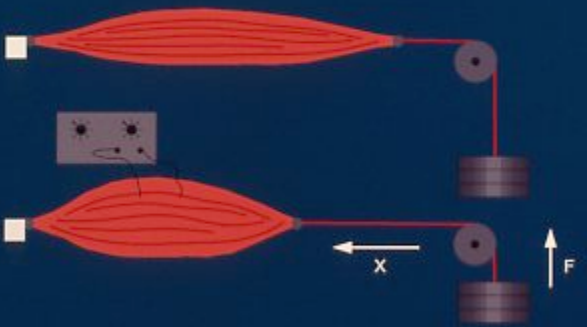
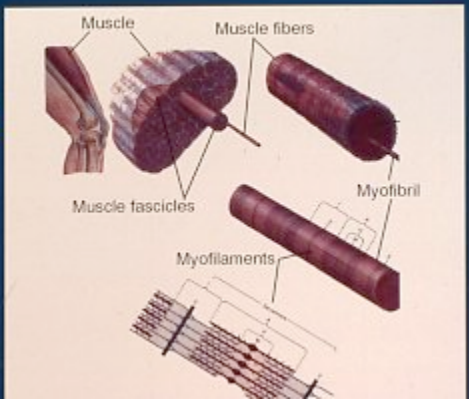
Rationale for Excercise in Space Flight

W. Thornton, M.D.

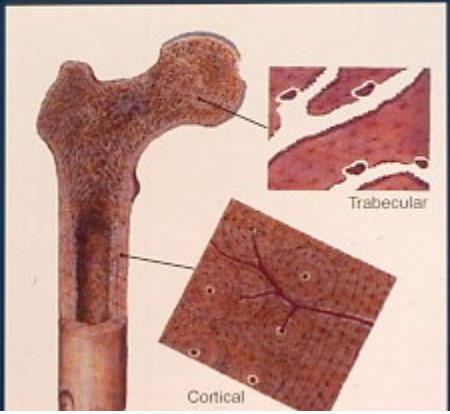
Muscle Contraction



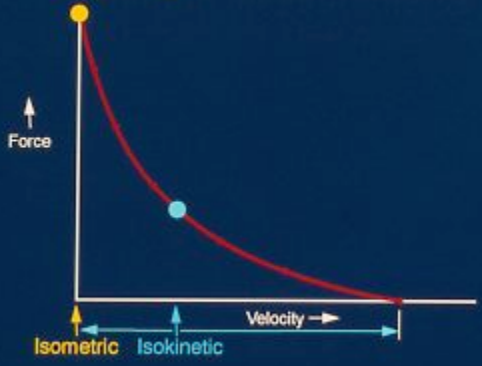
Skeletal Muscle Fiber Arrangement



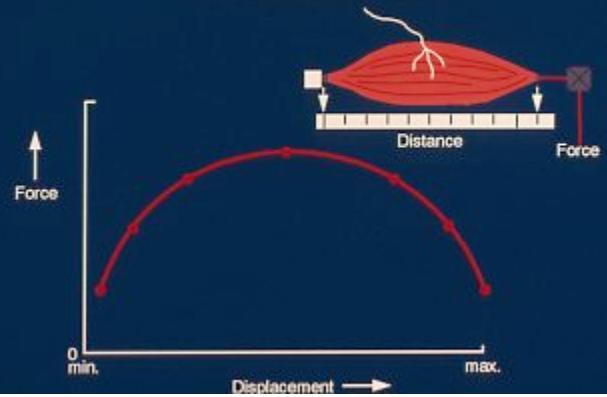
Structure of Bone



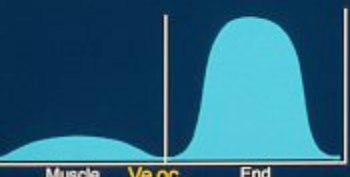
Strength Measurements

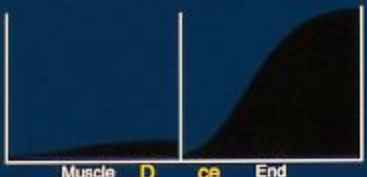


Force/Distance

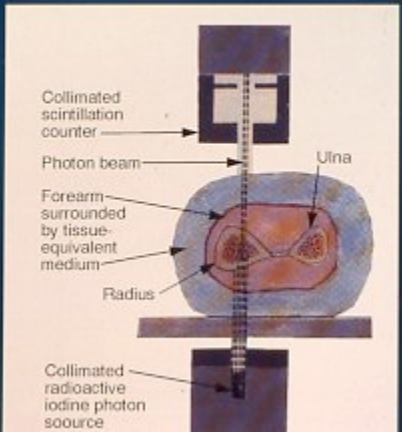


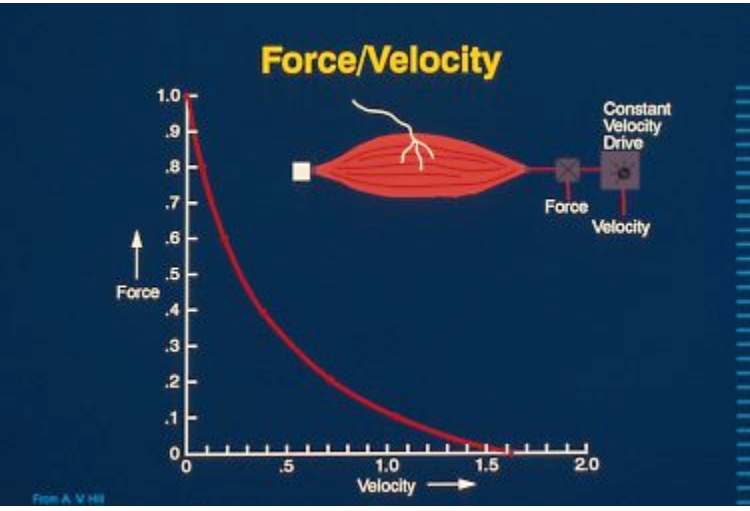
Arm Leverage



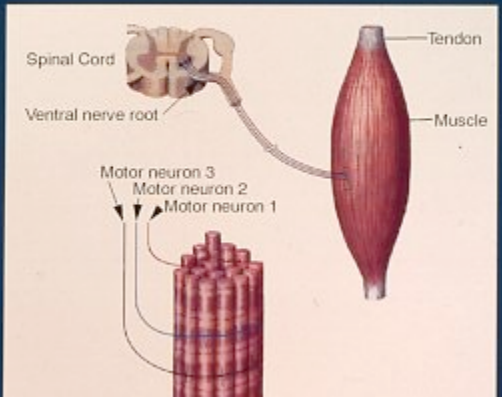


Single-Photon Absorptiometry




Force/Velocity
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
Force
0
.5
1.0
1.5
2.0
Velocity
Constant
Velocity
Drive
Force
Velocity
From A. V. Hill

Nerve Supply



Shoulder Joint

Musculoskeletal Effects of Weightlessness

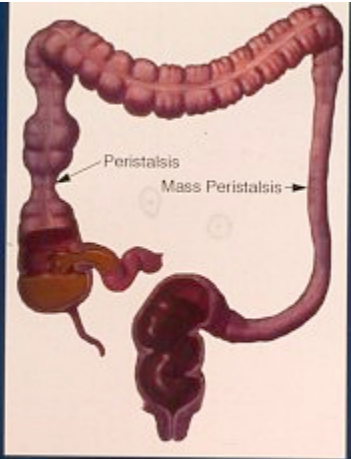
These findings led Rambaut and Johnston to postulate that a year of weightlessness could result in a loss of 25% of the body's total calcium reserve, 99% of which is stored in bone apatite.

Results of studies of metabolic balance also showed a profound loss of total body nitrogen, reflecting a concomitant precipitous loss of muscle mass.

Astronauts on later Skylab missions excercised vigoroulsy, but this did not restore or lessen their calcium loss.

Osteoporosis caused by weightlessness is more severe and unrelenting than any form of disuse osteoporosis.

First, the prolonged time in space required for interplanetary travel is likely to result in the severe and permanently disabling complications of profound osteoporosis.



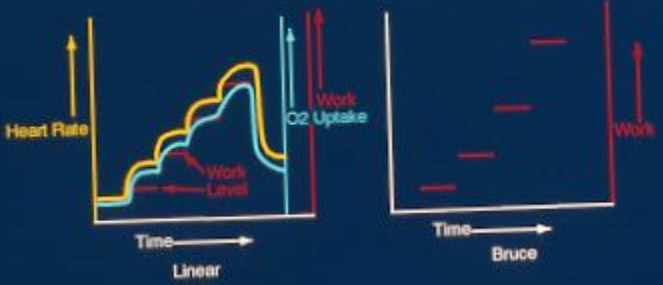
From Netter

Calcium Balance

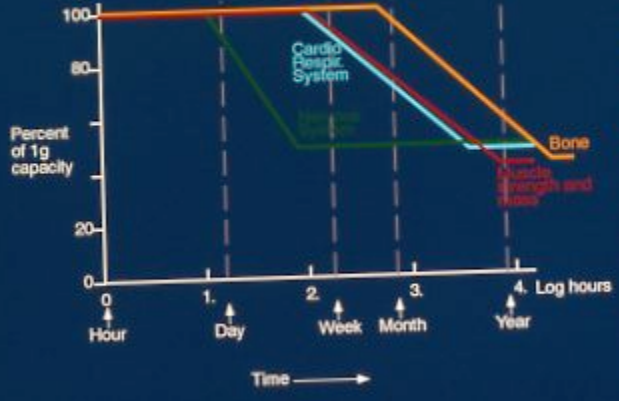
$$\text{Balance} = \frac{Ca^{++}\,(out)}{Ca^{++}\,(in)}$$

Stress Tests

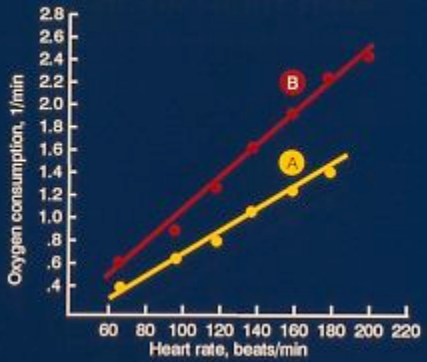
$\dot{V}O_2$ $\frac{\text{ml. } O_2 \text{ (consumed)\min}}{\text{Kg. (of body mass)}}$



Time Course of Adaptation to Weightlessness



$\dot{V}O_2$ vs. Heart Rate



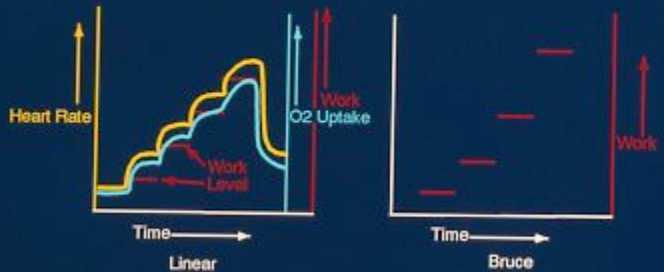
Energy Balance

Balance

In = Basic requirements
+ Physical Work
± Fat (stored)

Stress Tests

$\dot{V}O_2$ $\frac{\text{ml. } O_2 \text{ (consumed)\min}}{\text{Kg. (of body mass)}}$



Energy Division

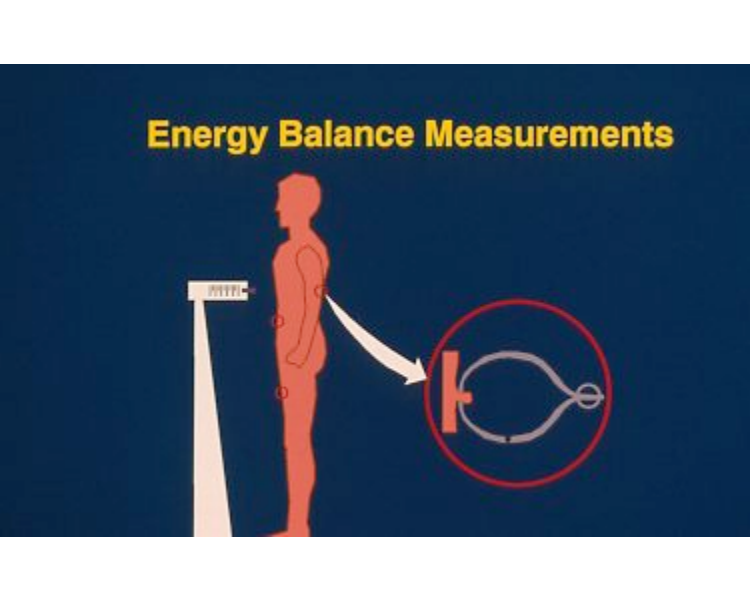
Resting Metabolic Rate (~60-75%)

- Sleeping metabolism
- Basal metabolism
- Arousal metabolism

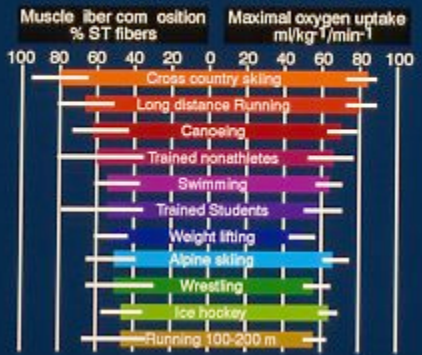
Thermic effect of feeding (±10%)

Thermic effect of physical activity (±15-30%)

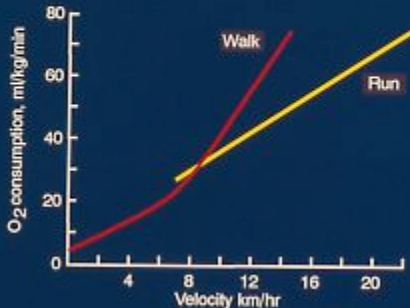
Energy Balance Measurements



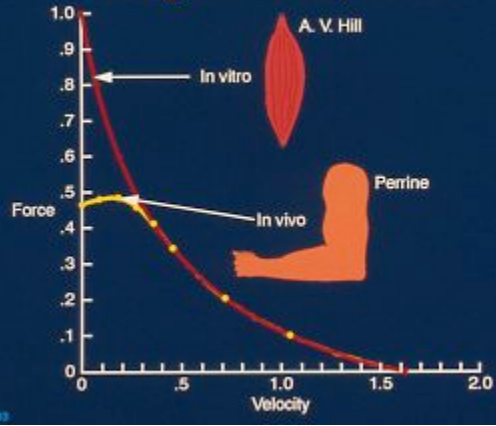
Fiber Composition



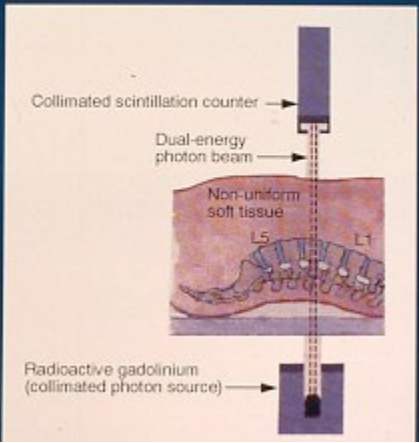
$\dot{V}O_2$ vs. Heart Rate



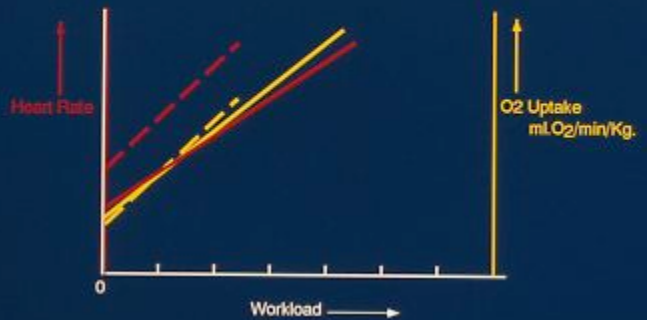
Strength in vivo, in vitro



Dual-Photon Absorptiometry



Individual Response to Aerobic Training (Metabolic)



Species Adaptations

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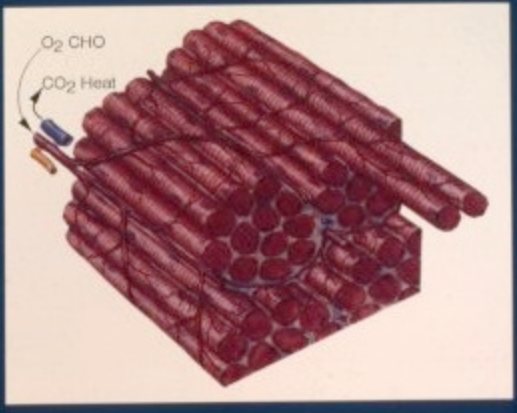
Gender Adaptation

Blood Supply



From Netter