Basic Concepts of Biomechanics

Anatomy and Physiology of Human Movement

Outline

- Introduction
- Levers
- Anatomical Levers
- Laws of Motion

Biomechanics

- Biomechanics - study of the mechanics as it relates to the functional and anatomical analysis of biological systems and especially humans
  - Necessary to study the body's mechanical characteristics & principles to understand its movements

Biomechanics

- Mechanics - study of physical actions of forces
- Mechanics is divided into:
  - Statics
  - Dynamics

Biomechanics

- Statics - study of systems that are in a constant state of motion, whether at rest with no motion or moving at a constant velocity without acceleration
  - Statics involves all forces acting on the body being in balance resulting in the body being in equilibrium
- Dynamics - study of systems in motion with acceleration
  - A system in acceleration is unbalanced due to unequal forces acting on the body

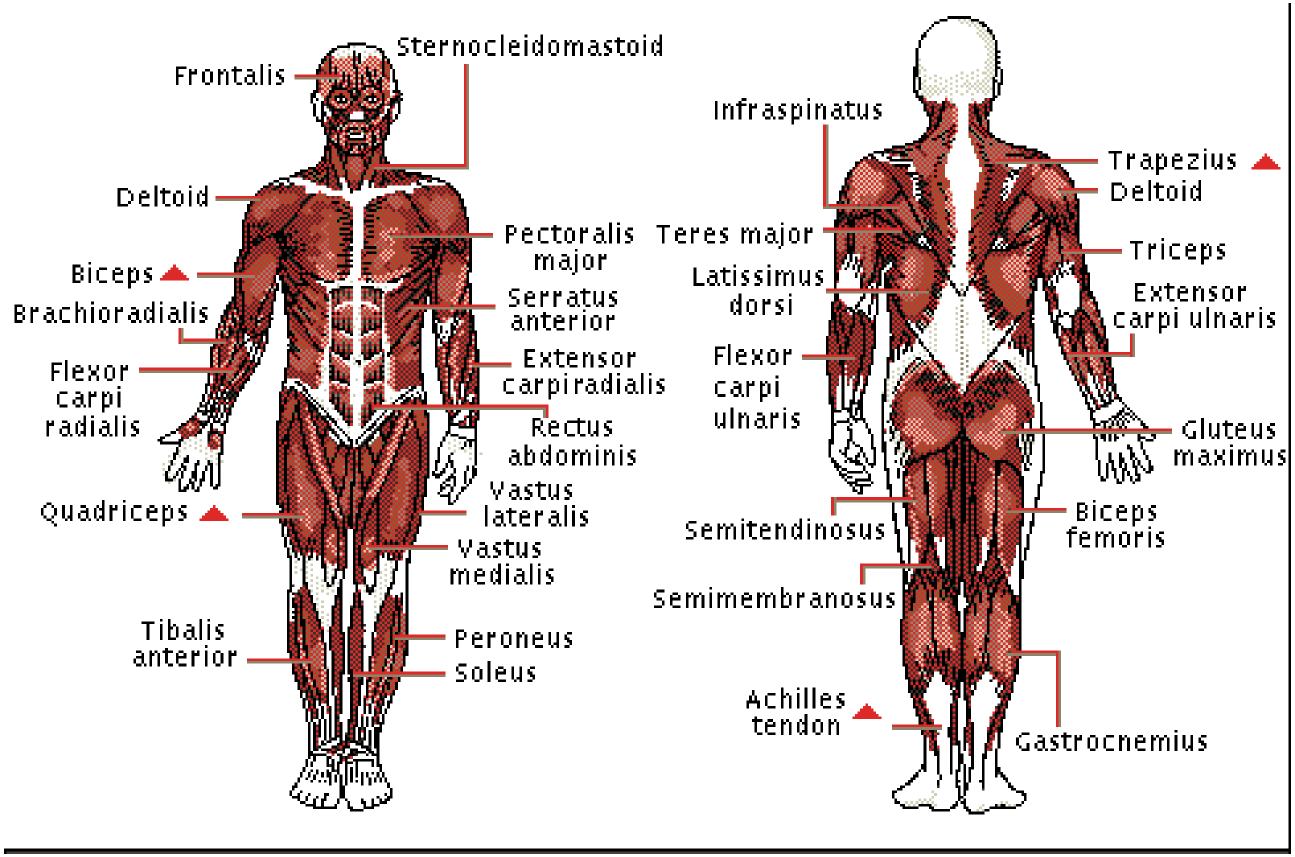
Bones

- 206 bones
- Body “framework”
- Protective: rib cage and skull
- Provide for action: arms, legs
- linked at joints by tendons and ligaments
- Tendons: connect bone to muscle
- Ligaments: connect bone to bone

Muscles

- 400 muscles
- 40-50% of your body weight
- half of your body’s energy needs

Muscles



Sternocleidomastoid
Frontalis
Deltoid
Pectoralis major
Biceps
Brachioradialis
Serratus anterior
Extensor carpiradialis
Flexor carpi radialis
Rectus abdominis
Quadriceps
Vastus lateralis
Vastus medialis
Tibalis anterior
Peroneus
Soleus
Infraspinatus
Trapezius
Deltoid
Teres major
Triceps
Latissimus dorsi
Extensor carpi ulnaris
Flexor carpi ulnaris
Gluteus maximus
Semitendinosus
Biceps femoris
Semimembranosus
Achilles tendon
Gastrocnemius

Joints

Ball and socket – Shoulder, Hip

Hinge – Elbow, Knee

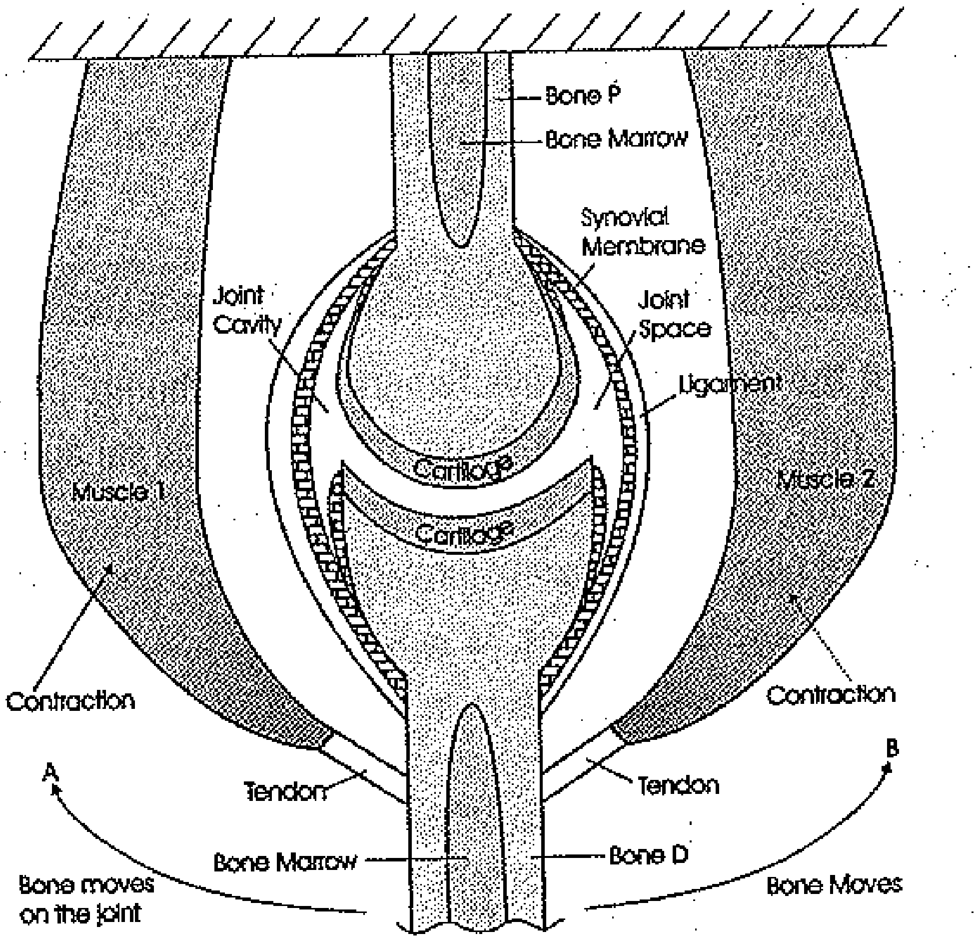
Pivot – Between ulna and radius

Fixed - Skull

Bursa

A small, flat, fluid filled sack protects ligaments from friction with bones

Bursitis – inflamed bursa

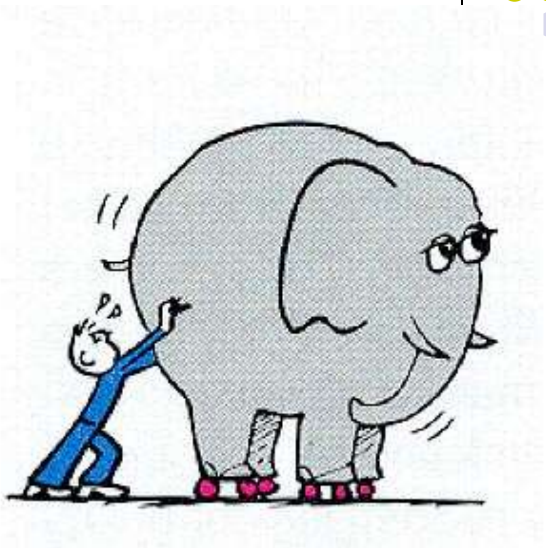


Isaac Newton's "3 Laws of Motion"

- 1. The Law of Inertia
- 2. The Law of Acceleration
- 3. The Law of Reaction

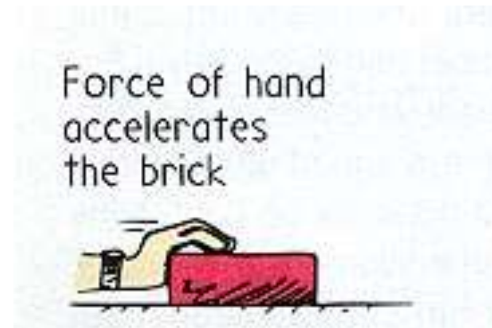
Isaac Newton's "3 Laws of Motion"

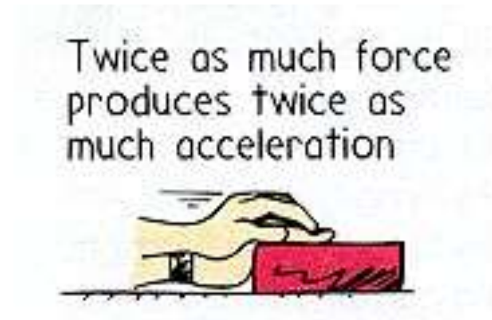
- 1. **The Law of Inertia**
  - An object at rest tends to stay at rest and an object in motion tends to stay in motion (unless an external force is applied eg. friction or gravity).

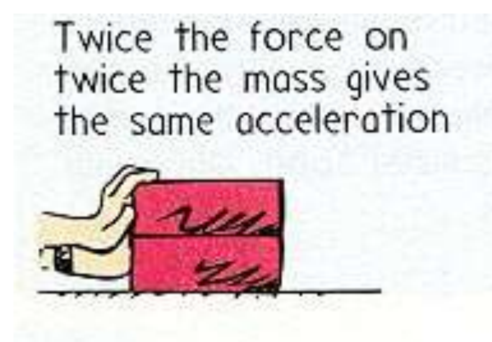


Isaac Newton's "3 Laws of Motion"

- **2. The Law of Acceleration**
- A force applied to a body causes an acceleration proportional to the force, in the direction of the force, and inversely proportional to the body's mass.
- F = MA







Isaac Newton's "3 Laws of Motion"

- **2. The Law of Acceleration**

Isaac Newton's "3 Laws of Motion"

- **3. The Law of Reaction**

- For every action there is an equal and opposite reaction.

Rotational Motion (Angular)

- Most human movements are rotational ie they take place around an axis.

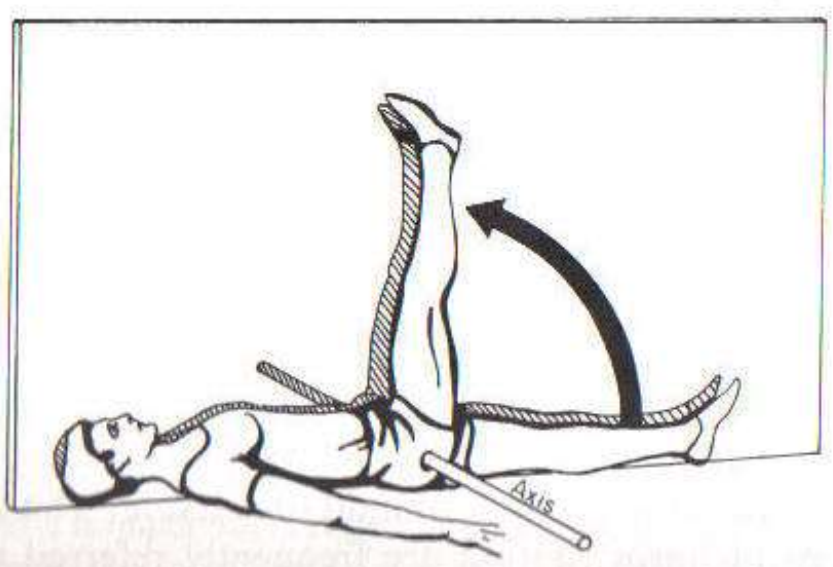


Fig. 4. Angular motion about an internal axis.

Biomechanics

- Kinematics & kinetics
  - Kinematics - description of motion and includes consideration of time, displacement, velocity, acceleration, and space factors of a system's motion
  - Kinetics - study of forces associated with the motion of a body
- Mechanical advantage
  - Load/effort or load divided by effort
  - Ideally using a relatively small force, or effort to move a much greater resistance

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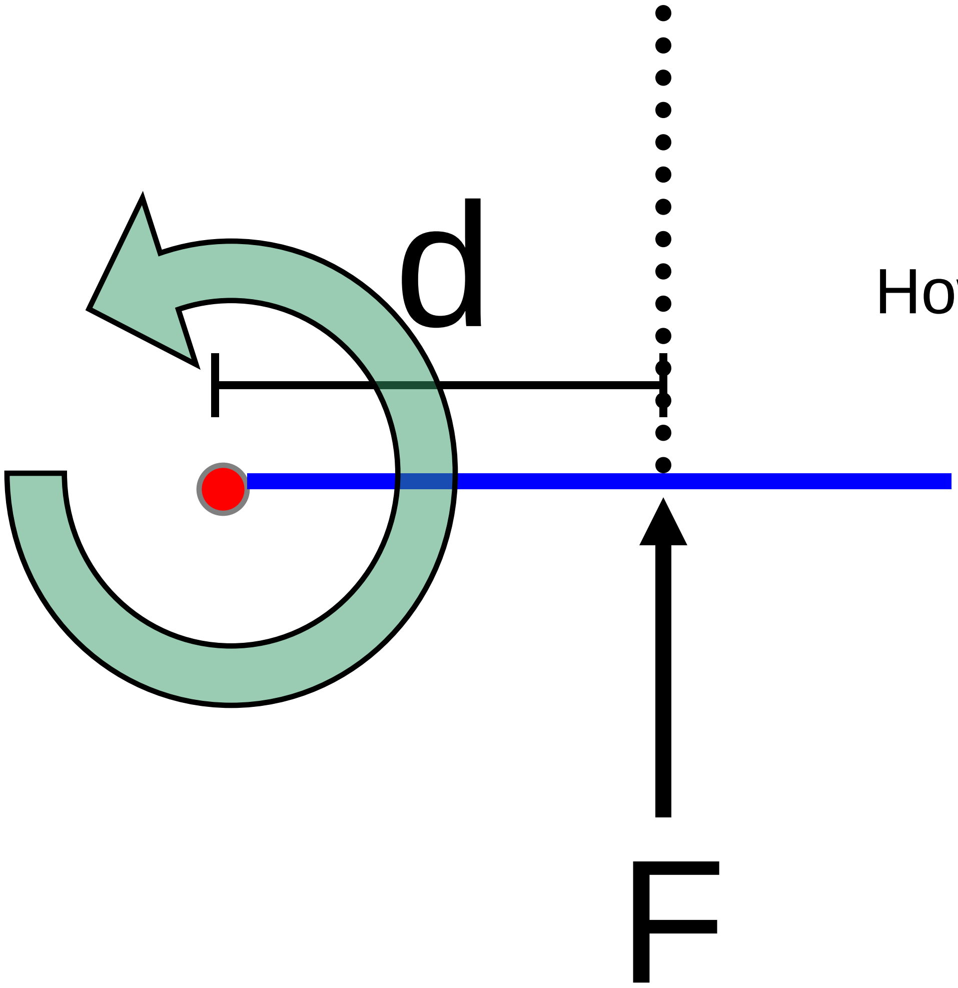
Introduction to Levers

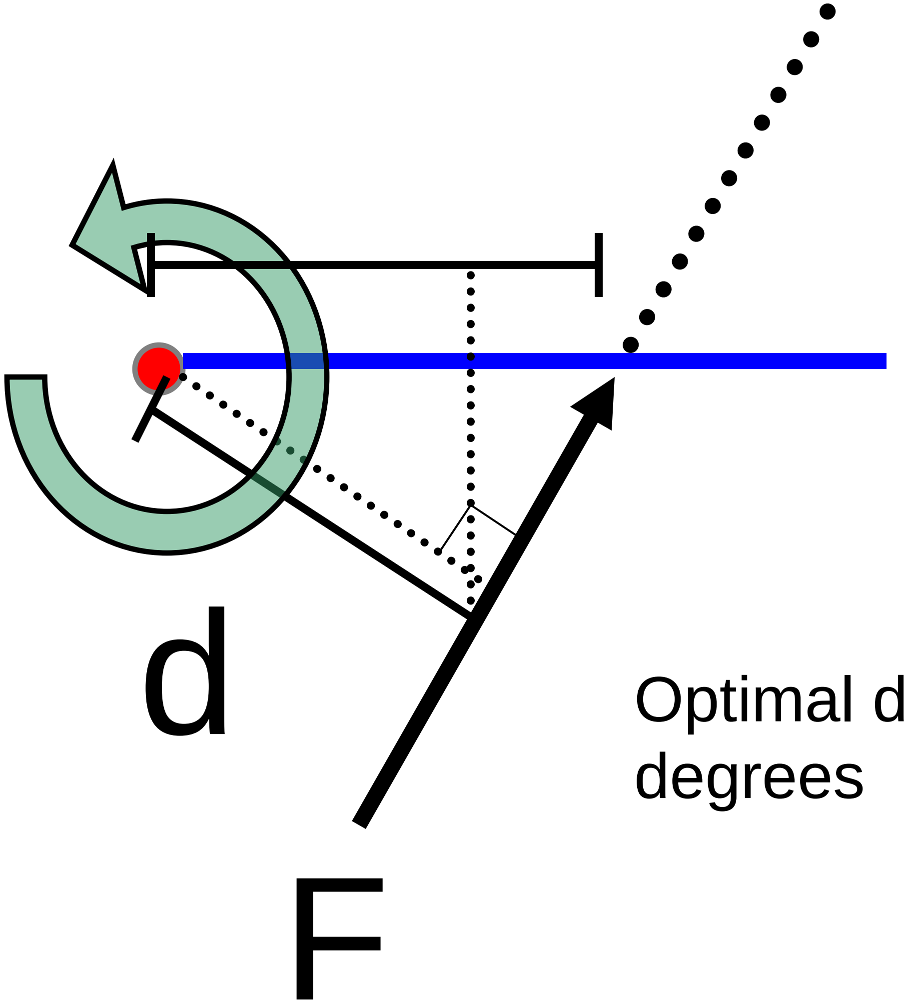
- Lever: Simple machine that operates according to principle of torques
- Torque: The turning effect of a force

  $T = Fd$



How can you change torque?

1. Change F
2. Change d
3. Change direction of F



Optimal direction = 90 degrees

Function of Levers

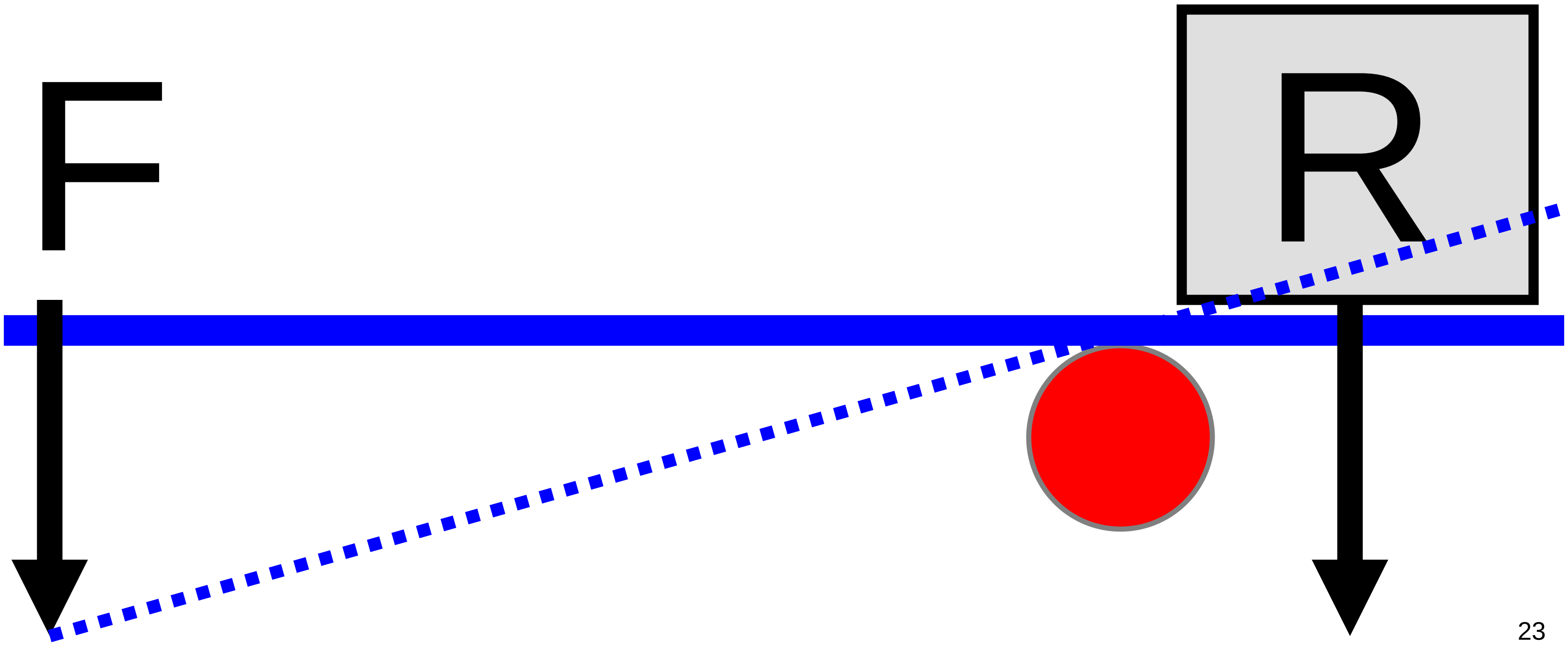
- Two functions:

  1. Force

  2. Speed

Function of Levers

- Force
  - Examples?
- Common traits?
  - Rigid bar
  - Fixed point
  - Lever movement vs. resistance movement


F
R

Function of Levers

- Speed
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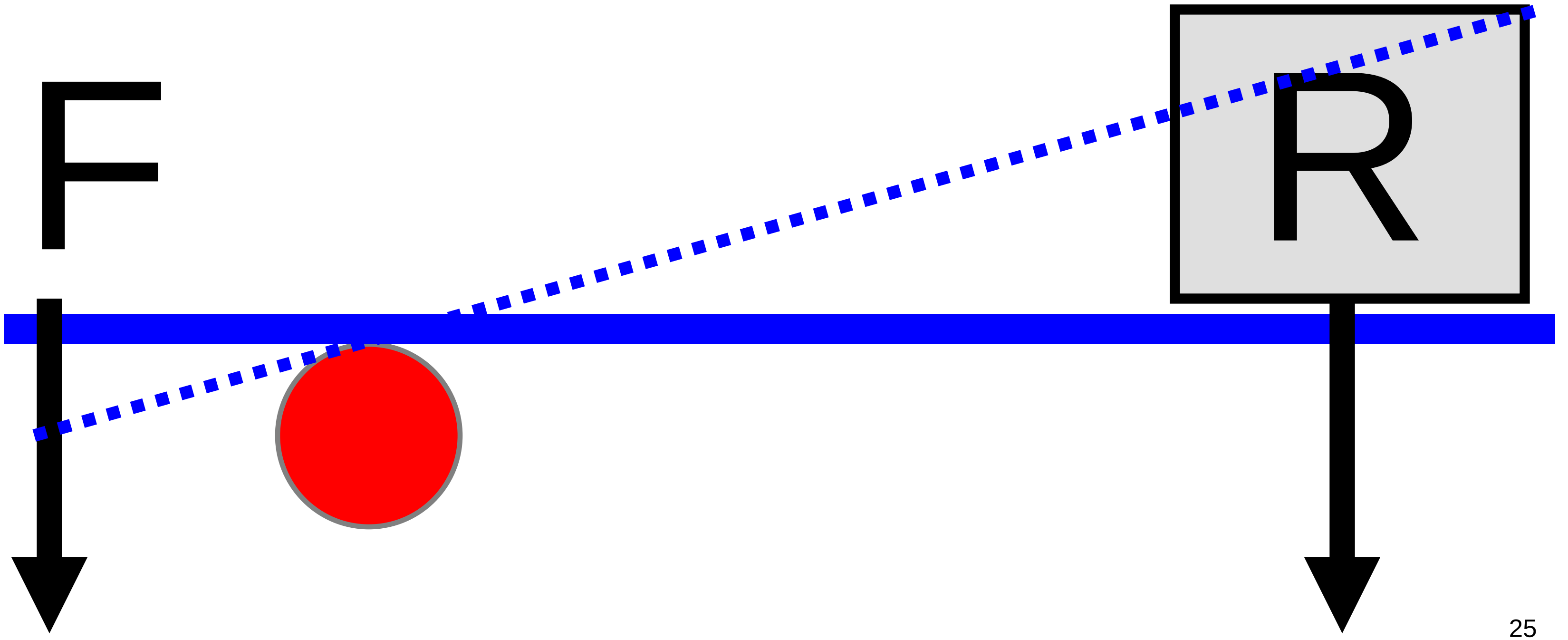
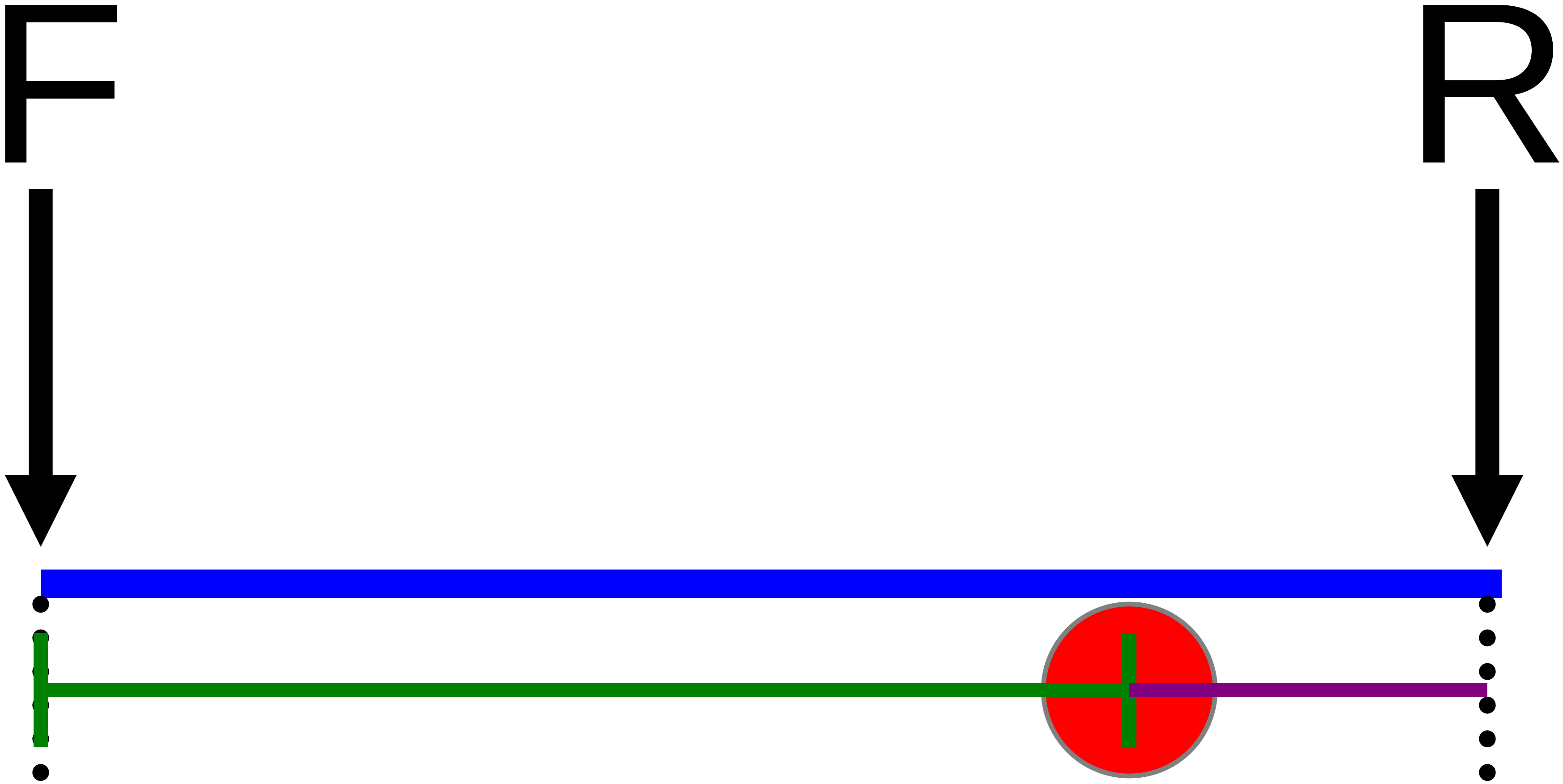

F
R

Components of a Lever System

- Lever: Rigid bar
- Fulcrum: Axis of rotation/fixed point
- Force:
  - Applied force (F)
  - Resistance force (R)
- Moment arm: d
  - Applied force
  - Resistance

More Concepts

- Mechanical advantage
  - Levers designed for force
- Mechanical disadvantage
  - Levers designed for speed/ROM

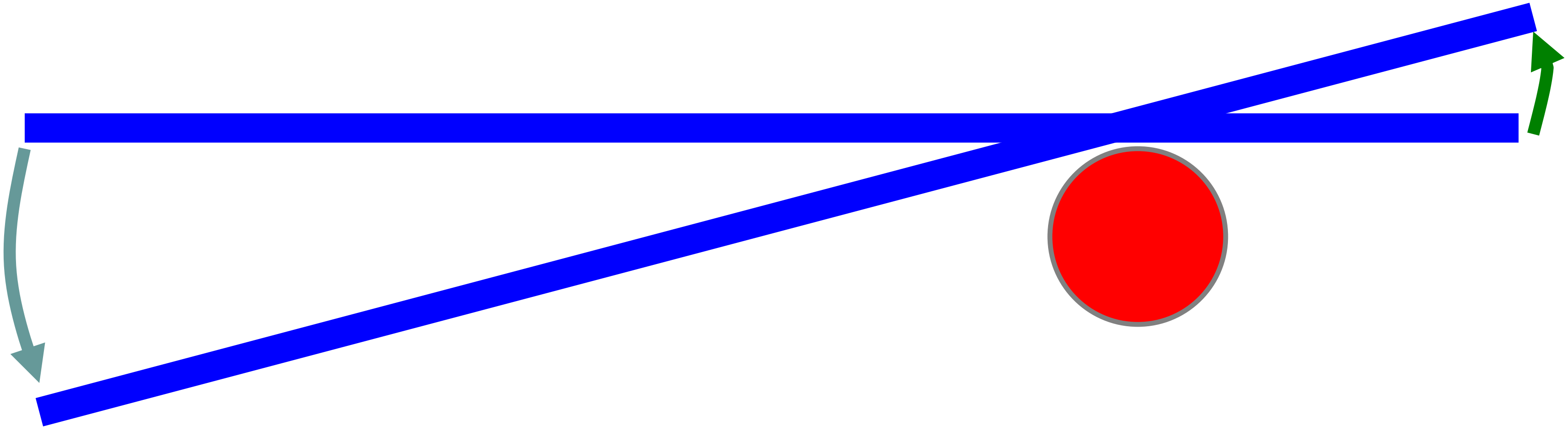


Mechanical advantage or disadvantage?

How does mechanical advantage affect movement of the lever?

Advantage: Small effort moves big resistance

Disadvantage: Big movement required to move resistance a small distance



Human Application?

- Lever?

  Bones (Not always a bar)
- Fulcrum?

  Joints
- Applied force?

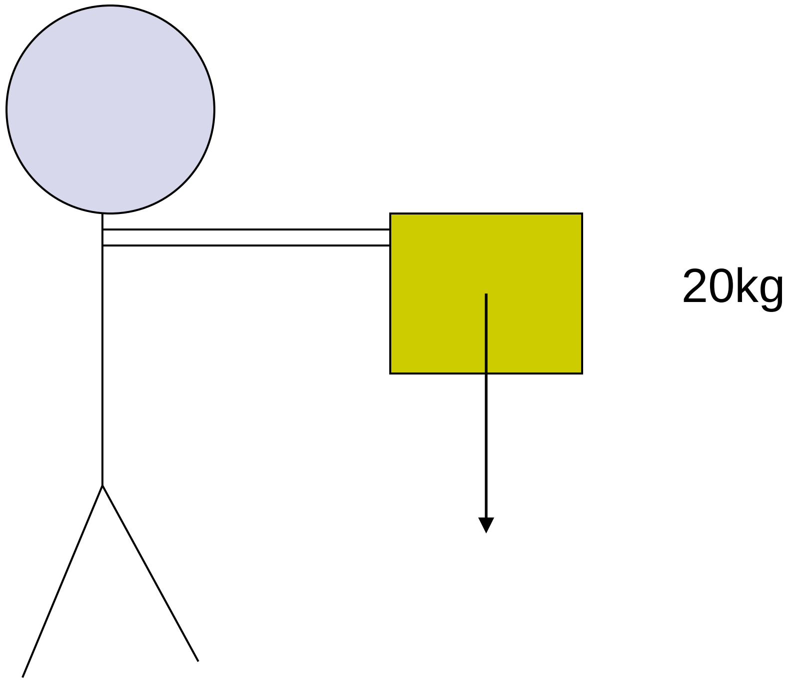
  Muscles
- Resistance force?

  Weight of limb, external resistance

Basic Biomechanics

- Statics model ($\sum F=0$, $\sum$ Moments=0), isometric contraction
- Force at the point of application of the load
- Weight of the limb is also a force at the center of gravity of the limb
- $\sum F$ can be calculated

Problem in Text



Person holding a 20kg weight in both hands. What are the force and moment at the elbow?

Given:

Mass =20kg

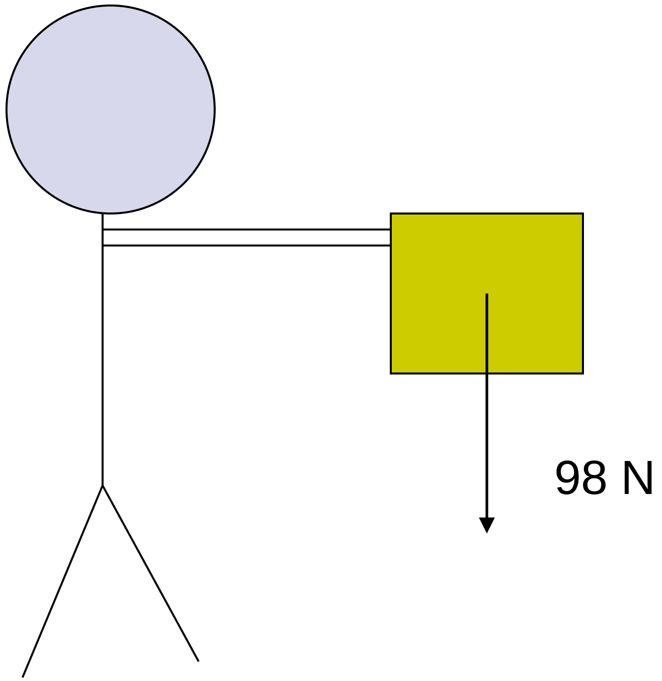
Force of segment = 16N

Length of segment = .36m

Assume:

COG of segment is at the midpoint!

Problem in Text



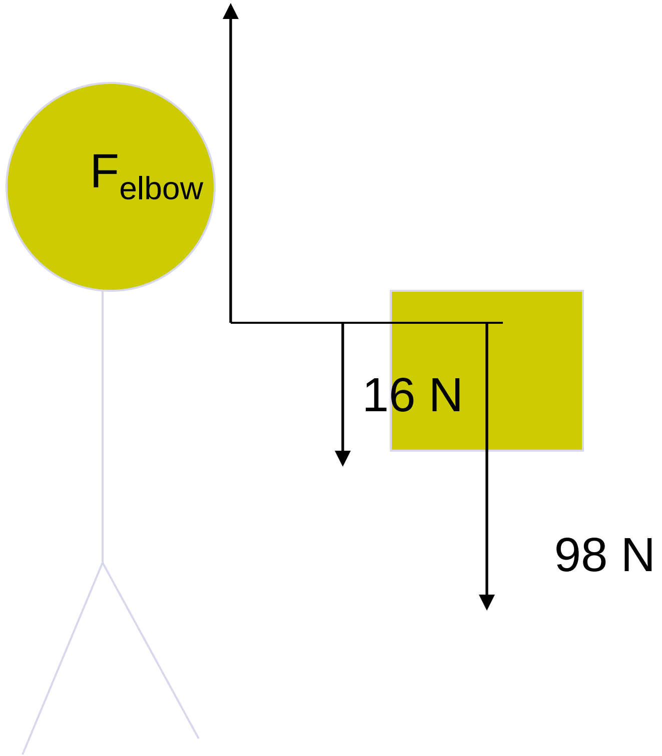
1. Convert mass to Force

*20kg*9.8 m/s^2 = 196 N*

2. Divide by # of hands.

196N/2 hands = 98N/hand

Problem



1. Convert mass to Force

*20kg*9.8 m/s² = 196 N* → $20kg \times 9.8\ m/s^2 = 196\ N$

2. Divide by # of hands.

196N/2 hands = 98N/hand

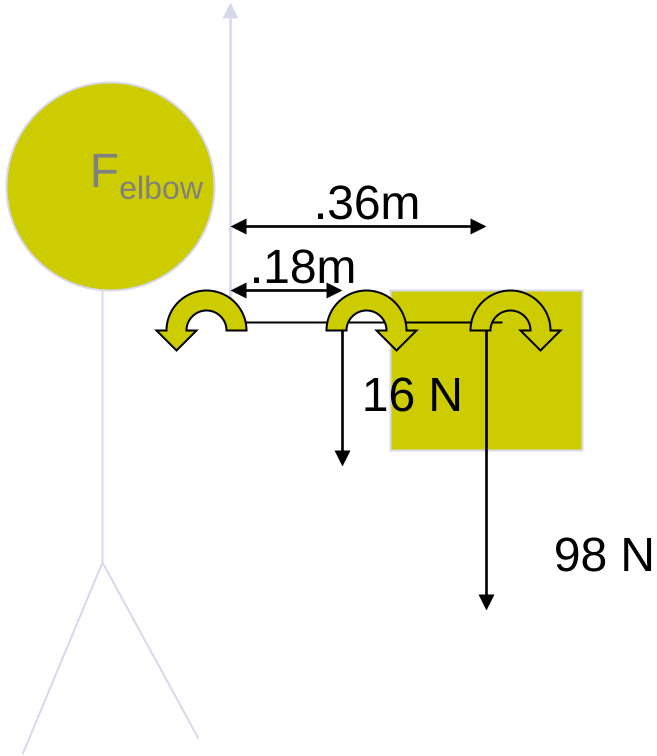
3. Calculate F_{elbow}.

$$\sum F=0$$

$$F_{elbow} - 16N - 98N = 0$$

$$F_{elbow} = 114N\ [up]$$

Problem



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$\sum F=0$

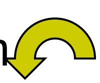
$F_{elbow} - 16N - 98N = 0$

$F_{elbow} = 114N$ [up]

4. Calculate M elbow.

$\sum M=0$

Melbow–16N∗.18m +(-98N)*.36m

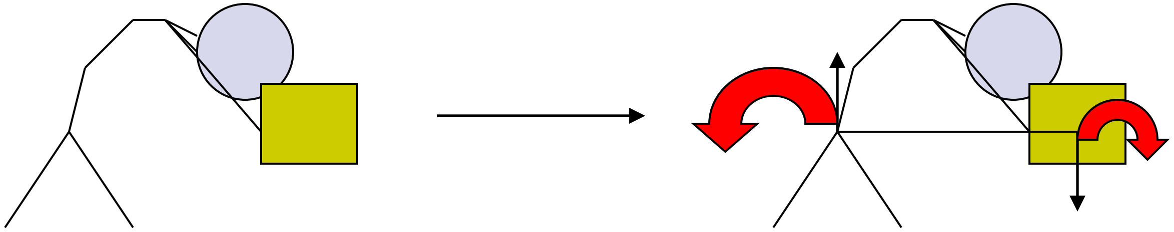
Melbow=38.16N*m 

Lower Back Pain

- estimated at 1/3 of worker’s compensation payments
- may affect 50-70% of the population in general
- Both in high lifting jobs and jobs with prolonged sitting

Biomechanics of Lower Back Pain

- Calculation in text 300N load to 5458N back compressive force
- Back must support many times the lifted load, largely due to the moment arms involved
- Calculation of compressive forces vs. muscle strength can identify problems



Classification of Levers

- Lever classification based on the relative location of:
  1. Axis of rotation/fulcrum (A)
  2. Resistance force (R)
  3. Applied force (F)

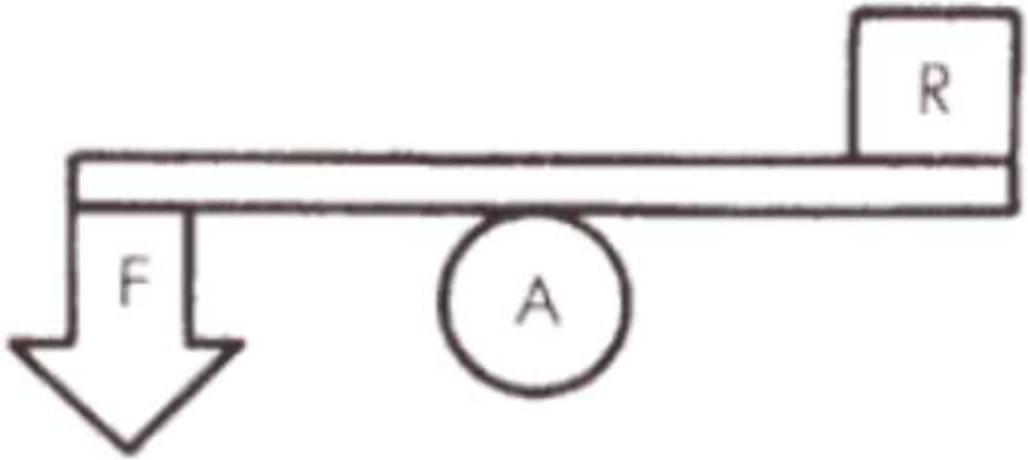
A R F

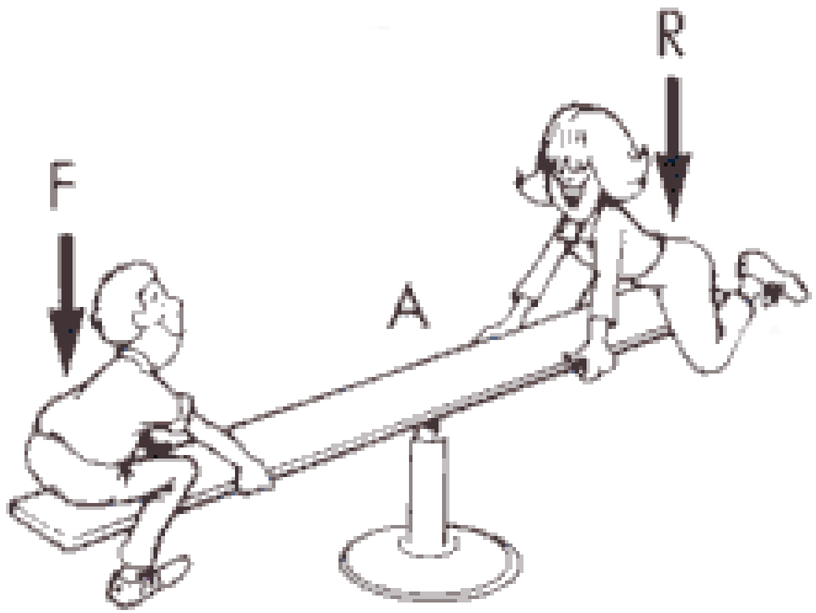
First Class Lever

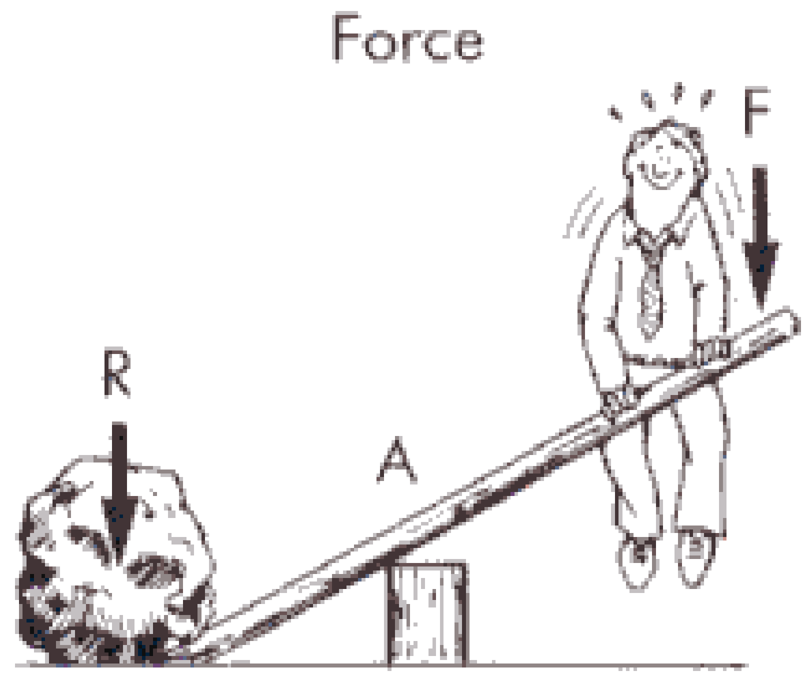
- Center: (A) – Axis of rotation/fulcrum
- Mechanical advantage
- Mechanical disadvantage
- Examples

  Crow bar

  Seesaw







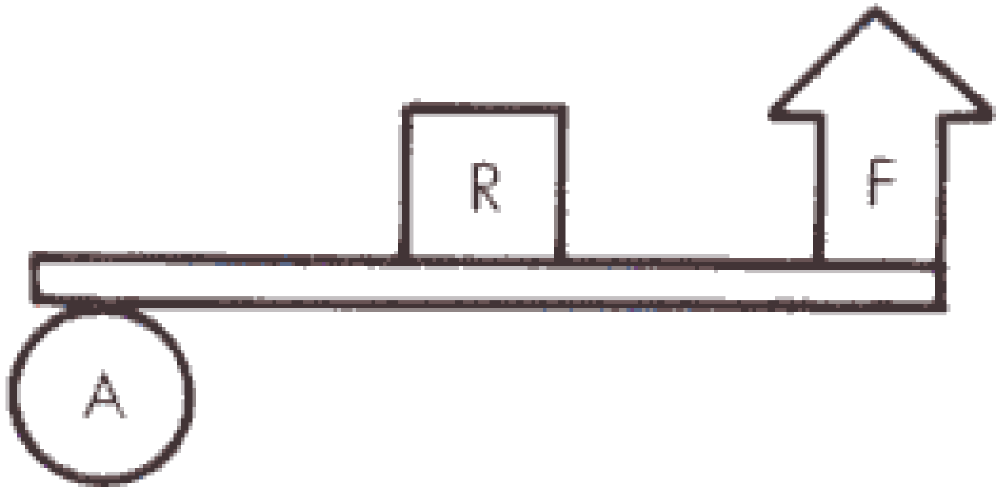
Advantage or disadvantage?

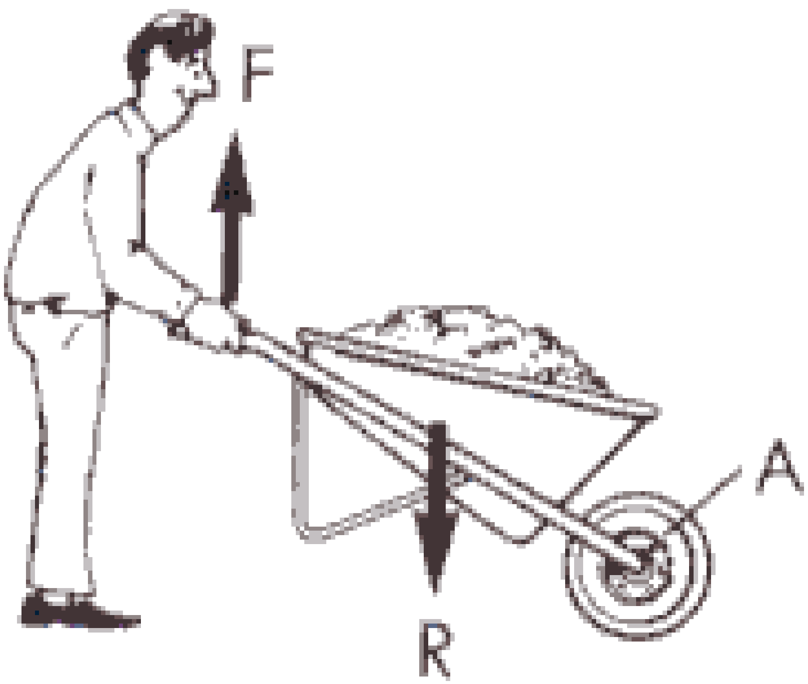
Second Class Lever

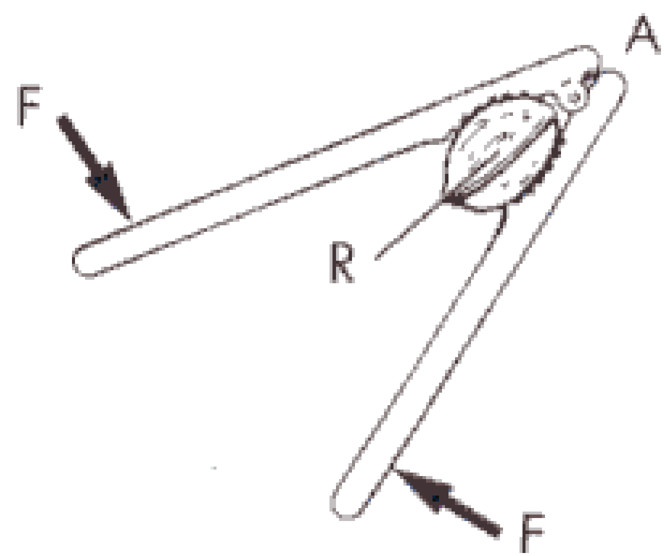
- Center: (R) – Resistance force
- Mechanical advantage
  - Always
- Mechanical disadvantage
  - Never
- Examples

  Wheelbarrow

  Nutcracker


R
F
A


F
A
R


A
F
R
F

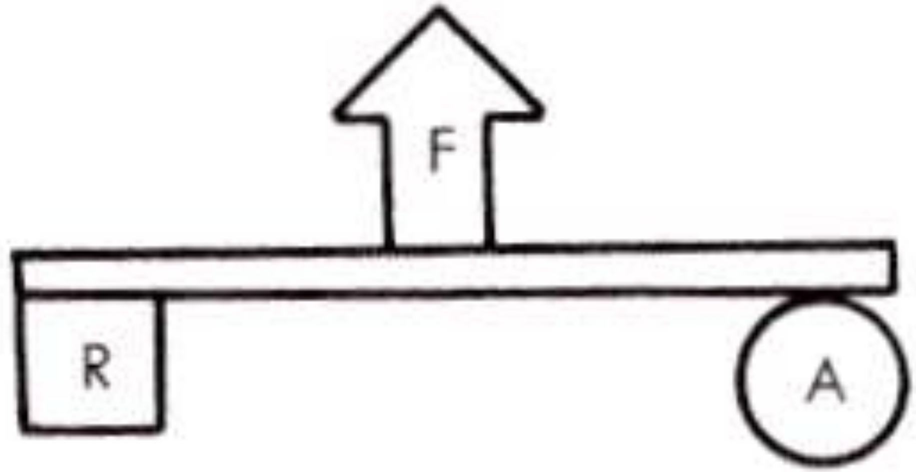
Third Class Lever

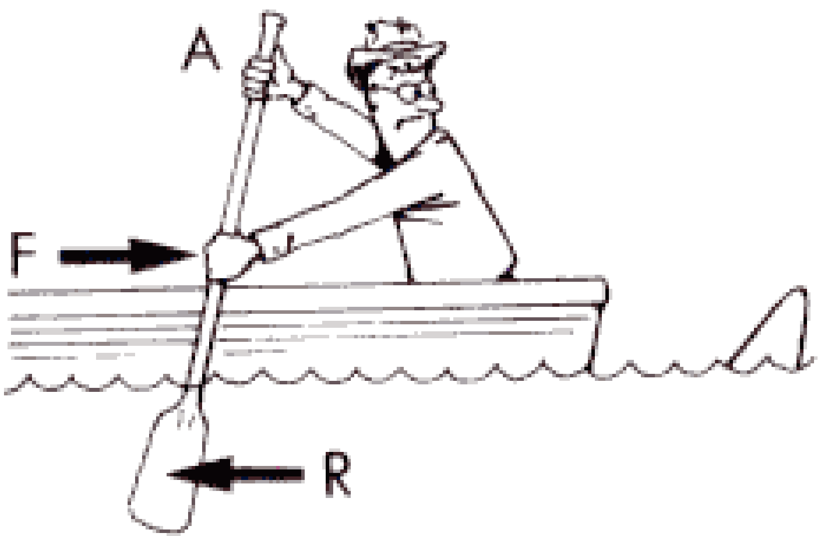
- Center: (F) – Applied force
- Mechanical advantage
  - Never
- Mechanical disadvantage
  - Always
- Examples

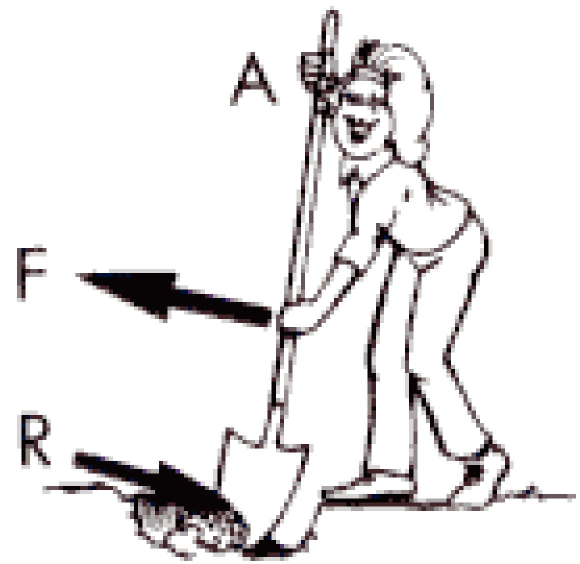
  Rowing

  Shoveling

  Bat, tennis racket





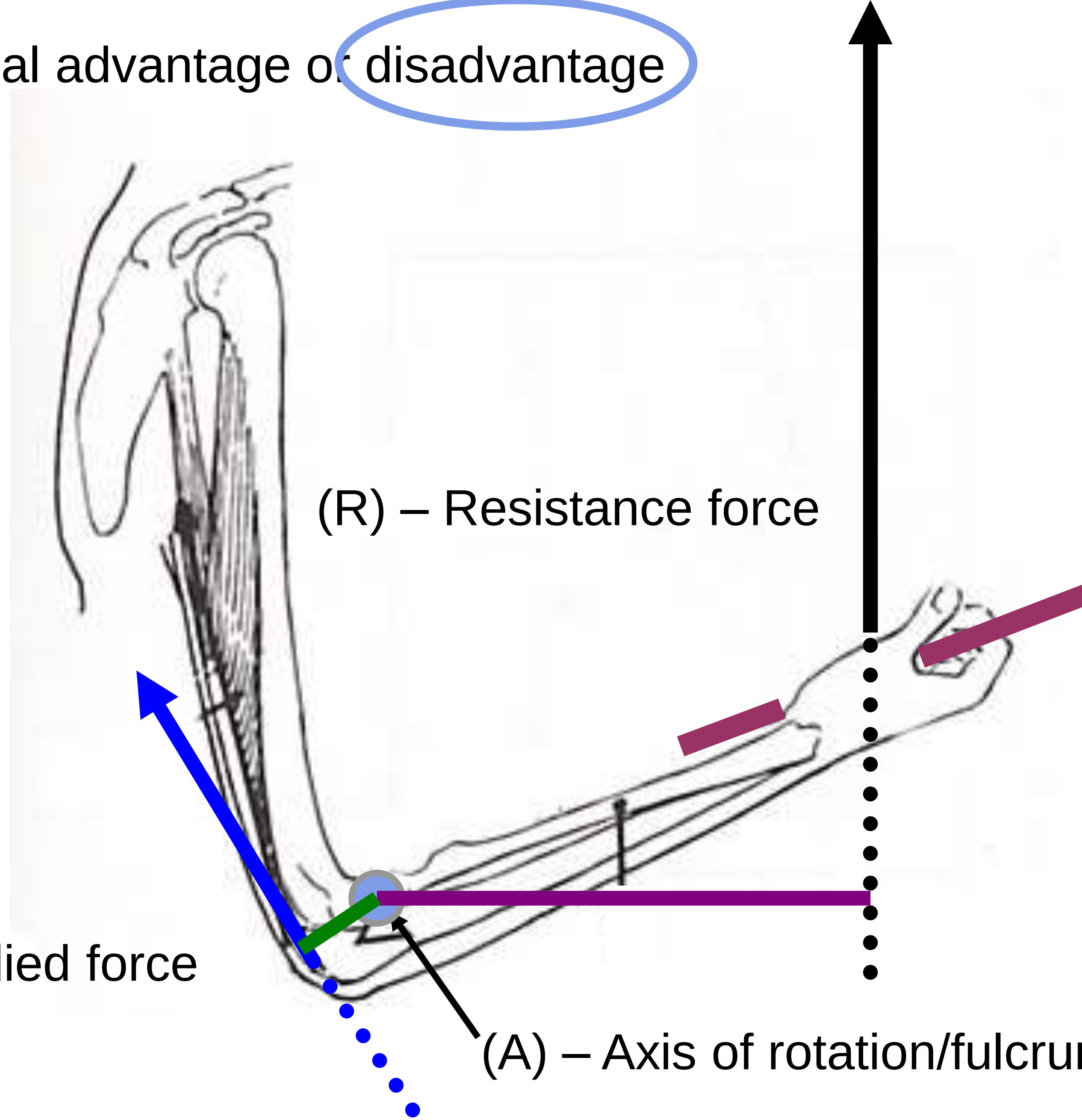


Baseball, tennis?

Human Application

- First class lever
  - Elbow extension against a resistance

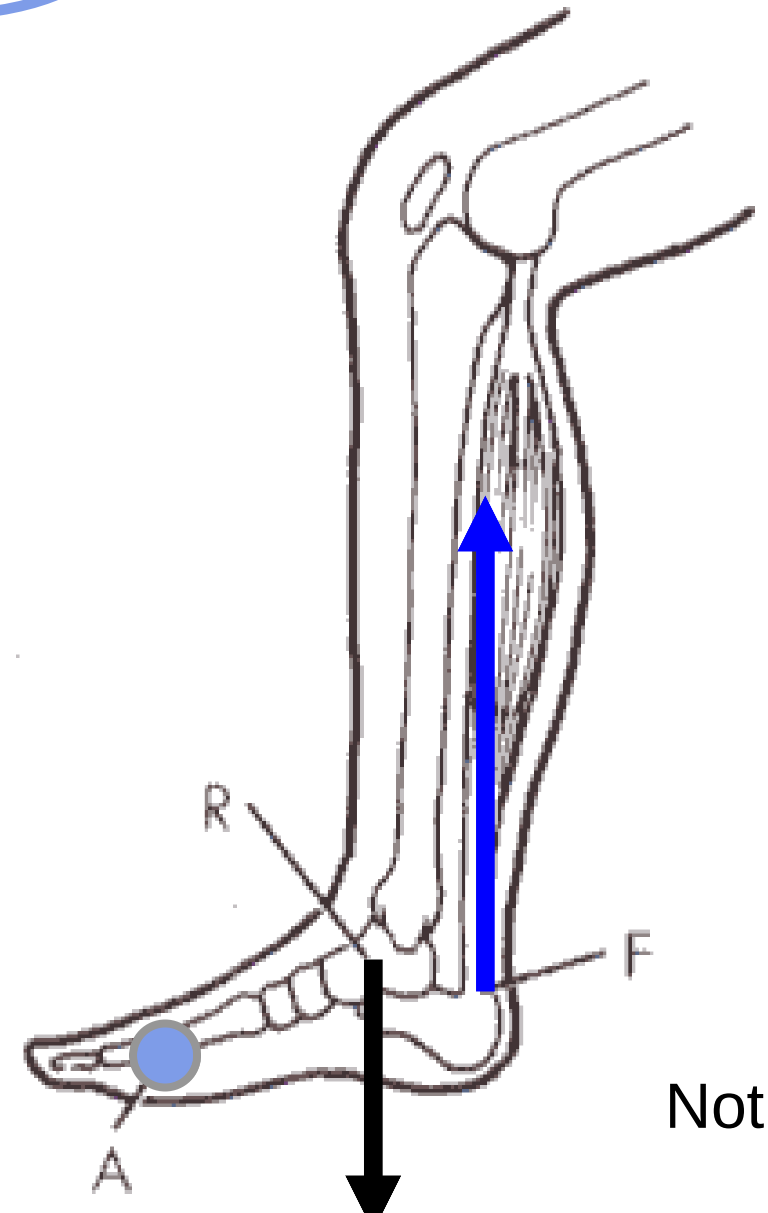
Mechanical advantage or disadvantage



Human Application

- Second class lever
  - Ankle plantar flexion

Mechanical advantage or disadvantage?

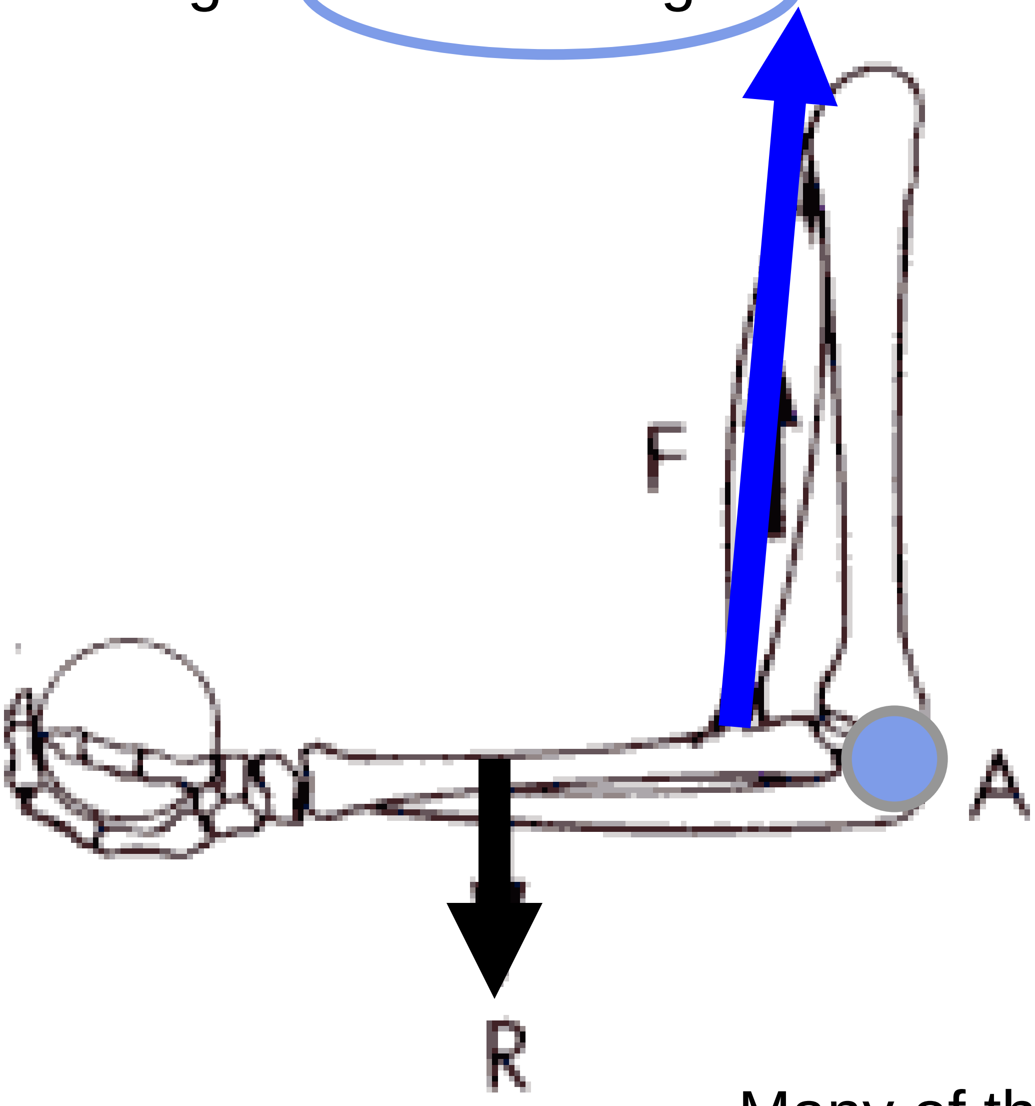


Not many in the body

Human Application

- Third class lever
  - Elbow flexion

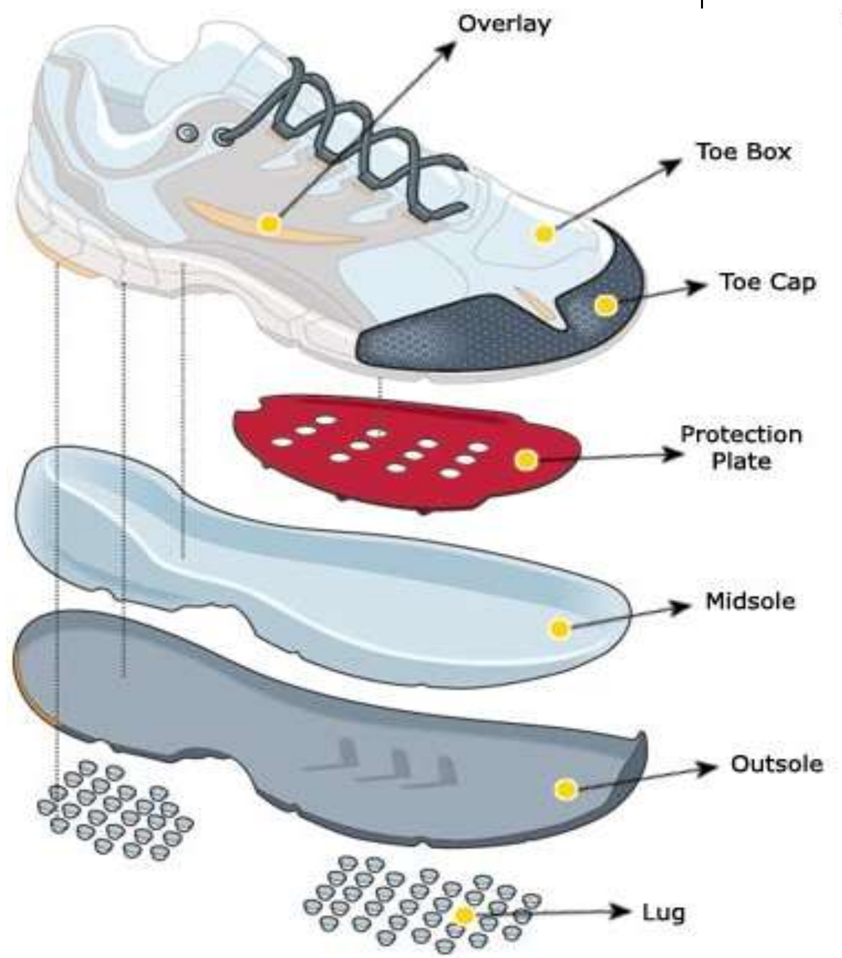
Mechanical advantage or disadvantage?



Many of these in body

Running shoes and the Biomechanics of your feet

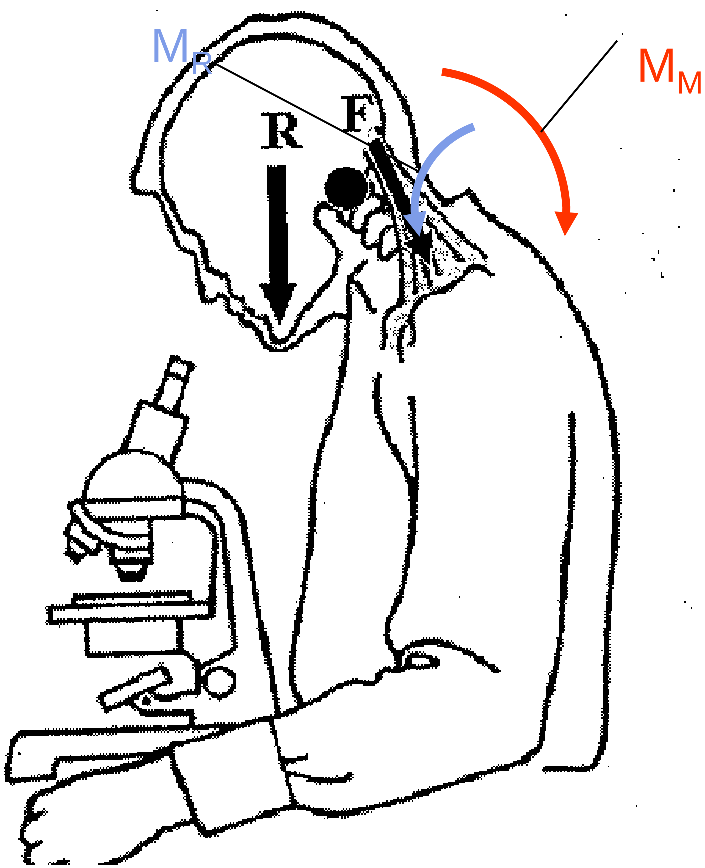
- **Running shoes are continually evolving**
  - each model of shoe within each brand is built for specific foot types**!**
- **There is no "perfect" or "best" shoe on the market.**
- **Everyone's feet are different in shape and function differently.**



How to choose the right running shoes?

- you need to know how your feet work.
  - Knowing the biomechanics of your feet will help you better understand what type of running shoe is right for you.
  - A visit to your local podiatrist is a great start for a complete foot evaluation.
- At the store: An experienced salesman who has been fitting shoes for years can help you.

Biomechanics of head and neck



Head-neck – 7% of BW =0.07*150 = 10.5 lb

Ratio of moment arm = 2:1

Muscle force = 21 lb

Joint compressive force = 31.5 lb

Biomechanics of posture

All body segment is subjected to gravitational force

When CG of a body segment is vertically aligned with a joint – joint tension or compression = weight of the body segment

Due to postural changes, CG of the body segment moves away from the joint's vertical alignment. This creates a moment around the joint.

M = Force*Moment arm (perpendicular distance from the joint axis).

This moment due to gravitational force is countered internally by the muscles to maintain the posture.

To maintain the posture $M_R = M_M$

$M_R =$ Moment due to external forces

M_M = Moment due to internal muscle forces