

# Lecture 2.

## Statics & Dynamics of Rigid Bodies: Human body

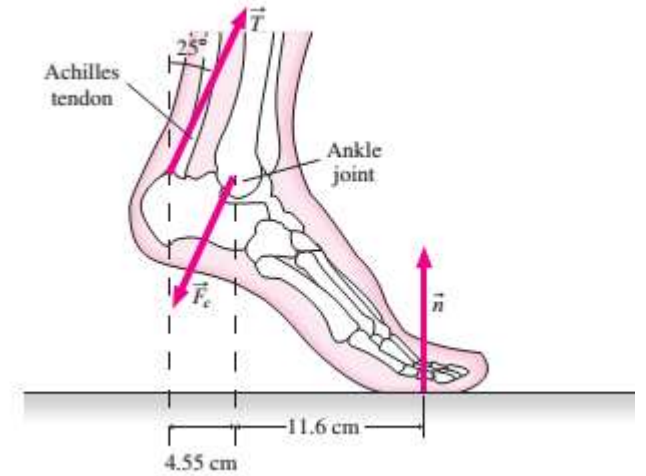
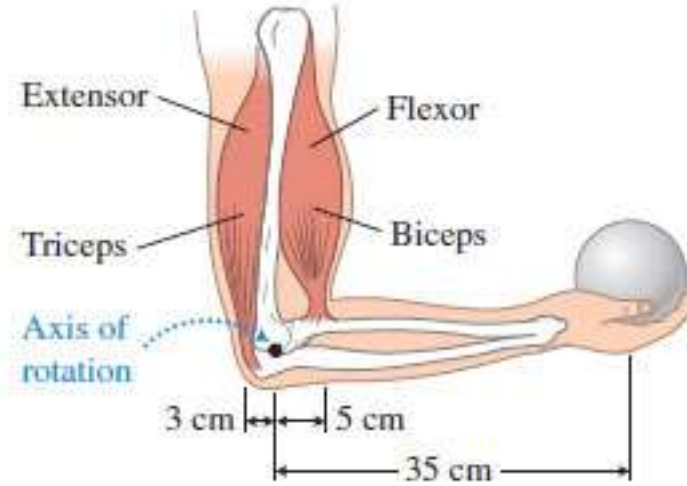
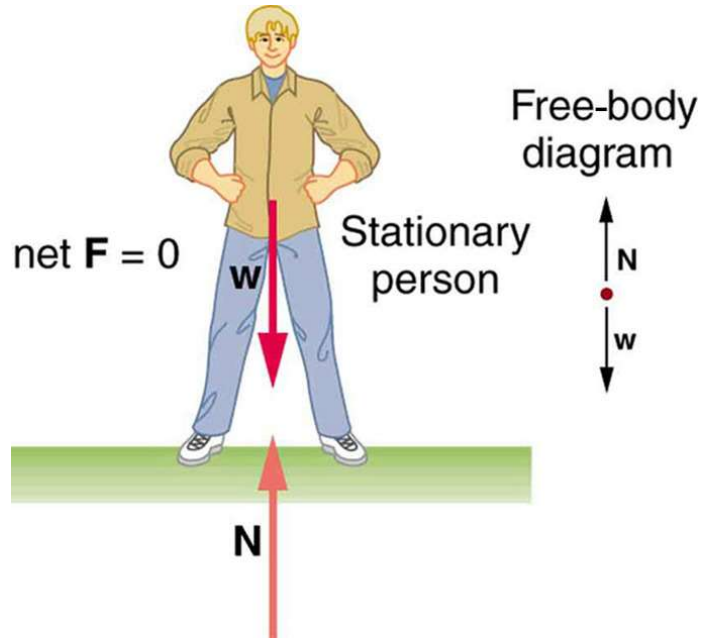
30 August 2018

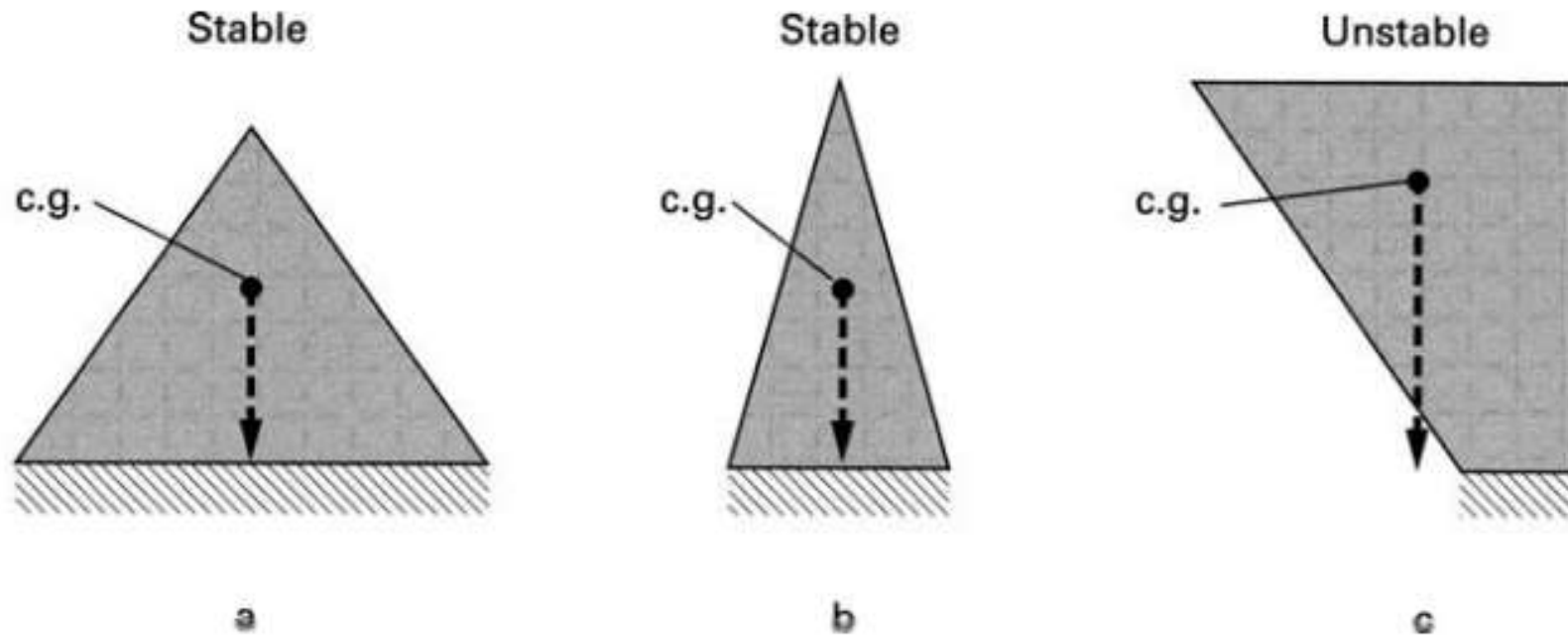
Wannapong Triampo, Ph.D.



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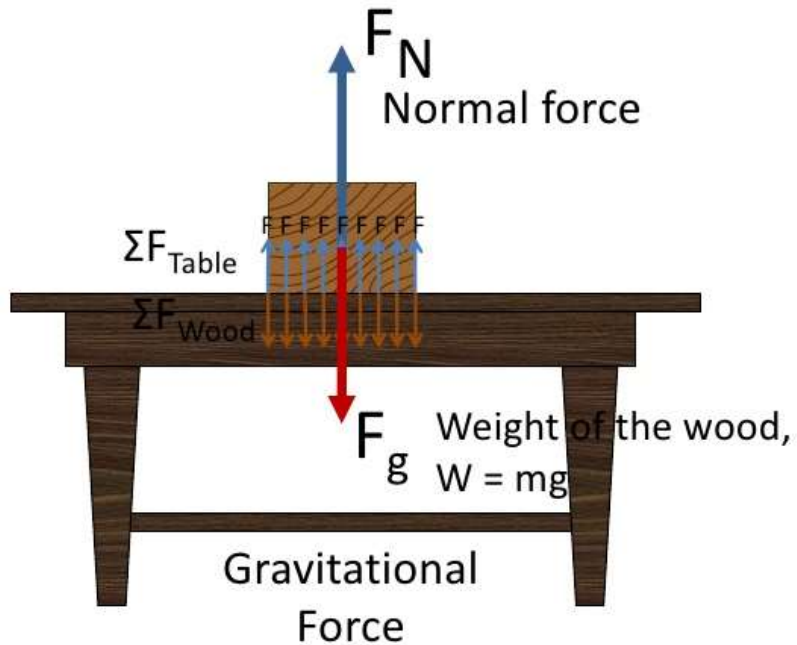
# Static forces of Human Body





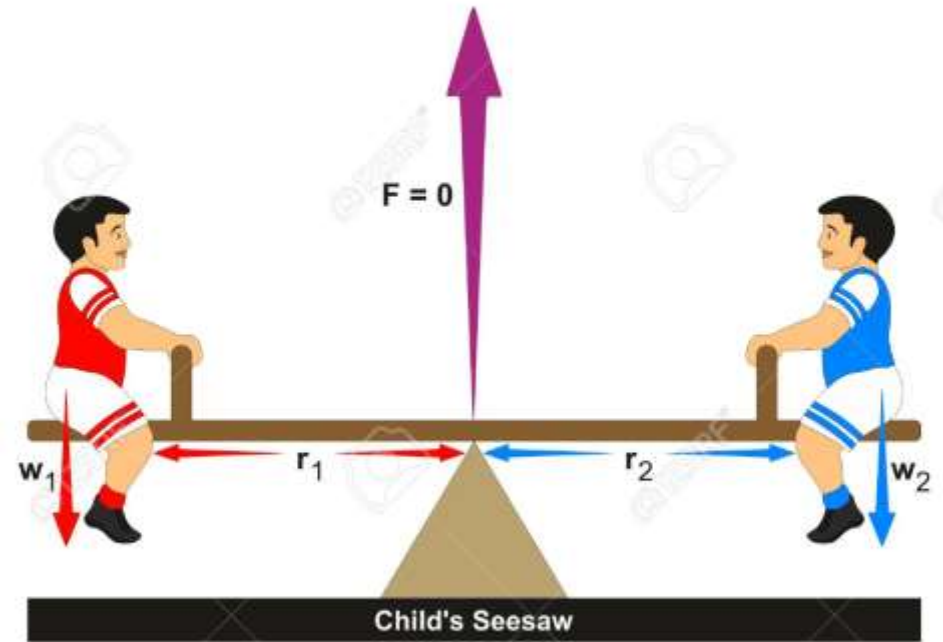
Stability of bodies.

## STATIC EQUILIBRIUM



## Trigonometry Static Equilibrium

The Physical State in which all Components of a System are at Rest and the Net Force is Equal to Zero throughout the System



$r$  is the distance from the pivot point to the point where the force is applied

$F$  magnitude of the force

$w$  is weight

$$(w_1)(r_1) = (w_2)(r_2)$$



## Conditions for Static Equilibrium

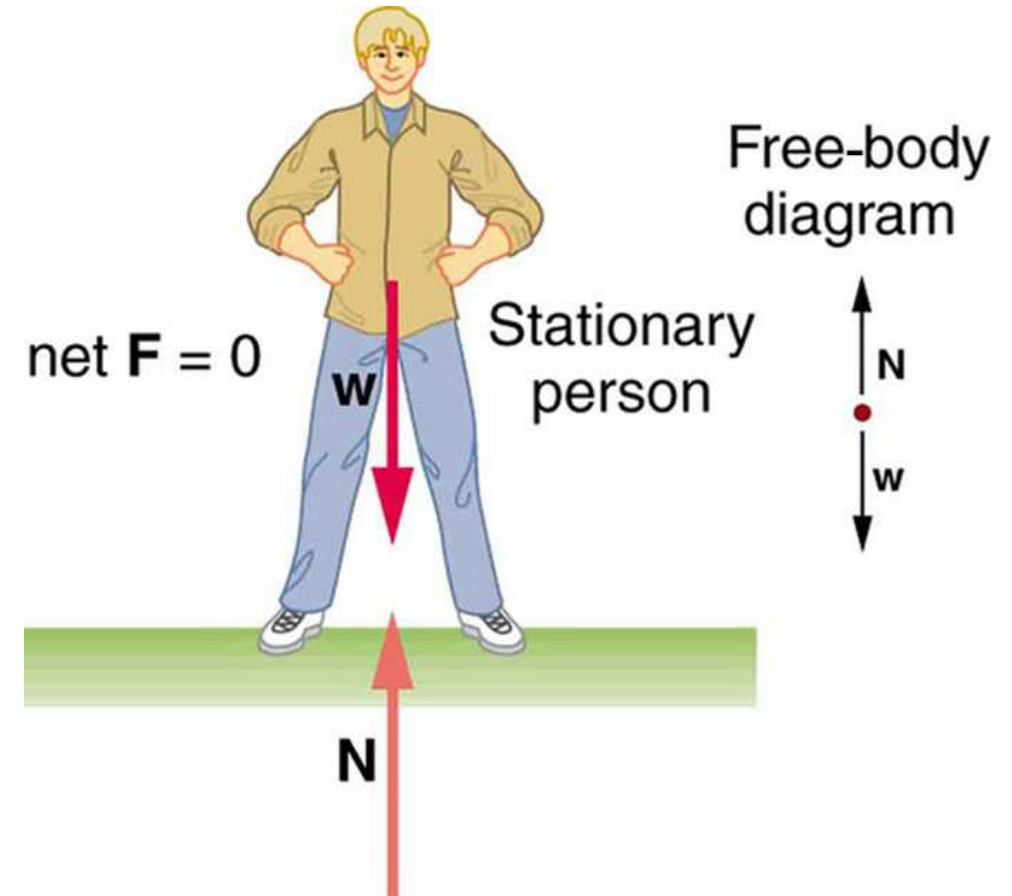
If a rigid body is in “static equilibrium,” it is at rest -  
- no translational acceleration and no rotational  
acceleration. **BOTH** of the following must be true  
for any body in static equilibrium:

- 1 The vector sum of external forces must be zero:

$$\Sigma \mathbf{F} = 0$$

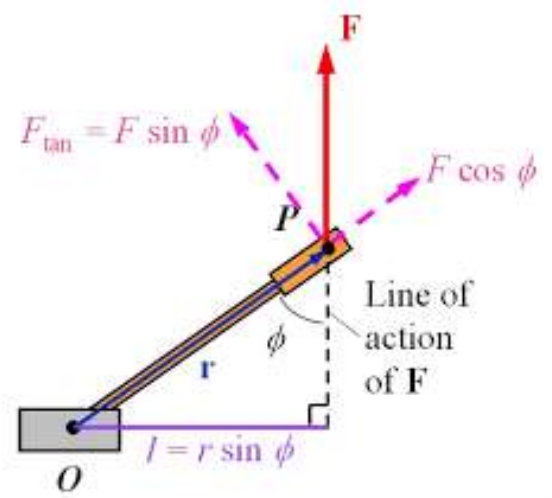
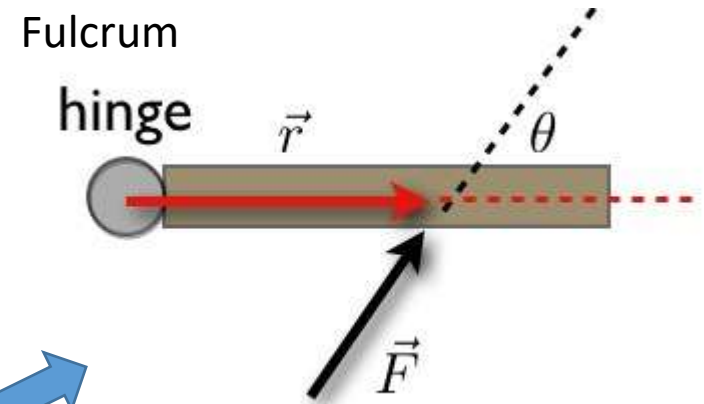
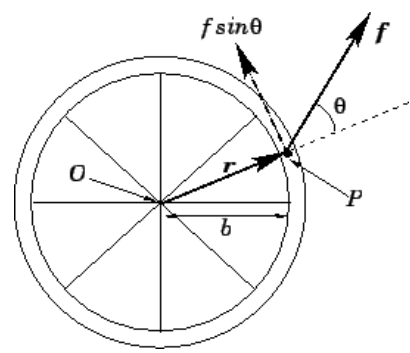
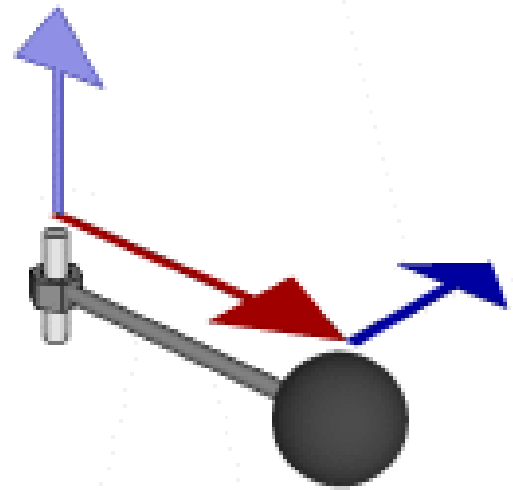
- 2 The sum of torques due to all external forces about any axis must also be zero:

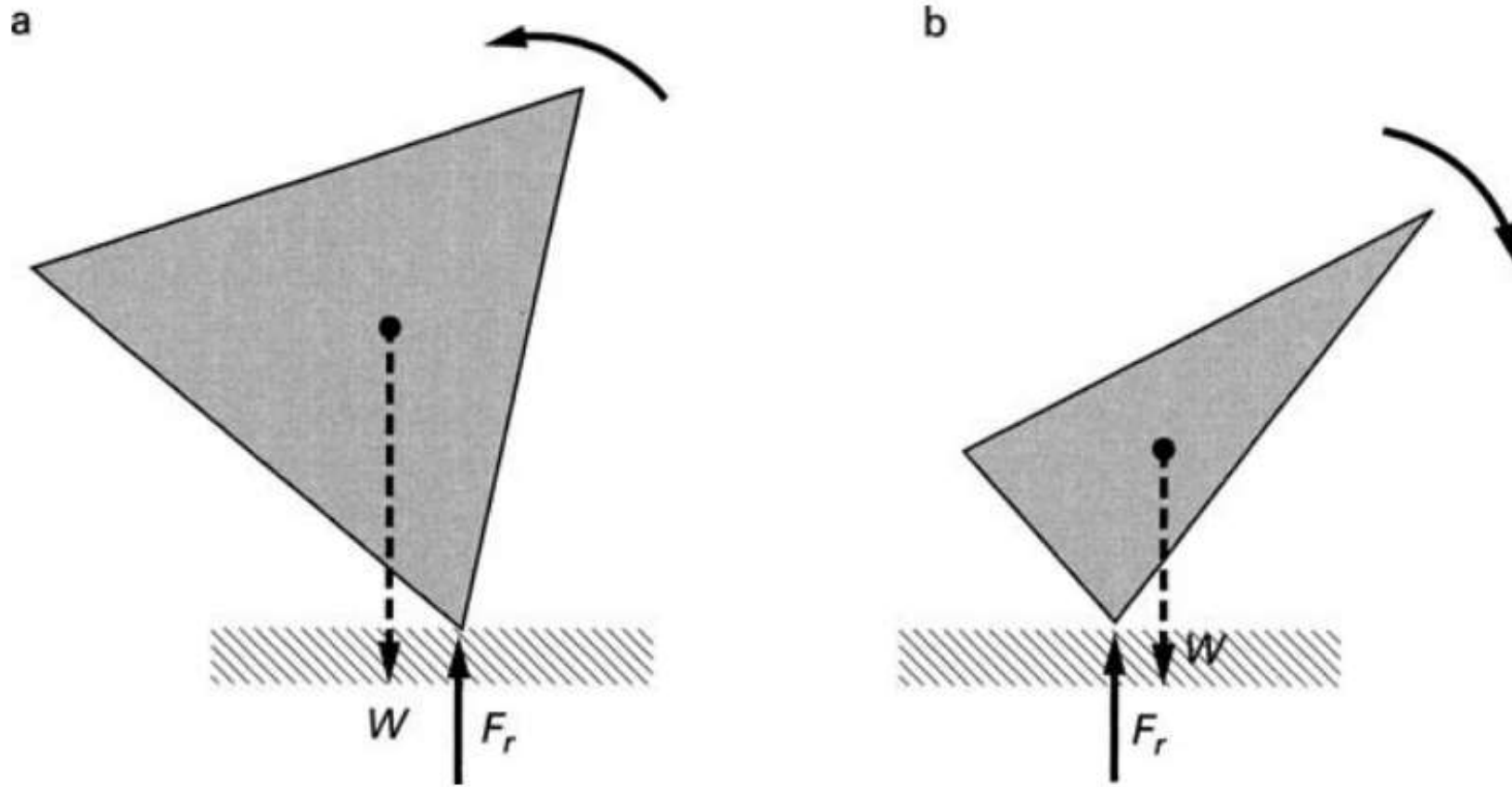
$$\Sigma \boldsymbol{\tau} = 0$$



$$\boldsymbol{\tau} = \mathbf{r} \times \mathbf{F}$$

$$\mathbf{L} = \mathbf{r} \times \mathbf{p}$$



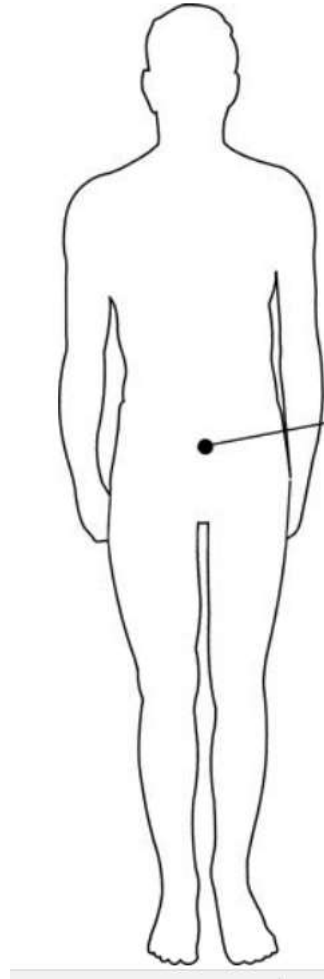


(a) Torque produced by the weight will restore the body to its original position. (b) Torque produced by the weight will topple the body

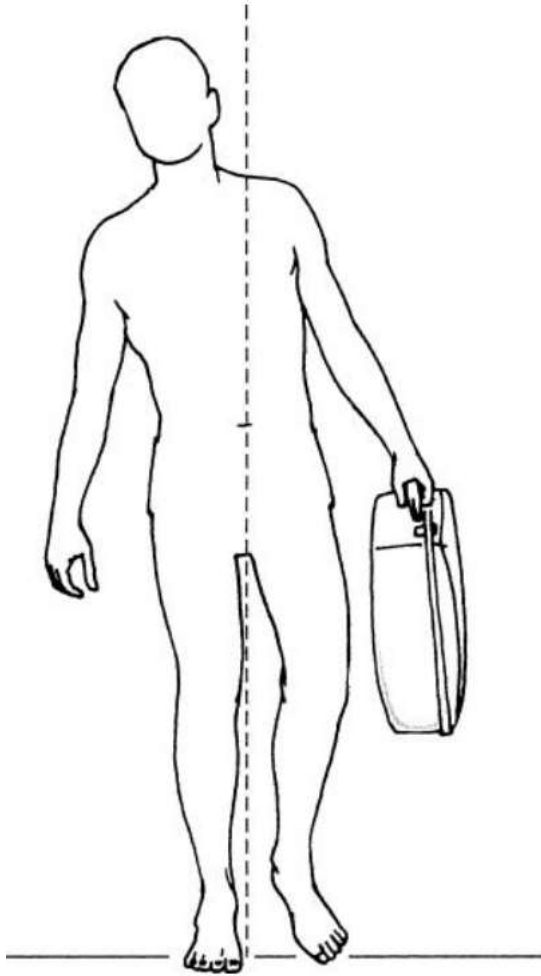


# Equilibrium Considerations for the Human Body

The center of gravity (c.g.) of an erect person with arms at the side is at approximately **56%** of the person's height measured from the soles of the feet



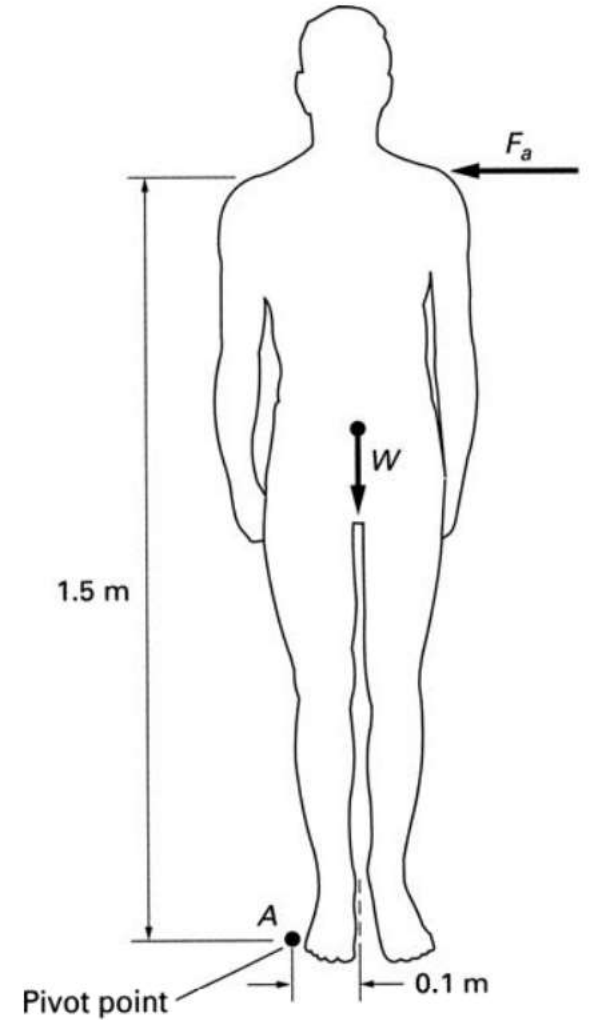
# Stability of the Human Body under the Action of an External Force

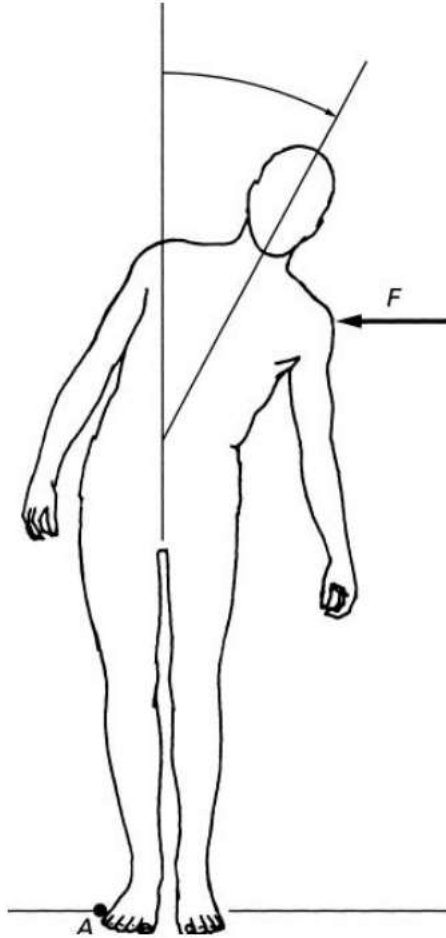


the base of support.

The applied force  $F_a$  tends to topple the body

$$F_a = \text{????}$$

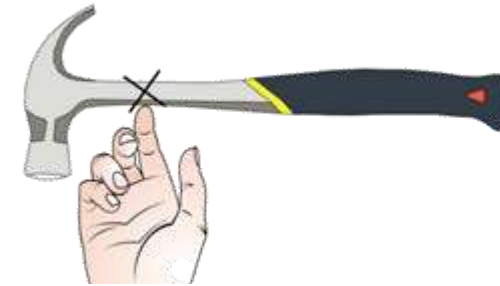
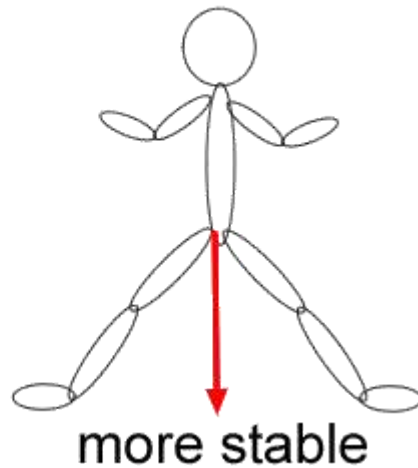
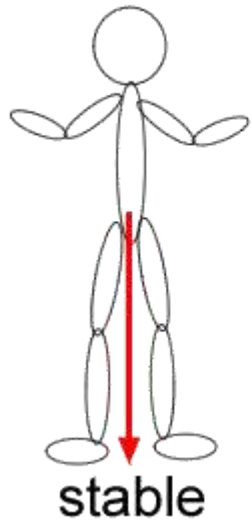
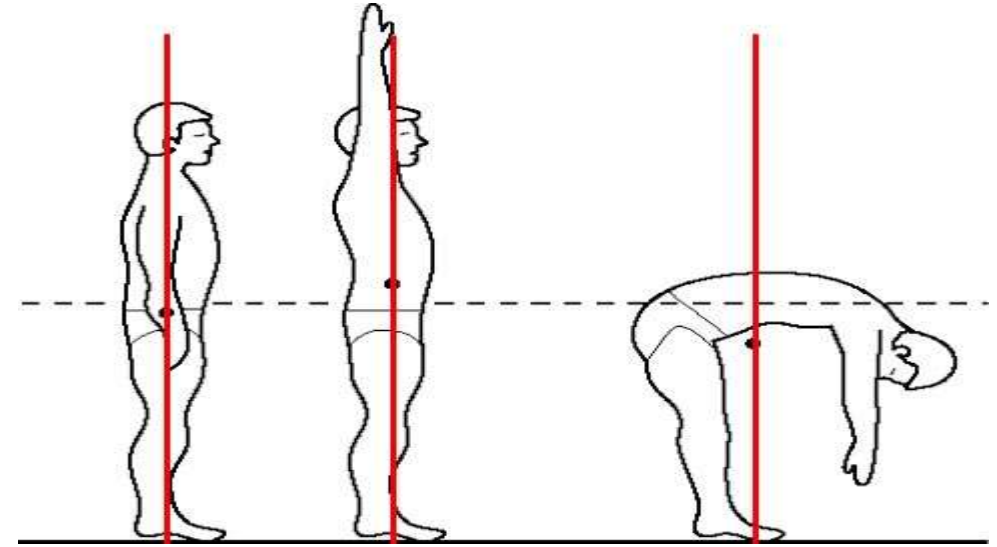
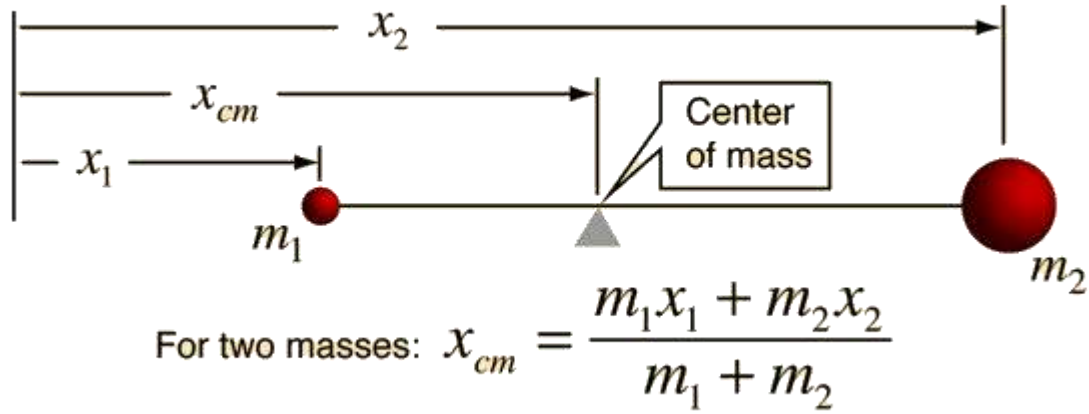




Compensating for a side-pushing force

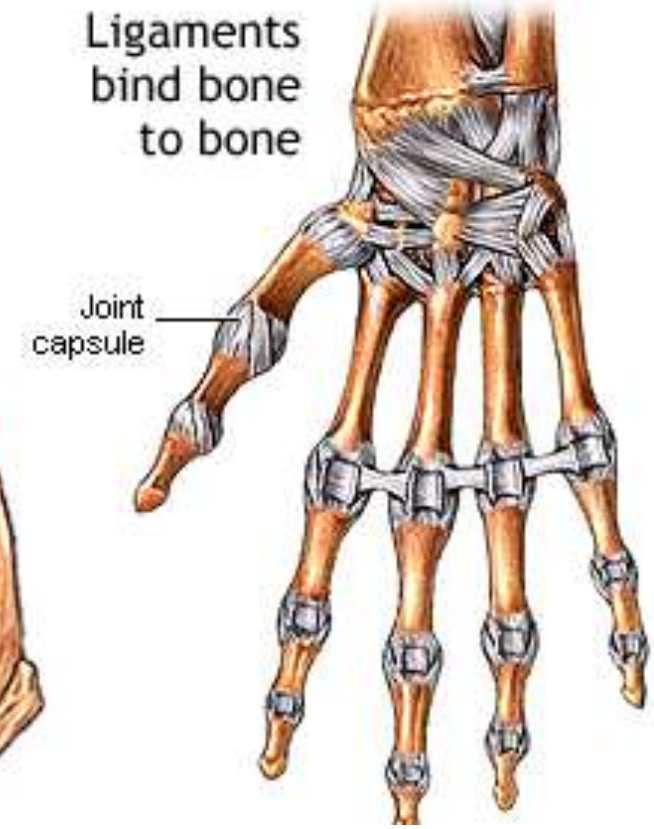
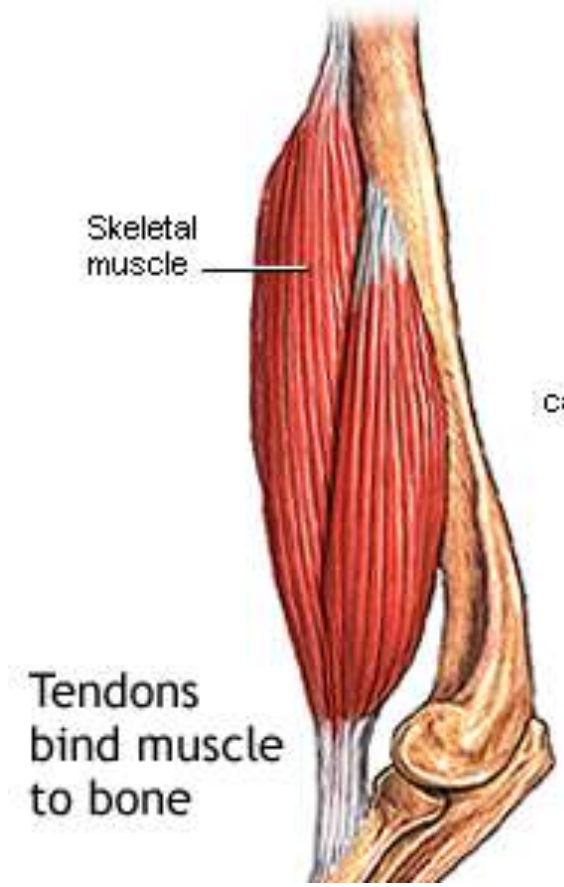
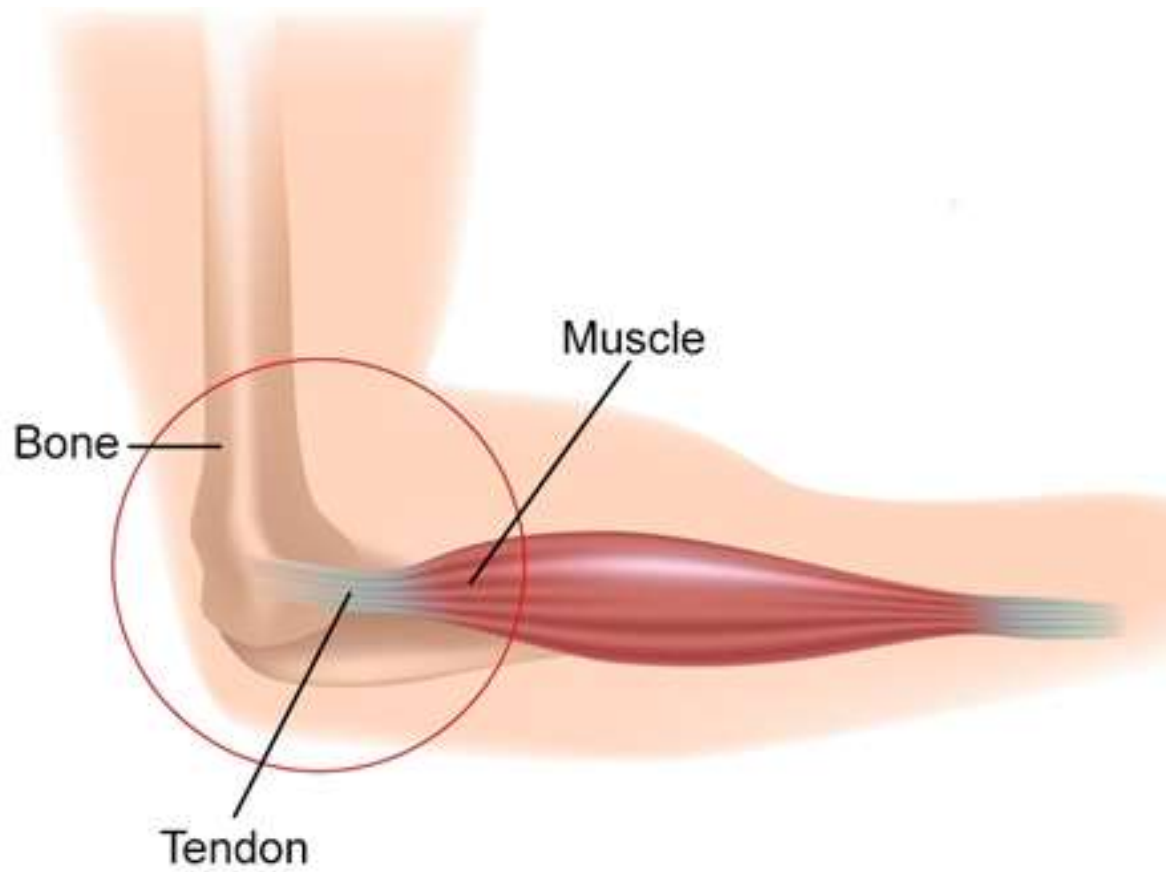


# Remark

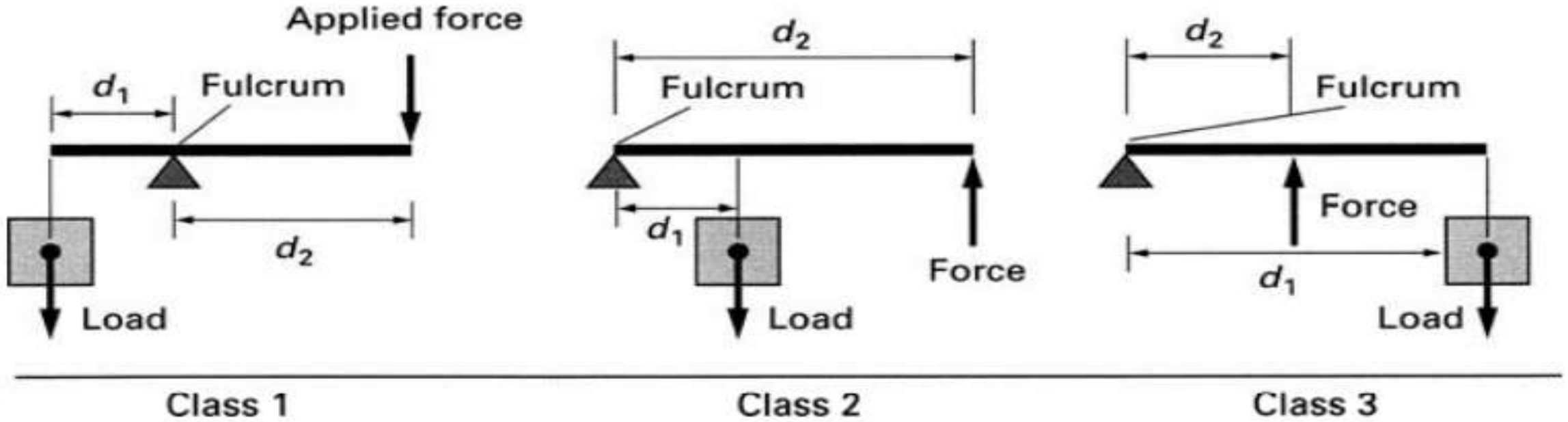




# Skeletal Muscles



# Levers

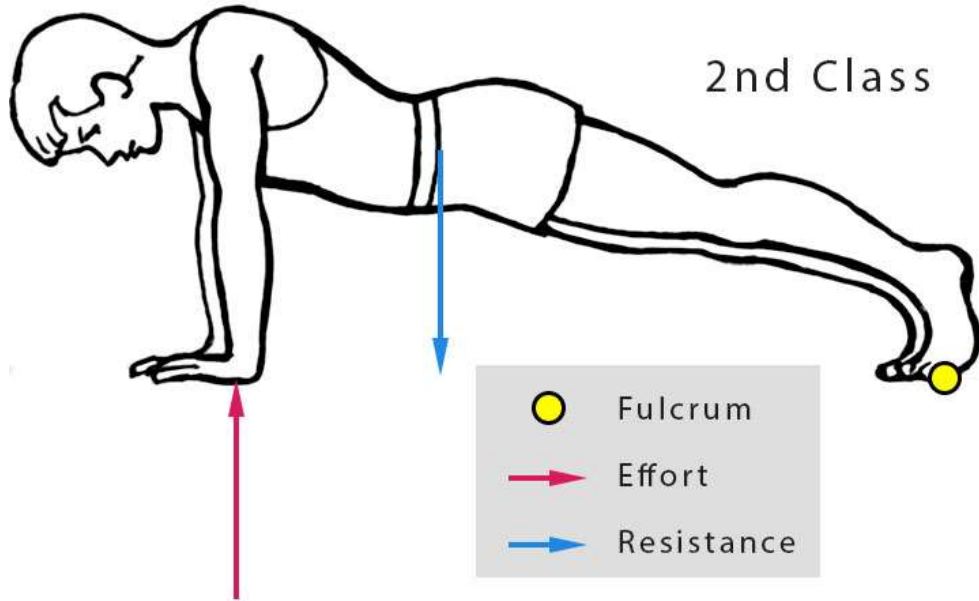


Crowbar

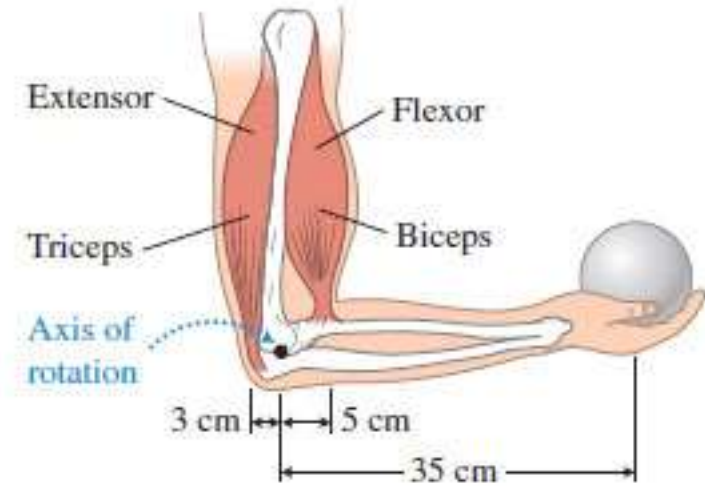


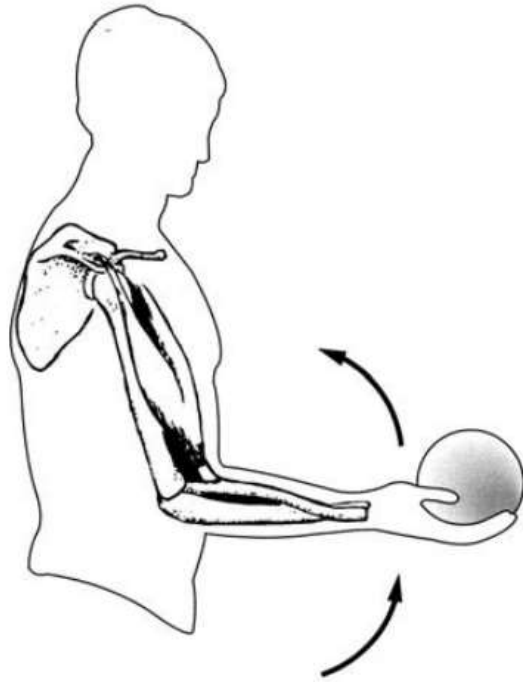
Wheelbarrow

As we will see, many of the limb movements of animals are performed by Class 3 levers.

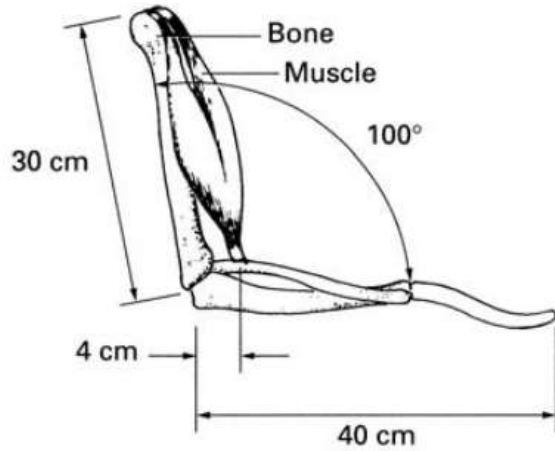


Levers referenced as whole body

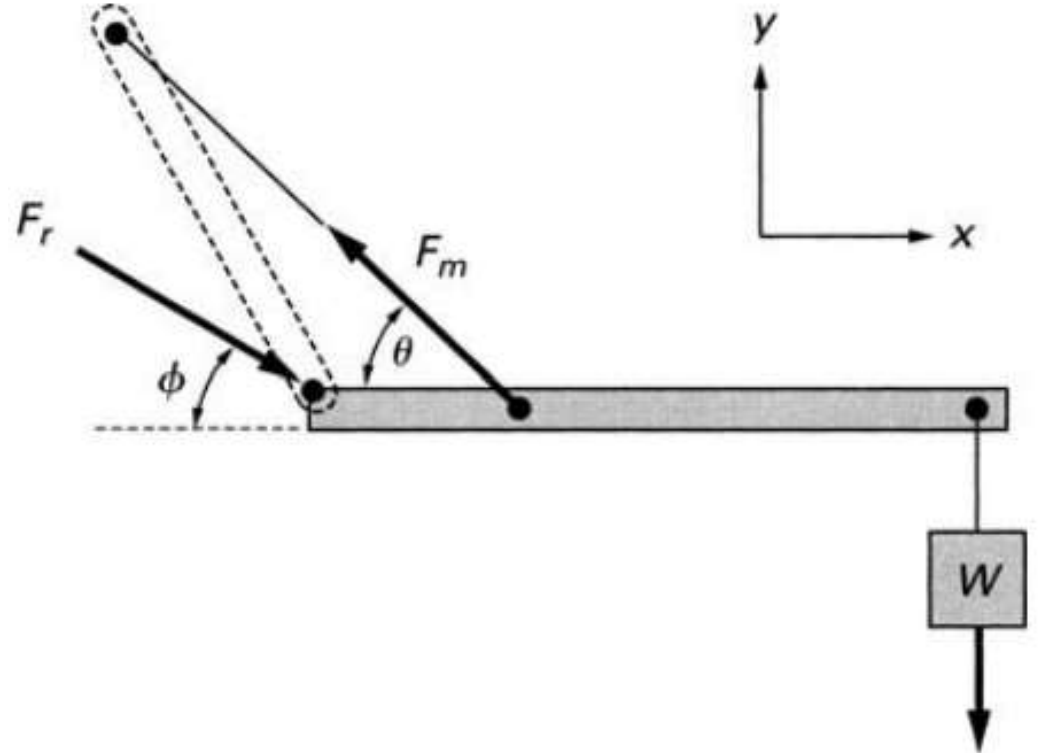




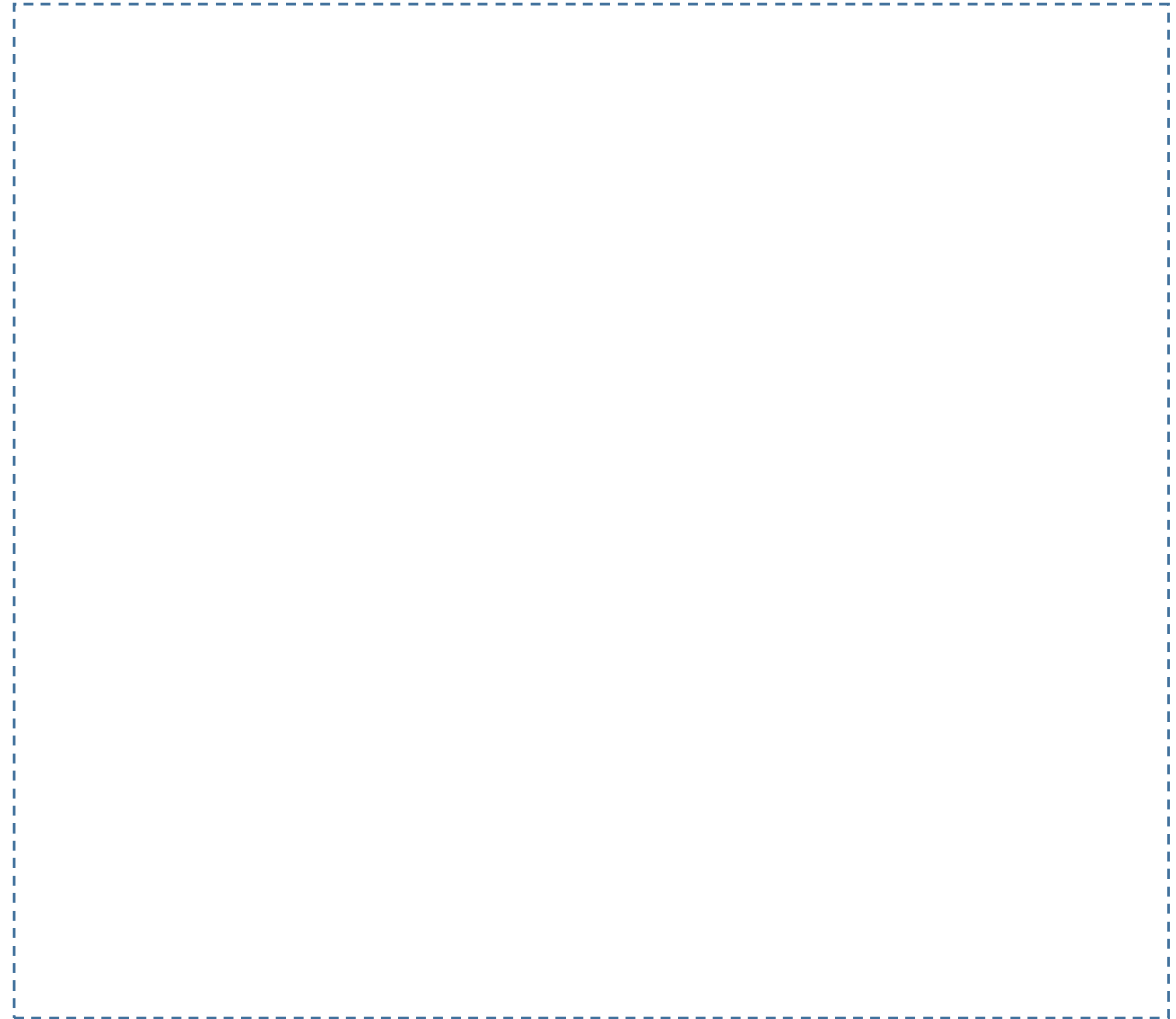
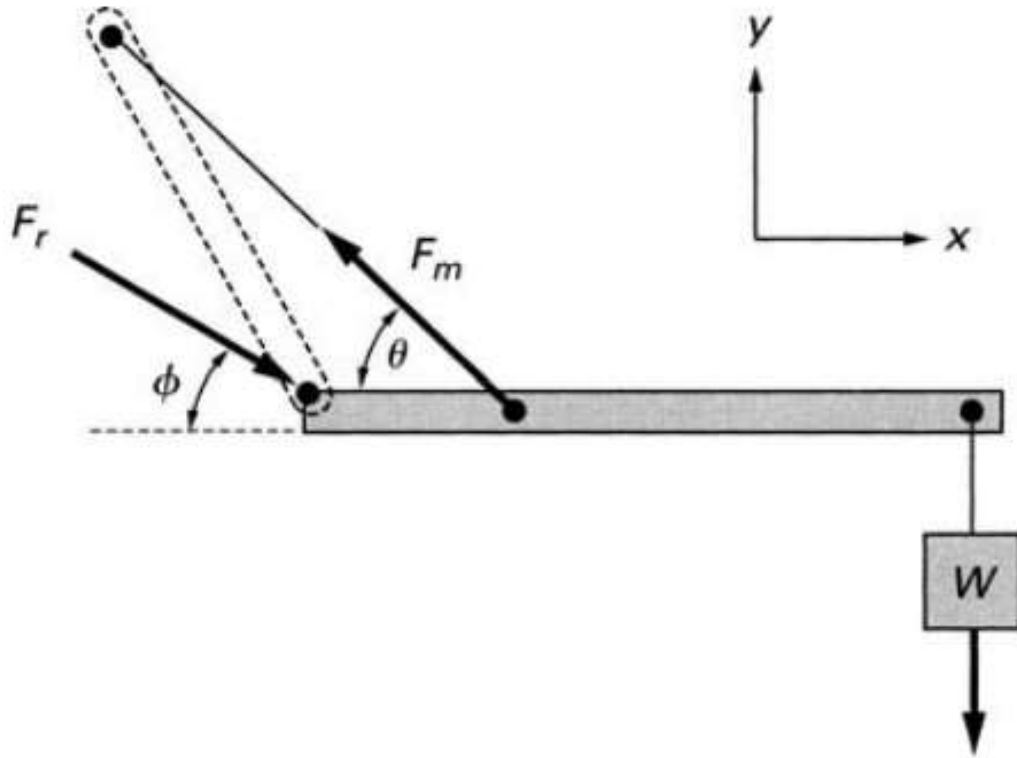
a



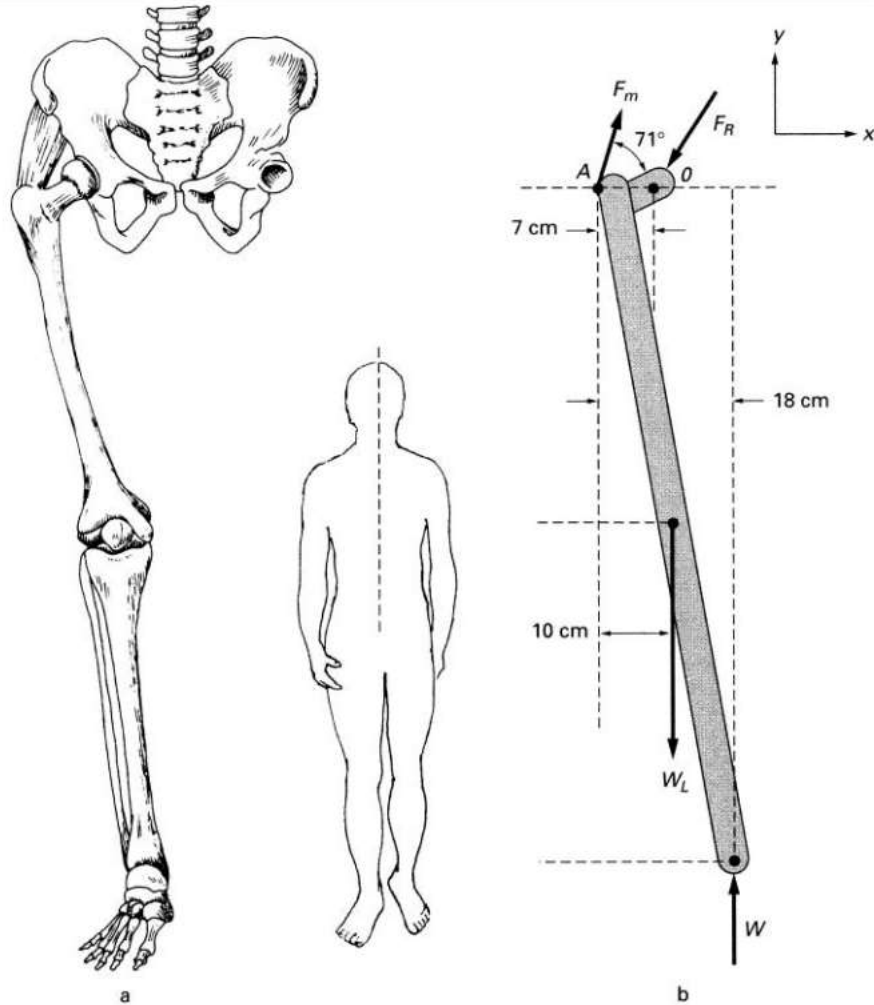
b







# The Hip



We will now calculate the magnitude of the muscle force  $F_m$  and the force  $F_R$  at the hip joint when the person is standing erect on one foot as in a slow walk,

(a) The hip. (b) Its lever representation

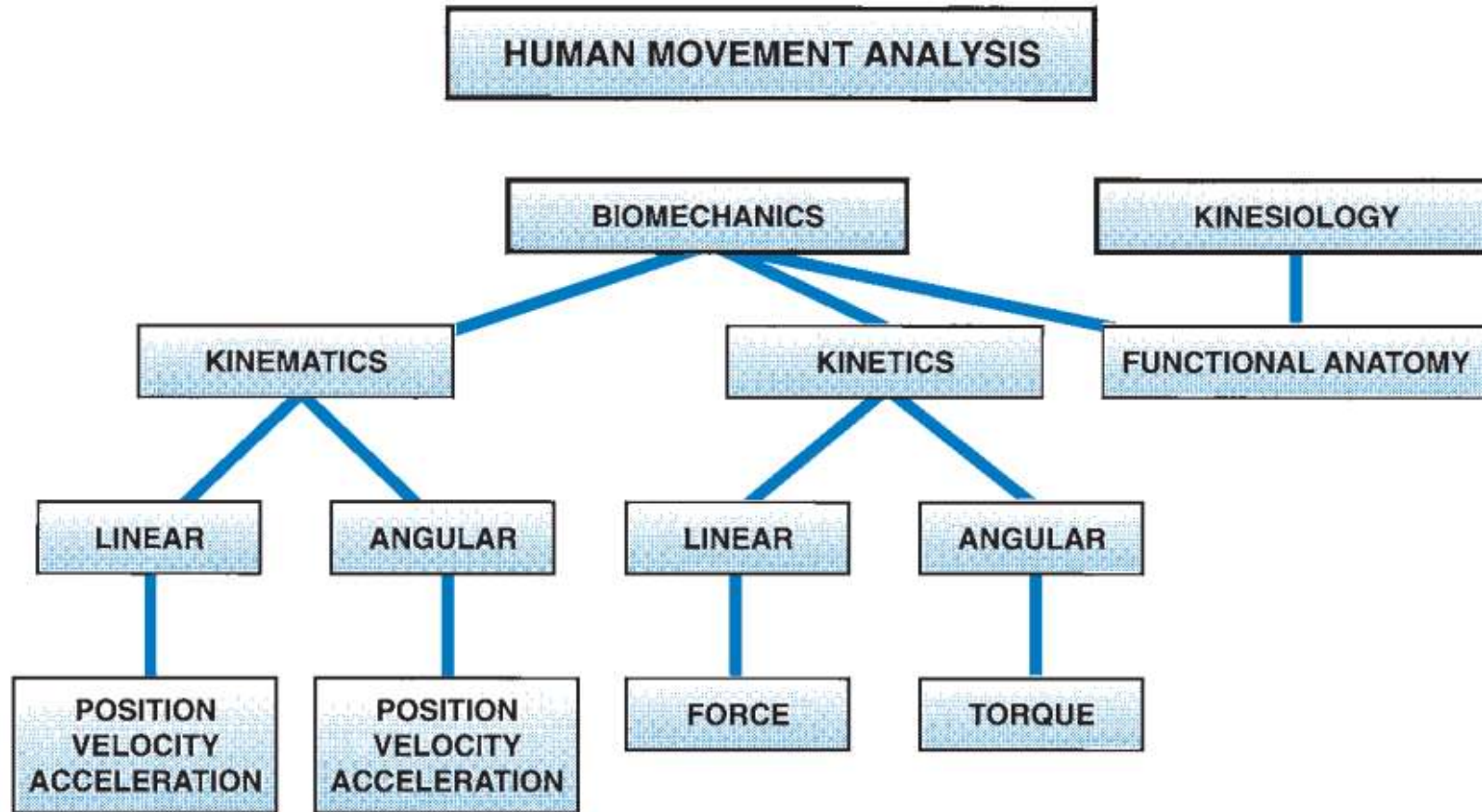
# Body Mechanics

Definition: the use of one's body to produce motion that is:

- safe,
- energy conserving,
- efficient,

all of which allows the person to

*maintain balance and control*



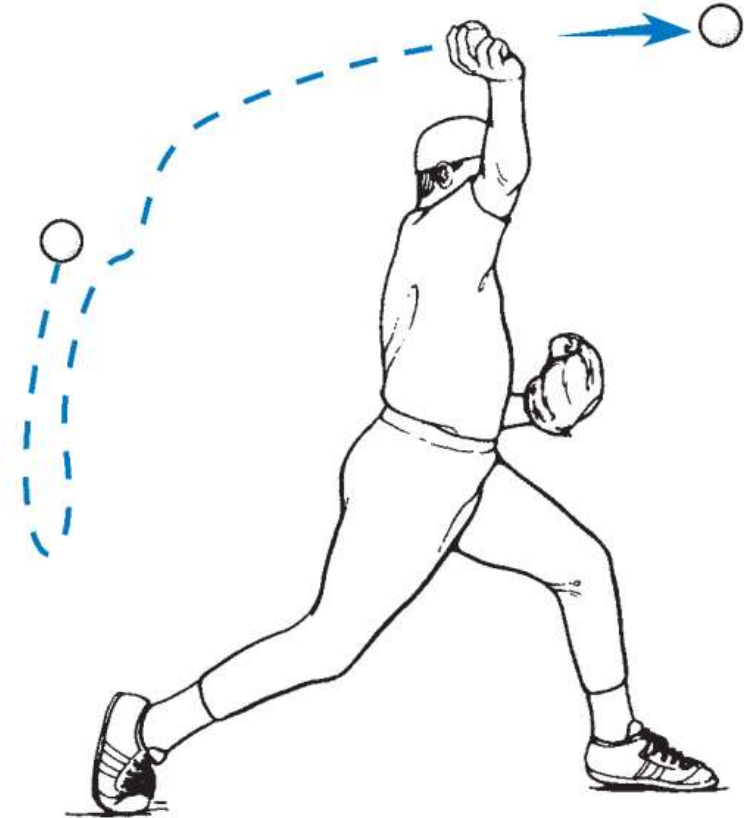
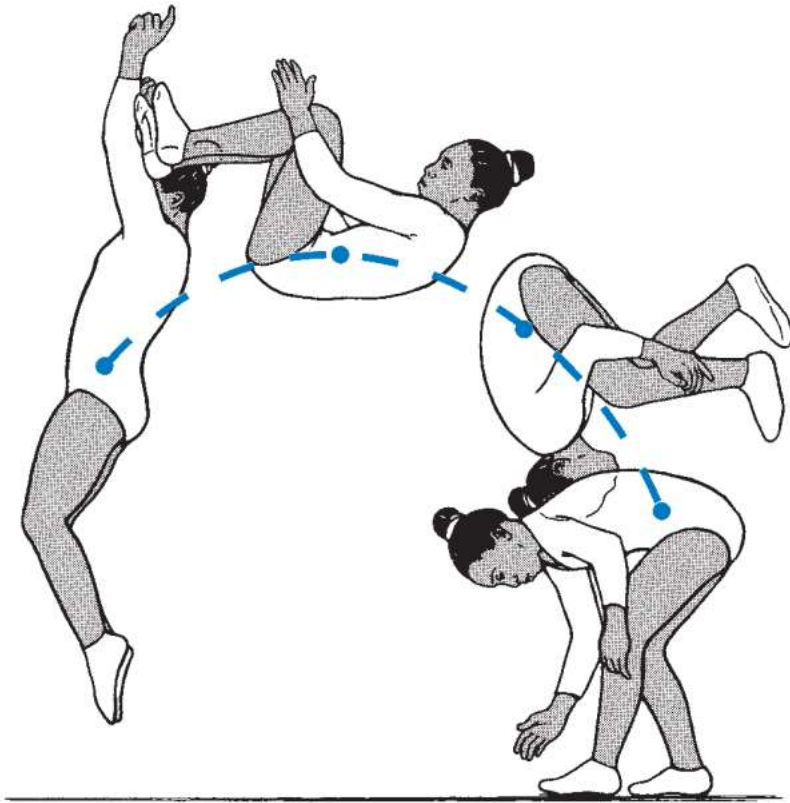


Movement or motion is a change in place, position, or posture occurring over time and relative to some point in the environment.

Two types of motion are present in a human movement or an object propelled by a human.

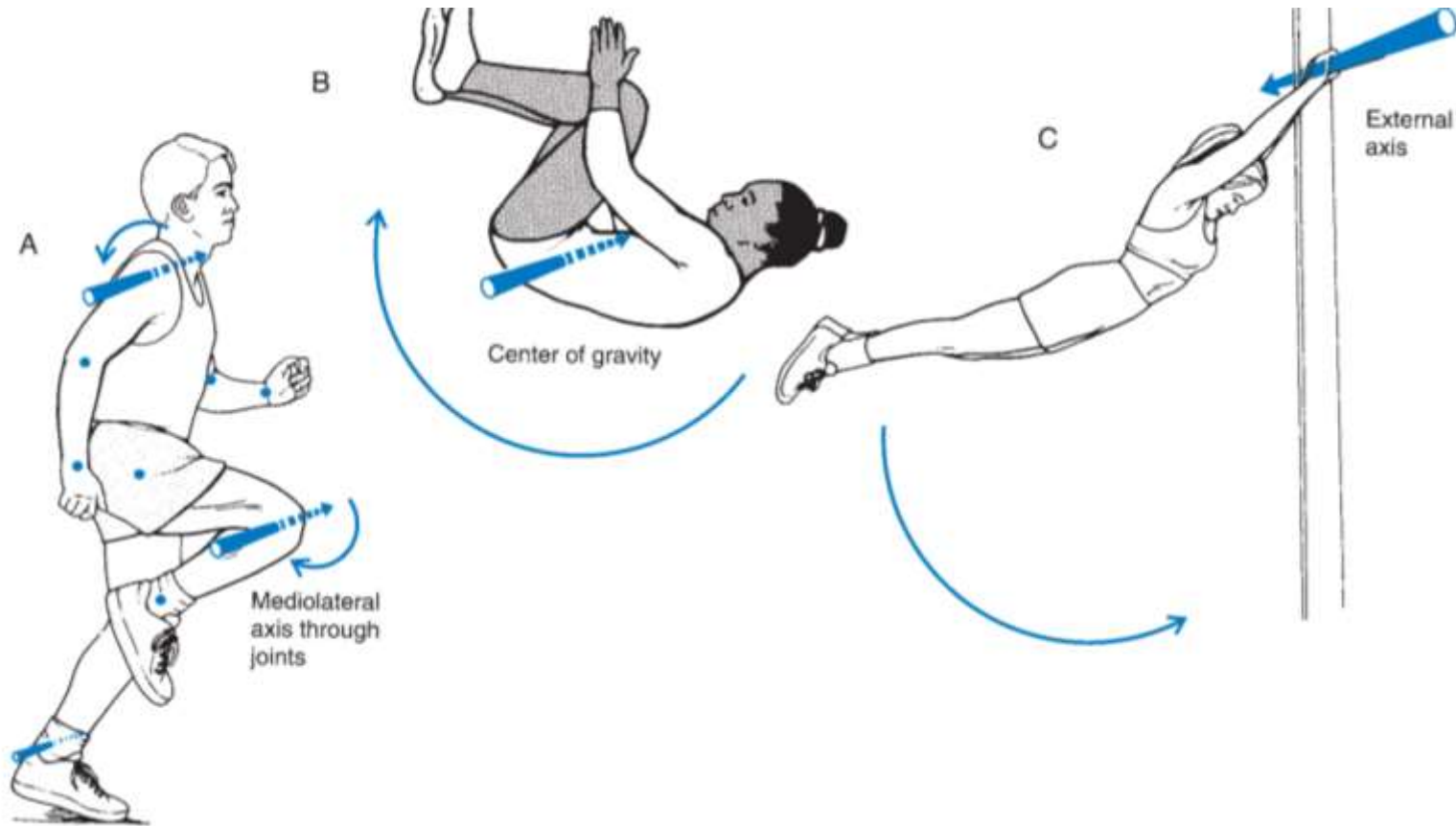
First is linear motion, often termed translation or translational motion

Linear motion is movement along a straight or curved pathway in which all points on a body or an object move the same distance in the same amount of time. Examples are the path of a sprinter, the trajectory of a baseball, the bar movement in a bench press, and the movement of the foot during a football punt.



Examples of linear motion. Ways to apply linear motion analysis include examination of the motion of the center of gravity or the path of a projected object.

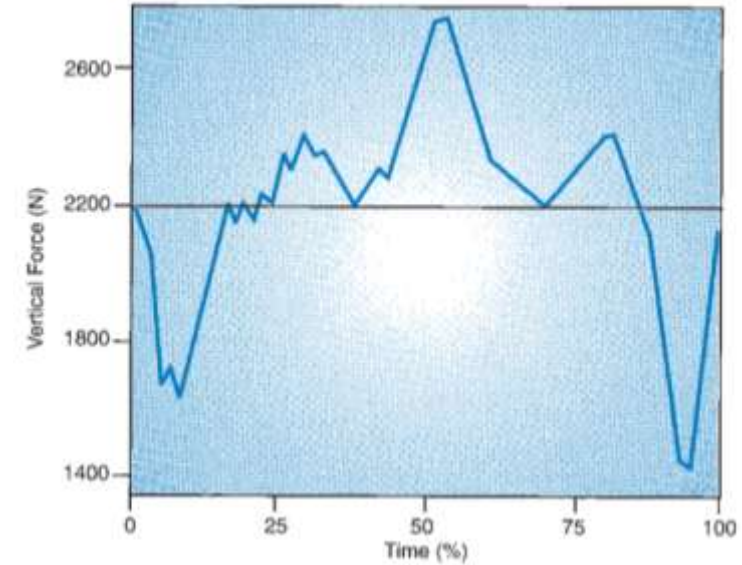
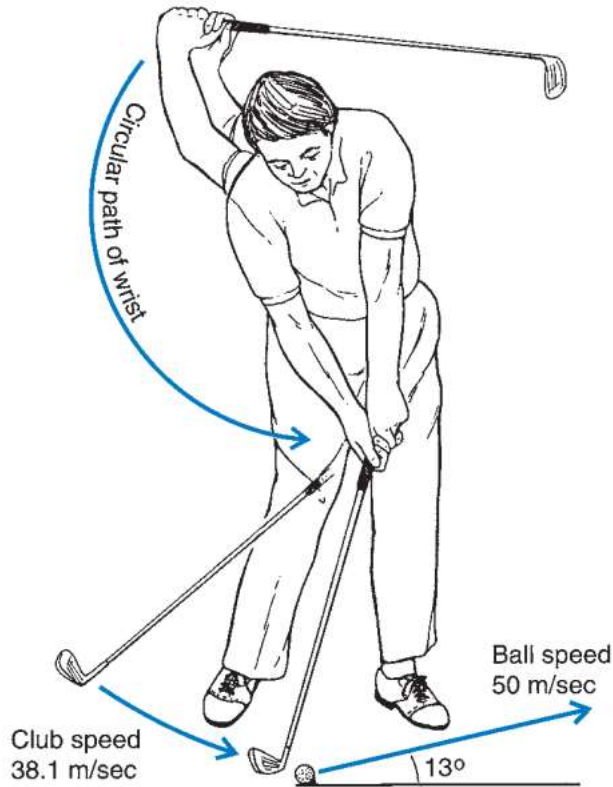
The second type of motion is angular motion, which is motion around some point so that different regions of the same body segment or object do not move through the same distance in a given amount of time.



Examples of angular motion. Angular motion of the body, an object, or segment can take place around an axis running through a joint (A), through the center of gravity (B), or about an external axis (C)

It is typical in biomechanics to examine the linear motion characteristics of an activity and then follow up with a closer look at the angular motions that create and contribute to the linear motion.

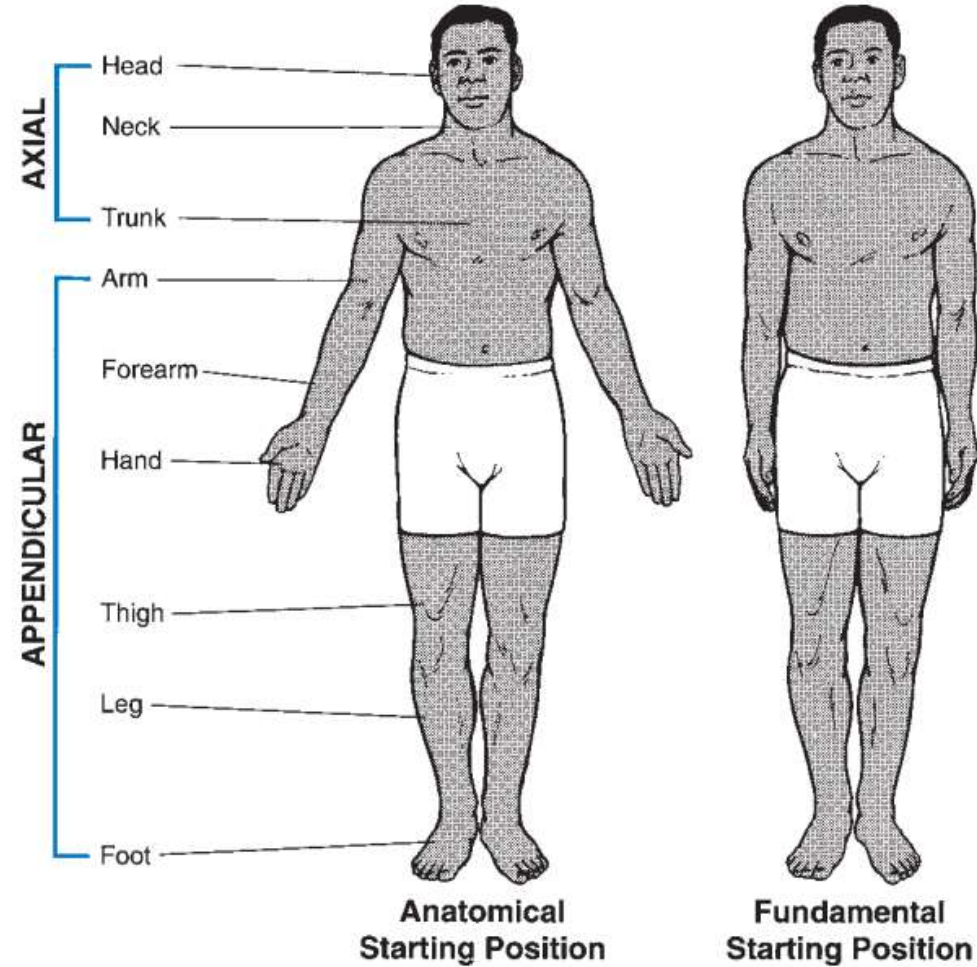




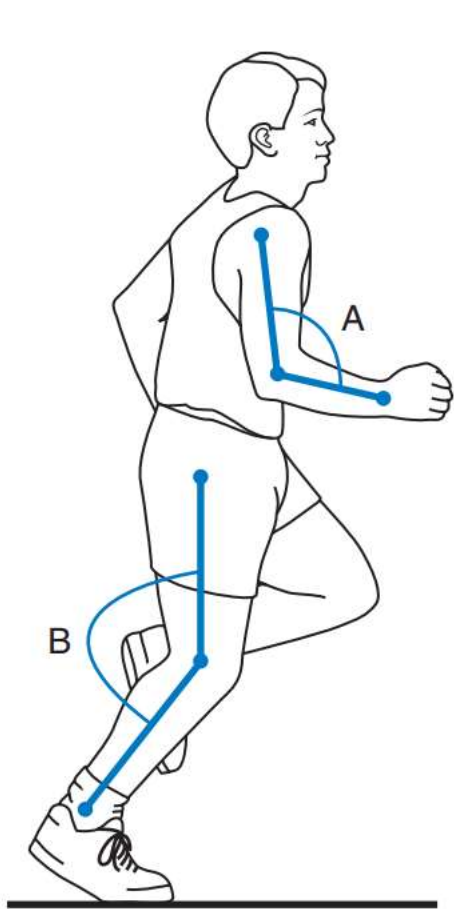
Examples of kinetic movement analysis. Kinetic analysis focuses on the cause of movement. The weight lifter demonstrates how lifting can be analyzed by looking at the vertical forces on the ground that produce the lift (linear) and the torques produced at the three lower extremity joints that generate the muscular force required for the lift. (Redrawn from Lander, J. et al. [1986]. Biomechanics of the squat exercise using a modified center of mass bar. *Medicine & Science in Sports & Exercise*, 18:469–478.)



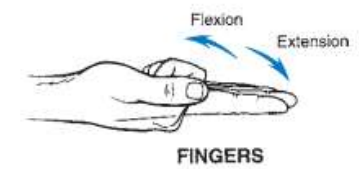
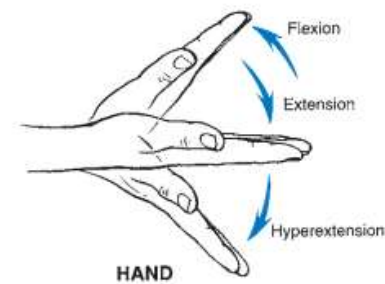
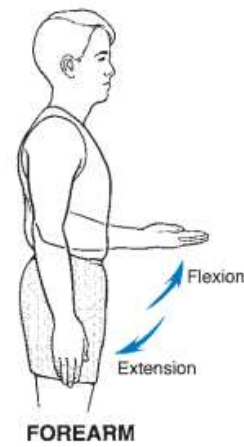
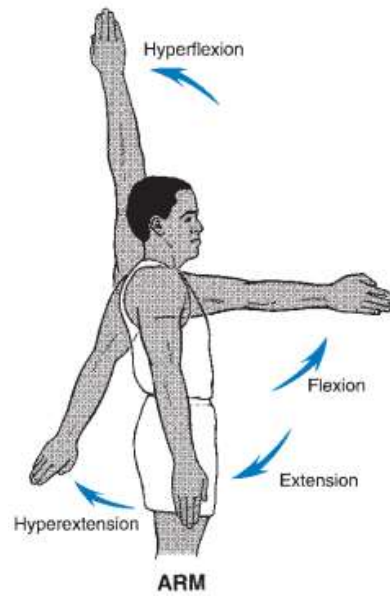
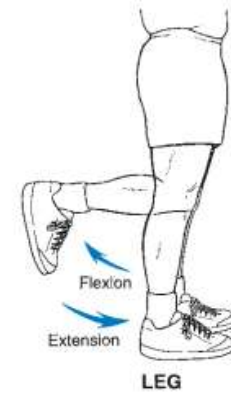
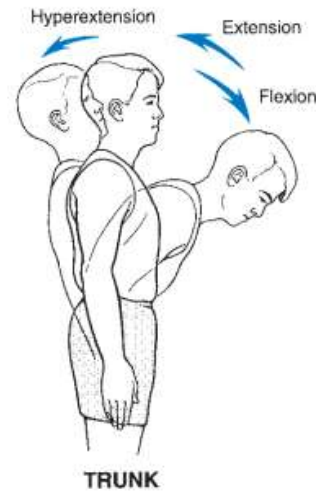
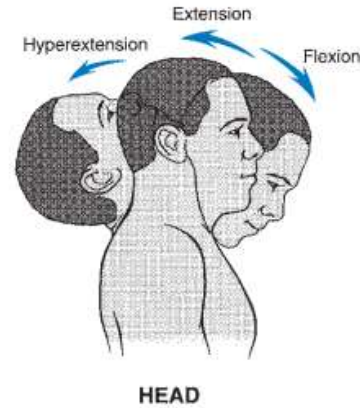
## Anatomical Movement Descriptors: SEGMENT NAMES



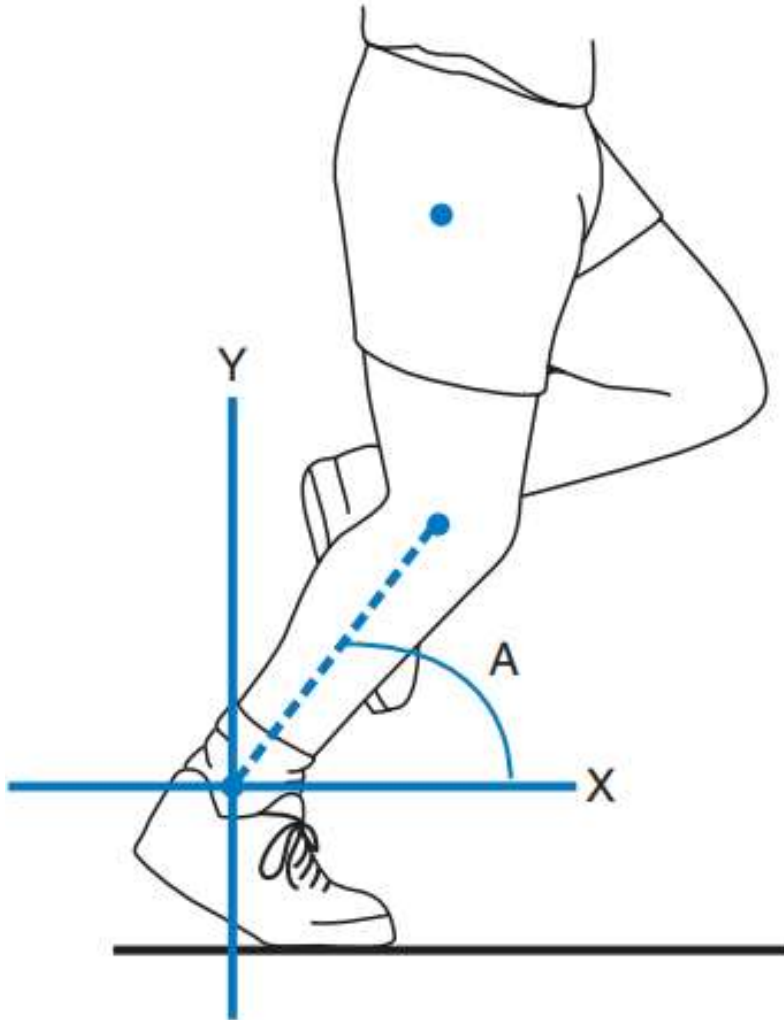
Anatomical versus fundamental starting position. The anatomical and fundamental starting positions serve as a reference point for the description of joint movements.



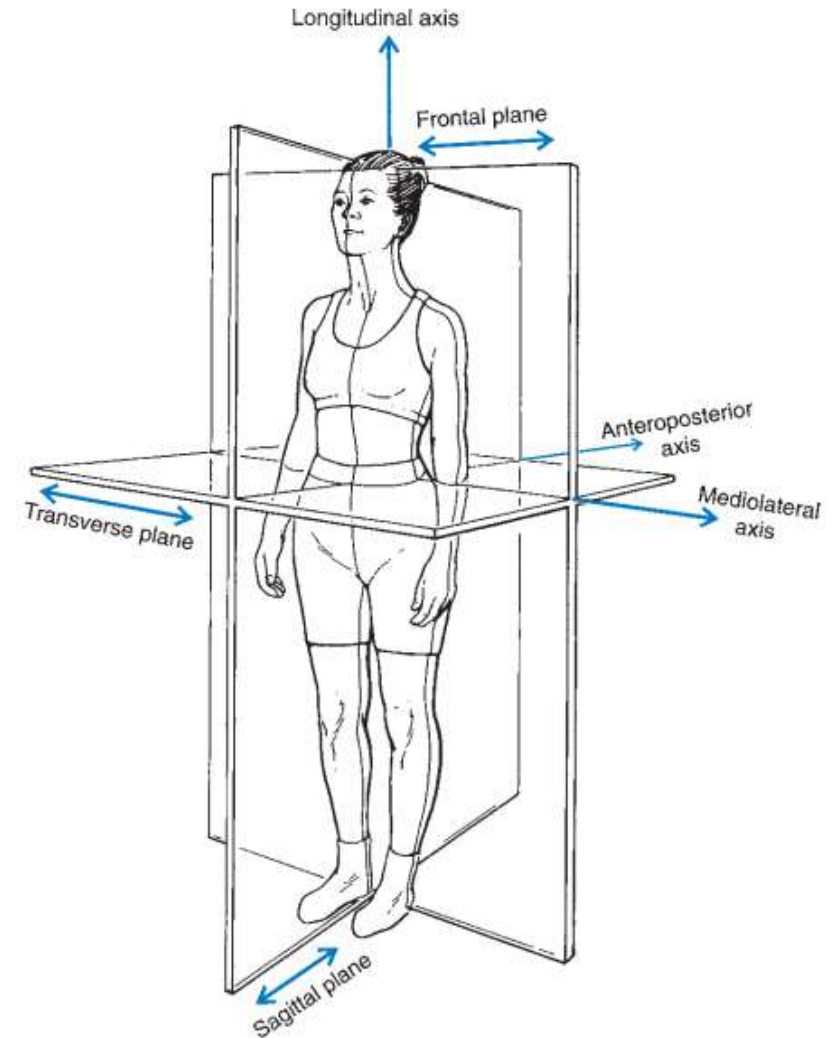
Relative angles of the elbow (A) and knee (B)



## Reference Systems

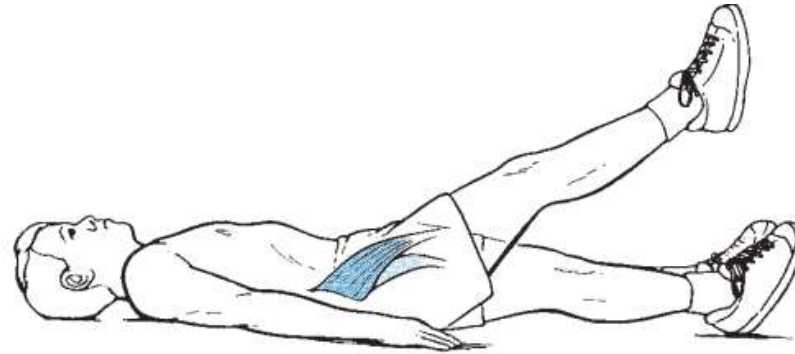


## PLANES AND AXES

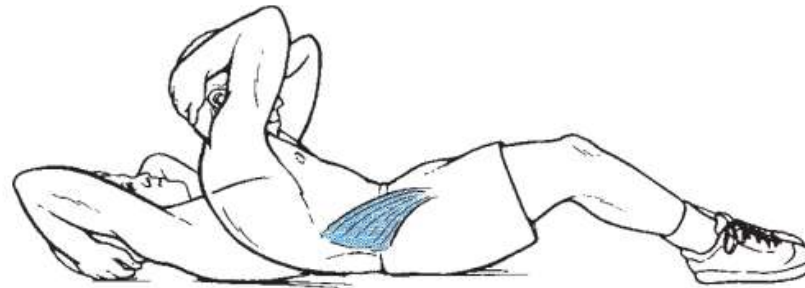




## DEVELOPING TORQUE



Single-leg raise



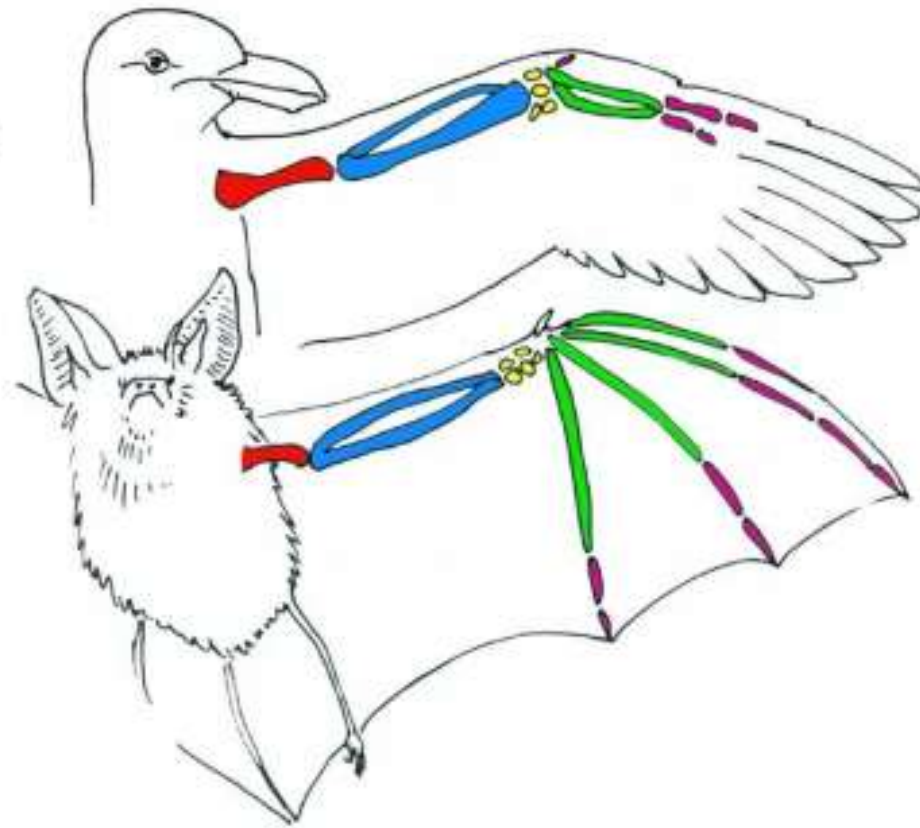
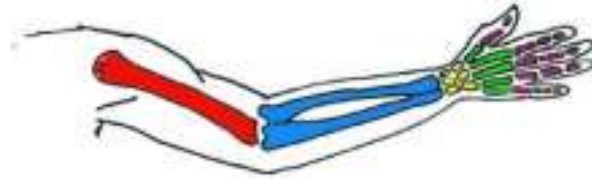
Sit-up

With the trunk stabilized, the femur moves (leg raise),  
and with the legs stabilized, the trunk moves (sit-up)





-  Humerus (upper arm bone)
-  Radius, Ulna (forearm bones)
-  Carpus (wrist bones)
-  Metacarpus (palm bones)
-  Phalanges (finger bones)







# Body Mechanics and Ergonomic Positioning



**PEEKABOO!!**



The Calgary Zoological Society



**Figure 10-1**

Kamala (her name means "lotus flower") was born in 1975 in Sri Lanka's Yala National Park and orphaned shortly thereafter. She was adopted by the Calgary, Alberta, Zoological Society. Elephants were first observed to paint with sticks or rocks in the dust, and some have become accomplished artists when given paints and a brush. Kamala began painting as part of an environmental enrichment program and her paintings are widely sold to collectors.

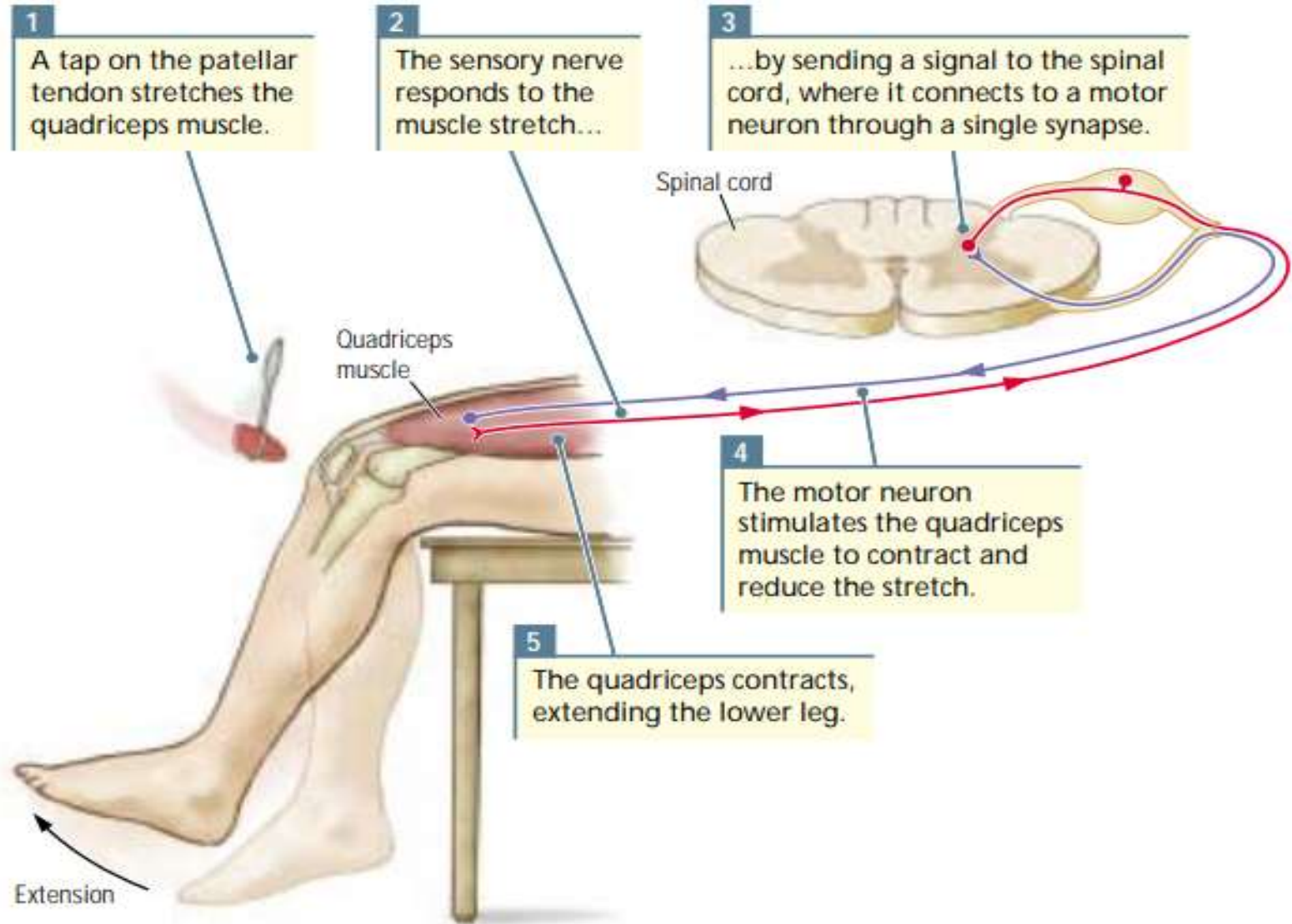
contributions of the neocortex, the brainstem, and the spinal cord to movement. Of particular interest is how neurons of the motor cortex take part in producing skilled movements. Next, we investigate how the basal ganglia and the cerebellum help to fine-tune our control of movement. Finally, we turn to the role of the somatosensory system. Although other senses, such as vision, play a part in enabling movement, body senses play a special role, as you will soon discover.



The Calgary Zoological Society

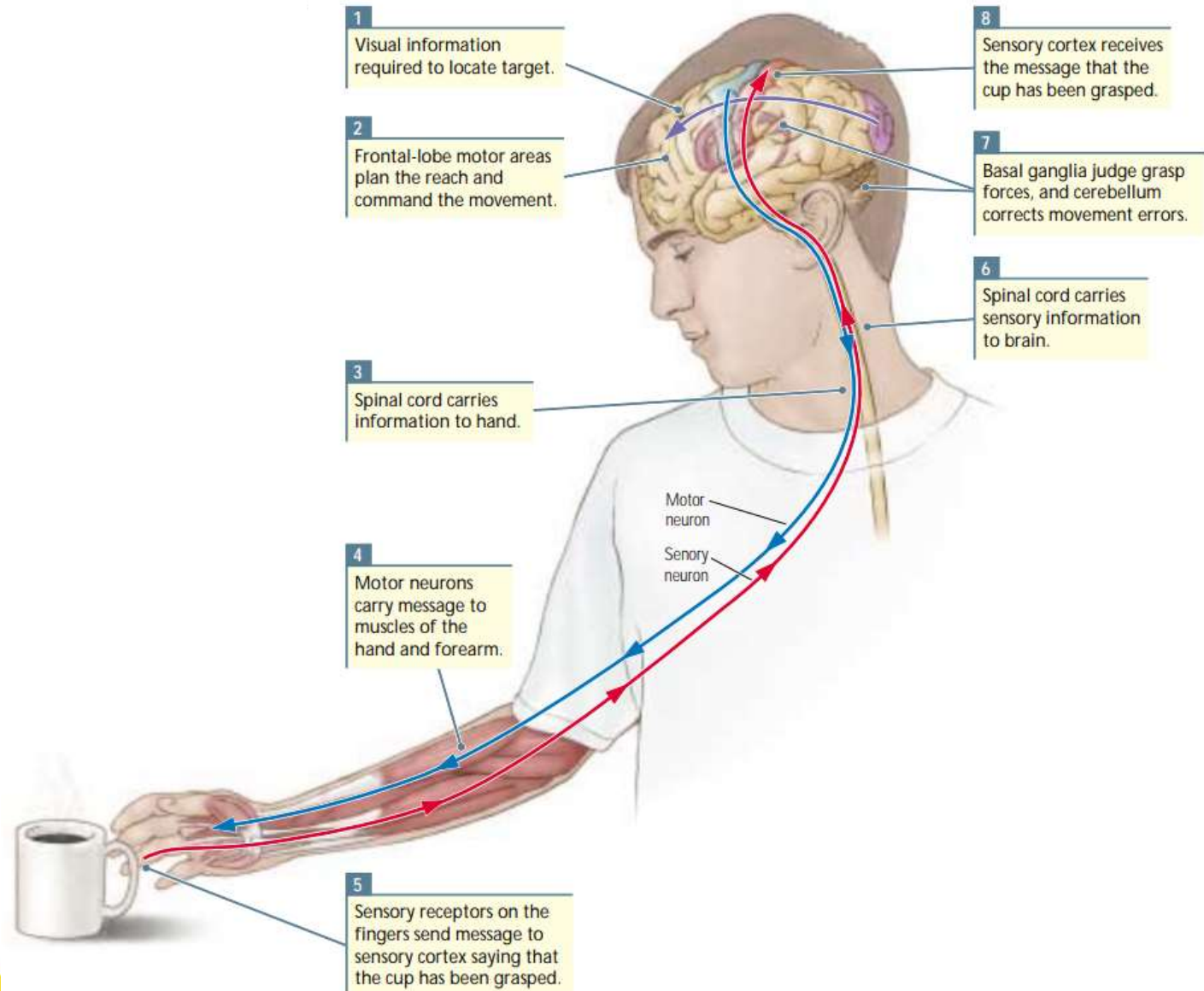


The “knee-jerk,” or stretch, reflex produced by a light tap on the patellar tendon. The subject is seated on a table so that the lower leg hangs free. The tap on the patellar stretches the quadriceps muscle to which it is attached. Stretch receptors in the muscle send a brief burst of action potentials to the spinal cord to activate the motor neuron to the quadriceps by a single synapse. The contraction of the quadriceps causes the lower leg to extend.



**Figure 10-2**

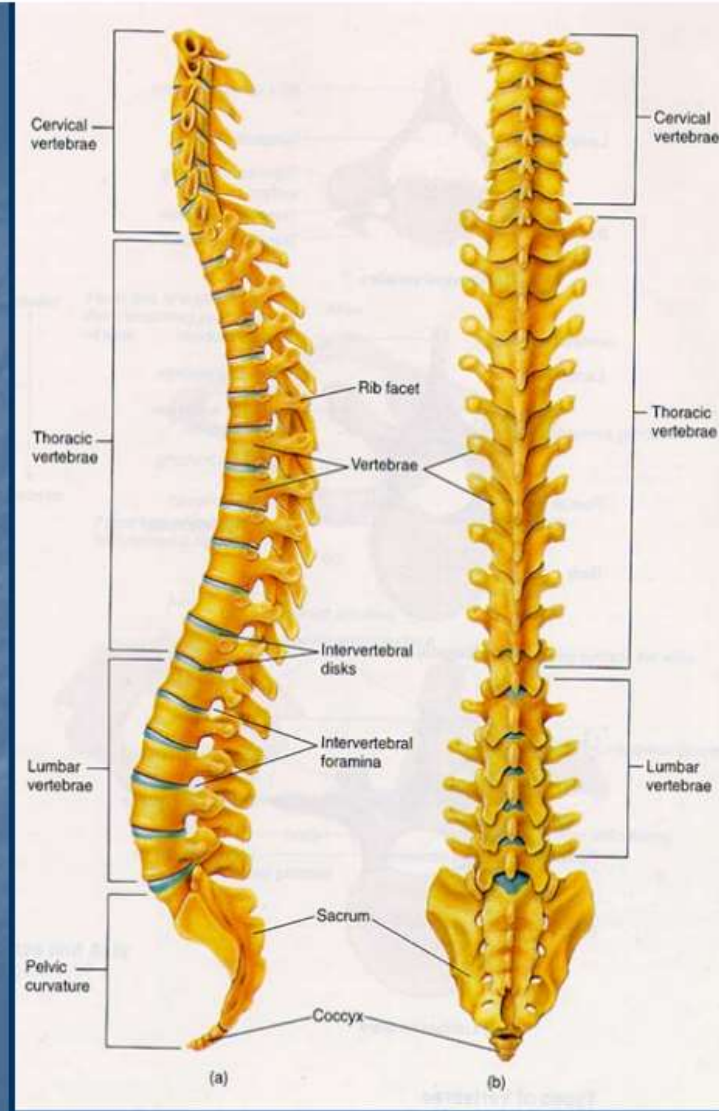
The brain tells the hand to reach, and the hand tells the brain that it has succeeded. Movements such as reaching for a cup require the participation of wide areas of the nervous system. The motor regions of the frontal lobe formulate the plan and command the movements required to reach for the cup. The message to the muscles is carried by pathways from the frontal lobe to the spinal cord. Motor neurons of the spinal cord carry the message to the muscles of the hand and arm. Sensory information from the visual system is required to direct the hand to the cup, and sensory information from sensory receptors in the hand is required to confirm that the cup has been grasped. The basal ganglia participate in the movement by estimating the forces required to make the grasp, and the cerebellum participates by correcting errors in the movement as it is made.





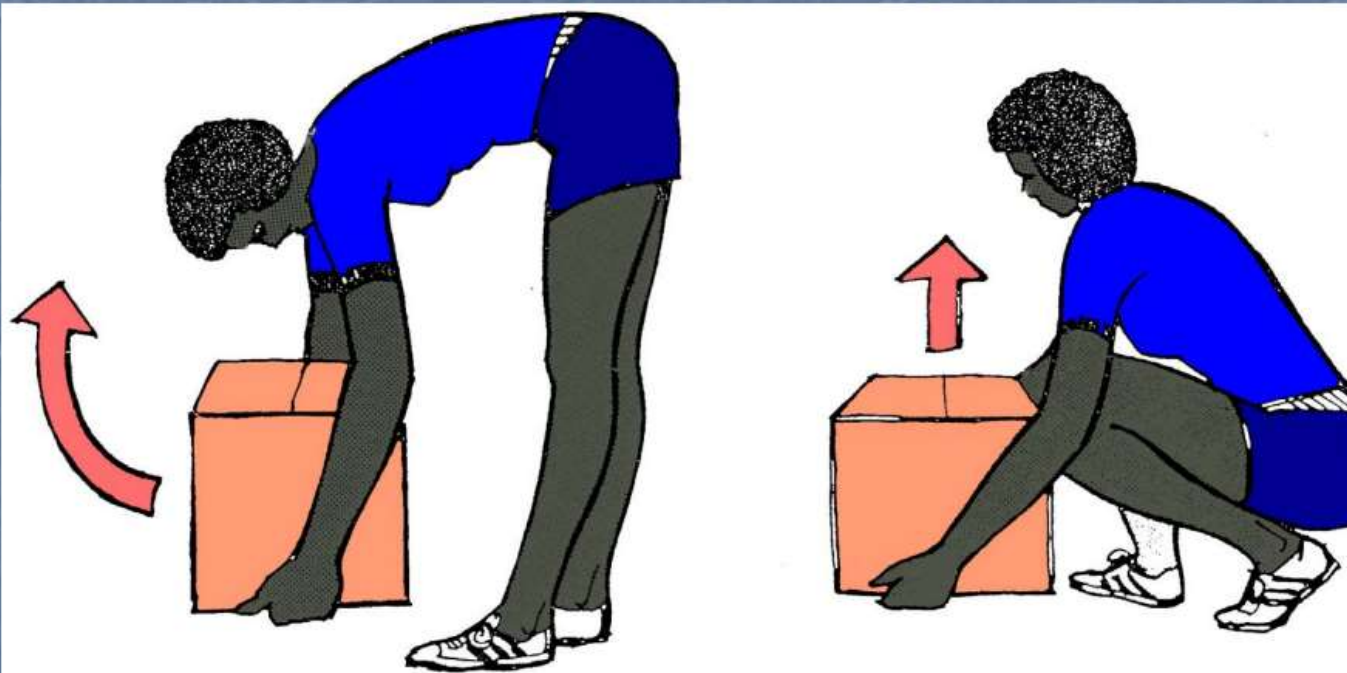
# Functions of Spinal Column

- Load bearing
- Permits movement
- Protects spinal cord





## Demonstration of Bad and Good Lifting Technique



**Incorrect**

**Correct**

# Engineering Mechanics

## Rigid-body Mechanics

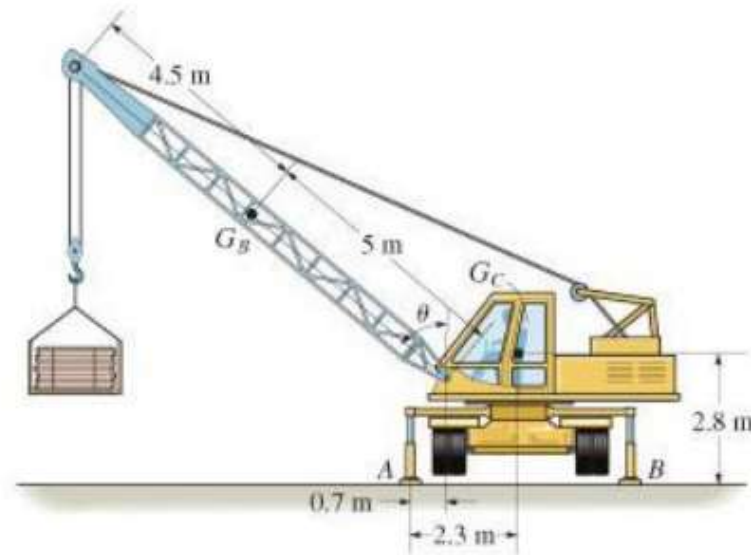
- a basic requirement for the study of the mechanics of deformable bodies and the mechanics of fluids (advanced courses).
- essential for the design and analysis of many types of structural members, mechanical components, electrical devices, etc, encountered in engineering.

**A rigid body does not deform under load!**

# Engineering Mechanics

## Rigid-body Mechanics

**Statics:** deals with equilibrium of bodies under action of forces (bodies may be either at rest or move with a constant velocity).



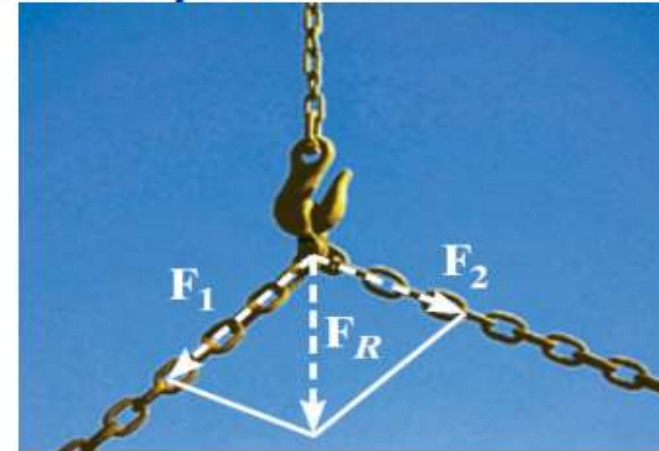


## Vector Addition: Procedure for Analysis

### Parallelogram Law (Graphical)

Resultant Force (diagonal)

Components (sides of  
parallelogram)



### Algebraic Solution

Using the coordinate system

Cosine law:

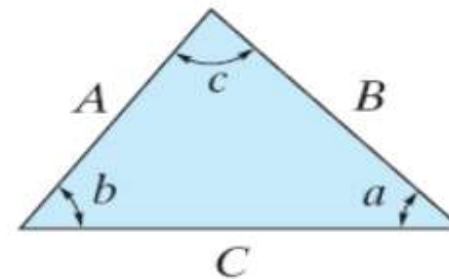
$$C = \sqrt{A^2 + B^2 - 2AB \cos c}$$

Sine law:

$$\frac{A}{\sin a} = \frac{B}{\sin b} = \frac{C}{\sin c}$$

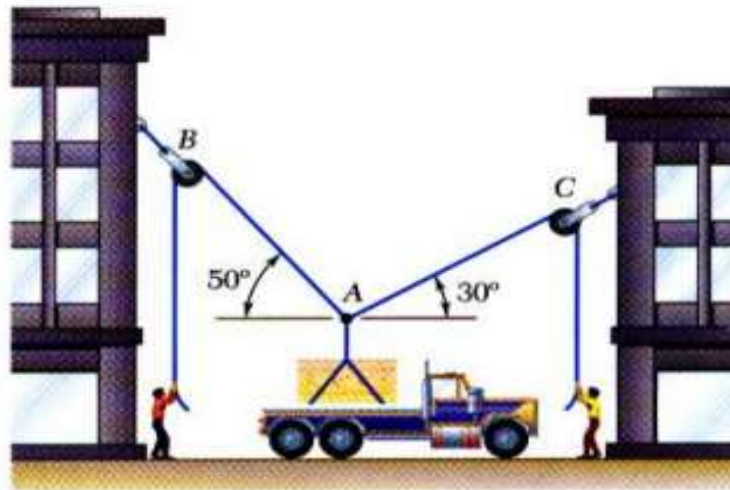
### Trigonometry (Geometry)

Resultant Force and Components  
from Law of Cosines and Law of  
Sines

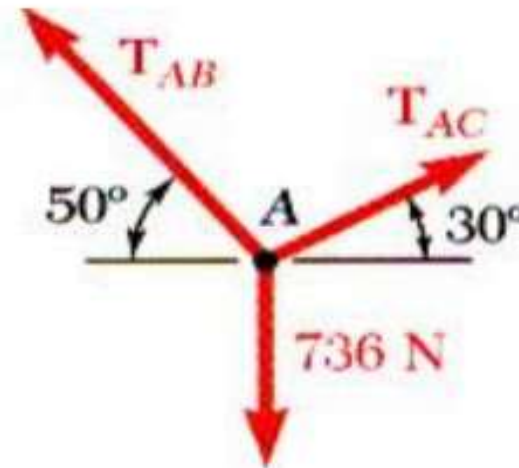


# Rigid Body Equilibrium

## Free-Body Diagrams



*Space Diagram:* A sketch showing the physical conditions of the problem.



*Free-Body Diagram:* A sketch showing only the forces on the selected particle.



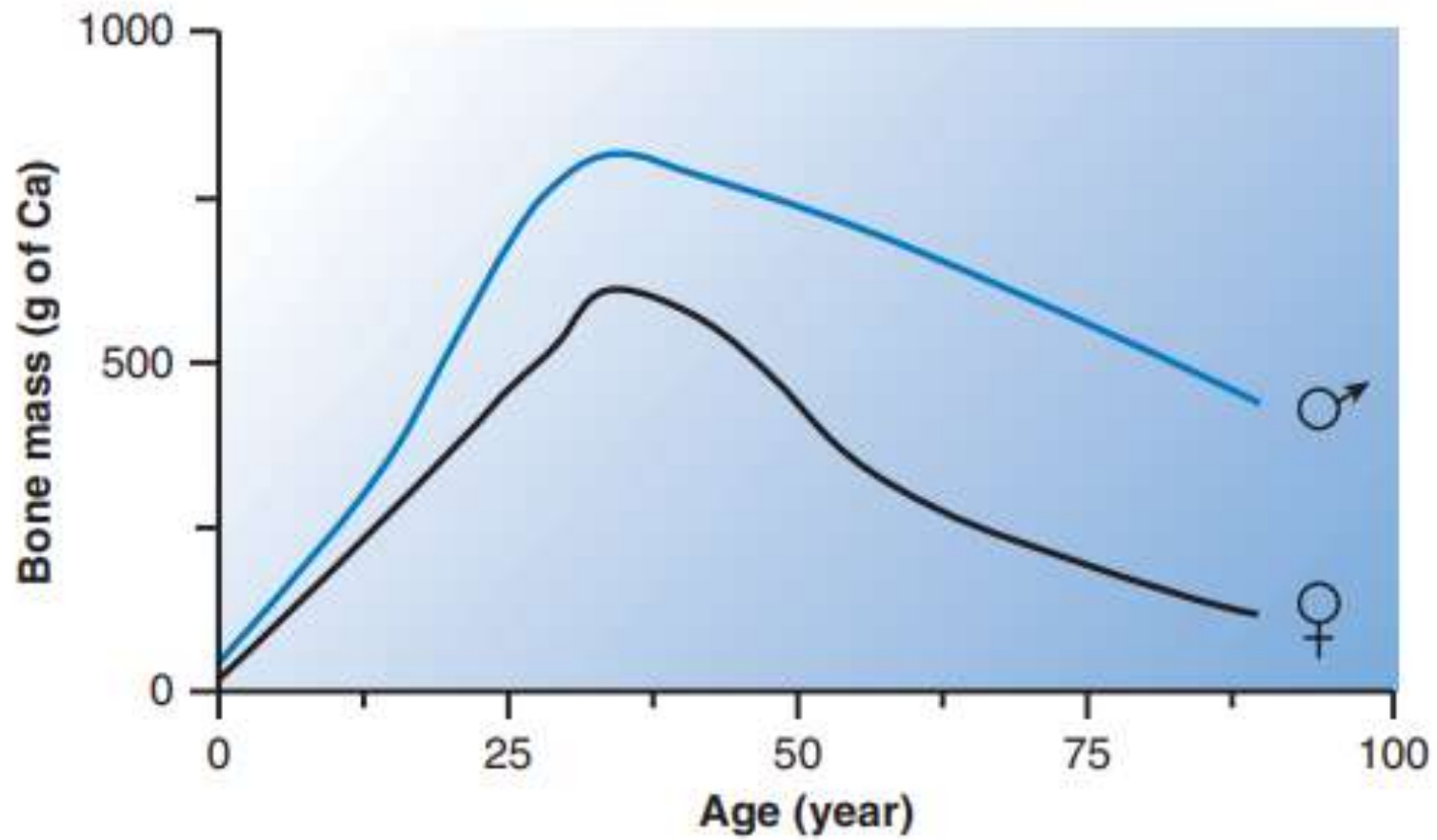
consists of both **fused and individual bones** supported and supplemented by **ligaments, tendons, anchoring muscles and cartilage**.

Skeleton of **adult** human consists of **206 bones**

**New-born children** have about **300 bones** [grow together].

Fused bones include those of **the pelvis and the cranium**.

The development of whole skeleton is accomplished in the **age of 20 years**.



Peak bone mass occurs during the late third decade of life. Females have a lower peak bone mass and greater reductions in later life, especially after menopause.



Frontal or Coronal Plane

Median or Sagittal Plane

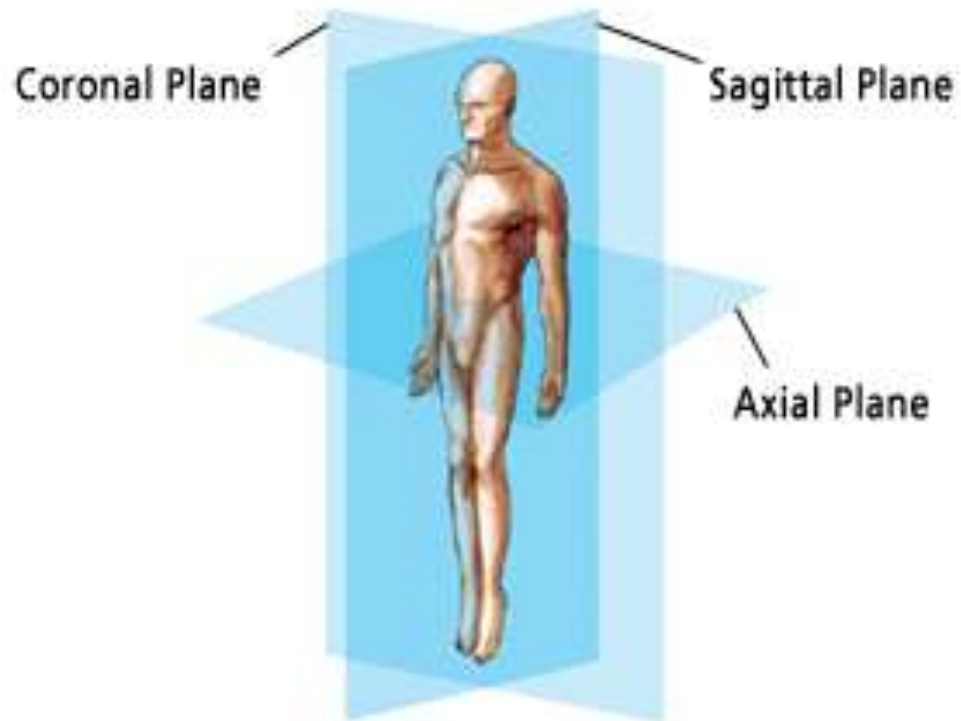
Transverse or Axial Plane

## Meaning

Divides the front and back halves of the entire body.

Divides the left and right sides of the entire body.

Divides the body at the waist (top and bottom halves of the body).



**ventral (anterior)**

**dorsal (posterior)**

**lateral**

**medial**

**proximal**

**distal**

# Fuselage framework

Backbone (*columna vertebralis*)

33-34 vertebrae, ribs, sternum

- 7 cervical (*vv. cervicales*) C1- C7

(*atlas, axis*)

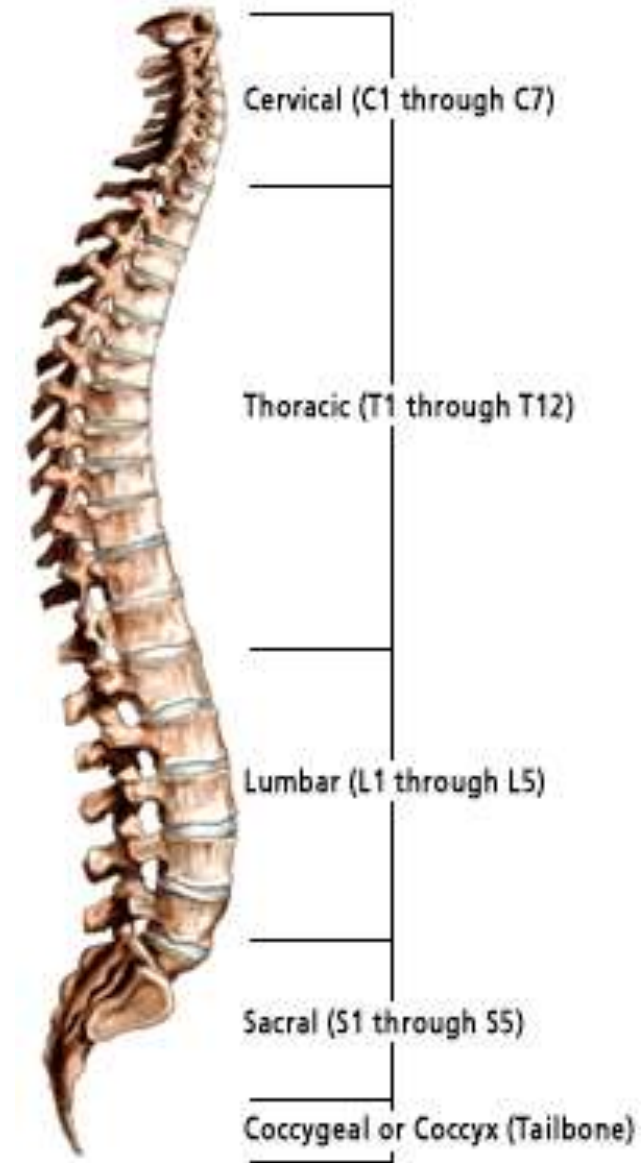
- 12 thoracic (*vv. thoracicae*)

Th1-Th12

- 5 lumbar (*vv. lumbales*) L1-5

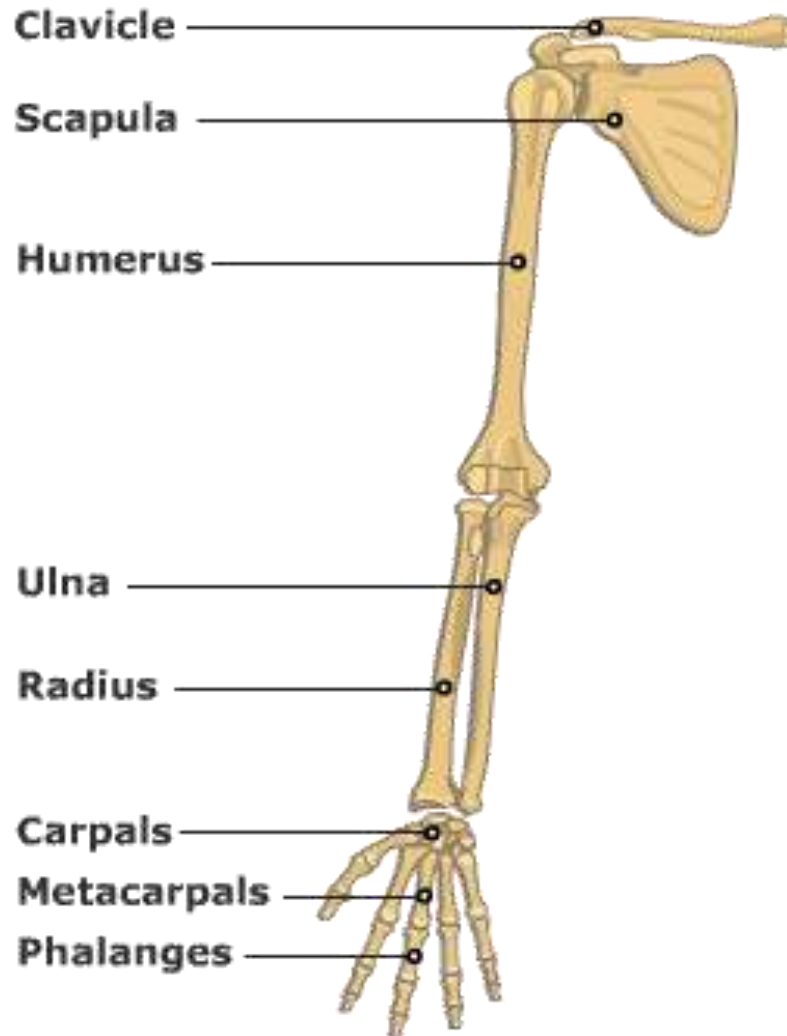
- 5 sacral (*vv. sacrales*) S1 -5

- 4-5 coccygeal (*vv. coccygae*) Co1- 4-5

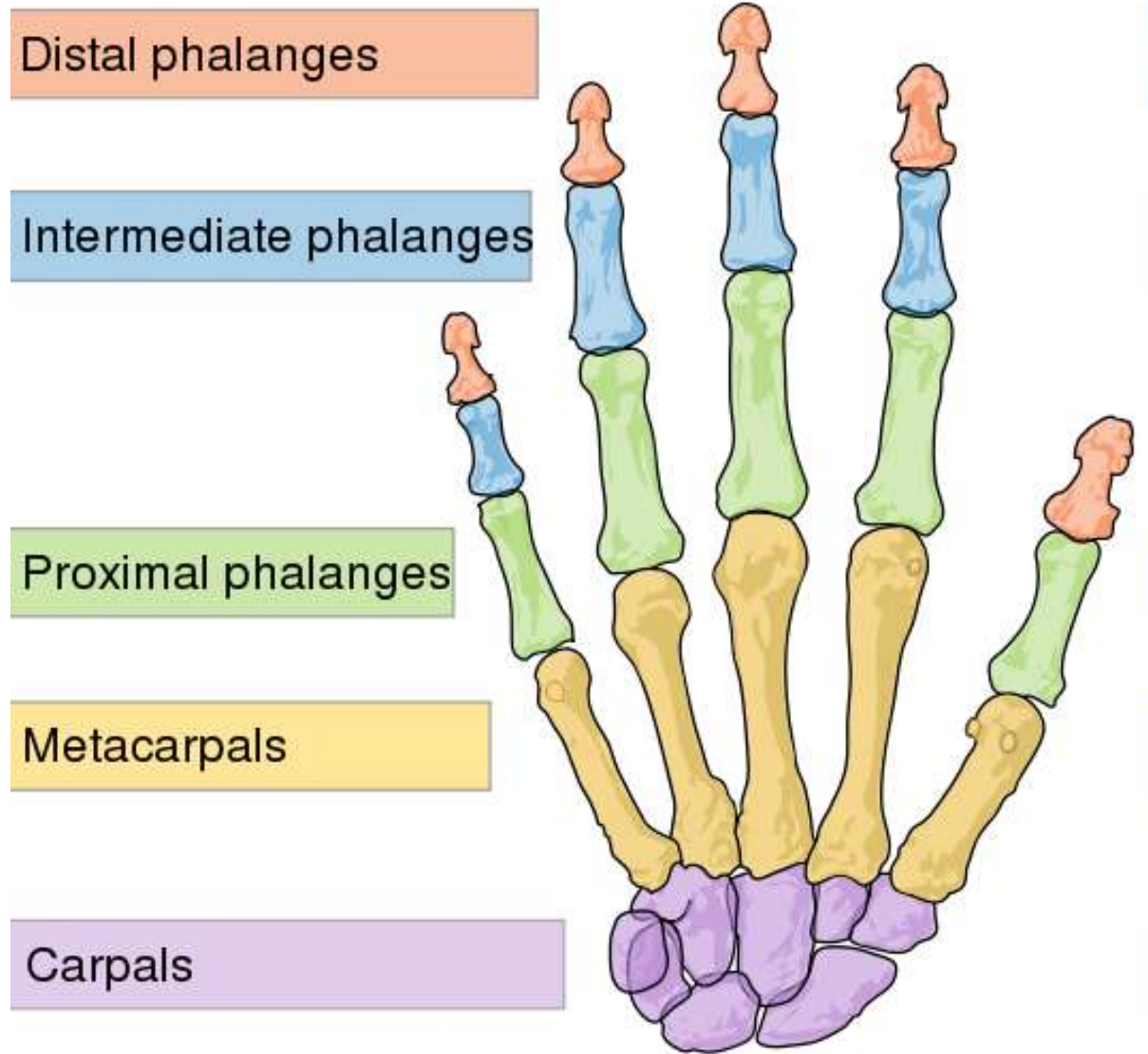




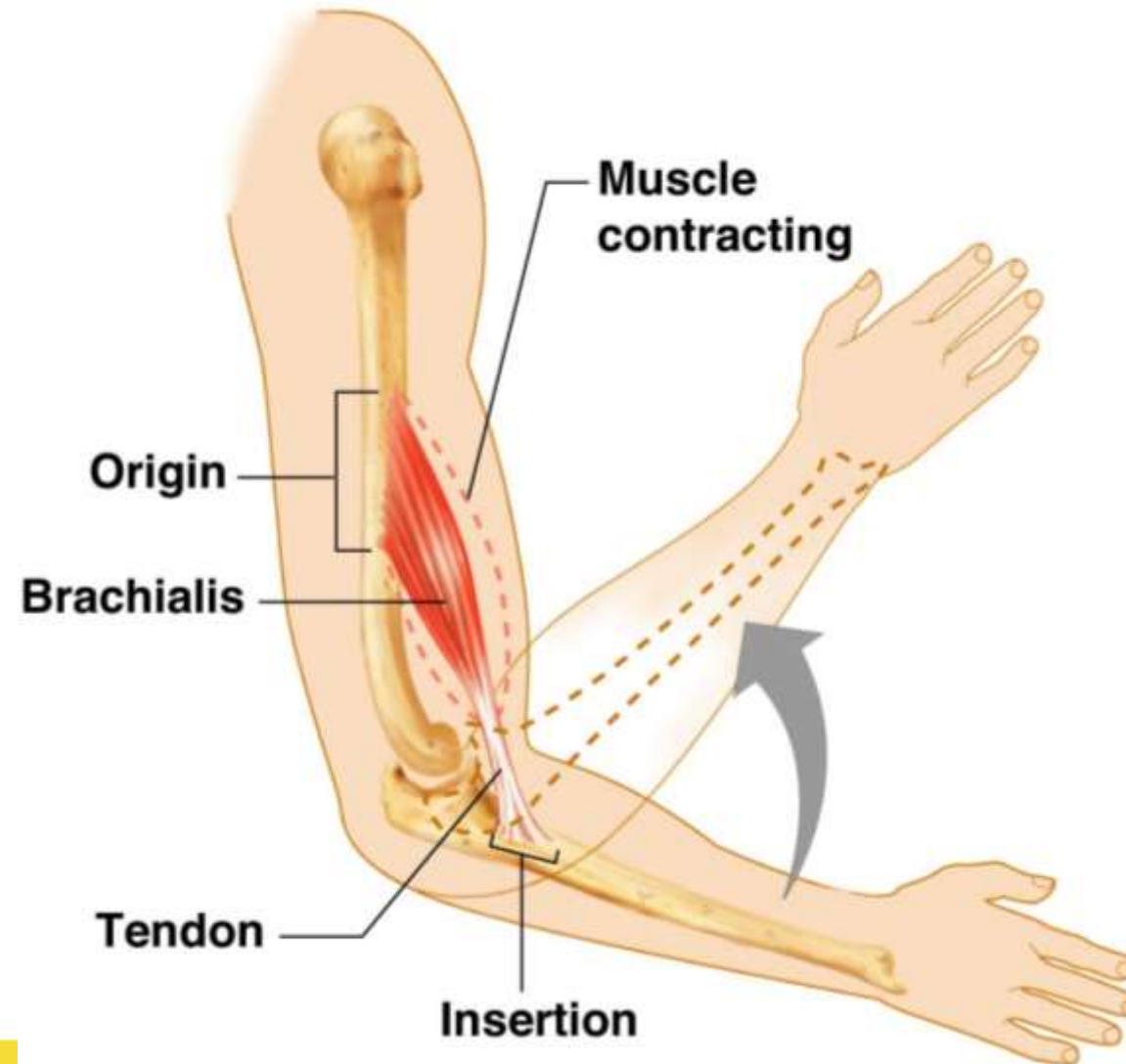
# Upper limb, Arm



- Clavicle
- Scapula
- Humerus
- Radius
- Ulna
- Carpal bones
- Metacarpals
- Phalanges



# Muscles and Body Movements

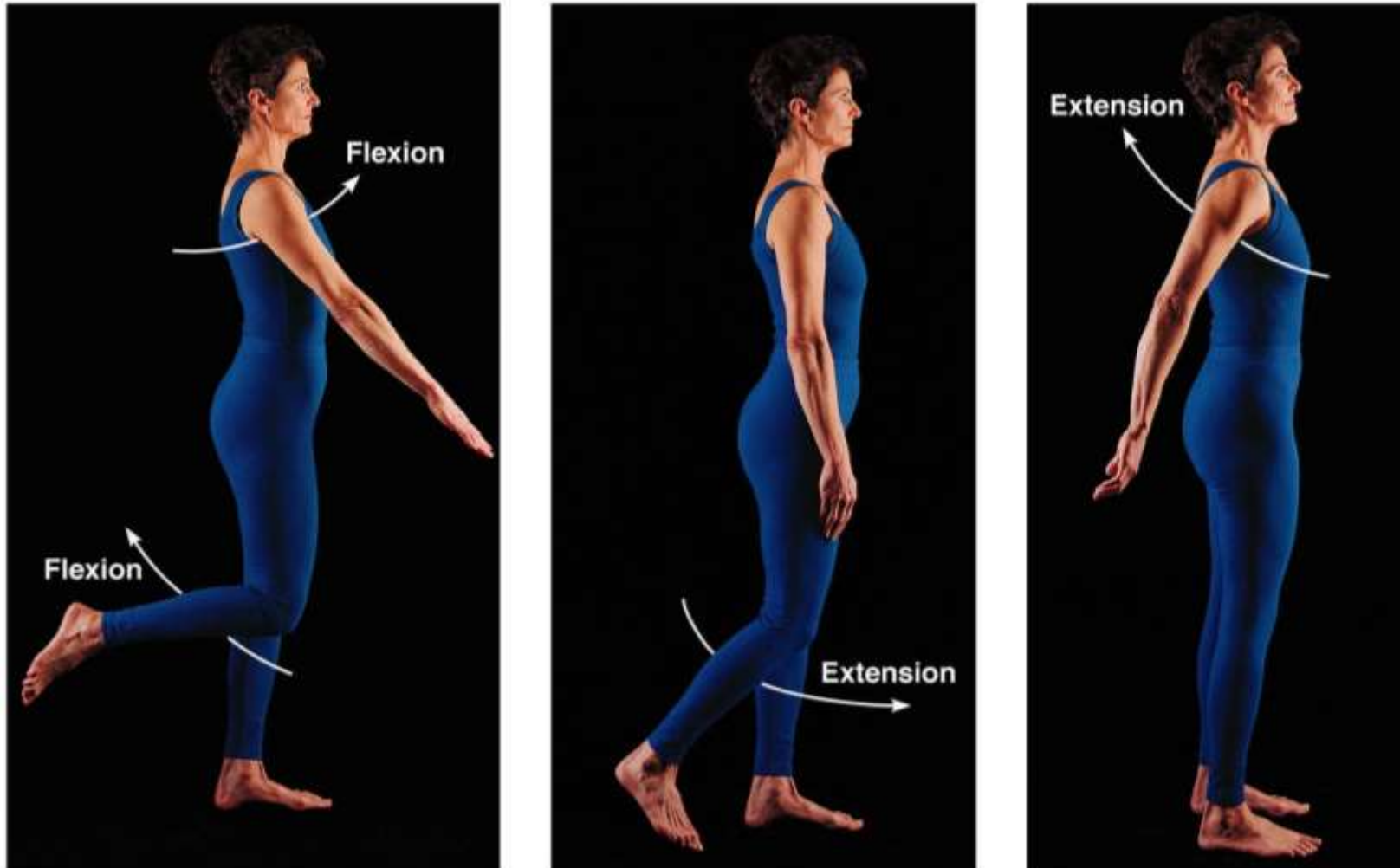


# Types of Ordinary Body Movements

- Flexion
  - Decreases the angle of the joint
  - Brings two bones closer together
  - Typical of hinge joints like knee and elbow
- Extension
  - Opposite of flexion
  - Increases angle between two bones



# Types of Ordinary Body Movements



(a) Flexion and extension of the shoulder and knee

