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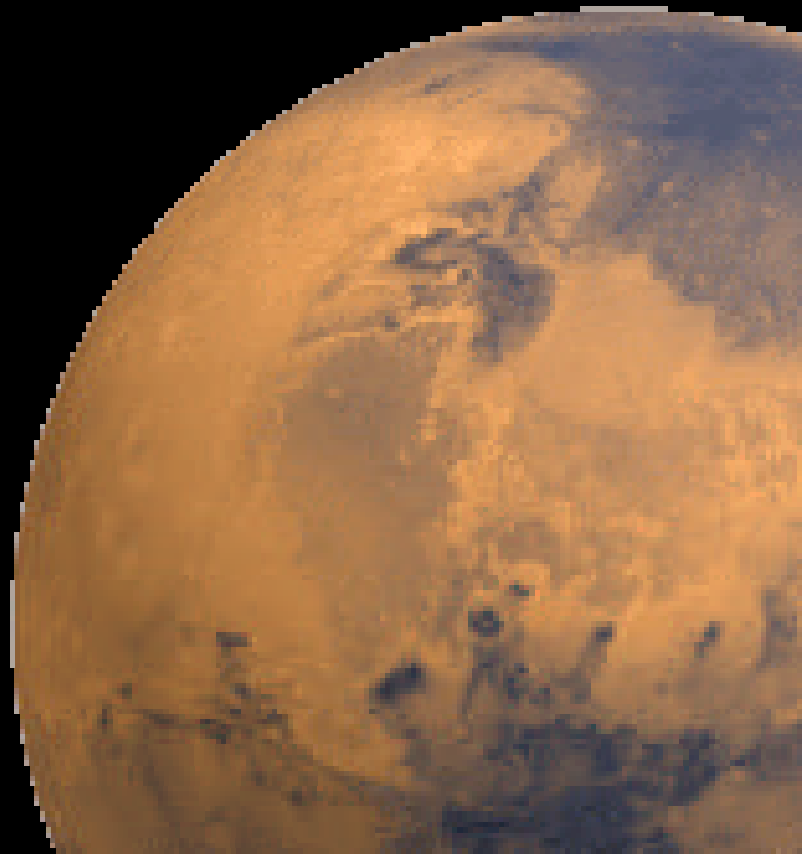
Updates in Space Medicine



Contents

- **Planning for human space missions: today**
  - Human
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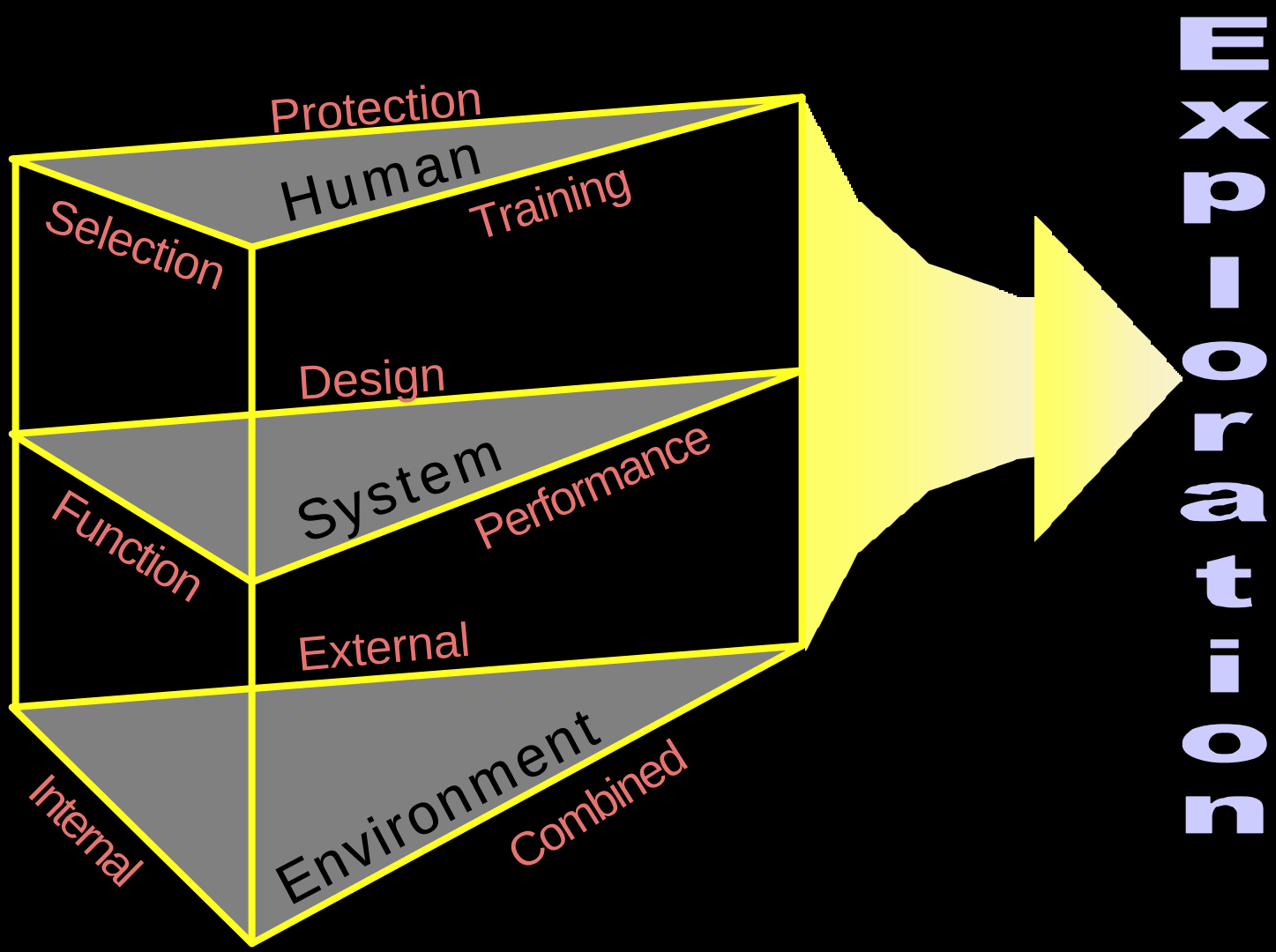
  - Environment
- **Biomedical responses to space flight**
  - The human element
  - The future of medical care
  - Human-machine interface
- **The International Space Station**
- **Planning for human space missions: the future**
- **Conclusion**

Human Space Missions: Today



Selection & Retention

- **Selection criteria**
  - Medical history and physical
  - Lab & functional testing
- **Retention criteria**
  - Health maintenance
  - Acceptance of certain risks with changes

Concerns
Class I, II, III

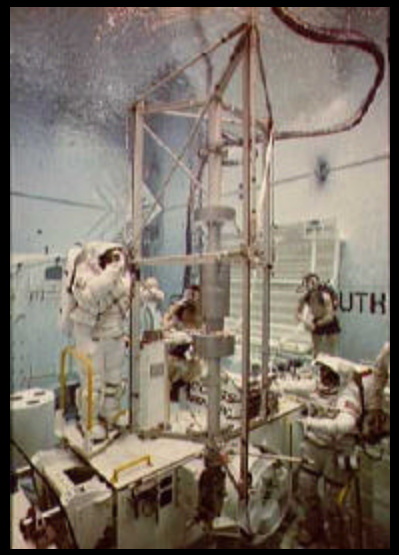
- **Short-duration mission**
  - Neurosensory
  - Neuromotor
  - Cardiovascular/ cardiopulmonary
  - Fluid & electrolyte balance
- **All missions**
  - Performance
  - Psychosocial suitability
  - Survival
- **Long-duration mission**
  - Musculoskeletal structure & function
  - Radiation
  - Metabolic/endocrine changes
  - Hematology/immunology

Types of Physical Examination

- **Pre- and post-flight physical examination**
- **Annual physical examination**
  - ECG
  - Exercise tolerance test
  - Chest x-ray
  - Proctosigmoidoscopy
  - Vision
  - Pelvic exam
  - Mammogram
- **Annual comprehensive laboratory examination**
  - Hematology panel
  - Chemistry panel
  - Lipid panel
  - Routine and 24-hour urinalysis
  - Protein panel
  - Electrophoresis panel
  - Serology panel
  - Thyroid panel
  - Endocrinology panel
  - Imaging

Training

- Survival
- Mission-specific
- Experiments
- Medical skills



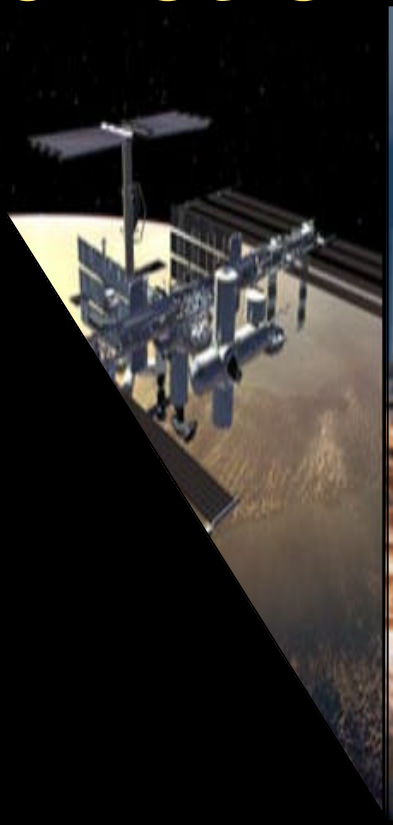
Protection

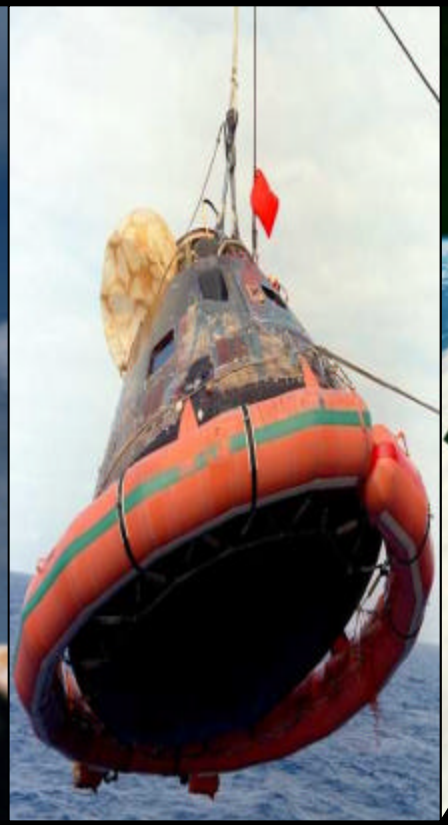
- **Preventive care**
- **Interventions**
  - Countermeasures
  - Medical care

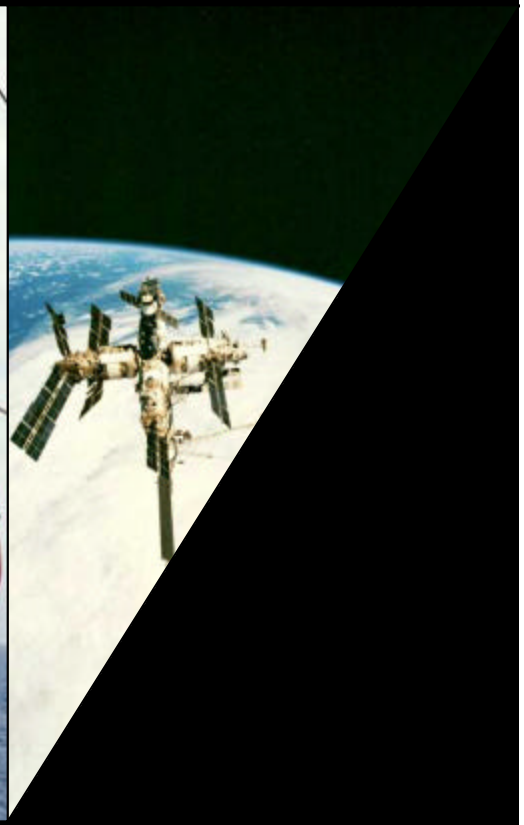
Systems

Function

Performance





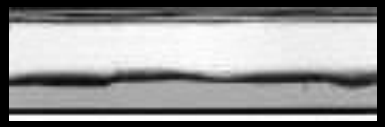
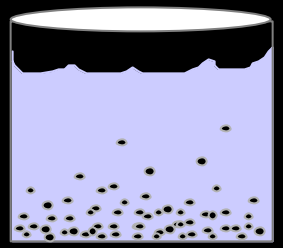
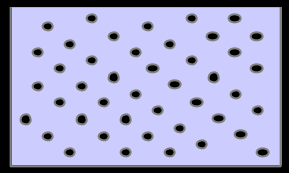


Design

The Space Environment

- Microgravity
- Time & distance
- Radiation

Attributes of Microgravity

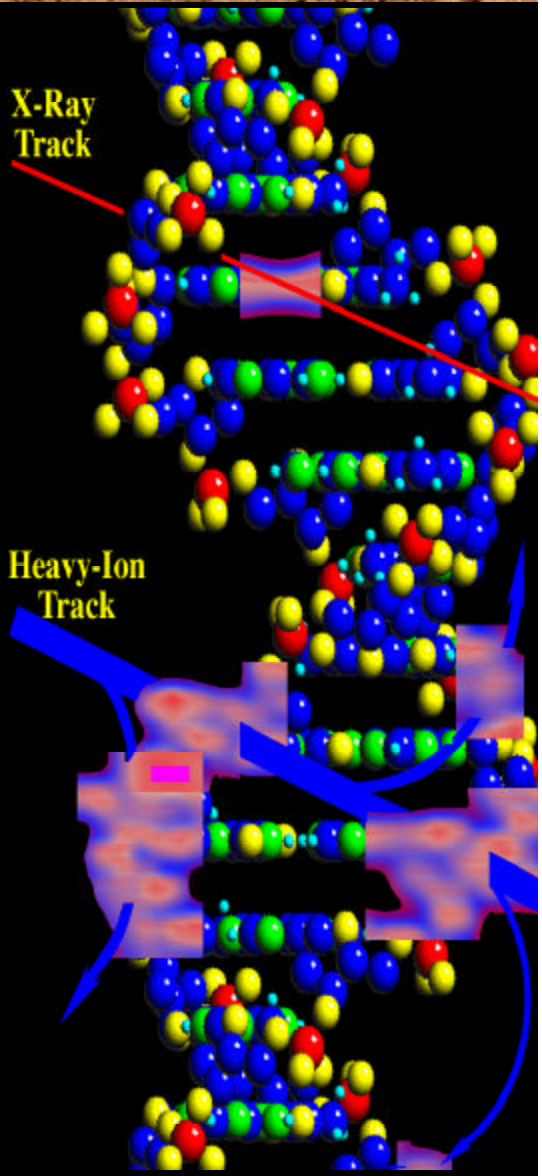
	Convection	Buoyancy	Sedimentation
Earth			
Space			

Time/Distance

Radiation

Secondaries

Heavy particles
Protons
Neutrons
Electrons



The Human Element

Health

Psychosocial

Cultural

System-level Responses to µg

Adaptive

Pathological

Neurosensory & Neuromotor

Cardiovascular/ Pulmonary

Endocrine

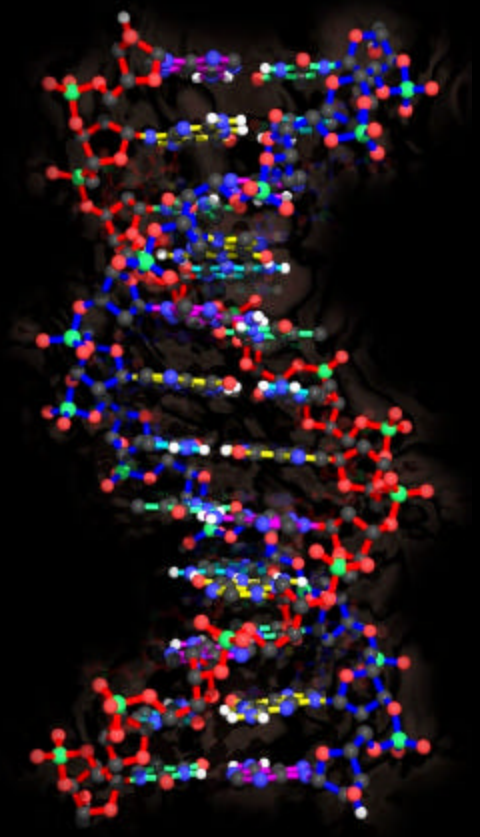
Musculoskeletal

Radiation

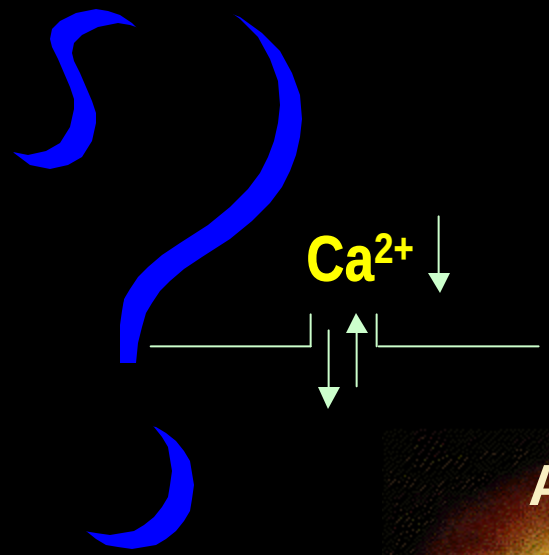
Confinement

parallels with aging…

Potential Molecular Responses



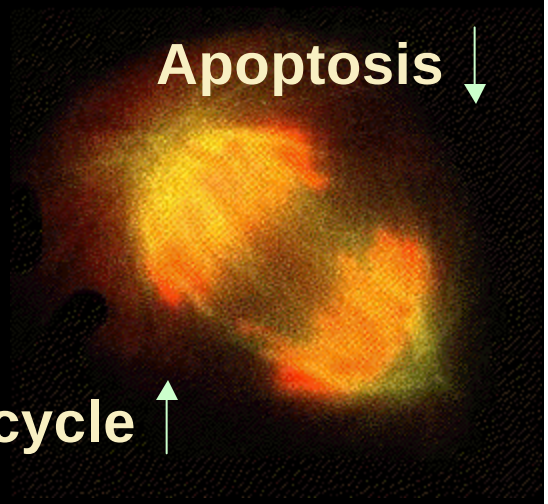
Gene expression ↓↑



Ca^{2+} ↓

↓↑

Calmoduline ↓

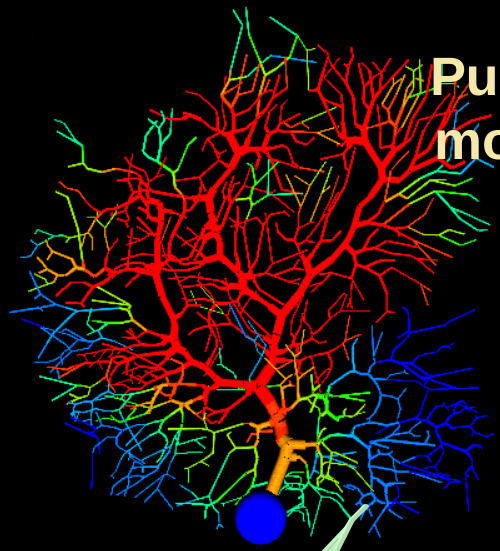


Apoptosis ↓

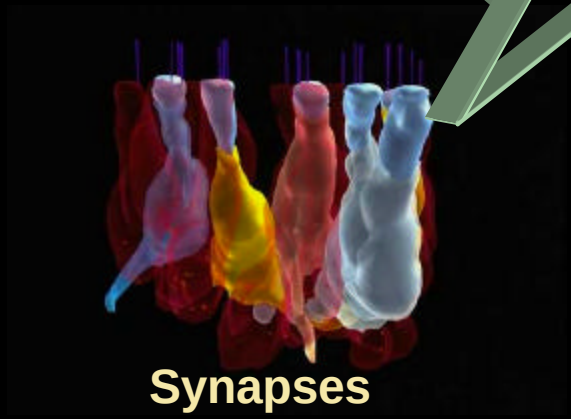
Cell life-cycle ↑

Plasticity

Rapid changes in function and structure to high or low acceleration forces



Purkinje cell morphology

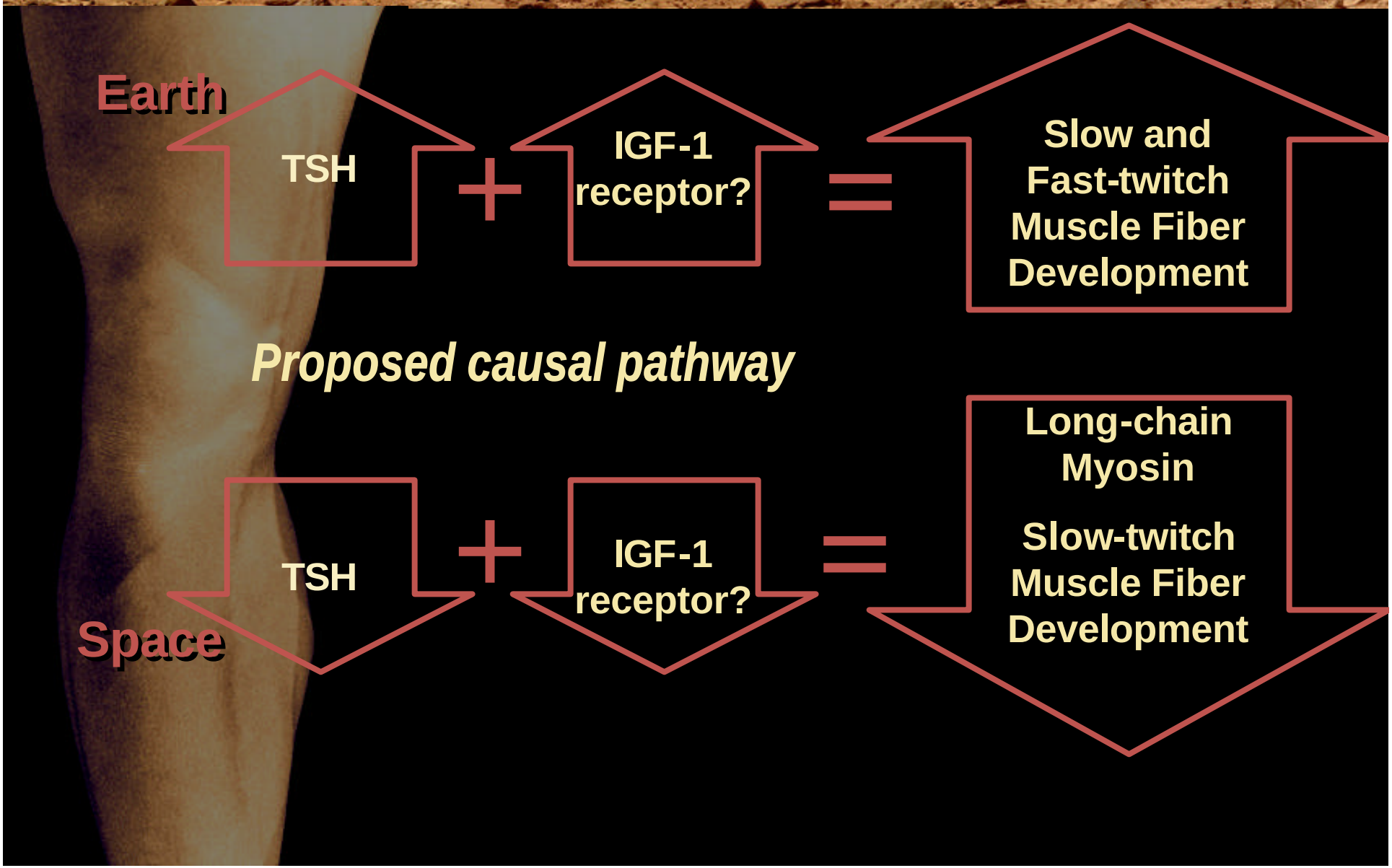


Synapses

Type of Response

Ataxia
SMS
Occular

Muscular Response



Bone Response

Bone Formation

Bone Density

Earth

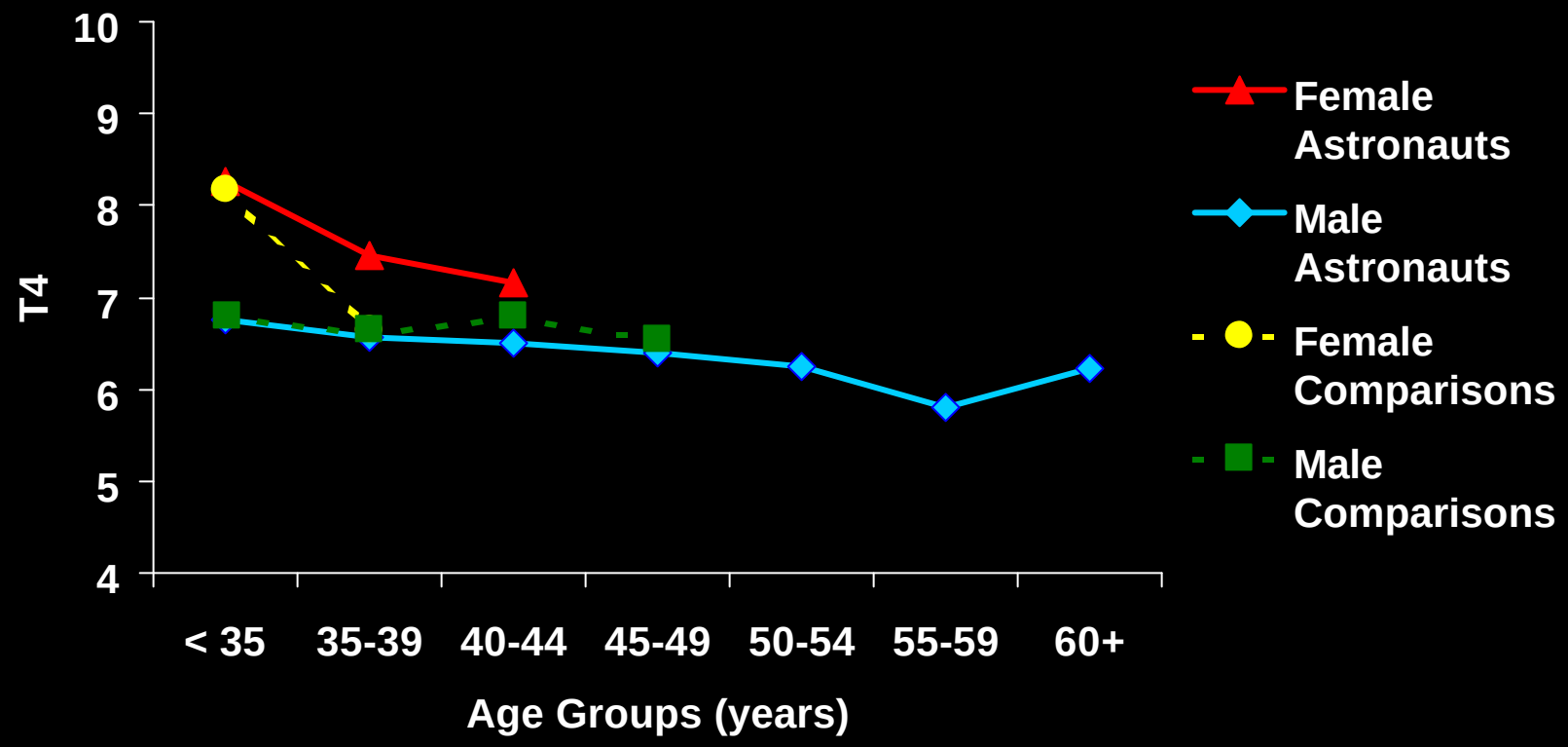
PTH & IGF-I ↑ = Osteoprogenitor Number & Bone Mineralization

Space

PTH & IGF-I ↑ ≠ = Osteoprogenitor Number & Bone Mineralization

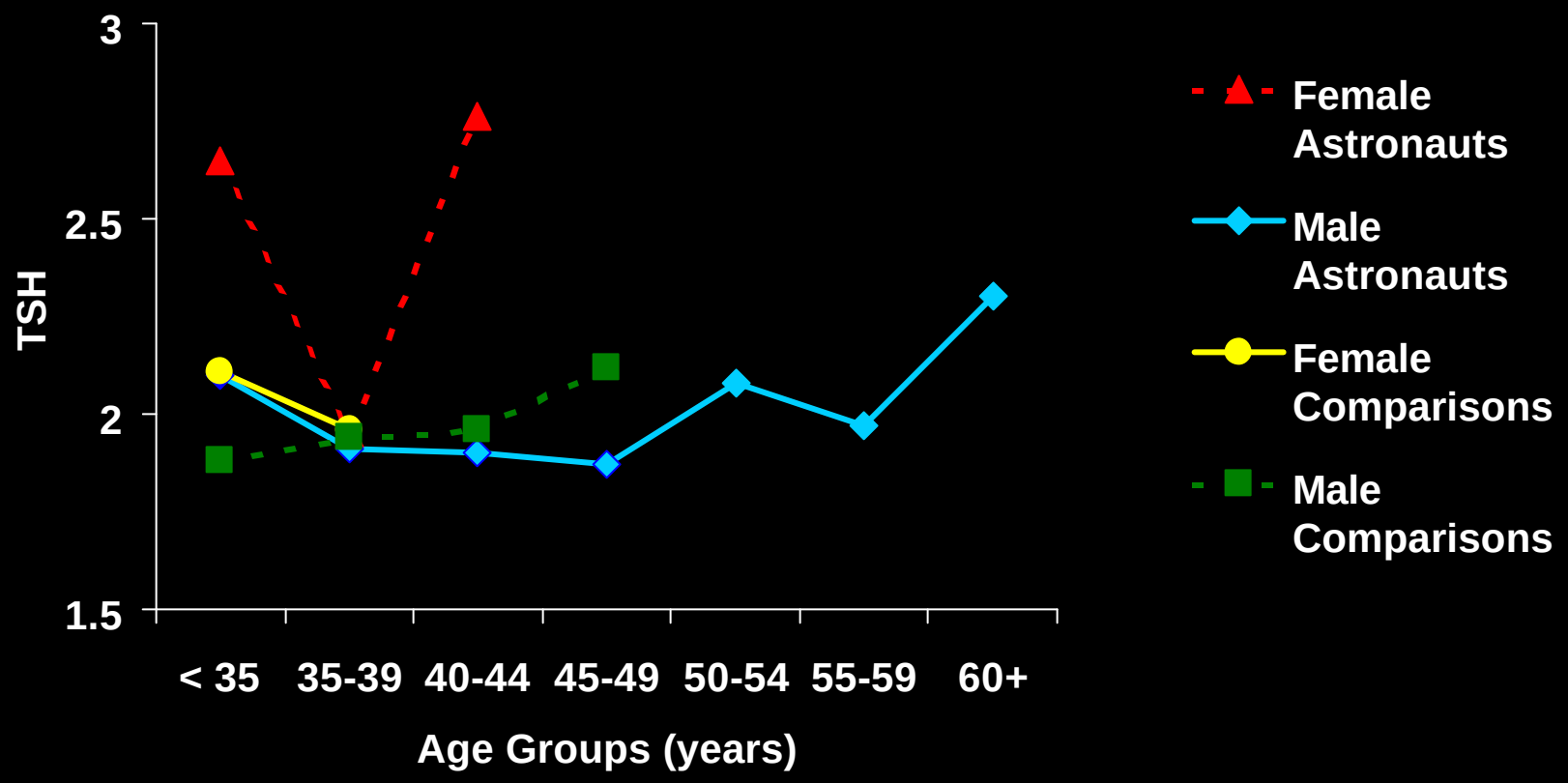
Thyroxine (T4)

Mean Values by Age
(Cross-sectional data, 1991-1998)



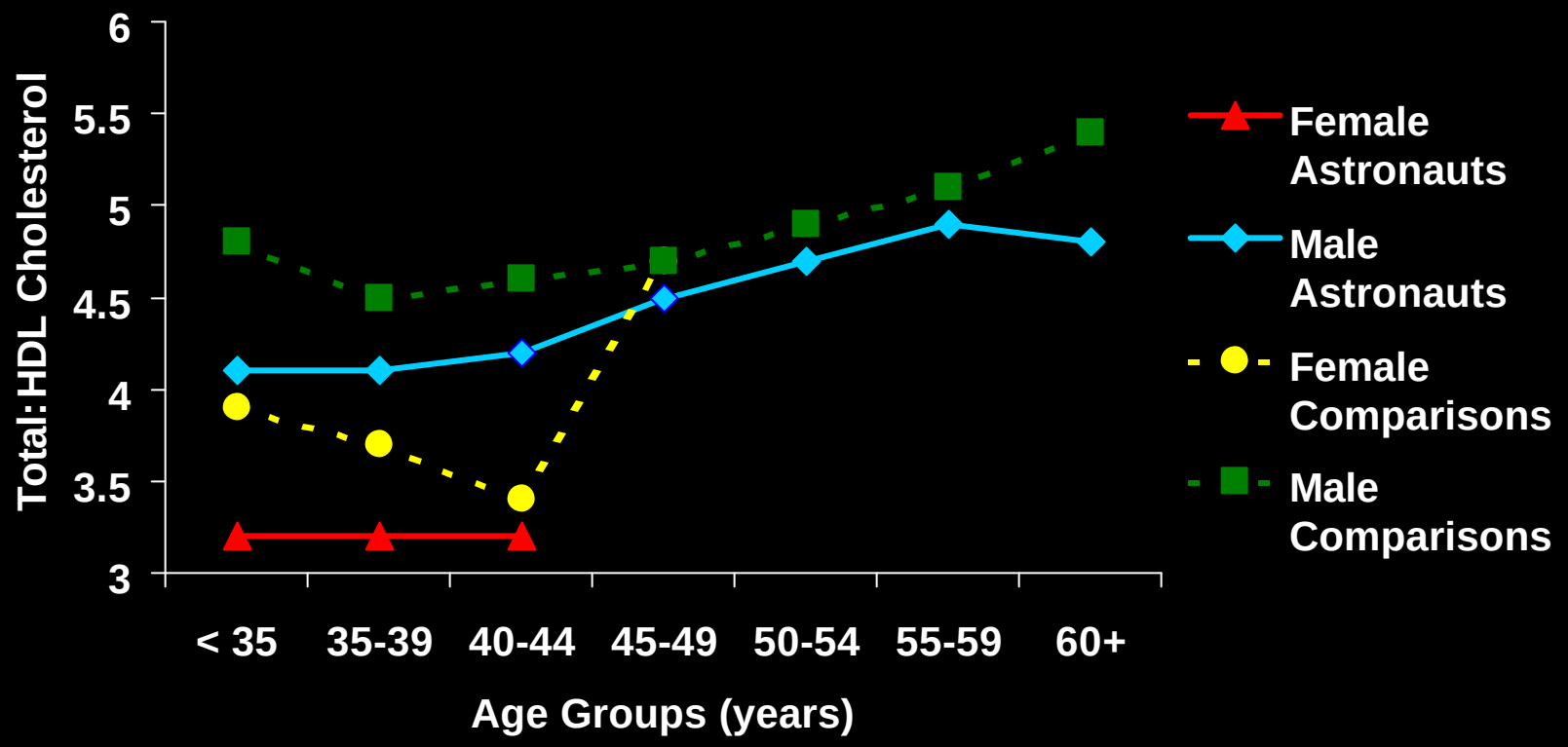
Thyroid Stimulating Hormone (TSH)

Mean Values by Age
(Cross-sectional data, 1991-1998)



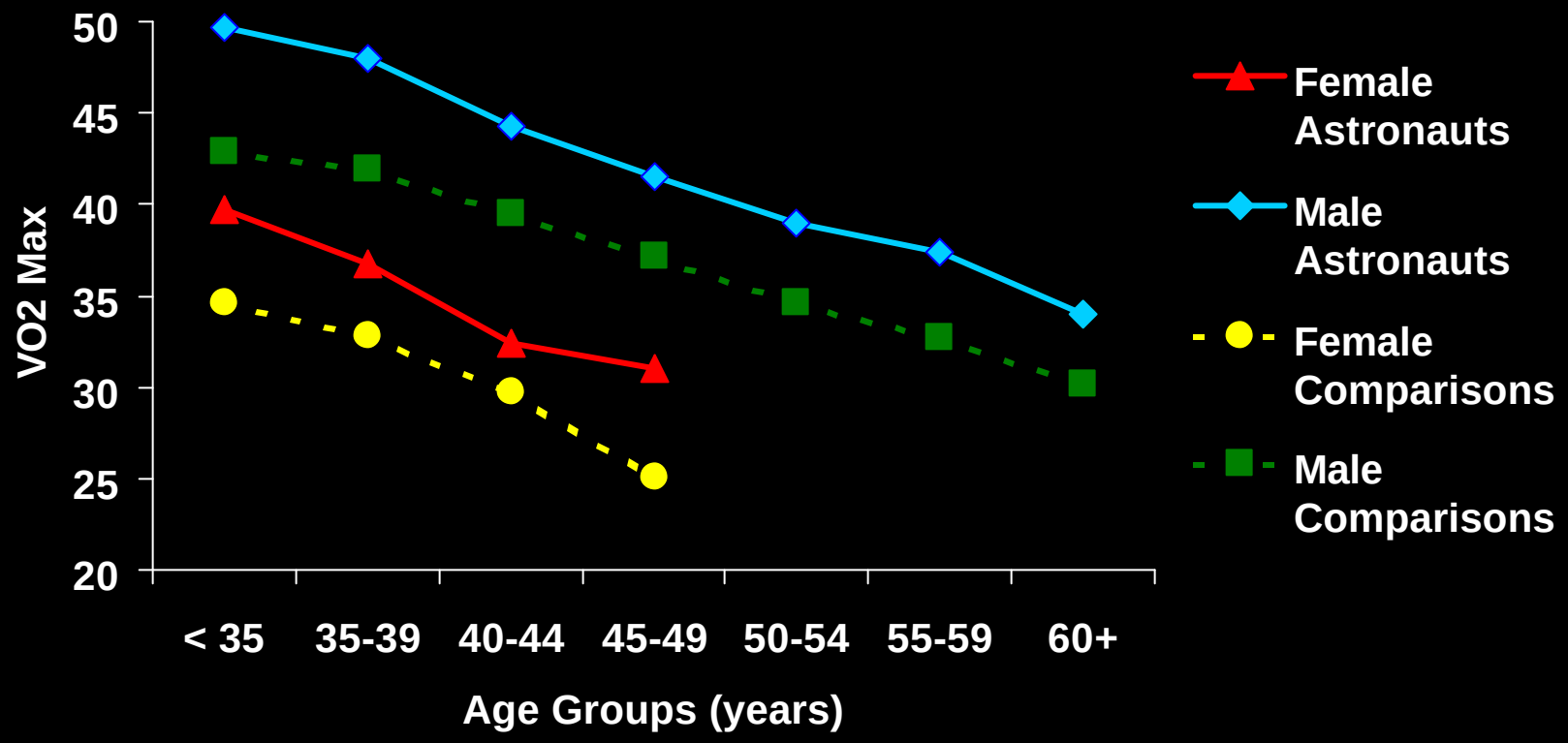
Ratio of Total to HDL Cholesterol

Mean Values by Age (Cross-Sectional Data)



VO2 Max

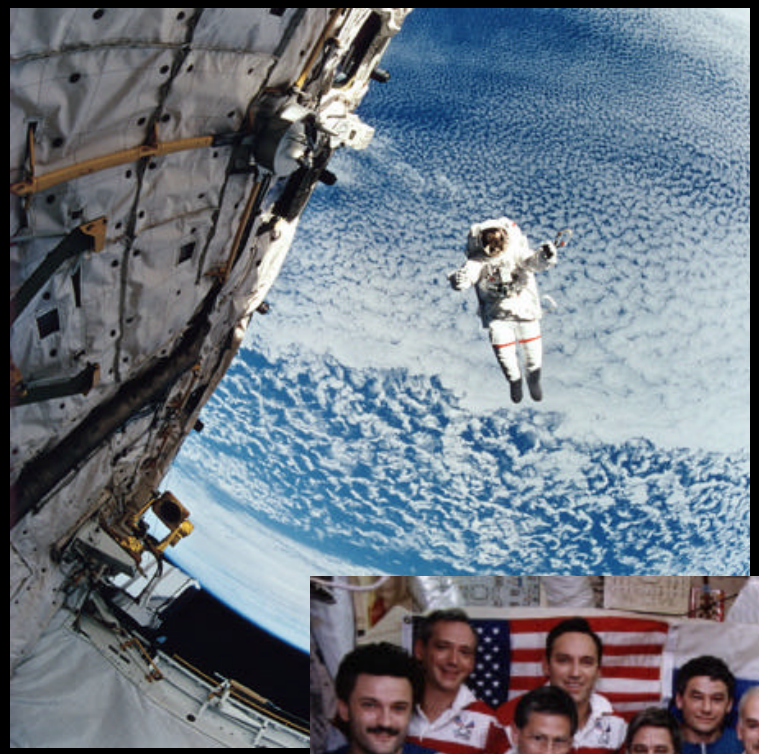
Mean Values by Age (Cross-Sectional Data)



Injuries & Illnesses Experienced In-flight

Musculoskeletal
Space motion sickness
Surface burn, hands
Glossitis
Heartburn/gas
Bone & muscle loss
Asthenia
Arrhythmia
Musculoskeletal
Laryngitis
Bruise
Hematoma
Sleep disorders
Infection/irritation
Constipation
Gastrointestinal
Tiredness
Conjunctivitis
Contusion of eyeball
Hemorrhoids
Psychiatric
Cardiovascular changes
Dental
Headache
Sleeplessness
Contact dermatitis
Dental caries
Wax in ear
Fatigue
Neurovestibular disturbance
Superficial injury
Acute respiratory infection
Foreign body in eye
Nasal congestion, irritation
Dry skin
Erythema of face, hands
Injury, trauma

Psychosocial Elements



- Isolation
- Confinement
- Multicultural factors
- Societal issues

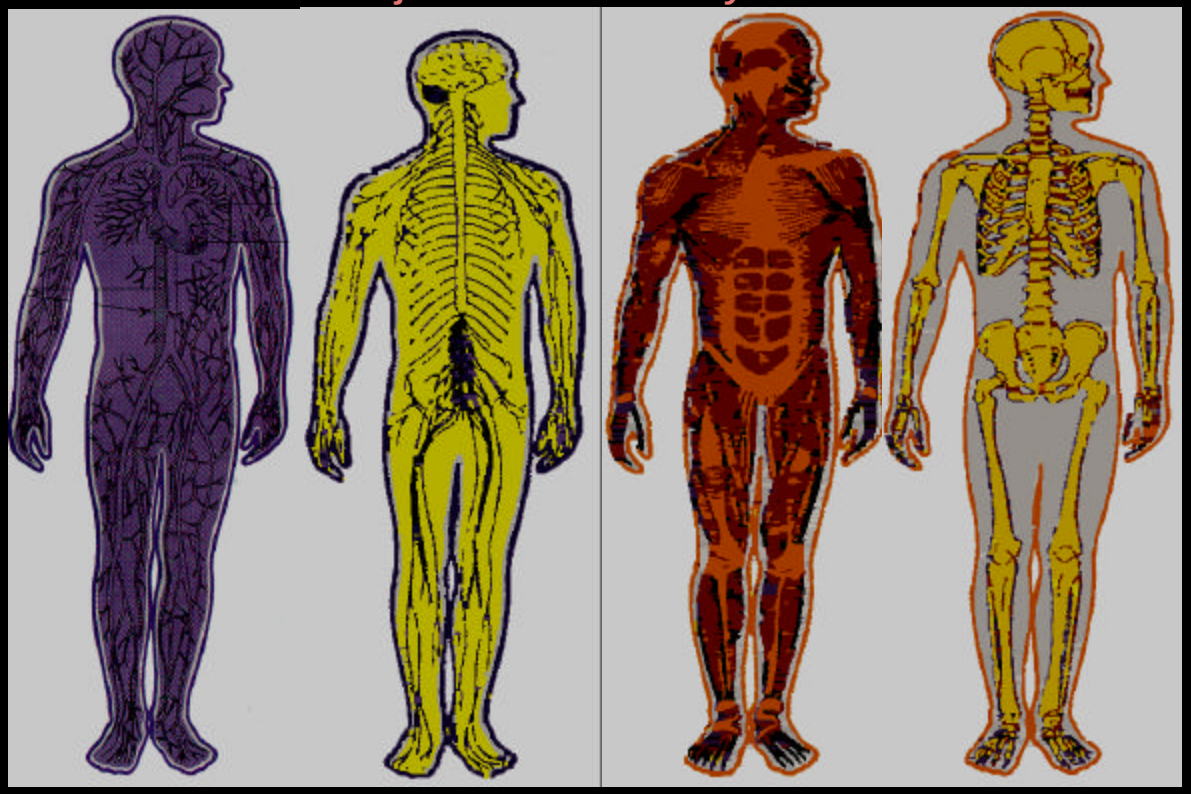
Protective Solutions

- Countermeasures
- Medical care
- Life support

Countermeasures

Mechanism

Plasticity	Receptor adjustment	Long chain myosin	Bone formation



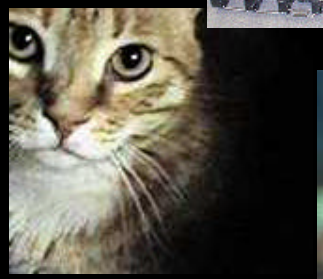
Manifestation			
Ataxia	Fluid loss Blood pressure control	Reduction in muscle strength	Reduction 1% a month

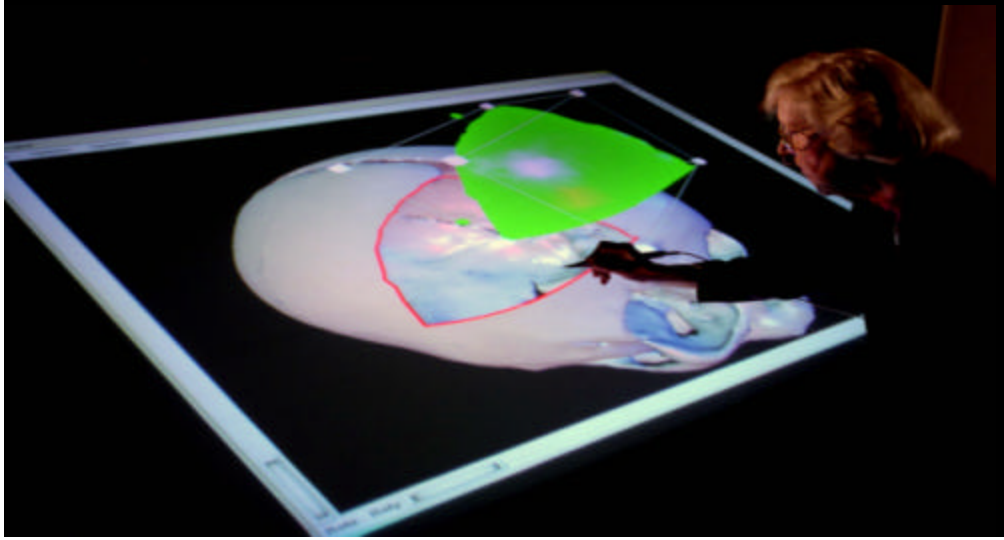
- **Traditional**
  - Exercise
  - Nutrition
  - Fluids
  - Pharmacological supplements
- **Non-traditional**
  - Artificial gravity
  - Intervention at genetic/molecular level

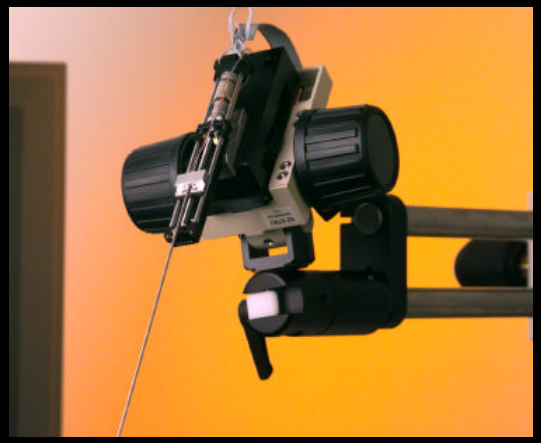
The Future of Medical Care

Solutions to overcome time and distance

- **Portability**
- **Virtual reality**
- **Haptic "smart" systems**
- **Biologically-inspired technologies**







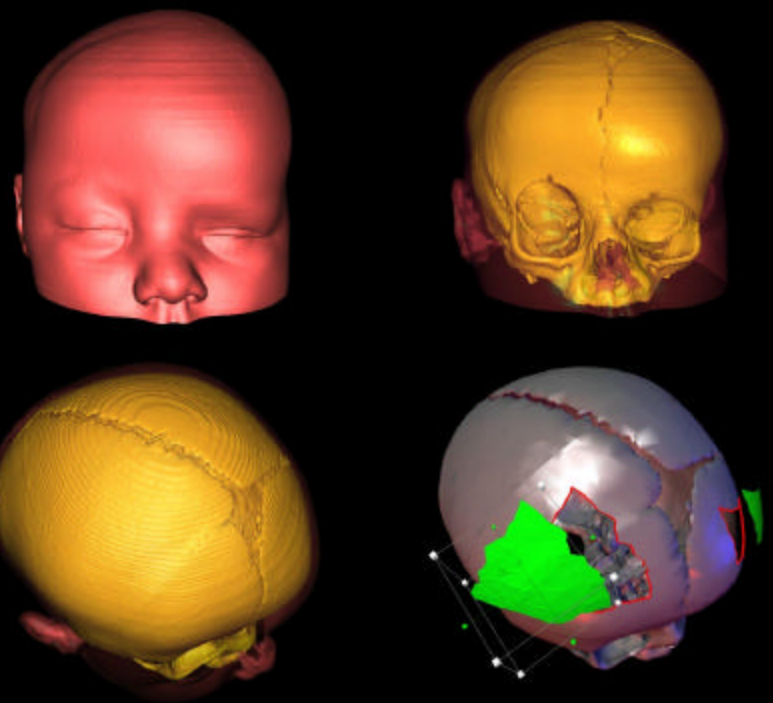
Convergence

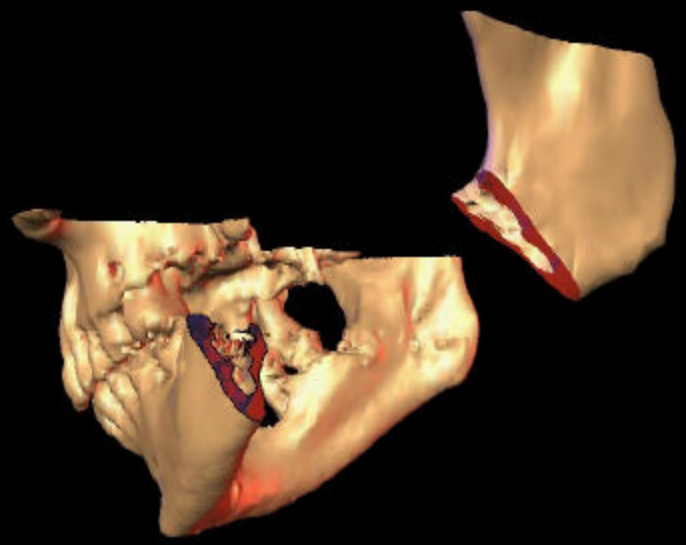
Future medical care will combine...

- **Informatics**
- **Miniaturization**
- **Nanotechnology**
- **Biology / Medicine**

Informatics

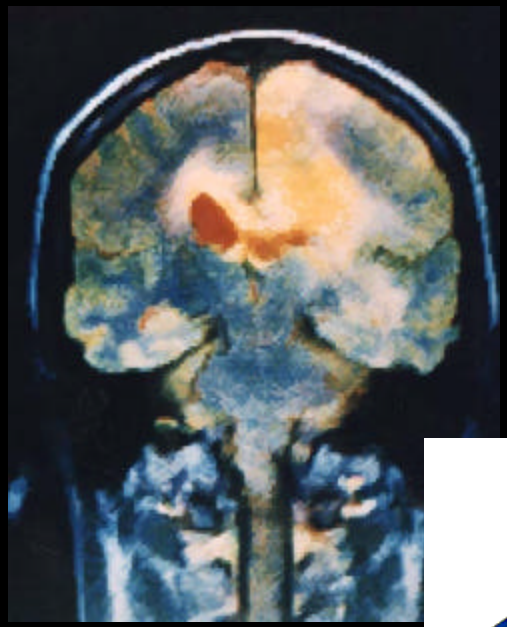
- Biocomputation
- Imaging
- Training and simulation
- Telemedicine





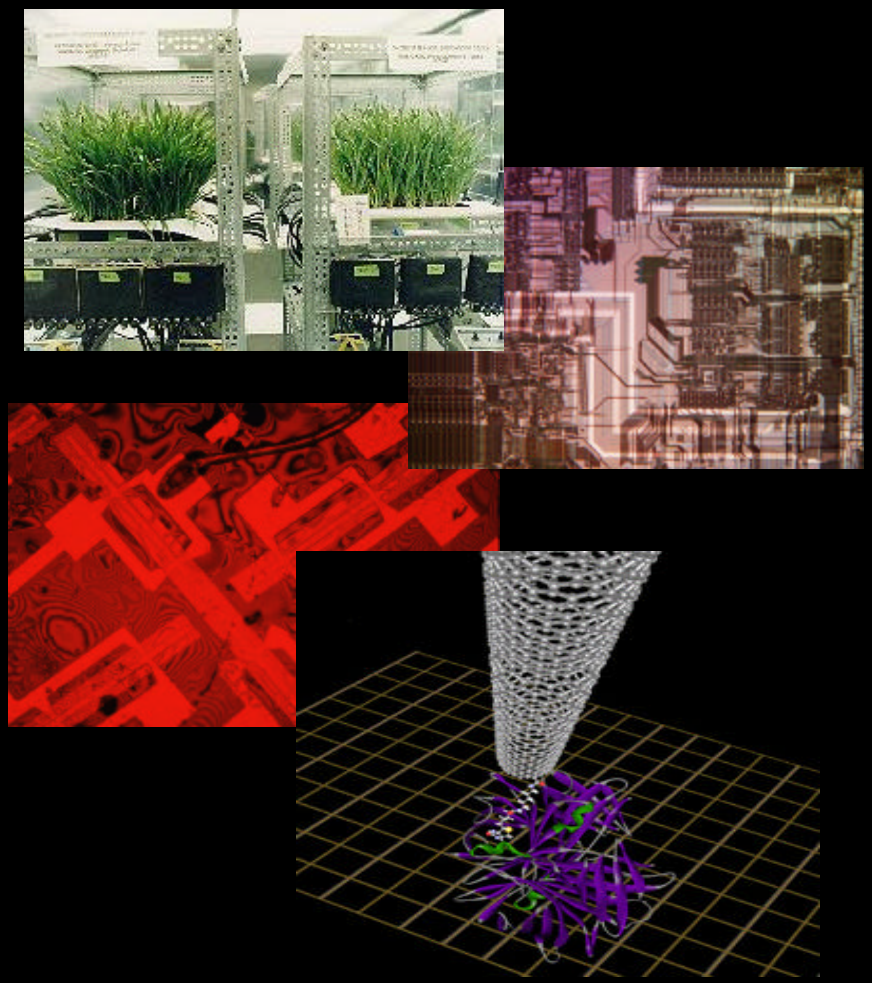
Miniaturization

- **Imagers**
  - X-ray
  - MRI
  - Ultrasound
- **Sensors, effectors, and transmitters**
  - Surgical instruments
  - Analyzers
- **Microsatellites**
  - Multipurpose
  - Regional coverage
  - Steerable beams



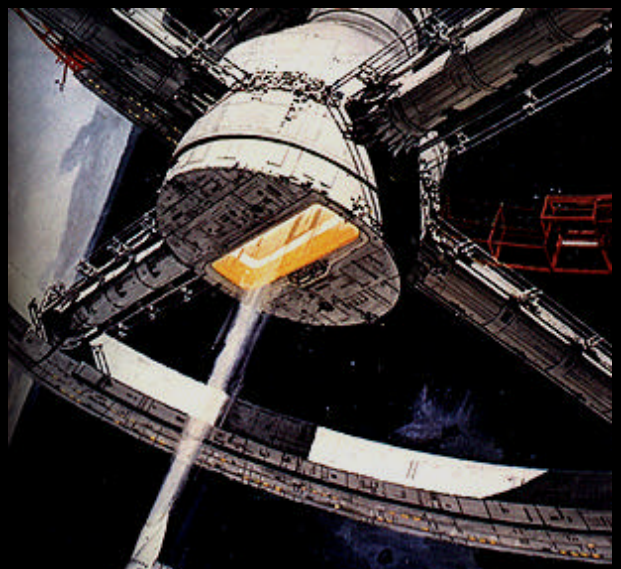
Nanotechnology

- **Life support**
  - Sensors and effectors
  - Bioregeneration
  - “Humans-on-a-chip”
  - Biological niches
- **Medical care**
  - Diagnostic probes
  - Treatment & delivery systems
  - “Keyhole” surgery
  - Tissue replacement

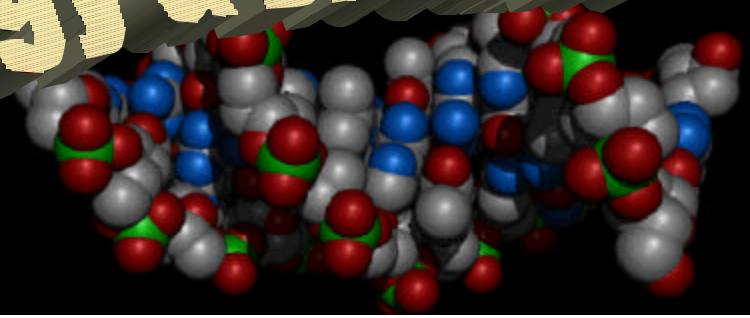


Biology / Medicine

- **Genetic profile of travelers**
  - Tailored medical preparations
  - Individual health maintenance
- **DNA therapies**
  - Countermeasures
    - artificial gravity as a medical tool
  - Illness risk reduction
  - Pre-clinical treatments

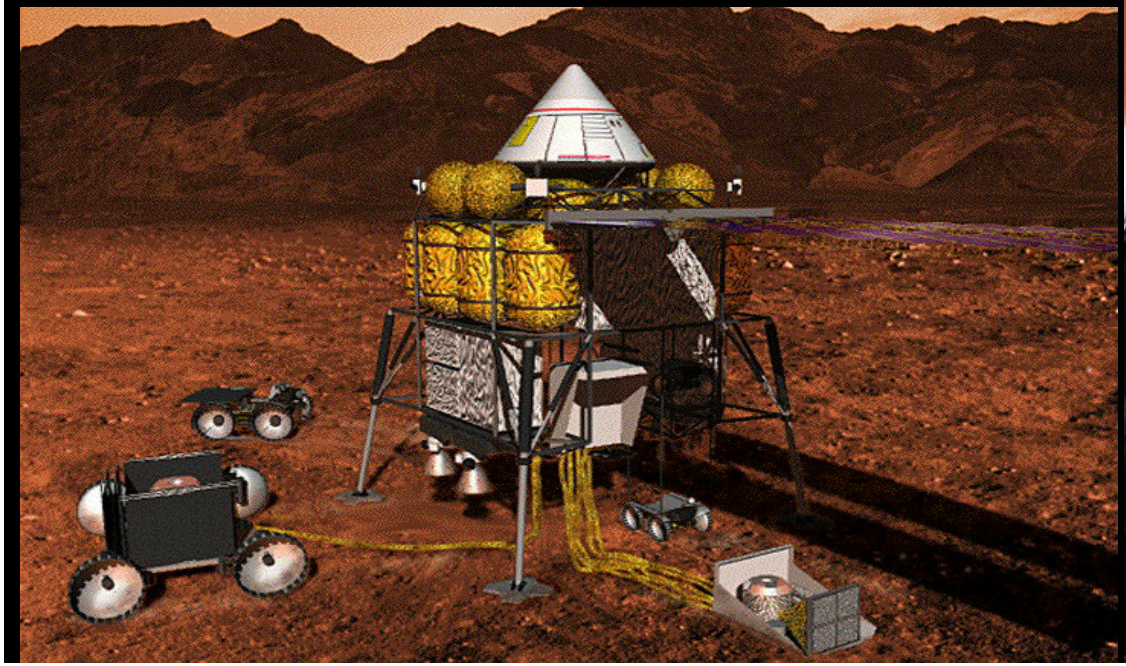


Technology & Bioethics



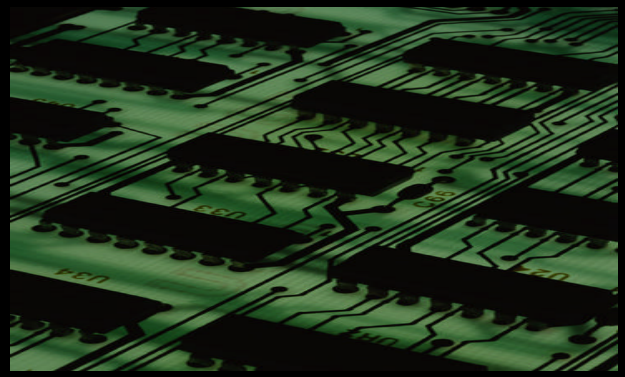
Life Support

- Atmosphere
- Comfort/control
- Food production
- Waste management



Human-Machine Interface

Human-centered systems are an integral part of mission design

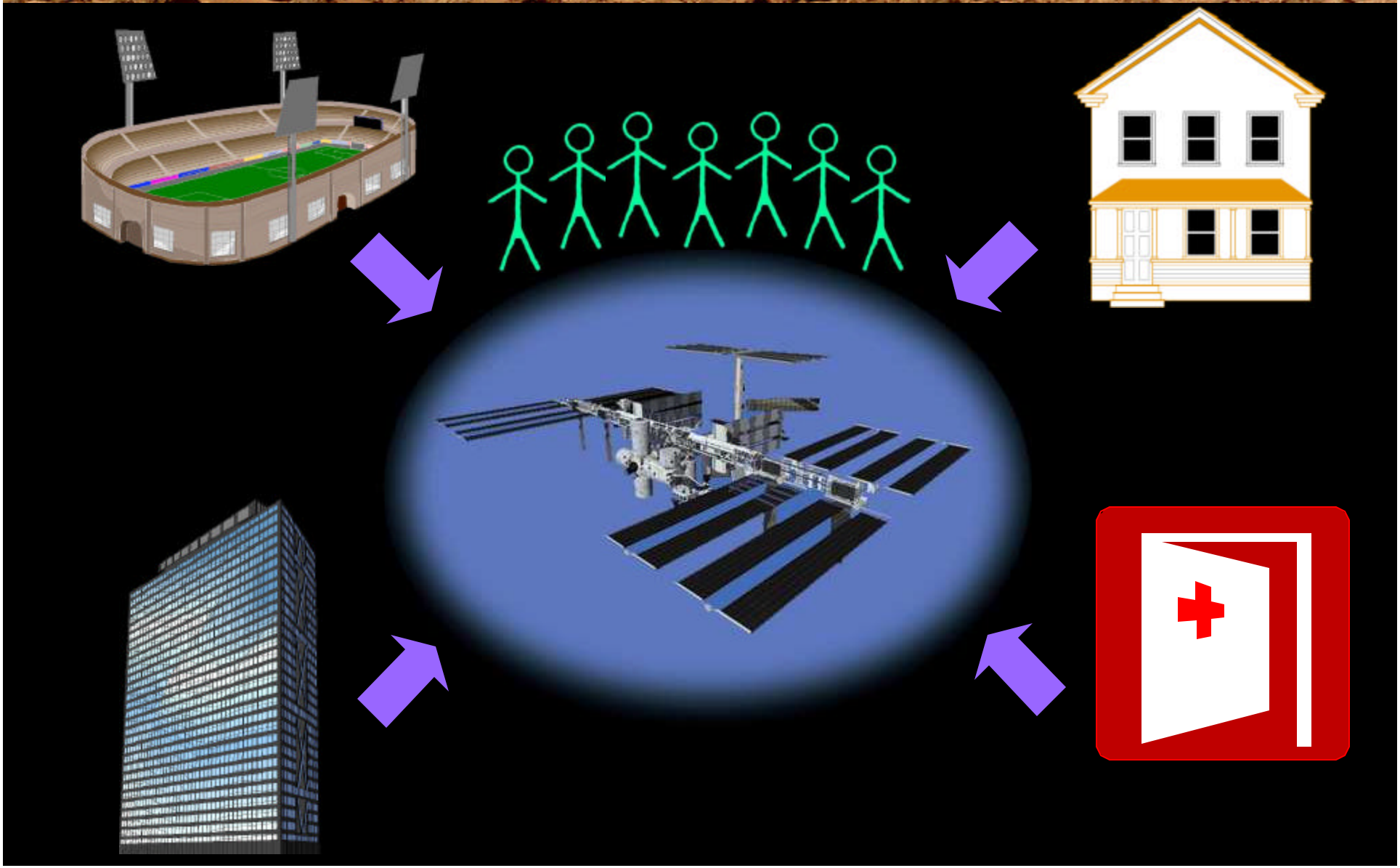


The International Space Station

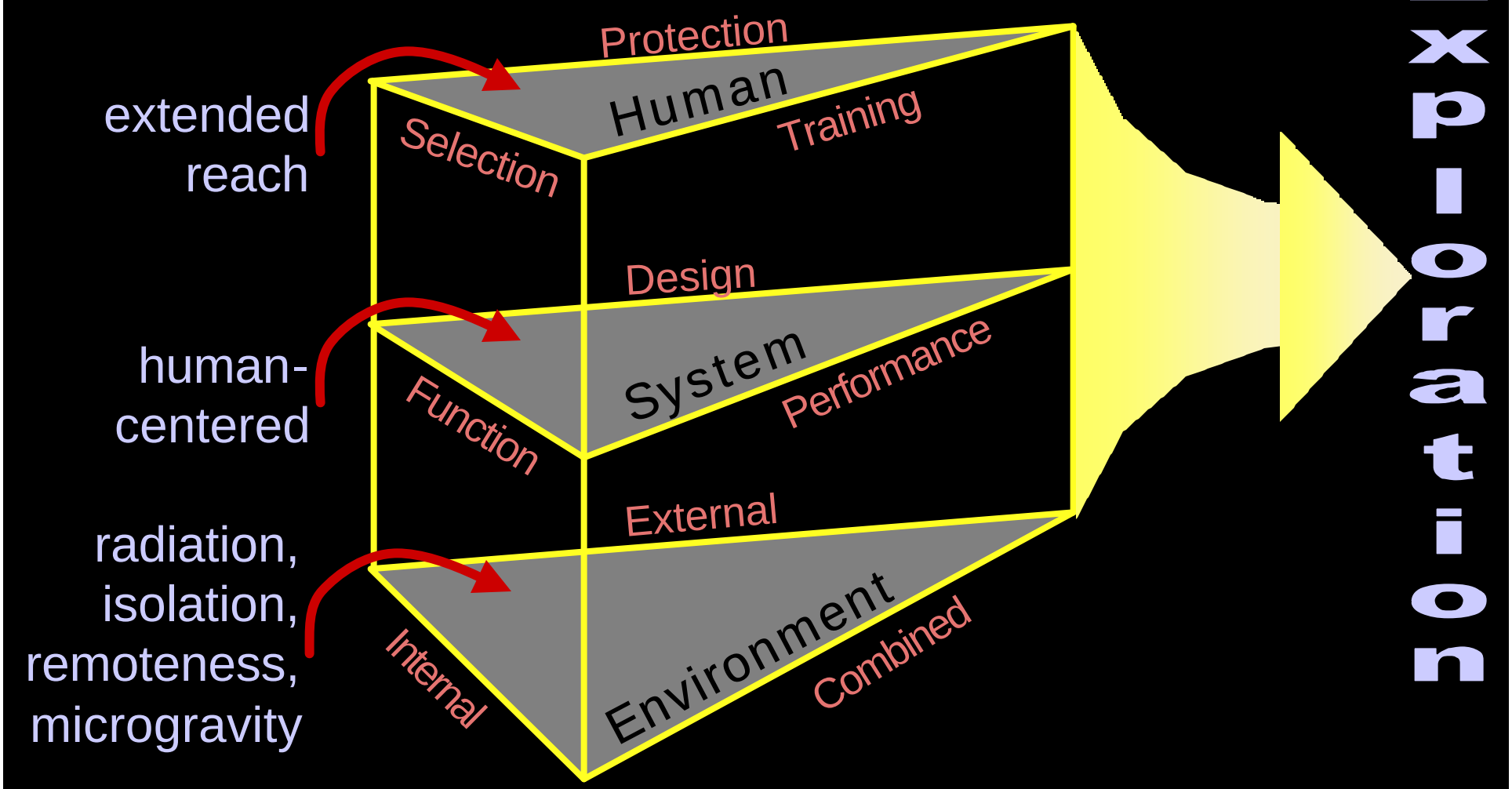
The ISS is a testbed for:

- **Exploration technology demonstration**
- **Applying space technologies to health care on Earth**

The Multipurpose ISS



Human Space Missions: The Future



Conclusion

- Understand the human and the environment
- Research and understand the Earth-space connection
- Apply technology to challenging environments on Earth

Backup

Differences in Medical Standards

	Pilots (Class I)	Mission Specialist (Class II)	Payload Specialists (Class III)
Distant vision	20/50 or better uncorr.; corr. to 20/20 each eye	20/150 or better uncorr.; corr. to 20/20 each eye	corr. to 20/40 best eye
Near vision	Uncorr. <20/20 each eye	Uncorr. <20/20 each eye	Not spec.
Hearing loss	Each ear: 30 db@ 500 Hz; 25 db @ 1000 Hz; 25 db 2000 Hz; 50 db @ 4000 Hz	Same as I	Better ear: 30 db@ 500 Hz; 30 db @ 1000 Hz; 30 db 2000 Hz
Height	64-76”	60-76”	Not spec.
Refraction/astig.	Specified	Specified	Not spec.
Visual field	15°	15°	30°
Phorias	eso>15; exo>8, hyper>2	eso>15; exo>8, hyper>2	Not spec.
Depth perception	No errors in 16 Verhoeff stereopter tests	Same as I	Not spec.
Color vision	Farnsworth lantern test	Farnsworth lantern test	Not spec.
Blood pressure	140/190	140/190	150/90 Rx allowed
Radiation exposure	<5 rem/yr	<5 rem/yr	Not spec.

Potential Risks

Medical selection procedures must take into account risks from...

- **Adaptation**
  - Anemia
  - Dehydration
  - Decreased cardiovascular performance
  - Changes in neural control (blood pressure)
  - Possible decreased receptor sensitivity
- **Pathophysiology**
  - Radiation
  - Bone & muscle loss
  - Closed environment
    - toxicology
    - behavior
  - Immunology
  - Metabolism/ endocrinology

Development

Key developmental processes in mammals require gravity stimuli

Locomotion behavior