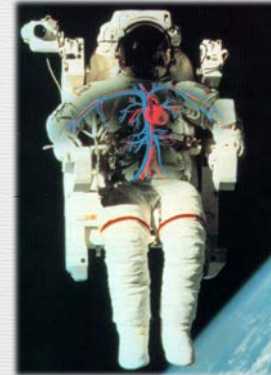




Physical Deconditioning with Space Flight

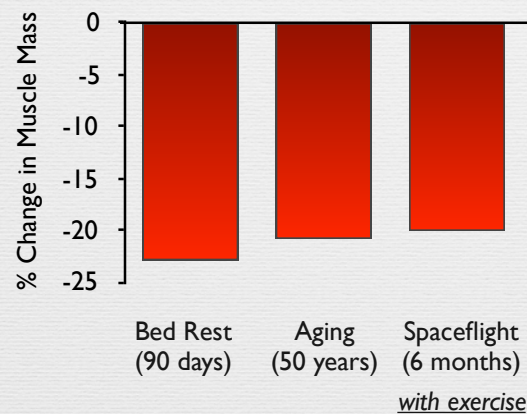


**Cardiovascular
Deconditioning**



**Musculoskeletal
Wasting**

Muscle Wasting



Skeletal Muscle Plasticity



Athletes: ~5 to 10% shift possible



**Unloading: ~20 to 30% shift possible
- preventable with exercise**



**Aging: ~20 to 30% shift possible
- reversible with exercise**



**Extreme disuse (SCI):
~60% shift possible
- partially reversible with E-Stim**

Current Generation Exercise Program



Exercise Astronauts
Like Athletes



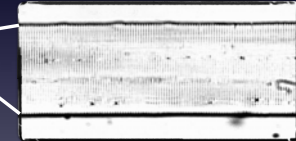
Human Muscle Function with Space Flight



Whole Muscle → Single Fiber



MRI



Human Muscle Fiber
Magnified 400 times

Single Muscle Fiber Performance

Size

Strength

Speed

Power

Single Muscle Fiber Technique

Slow and fast fibers respond differently
to exercise and space flight



Meb Keflezighi
Boston Marathon Winner

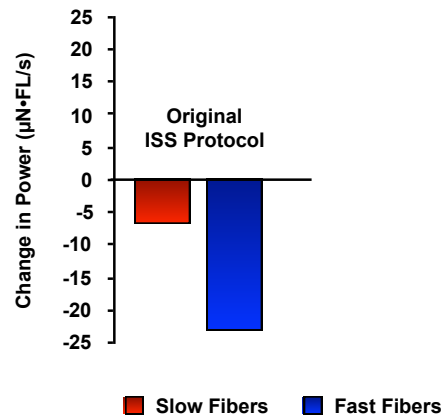
Mostly Slow Fibers



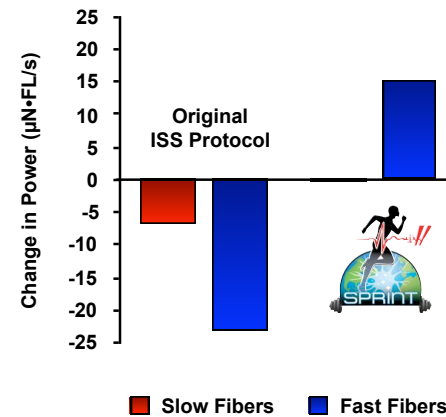
Colin Jackson
World Champion Sprinter

Mostly Fast Fibers

Single Muscle Fiber Power with Space Flight



Single Muscle Fiber Power with Space Flight



Heterogeneity in Skeletal Muscle



New Astronaut data slide to be made

Astronaut Health for a Mars Mission



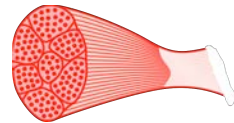
The Health Benefits of Exercise



Heart Health



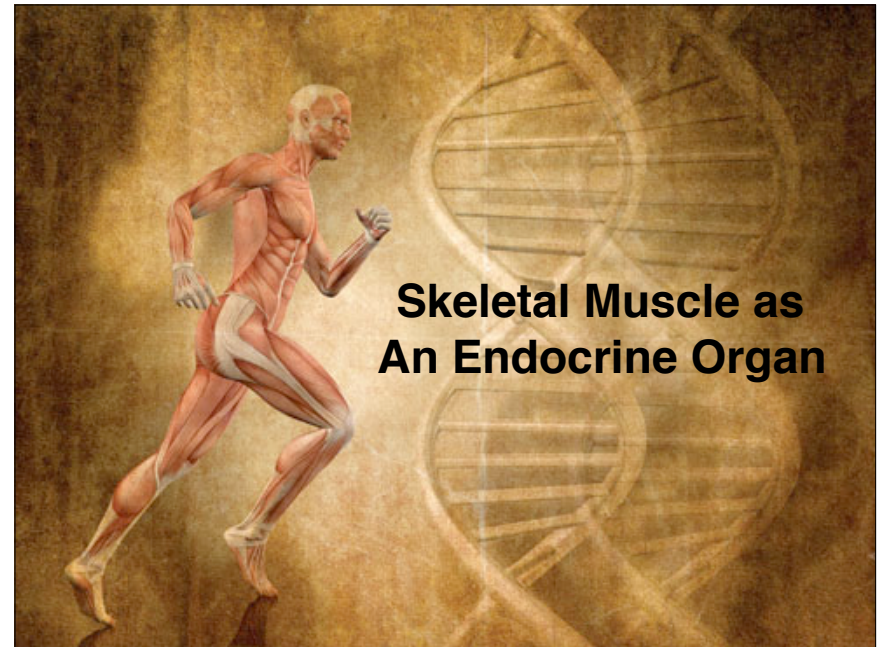
Brain Health



Skeletal Muscle Health

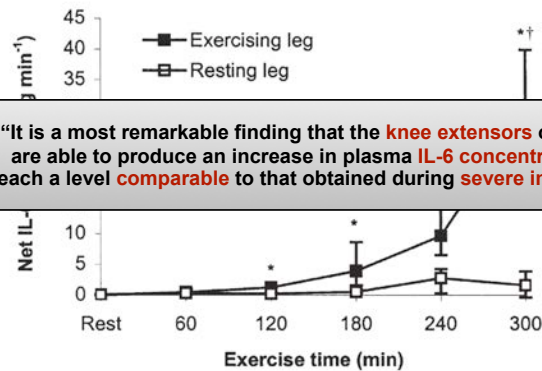


Bone Health



Skeletal Muscle as An Endocrine Organ

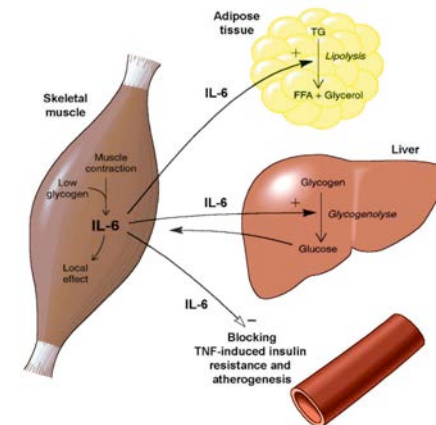
Skeletal Muscle Contraction Induced IL-6 Release



"It is a most remarkable finding that the **knee extensors** of the leg are able to produce an increase in plasma **IL-6 concentration** to reach a level **comparable** to that obtained during **severe infections**"

J Physiol 529: 237-244, 2000

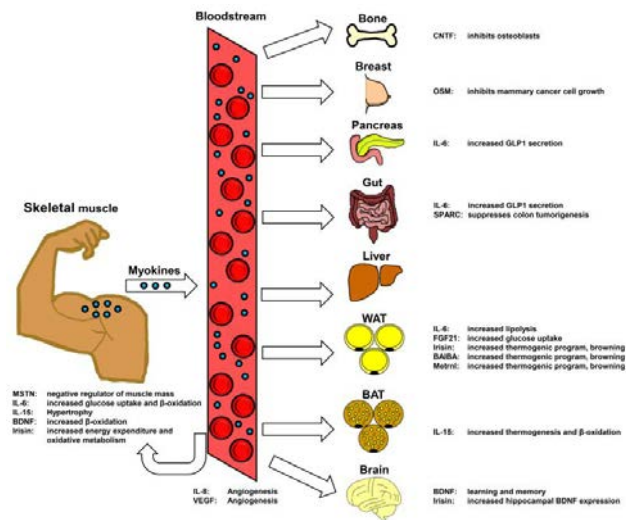
Muscle-Derived IL-6: A Biological Role?



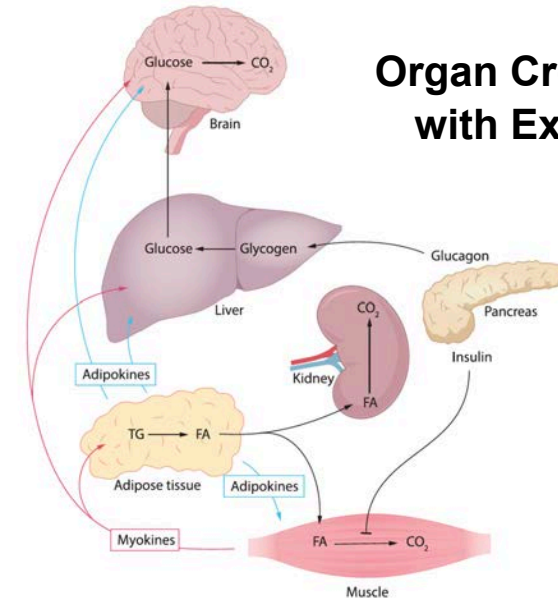
Muscle-derived IL-6 purported to work in a hormone-like fashion, contributing to maintenance of glucose homeostasis during exercise

J Physiol 536: 329-237, 2001

Myokines are Pluripotent

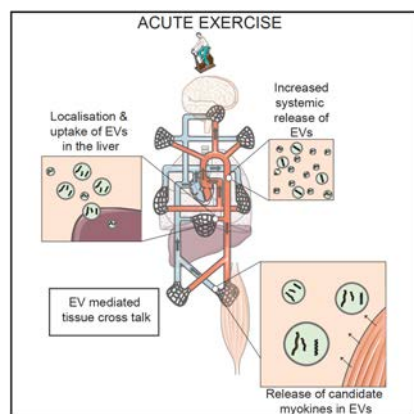


Organ Cross-Talk with Exercise



Gabriel & Zierath *Cell Metabolism* 25: 1000-1001, 2017

Exosome Biology and Exercise

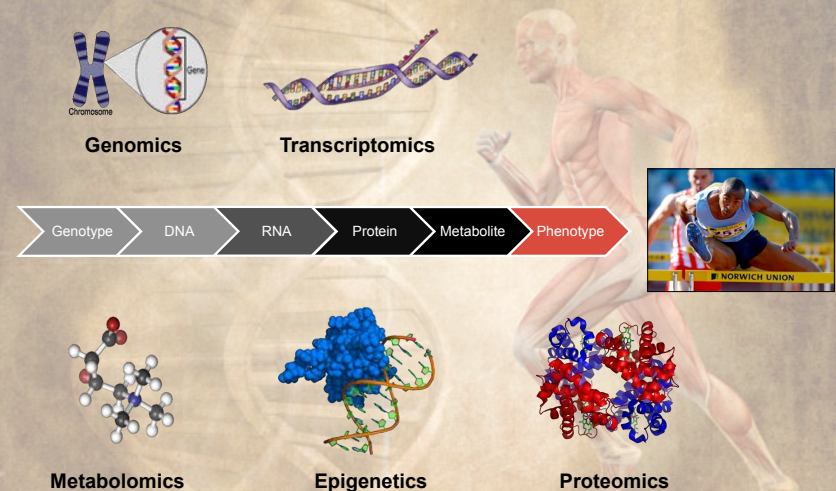


What Are Exosomes?

- Exosomes are small vesicles
- Released from skeletal muscle into circulation with exercise
- Carry cargo (i.e. proteins and myokines) to other tissues
- Novel and powerful communication network

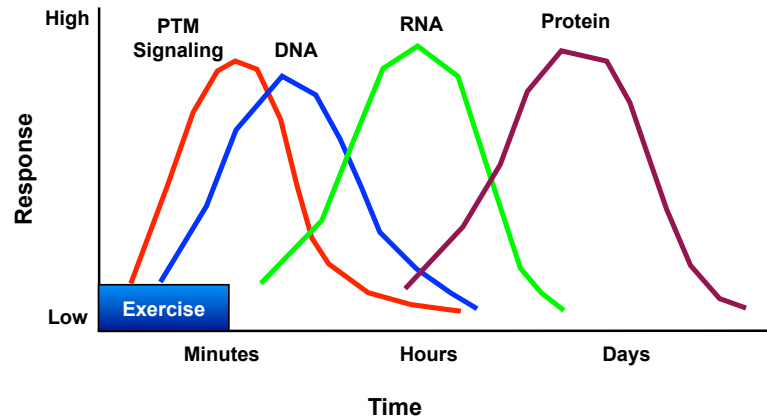
Whitham *Cell Metabolism* 27: 237-251, 2018

Functional Genomics and Health

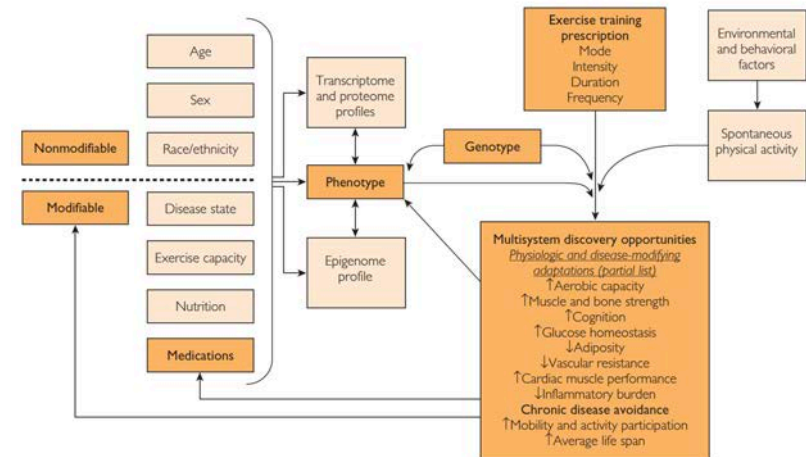


Molecular Transducers with Exercise

Conceptual Framework from Available Data



Exercise Biology Discovery



Mayo Clin Proc 89: 148-153, 2014



The Athlome Project Consortium



A Concerted Effort to Discover Genomic and other "OMIC" Markers of Athletic Performance



Molecular Transducers of Physical Activity Consortium (MoTrPAC)

National Institutes of Health
\$170 Million (2017-2023)

Largest, most complex and highly coordinated human exercise physiology training study in the history of the field





Goal: Assemble a genetic map of the health benefits of exercise



56 years of Exercise in Space



John Glenn
First Exercise in Space
Bungee Device
2/20/1962

*<10 Physiological
Variables Measured*



Skylab - 1970's
First Multifaceted Exercise
Program

*100's of Physiological
Variables Measured*

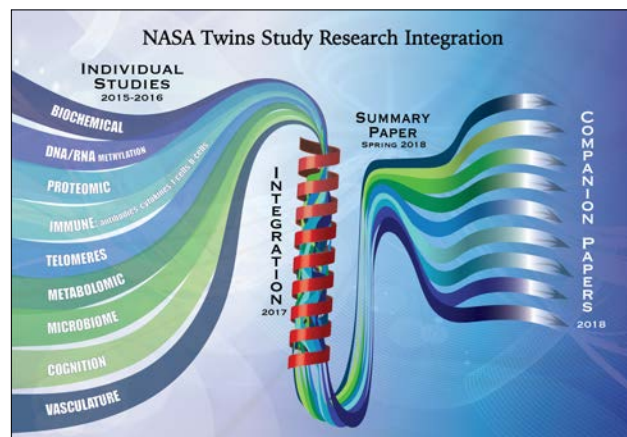


Space Shuttle Era
More Complex Measures
More Organ Systems

*1000's of Physiological
Variables Measured*



New Frontiers in Space Medicine



100,000's of Physiological Variables Measured

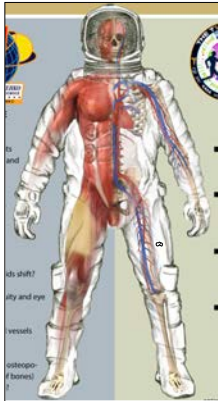


Take Home Message

- High degree of plasticity (all organs)
- Skeletal muscle is an endocrine organ
- Exercise triggers biological events lasting from minutes to hours to days
- Exercise stimulates numerous organ systems (pluripotent and multi-system cross-talk)
- Molecular transducers (“-omics”) is an emerging and maturing frontier of discovery



Exercise is Medicine



Whole body to Gene

- ✓ Exercise Heterogeneity
- ✓ Exercise Dose Response
- ✓ Organ Cross-Talk
- ✓ Functional Genomics

*Health Effects Observed on
Earth and in Space*



Human Performance Laboratory Ball State University



Funding & Collaborators



Robert Fitts and Danny Riley



Shawn Estrem, Hui-Rong Qian
Leah Helvering, Rosamund Smith



Alex Freeman, Nigel Walk
Colin Jackson



Per Tesch and Bjorn Alkner

ISS and Bed Rest Teams

Hagens Team
Biolo Team
Muscle Team
MEDES Team
Wyle Laboratories
MRI Technicians
Exercise Trainers
Simone Thomas - NASA



Exercise is Medicine