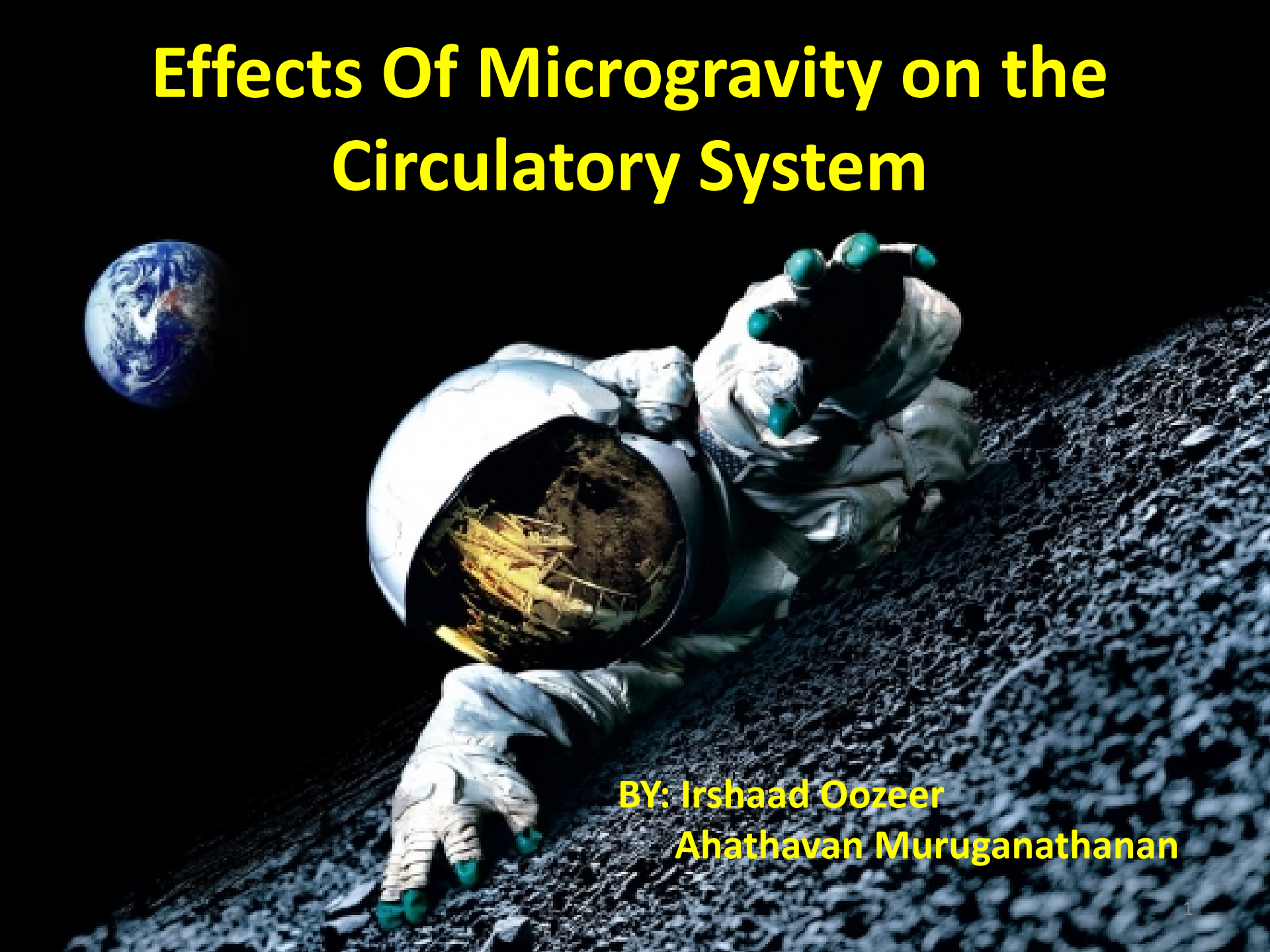
Effects Of Microgravity on the Circulatory System



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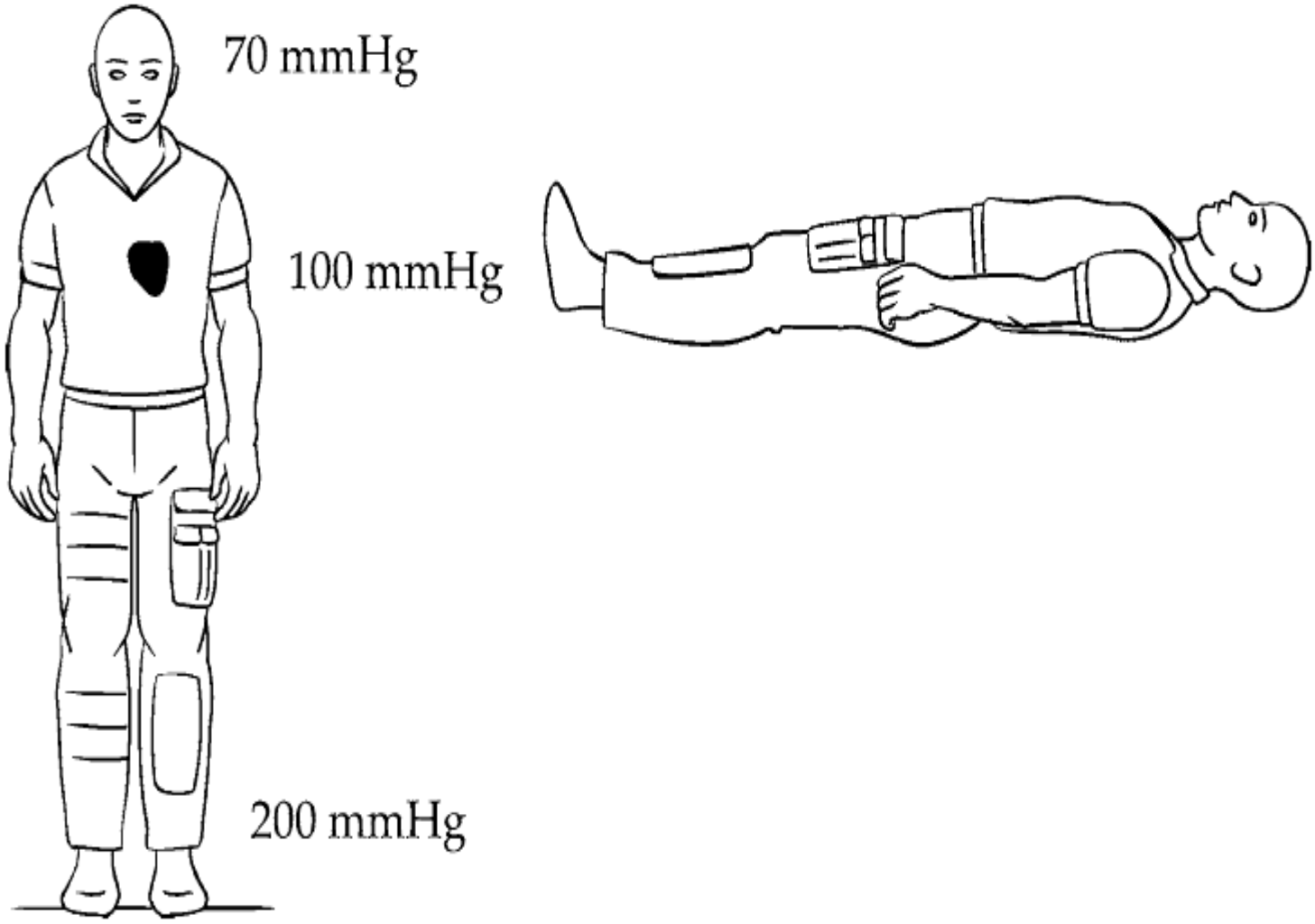
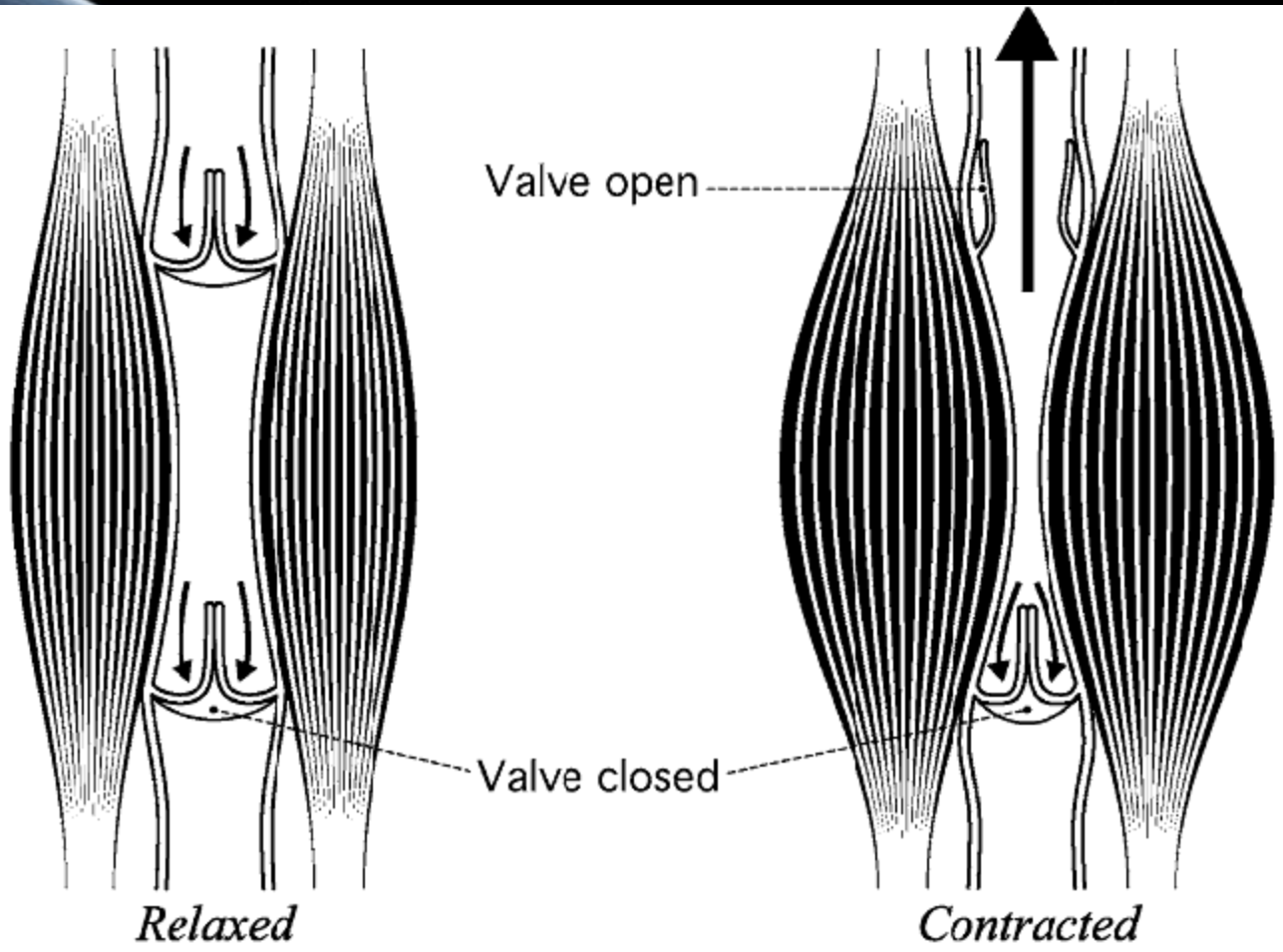
What is Microgravity?

- Also called weightlessness or zero gravity, is the absence of gravity.
- Is best illustrated by astronauts floating in their spacecraft
- Can be experienced by every day activities like jumping off diving boards
- It is the "free fall" period of these activities when the microgravity occurs and only lasts for a short period of time



On Earth, When We Are Standing, There Is a Hydrostatic Pressure Gradient from Head-to-Foot.



The Contraction of Skeletal Muscles in the Legs Helps to Pump Blood Toward the Heart, but Is Prevented from Pushing Blood Away from the Heart by Closure of the Venous Valves.

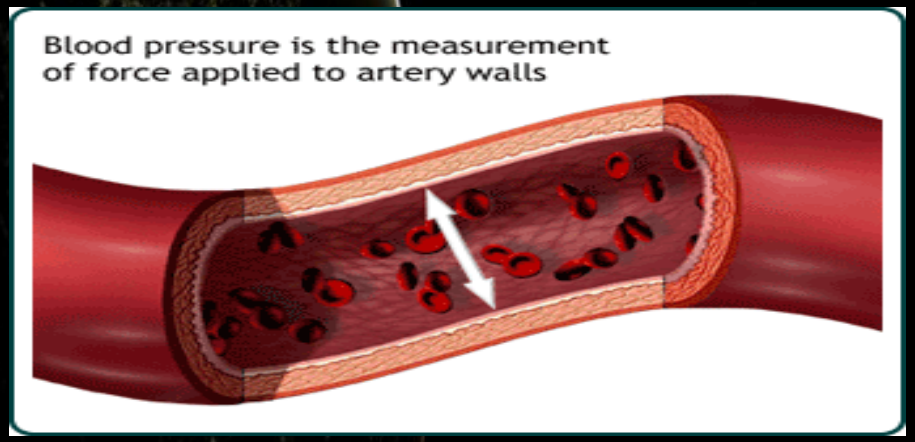
Blood Pressure

- Increasing total blood volume ultimately increases the "filling pressure" of the vascular system and the amount of blood to be ejected by the heart with each stroke
- The amount of blood pumped by the heart in 1 min is called the cardiac output:

$$\text{Cardiac Output} = \text{Stroke Volume} \times \text{Heart Rate}$$

$$(\text{mL of blood / min})(\text{mL of blood / beat})(\text{beats / min})$$

- Blood pressure will also vary as a function of the viscosity of the blood, such as the quantity of blood cells within the plasma



Blood Pressure

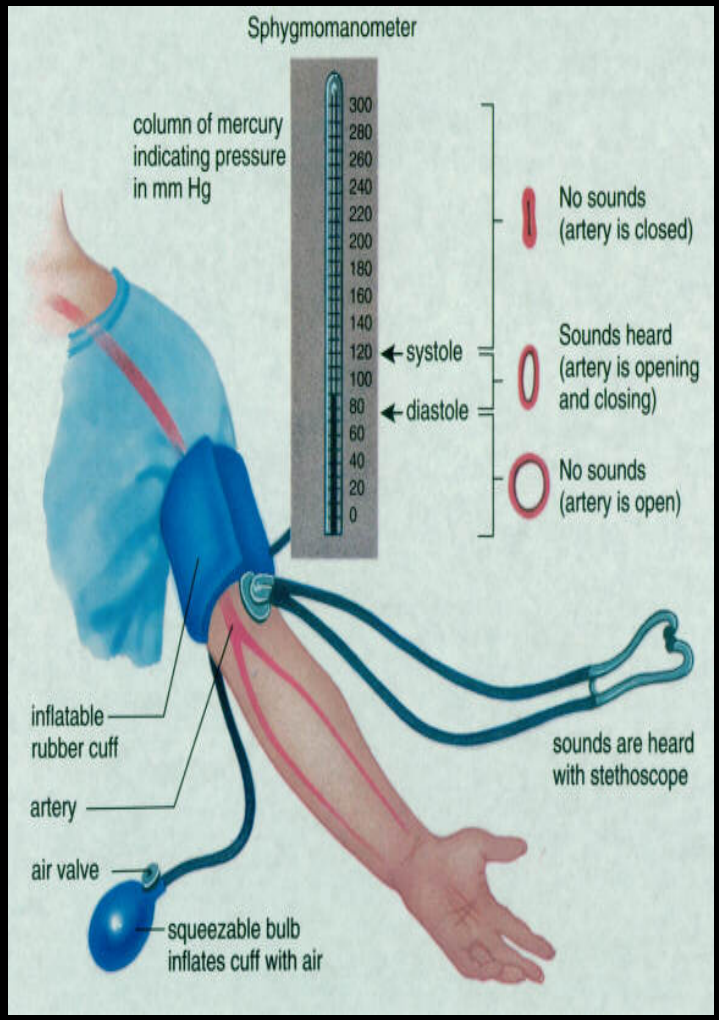
Some Factors That Influence Arterial Blood Pressure and the Associated Mechanisms.

Factors	Why Blood Pressure Increases
Increase in blood volume	Increased total "filling pressure" in the semi-flexible cardio-vascular system; increased venous return to the heart, leading to higher stroke volume
Increase in heart hate	Increased cardiac output which, without a countering change in peripheral resistance, increases pressure
Increase in stroke volume	Same as increased heart rate
Increase in peripheral resistance	Normally varied by changing vessel diameter, particularly in the arterioles, increased constrictive resistance increase pressure in the vessels leading up to it
Increase in blood viscosity	Increased resistance, as thicker blood does not flow as easily

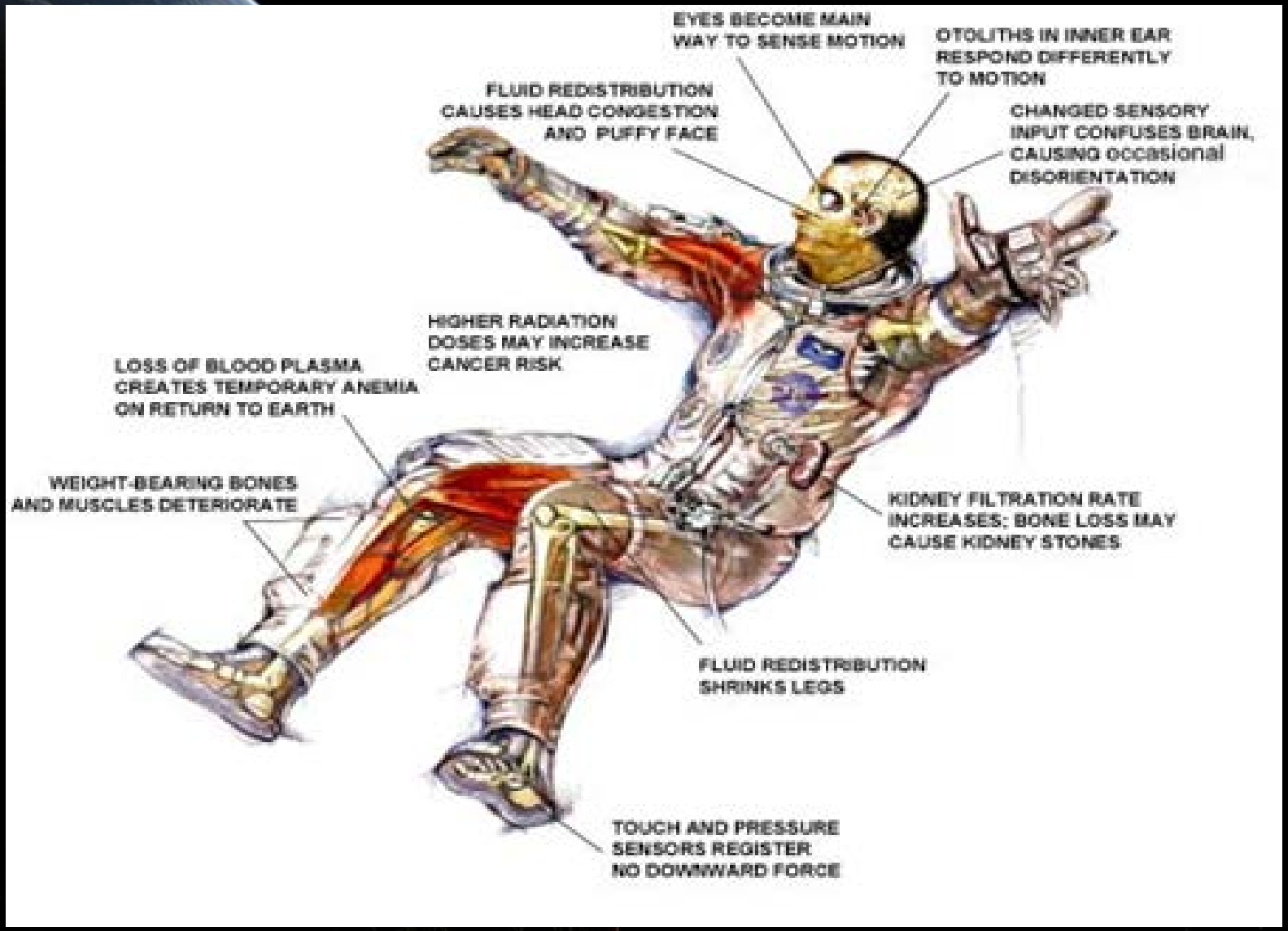
- Baroreceptors, or "pressure receptors," are specialized nerve endings located in both the arterial and venous systems, which are stimulated when the blood vessels are stretched by increased pressure

Blood Pressure

- When blood pressure increases, the corrective response via the stimulation of the baroreceptors and sympathetic nervous system includes a decrease in heart rate and stroke volume and vasodilatation of the arterioles to decrease vascular peripheral resistance
- Secondary effects act on the kidney to allow increased urine production. The reverse effects take place if blood pressure is decreased
- Although the baroreceptors and vestibular receptors respond rapidly to pressure and acceleration changes, respectively, the response is not immediate



What happens in microgravity?



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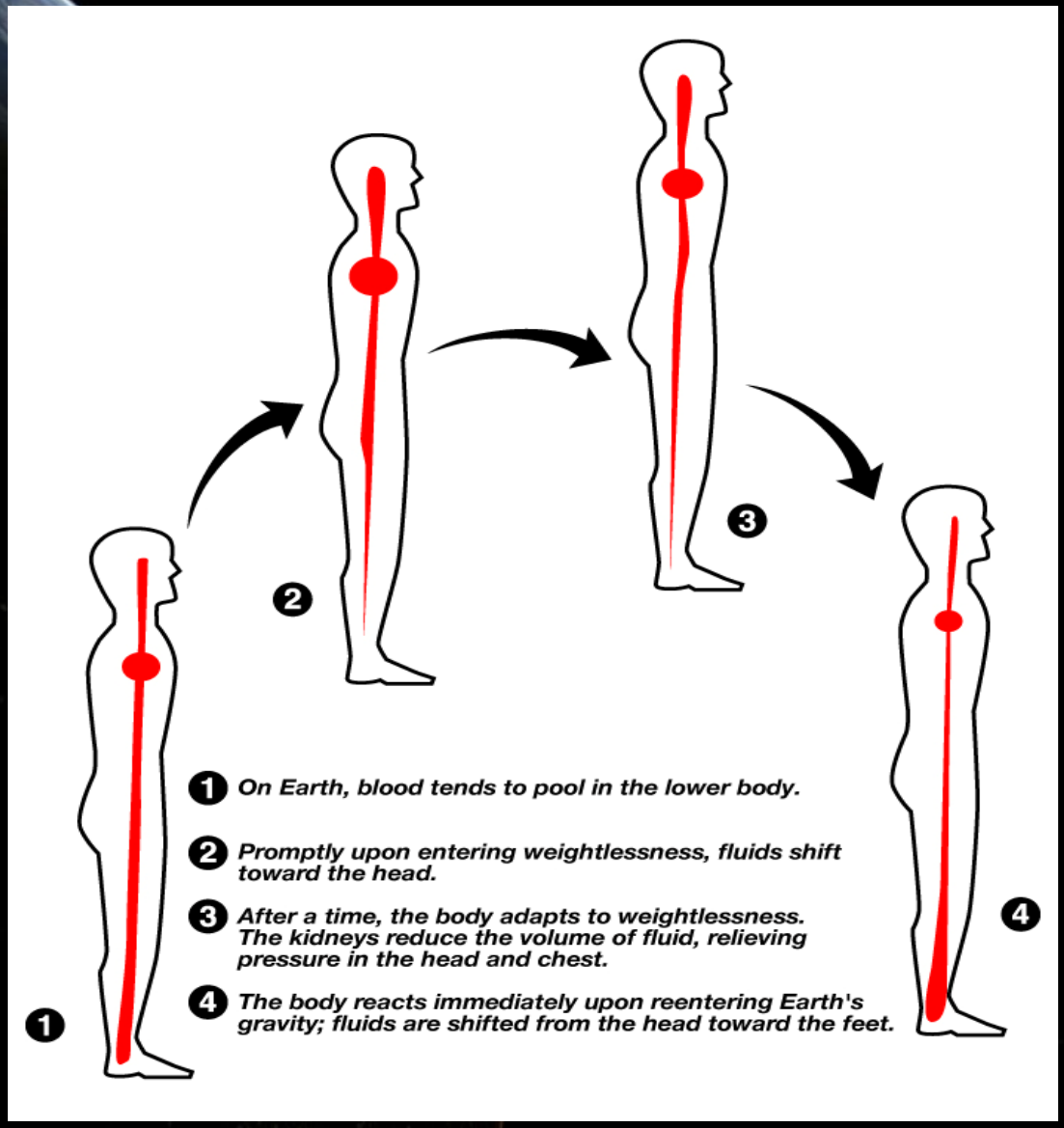


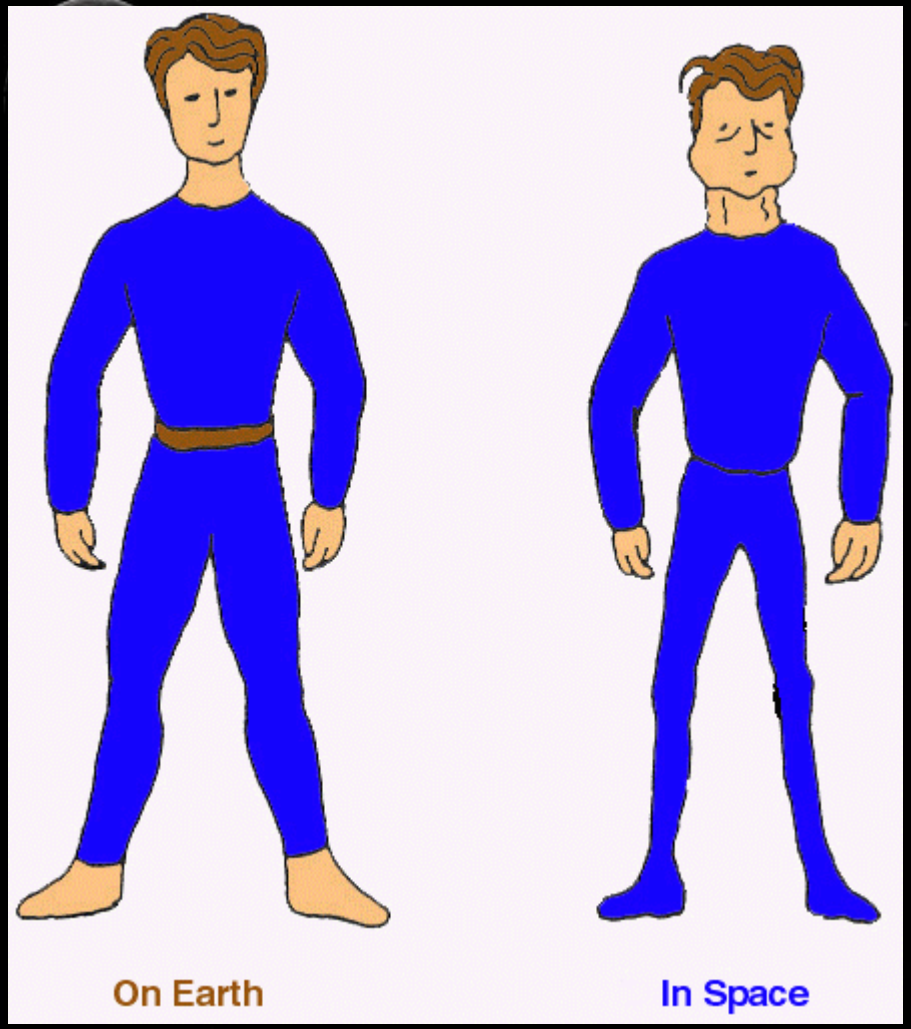
What happens in microgravity?

- While under the effect of microgravity, people even look different

An example of "puffy face syndrome“

What happens in microgravity?

Inflight measurement of the leg circumference to determine the extent of "bird legs" that the astronaut has developed

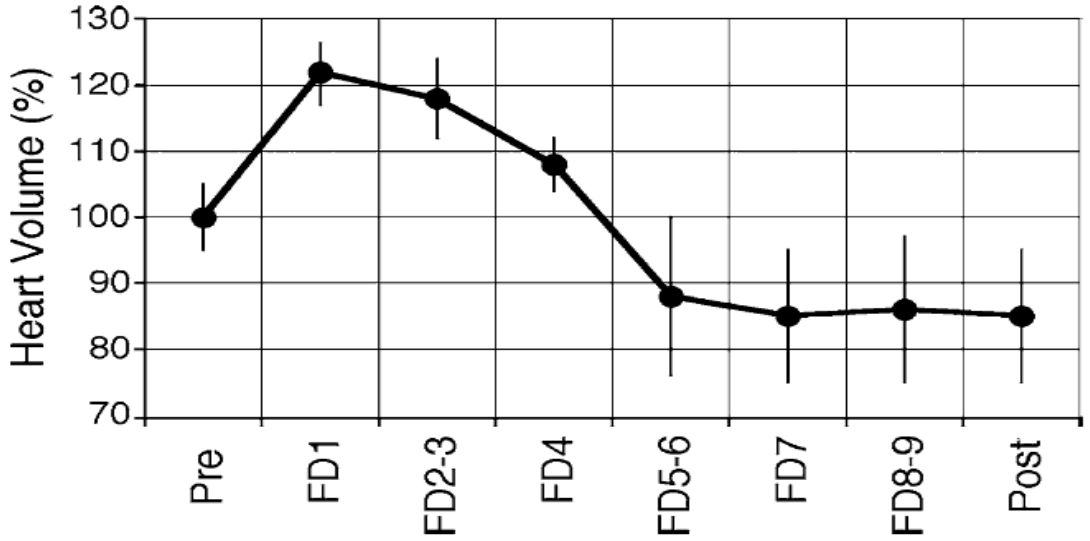


What happens in microgravity?

- The heart shrinks
- The ventricles shrink and cardiac output decrease
- Stroke volumes decrease
- Total loss of fluid from the vascular and tissue spaces of the lower extremities has been found to be 1–2L
- Within 3–5 days in space, total body water stabilizes at about 2–4% below the normal level and plasma volume decreases by about 22%

What happens in microgravity?

- Total body water is unchanged although the extracellular fluid and plasma volume are decreased

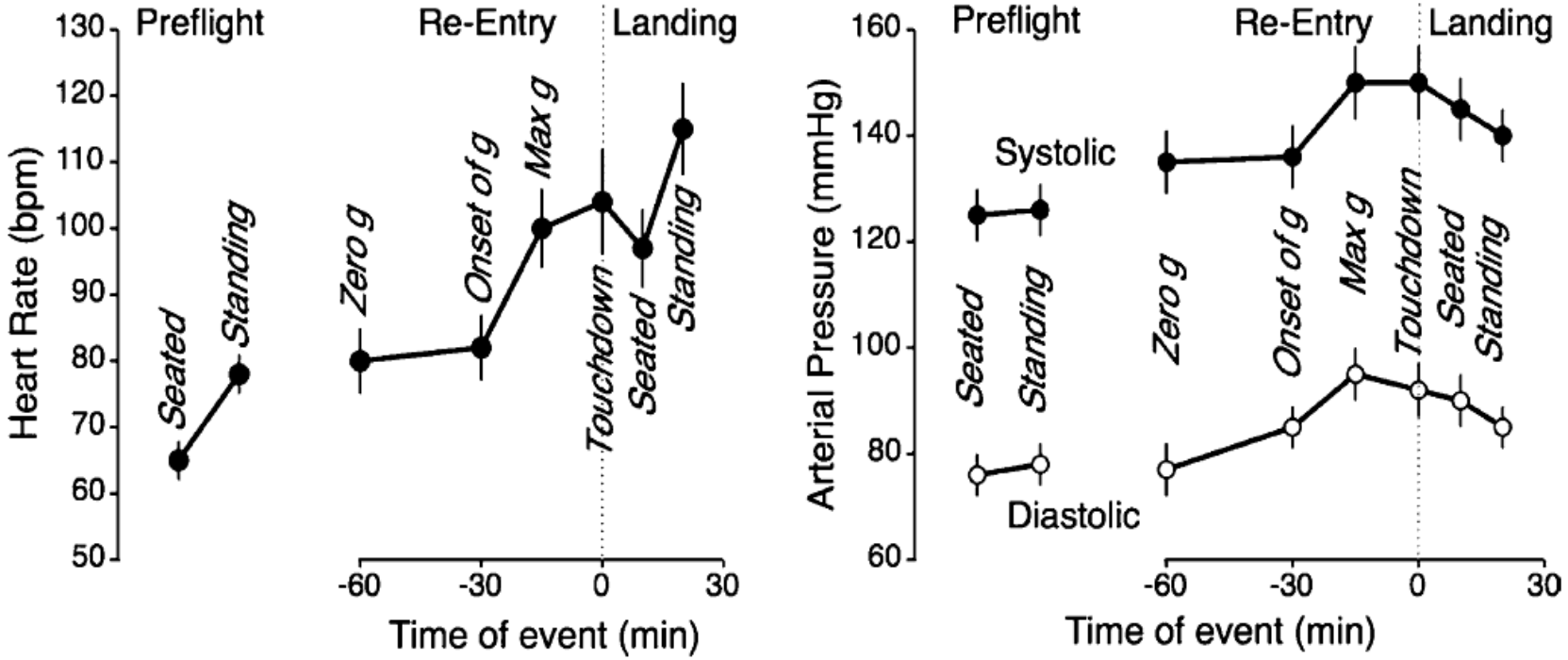


Changes in the Volume of the Left Ventricle Just Before Contraction Prior to, During (*FD* Flight Day), and After a Spaceflight. Ventricular Filling Increases Early In-Flight and Decreases After a Few Days Relative to Preflight Levels.

What happens in microgravity?

- Blood vessels appear to become slightly smaller and stiffer
- Rise in abdominal pressures
- Increased renal perfusion
- Increased arterial pressure

What happens in microgravity?



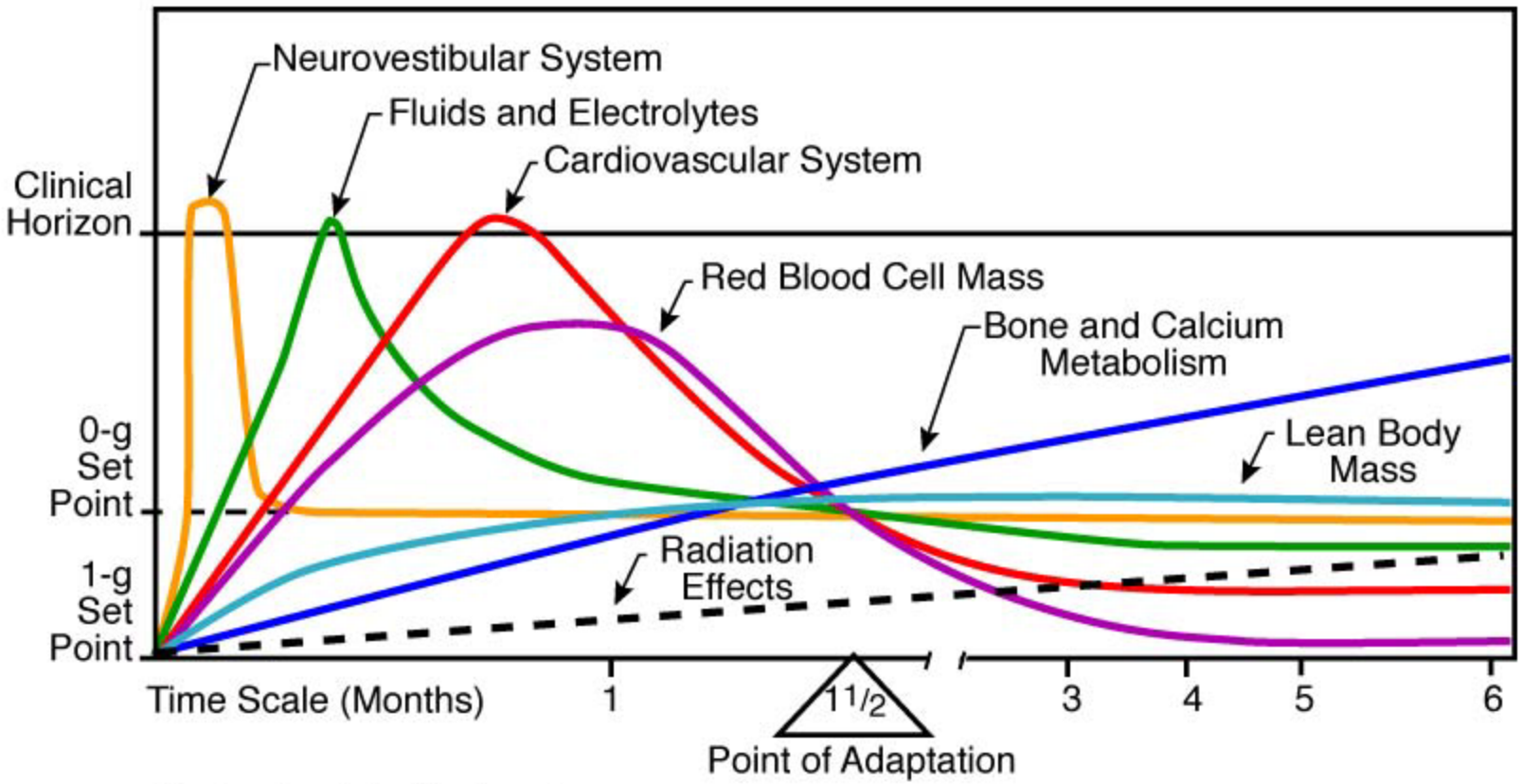
Changes in Heart Rate and Arterial Pressure When Going from the Seated to a Standing Position Preflight and Postflight, and During Re-entry and Landing (0-g to Touchdown). When Standing Postflight, Despite an Increase in Heart Rate, There Is a Decrease in Arterial Pressure, Which Can Lead to Pre-syncope or Syncope. (Adapted from Sawin et al. [1998]).

What happens in microgravity?

- Symptoms Astronauts initially complain of*:
- Headaches
- Head & sinus congestion
- Engorged neck veins
- Increased urine output

** Over time the symptoms abate*

What happens in microgravity?

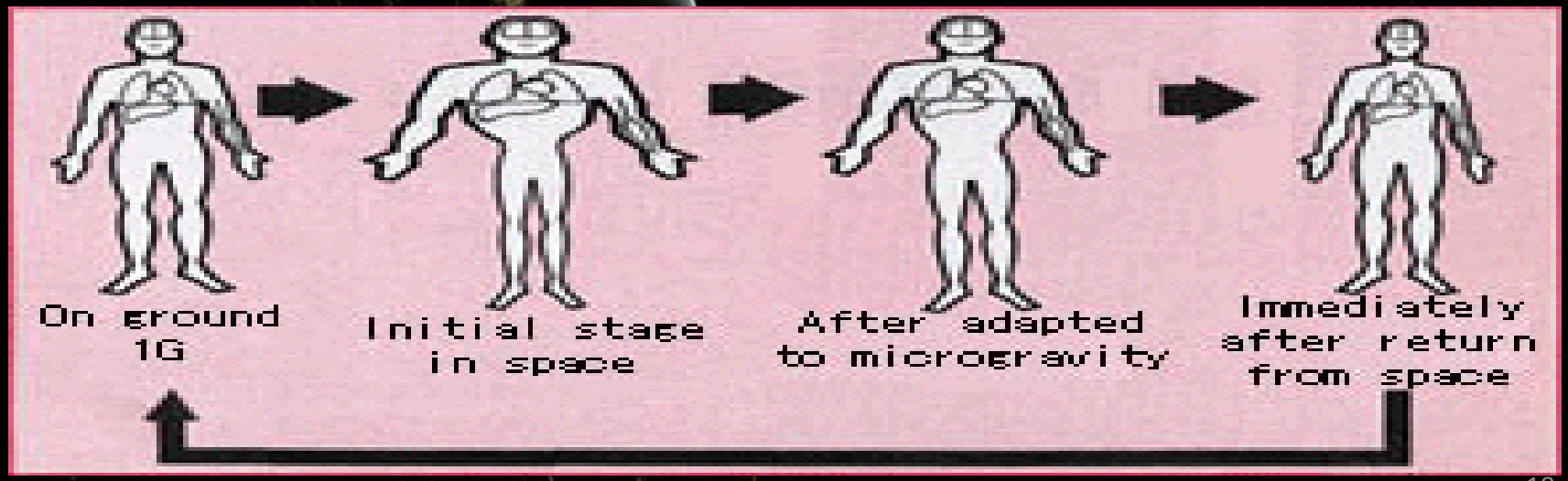


Each physiological system acclimates to microgravity at a different rate

A New Homeostatic Set Point

- In a gravitational field, baroreceptors and other components of the cardiovascular control system preserve blood flow to a biped's brain despite positionally dependent changes in preload and afterload.
- In microgravity, however, there are no orthostatic challenges associated with changes in position, and as a result, the cardiovascular control centers do not receive moment-to-moment stimuli
- This, coupled with the cephalic fluid shift, results in a new homeostatic set point

Back To Earth…



Post flight Effects

- The new equilibrium point, while adaptive for the microgravity environment, is profoundly maladaptive upon return to a one-g field
- Orthostatic intolerance is frequently seen during and following landing, due to the body's inability to respond to rapid position-related circulatory changes
- Astronauts experience dizziness, orthostatic hypotension, possible syncope.
- Inability to assume standing position (Orthostatic intolerance)
- Both the heart rate and arterial pressure increase

Orthostatic Intolerance

- Orthostatic intolerance is presumably caused by three factors that are related to each other: the volume of blood in the blood vessels, the ability of blood vessels to expand or constrict to maintain blood pressure, and the functioning of the heart itself
- Is felt when Standing and Sitting too fast
- Baroreceptors are trying to re-adapt
- When an astronaut returns to Earth and blood rushes to his/her legs, the vessels might respond not by constricting, to force the blood back up, but by dilating further resulting in less blood in the astronaut's upper body and head. Hence, they faint
- Symptoms and recovery duration depend on the length of time subject is exposed to microgravity

ORTHOSTATIC INTOLERANCE

The inability to remain standing because of subjective findings (symptoms) or objective findings such as hypotension (signs)

Acknowledgement: Prof J.M. Stewart New York Medical College

Orthostatic Intolerance

- In summary, hypovolemia, cardiac atrophy, and autonomic dysfunction have each been hypothesized to contribute to postflight orthostatic intolerance, but their relative importance is unclear
- Furthermore, it is unknown whether actual abnormalities in the myocardium itself develop with long-duration spaceflight.
- Therefore, reliable portable noninvasive methods are needed to detect and quantify these changes

Current Countermeasures

- Anti-G Suits
  - designed to provide transient hypertension at the aortic
  - increases total peripheral resistance
  - Raises the position of the heart
  - Increases venous return
  - effectiveness depends on the amount of pressure applied (and tolerated) to the abdomen and trunk, the area of application, and the volume of the bladders

Current Countermeasures

On the left is a conventional anti-G suit used during World War II. On the right is a modern anti-G suit used in the CF-18 Hornet. Note the small change in the basic design over 50 years.

Current Countermeasures

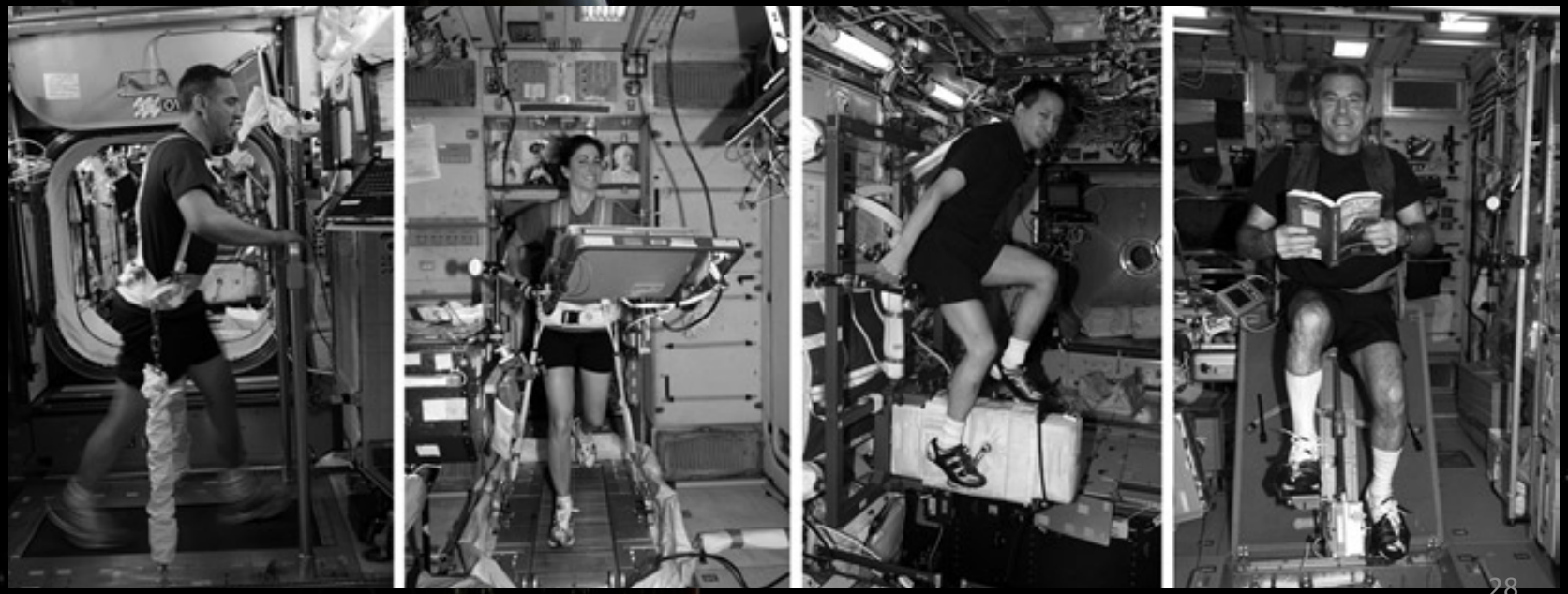
Current Countermeasures

- Supine Position
  - blood volume is placed above the heart
  - Increases central venous pressure and Cadiac Output
  - Prevents Blood from Pooling in the Legs During Ascent and Assists the Heart in Pumping Blood to the Rest of the Body.

During Launch on Board Soyuz, Astronauts Are Reclined on Their Backs in
Molded Couches, with Their Legs Higher Than Their Heads.

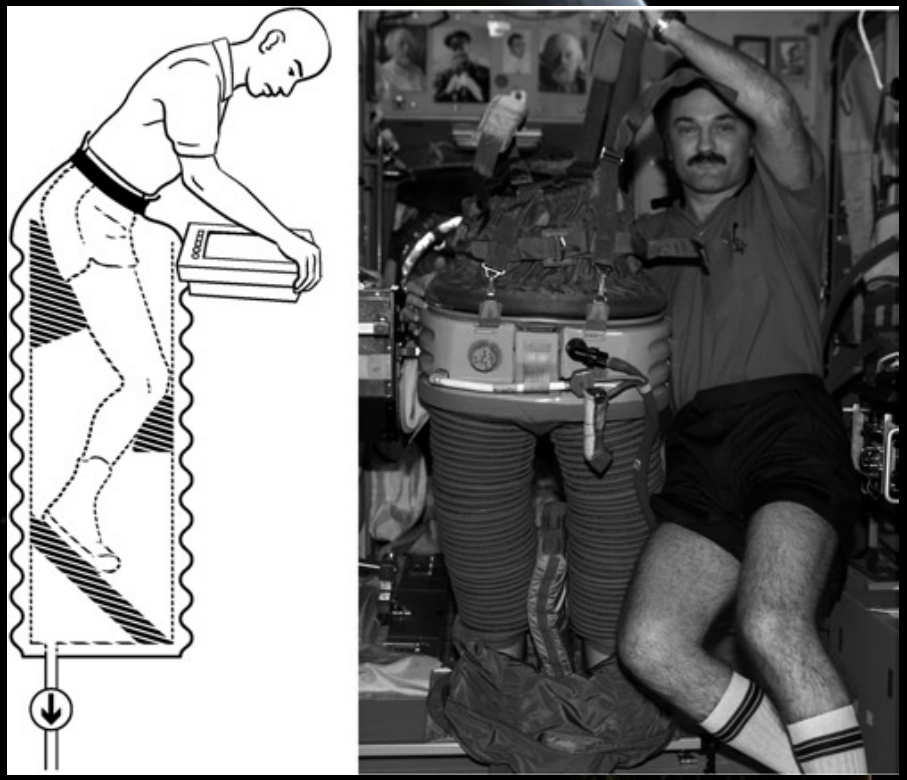
Current Countermeasures

- Exercise
  - has a protective effect on the increase in heart rate and fall in blood pressure during standing after flight
  - partially effective in maintaining postflight aerobic capacity



Current Countermeasures

- Lower body negative Pressure



- maintains a controlled pressure differential below ambient
- is used in conjunction with heart rate and blood pressure monitoring capabilities
- provides a continuous decompression and maintenance of −60 mmHg
- Causes the Intravascular Volume to Shift Towards the Lower Extremities

Current Countermeasures

- Salt Solution
  - Increases viscosity of blood
  - Increase blood pressure
  - Flight rule: astronauts are required to drink 2 liters of salt solution prior to deorbit to potentially mitigate post flight orthostatic Intolerance

Current Countermeasures

- Medication
- Midodrine given to astronauts
  - selective alpha-1 adrenergic agonist
  - produces arterial and venous constriction resulting in an increase in blood pressure by baroreceptor reflexes
  - Very safe and effective therapy for orthostatic hypotension
  - has no central stimulant effects

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