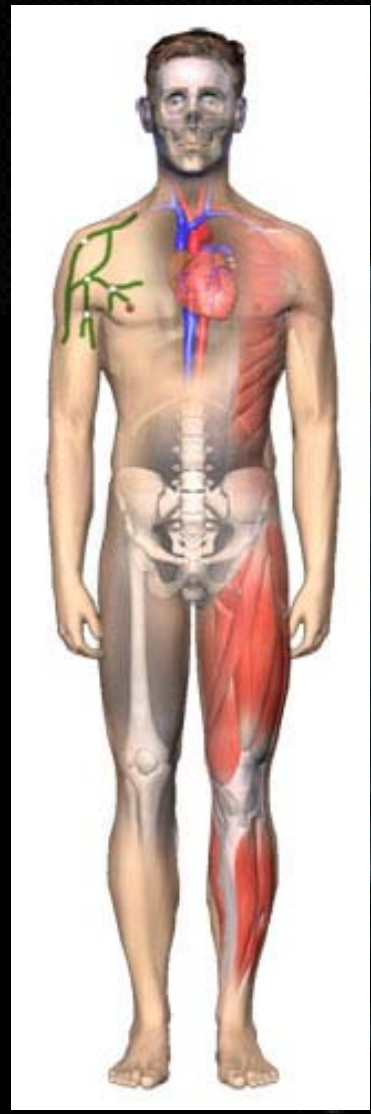
Human Space Flight Challenges

Get a Leg Up

Adaptation begins nearly immediately after crew members experience microgravity and continue to effect multiple systems because of the complex integration of the human body.



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Non-Exercise Physiological Countermeasure Project

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Cardiovascular System & Fluid Shift Lecture
Learning Objectives

After this lecture, you will be able to:

- Name two of four of the signs and symptoms of fluid shift in the astronaut when they fly in low earth orbit.
- Describe how the leg muscles influence blood flow
- Outline the four phases of “fluid shift” and where the majority of the central volume of blood is located in the body
- Name at least two other changes to the body systems as a result of Fluid Shift

FD 2 – STS-122 Pilot Alan Poindexter on the aft Flight Deck of Atlantis during STS-122

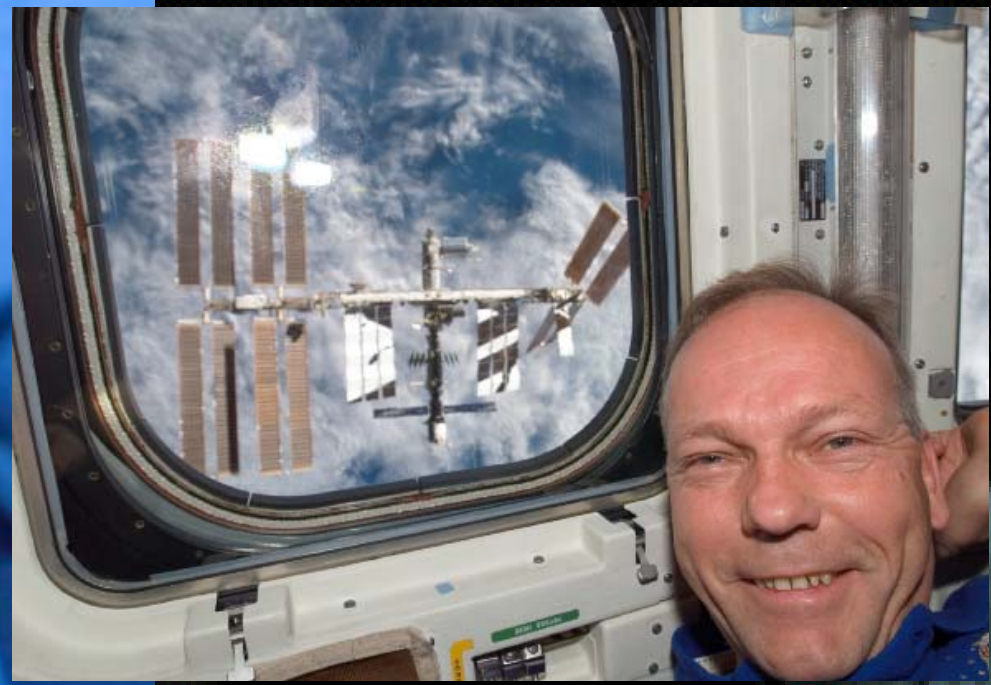
Alan Poindexter on FD 12

Alan Poindexter preflight

STS-122 Commander Steve Frick and Pilot Alan Poindexter on the aft Flight Deck of Atlantis on FD 2

Steve Frick preflight

STS-122 Mission specialist and European Space Agency (ESA) astronaut Hans Schlegel on FD 2



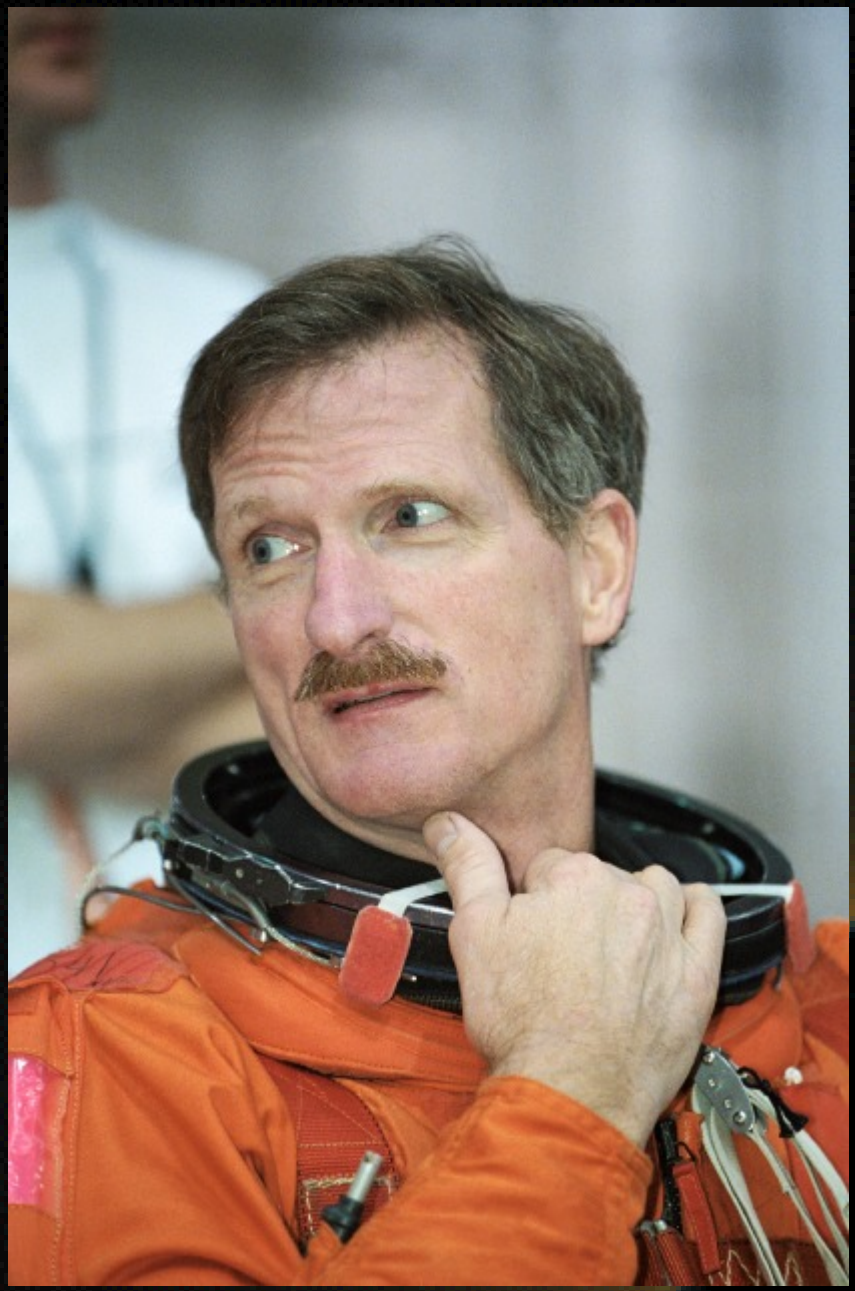
Hans Schlegel on FD 12

Schlegel preflight during water survival training at the Neutral Buoyancy Laboratory

STS-122 Mission specialist Leland Melvin on FD 2

Leland Melvin on FD 12

Leland Melvin preflight



Before flight

During flight (FD 2/3)

Before flight

During flight (FD 2/3)

During flight (FD 2/3)

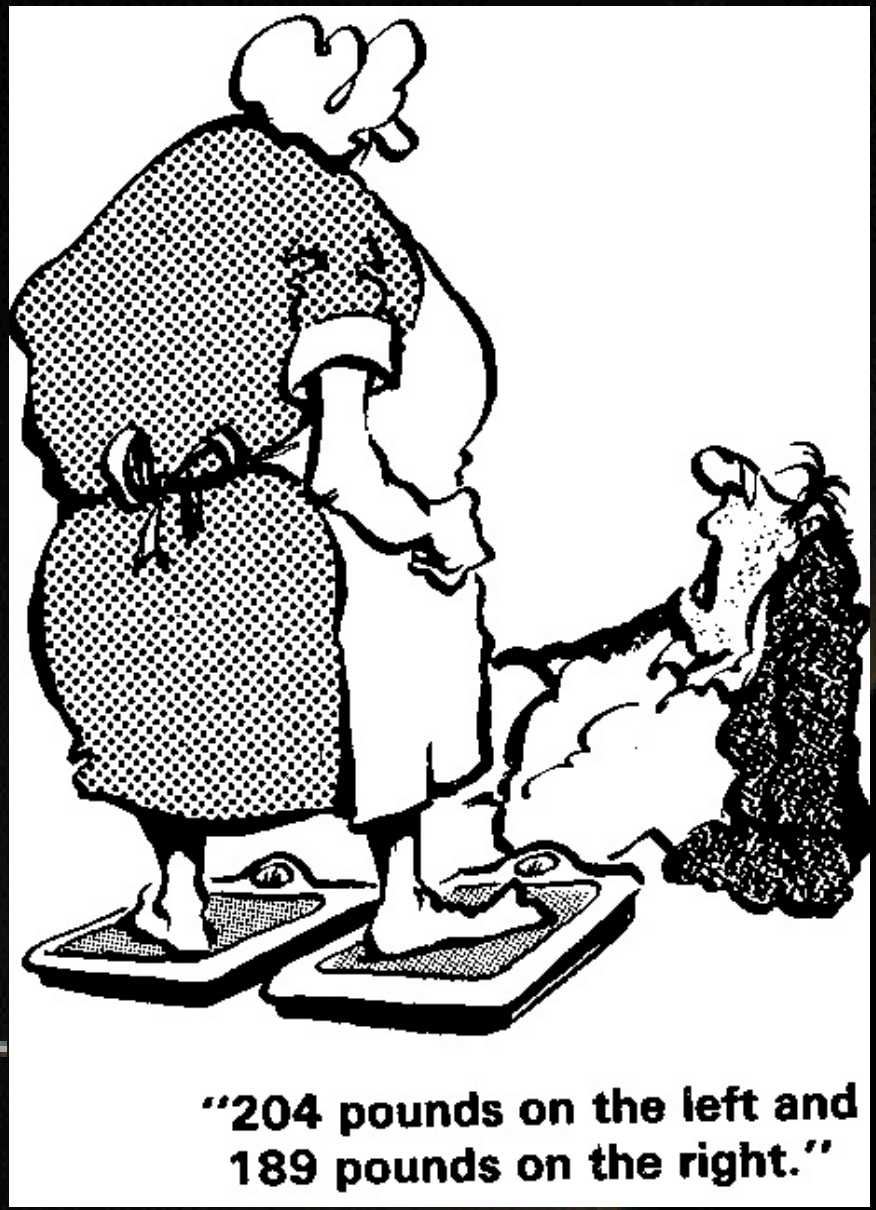
Before flight

The Problem

- **U.S. space program**
  - Mercury-8 (9 hrs): modest increase in heart rate postflight
  - Mercury-9 (34 hrs): increase in heart rate (132 supine; 188 standing) postflight
  - Gemini: fainting episode
  - Apollo: heart rhythm disturbances
  - Shuttle: 8 episodes of dizziness or fainting in the first 26 missions
- **Soviet/Russian space program**
  - Soyuz-9 crew was so severely debilitated they could not egress the capsule without assistance
  - Long-duration spaceflights: many returning crews are incapacitated and are unable to egress the capsule without help

Photo NASA

NASA Astronaut Selection

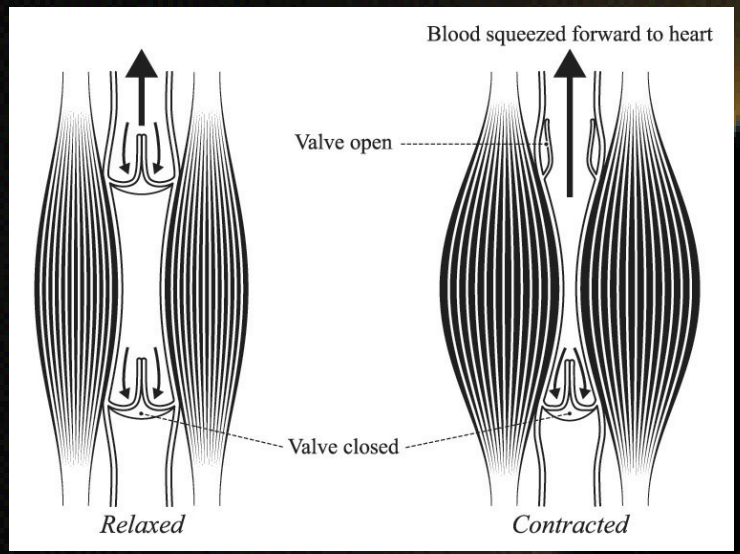


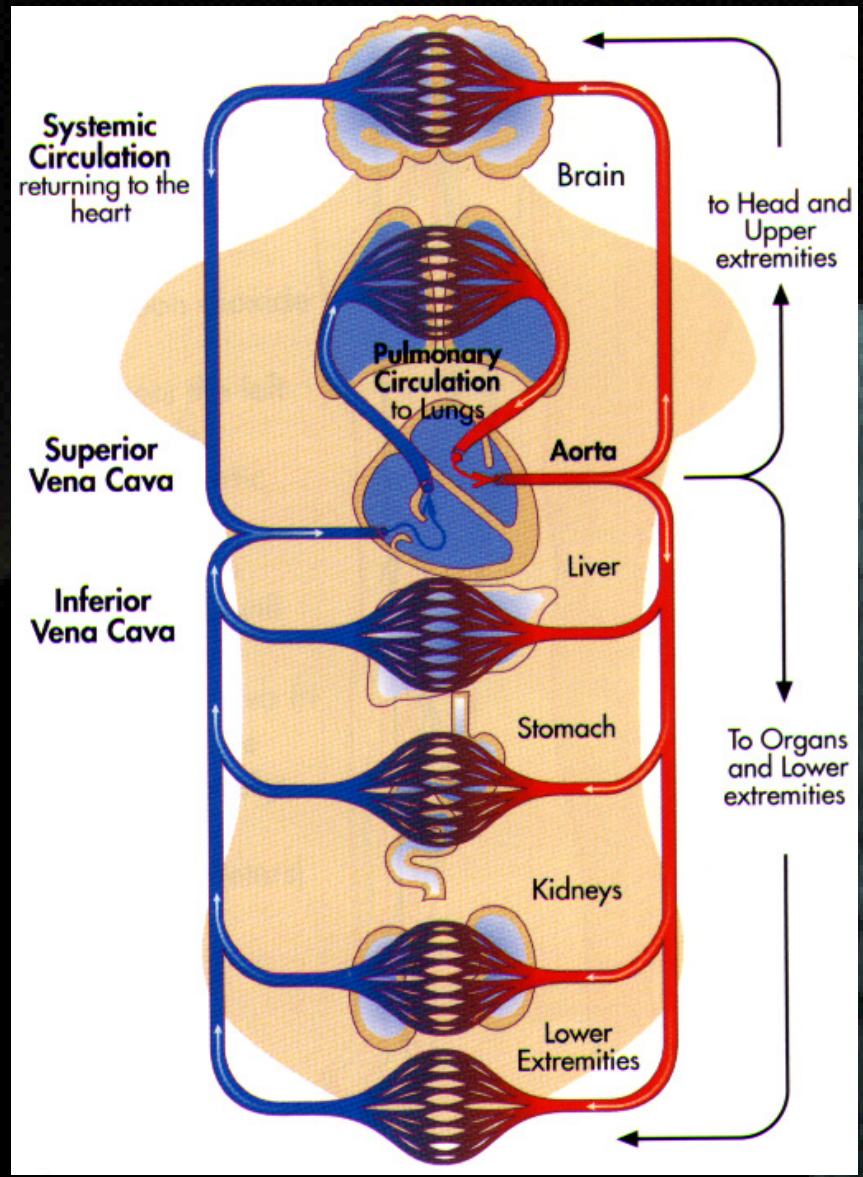
- As a rule, astronaut candidates are in excellent physical shape
- Astronaut candidates under go an initial physical examination which includes examination of their cardio-vascular system
  - Much like what U.S. Air Force pilots must have

Cardiovascular Physiology

- The heart pumps blood through blood vessels to **deliver oxygen** and **pick up CO_2** from various organs

- Contraction of leg muscles helps to pump blood toward the heart (**venous return**)

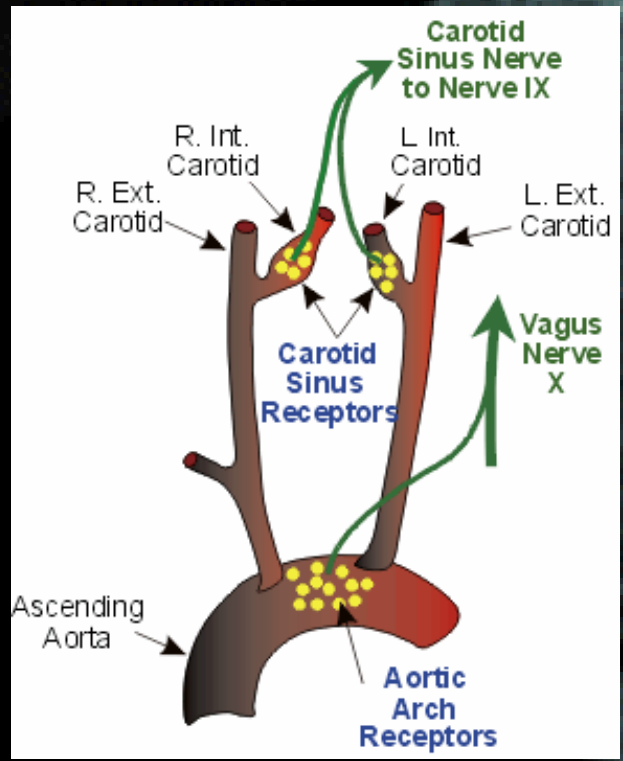




Adapted from Lujan and White (1994)

Baroreceptors

- The rapid transition between upright, sitting, and lying down postures requires that the heart and blood vessels **adjust very quickly**
  - The **baroreceptor reflex** is the body's rapid response system for dealing with changes in blood pressure
  - **Baroreceptors** are located in the carotid artery and in the aorta



- Microgravity **deconditions** baroreceptor response.
  - resulting in larger changes required for baroreceptor to induce the same changes in heart rate compared to 1-g

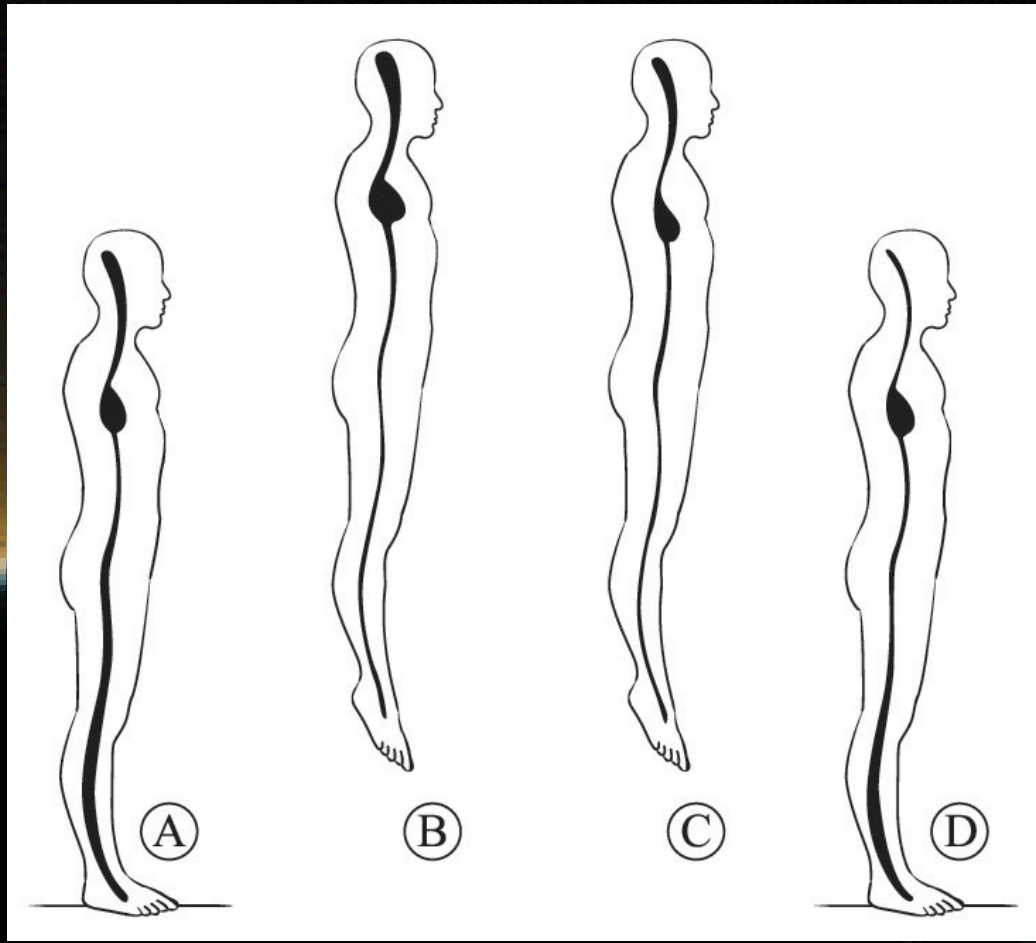
Early On-Orbit — Fluid Shift

a. On Earth, gravity exerts a **downward force** to keep fluids flowing to the lower body (A)

b. In space, the fluids tend to **redistribute** toward the chest and upper body (B). This is responsible for the face congestion.

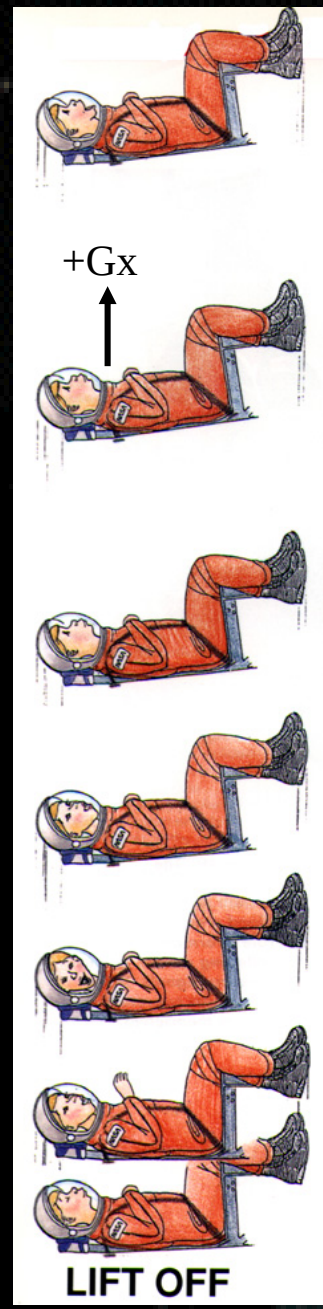
c. The body functions with less fluid and the heart becomes **smaller** (C)

d. Upon return to Earth, gravity again pulls the fluid **downward**, but there is not enough fluid to function normally on Earth (D)



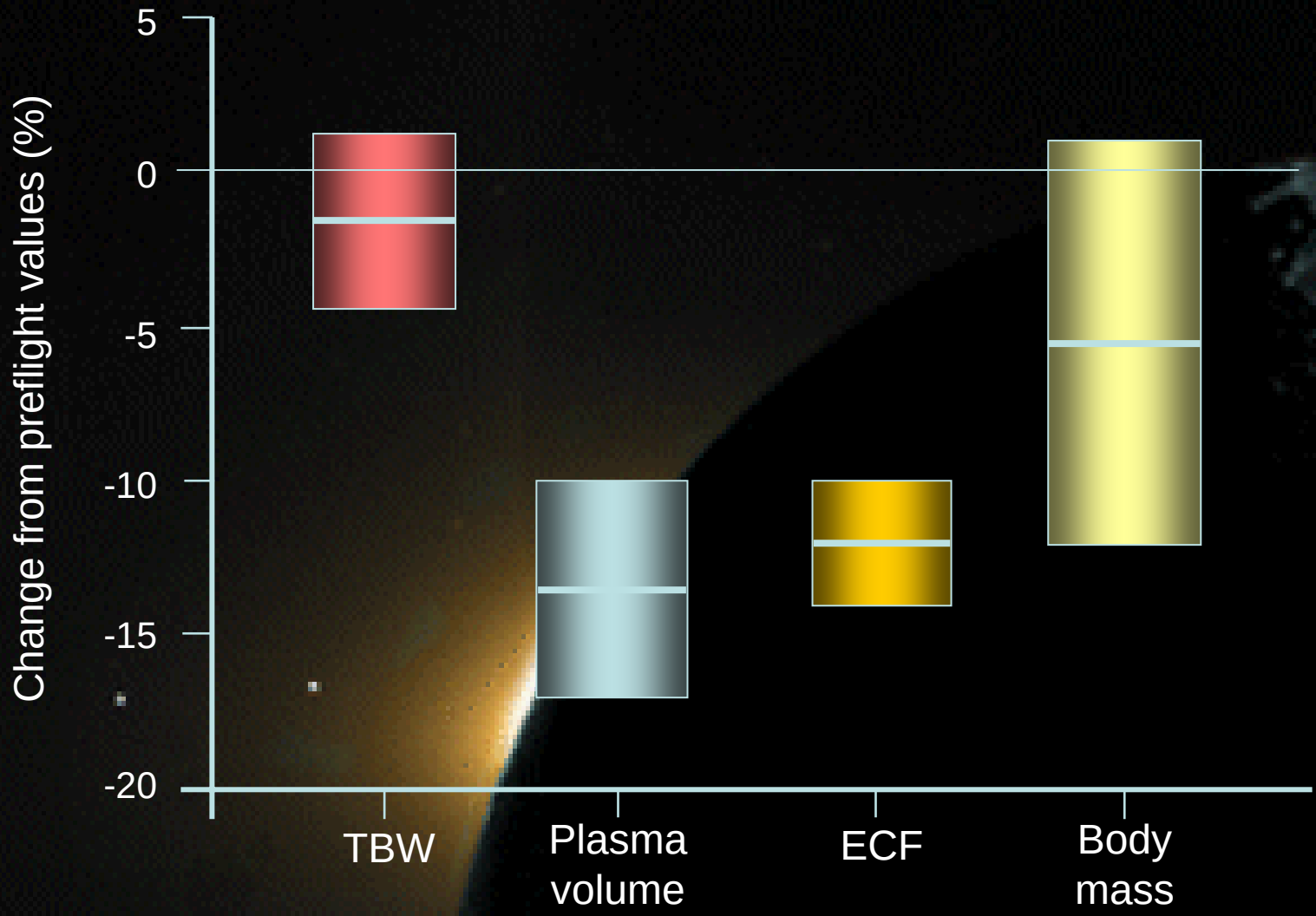
Pre-Launch Position

- The crew is placed in the Shuttle approximately **1 hour** prior to expected launch
- Crew can be in the Shuttle for as long as **4 hours** before mission control considers a launch scrub
- Supine position with 90° hip and knee flexion in order to limit launch acceleration to the **+Gx** direction
- The effect is that significant blood volume is placed above the heart, increasing load to the heart
- The body compensates for this by **reducing blood volume** through urination and reduced thirst
- The astronauts sometimes prefer to restrict their fluid intake prior to launch and “fly dry”
- Reduction in blood volume on the launch pad may impair the ability to emergency egress (syncope upon standing)



Adapted from Lujan and White (1994)

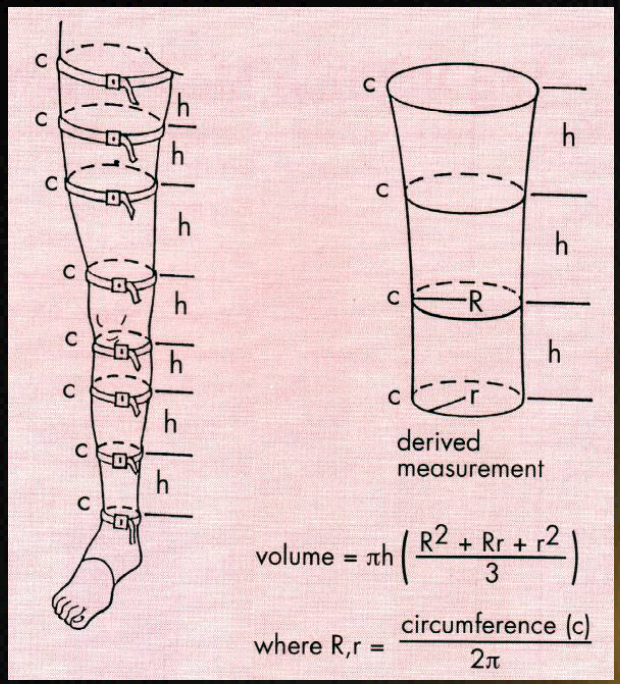
Change in Fluid Spaces During Space Flight

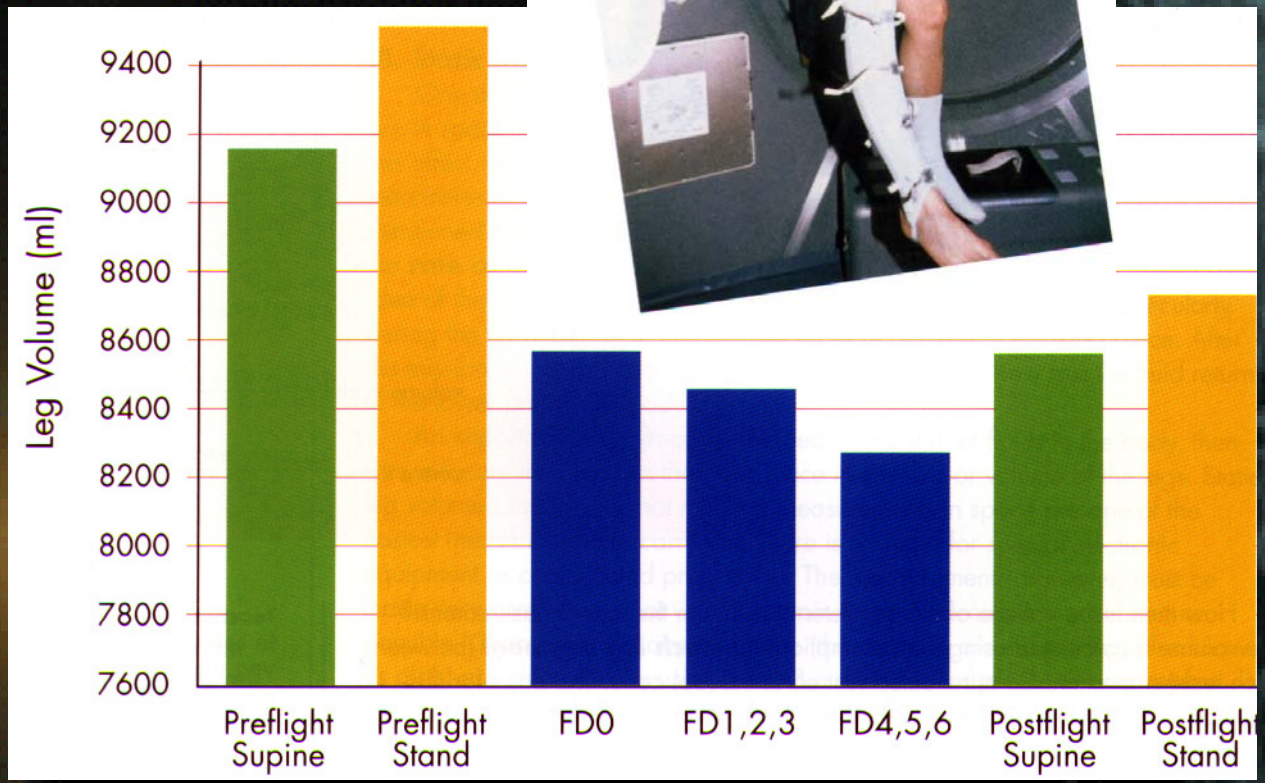


From: H. Lane and D. Schoeller, 2000.

On Orbit — Fluid Loss

- **Total loss of fluid** from the vascular and tissue spaces is about 1-2 liters (about a 10% volume change compared to preflight)





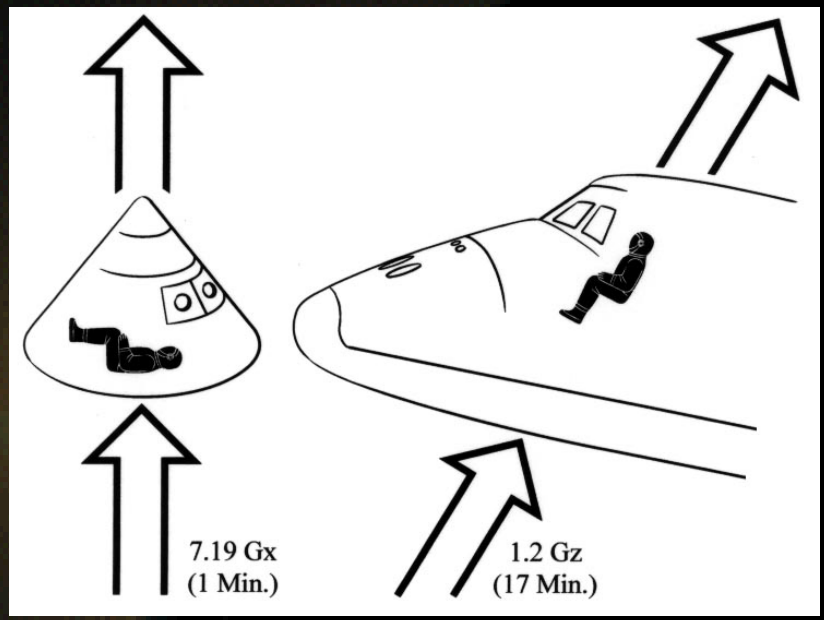
Adapted from Lujan and White (1994)

Bed Rest Model

- Bed rest with -6 deg head down **simulates** the effects of microgravity on cardio-vascular response
- Within the first week, noticeable **atrophy (loss) of muscle** tissue longer time is needed for other changes
- **Exercise** regimens and **other countermeasures** are being tested during bed rest to determine if they are effective at preventing:
  - Cardiovascular deconditioning
  - Orthostatic intolerance
  - Loss in muscle and bone
  - Fluid shift

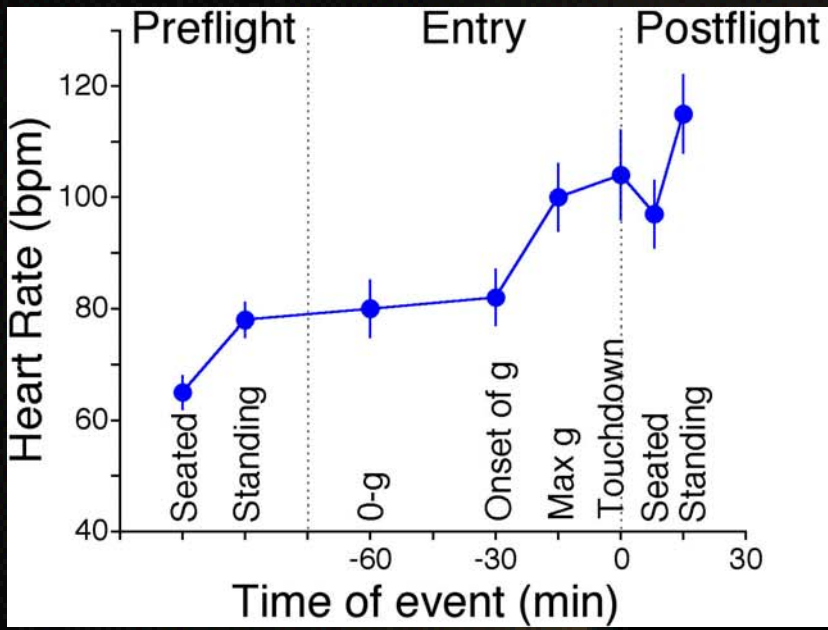
Re-entry — Effects of G Forces

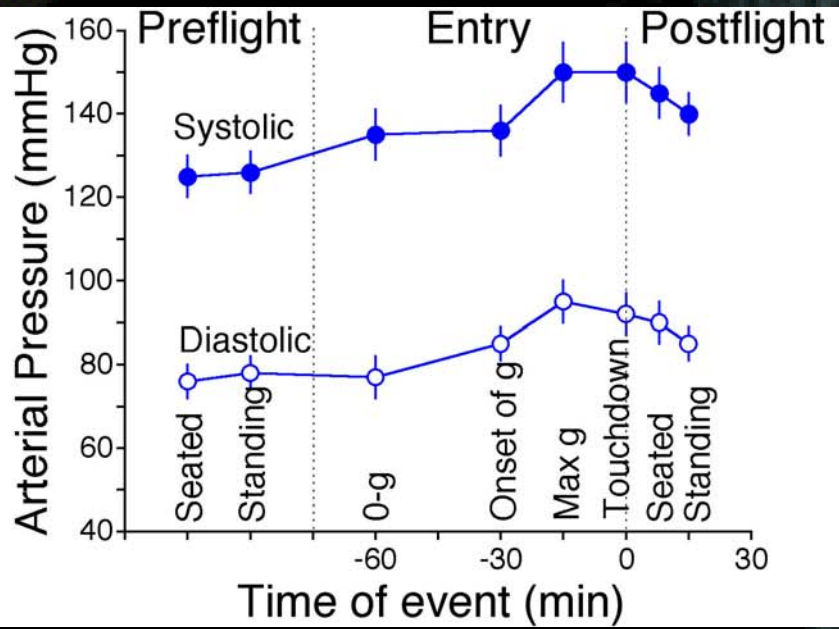
- Reentry forces exerted along **G_x axis in capsules** : no need for the astronaut to “fly” the vehicle
- **G_z forces in Shuttle.** However, 1-2 G_z during re-entry after 16 days of cardio-vascular deconditioning in microgravity may be as provocative as 5-6 G_z in a fighter aircraft
- **Loss of conciousness** (syncope) may result from a decrease in blood flow to the brain (cerebral hypoperfusion)



Landing

- Both heart rate and blood pressure increase during entry and just after landing (in the seated position)
  - After Shuttle missions, 27% of the crew are **unable to complete** a 10-minute **stand test** on landing day, and need to sit down to prevent syncope (loss of consciousness)



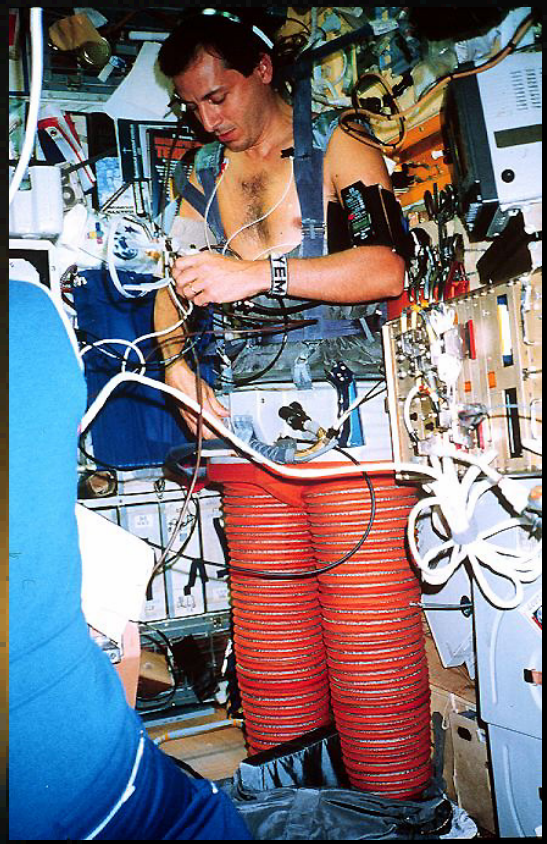


Countermeasures — In-flight

In-flight exercise and Low Body Negative Pressure (LBNP) have a protective effect on the increase in heart rate and fall in blood pressure during standing after flight

Loading suits ("Penguin")

LBNP ("Chibis")



Thigh cuffs ("Brazlet")

Photos NASA & RSA

Countermeasures — Reentry and Landing

- Fluid and salt loading
- Anti-G garment
- Liquid cooling garment
- Recumbent seating during re-entry for flights > 30 days

Questions?