Lecture 3:Forces and Torques&Body Mechanics


Laura Wilkinson

Forces and the Body

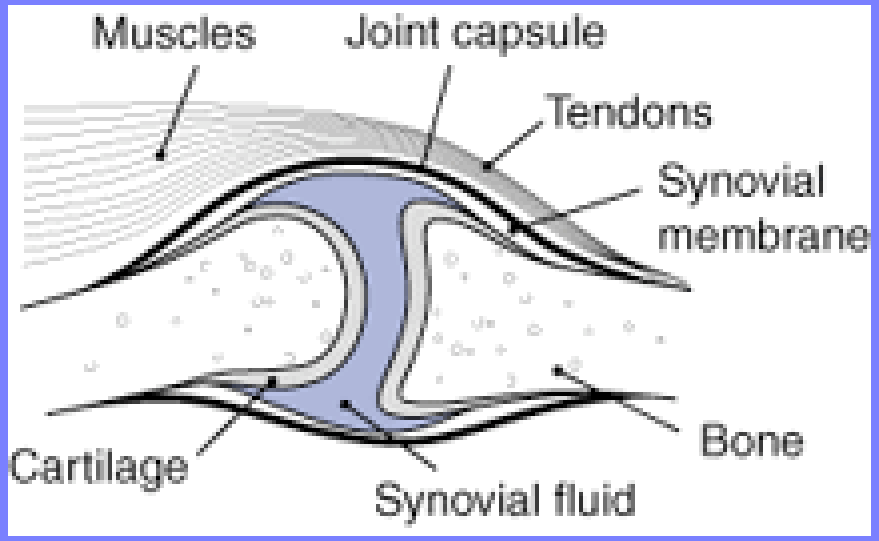
- Electro-chemical forces
  - Chemical binding
  - Nerve conduction
  - Muscle fibers
- Body Forces
  - Gravity (mg)
  - Friction (Electromagnetic)
  - Air resistance (friction)

- **Other Forces:**
  - Magnetic (show brain activity -- NMR)
  - Strong Nuclear Force (Binds Nucleus)
  - Weak Nuclear Force (Radioactivity)

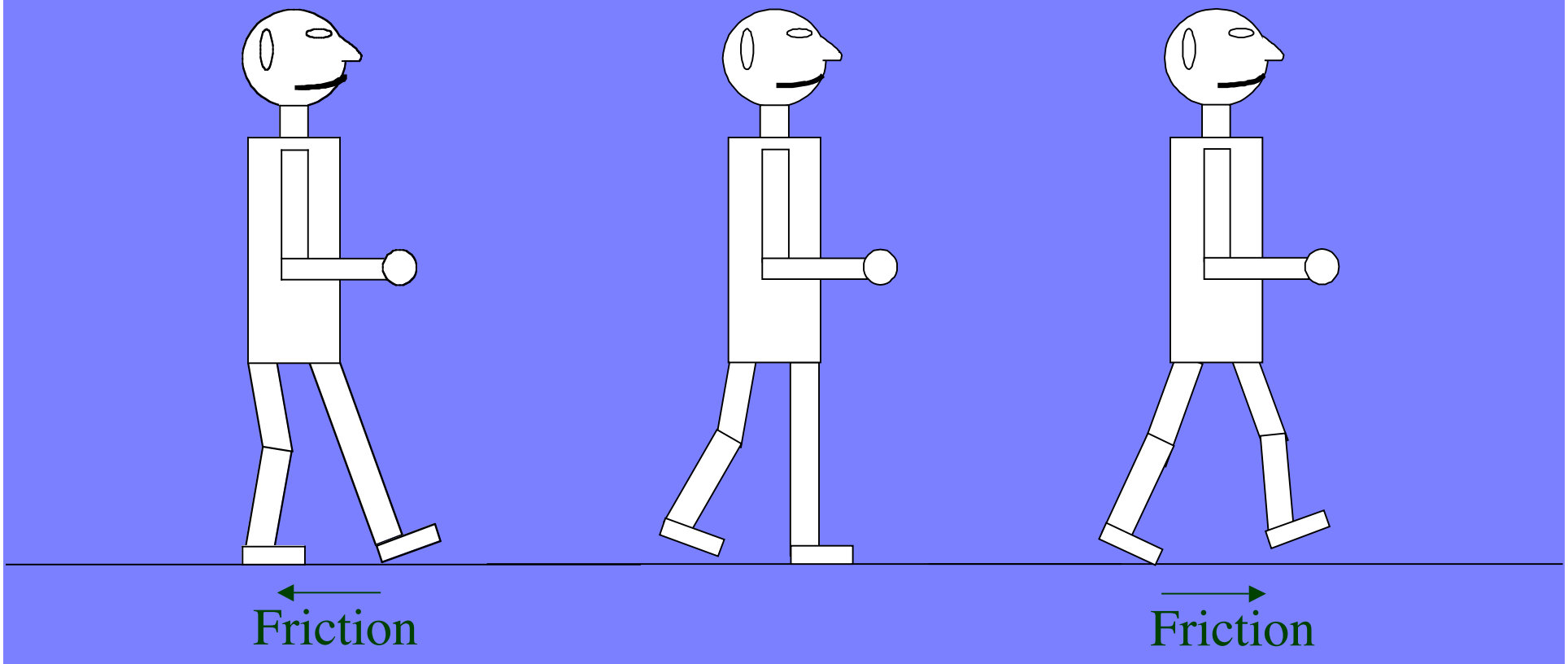
Friction

- Materials in contact make and break weak bonds
- Sliding friction and static friction are different
- Static Friction ($F_f < \mu N$)

Reduced Friction in Joints



WALKING

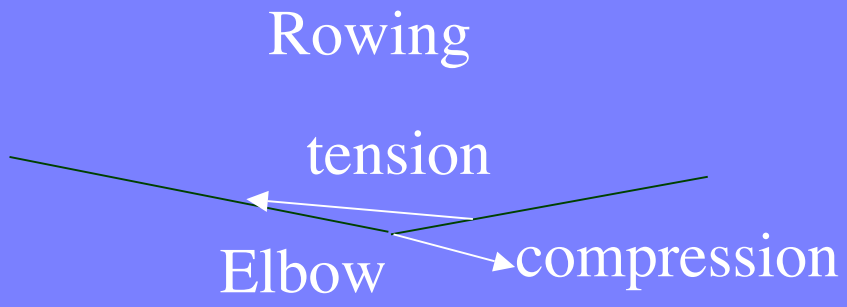


Coefficients of Friction:

Rubber Heel on Road	1.00 (dry)
Steel on ice (skating)	0.03
Steel on steel (ouch)	0.15
Cartilage (joint)	0.003
Tendon and sheath	0.013

Joints: Where Muscle Meets Bone

- Muscles Contract and Pull -- TENSION
- Bones Compress and Push -- COMPRESSION

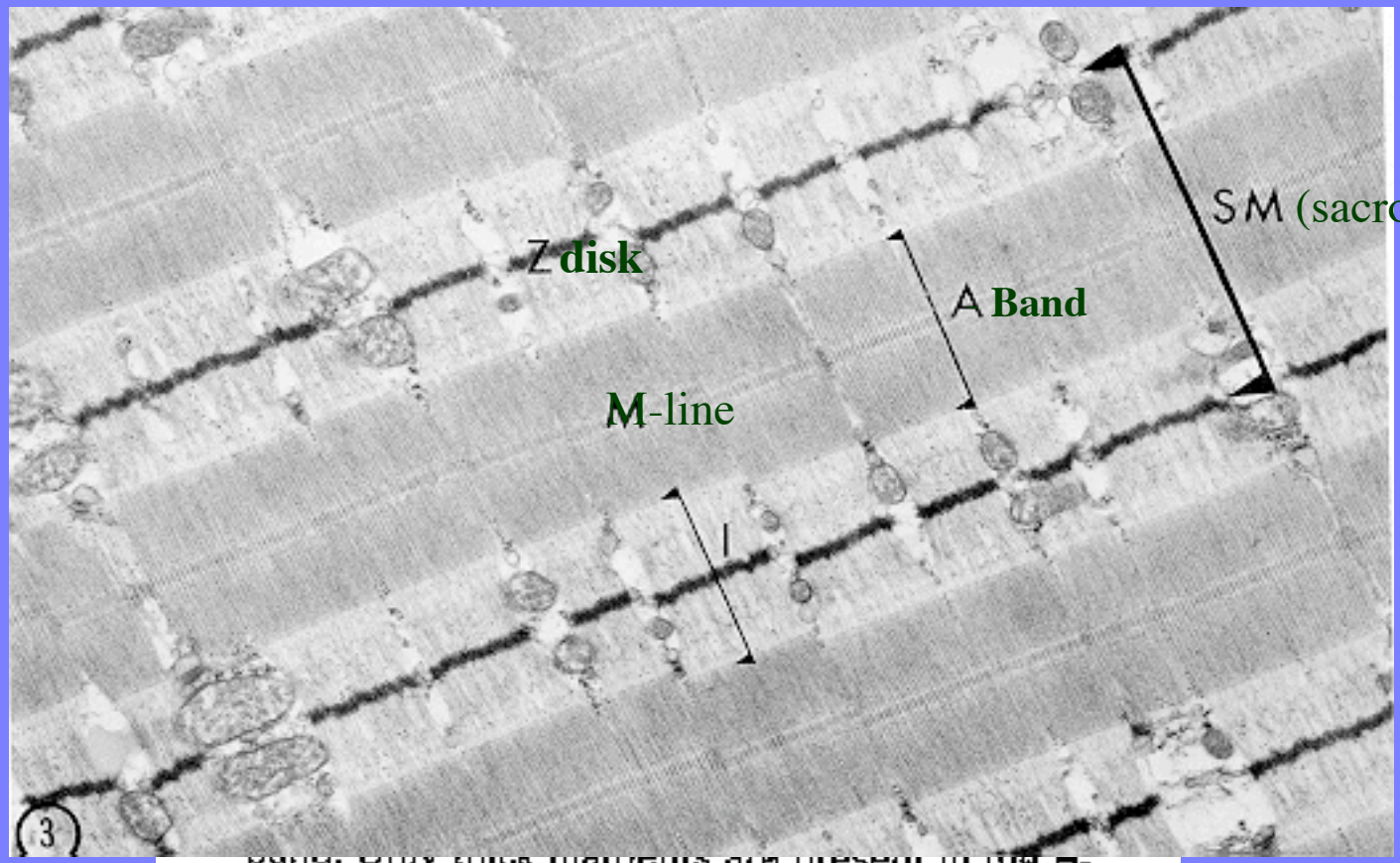


Muscle and Bone Work as Levers

Muscles Contract

- Protein Filaments
  - Actin (5 nm x 1.5 □m) forms filaments
  - Myosin II (10 nm x 2 □m) ATP energy source
  - Ca^{++} activated: negative myosin heads -> positive actin end
- Skeletal Muscle
  - Striated
  - Fast (0.1 sec)
  - Move bones
  - Connect to tendons
  - Fibers/cells fuse
    - 1-2 cm long
    - 100 □m diameter
  - Myofibril units
  - 15-20% contraction
- Cardiac muscle
  - Striated
  - Slower (1 sec)
  - Involuntary
  - Single nucleus cells
  - Synchronized contractions
- Smooth muscle
  - Non-striated
  - Slower (few sec)
  - 100% contraction
    - Sphincters
    - Paristolic channels
    - Arterial walls

Muscle Contraction:
Actin and Myosin II Fibers Slide

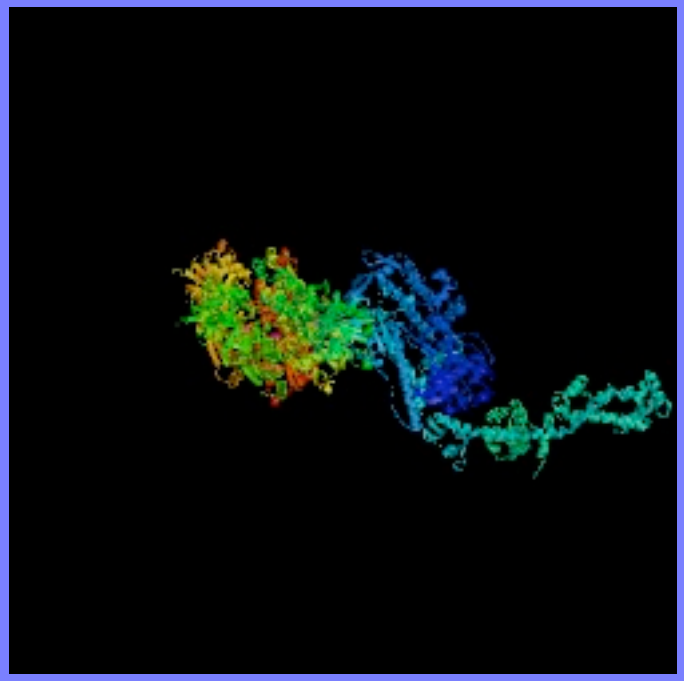


zone of the A-band. In the A-band it is seen that six actin filaments surround each myosin filament. This is the pattern found in rabbit psoas muscle, and other arrangements are found in different animals.

(thin) actin filament

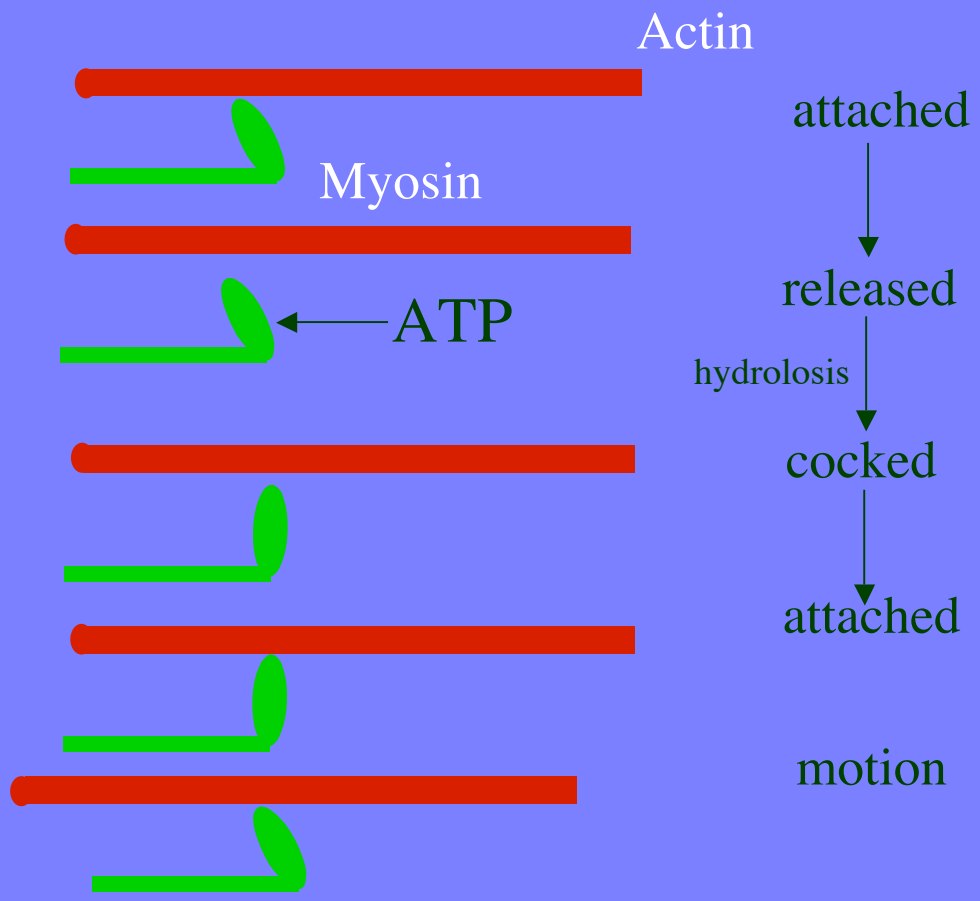
(thick) myosin II

Myosin Head "Walks" to + end of Actin



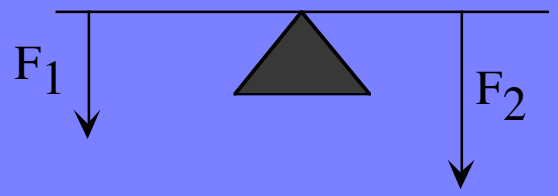
Myosin with Globular Head

Myosin II head hydrolizes ATP producing structural (allosteric) changes - a kind of lever.

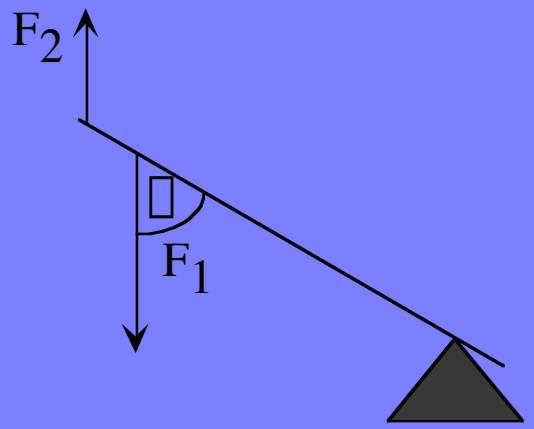


Skeletal Levers

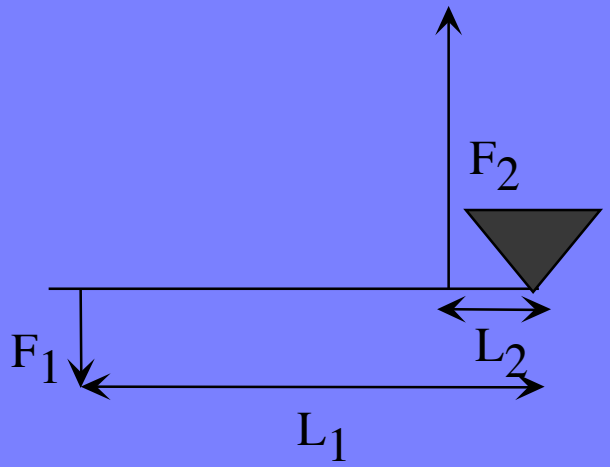
- First Class Lever



- Second Class
  - TippyToes

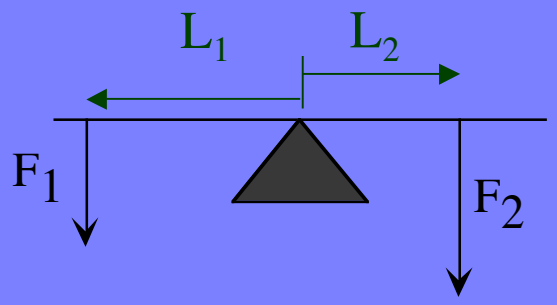


- Third Class:
  - Forearm Curl



Levers

First Class Lever



Torque: $\tau = FL \sin \theta$

$$F_1L_1 - F_2L_2 = 0$$

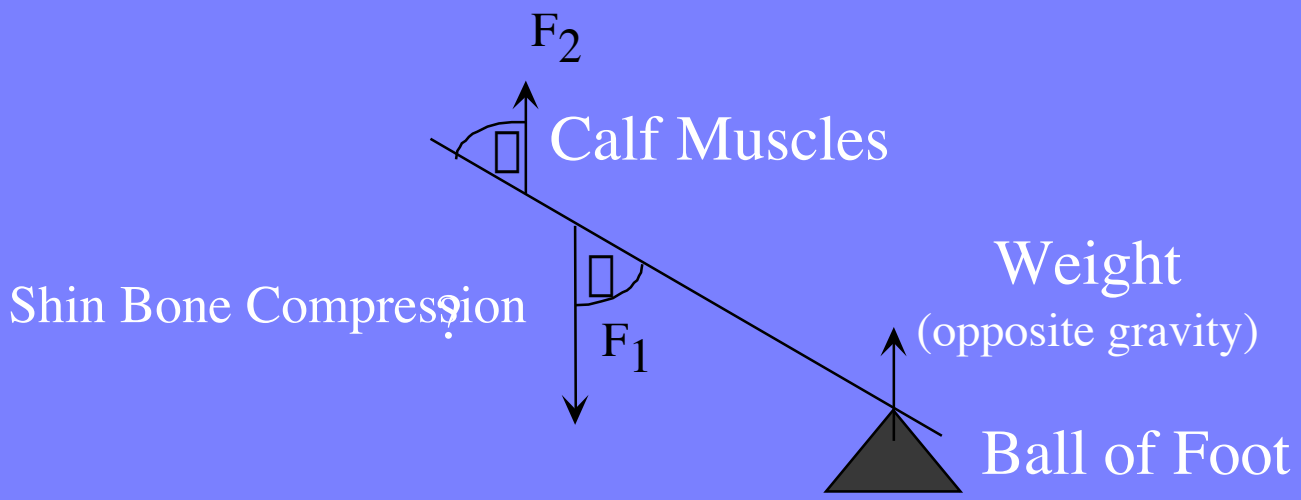
torques balance

$$F_1 + F_2 = F_{fulcrum} \text{ (up)}$$

forces balance

Tippy Toes

Second Class Lever



Torque: $\tau = FL \sin \theta$

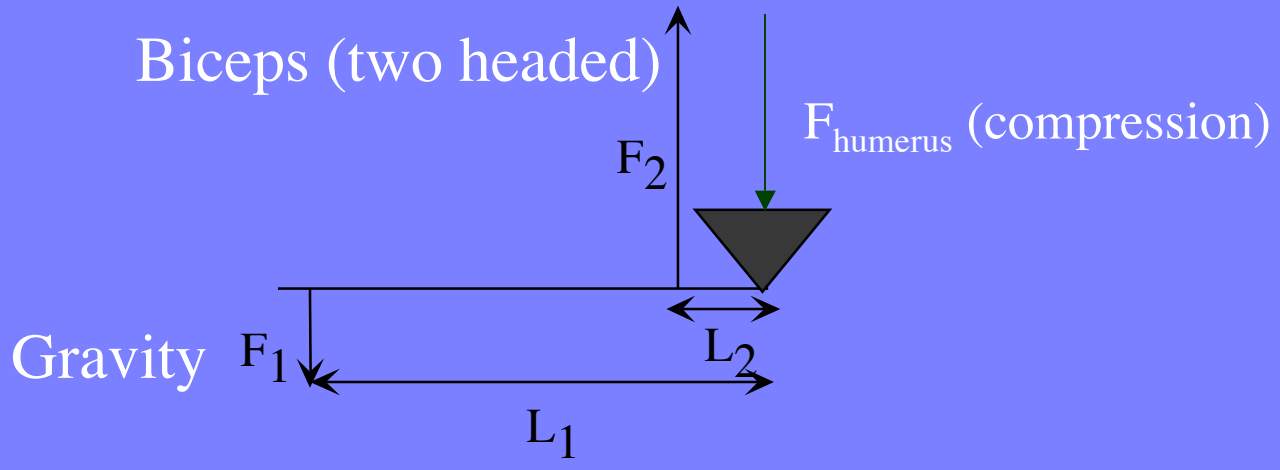
$F_1L_1 - F_2L_2 = 0$

$F_1 - F_2 = F_{gravity}$ (weight)

Skeletal Levers

Third Class:

Forearm Curl

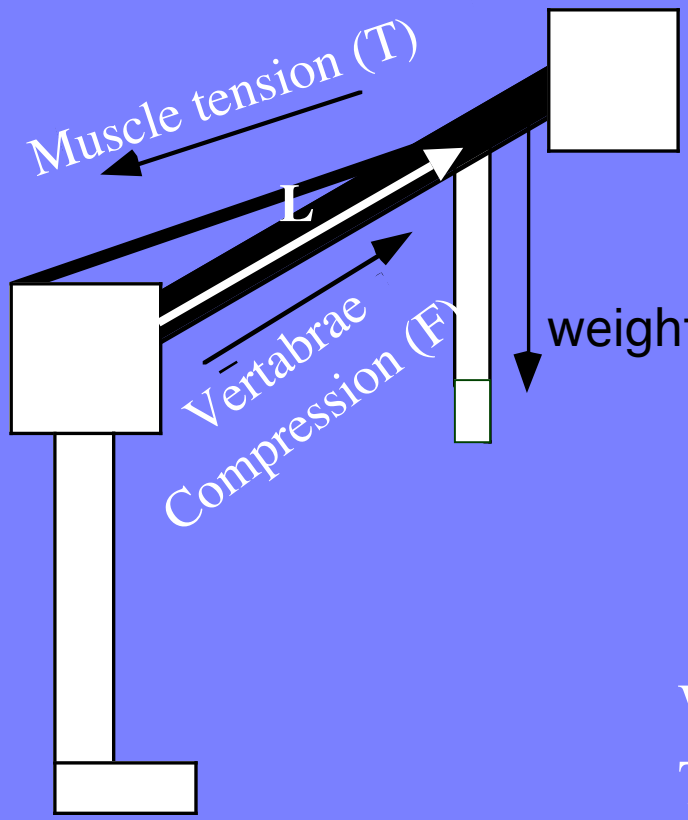


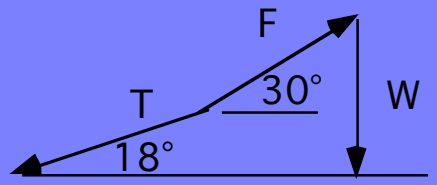
Torque: $\tau = FL \sin \theta$

$F_1L_1 - F_2L_2 = 0$

$F_2 - F_1 = F_{humerus}$ (down)

HEAVY LIFITING





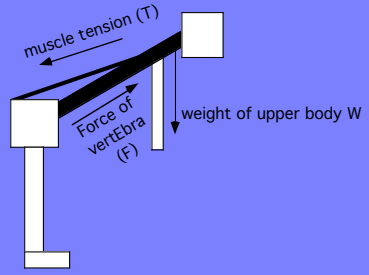
WL sin 60° - 3/4L T sin 12° = 0

T = 5.6 W

W= Fsin 30° - T sin 18°

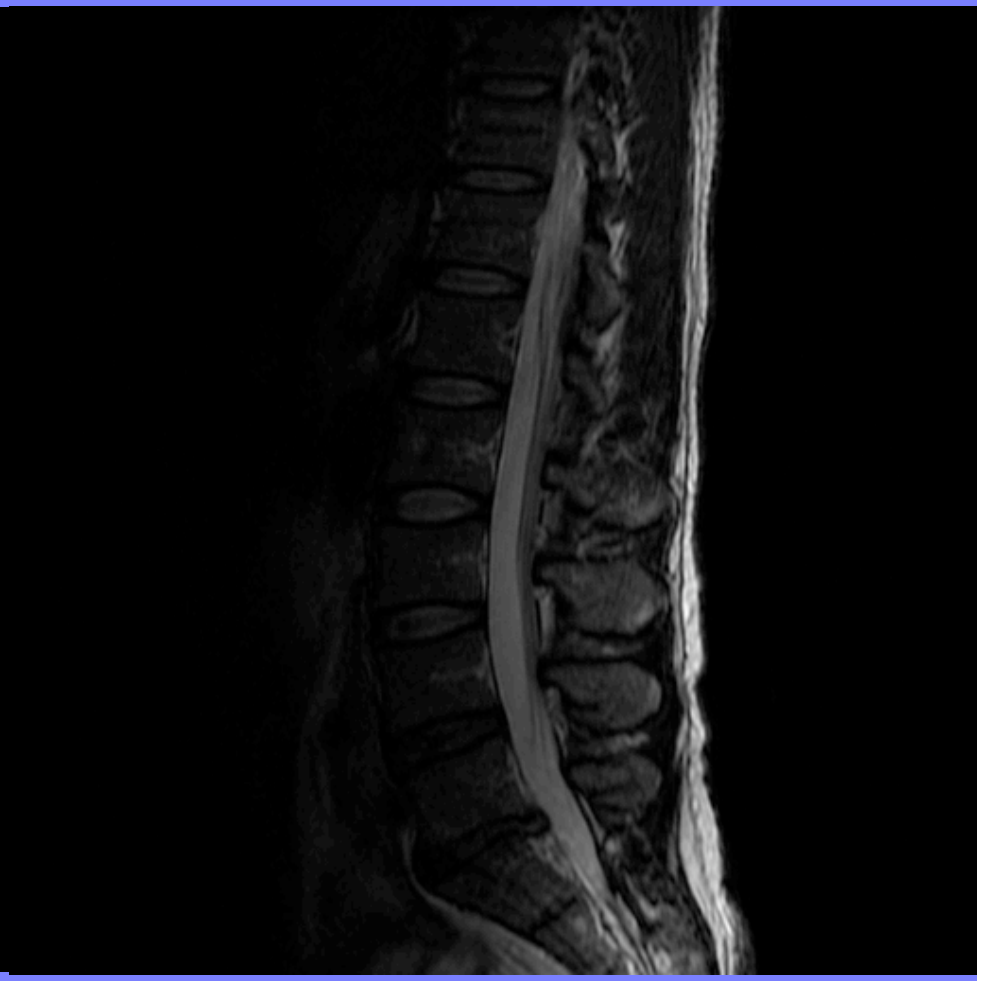
= 0.5 F - 1.7 W

F = 5.4 W



Don’t do it!!!

Proton Spin Density MRI



T_2 weighted MRI

Lecture 3: Physics of the Skeleton