Monitoring astronaut health in space

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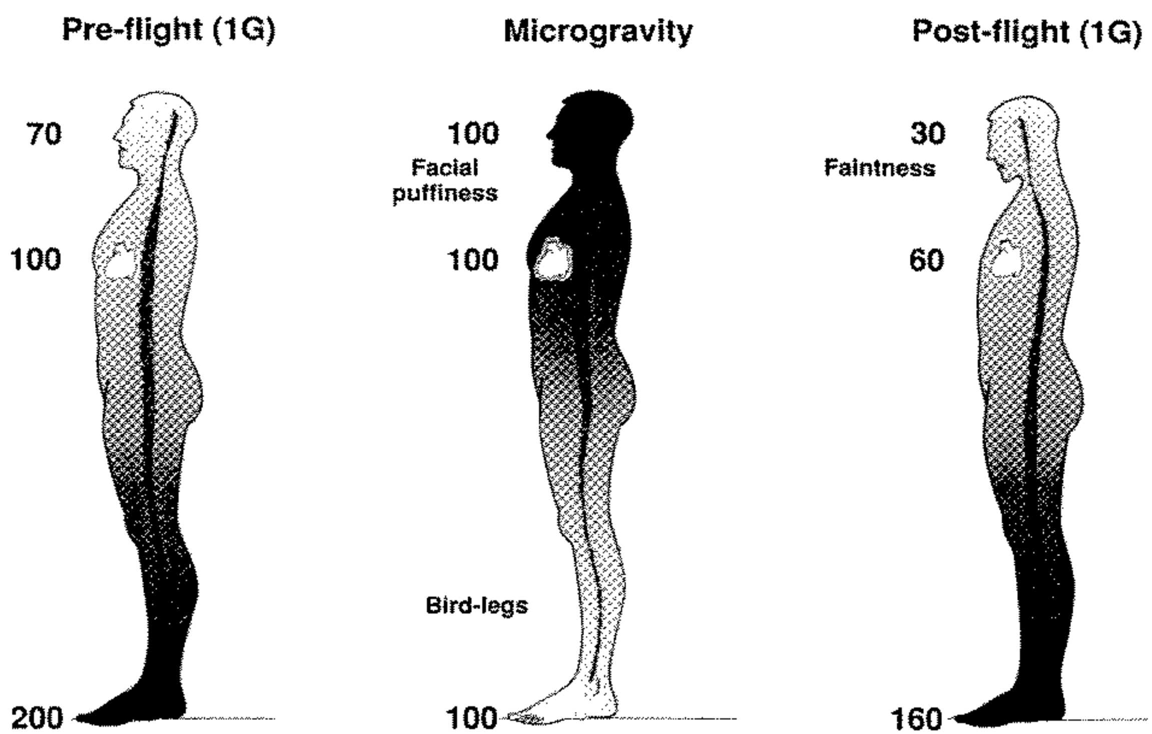
Sensing Technologies for Global Health, Military Medicine and Environmental Monitoring
Baltimore, MD

Things are different in microgravity

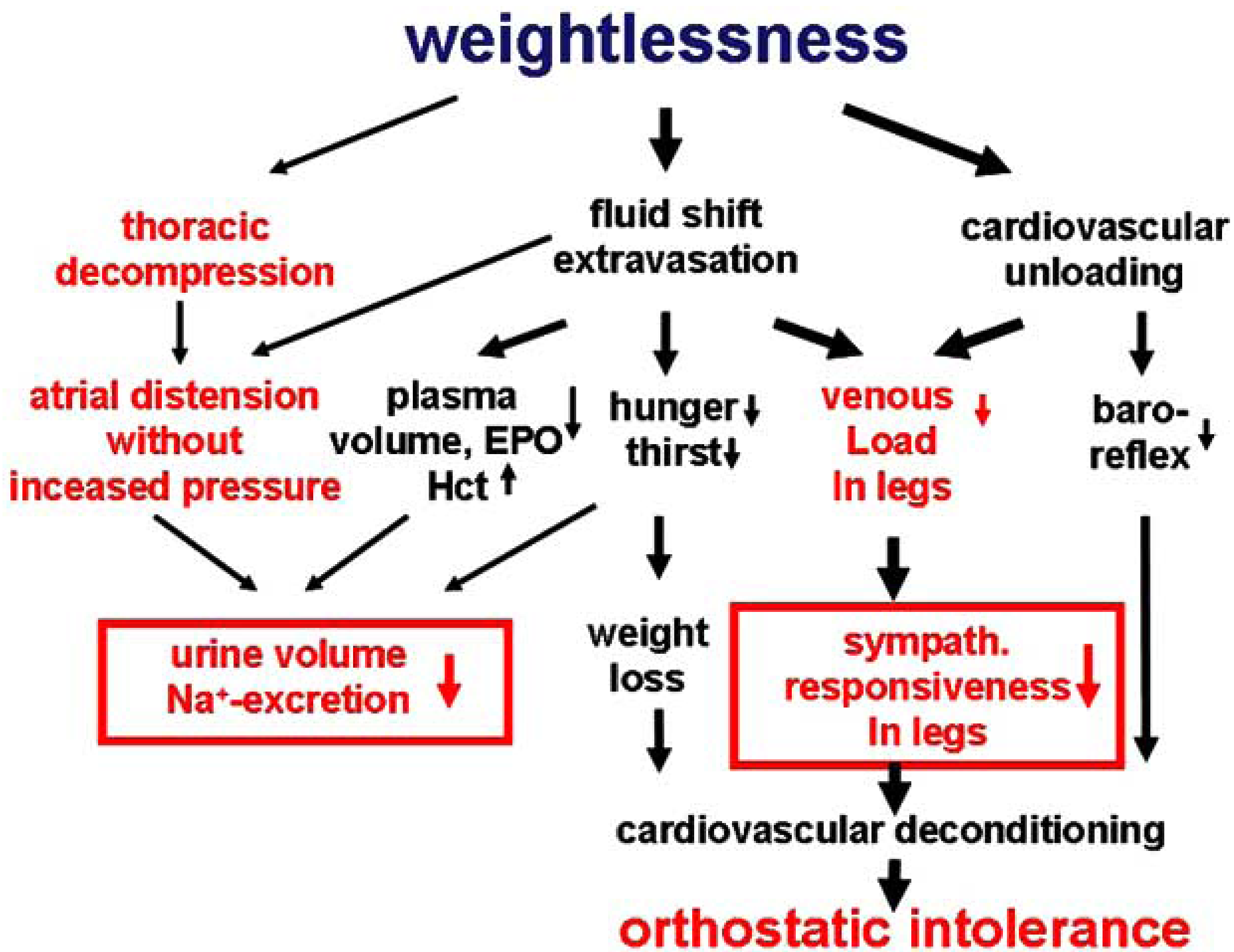
Even people are different in microgravity

Decreased gravity makes body fluids shift upward



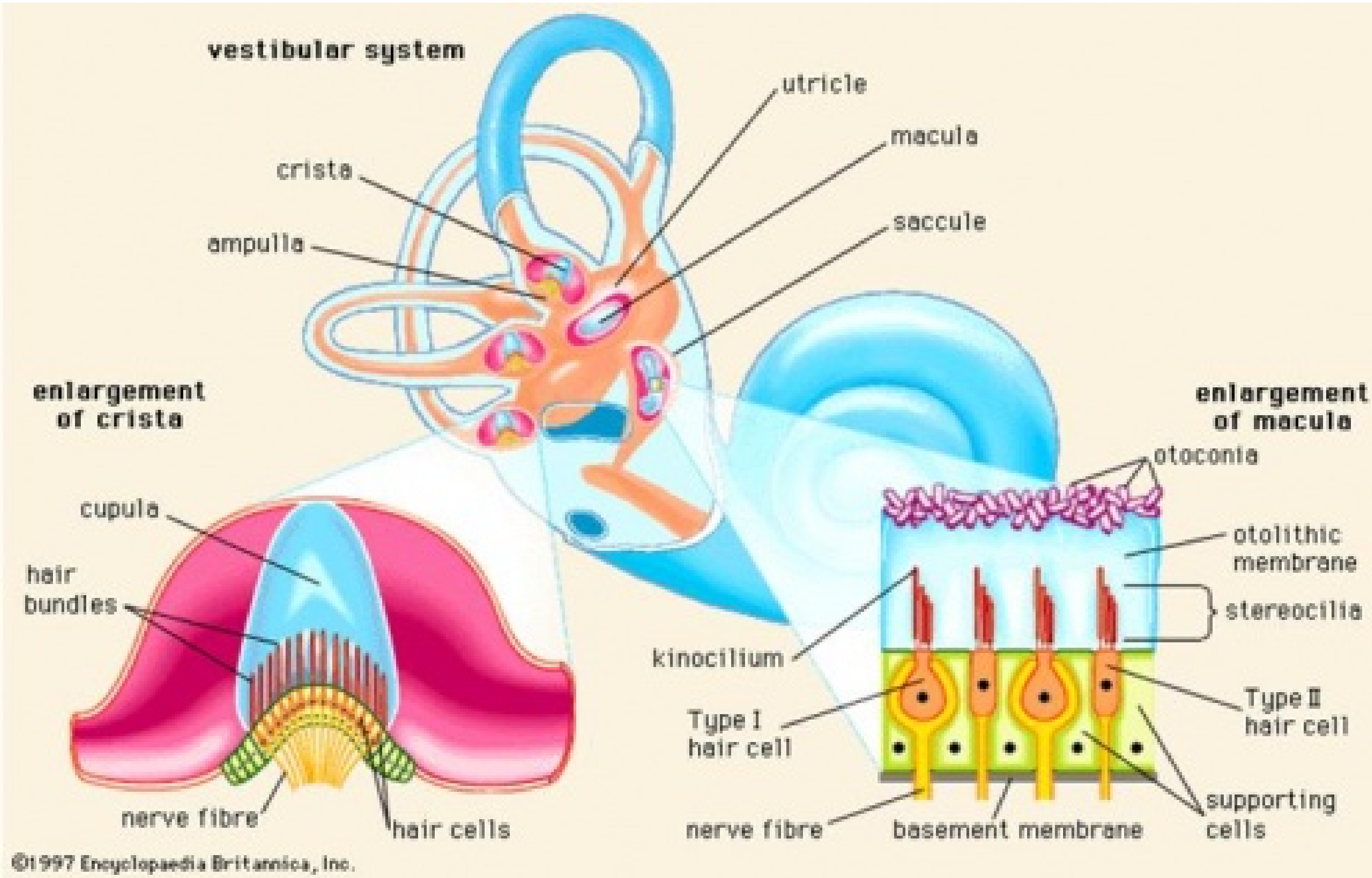
Cardiovascular adaptations, fluid shifts, and countermeasures related to space flight☆

Alan R. Hargens[a,*], Sara Richardson[b] *Respiratory Physiology & Neurobiology 169S (2009) S30–S33*



Regulation of Body Fluid and Salt Homeostasis – from Observations in Space to New Concepts on Earth. R. Gerzer and M. Heer *Current Pharmaceutical Biotechnology, 2005, 6, 299-304 299*

Decreased gravity disrupts the sense of balance



http://www.skybrary.aero/index.php/Vestibular_System_and_Illusions_(OGHFA_BN)

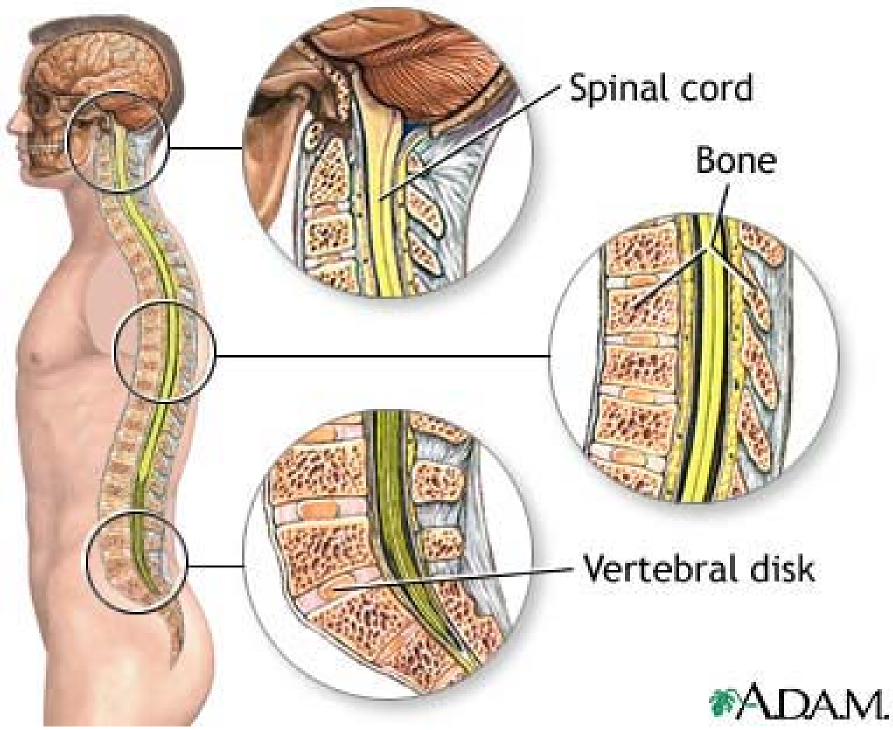
Medical Complaints Associated with Spaceflight

Weight loss
Bone loss
Muscle atrophy

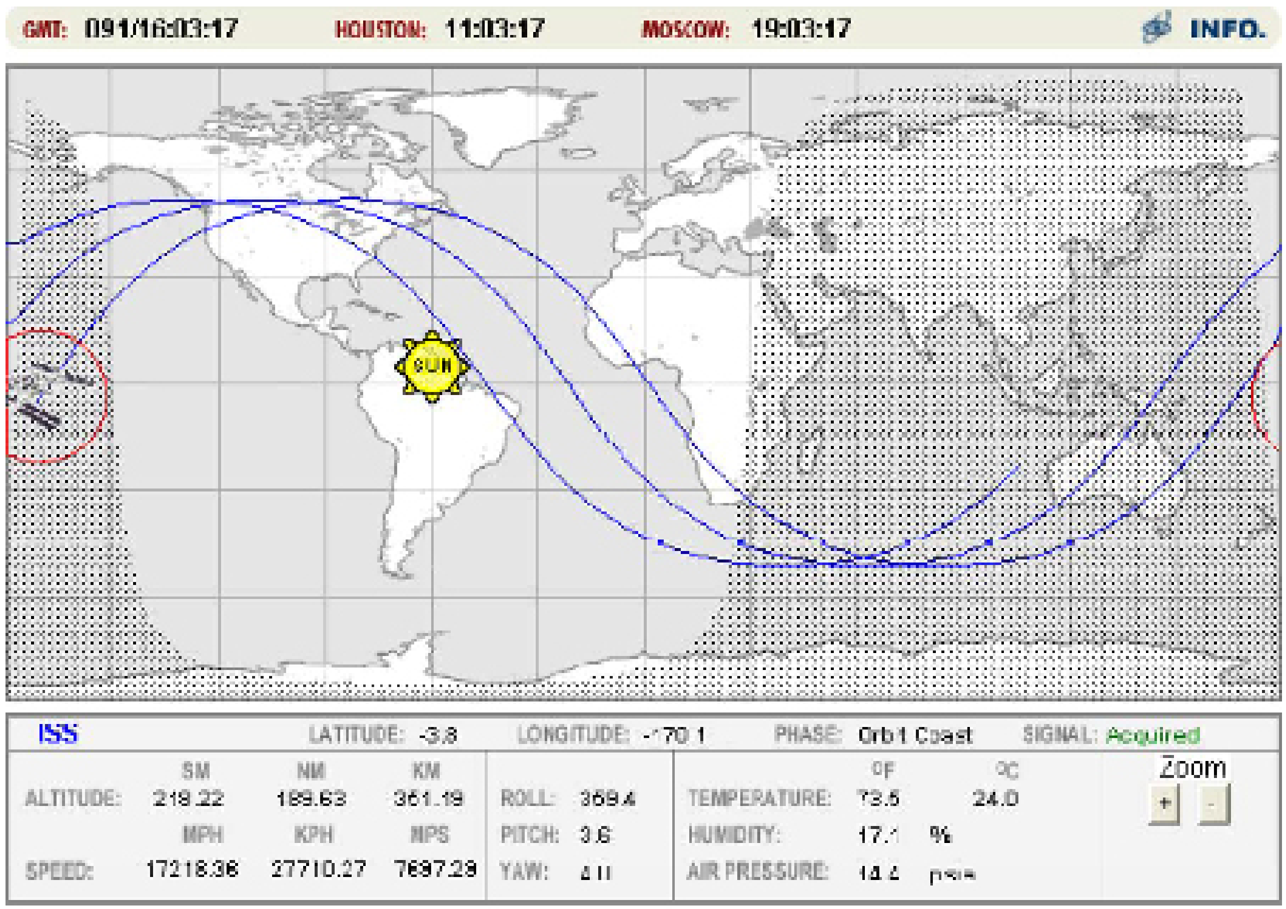
Loss of Bone Mineral Density

Russian ground personal members and doctors carry Italian ESA astronaut Roberto Vittori to the medical tent upon his arrival to the town of Arkalyk, northern Kazakhstan, early Monday, April 25, 2005. [AP]

Body Pain



Circadian Rhythm Disruption



Medical Complaints in Space

Based on ISS Missions:

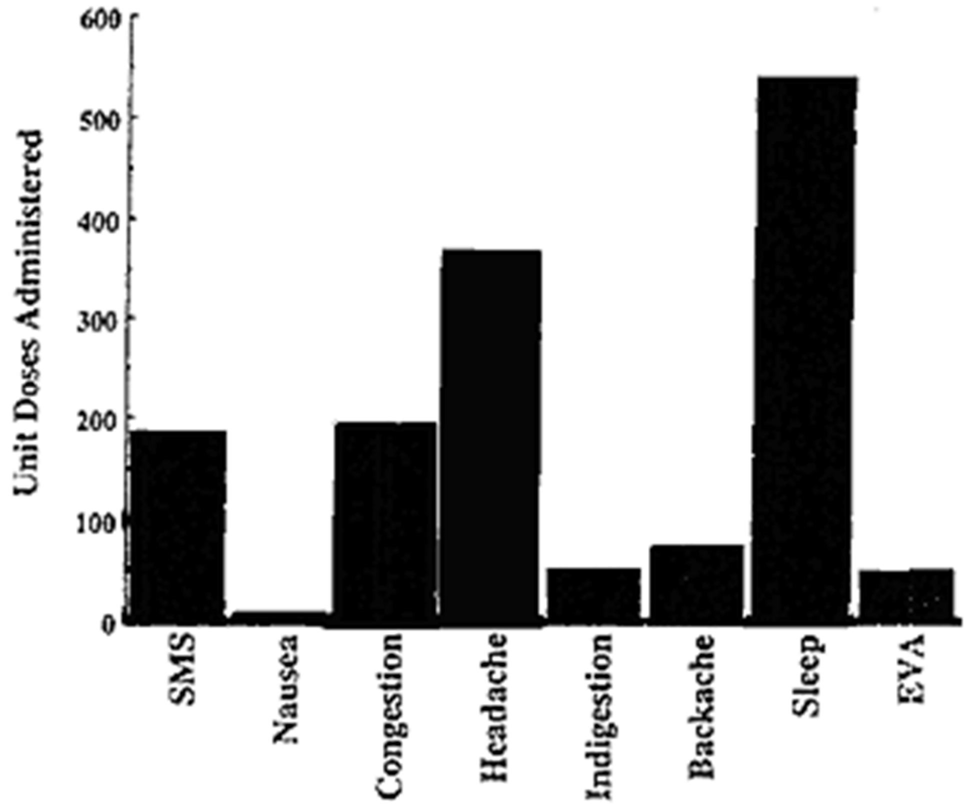
Anorexia
Space motion sickness
Fatigue
Insomnia
Dehydration
Dermatitis
Back pain
Upper respiratory infection
Conjunctival irritation
Subungual hemorrhage
Urinary tract infection
Cardiac arrhythmia
Headache
Muscle strain
Diarrhea
Constipation

From Clement , Fundamentals of Space Medicine, 2003

Based on Space Shuttle, 1988- 1995

Facial Fullness
Headache
Sinus congestion
Dry skin, irritation, rash
Eye irritation, dryness, redness
Foreign body in eye
Sneezing/coughing
Sensory changes
Upper respiratory infection
Back muscle pain
Leg/foot muscle pain
Cuts
Shoulder/trunk muscle pain
Hand/arm muscle pain
Anxiety/annoyance
Contusions
Ear problems (usu. Pain)
Neck muscle pain
Stress/tension
Muscle cramp
Abrasions
Fever, chills
Nosebleed
Psoriasis, folliculitis, seborrhea
Low heart rate
Myoclonic jerks

Pharmaceutical Use on Shuttle



Putcha L, Berens KL, Marshburn TH, Ortega HJ, Billica RD. *Pharmaceutical use by U.S. astronauts on space shuttle missions.* Aviat Space Environ Med 1999; 70:705–8.

Our Mission at the JSC Pharmacology Lab…

…is to ensure that flight surgeons have good information about how administered pharmaceuticals will work in the extreme conditions of spaceflight

…which means that we have to understand the physiological changes caused by living in the spaceflight environment

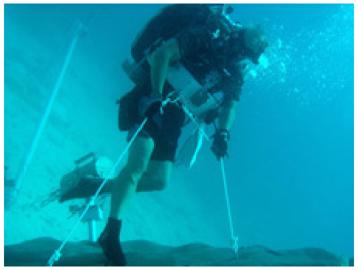
…as well as the effect of the spaceflight environment on the stored drugs themselves

…as well as the pharmaceuticals’ mechanism of action

How and where we do our Research

In order to conduct the kind of studies that can help improve the safety and productivity of space travel, the HRP has established a number of experimental facilities known as “analogs” that mimic environmental conditions in space.

- NASA Extreme Environment Mission Operations (NEEMO)
- Haughton Mars Project
- Desert Research and Technology Studies (Desert RATS)
- Bedrest Studies
- Human-Related Altitude Chamber Complex
- Antarctica



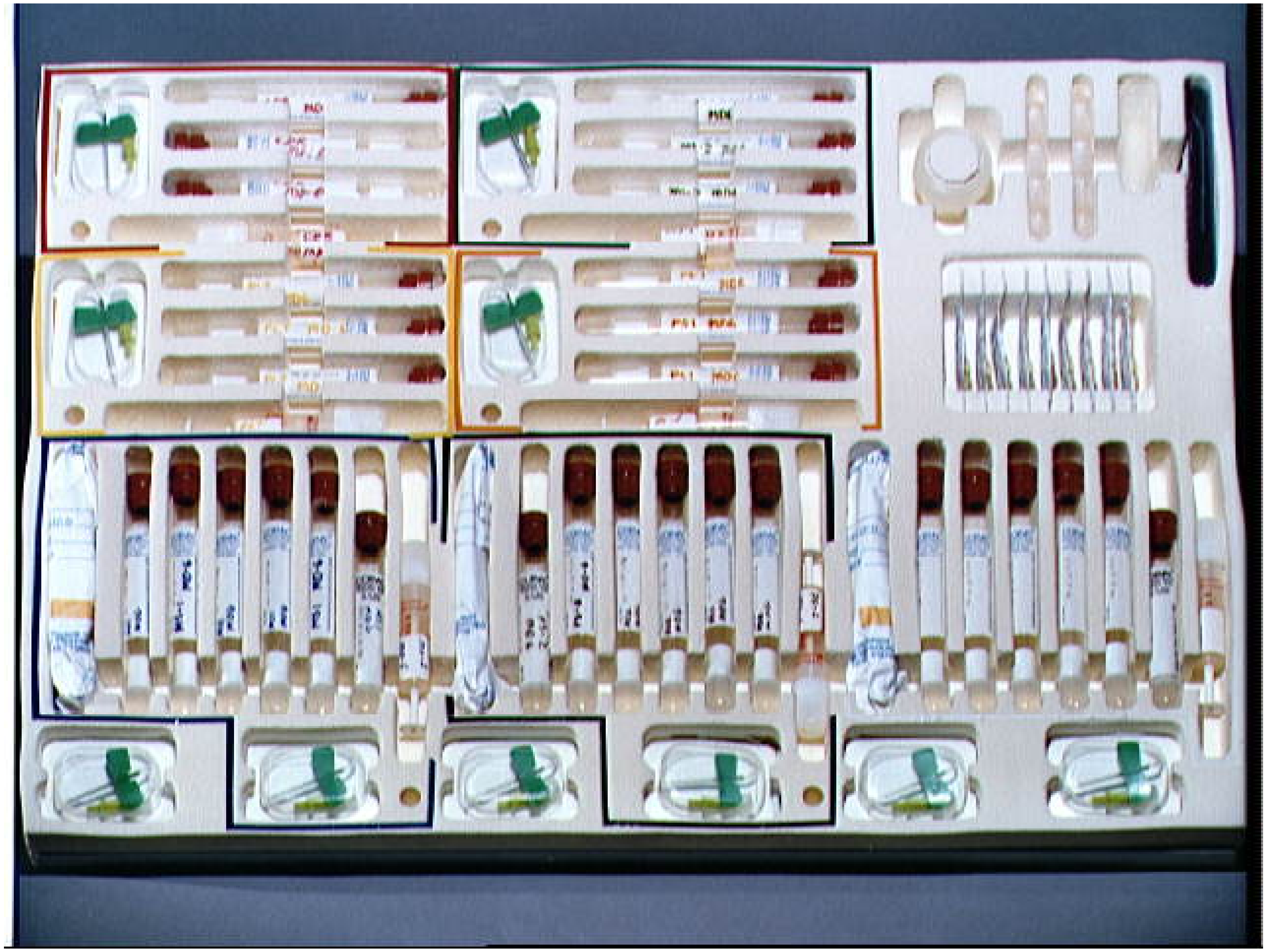
Limitations of Spaceflight Experiments:

- Non-invasive methods best
- Non-toxic
- Lightweight and small equipment
- No degassing, explosion or fire risk
- Low power consumption
- Low impact on crew schedule
- N will be small (~400 people have flown to space)

Current model: return samples to Earth for analysis

Inside the science module aboard the Earth-orbiting Space Shuttle Columbia, Astronaut David A. Wolf draws blood from payload specialist Martin J. Fettman, DVM. Blood samples from crew members are critical to Life Sciences investigations, but must be returned to Earth for analyses.

Blood collection kit for Space Lab 1
1981



-80 Freezer is available

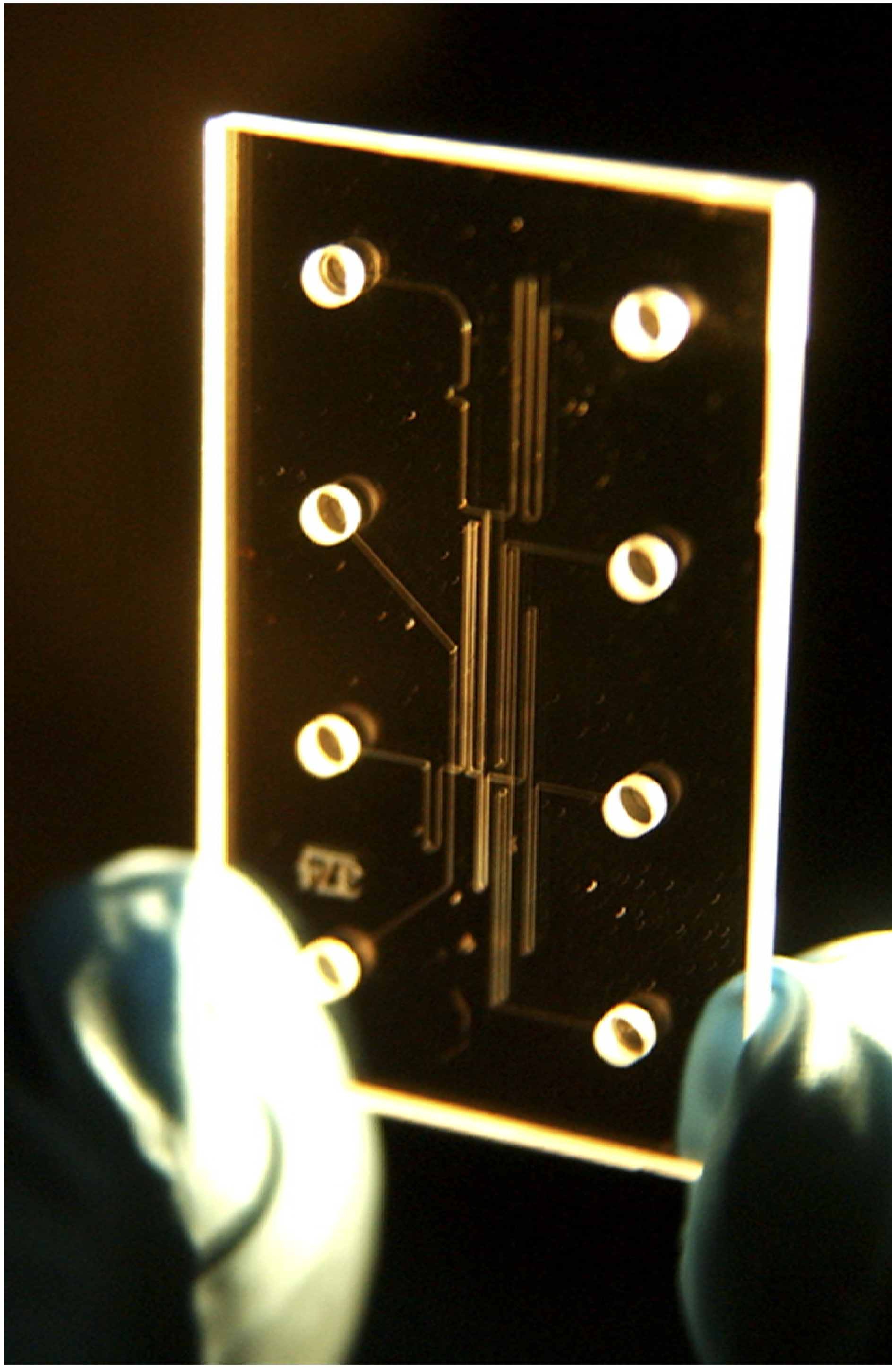
ISS013E64639

Some tests can be performed inflight, with data transmitted to ground

ISS commander and science officer Leroy Chiao performs an ultrasound scan on the eye of flight engineer Salizhan Sharipov during during ISS Expedition 10. Crewmembers may be guided real-time by flight surgeons and/or an experienced ultrasound technician.

Lab on a chip may enable inflight analysis

The eight holes on this chip are ports that can be filled with fluids or chemicals. Tiny valves control the chemical processes by mixing fluids that move in the tiny channels that look like lines, connecting the ports. Scientists at NASA's Marshall Space Flight Center in Huntsville, Alabama designed this chip to grow biological crystals on the ISS. These chips, the size of dimes, could be loaded on a rover looking for biosignatures of past or present life. Other types of chips could be placed in handheld devices used to monitor microbes in water or to quickly conduct medical tests on astronauts. (NASA/MSFC/D.Stoffer)



Human Research Roadmap

A web tool that is an excellent source of information on each of the identified HRP Risks to human spaceflight.

http://humanresearchroadmap.nasa.gov/

http://humanresearchroadmap.nasa.gov/

Risks

Risks 1 - 32 (of 32)

Search Risk Titles...

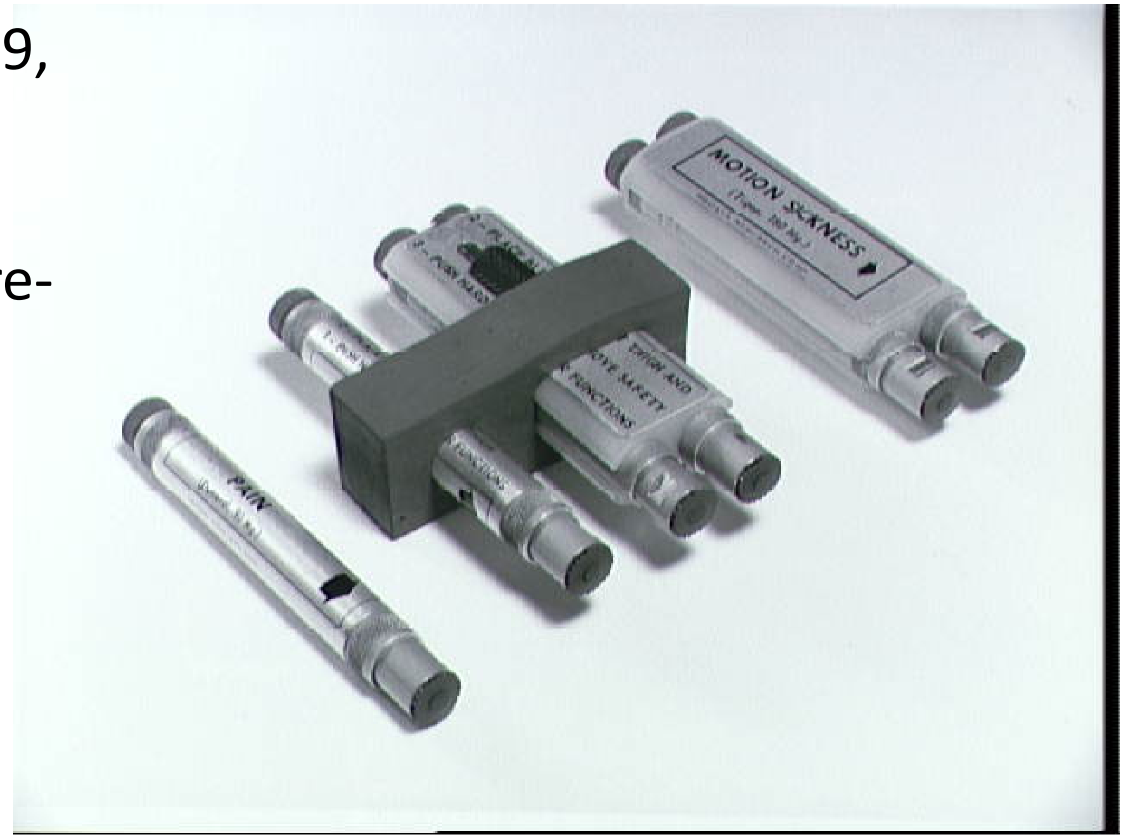
- Risk Factor of Inadequate Nutrition
- Risk of Acute and Late Central Nervous System Effects from Radiation Exposure
- Risk of Acute Radiation Syndromes Due to Solar Particle Events (SPEs)
- Risk of Adverse Behavioral Conditions and Psychiatric Disorders
- Risk of Adverse Health Effects Due to Alterations in Host-Microorganism Interactions
- Risk of Adverse Health Effects of Exposure to Dust and Volatiles During Exploration of Celestial Bodies
- Risk of an Incompatible Vehicle/Habitat Design
- Risk of Bone Fracture
- Risk of Cardiac Rhythm Problems
- Risk of Clinically Relevant Unpredicted Effects of Medication
- Risk of Compromised EVA Performance and Crew Health Due to Inadequate EVA Suit Systems
- Risk of Crew Adverse Health Event Due to Altered Immune Response
- Risk of Decompression Sickness
- Risk Of Degenerative Tissue Or Other Health Effects From Radiation Exposure
- Risk Of Early Onset Osteoporosis Due To Spaceflight
- Risk of Impaired Control of Spacecraft, Associated Systems and Immediate Vehicle Egress Due to Vestibular/Sensorimotor Alterations Associated with Space Flight
- Risk of Impaired Performance Due to Reduced Muscle Mass, Strength and Endurance
- Risk of Inadequate Critical Task Design
- Risk of Inadequate Design of Human and Automation/Robotic Integration
- Risk of Inadequate Human-Computer Interaction
- Risk of Injury from Dynamic Loads
- Risk of Intervertebral Disk Damage
- Risk of Orthostatic Intolerance During Re-Exposure to Gravity
- Risk of Performance Decrement and Crew Illness Due to an Inadequate Food System
- Risk of Performance Decrements Due to Inadequate Cooperation, Coordination, Communication, and Psychosocial Adaptation within a Team

First pharmaceuticals in US spaceflight

In 1963 on Mercury Atlas 9, 22 Earth orbits, 35 hours

Gordon Cooper carried pre-loaded drug injectors in space suit pocket

Demerol – pain relief
Tigan - motion sickness



Before 1988, there were no pharmacological countermeasures- just exercise, fluid loading and g suits.
Shuttle missions lasted no more than 7 days.
In 1988 Congress approved funds to expand missions to 16 days.
Countermeasure development began in earnest.
Currently, 6 months on the ISS is routine and the first 1 year mission will begin later this year.
We are planning exploration missions that may last 3 years and the countermeasures (many of them pharmaceutical) that will be required to maintain crew health over periods of years.

Research in JSC Pharmacology

Pharmaceuticals

- Usage tracking
- Stability

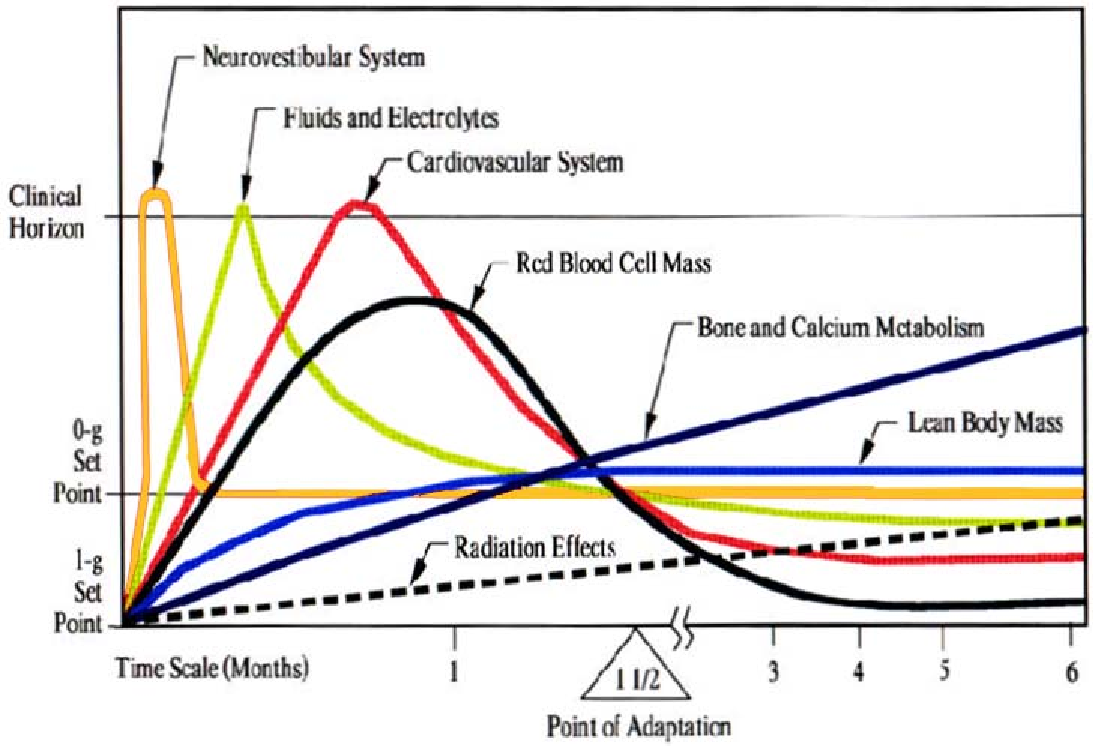
Pharmacokinetics

- Absorption/Distribution
- Metabolism/Excretion

Pharmacodynamics

- all the indications that people treat

Many physiological systems are affected by spaceflight



Evidence: Flight studies

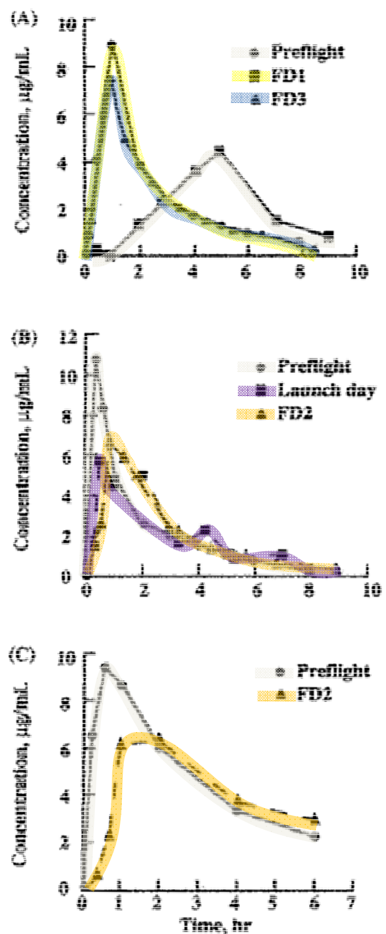


Fig. 2 Saliva concentrations of acetaminophen over time after oral administration of a 650 mg dose to crew members.

Cintron & Putcha acetaminophen case studies, 1987

Salivary acetaminophen measured over time after oral administration of tablets (acetaminophen is the gold standard for examination of oral absorption, but substitution of saliva concentrations for plasma not established)

3 individuals - each panel shows data from a single individual. Use of other medications is unspecified.

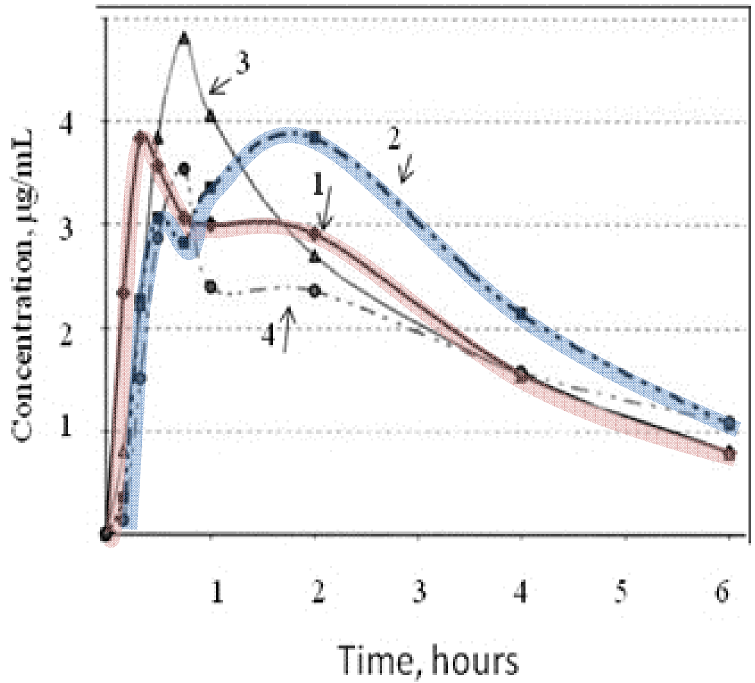
Two individuals show reduced peak concentration for FD1-2 (middle and lower)

One person shows slower absorption preflight, but this value is much slower than average ground values from the literature (0.8 h).

<u>Paucity of data and variability in data preclude definitive conclusion.</u>

Evidence: Flight studies

Average pharmacokinetic curves after acetaminophen <u>tablet</u> administration.



1. **tablets**, on ground;
2. **tablets** during spaceflight;
3. capsules, ground;
4. capsules during spaceflight.

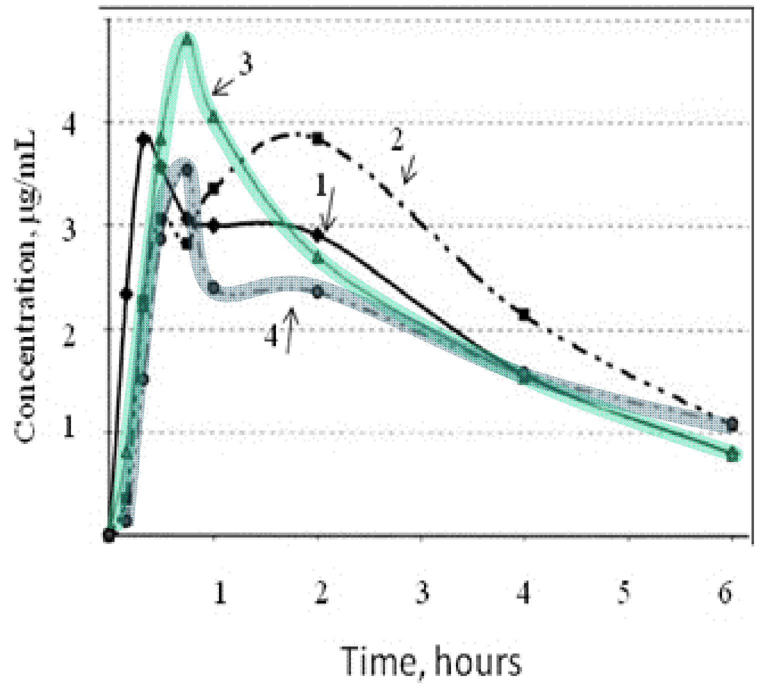
<u>AUC is the same, peak looks slower (but not significantly so)</u>

Long duration ISS crew (sampling date unspecified), males, N= 5, free of other medications, salivary sampling. The absence of error bars on this graph exaggerates differences between curves.

Kovachevich *et al.*,2009

Evidence: Flight studies

Average pharmacokinetic curves after acetaminophen **capsule** administration.



1. tablets, on ground;
2. tablets during spaceflight;
3. **capsules**, ground;
4. **capsules** during spaceflight.

Time to peak is the same, but the half-life is significantly longer.

Long duration ISS crew (sampling date unspecified), males, N= 5 (different 5 than tablet group), free of other medications, salivary sampling. The absence of error bars on this graph makes comparisons difficult.

Kovachevich *et al.*,2009

PK- Does the spaceflight environment (radiation, microgravity, etc) alter ADME?

Use of salivary sampling for PK studies would improve feasibility inflight

Inflight analysis would remove the requirements for sample storage (in costly frozen conditions) and sample return

Salivary sampling use in spaceflight

- Collection of saliva is one such technique that has been frequently been used for pharmacologic, metabolic, ciracadian and immune studies.
- About 40 studies, on Apollo, Mir, Apollo-Soyuz Test Project, Shuttle and ISS

Need more ?

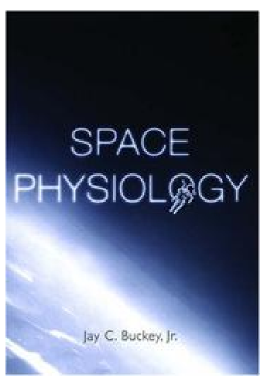
General NASA info: http://www.nasa.gov

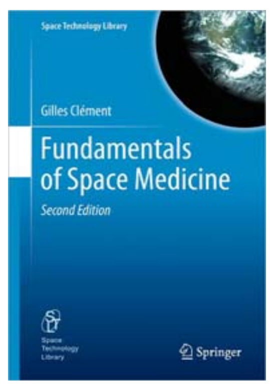
Human Research at NASA: http://humanresearch.jsc.nasa.gov/

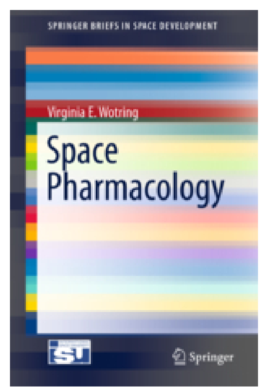
NASA Research Grants: http://nspires.nasaprs.com/external/

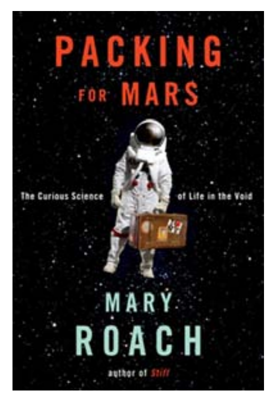
Don Pettit's Blog http://blogs.airspacemag.com/pettit/

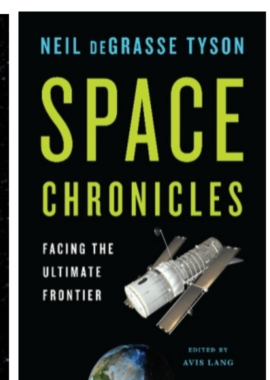
Ginger virginia.e.wotring@nasa.gov











The NASA budget is about $17B.

Half a penny of every tax dollar goes to NASA.

NIH budget is about $30B.

Americans spend more on pizza ($27B) than on the space program.

NASA