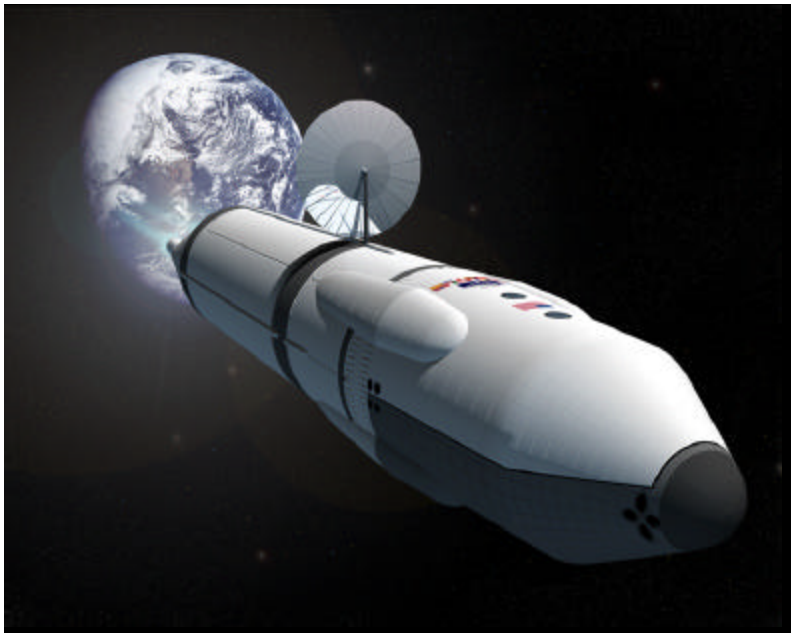
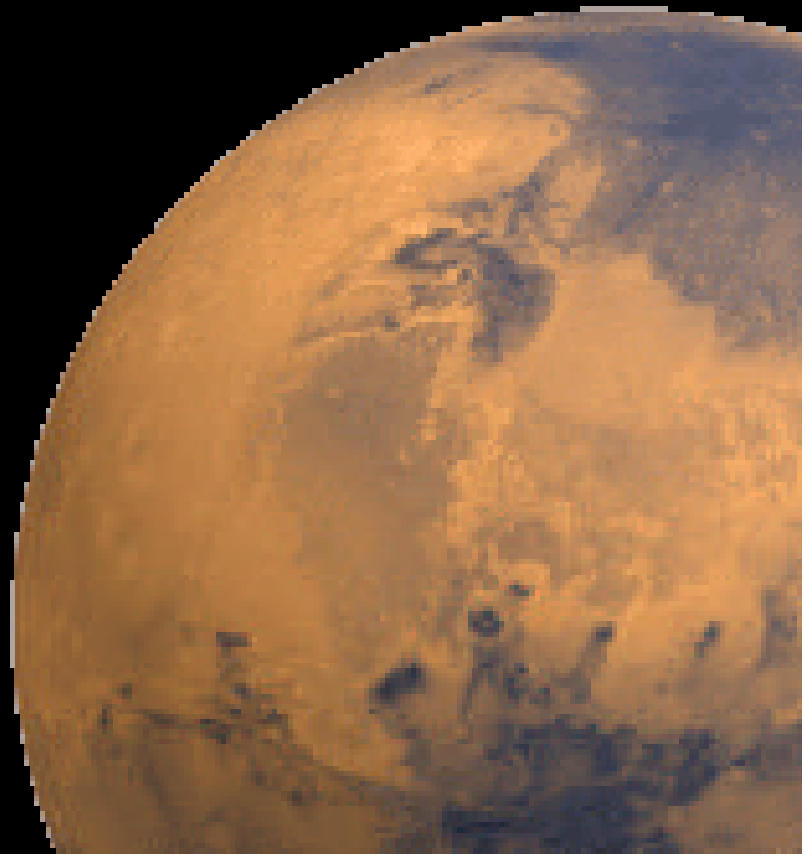


00-087

Challenges of Human Space Flight



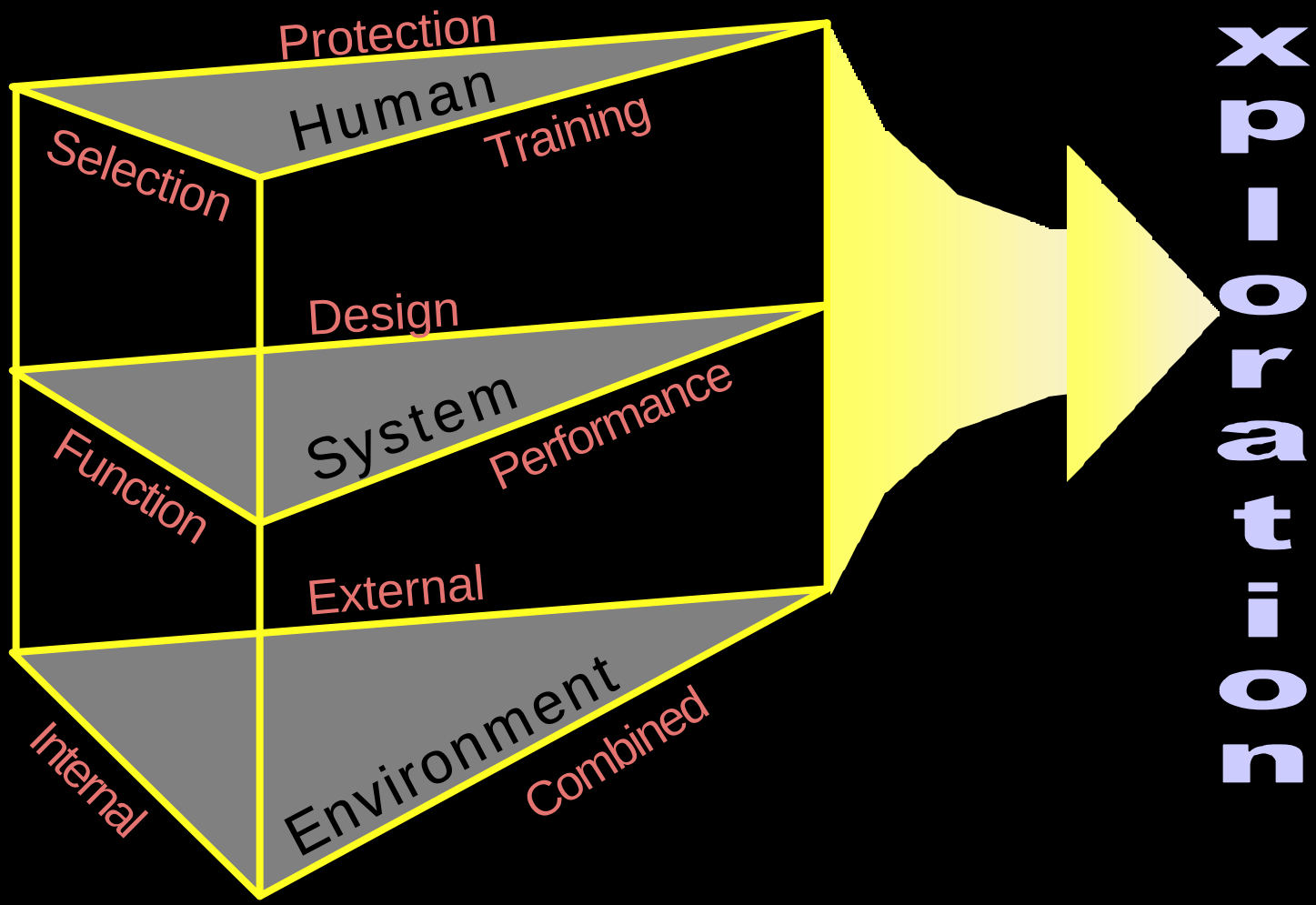
Contents

- **Planning for human space mission health and safety**
  - Human
  - System
  - Environment
- **Confronting biomedical responses to space flight**
  - Physiological response
  - Countermeasures
- **Advanced technologies for human support**
- **The International Space Station as a testbed**
- **Conclusion**

Components of Mission Health & Safety

Human Space Missions

System Human Environment



Physical Examinations

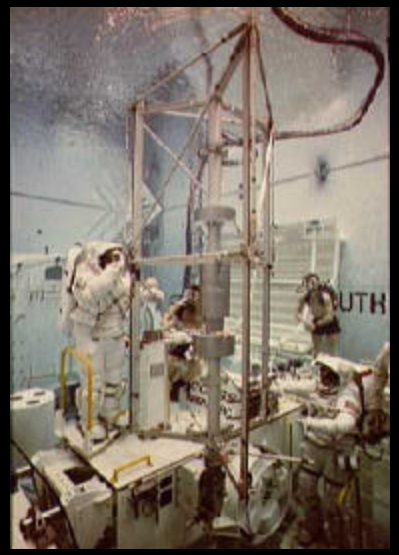
- **Types of examinations**
  - Selection
  - Retention
  - Pre-flight
  - Post-flight
  - Post-retirement
- **Components of examinations**
  - Physical exam
  - Laboratory analysis
  - Imaging
  - Special studies

Longitudinal Study of Astronaut Health

Training

Human System Environment

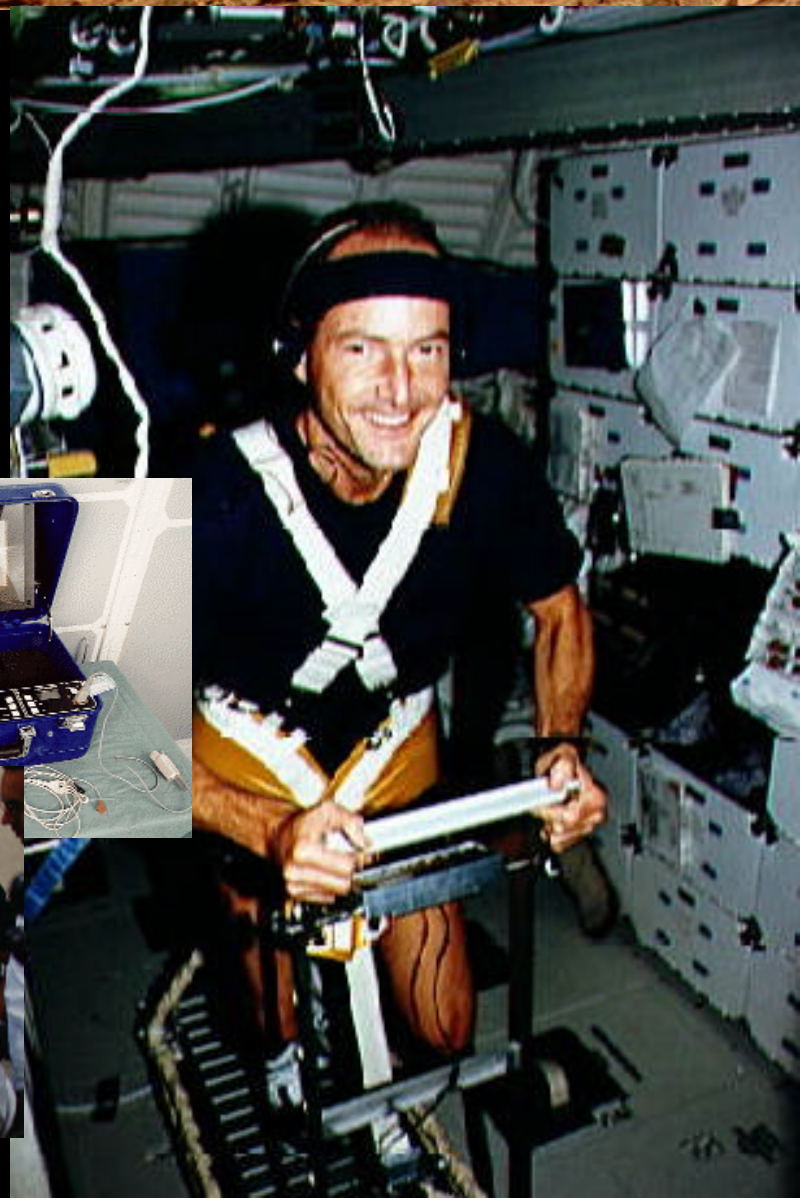
- Survival
- Mission-specific
- Experiments
- Medical skills



Human System Environment

Protection

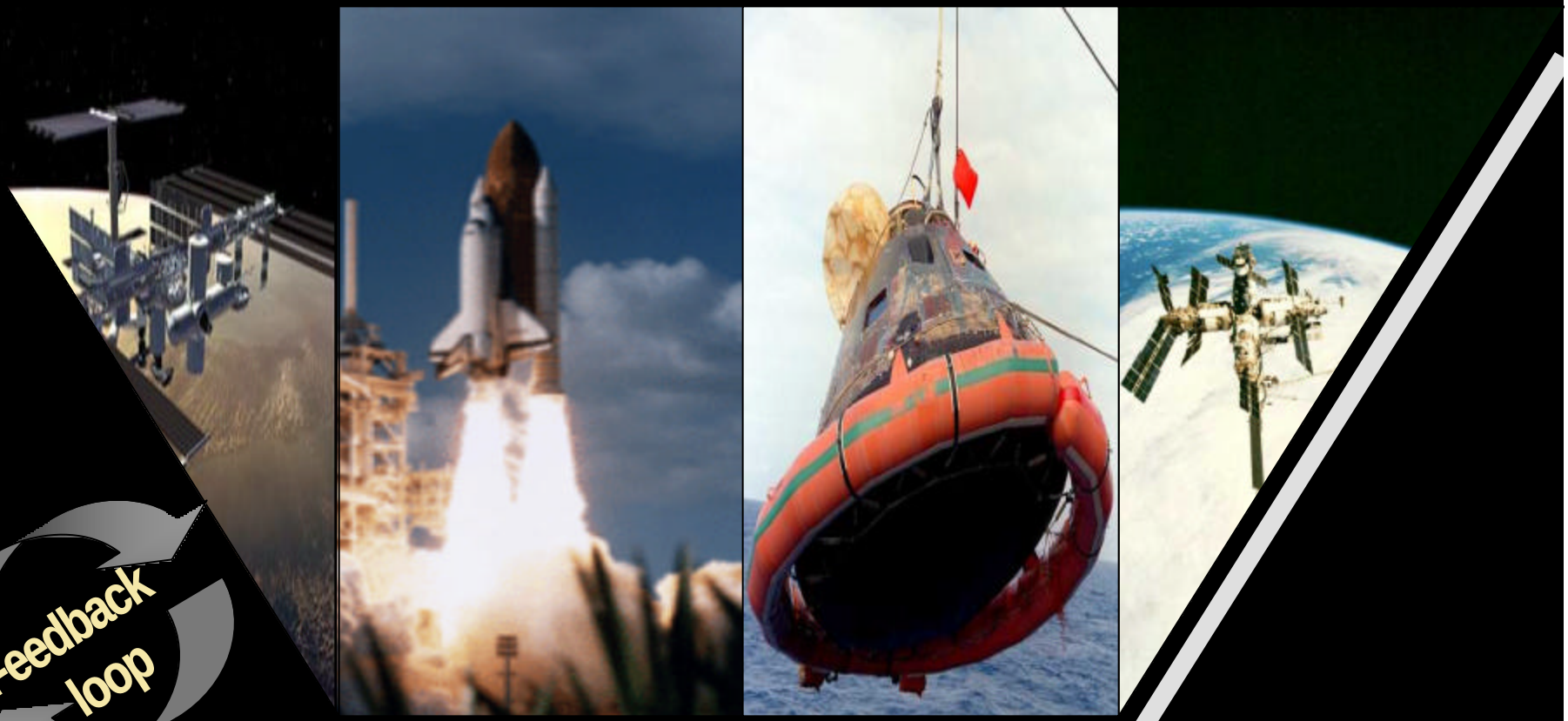
- **Preventive care**
- **Interventions**
  - Countermeasures
  - Medical care
- **Life support design choices (system)**



System

System
Human
Environment

Function → Performance



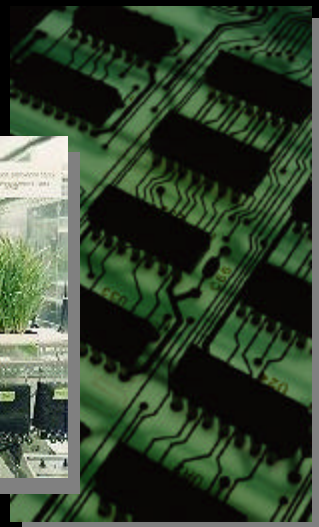
Feedback loop

Design

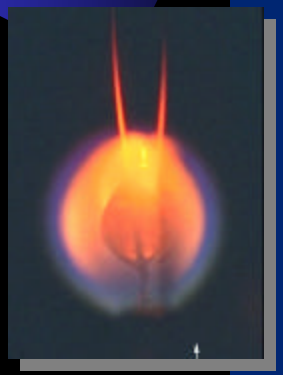
Function

System Human Environment

The System is chosen to fulfill a function. This function includes mission objectives and crew protection.



- **Life support**
- **Environmental control**
- **Radiation shielding**
- **Medical capability**



Underlying research

Fluids management

Materials research

Combustion science (fire suppression)

Gravitational biology (biomass production)

Biological interface

Performance

System Human Environment

Performance parameters are chosen to optimize system and crew function.

- **System performance parameters/limits**
- **Standard operating procedures**
  - Vehicle/habitat operations
  - Maintenance procedures
  - Health risk minimization
  - Work/rest cycles

Design

System Human Environment

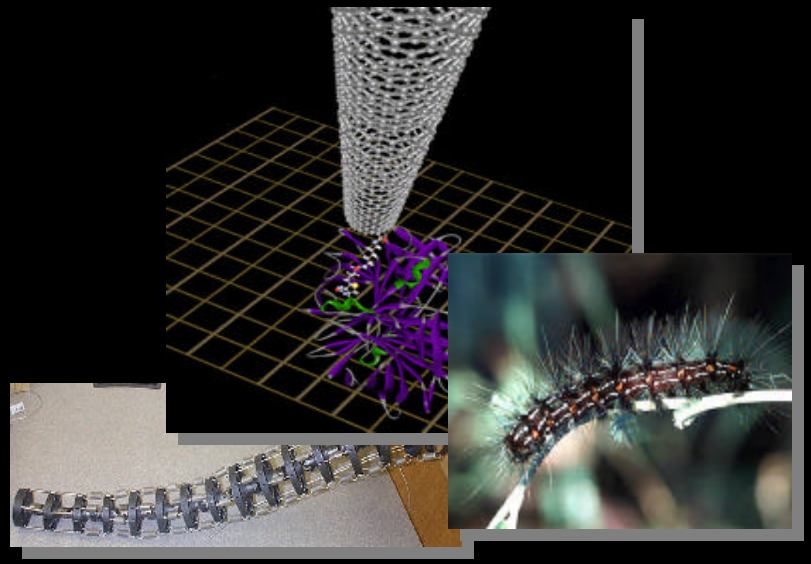
System design needs to accommodate constraints on available power; mass; and crew size, expertise, and availability.

- **Miniaturization**
- **Autonomy**
- **Redundancy**

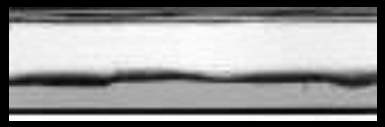
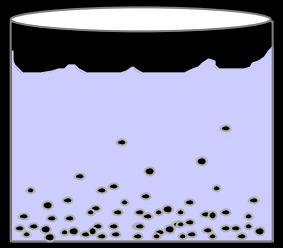
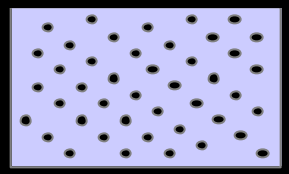
Biologically-inspired technologies

- **Accessibility**
- **Ease-of-use**
- **Emergency procedures**

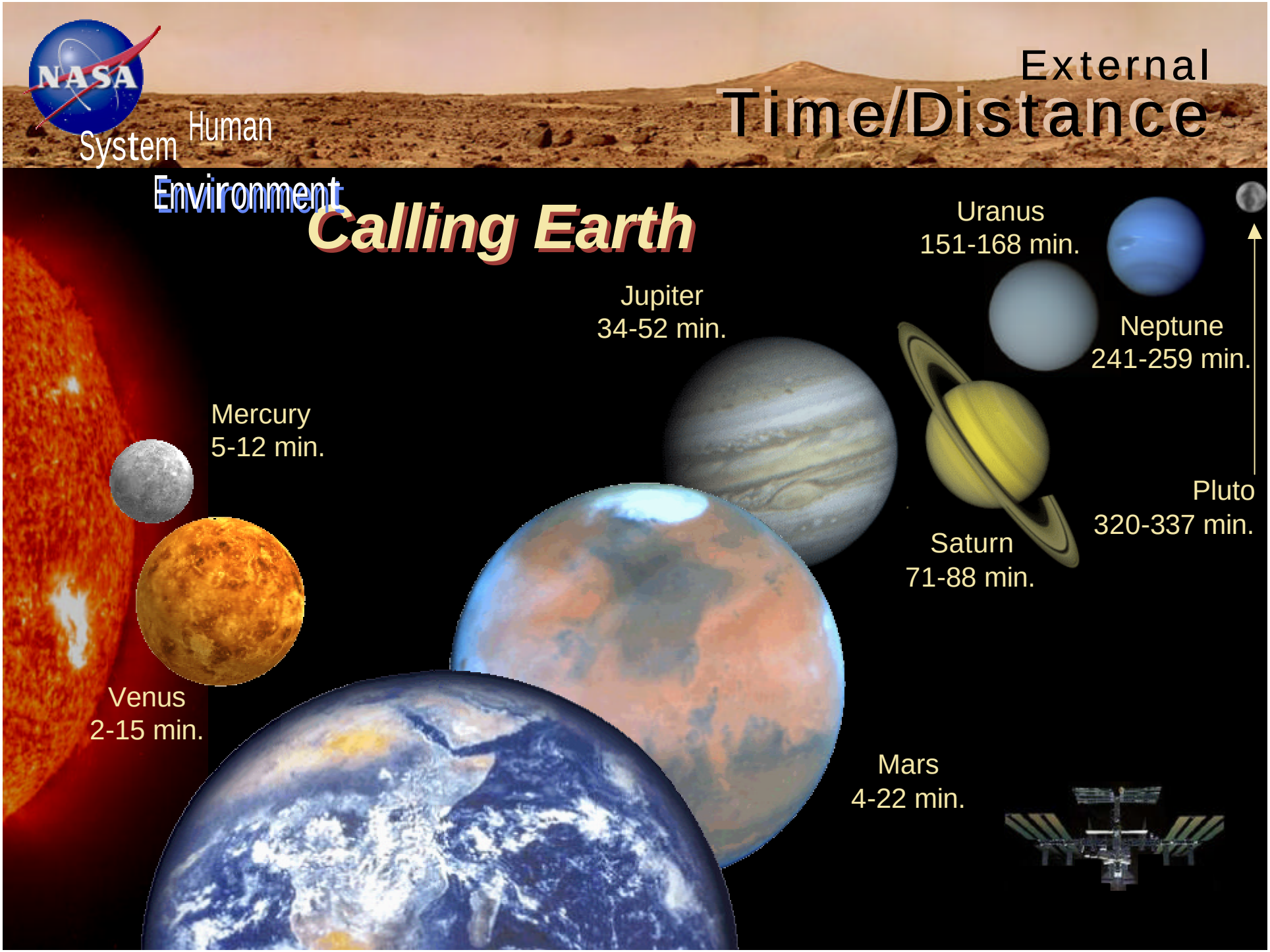
Human factors



Microgravity

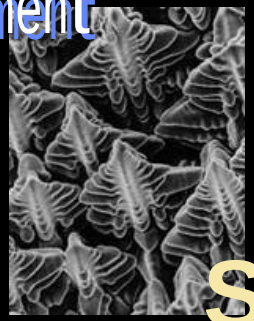
	Convection	Buoyancy	Sedimentation
Earth			
Space			

External Time/Distance



External Radiation

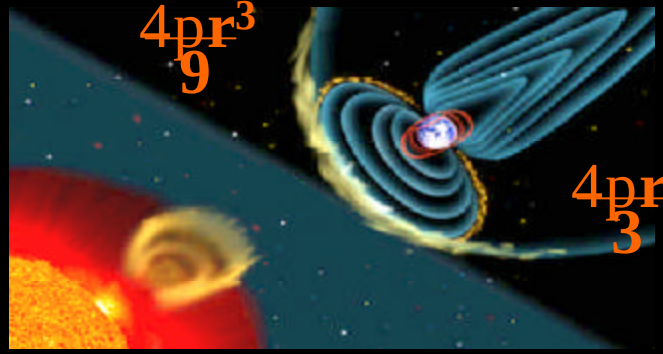
Human System Environment



Secondaries

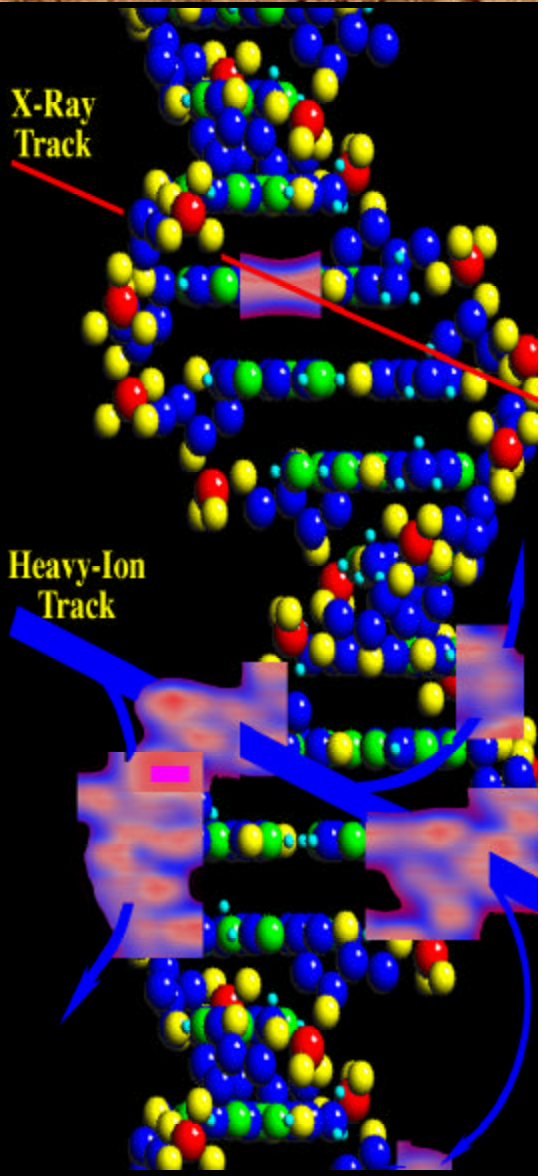
Heavy particles
Protons
Neutrons
Electrons

H^-



$\frac{4pr^3}{9}$

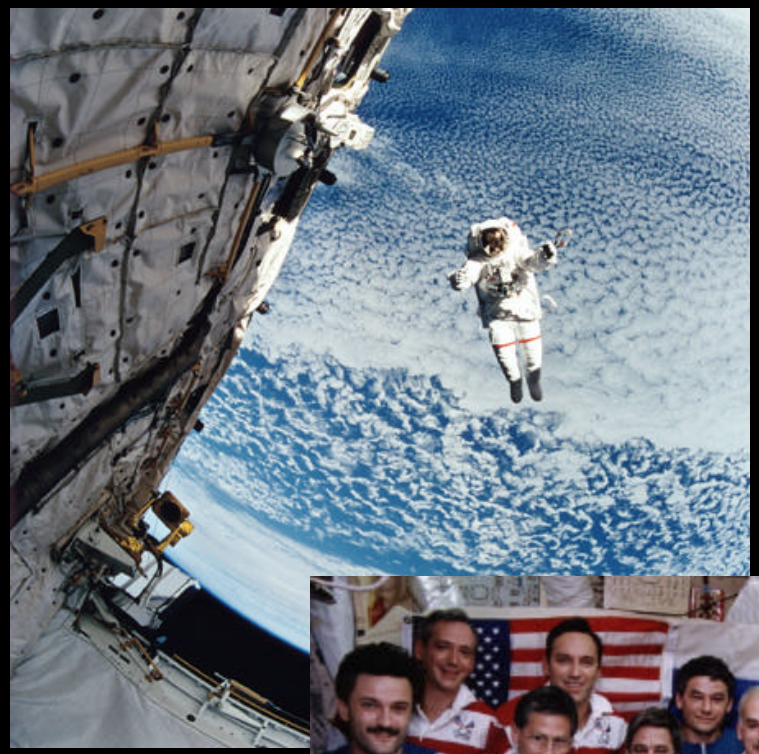
$\frac{4pr^3}{3}$



Internal

Psychosocial Elements

System Human Environment



- Isolation
- Confinement
- Multicultural factors
- Societal issues

Adaptation

Adaptive

Pathological

Neurosensory & Neuromotor

Cardiovascular/
Pulmonary

Endocrine

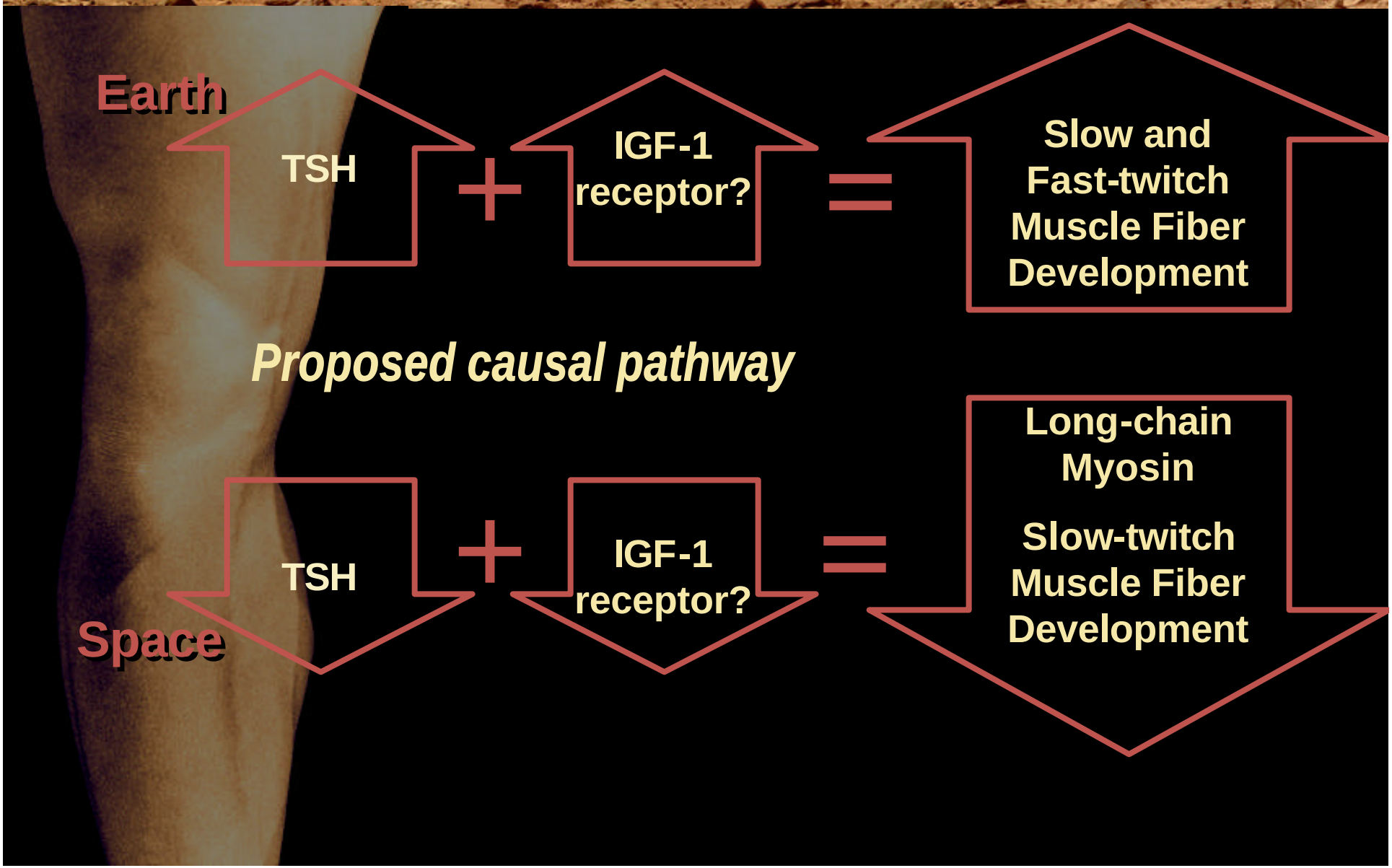
Musculoskeletal

Radiation

Confinement

parallels with aging…

Muscle Fiber Response



Bone Response

Bone Formation & Density

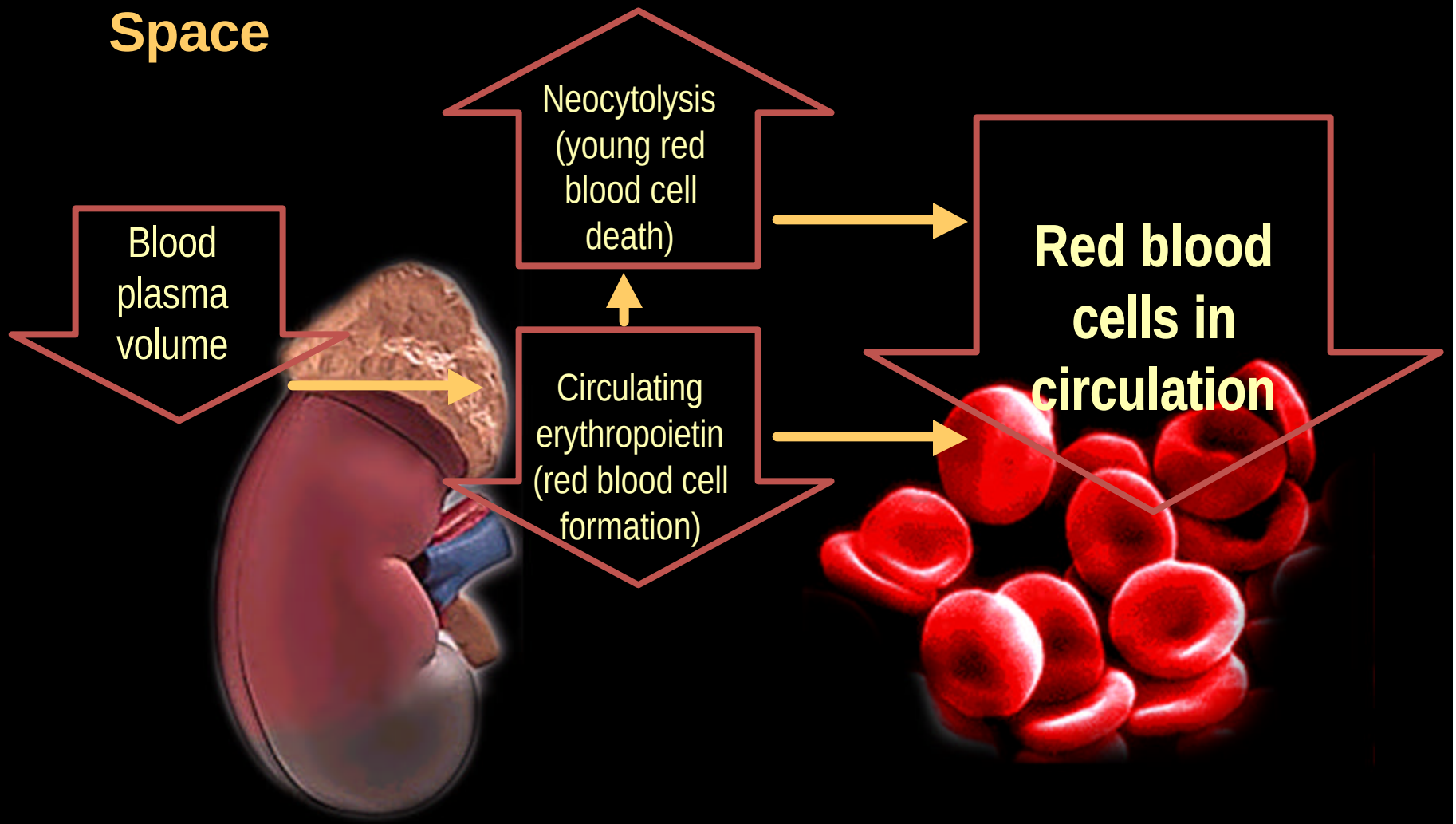
Earth

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

Space

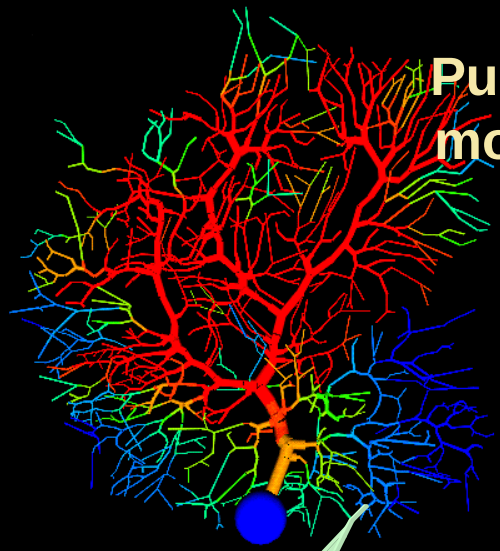
PTH & IGF-I ↑ = Osteoprogenitor Number & Bone Mineralization

Red Blood Cell Response



Plasticity

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



Type of Response

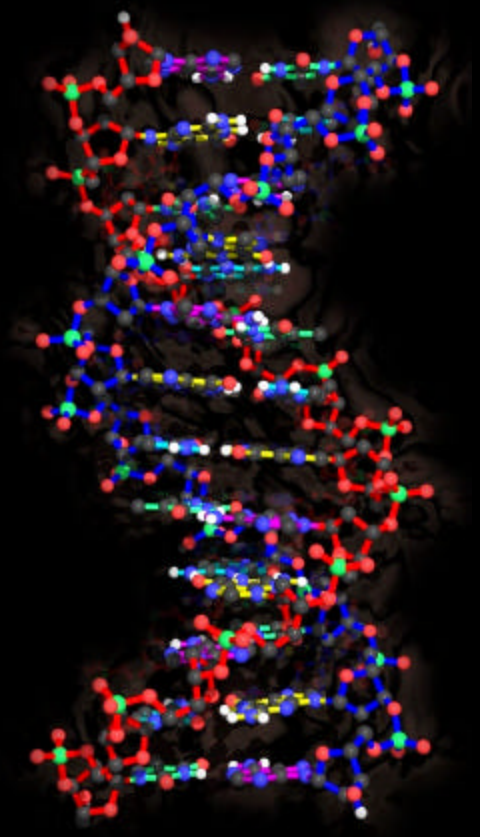
Ataxia
SMS
Occular

Development

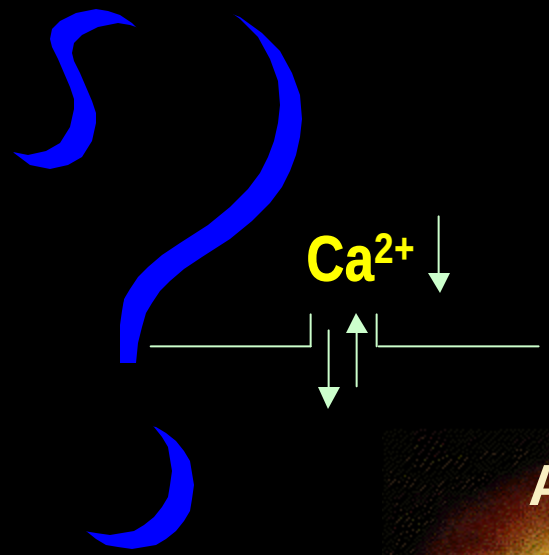
Key developmental processes in mammals require gravity stimuli

Locomotion behavior

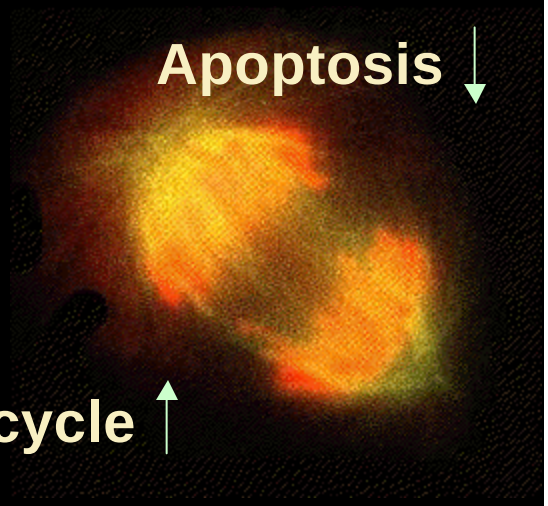
Molecular Observations



Gene expression ↓↑



Calmoduline ↓

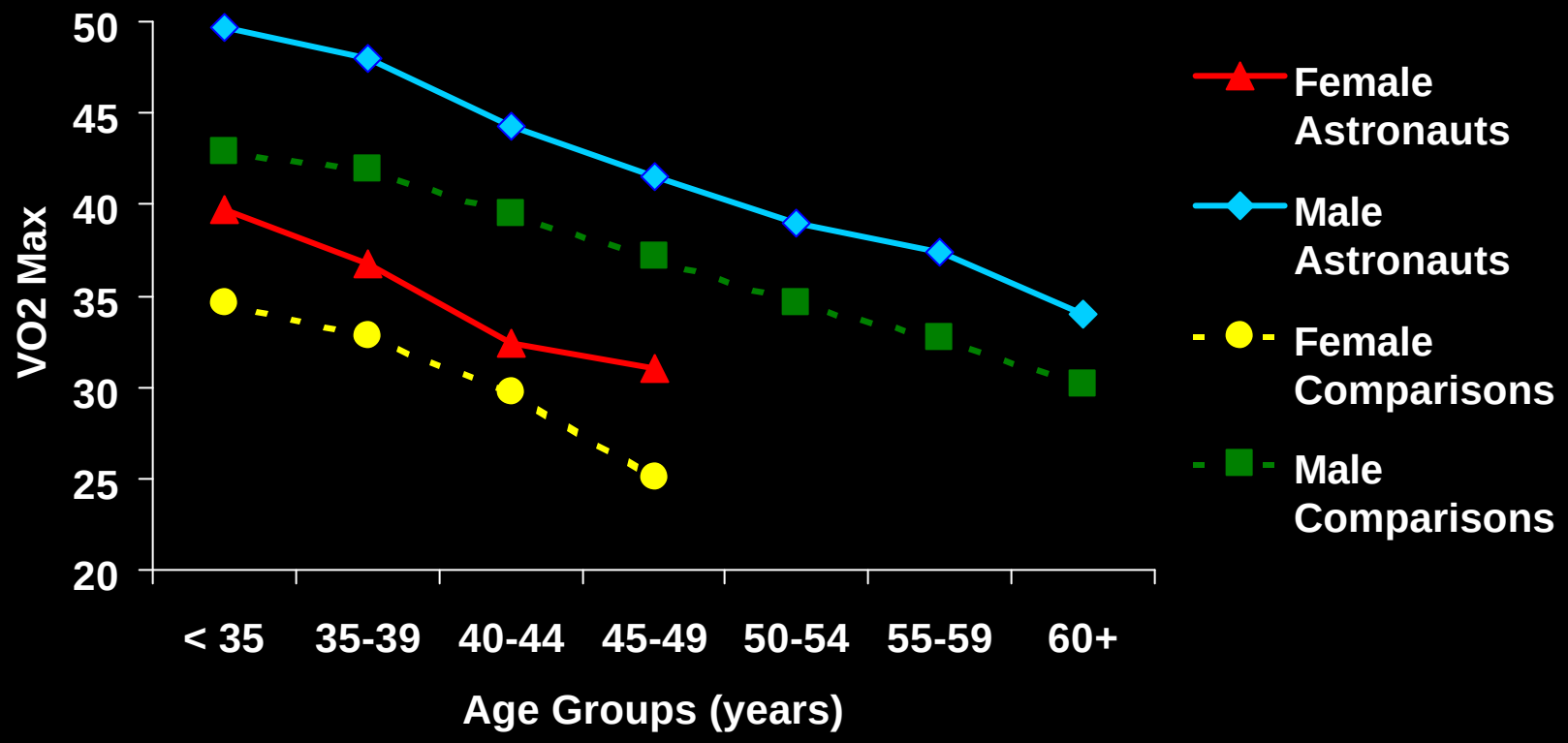


Apoptosis ↓

Cell life-cycle ↑

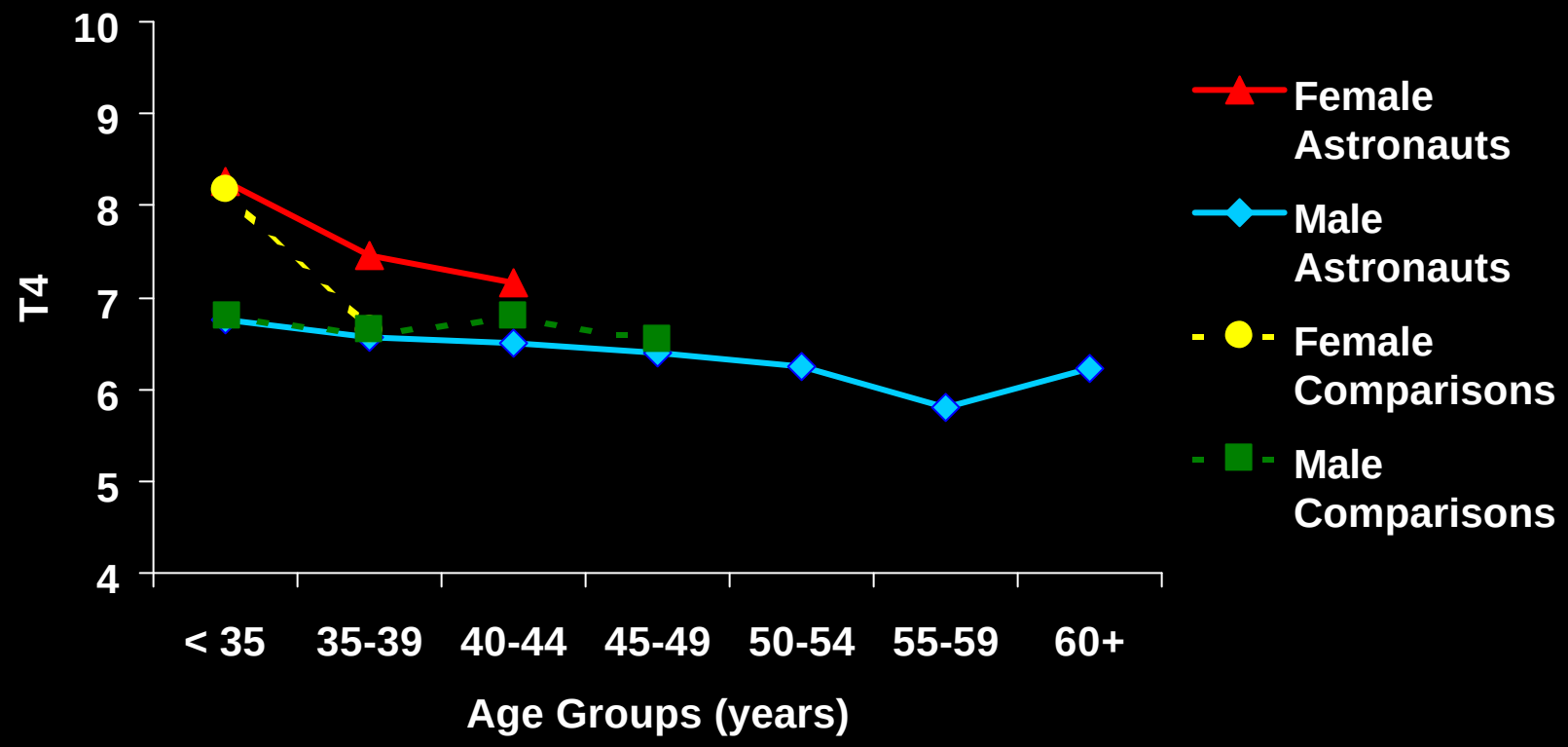
VO2 Max

Mean Values by Age (Cross-Sectional Data)



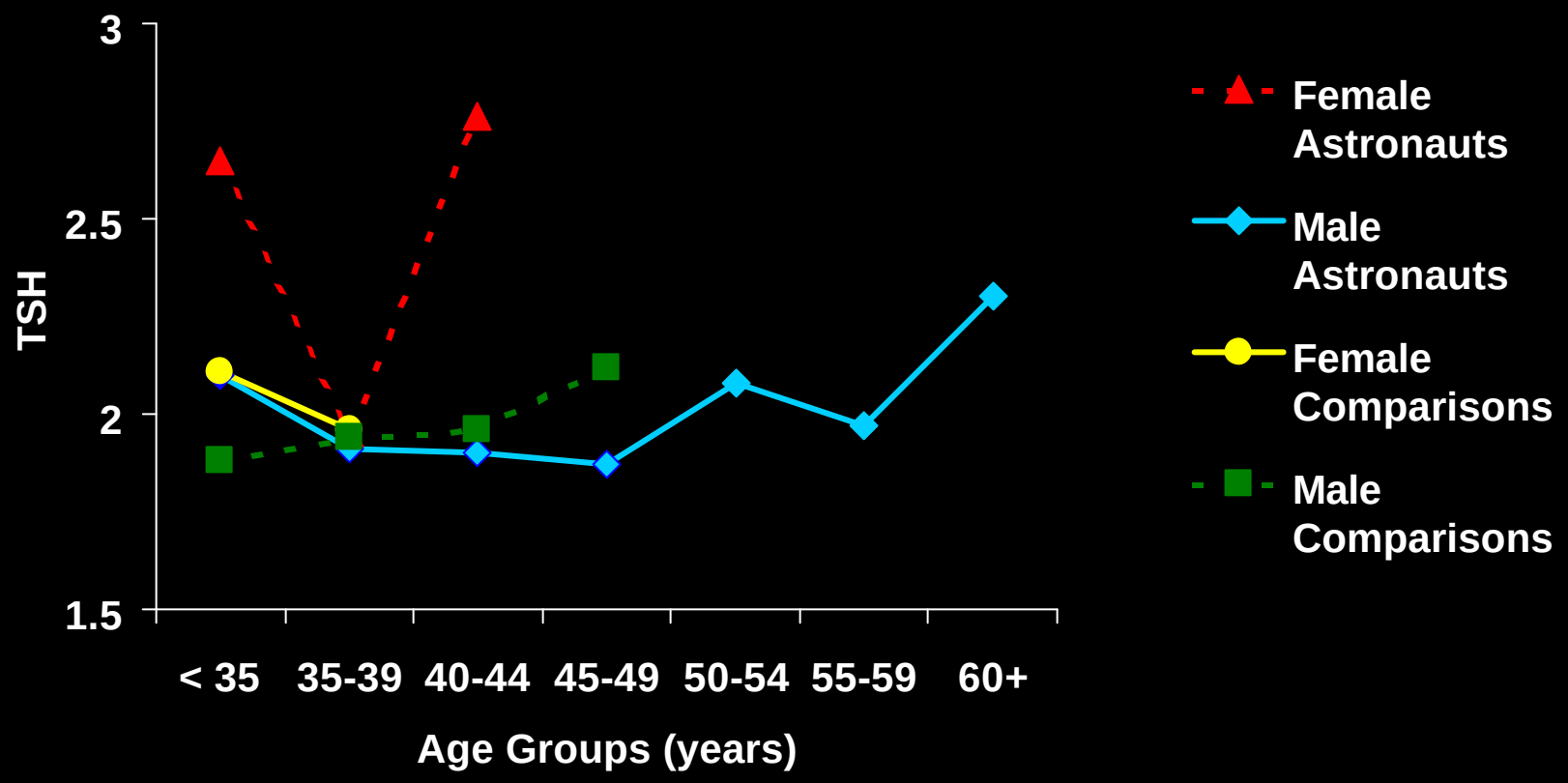
Thyroxine (T4)

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



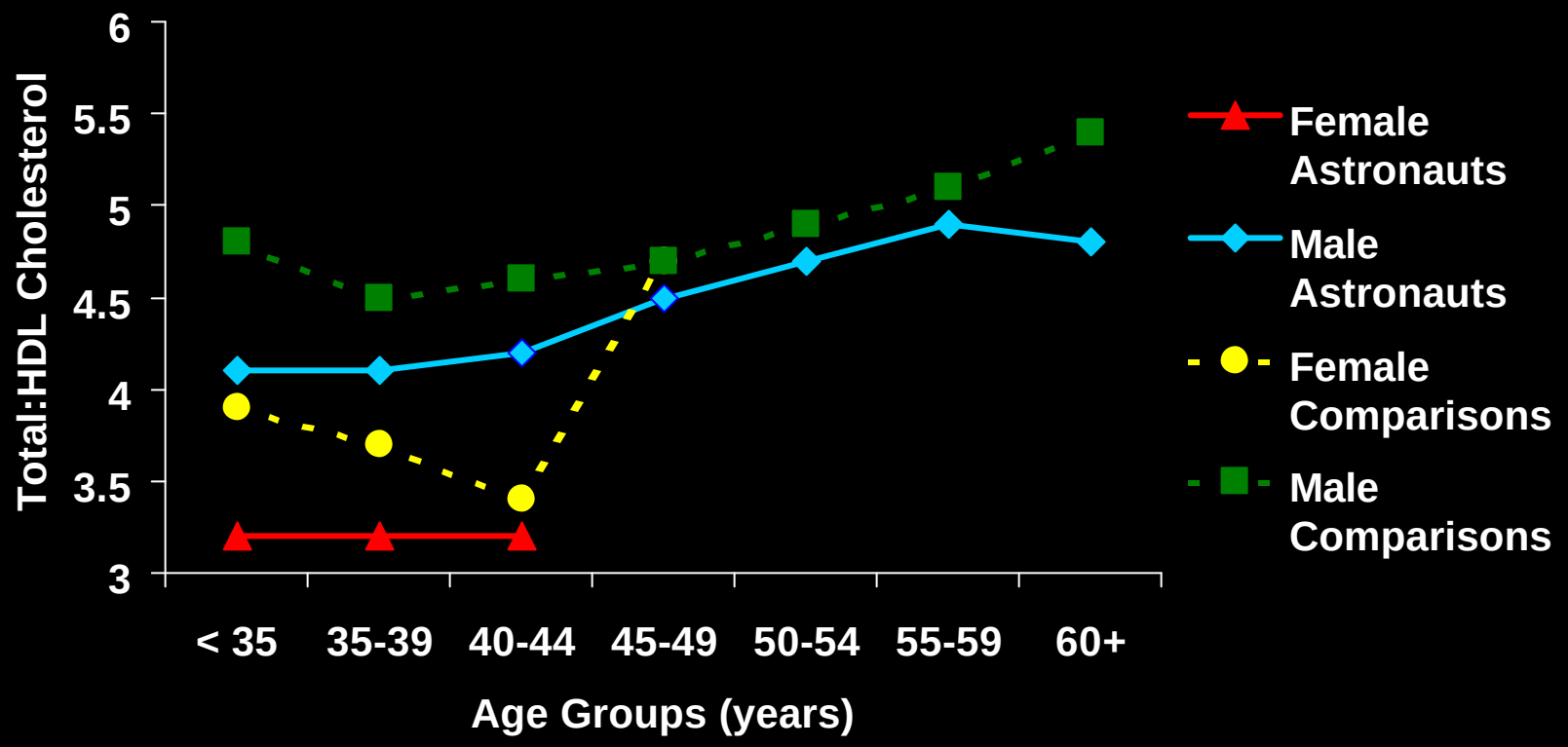
Thyroid Stimulating Hormone (TSH)

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



Ratio of Total to HDL Cholesterol

Mean Values by Age (Cross-Sectional Data)



Medical Events

Cardio-vascular adaptations

Neuro-vestibular alterations

Bone & muscle changes

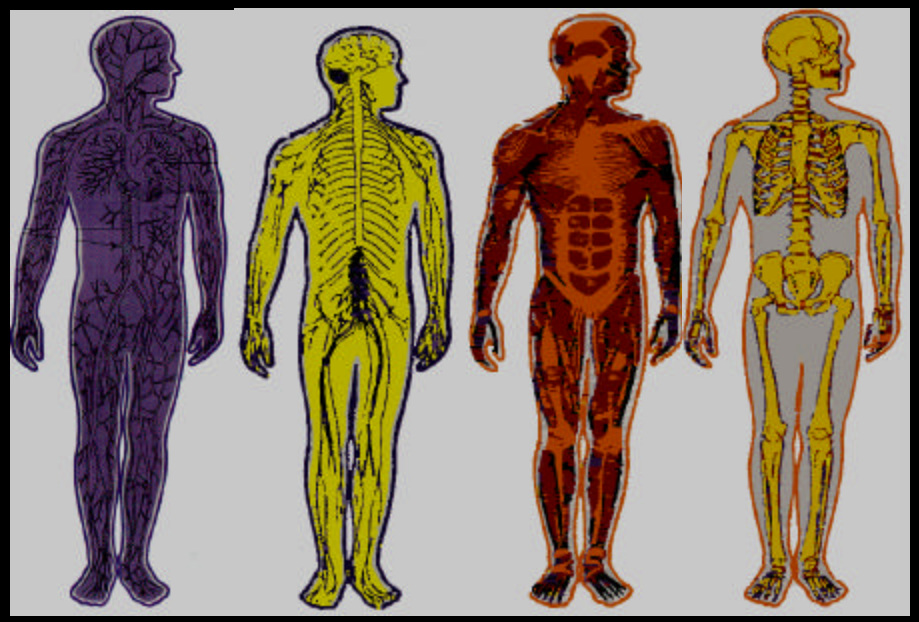
Metabolic/ hormonal shifts

Dry skin, Erythema of face & hands, Excessive wax in ear, Fatigue, Foreign body in eye, Gastrointestinal discomfort, Musculoskeletal changes, Nasal congestion/irritation, Psychiatric distress, Sleep disorders, Sleeplessness, Space motion sickness, Superficial injury, Surface burn to hands, Glossitis, Headache, Heartburn/ gas, Hematoma, Hemorrhoids, Injury/trauma, Laryngitis, Infection/irritation, Acute respiratory infection, Arrhythmia, Bruise, Conjunctivitis, Contact dermatitis, Contusion of eyeball, Dental caries

Countermeasures

Mechanism

Plasticity	Receptor adjustment	Long chain myosin	Bone formation

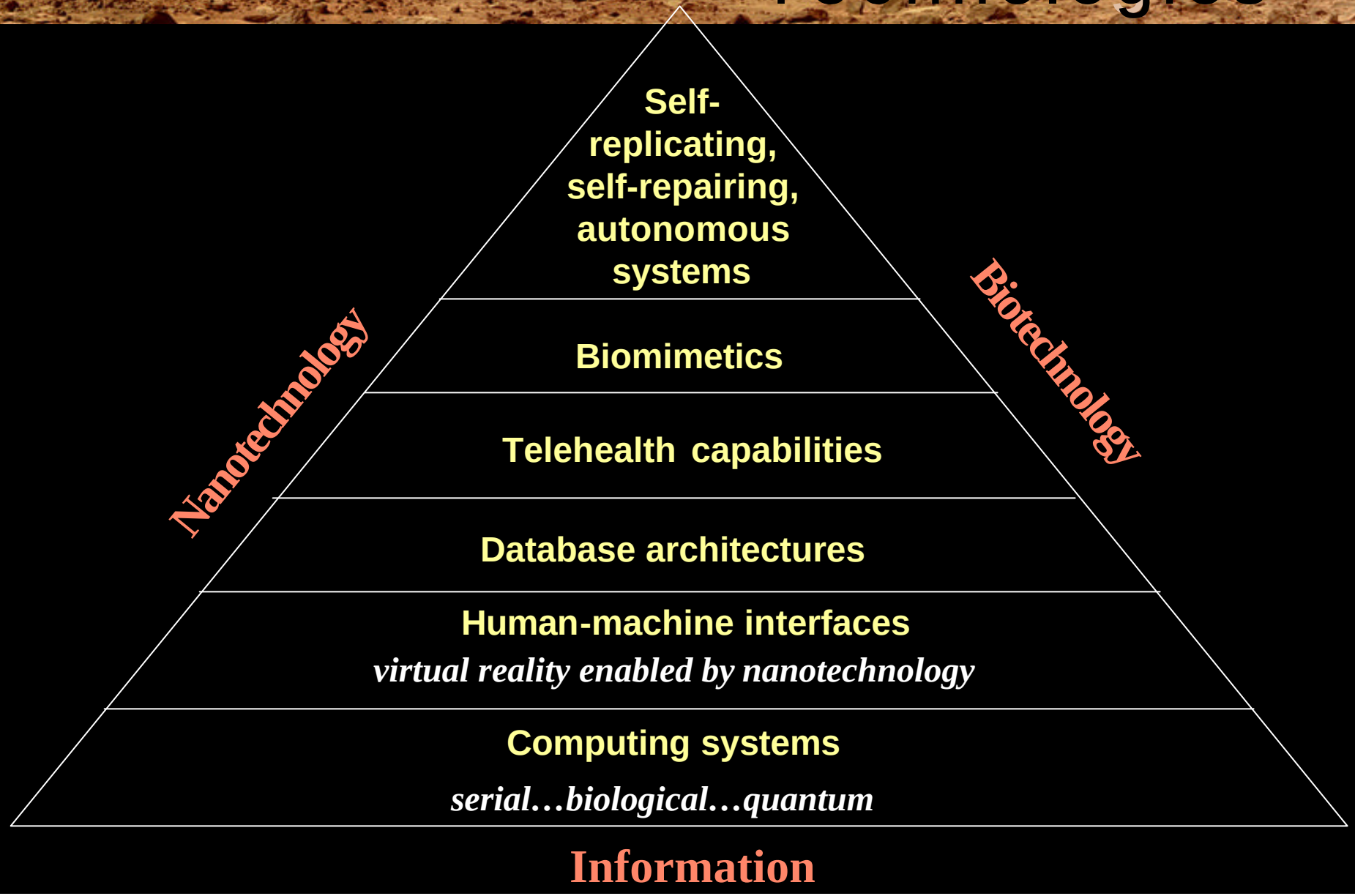


Ataxia	Fluid loss (2 L), BP control	Muscle fiber shift & strength decrease	Reduction 1%/ month

Manifestation

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

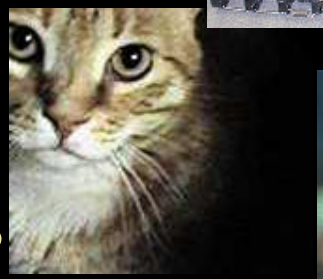
Hierarchy of Medical Technologies

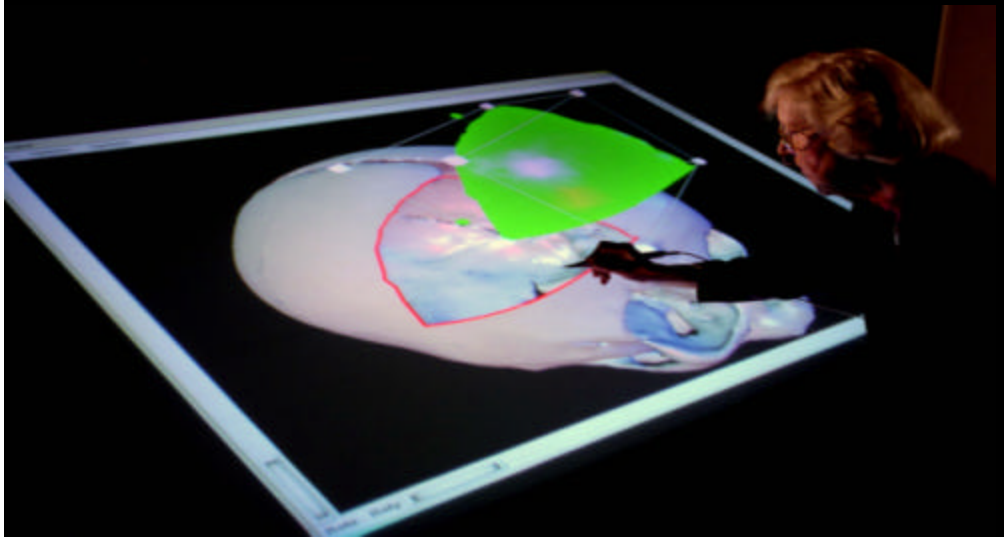


Medical Care Trends

Time and distance = self-sufficiency

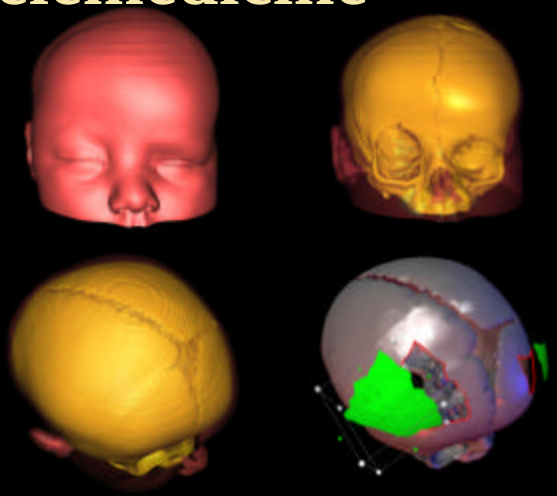
- **Portability**
- **Virtual reality**
- **Haptic "smart" systems**
- **Biologically-inspired technologies**

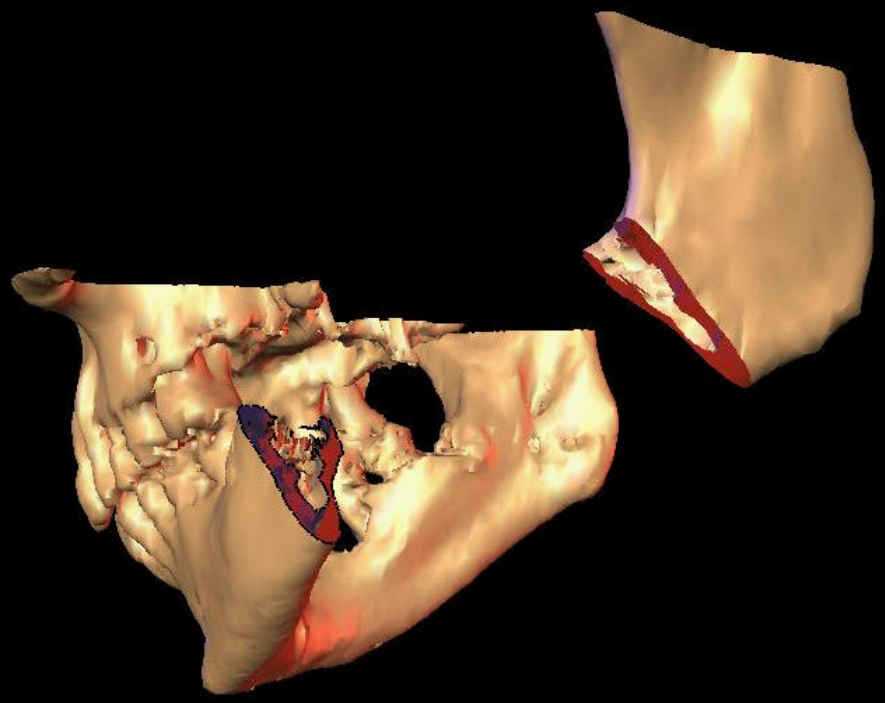




Informatics

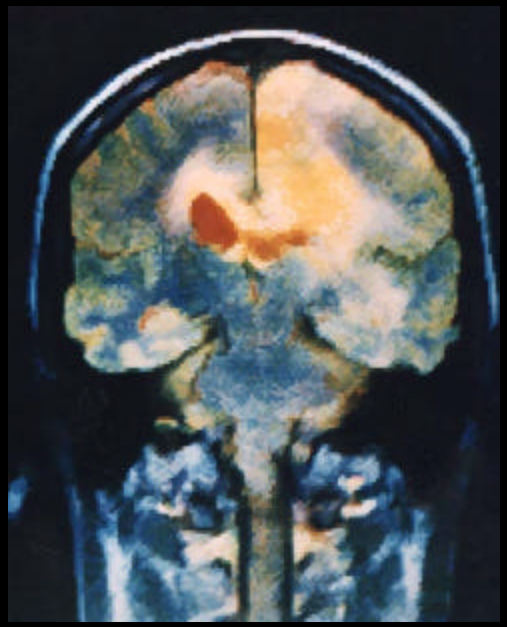
- Biocomputation
- Imaging
- Training and simulation
- Telemedicine





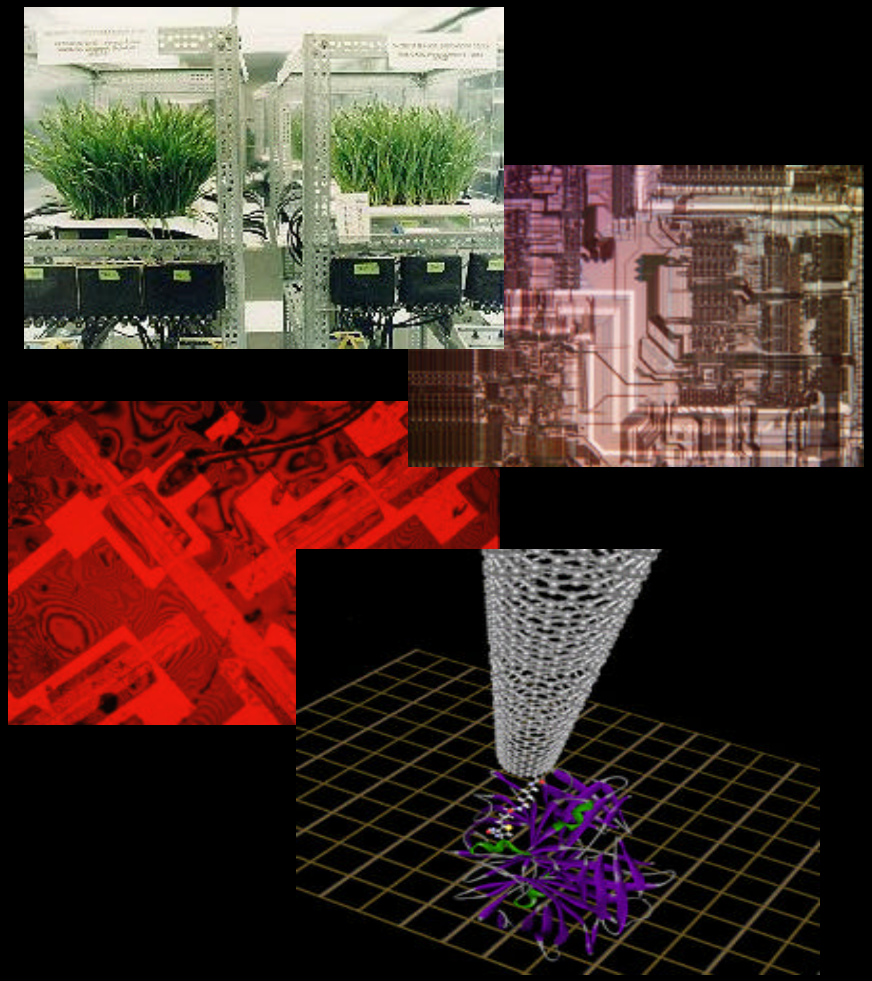
Miniaturization

- **Imagers**
  - X-ray
  - MRI
  - Ultrasound
- **Sensors, effectors, and transmitters**
  - Surgical instruments
  - Analyzers



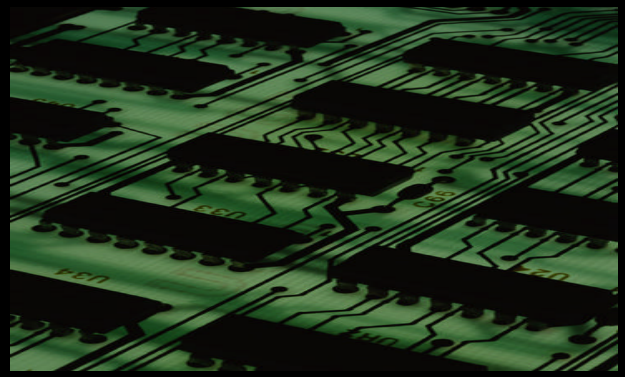
Nanotechnology

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



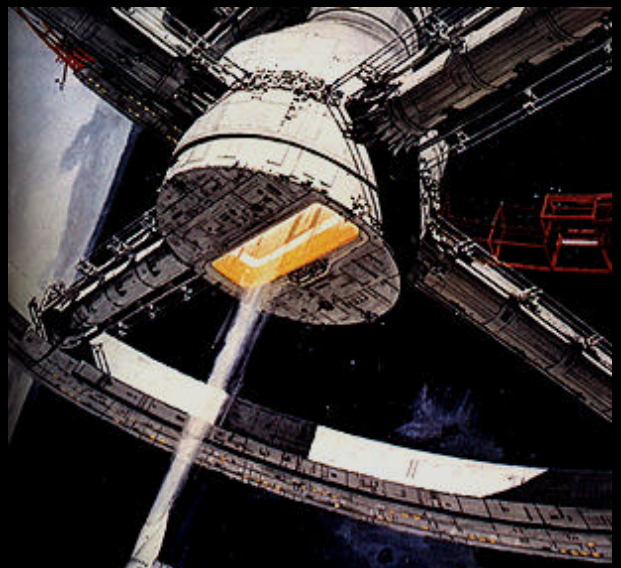
Human-Machine Interface

Human-centered systems are an integral part of mission design

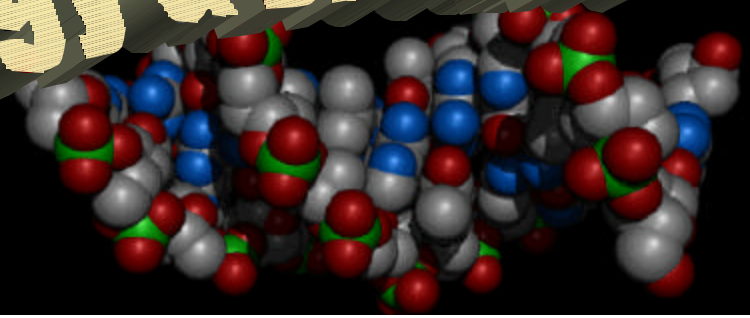


Biology / Medicine

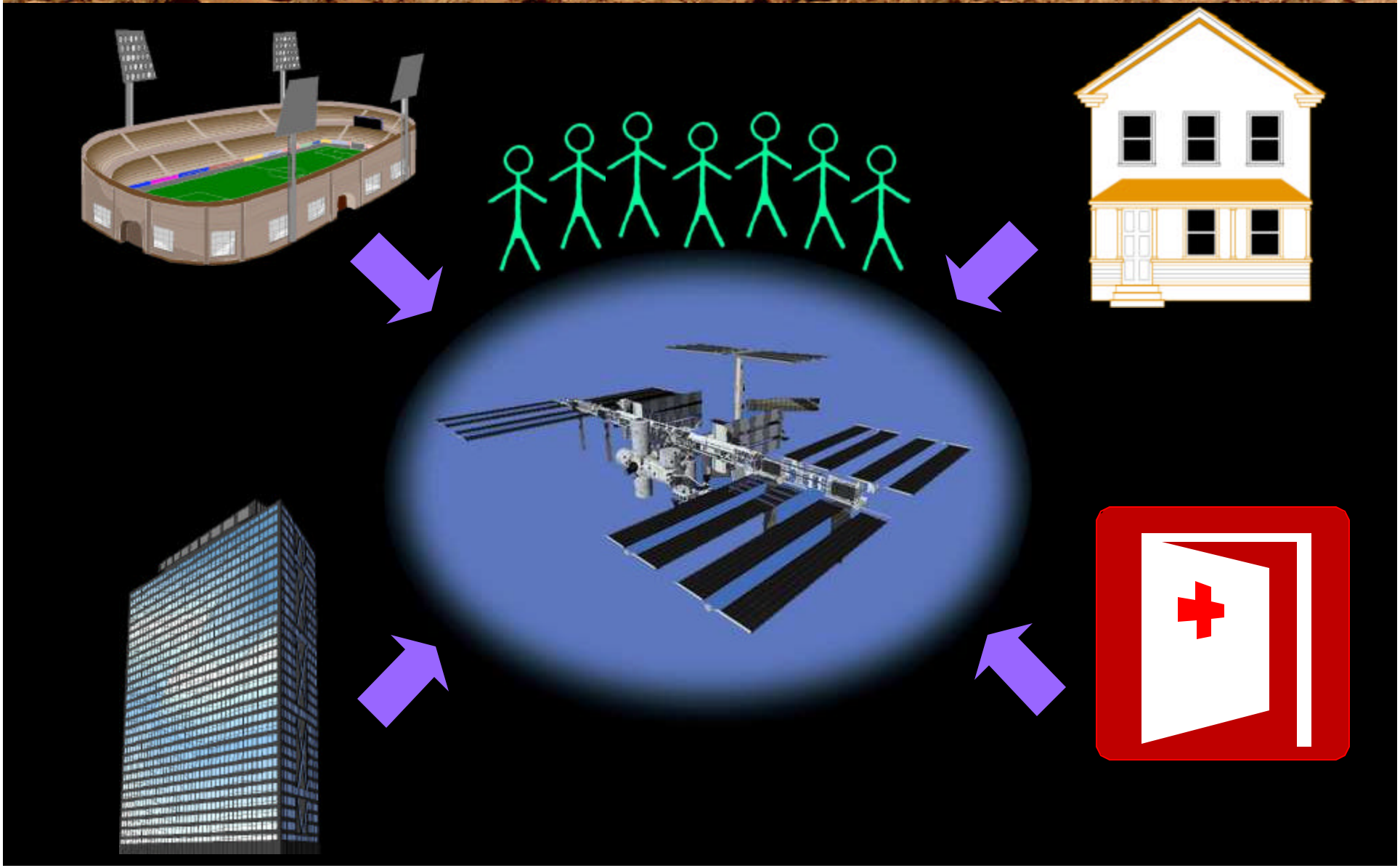
- **Genetic profile of travelers**
  - Tailored medical preparations
  - Individual health maintenance
- **DNA therapies**
  - Countermeasures
    - *artificial gravity as a medical tool*
  - Illness risk reduction
  - Pre-clinical treatments



Technology & Bioethics



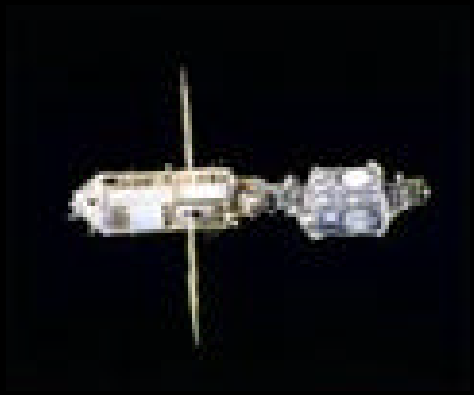
The Multipurpose ISS



Human Support Technology

Today

- **Mechanical**
- **Operator-dependent**

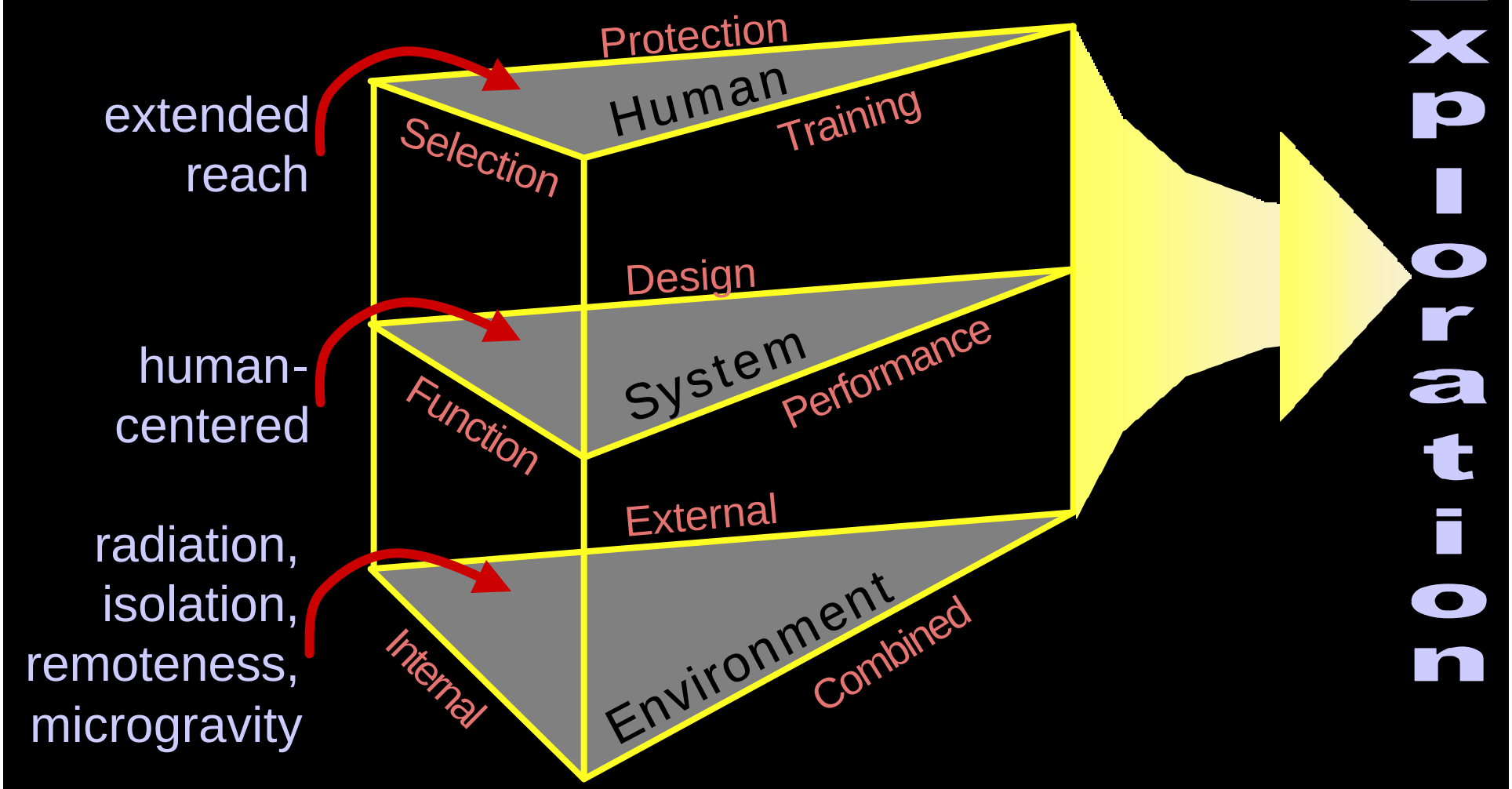


Technological Evolution & Revolution

Tomorrow

- **Adaptive**
- **Autonomous**
- **Self-replicating**
- **Virtual**
- **Human-centered**

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