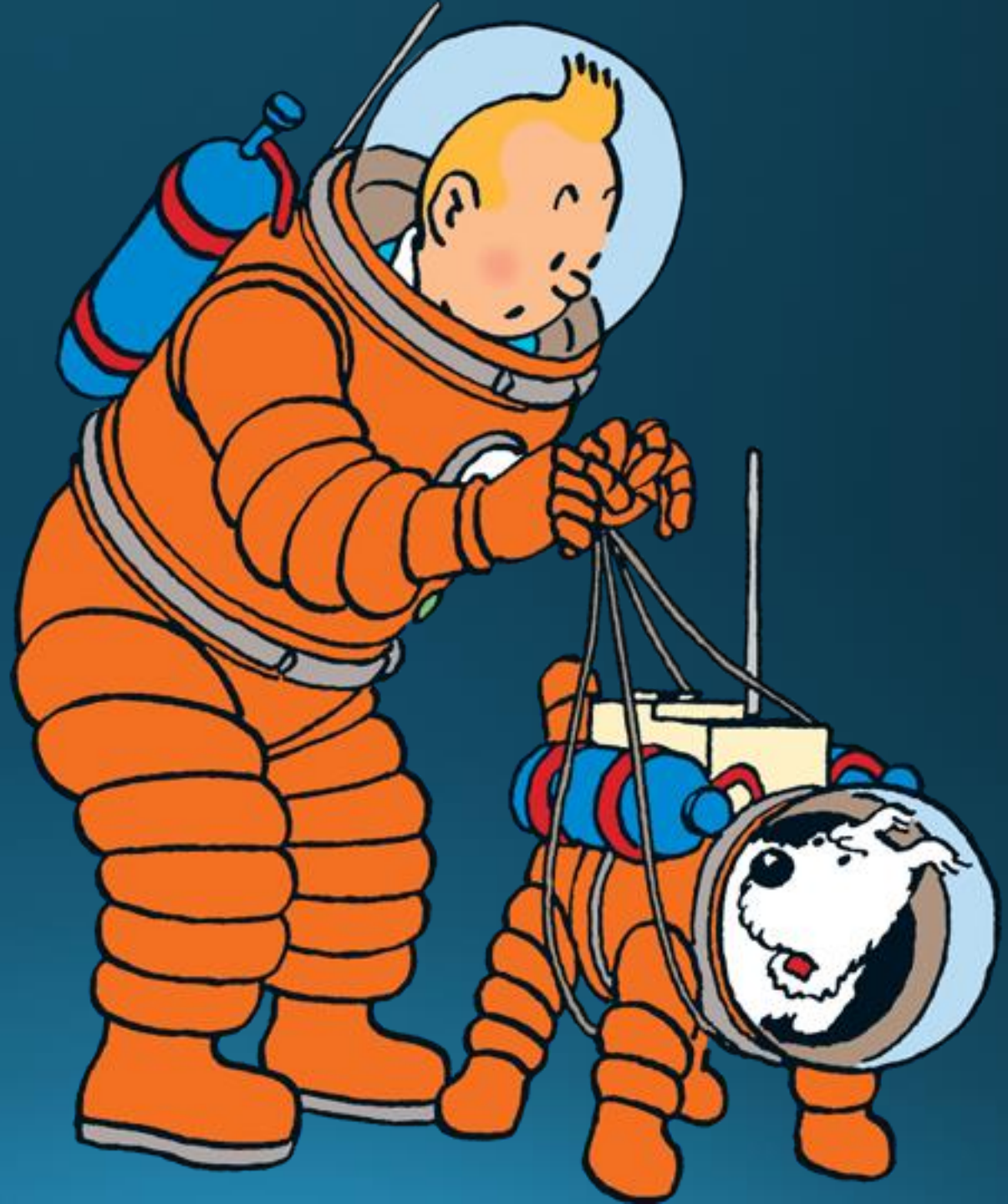
Effect of space travel on cardiac/hemodynamics
Effect van ruimtereizen op hart/hemodynamiek

Pr Vitalie FAORO
Vitalie.Faoro@ulb.be

Laboratory of Physics and Physiology – LPHYS, Medical Cardiology, Erasme Hospital
Laboratory of Cardiorespiratory Exercise Physiology, FSM, ULB

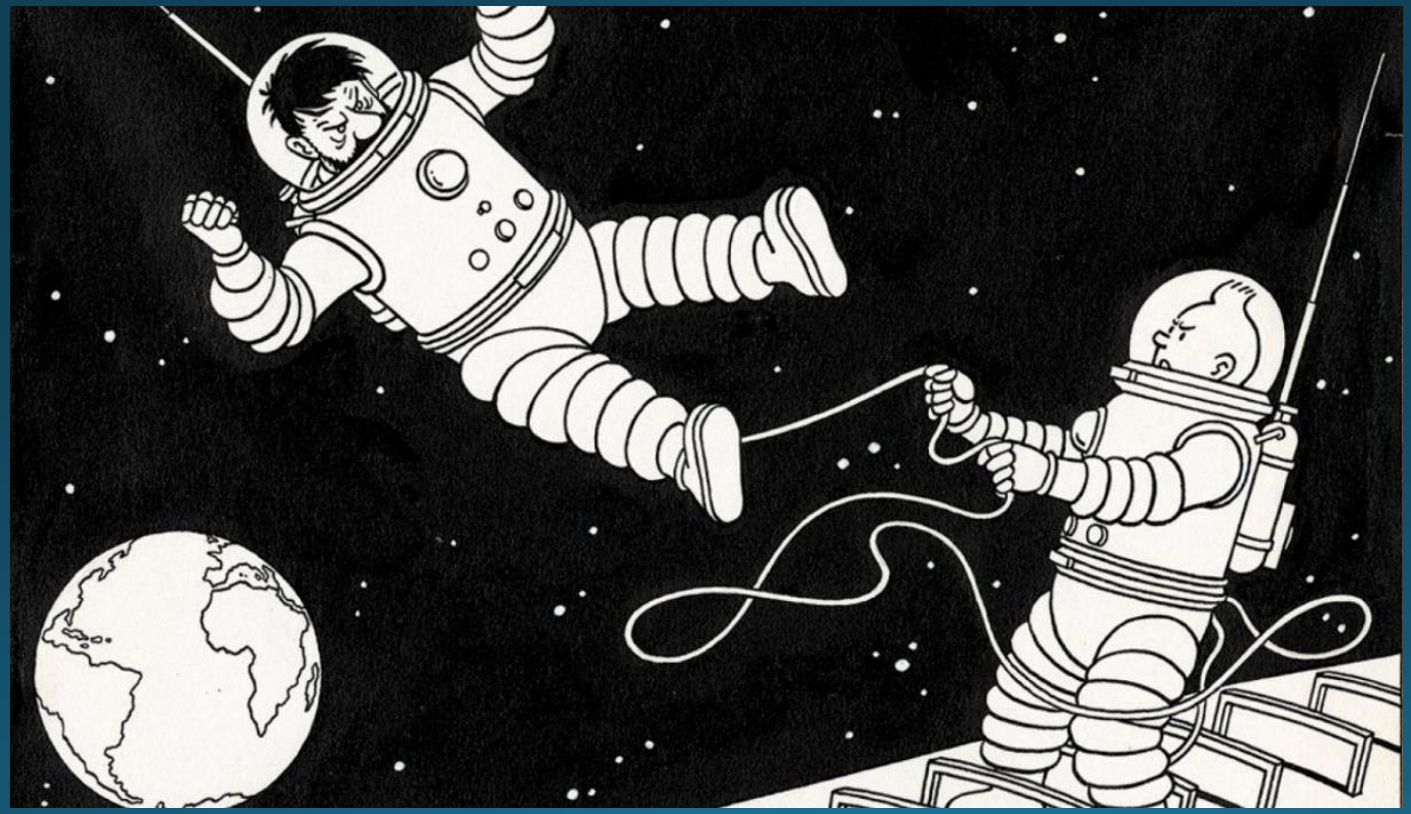
Overview

- Introduction
- Pre-flight
- Take-off
- Early-flight
- Mid-flight
- Post-flight



Introduction

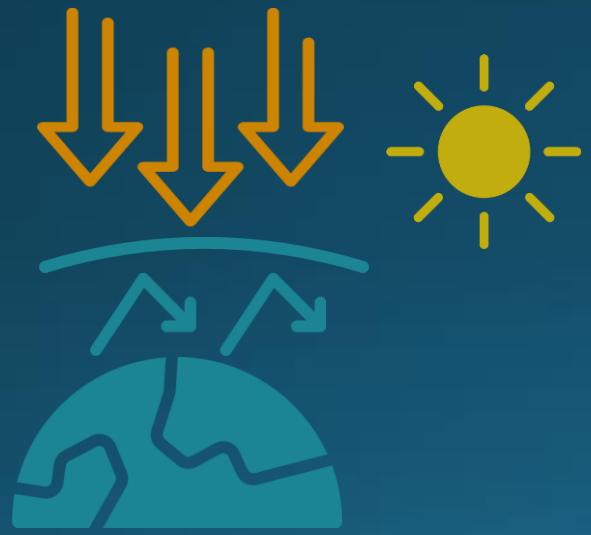
From fiction to … « Space Tourism »

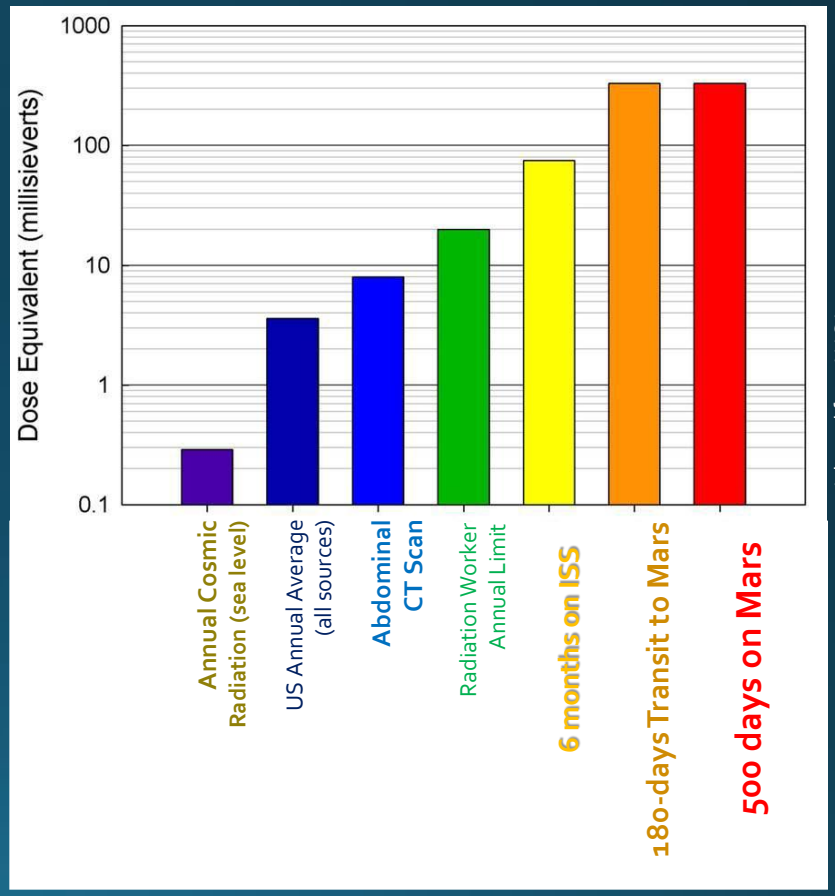


Cosmic Radiation

- Different types of particles involved from sun and galaxy
- Ionisation of molecules and DNA damage
- Damage of tissues: heart, CNS, eyes, digestive tract

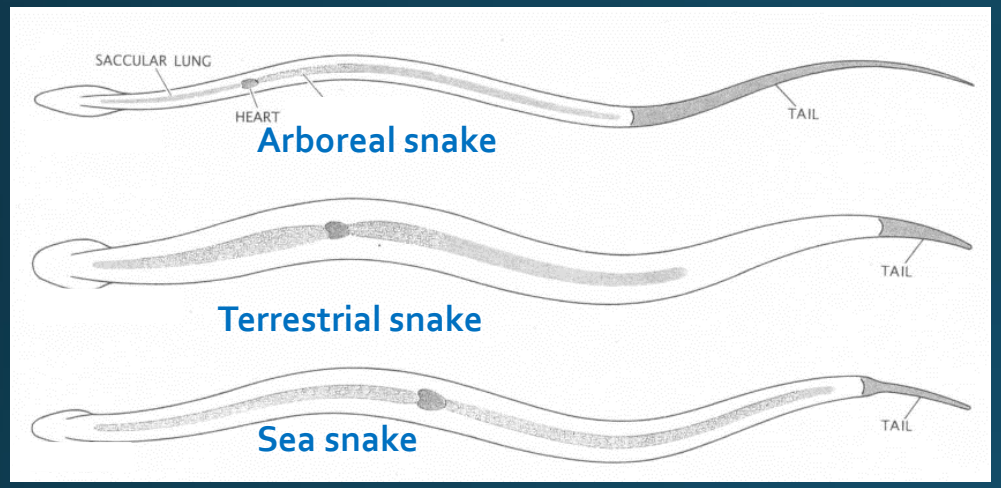
BUT also cancer, sterility, …

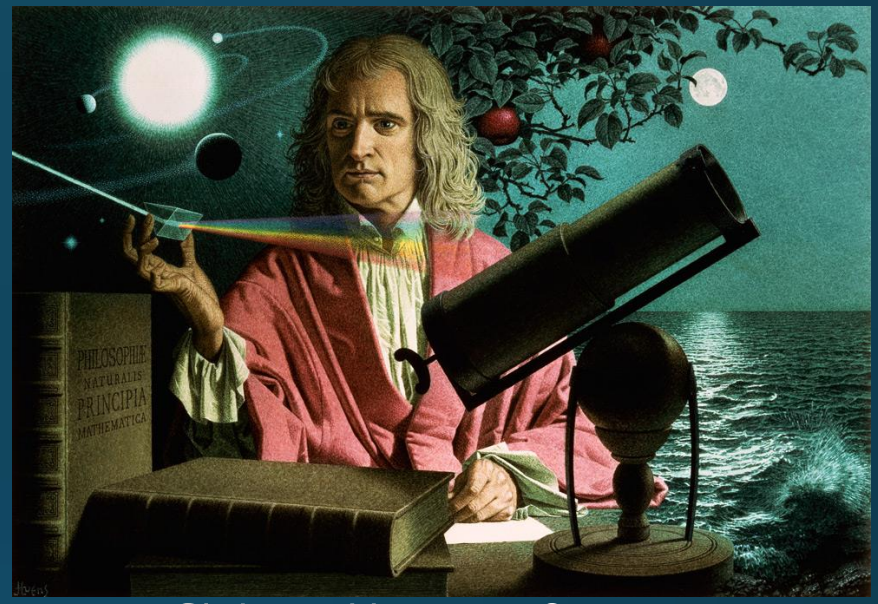




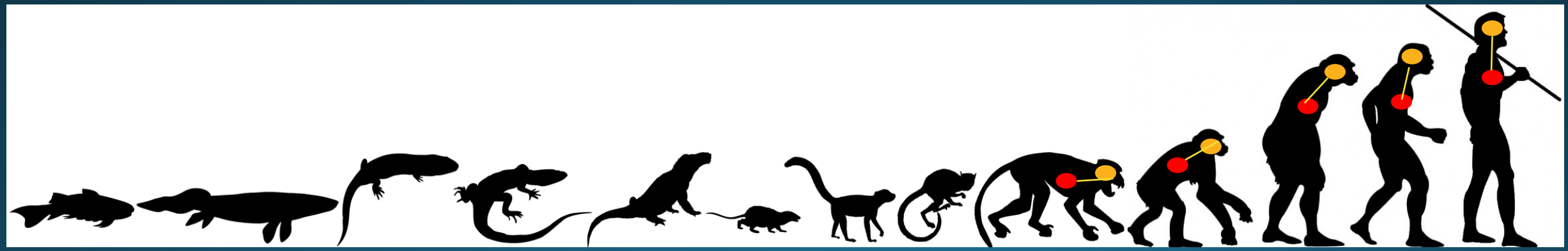
- Earth: >99% Protection by athmosphere and magnetic field
- Solutions: Shielding? Travel faster?

Gravity





Sir Isaac Newton 1643-1727



Gravity:
9,80665 m/s^2

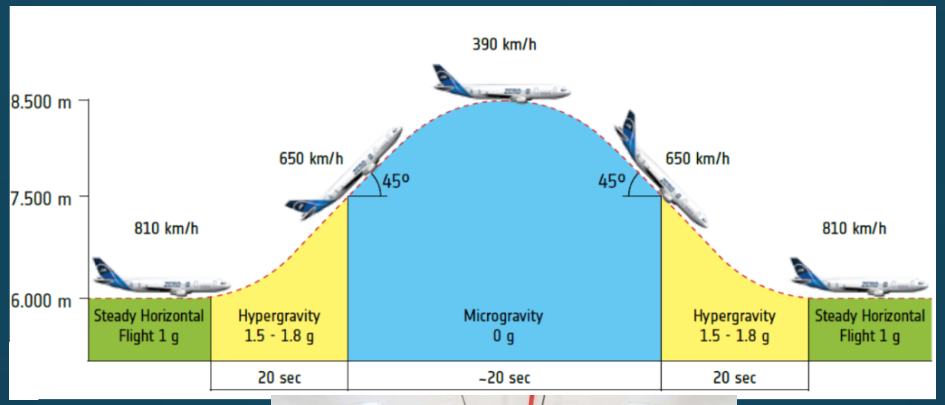
Time

Research

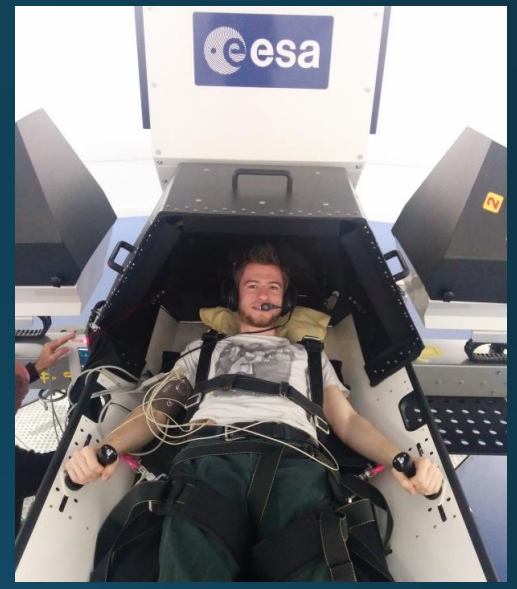
Bedest

Credits: DLR

Parabolic flights



Artificial gravity



Dry immersion

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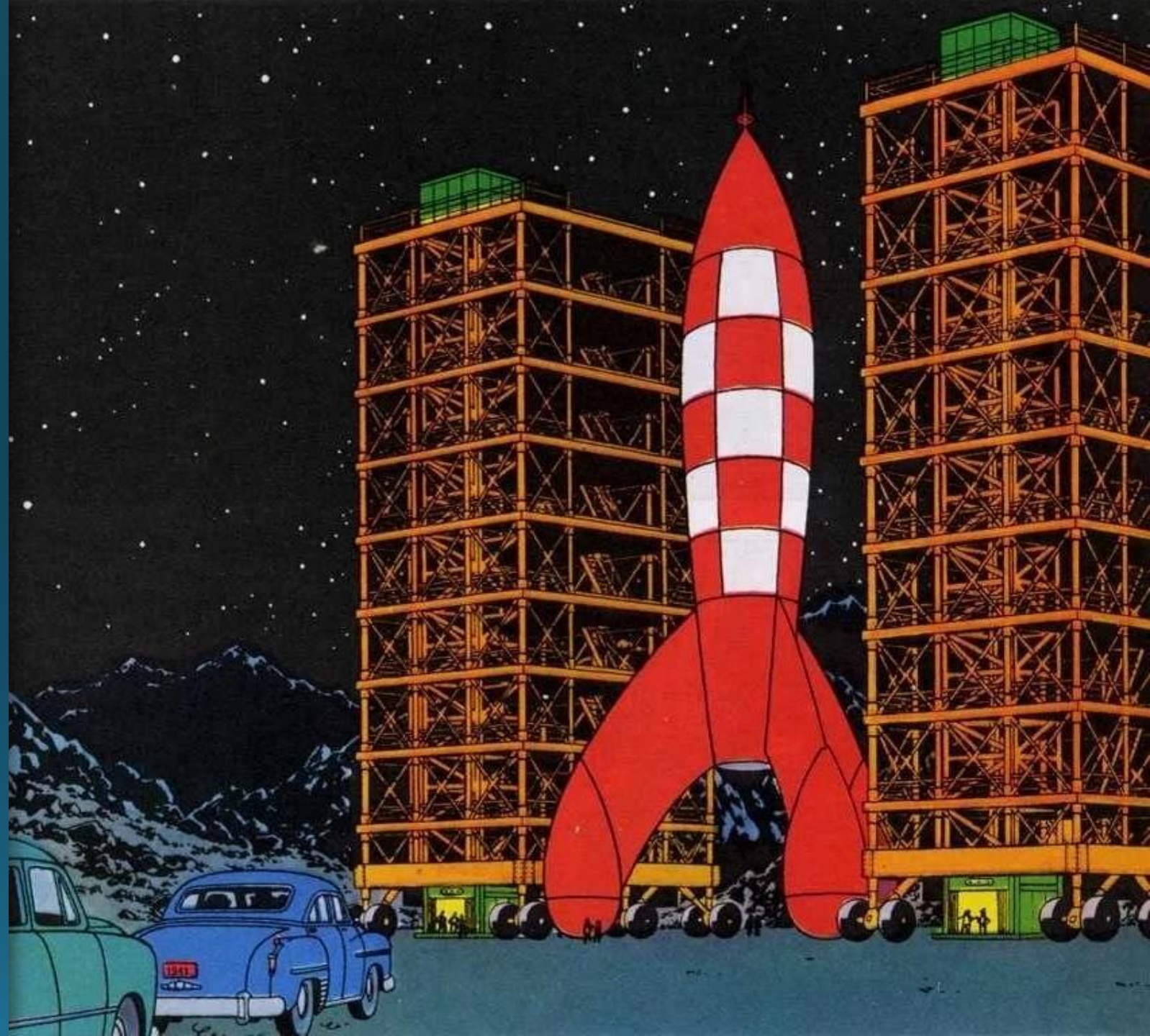
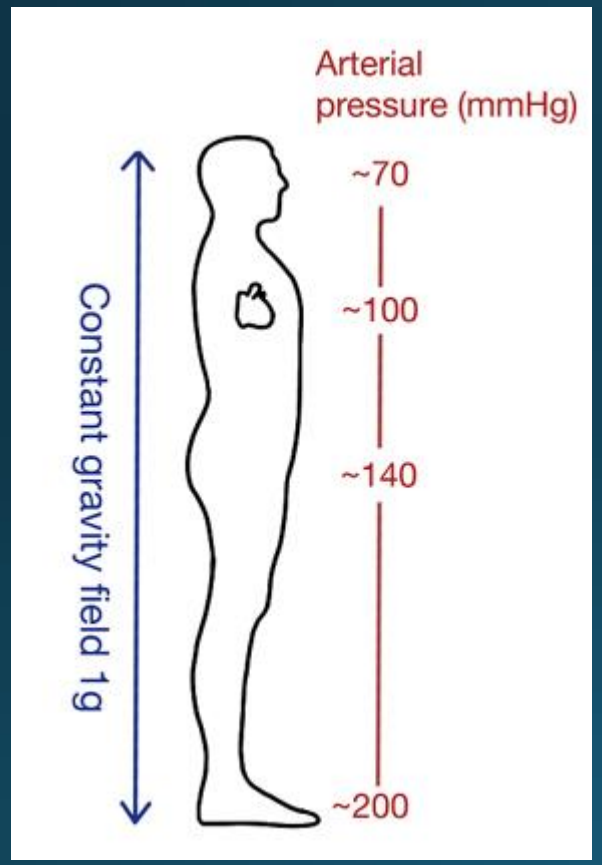
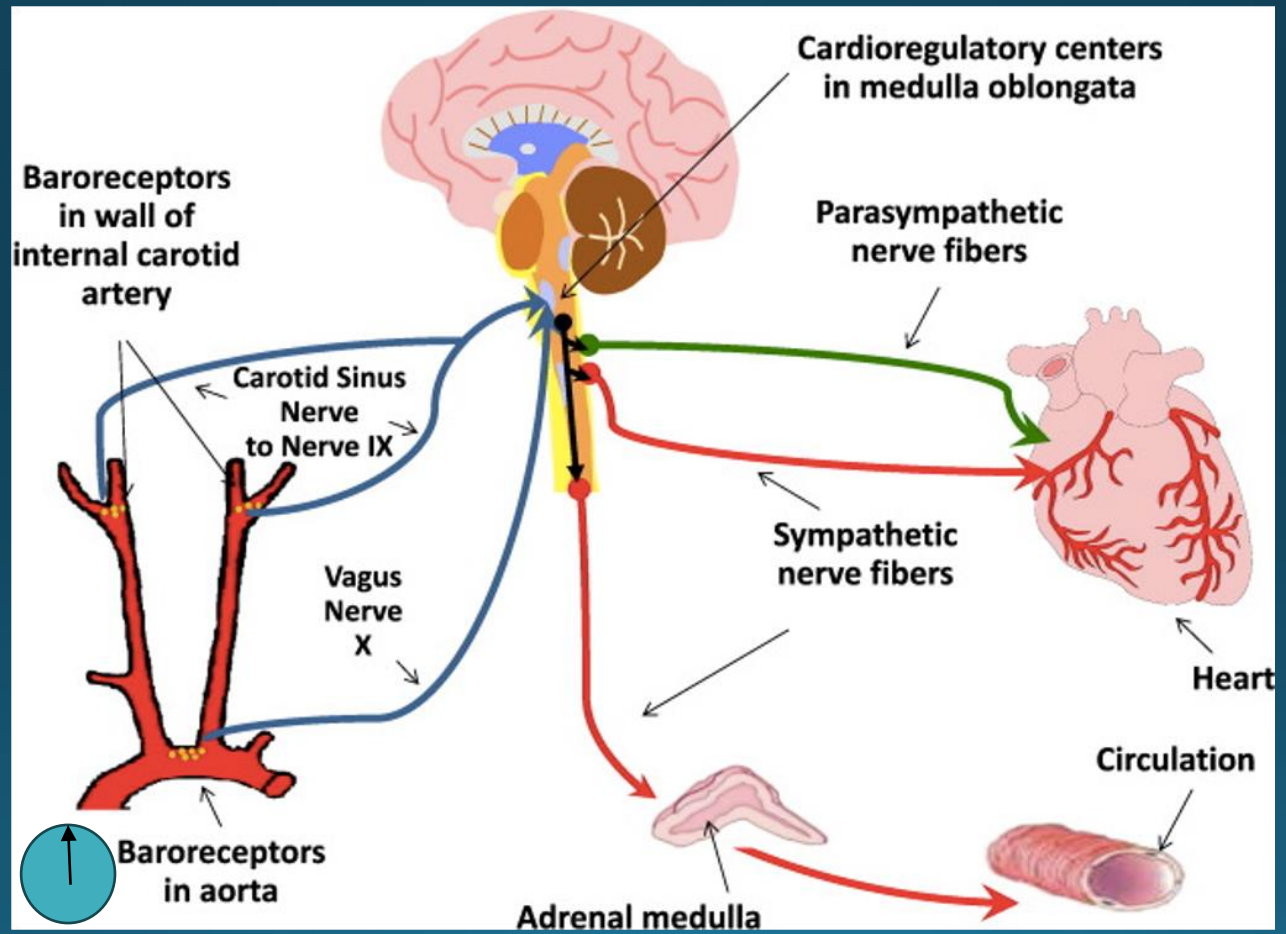


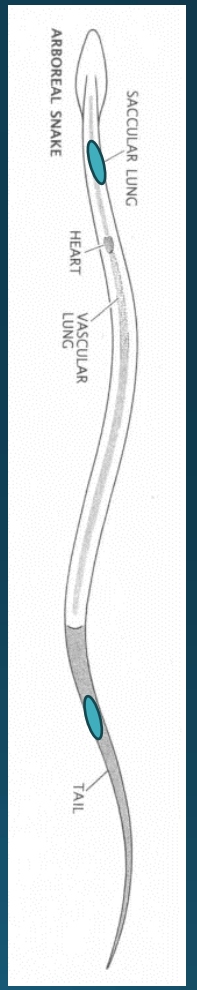
Pre-flight



1G



Arboral snake



Baroreceptors in tail

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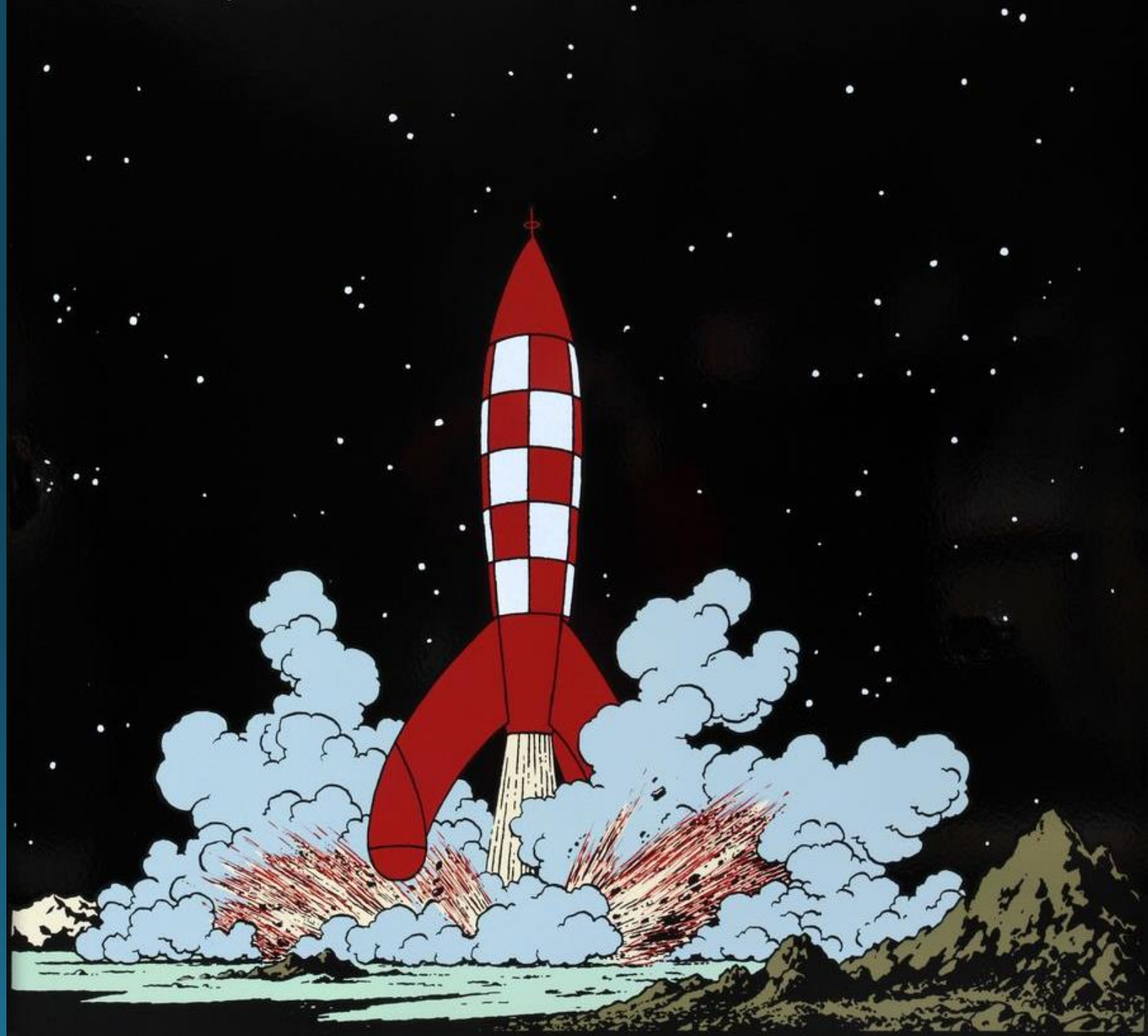
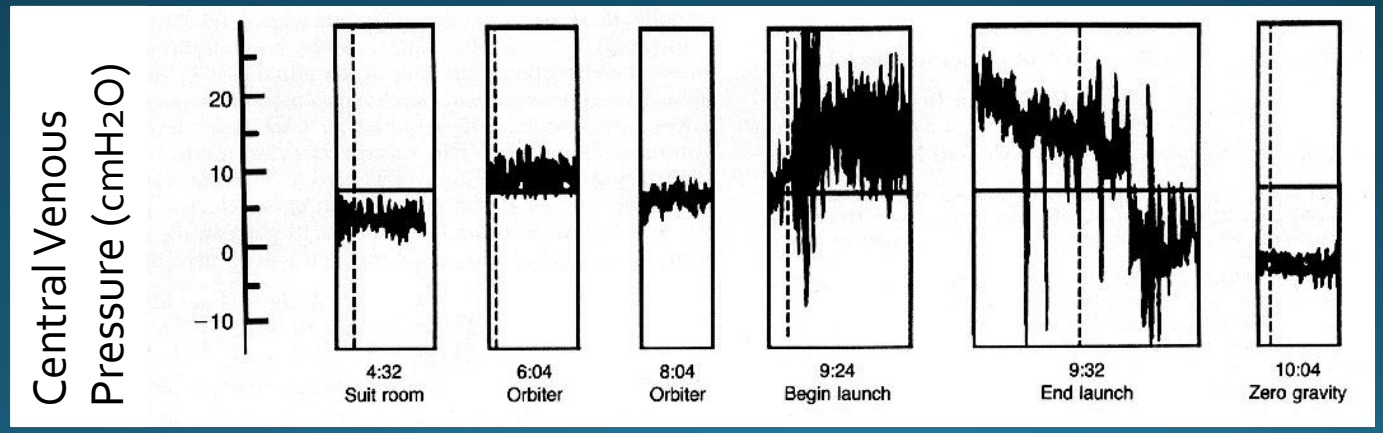


Take-off



Buckey et coll., 1993

4 G

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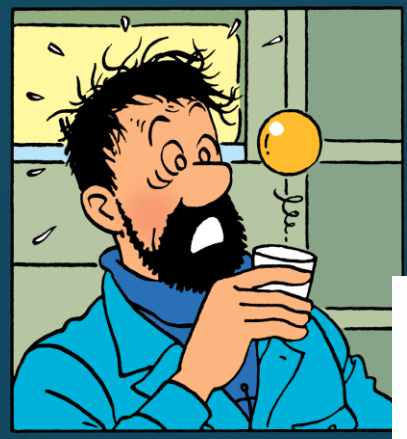
Microgravity

- Lunar Gravity: 0.17 G
- Mars Gravity: 0.38 G

Space flight

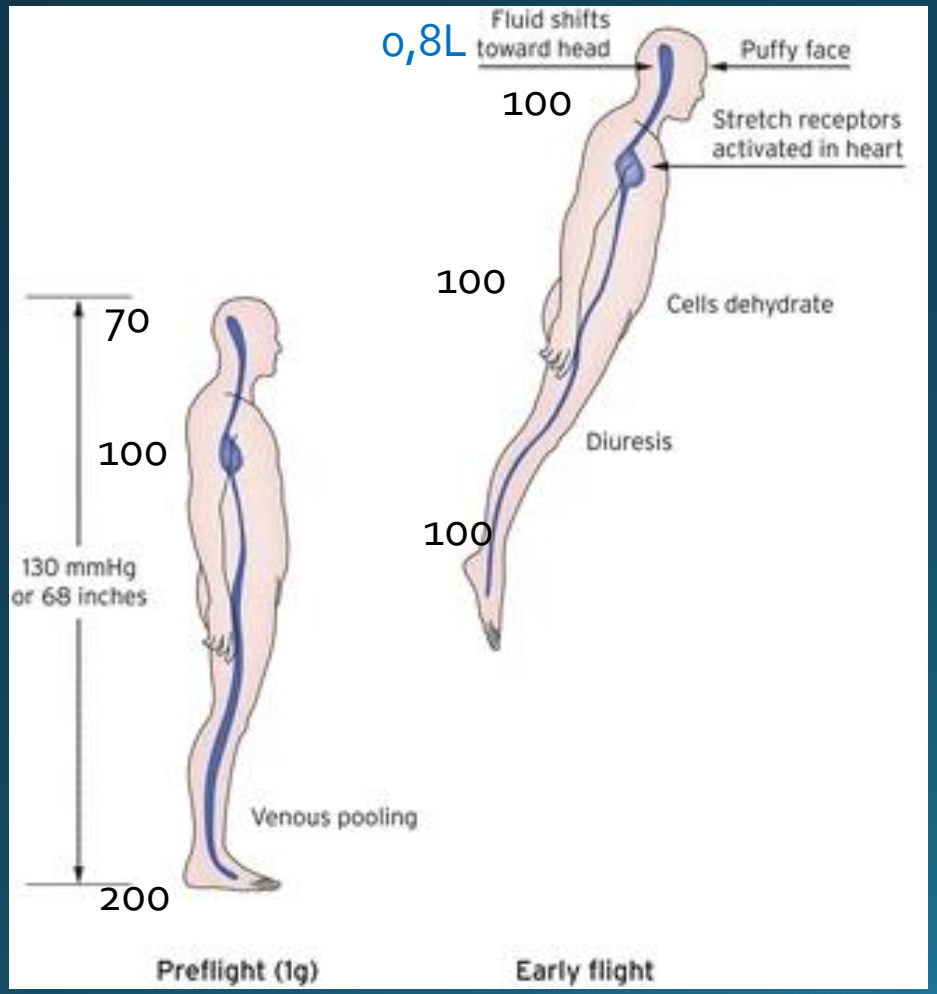


Loss of hydrostatic Pressure

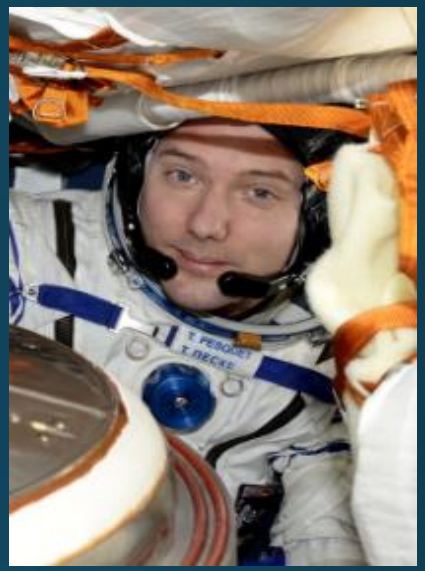
ISS station
https://www.youtube.com/@CnesFrance

Fluid schifts

Loss of hydrostatic pressure gradient



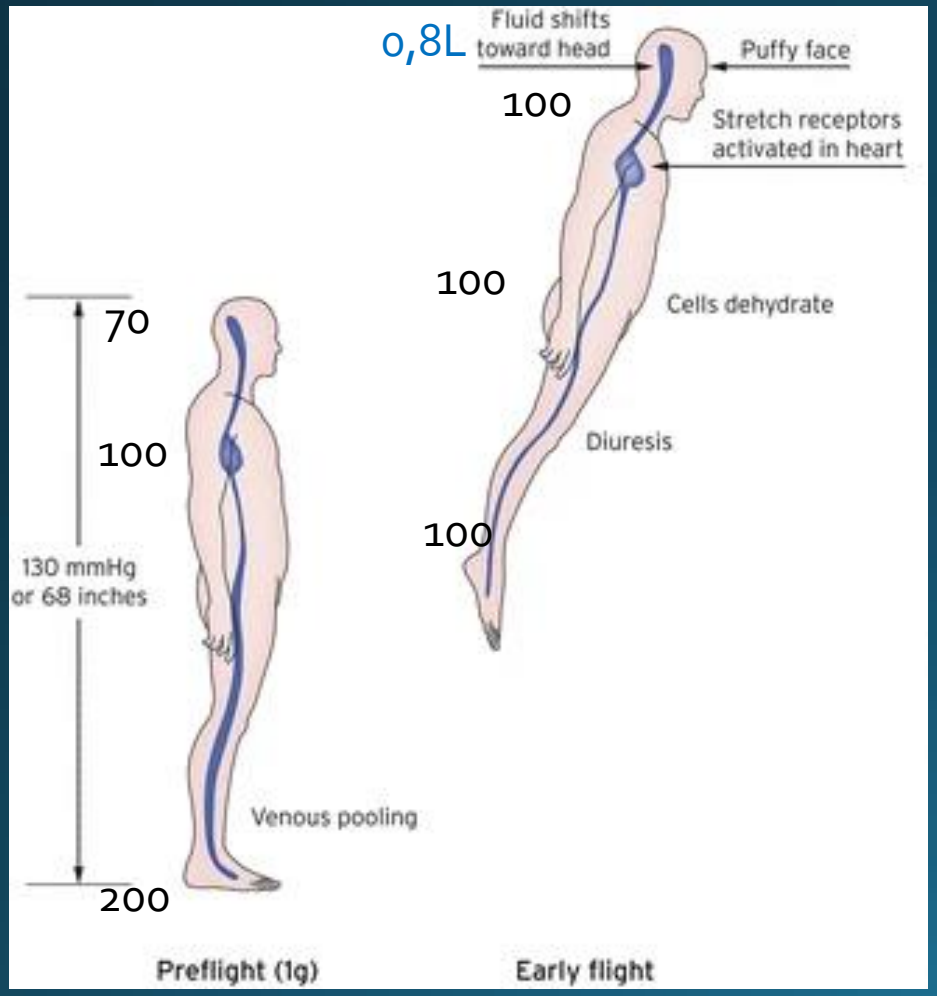
« Puffy-face » and « Bird-leg syndrome »



SPACE SICKNESS
Headaches
Nausea
Nasal congestion
Disorientation
visual disturbances

Fluid schifts

No Blood Pressure gradient



CARDIAC FUNCTION AFFECTION

ANP and BNP secretion

=> Sali-diuretic effect

=> diuresis/natriuresis

=> (relative) hypovolemia

Baroreceptors activated

=> ↓ SV and ↓ HR

=> ↓ Q

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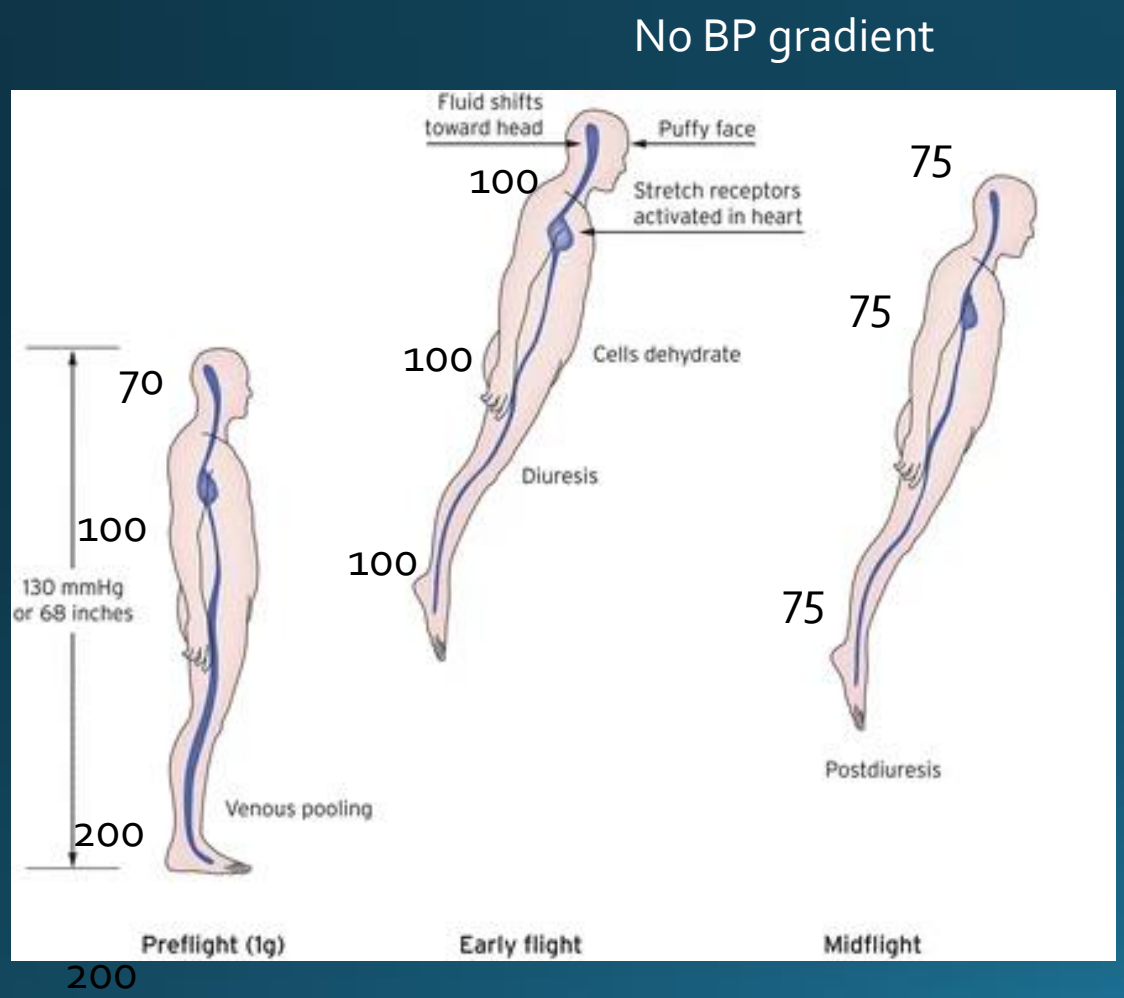
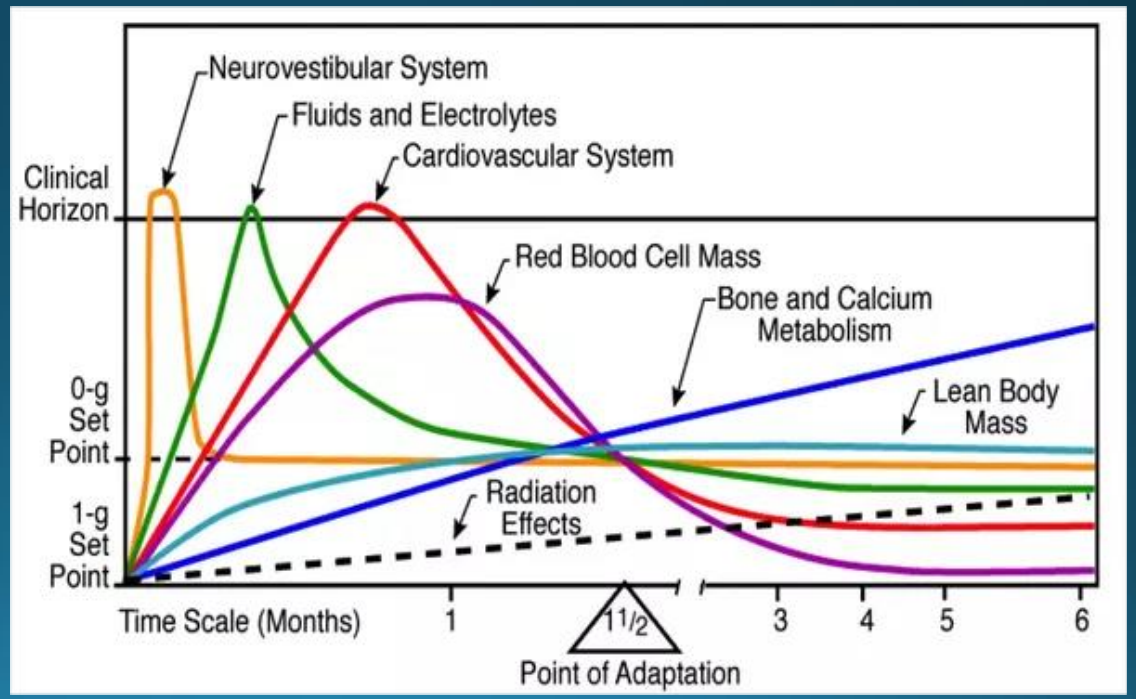
Long term adaptation



- Plasma and overall blood volume loss of 10-12%
- Loss of RBC -15% after 3 months
- Well tolerated for 1 to 1.5 years



Credits: NASA

Medical issues

1. Loss of appetite
2. Space motion sickness
3. Fatigue
4. Insomnia
5. Dehydration
6. Skin inflammation
7. Back pain
8. Respiratory infection
9. Eye irritation
10. subungual hematoma
11. Urinary infection
12. Cardiac arrythmia
13. Headache
14. Muscle pain
15. Diarrhea
16. Constipation
17. Barotraumatic otitis
18. Bends barotraumatique

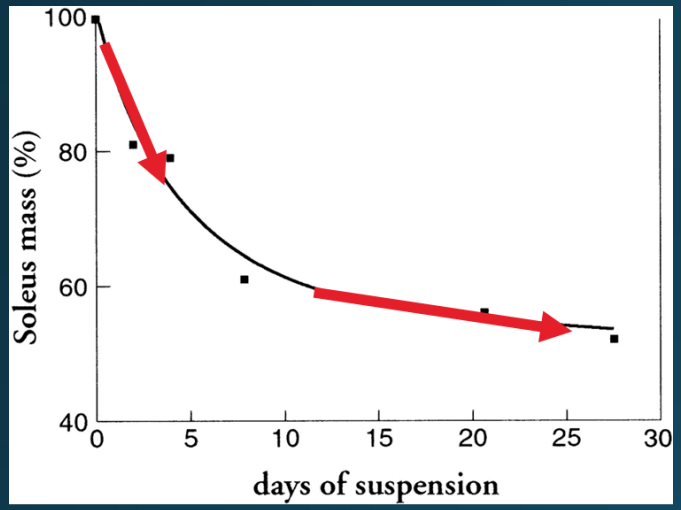
From G. Clément

Arrhythmia studies showed increased ventricular ectopy during spaceflight, but limited data on long term flights.

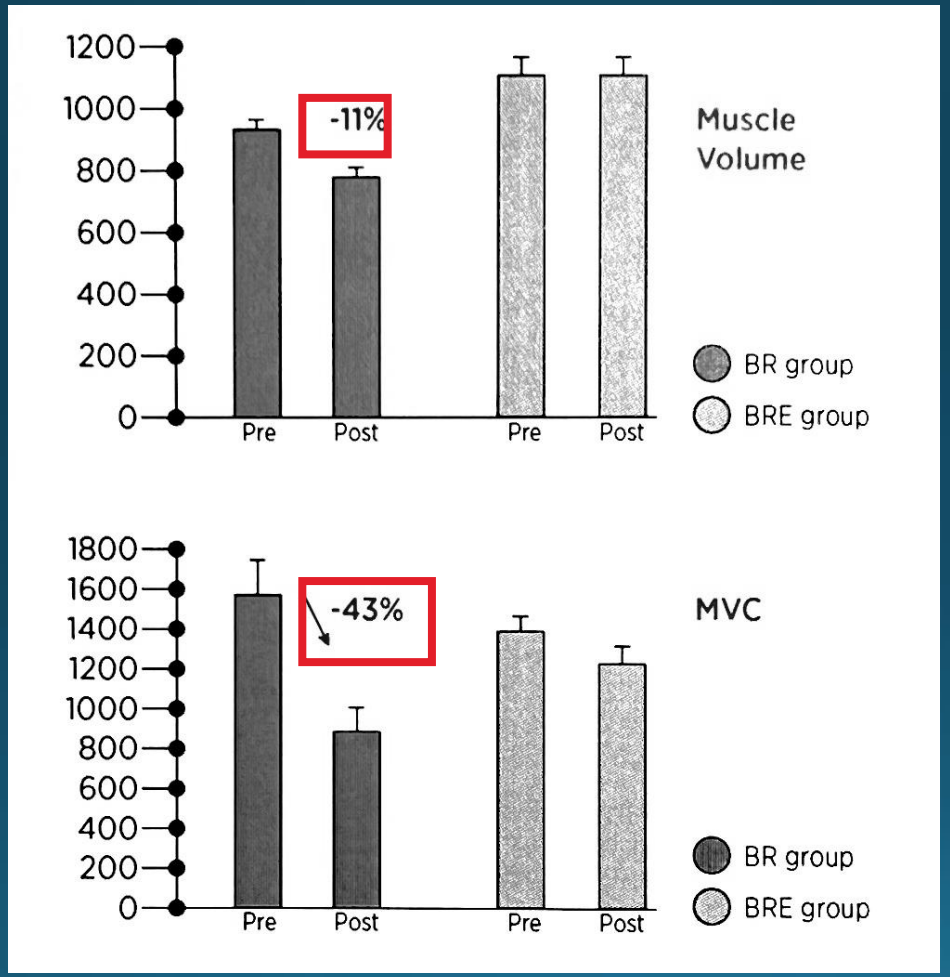
Krittanawong et al., 2023

Skeletal Muscle deconditionning

Nature of the most sensitive muscle:
Postural muscles

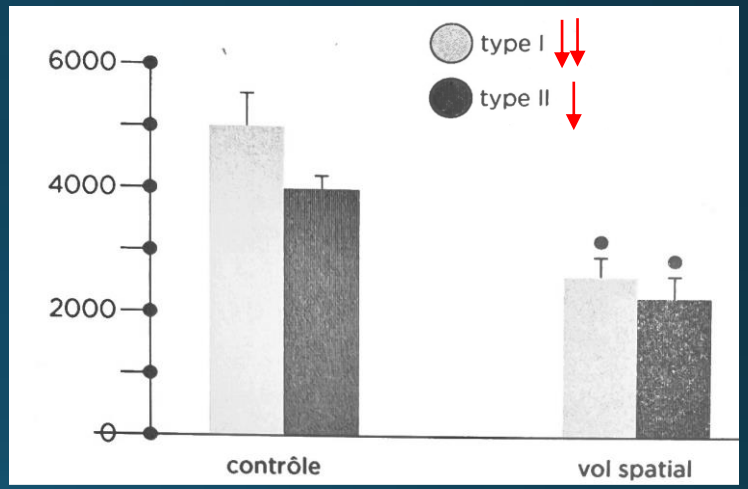


Cross et coll., 1999



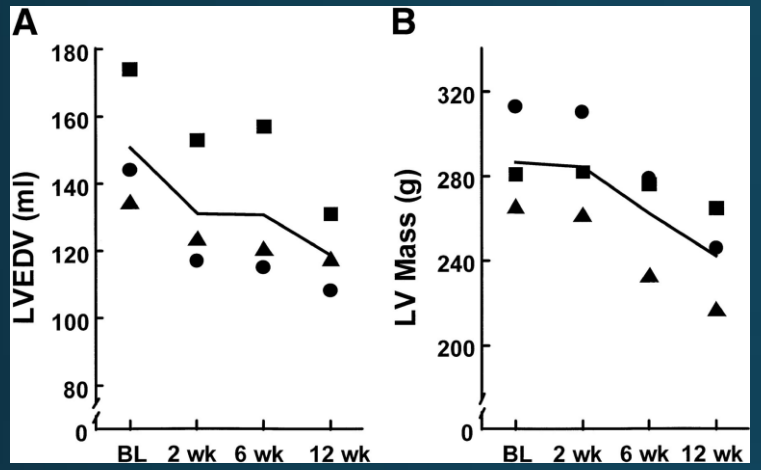
Trappe et coll., 2004

Increase fatigability



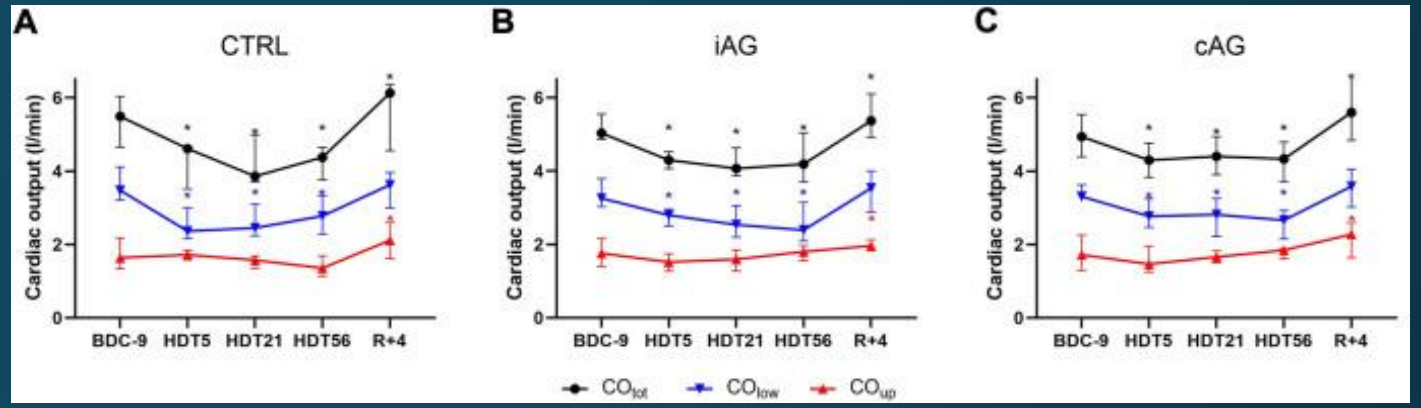
Chopard et al. 2009

Cardiac remodeling



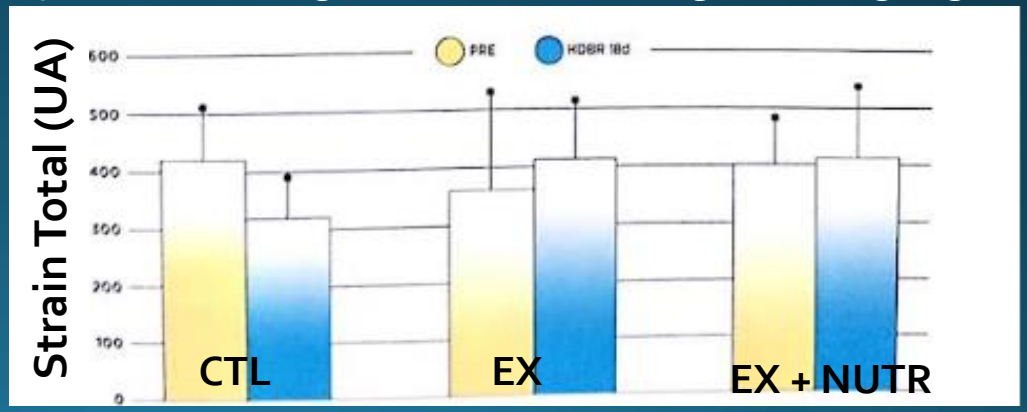
Perhonen et al., 2001

Dorfmann et al. 2007
Hughson et al. 2018



Rabineau et al., 2022

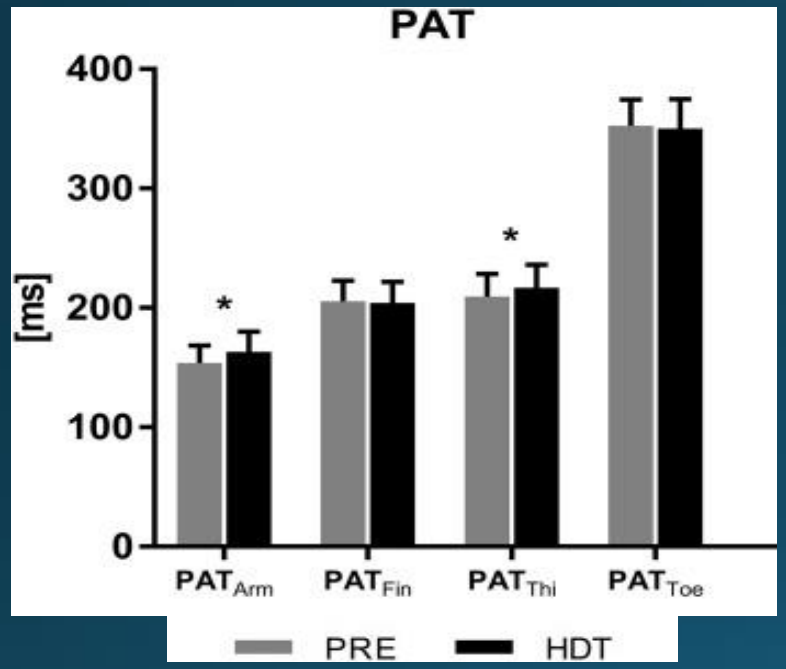
Speckle tracking : no obvious changes during flight



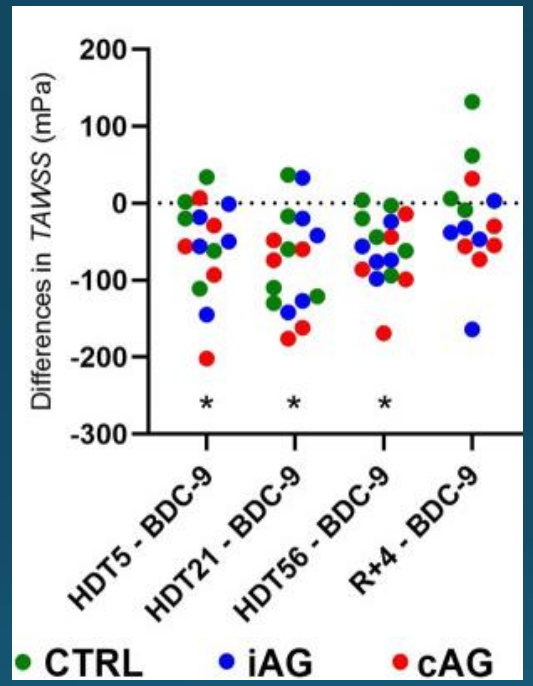
Arbeille et al., 2022

« Cardiovector-3 »: Decrease in papillary muscle volume, after flight (N=5)

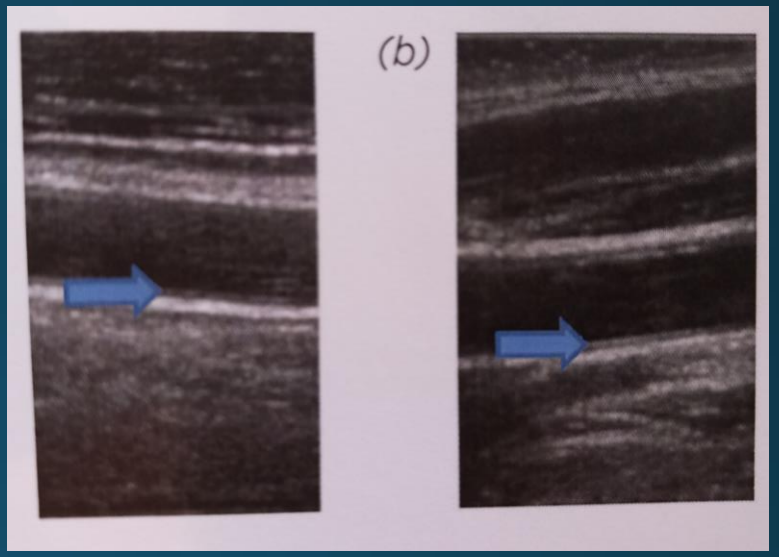
Vascular remodeling



Möstl et al., 2021



Rabineau et al., 2022



Reduced diameters
↓Compliance
Intima-media thickness +15%

Arbeille et al. 2016
Thijssen et al., 2011
Hughson et al., 2016
Navasiolava et al., 2020

☹ Endothelial dysfunction related to lower shear stress, radiation , metabolic trouble? with altered microcirculation

☺ no significantly increased atherosclerotic disease in astronauts

Demiot et al. 2007
Hesse et al., 2005

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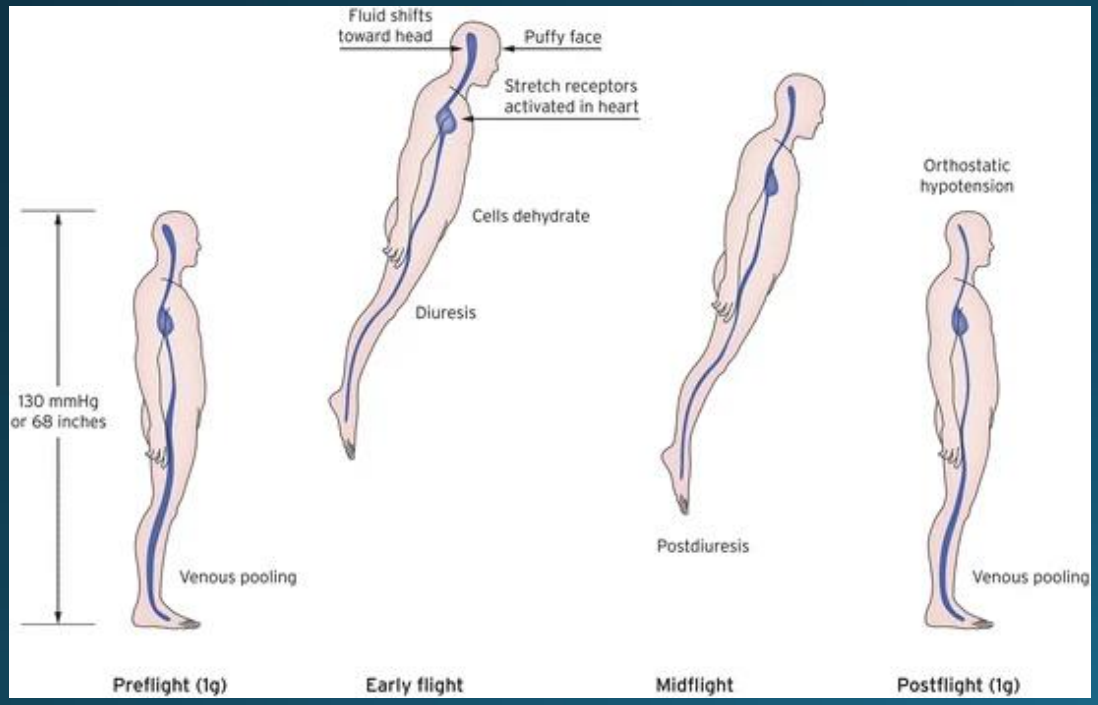
Consequences



- Heavy deconditionning and weakness
- ↓ reactivity
- Unable to maintain moderate or high activity
- Erect posture is also difficult…

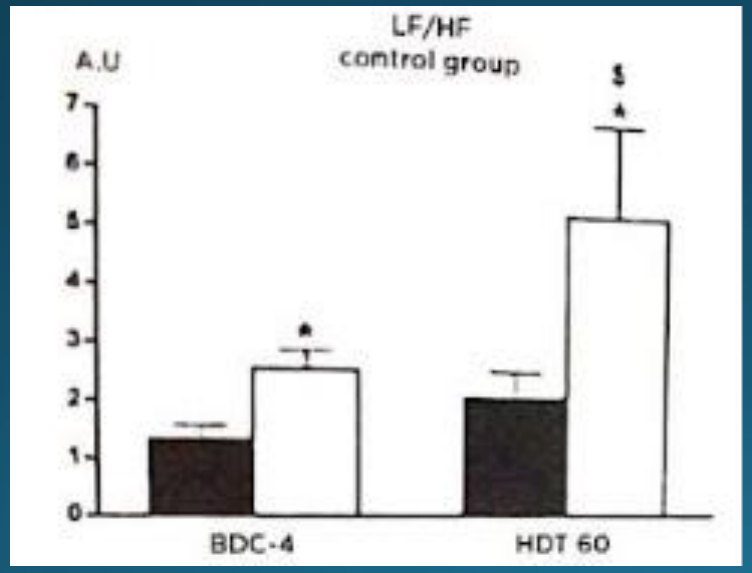
Orthostatic intollerance

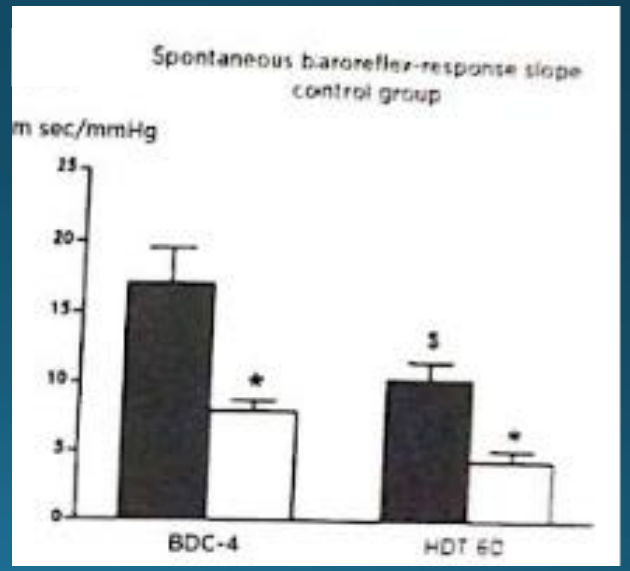
Heidemarie Stephanyshyn-Piper after a 12 days oG flight

Autonomic nervous system

- HRV: ↑LF/HF
- ↓ Baroreflex sensibility after micro-gravity exposure
- blood pressure changes post-flight

Mano et al. 2005
Coupé et al. 2009





supine stand

Coupé et al. 2011

Girafe

- Heart : 11 kg (2% total body mass)

Aim: perfuse the brain 2 m higher

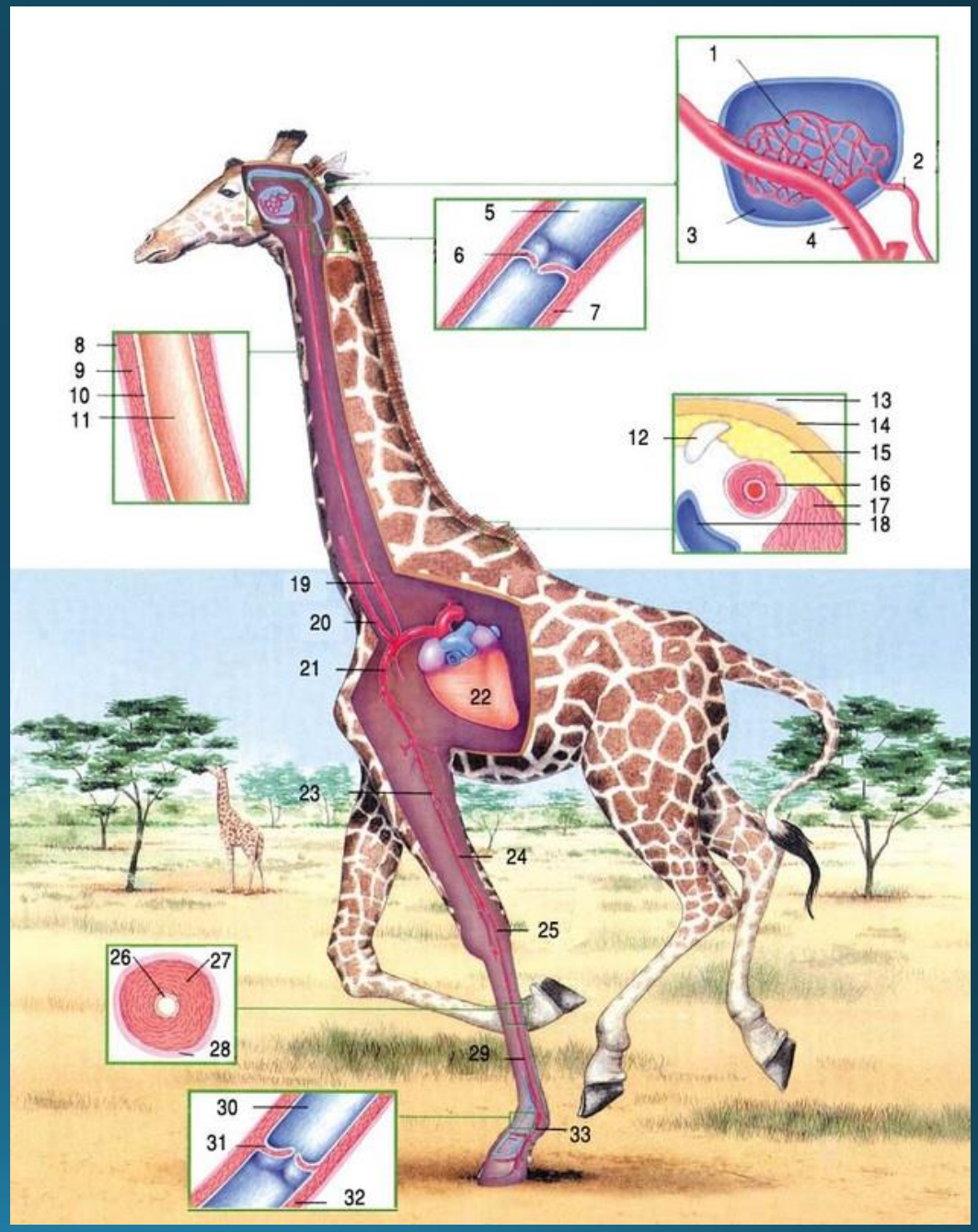
- High Pressure in the legs but:
  - No edema
  - Elastic and tight skin
  - Thicker media in arteries
  - but resistant capillaries

  => inspired the « anti-Gravity suits »

70mmHg

100 mmHg

400 mmHg



Countermeasures

LOWER BODY NEGATIVE PRESSURE

Trying to reset the baroreceptors

- Vacuum container
- Anti-G suit
- Compression socks

Astronaut pre-flight FITNESS has a bearing on the amount of deconditionning and subsequent reconditioning requirements

- Training before
- Training during (ISS:>2h/j)

Credits: ESA

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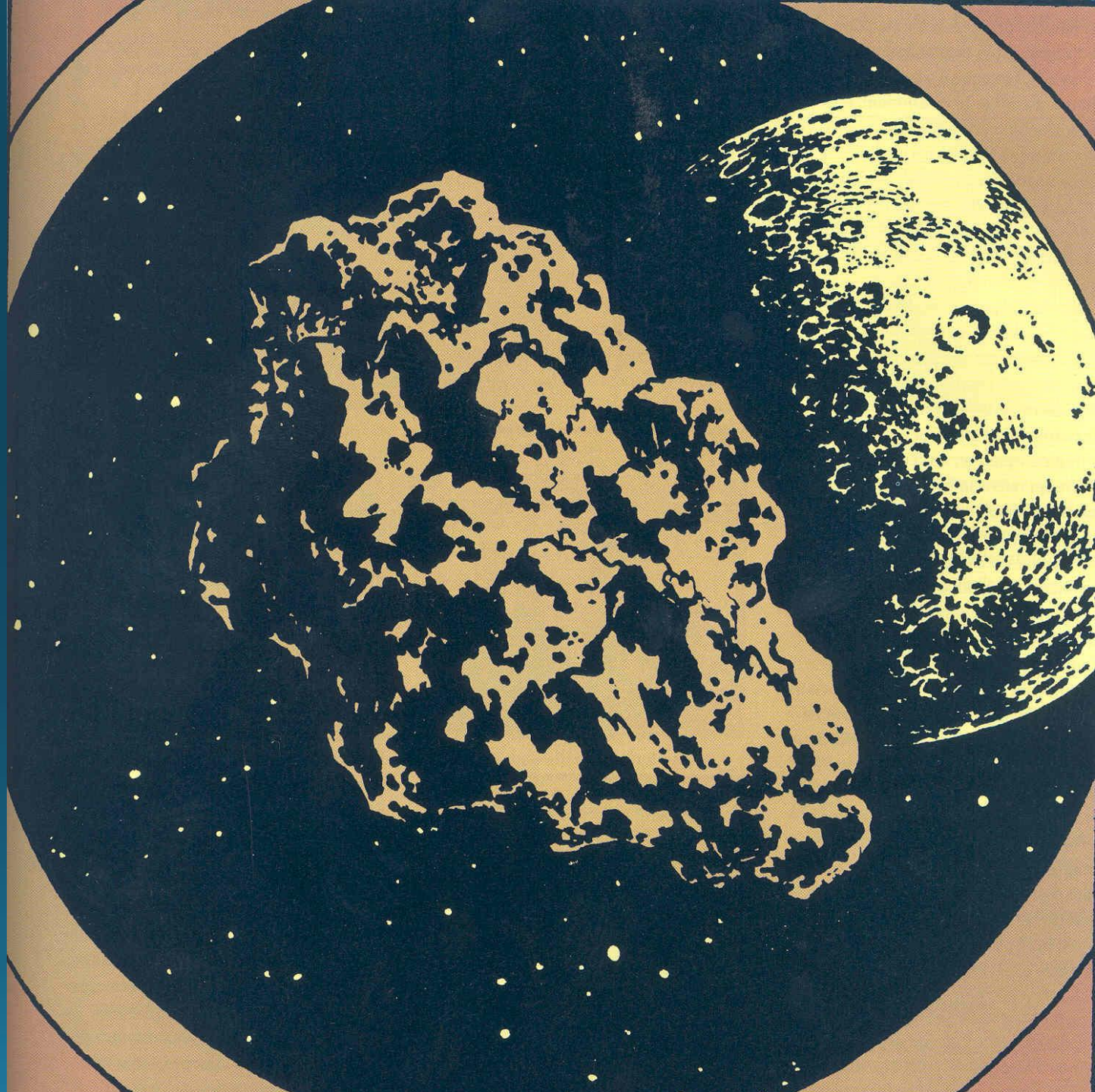
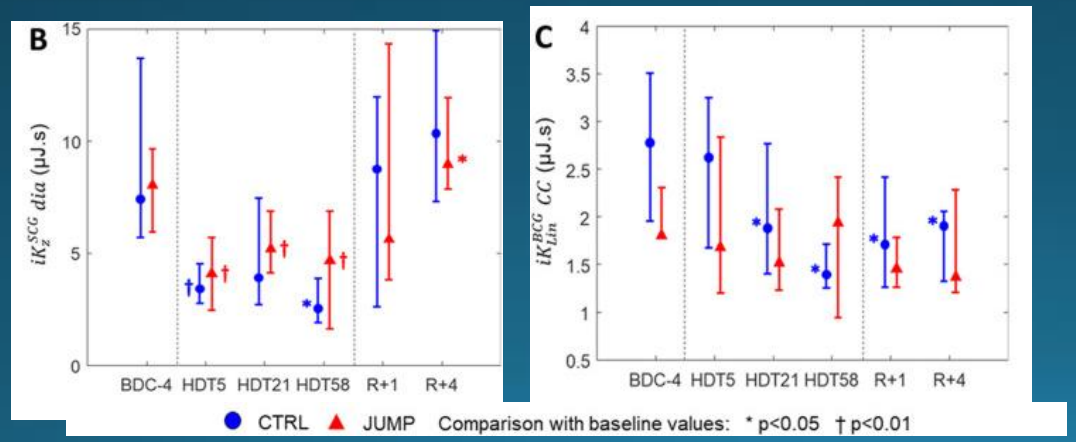
Perspectives &

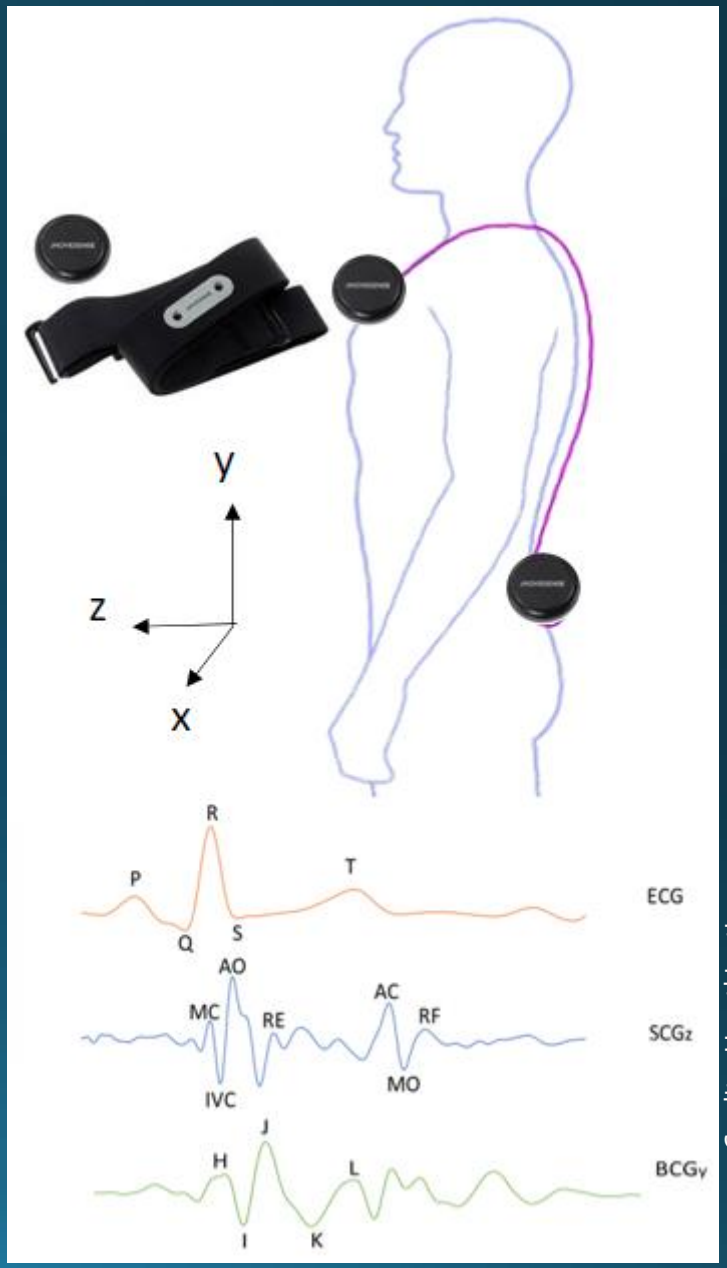
Conclusions



Perspectives

- Need for new countermeasures
- Unknown situation for gravity between 0 and 1 g
- Effectiveness evaluation
- Difficulty MRI and ultrasound
- Development of tele-medicine
- Kinocardiography





Credits: Heartkinetics

Rabineau et coll., 2020

Conclusions

- Studies representing 2696 space travelers : "Environmental space hazards impact the cardiovascular system through multiple mechanisms."

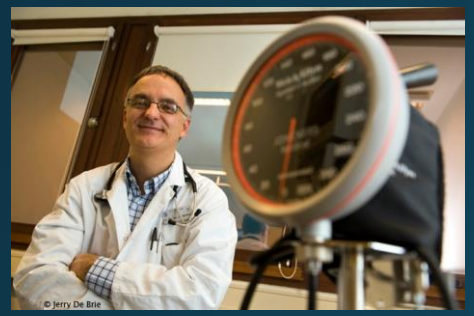
Krittanawong et al., 2023

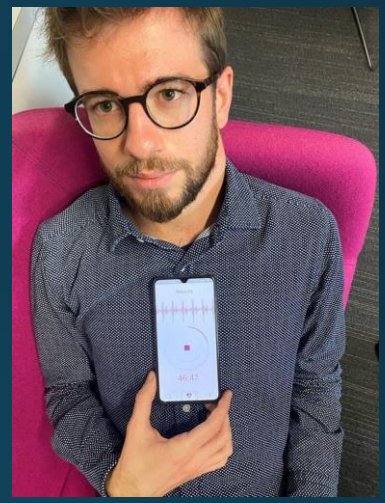
- Microgravity is generally well tolerated
  - Limited atherosclerosis evidence, with human data showing no significantly increased atherosclerotic disease in astronauts.
  - Lower cardiovascular mortality in astronauts *vs* general population. However, there was conflicting data.
- Microgravity « Cardio-vascular deconditionning »: ventricular atrophy, increased arterial stiffness, and altered blood flow distribution.
- Most effects appeared transient and reversible post-flight.
- Orthostatic intolerance with altered HRV, baroreflex response, and BP changes post-flight.

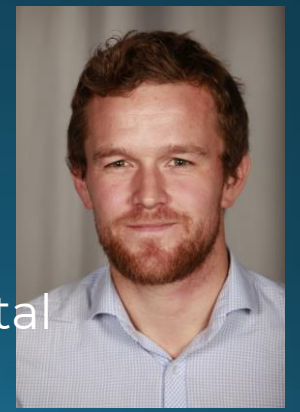
Remaining questions …

- Microgravity over a large period
- Fight agains inactivity
- Limit Radiation
- psychological difficulties of life small groups and small surfaces
- H_2O/O_2 availability & Waste management
- Travelling of unfit subjects and patients (?)
- …

Thank you!
Thanks to the team…







Laboratory of Physics and Physiology – LPHYS, Medical Cardiology, Erasme Hospital
Laboratory of Cardiorespiratory Exercise Physiology, FSM, ULB