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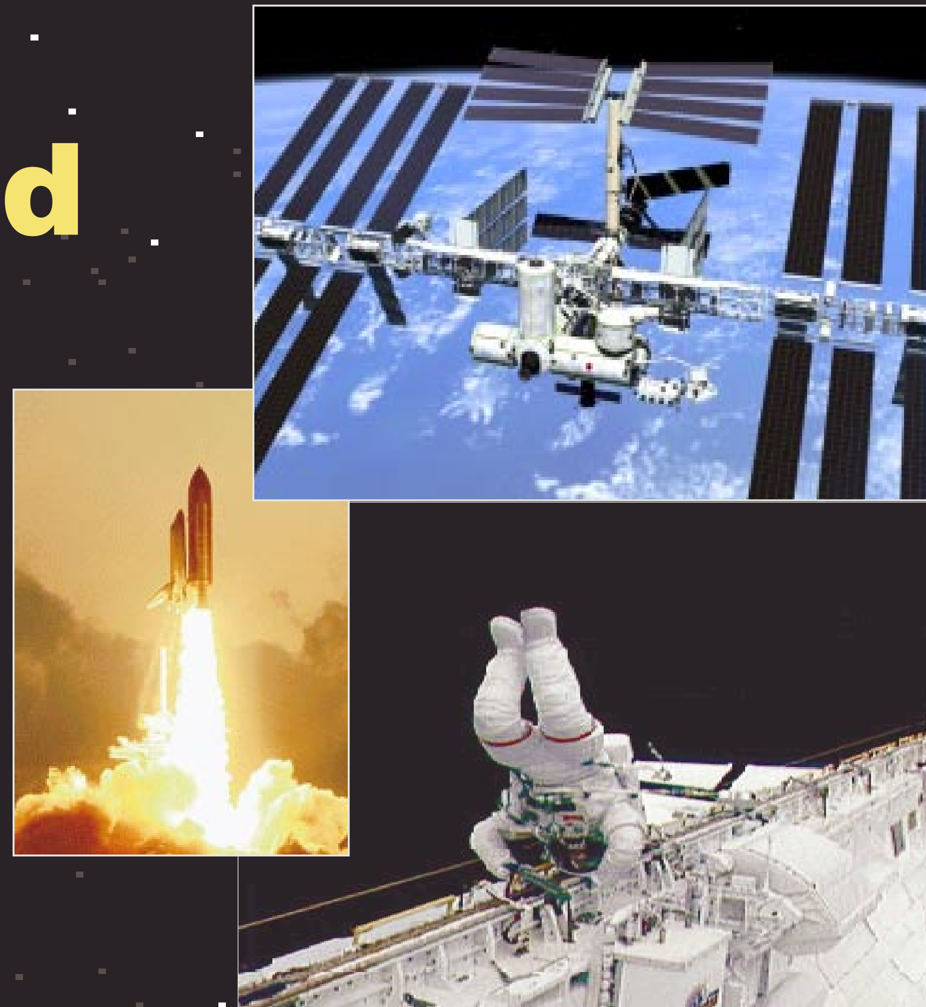

Helen W. Lane, Ph.D.
Principal Coordinating Scientist
Habitability and Environmental Factors
NASA Johnson Space Center, Houston TX, USA

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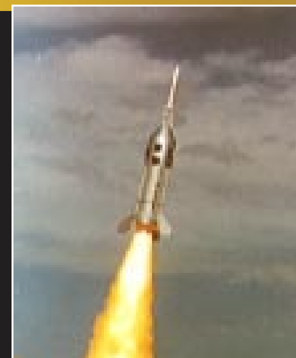

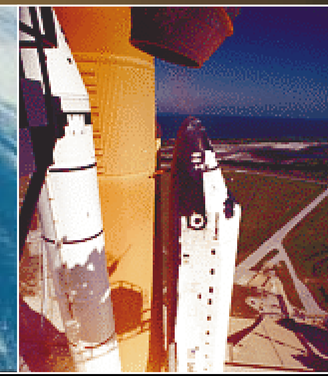

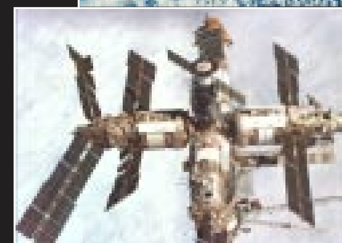

Mercury

Gemini

Apollo

Skylab

Space Shuttle

Shuttle/Mir

International Space Station

Libration Point

Mars/Asteroids

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Psychological/Behavioral/
Performance issues

Neurosensory adaptations

Taste and odor sensitivity

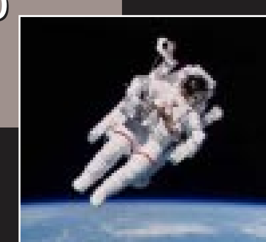
Fluid shifts and
electrolyte distribution

Cardiovascular and
renal changes

Musculoskeletal changes

Hematological changes

The human body experiences numerous changes during exposure to microgravity and the readaptation to Earth’s gravity.



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Gregory Harbaugh in training for STS-39

Sergei Krikalev and Yuri Gidzenko aboard the ISS

- Adaptation to cultural diversity
- Isolation
  - Lack of access to family and friends
  - Lack of normal leisure pursuits
- Time – intensive workloads
- Stress
- Monotony of stimuli, including food
- Nutritional impacts
  - Boredom with food, resulting in less eating
  - Skipping meals, dependence on snacking
  - Poor appetite

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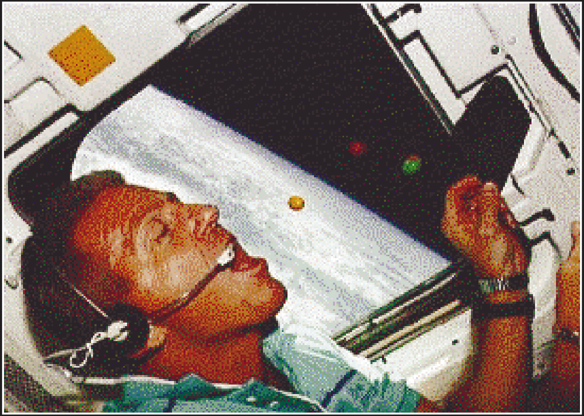
- Astronaut selection – refinement of the psychological evaluation
- Training to improve teamwork and adaptation to environment
- Support from family/friends and professional support
- Self-assessment tools
- Food
  - More variety in textures and taste
  - Resupply with fresh foods, especially fruits and vegetables
  - Frozen foods – taste similar to home cooking
  - Celebrations and party foods

International members of the ISS Expedition 2 crew



Loren J. Shriver on STS-46

Nuroaorsdatations

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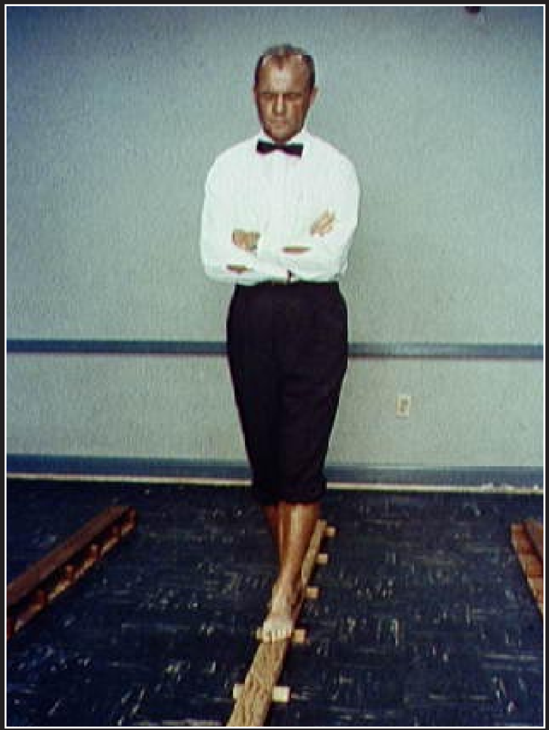
- Inability to maintain stable eye level
- Problems with gait and balance upon return to Earth
- Nutritional impacts
  - Space motion sickness (SMS)
    - Nausea
    - Decreased food consumption
    - Dehydration
- Mitigation
  - Preflight nutritional counseling to assure optimal nutritional status
  - Physical training and countermeasures to prevent SMS



Astronaut John Glenn performing balance tests (1964) atssand dor aitists

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ISS Expedition I crew Yuri Gidzenko, Bill Shepherd, and Sergei Krikalev

- Anecdotal data
  - Foods reportedly taste differently
  - Limited packaging odors in foods
  - Spacecraft has ambient odors
- Research
  - Little research has shown measurable changes in taste (ground and spaceflight) or odor (ground)
  - Two studies done on Skylab and by Canadian Space Agency on changes in taste (ground and spaceflight) and odor (ground)
- Mitigation
  - Supply frozen foods on the International Space Station to simulate home cooking
  - Include fresh foods
  - Improve ambient-storage foods, e.g., irradiated meats

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Loss of Body Fluids

Lack of Thirst – Dehydration

Effect on Cardiovascular Function

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Measurement	Method
Total Body Water (TBW)	$^{2}H_2O$
	$^{3}H_2O$
	$H_2{}^{18}O$
Plasma Volume	CO-rebreath-calculated*
	^{125}I-albumin
	Evans Blue
Extracellular Fluid (ECF)	NaBr

*Calculated from the hemoglobin values.

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

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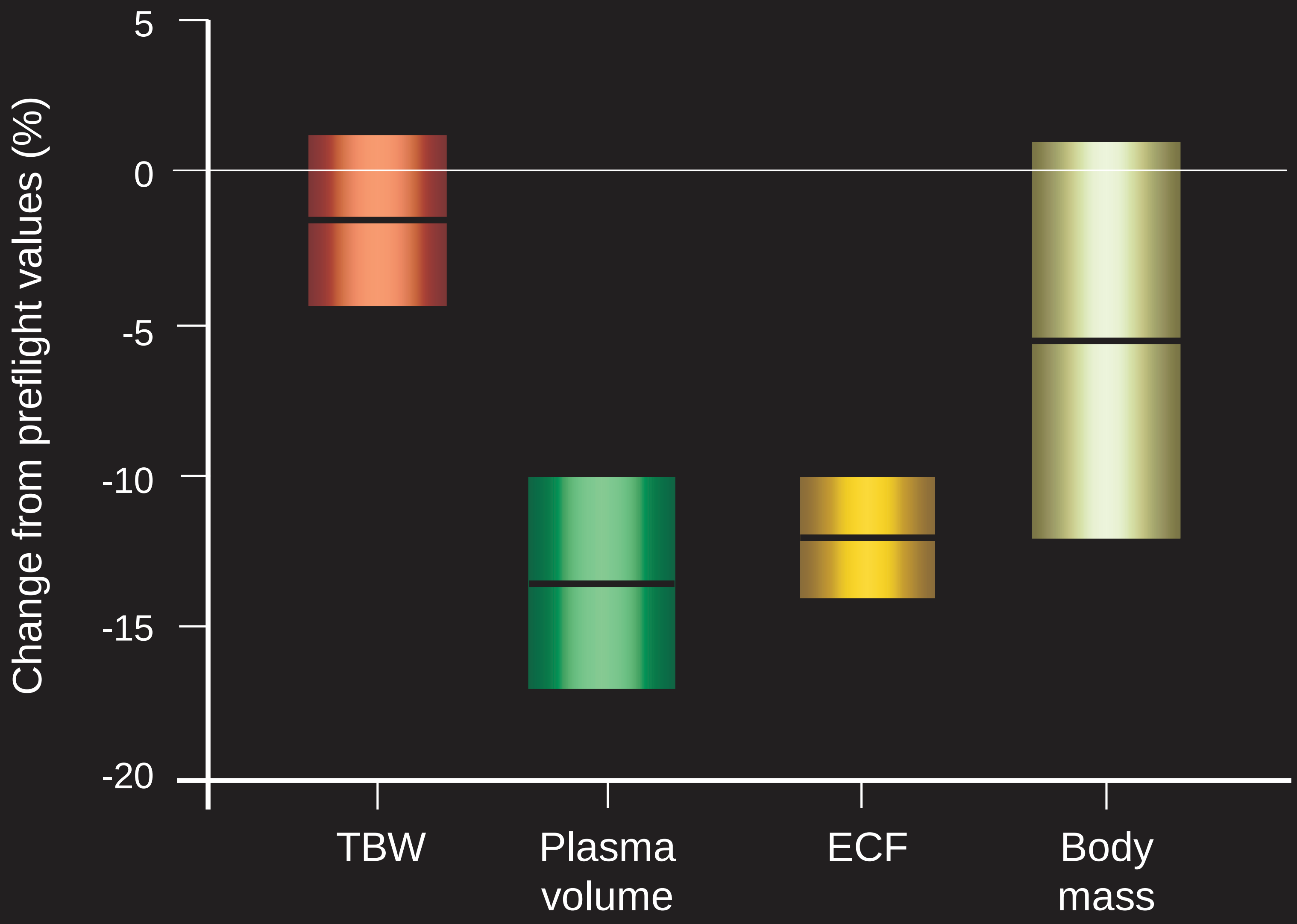

From: H. Lane and D. Schoeller, 2000.

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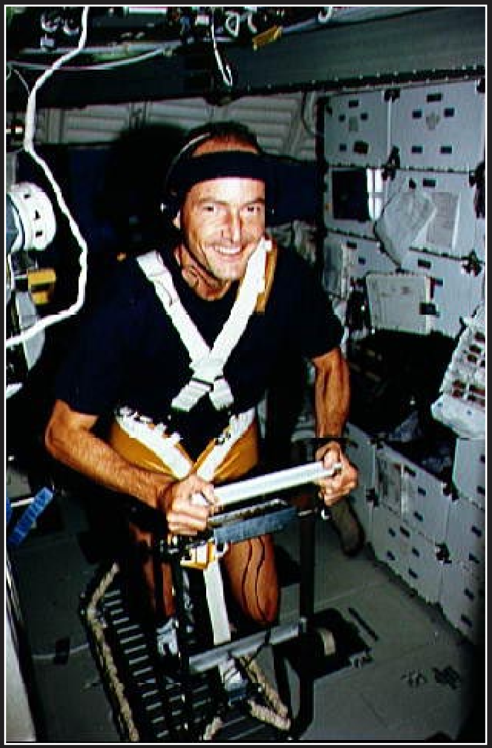
- Microgravity induces orthostatic intolerance in 75% of crews
- Dysrhythmia
  - Evidence of some susceptibility to dysrhythmias, but no statistical differences from incidences of age-related populations on Earth
  - Underlying mechanism being studied



David Low on STS-43

- Landing day
  - ↑ plasma norepinephrine
  - ↑ peripheral vascular pressure
  - ↑ systolic pressure
  - ↑ heart rate
- In flight
  - Without aerobic exercise, deconditioning exercise, treadmill or bike, crew cannot maintain cardiovascular conditioning
  - Fluid intake below 2000 ml/day → dehydration

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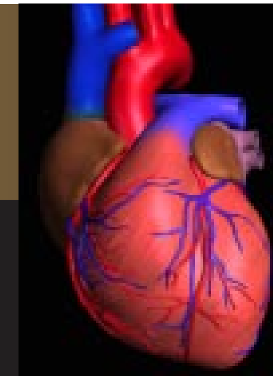

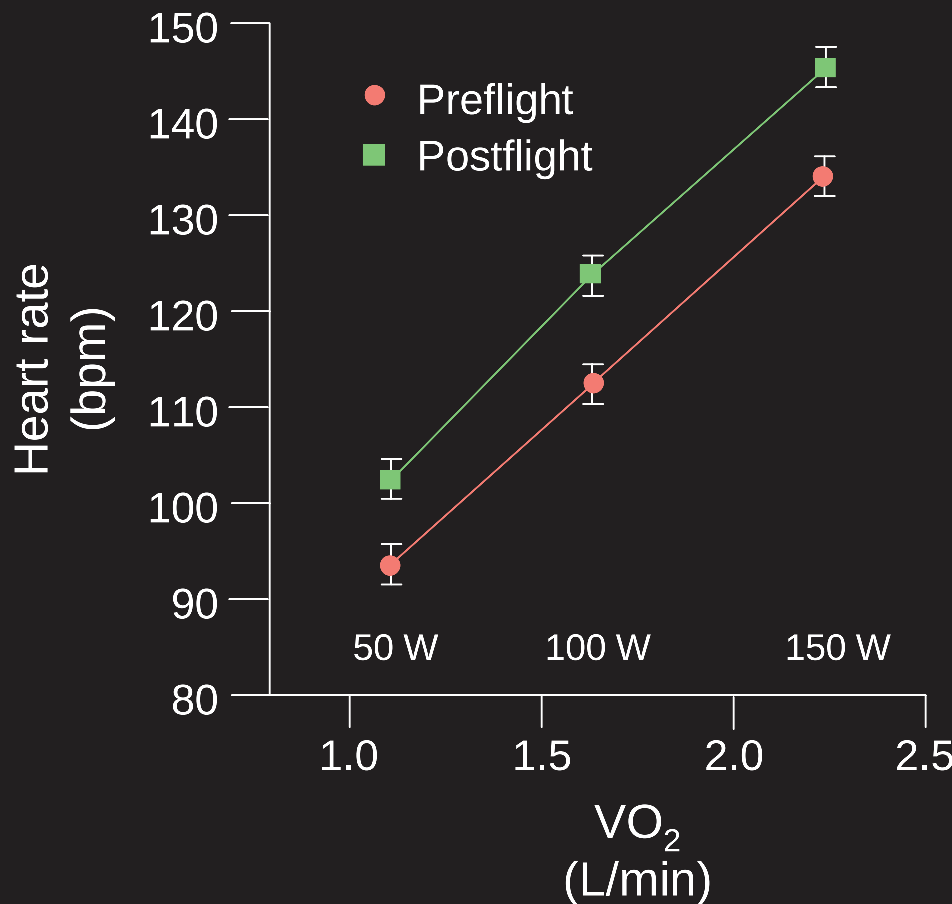

- Subjects (n = 25) who performed identical work rates before and after flight demonstrated increased cardiovascular stress by an increased heart rate, with no change in VO_2, within each exercise stage on landing day
- Decreased exercise tolerance affects musculoskeletal health

From: M. Greenison, et al., 1999.

Nutrition Situation

- Fluid intake
  - Prevent dehydration, especially with increased exercise
  - Data suggest thirst is lacking
- Fluid loading prior to landing to counter orthostatic intolerance
  - Sodium/water
- Potassium
  - Encourage consumption of potassium-containing foods
- Exercise
  - Provide nutritional support

Yury Usachev of the ISS Expedition 2 crew

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Volume

Metabolism

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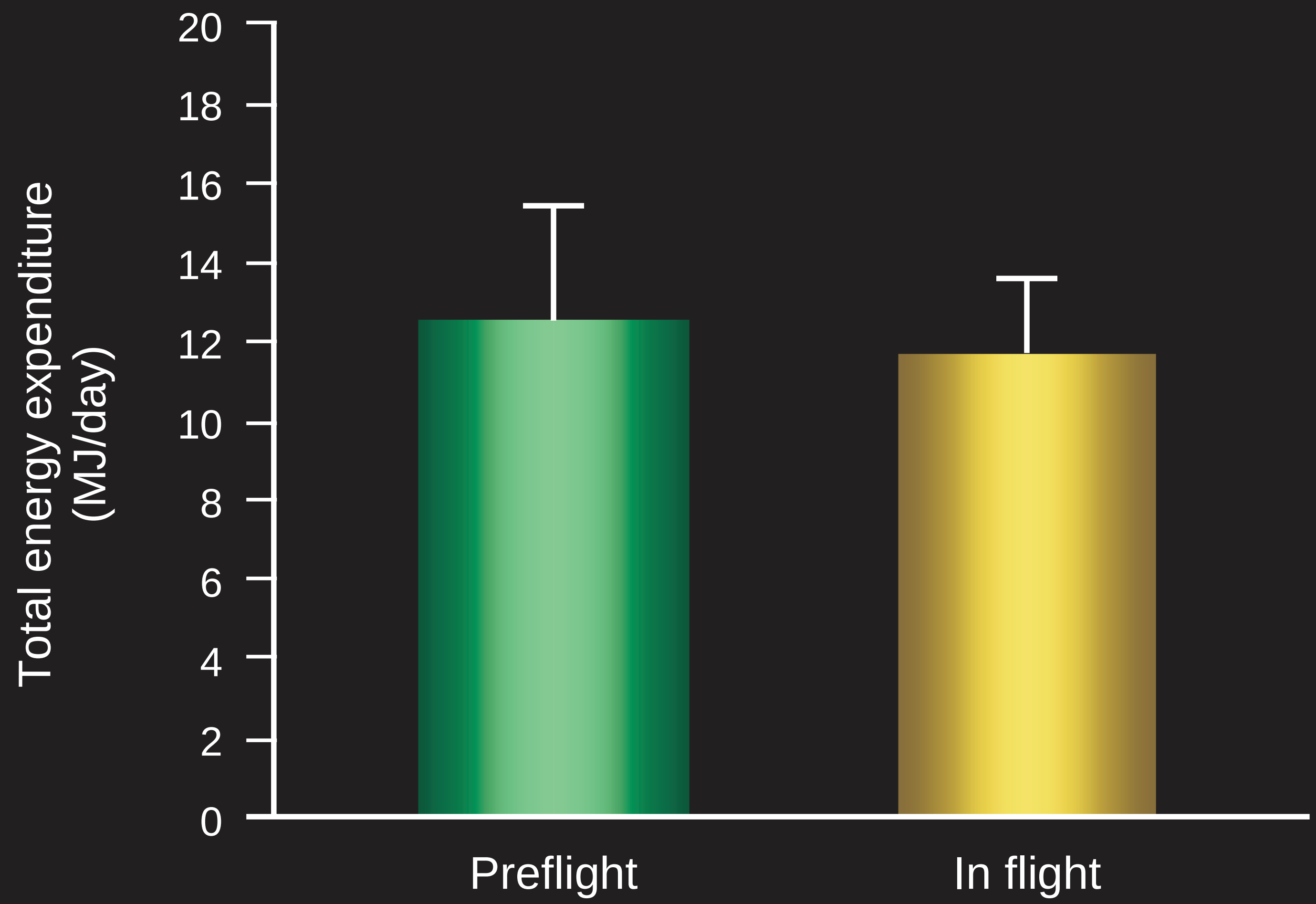
Energy expenditure is the same during spaceflight as on Earth.



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

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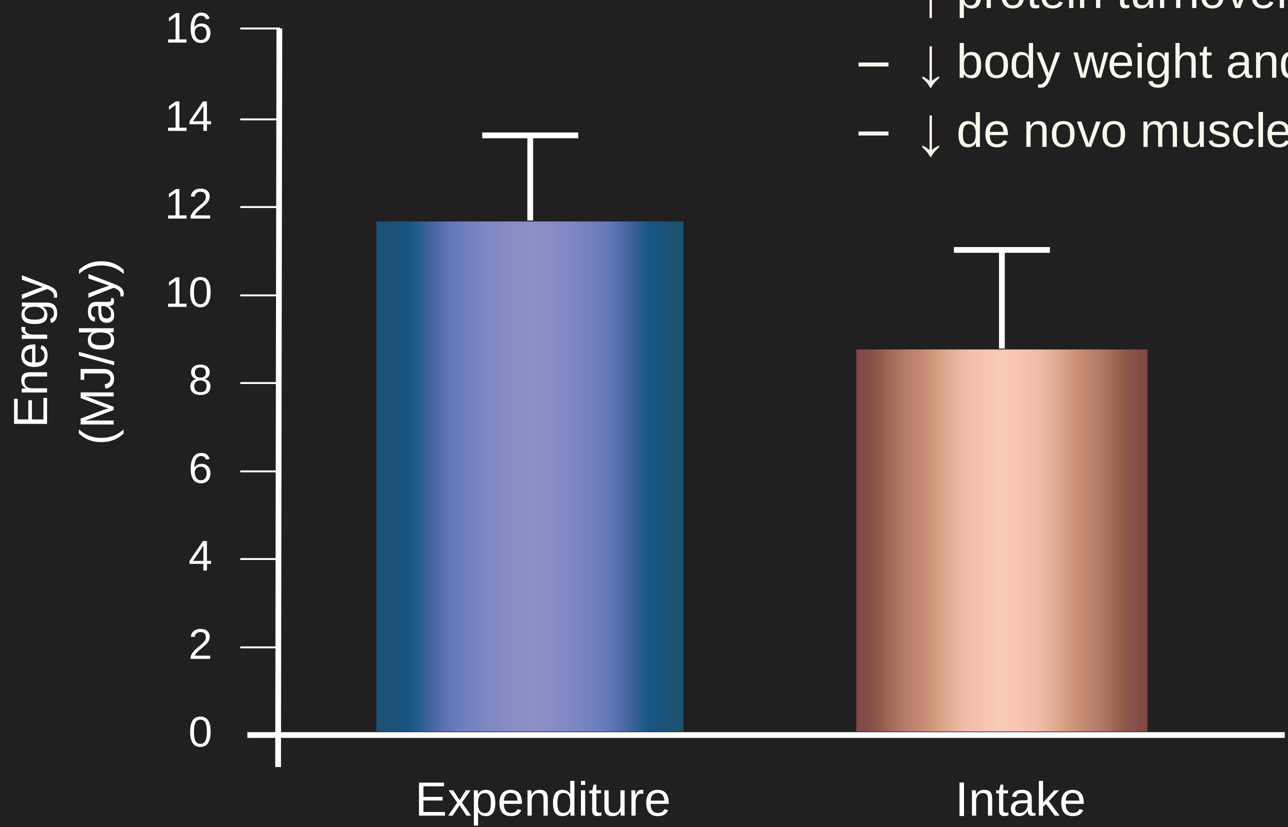
- Energy intake is lower than expected
- Suboptimal energy intake
  - ↑ protein turnover
  - ↓ body weight and muscle mass
  - ↓ de novo muscle protein synthesis



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

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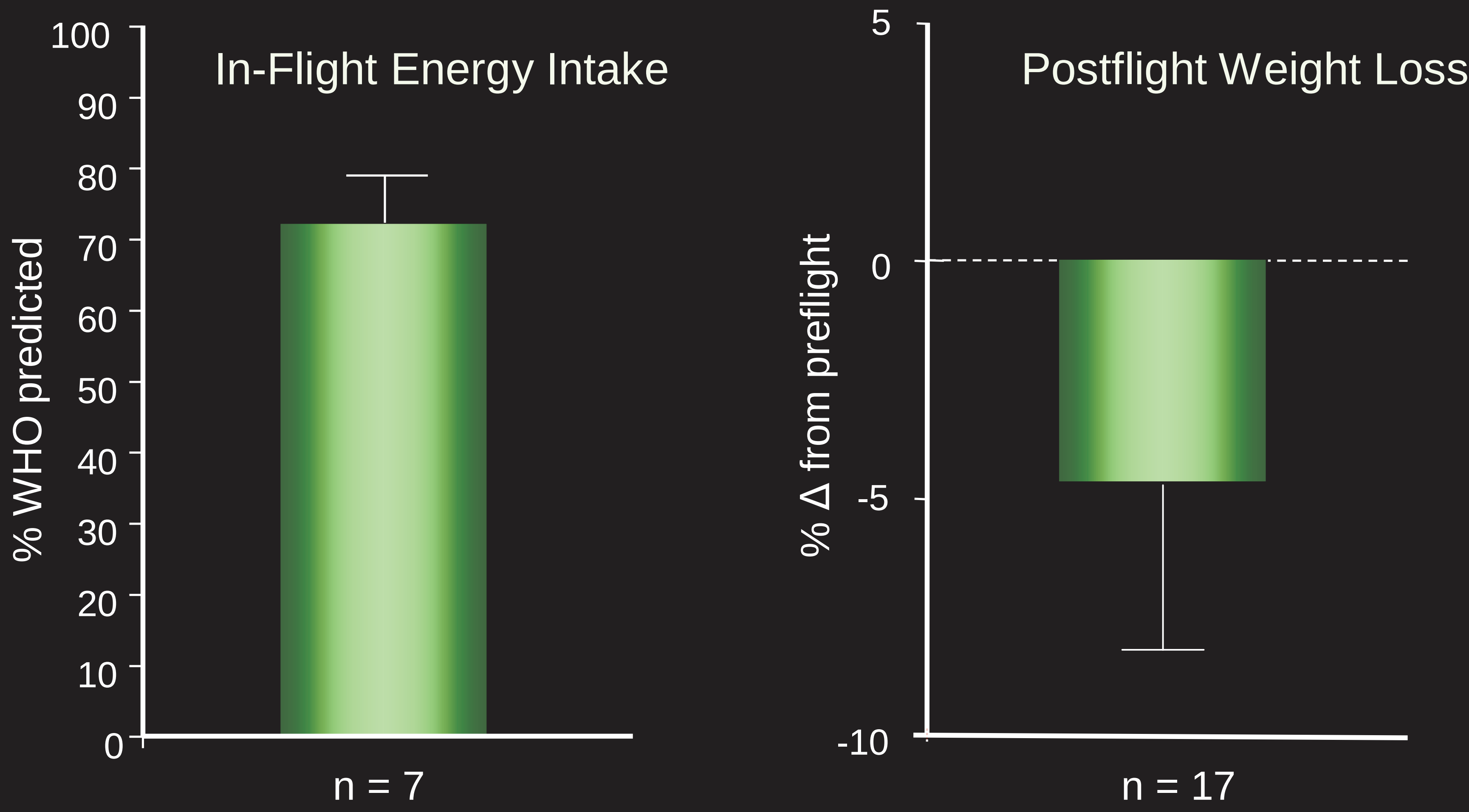
Mir Crew Members



From: Smith et al., 2000.

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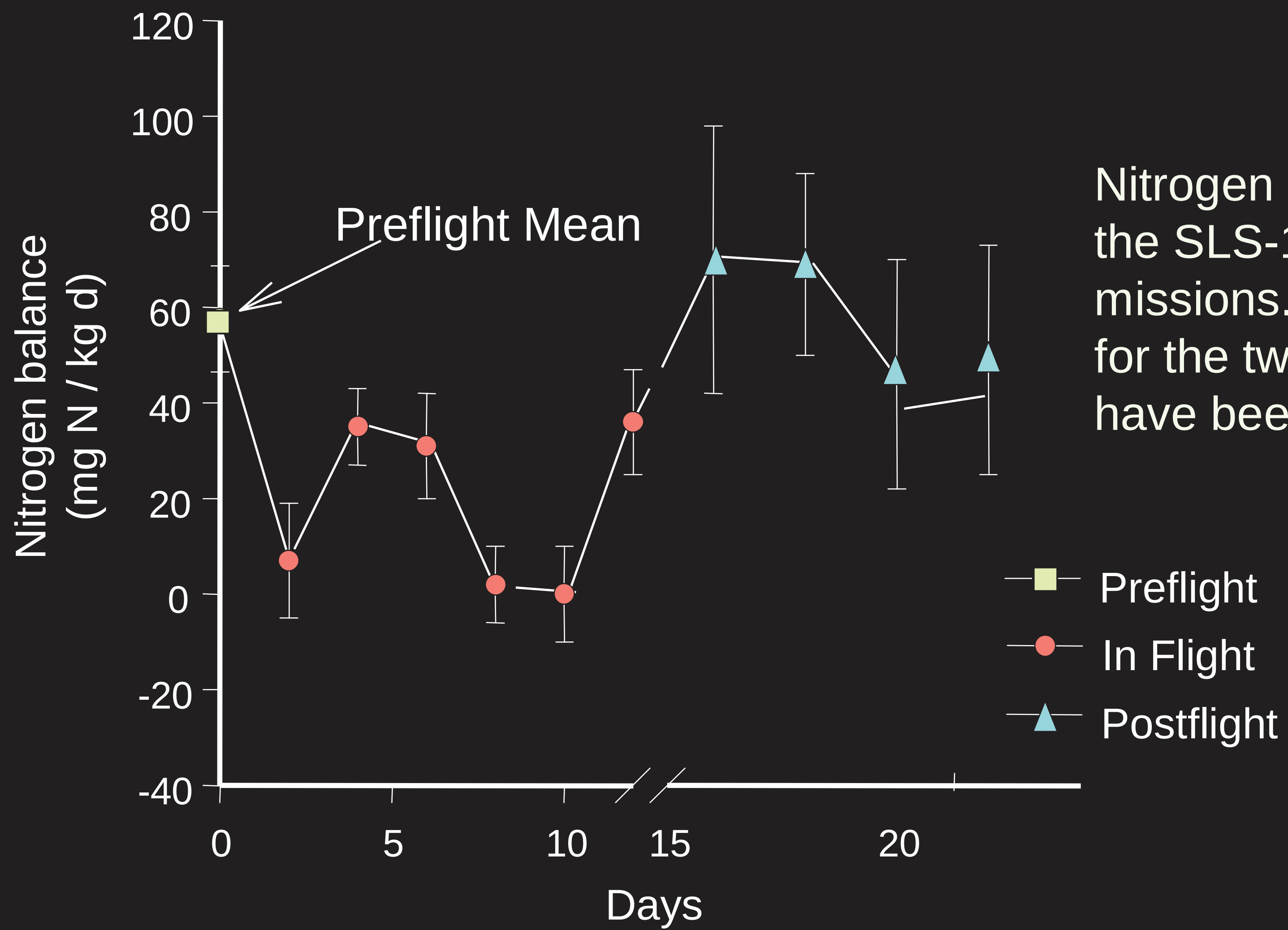

Nitrogen balance on the SLS-1 and SLS-2 missions. The data for the two missions have been combined.

From: T. Stein, et al., 1996.

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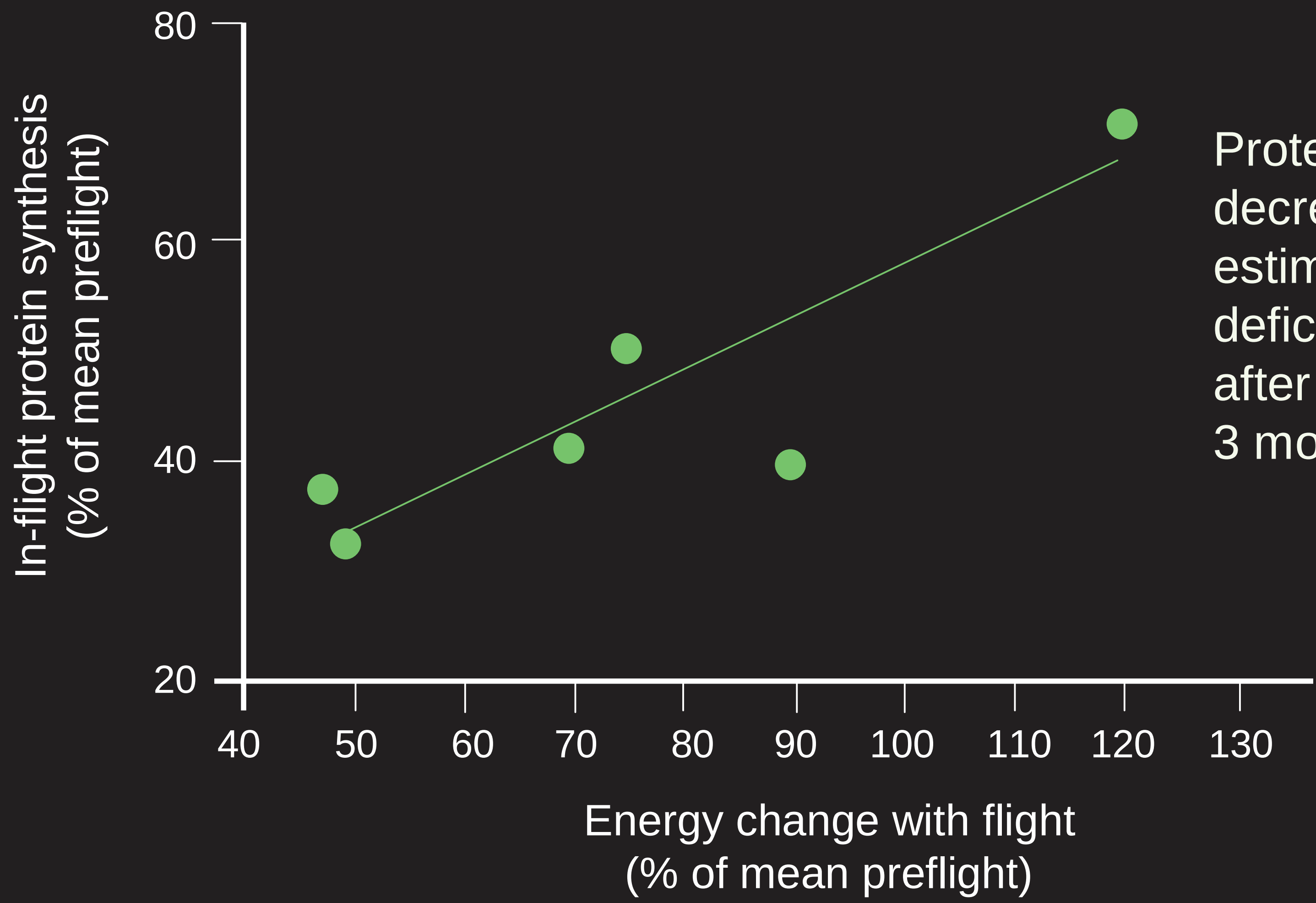

Protein synthesis decreased as the estimated energy deficit increased after more than 3 months on Mir.

 From: T. Stein, et al., 1999.

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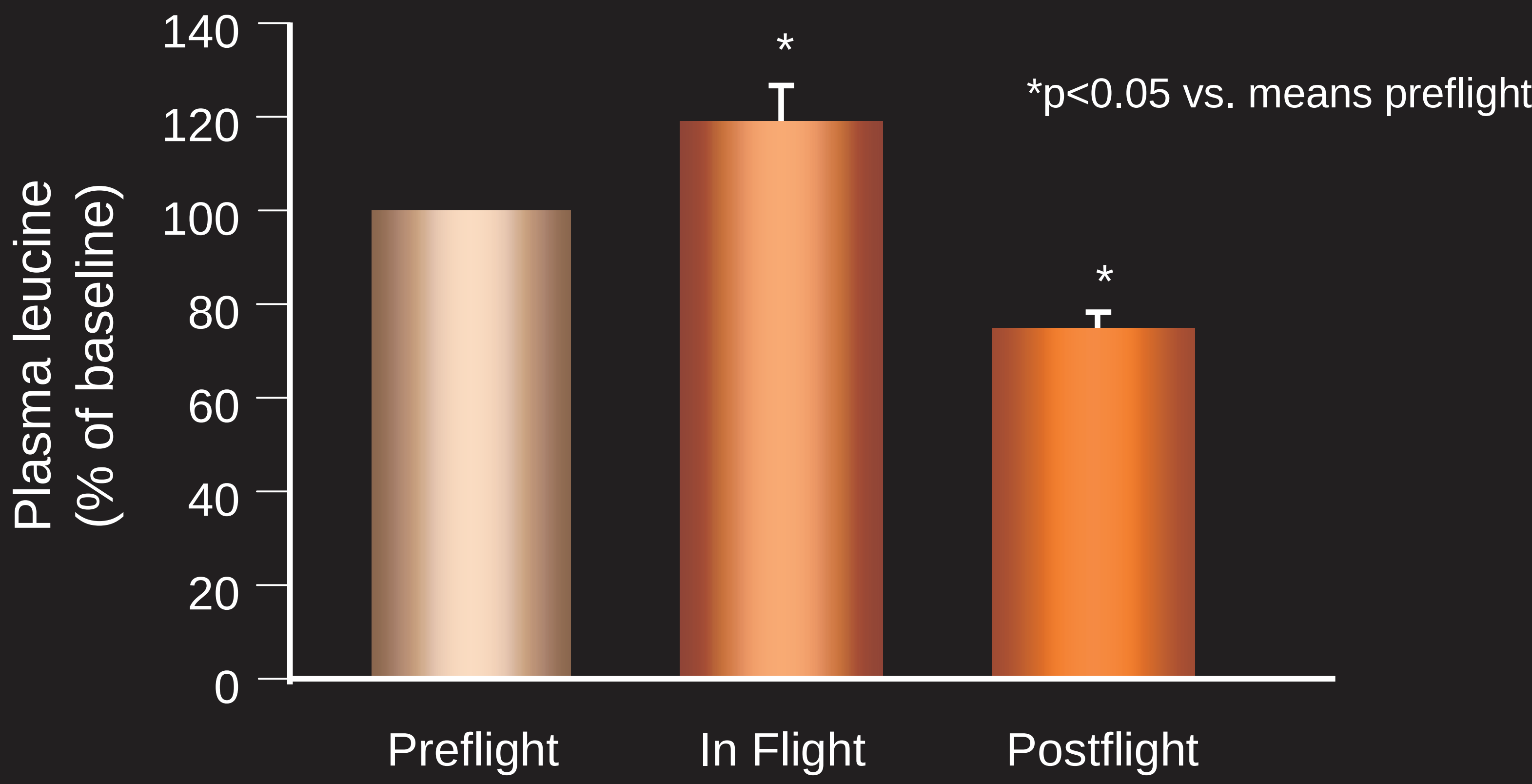

From: T. Stein, et al., 1998.

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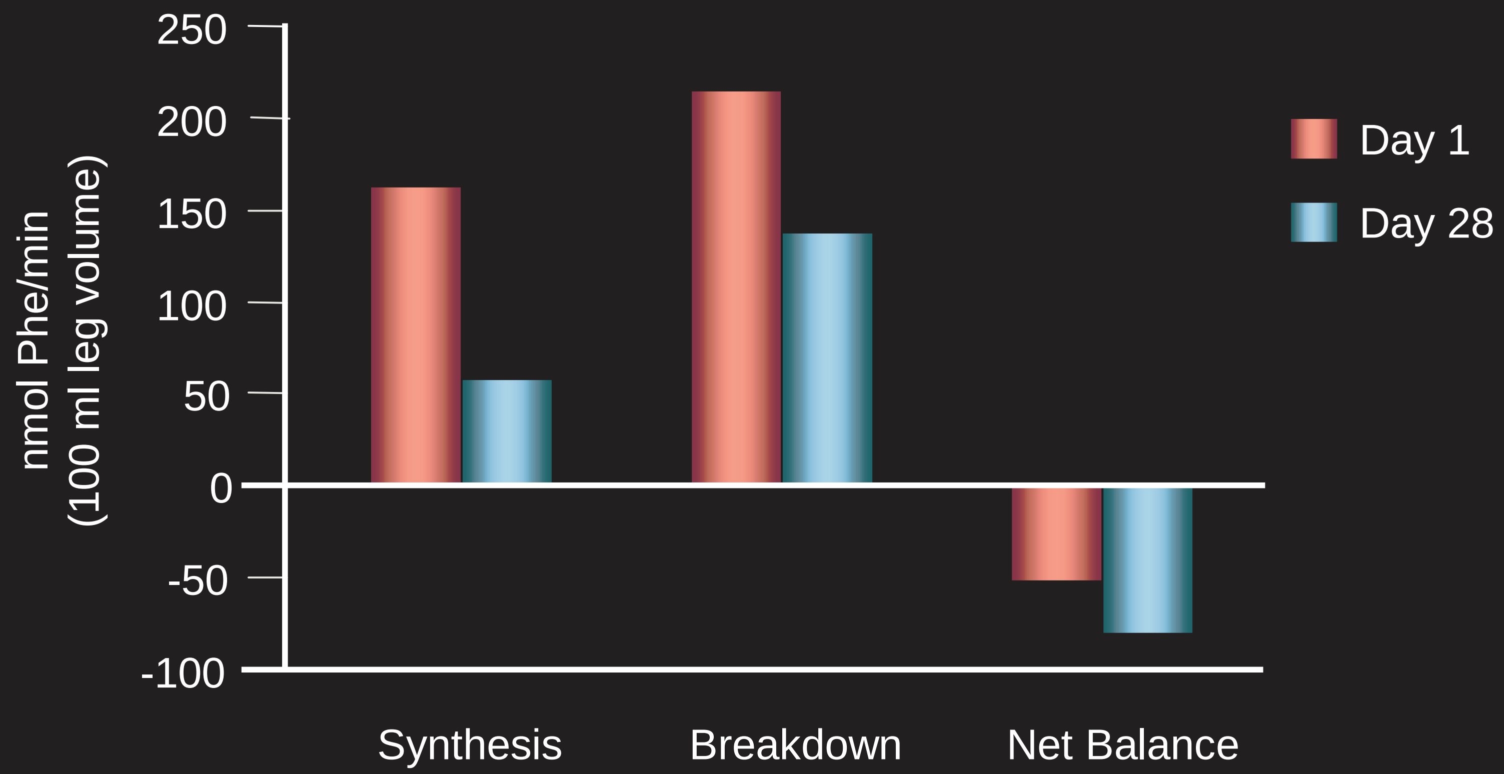
Synthesis and breakdown both decrease and have a larger negative balance at Day 28.



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

Muscles experience deconditioning and decreased leg volume due to inability to load muscles in microgravity.

Muscle	% Change (flight vs. preflight)
Calf	
Anterior	-3.9 ± 0.5^{a}
Soleus+Gastroc	-6.3 ± 0.6^{a}
Thigh	
Quadriceps	-6.0 ± 1.7^{b}
Hamstrings	-8.0 ± 0.9^{a}
Lumbar	
Intrinsic	-10.3 ± 2.4^{a}
Psoas	-3.1 ± 1.5

Changes in muscle volume of 4 astronauts, measured 1 day after an 8-day Space Shuttle mission

$^{a}p<0.05$
$^{b}p<0.07$ versus preflight

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

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- How to achieve adequate energy intake
  - Data suggest inadequate energy intake may limit effectiveness of resistive exercise
  - Monitor dietary intake with computerized food frequency counts
- Decreases in leg muscle volume and strength
  - International Space Station has resistive exercise device that can load major muscle groups

- Further research questions
  - Effectiveness of resistive exercise
  - Role of nutrition for muscles
    - Glucose/amino acid supplements
    - Interaction of endocrine changes (elevated cortisol) and protein metabolism
  - Understanding the relationship of muscle energy metabolism and muscle function
- Artificial gravity
  - Intermittent
  - Ground-based

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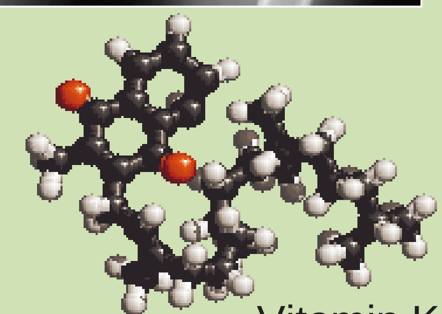
- Maintenance of bone
  - Bone resorption = formation
- Spaceflight conditions induce loss of bone
  - Δ bone resorption
  - Δ bone formation
- Solution
  - Reduce resorption with medical alendronate
  - Maintain formation
    - Heavy resistive exercise
    - Maintain nutrient needs
      - Vitamin D supplementation
      - Adequate vitamins and minerals (Ca, Mg, vitamin K) for bone



Vitamin K

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	Bone Mineral Density (% loss/month)
Lumbar spine	1.1 ± 0.6
Femur neck	1.2 ± 0.9
Trochanter	1.6 ± 1.0
Pelvis	1.4 ± 0.5
Legs	0.3 ± 0.3
Whole body	0.4 ± 0.3

Data is from long-duration flight.
N = 16-18 crew members

	Calcium Changes (mg/day)
Spaceflight	-250
Postflight	100

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

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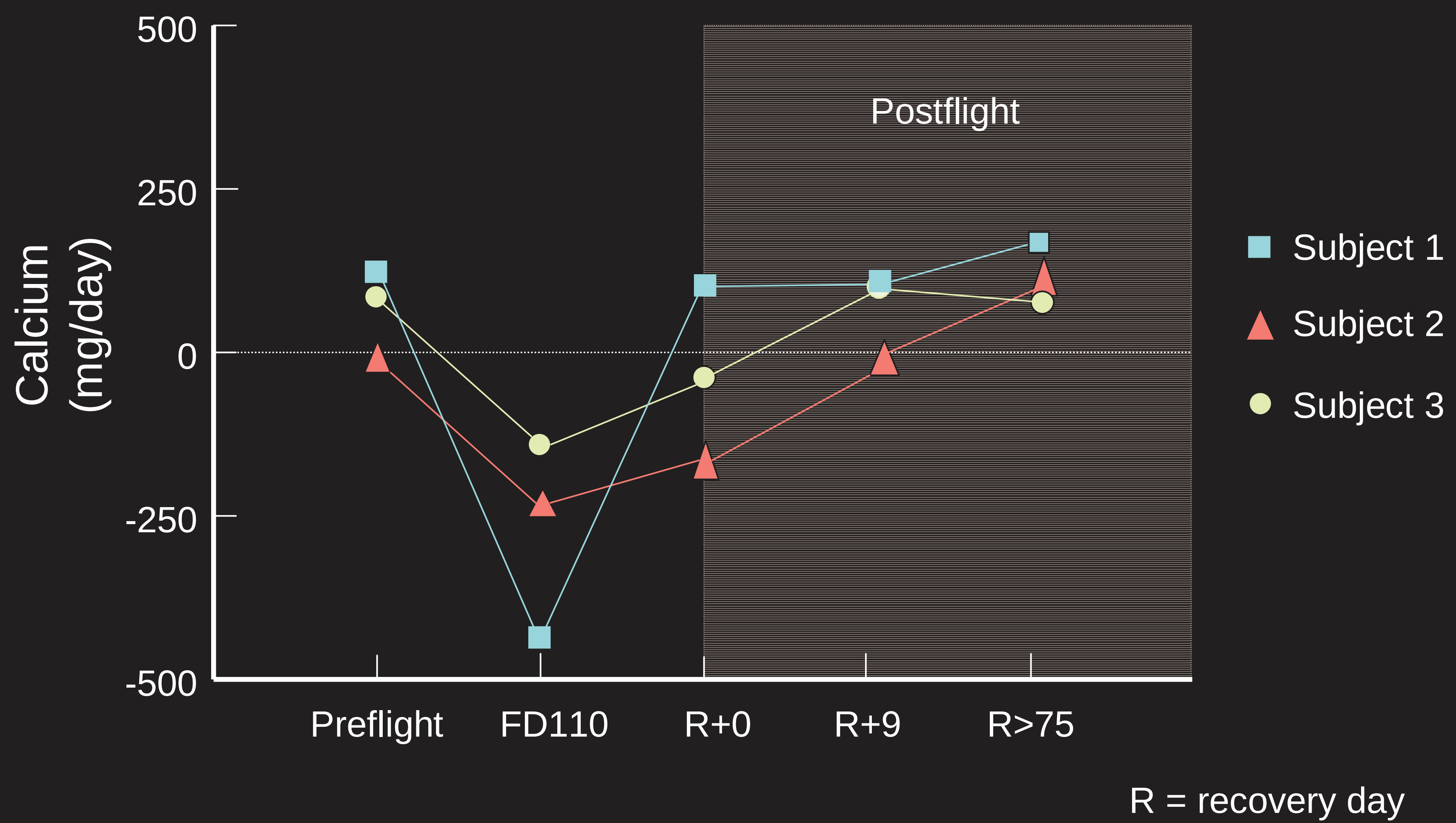

 From: Smith, et al., 1999.

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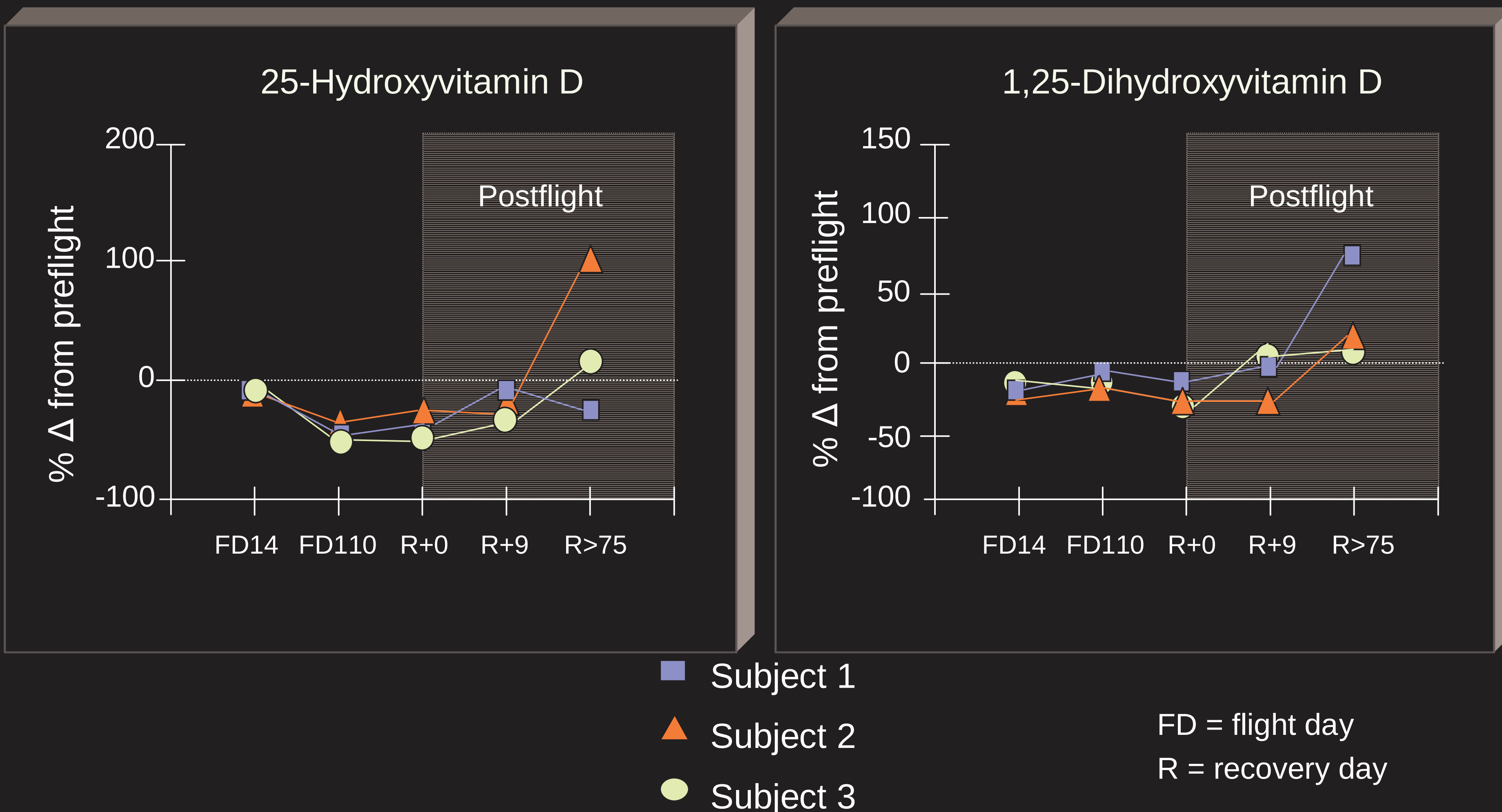
Biochemical and Endocrine Markers



From: Smith, et al., 1999.

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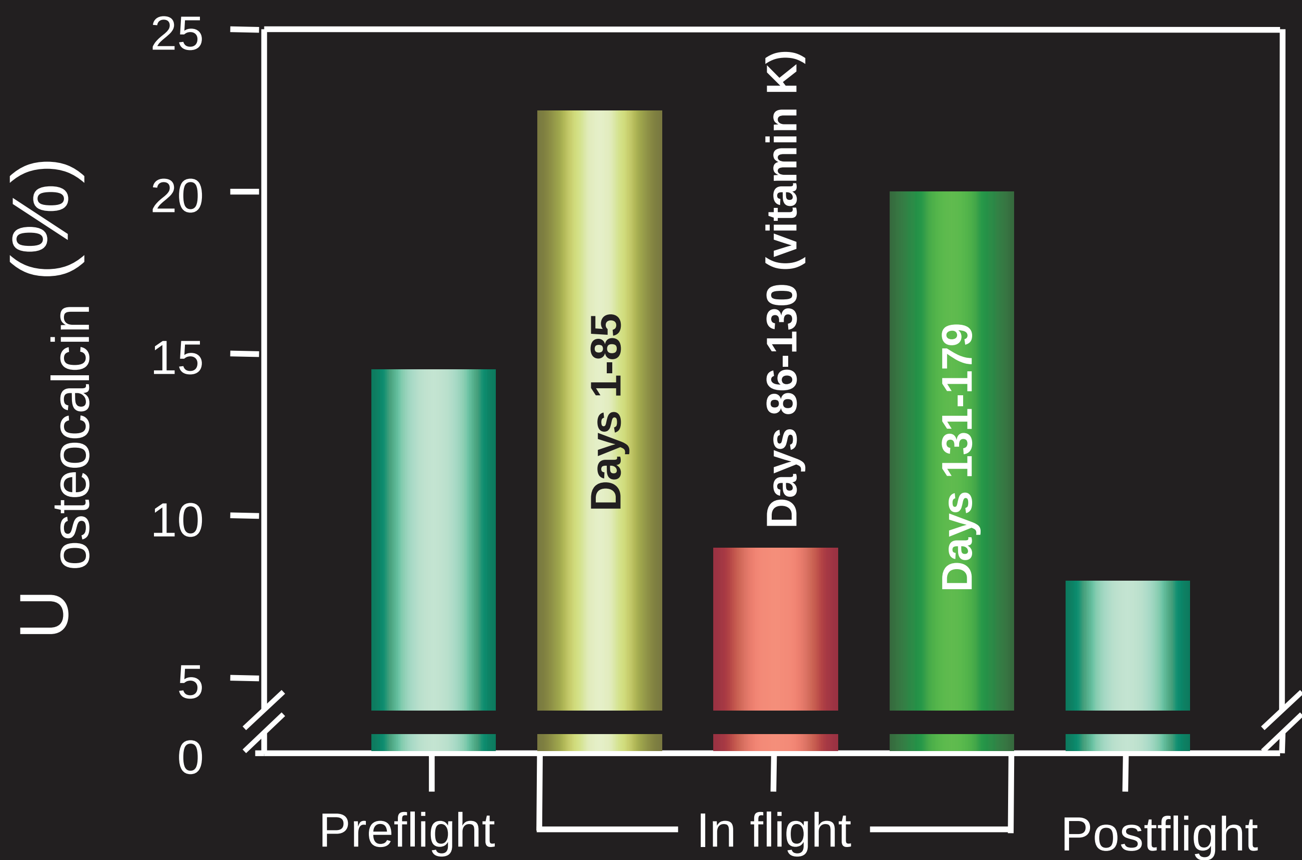
This Euromir 95 study of undercarboxylated osteocalcin involved one German astronaut.



From: Caillot-Augusseau, et al., 2000.

- Nutritional considerations
  - Preflight, Russia tour – low 25-OH vitamin D_3 blood levels
  - In flight – no light source for vitamin D synthesis
  - In flight – dietary vitamin D limited to fish oil or supplements
  - Preflight – vitamin K status unknown
  - In flight – dietary vitamin K levels unknown
  - Bone health, vitamin K, and vitamin D status monitored pre- and postflight ➢ diet counseling

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- Research
  - Role of excessive dietary sodium
  - Role of elevated urinary Ca with dehydration on Ca oxalate formation
  - Needed bed rest studies to simulate microgravity for effects of vitamin K
- Mitigation
  - Role of heavy resistive exercise
  - Alendronate-bisphosphate – issues of side effects
  - Weight-bearing exercise with treadmill
  - Vitamin D added to cereals, dehydrated milk, instant breakfast

Terence Henricks and Mario Runco, Jr. exercising on STS-44

Nutrition Stations

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

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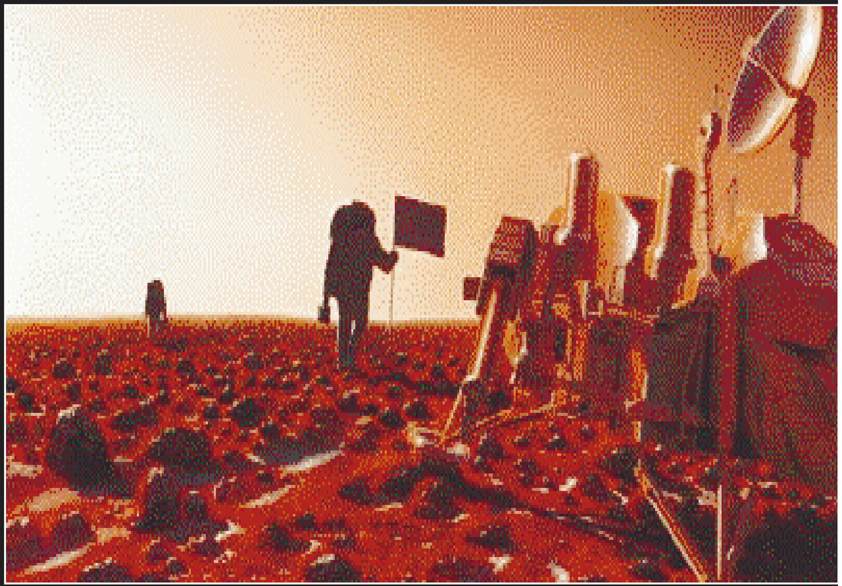

- What lies beyond our planet?
  - Develop microgravity tools to probe fundamental questions of science
    - the role of gravity in physical/chemical systems
    - extraterrestrial life
    - the origins of the universe
  - Research ways to enable humans to explore for scientific and technological advances, as well as for benefits to humankind
- The international community is forging the first step to answer this question with the International Space Station

Jan Davis on STS-47

Helen W. Lane

helen.w.lane1@jsc.nasa.gov

Summary of U.S. Nutrition Research. Lane HW and Schoeller DA. *Nutrition in Spaceflight and Weightlessness Models*. CRC Press: Boca Raton FL, USA, 2000.

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- Food Technology Commercial Space Center
  http://www.ag.iastate.edu/centers/ftcsc/
- Advanced Life Support Program
  http://advlifesupport.jsc.nasa.gov/
- NASA research opportunities
  http://peer1.nasaprs.com/peer_review/nra/nra.html
- Space Life Sciences Directorate at Johnson Space Center
  http://www.jsc.nasa.gov/pao/org/offices/sa.html

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Smith S, Davis-Street JE, Rice BL, Nillen JL, Gillman PL, Block G. Nutrition Status Assessment in Semiclosed Environments: Ground-Based and Space Flight Studies in Humans. *Journal of Nutrition* 2001; 131:2053-2061.

Smith, S., Wastney, M., Morukov, B., Larina, I., Nyquist, L., Abrams, S., Taran, E., Shih, C., Nillen, J., Davis-Street, J., Rice, B., and Lane, H. Calcium Metabolism Before, During, and After a 3-Month Spaceflight: Kinetic and Biochemical Changes. *American Journal of Physiology* 1999. 277: R1-R10.

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*Smith, S., Lane, H. Nutritional support. In: Barratt, M., Pool, S., eds. Principles of Clinical Medicine for Spaceflight. New York, NY: Springer-Verlag (in press).

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Stein, T., Leskiw, M., Schluter, M., Donaldson, M., and Larina, I. Protein Kinetics During and After Long-Term Spaceflight on Mir. *American Journal of Physiology* 1999. 81 (39): 1014-1021.

Stein, T., Schluter, M., Leskiw, M., Gretebeck, R., Lane, H., and Hoyt, R. One-Year Report of the LMS Shuttle Mission. NASA, Washington, D.C, 1998.