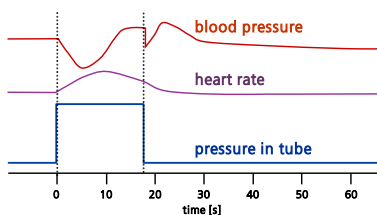


Fig. 3: Schematic diagram of a Valsalva manoeuvre: After a rise in pressure in the tube, the blood pressure decreases. The baro reflex ensures an elevated heart rate and a subsequent increase in blood pressure. Why does the blood pressure continue to rise even though the heart rate declines after a certain amount of time?

## Our experiment

We will test the baro reflex on volunteers from your group. We will measure the following parameters and discuss the results together:

- > ECG (electrocardiogram) using Einthoven's triangle (electrodes attached to forearms and one leg)
- > Continuous blood pressure and heart rate recording (using a finger cuff)
- > Pressure in tube during the Valsalva manoeuvre

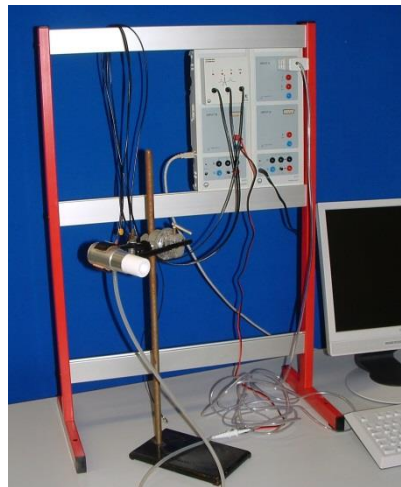


Fig. 4: Apparatus for Valsalva manoeuvre



Fig. 5: Valsalva experiment

## Literature

Ziemssen T., Süss M., Reichmann, H.: Die kardiovaskuläre Funktionsdiagnostik des autonomen Nervensystems – eine Einführung. Neurophysiol. Lab. 24/2 (2002), S. 57–77

Fox, B.C.: Statische Autoregulation der intrakraniellen venösen Hämodynamik unter Orthostase und Änderungen des Unterkörperumgebungsdrucks. Inauguraldissertation, Justus-Liebig-Universität Gießen (2003)

Saborowski, R.: Über die Beeinflussung der Lagewahrnehmung und des visuellen Systems mittels Über- und Unterdruck auf den Unterkörper. Inauguraldissertation, Justus-Liebig-Universität Gießen (2001)

## Web sites

<http://www.kardionet.de>

[http://www.dlr.de/me/desktopdefault.aspx/tabid-1935/2759\\_read-4226/](http://www.dlr.de/me/desktopdefault.aspx/tabid-1935/2759_read-4226/)



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## About DLR

DLR is the Federal Republic of Germany's research centre for aeronautics and space. We conduct research and development activities in the fields of aeronautics, space, energy, transport, security and digitalisation. The German Space Agency at DLR plans and implements the national space programme on behalf of the federal government. Two DLR project management agencies oversee funding programmes and support knowledge transfer.

Climate, mobility and technology are changing globally. DLR uses the expertise of its 55 research institutes and facilities to develop solutions to these challenges. Our 10000 employees share a mission – to explore Earth and space and develop technologies for a sustainable future. In doing so, DLR contributes to strengthening Germany's position as a prime location for research and industry.

## DLR Cologne

Aviation, space travel, transportation, energy and safety are the research areas pursued in the nine research facilities at DLR Cologne. The basis of the research and development carried out on site are the large testing facilities such as wind tunnels, turbine and materials test benches and a high-flux density solar furnace. The 55 hectare/ 136 acre site is home not only to the research and administrative facilities of the DLR, but also to the European Space Agency's (ESA) European Astronaut Centre (EAC). The DLR has around 1400 employees in Cologne.



## Deutsches Zentrum für Luft- und Raumfahrt

DLR\_School\_Lab Köln  
Linder Höhe  
51147 Köln

Head: Dr. Richard Bräucker  
Telephone: 02203 601-3093  
Telefax: 02203 601-13093  
E-Mail: schoollab-koeln@dlr.de  
Internet: www.DLR.de/dlrschoollab

### About the experiment:

Recommended for grade(s): 9 to 13  
Group size: 5 to 6  
Duration: 50 minutes  
Subject matter:  
medicine  
biology