Basics of Biomechanics of Neuromusculoskeletal System

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Biomechanics

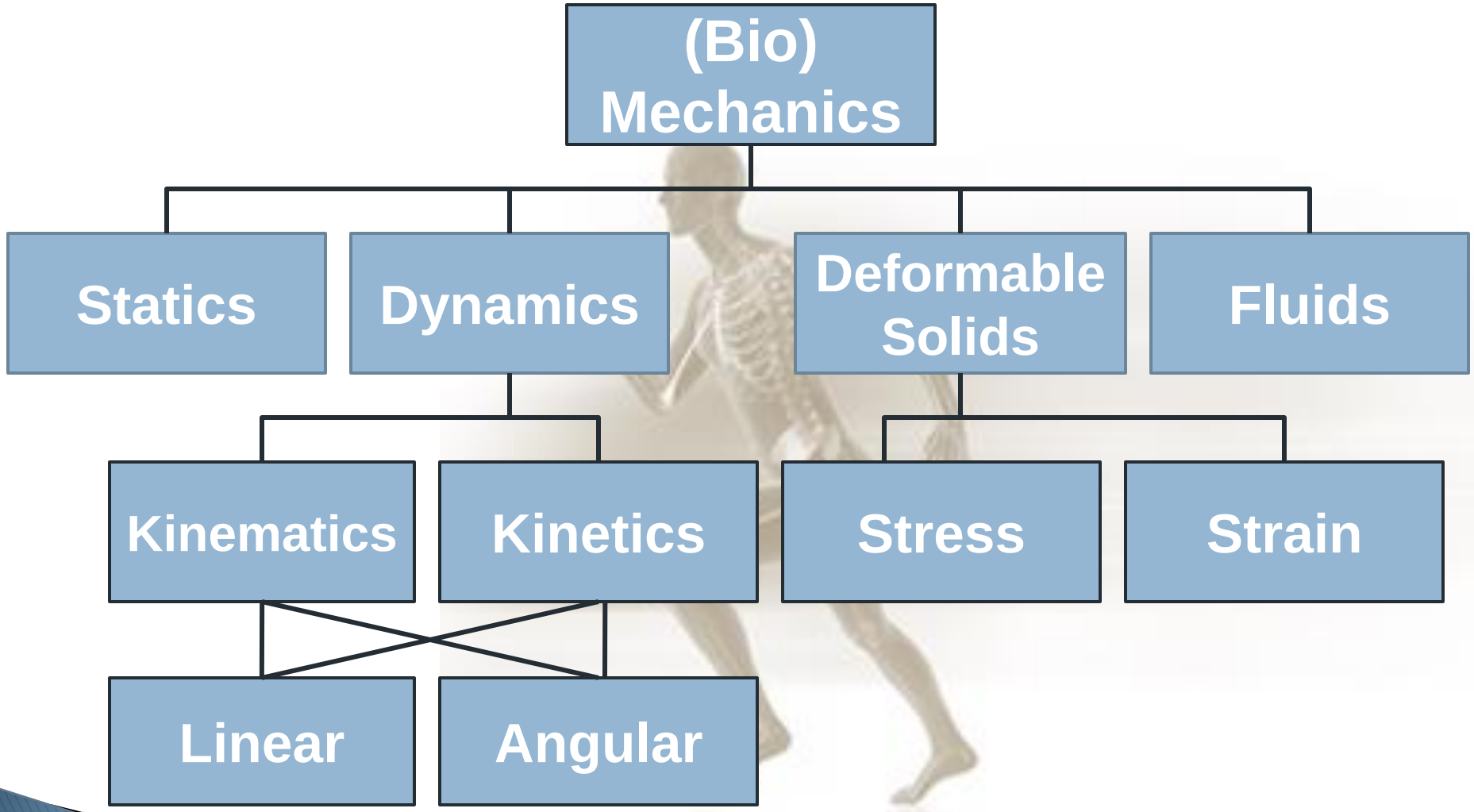
"**Biomechanics** is the study of the structure and function of biological systems".

Bio= Living

Mechanics= Forces and effects

This includes studies of the tissues including bone, cartilage, ligament, tendon, muscle, and nerve, at multiple scales ranging from the single cell to whole body.

Divisions of Biomechanics



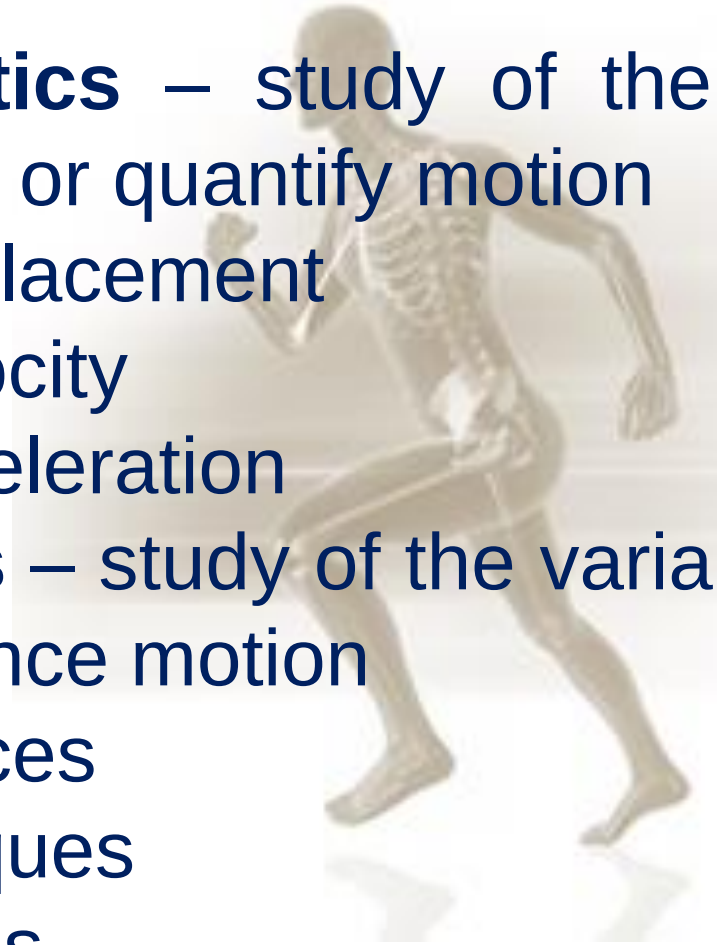
The study of mechanics in the human body divided into 2 areas:

Kinematics – study of the variables that describe or quantify motion

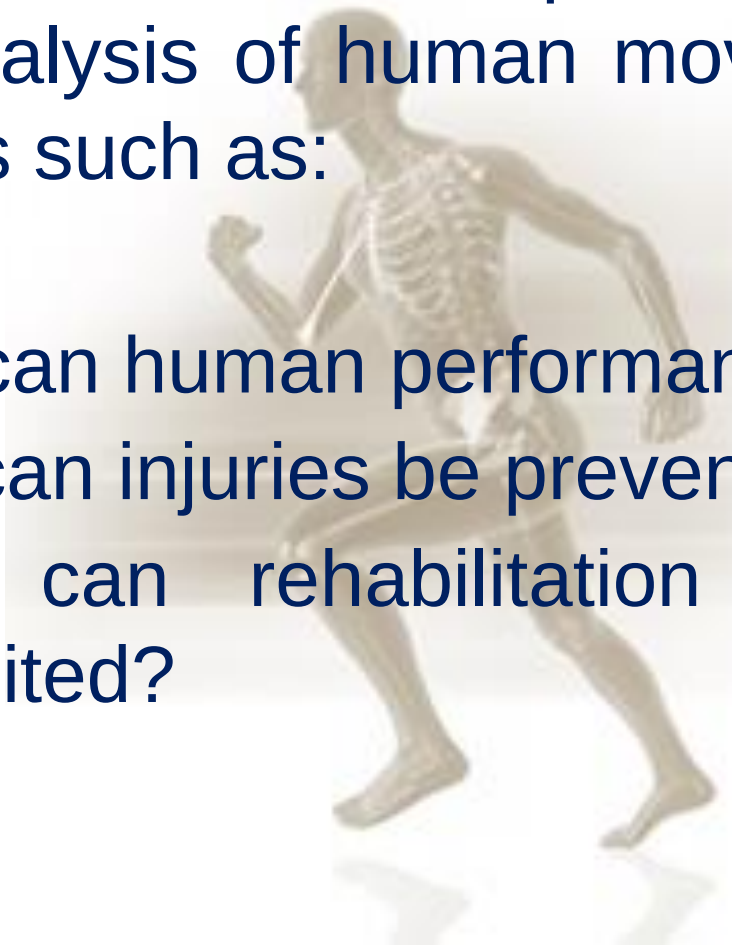
- Displacement
- Velocity
- Acceleration

Kinetics – study of the variables that cause or influence motion

- Forces
- Torques
- Mass



Biomechanists use the principles of mechanics in the analysis of human movement to answer questions such as:

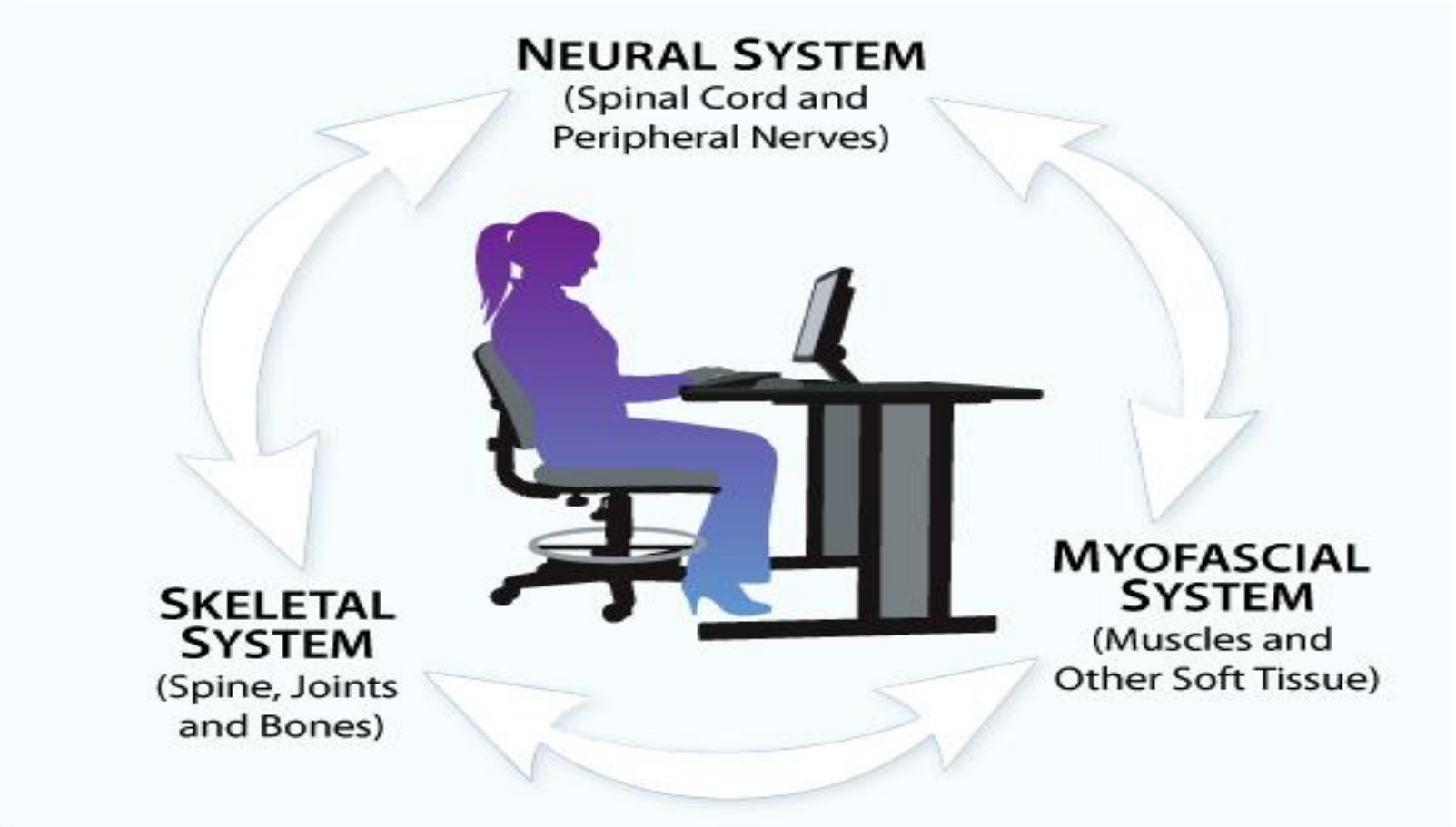


1. How can human performance be enhanced?
2. How can injuries be prevented?
3. How can rehabilitation from injury be expedited?

We need to know

- By having an understanding of the principles of analysis in biomechanics and the biomechanical properties of the primary tissues of the musculoskeletal system, we will be able to understand the mechanics of normal movement at each region and to appreciate the effects of impairments on the pathomechanics of movement.

Neuromuscular Skeletal Biomechanics



The Nervous System

Overview

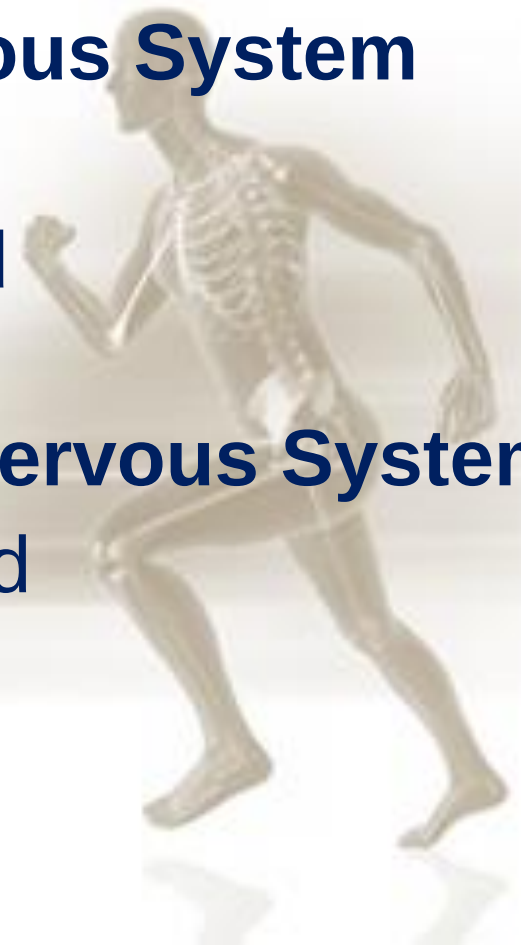
Functions of the NS

- **Sensory Input- gathering information**
  - To monitor changes occurring inside and outside the body
- **Integration**
  - To process and interpret sensory input and decide if action is needed
- **Motor output**
  - A response to stimuli activates muscles or glands

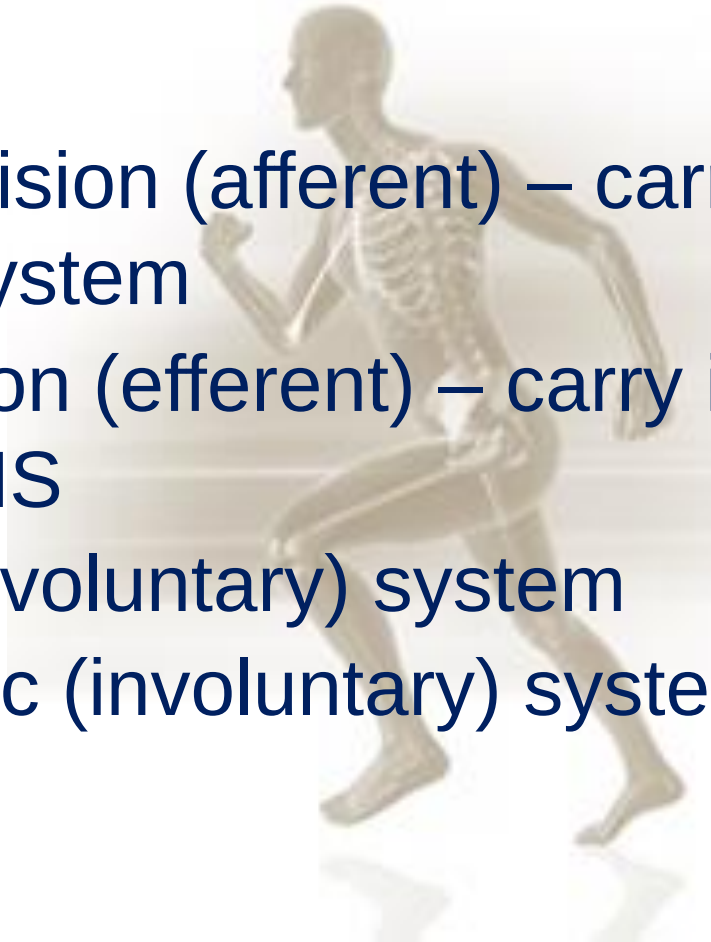
Classification of the NS

- **Central Nervous System**
  1. Brain
  2. Spinal cord

- **Peripheral Nervous System** –
  1- Cranial and
  2- Peripheral



Peripheral Nervous System



Two division:

1. Sensory division (afferent) – carry information to the CN system
2. Motor division (efferent) – carry impulses away from the CNS
   - Somatic (voluntary) system
   - Autonomic (involuntary) system

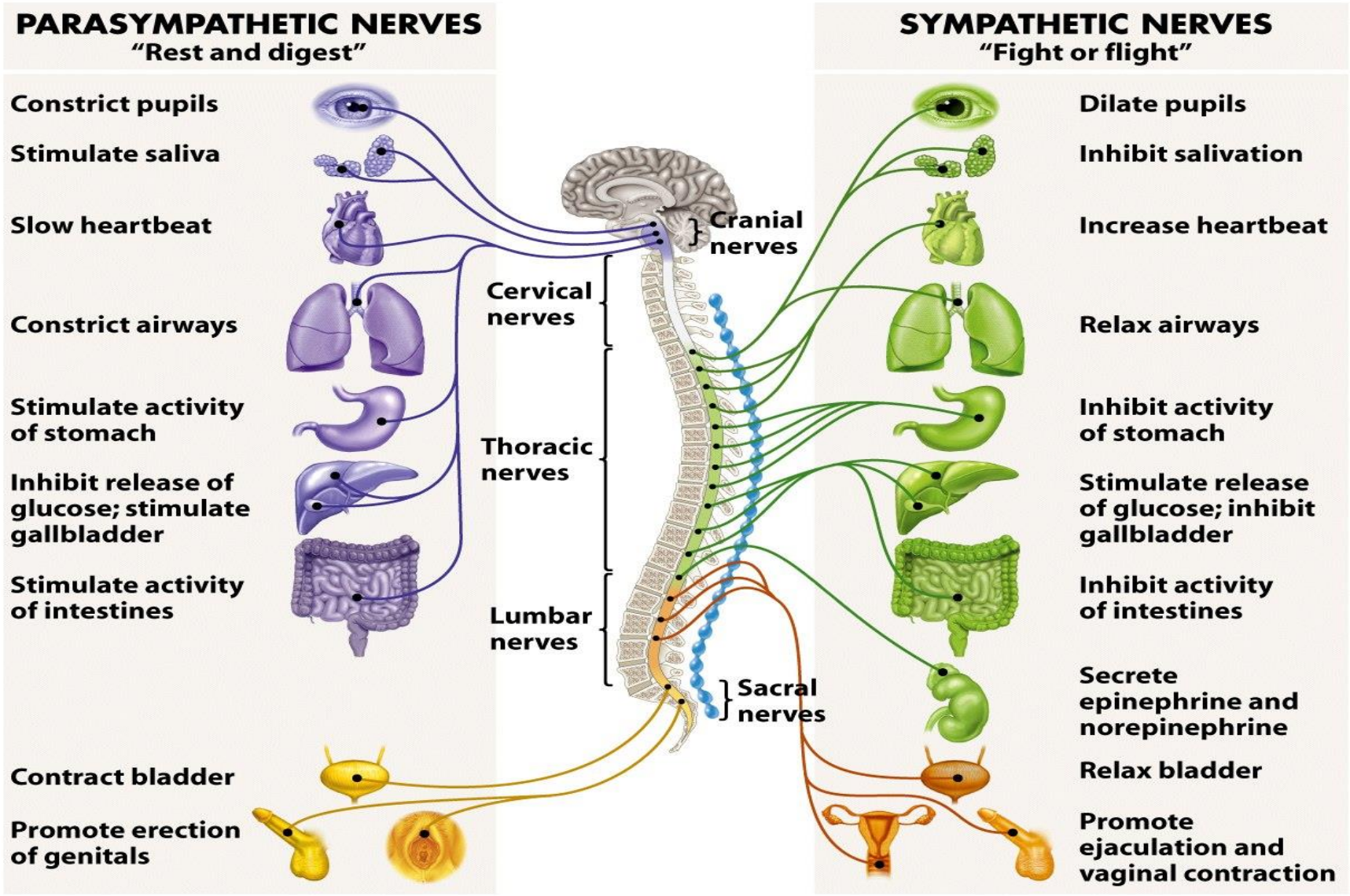


Figure 45-20 Biological Science, 2/e

Cells of the Nervous System

Cells are grouped into two functional categories

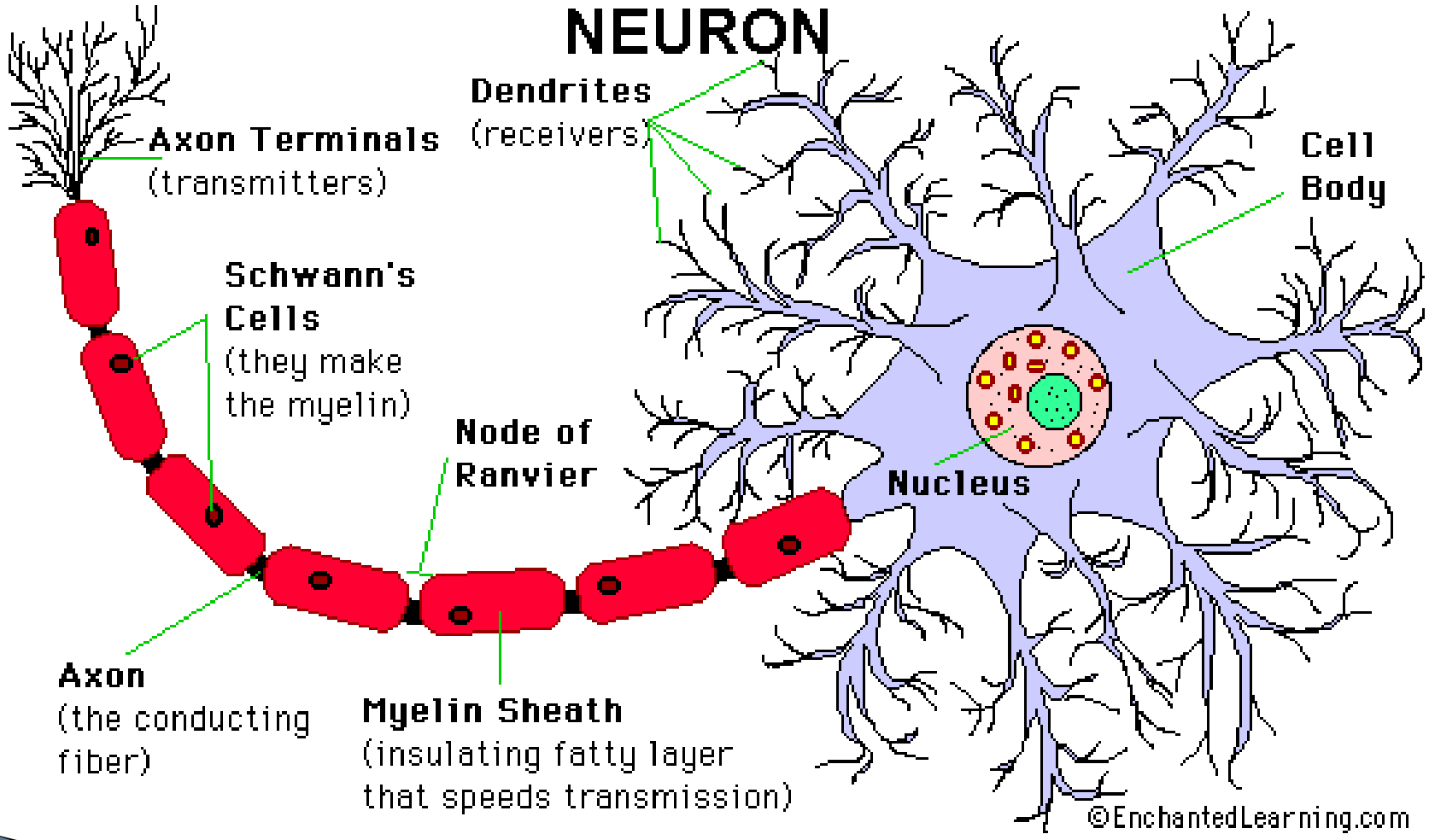
- **Neurons**
  - Do all of the major functions on their own, are
    1. Afferent
    2. Interneurons
    3. Efferent
- **Neuroglia**
  - Play a supporting role to the neurons
  - Divided into CNS and PNS Neuroglia

- **CNS**
  - Astrocytes
  - Oligodendrocytes
  - Microglia
  - Ependymal cells

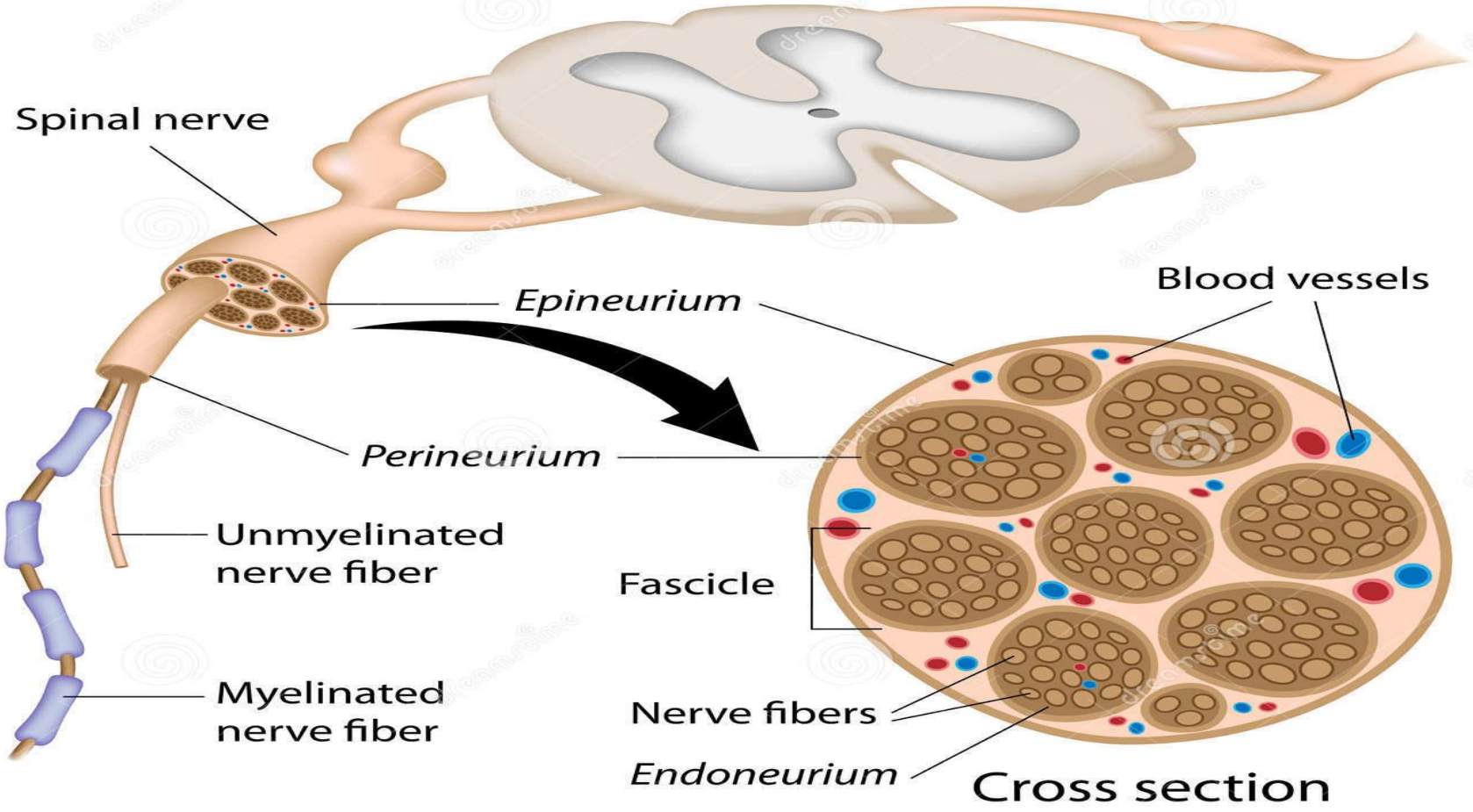
- **PNS**
  - Neurolemmocytes
  - Satellite cells

Neuron

- The general neuron & it's function



Anatomy of a Nerve



The Muscular System

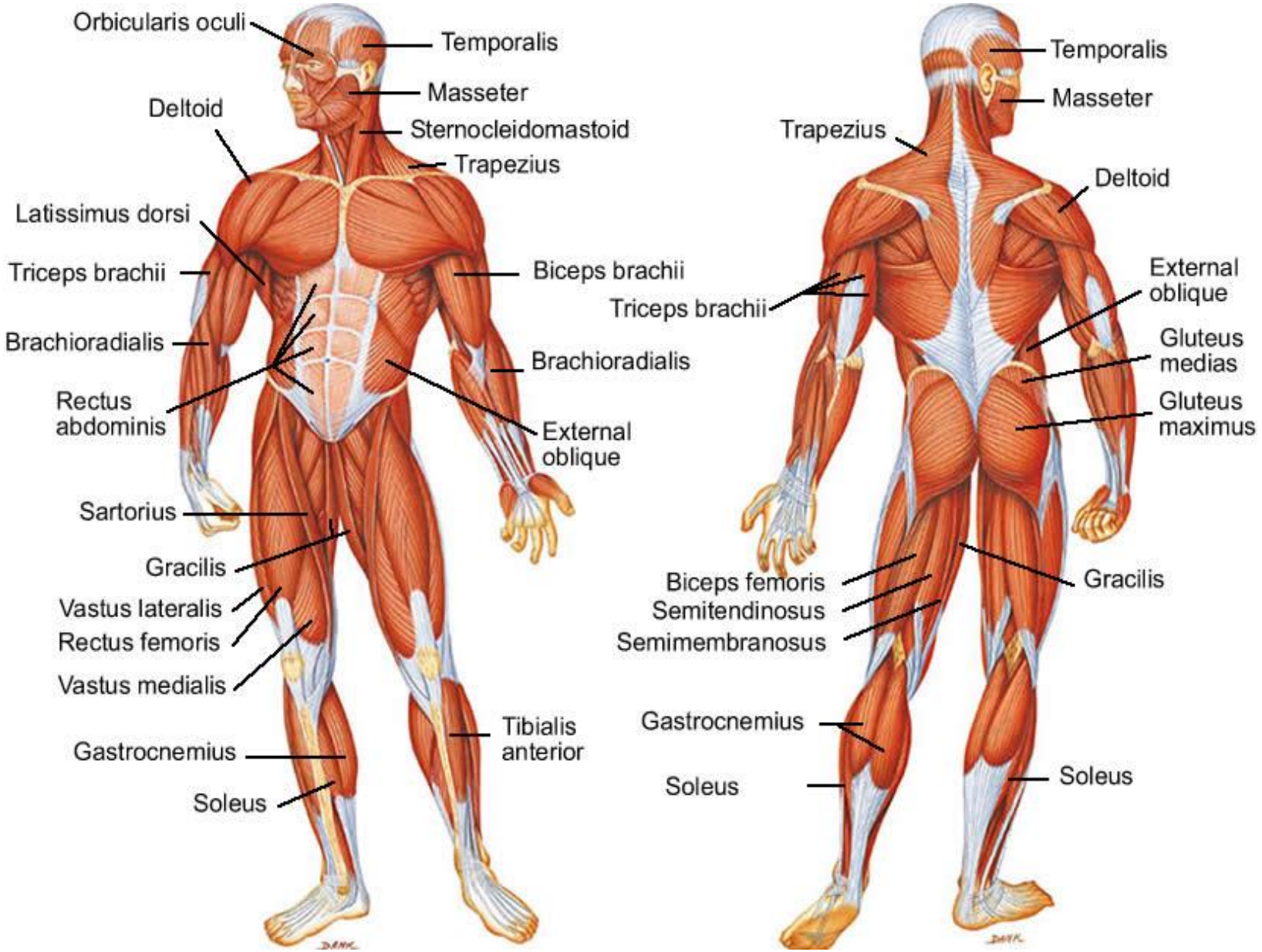
Muscular System

- Muscles provide the forces needed to make movement possible; they transmit their forces to tendons, whose forces in turn cause rotation of the bones about the joints.
- Muscles, however, are not simple force generators: the force developed by a muscle depends not only on the level of neural excitation provided by the central nervous system (CNS), but also on the length and speed at which the muscle is contracting.

Muscular System

- Muscles can shorten and pull but not push
- Most muscles are arranged in opposing teams e.g. agonistic/antagonistic - as each team pulls, the other team relaxes and gets stretched
- There are more than 640 muscles(320 in pairs). Nevertheless, exact number is difficult to define.
- The muscles make up about 40% of the body mass.

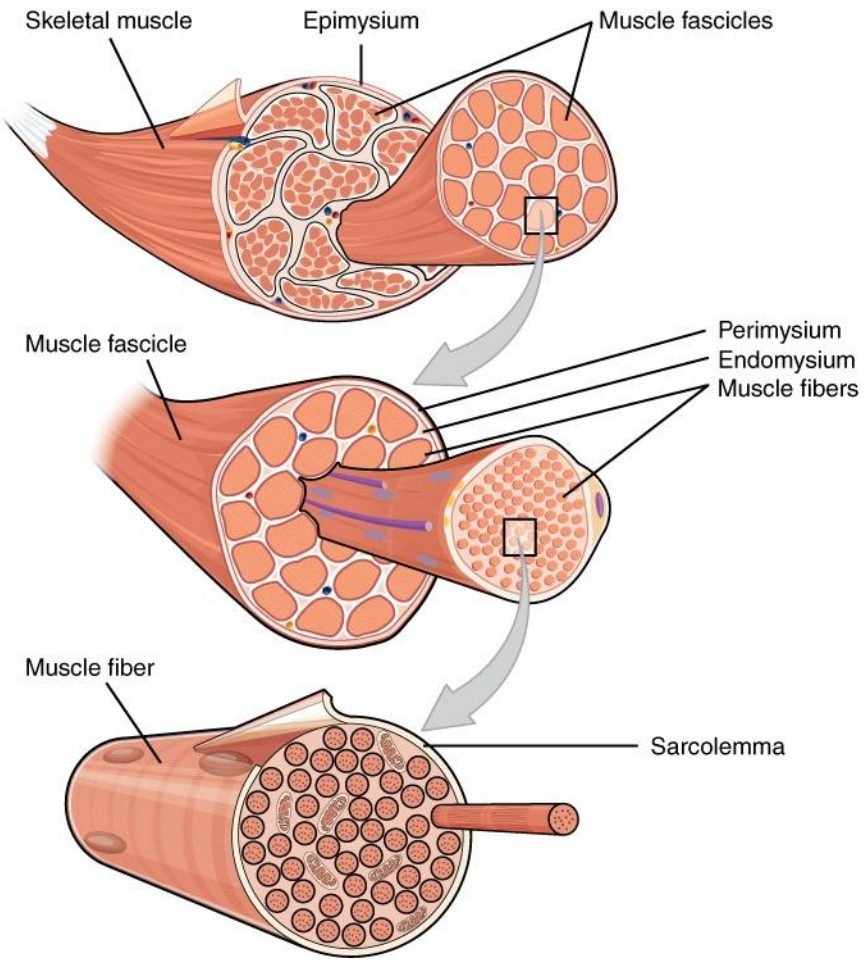
- The longest muscle in the body is ***Sartorius.***
- The smallest muscle in the body is ***Stapedius.*** It is located deep in the ear. It is only 5mm long and thinner than cotton thread. It is involved in hearing.
- The biggest muscle in the body is ***Gluteus Maximus*****.** It is located in the buttock. It pulls the leg backwards powerfully for walking and running.


Orbicularis oculi
Temporalis
Masseter
Deltoid
Sternocleidomastoid
Trapezius
Latissimus dorsi
Triceps brachii
Biceps brachii
Brachioradialis
Brachioradialis
Rectus abdominis
External oblique
Sartorius
Gracilis
Vastus lateralis
Rectus femoris
Vastus medialis
Tibialis anterior
Gastrocnemius
Soleus
Temporalis
Masseter
Trapezius
Deltoid
External oblique
Triceps brachii
Gluteus medias
Gluteus maximus
Biceps femoris
Semitendinosus
Semimembranosus
Gracilis
Gastrocnemius
Soleus
Soleus

Muscle

Gross Structure. Muscles are molecular machines that convert chemical energy into force. Individual muscle fibers are connected together by three levels of collagenous tissue endomysium, which surrounds individual muscle fibers; perimysium, which collects bundles of fibers into fascicles; and epimysium, which encloses the entire muscle belly.

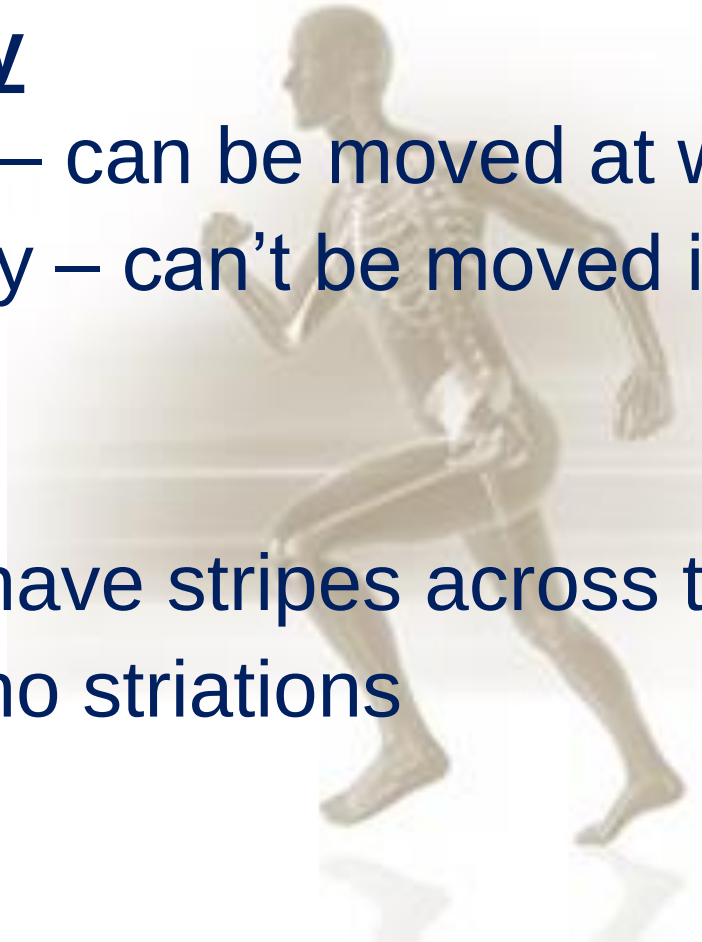
Structure of Muscle



Functions of Muscles

- Movement
- Maintenance of posture and muscle tone
- Heat production
- Protects the bones and internal organs.

Classification of Muscles



Functionally

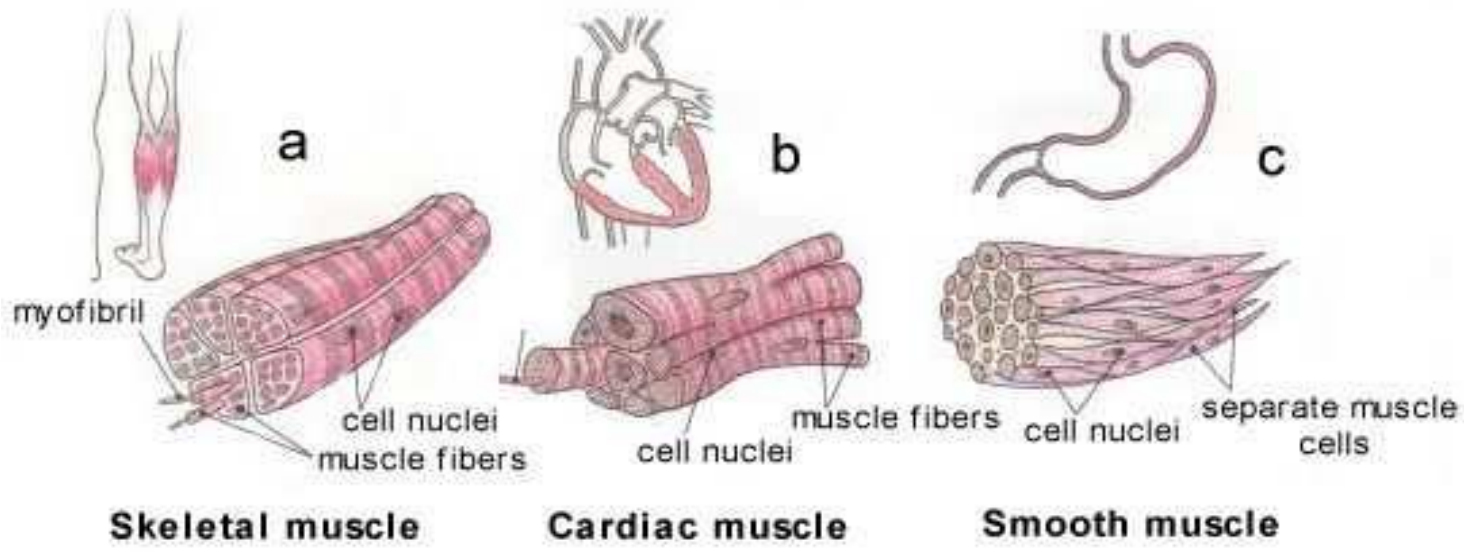
- Voluntarily – can be moved at will
- Involuntarily – can't be moved intentionally

Structurally

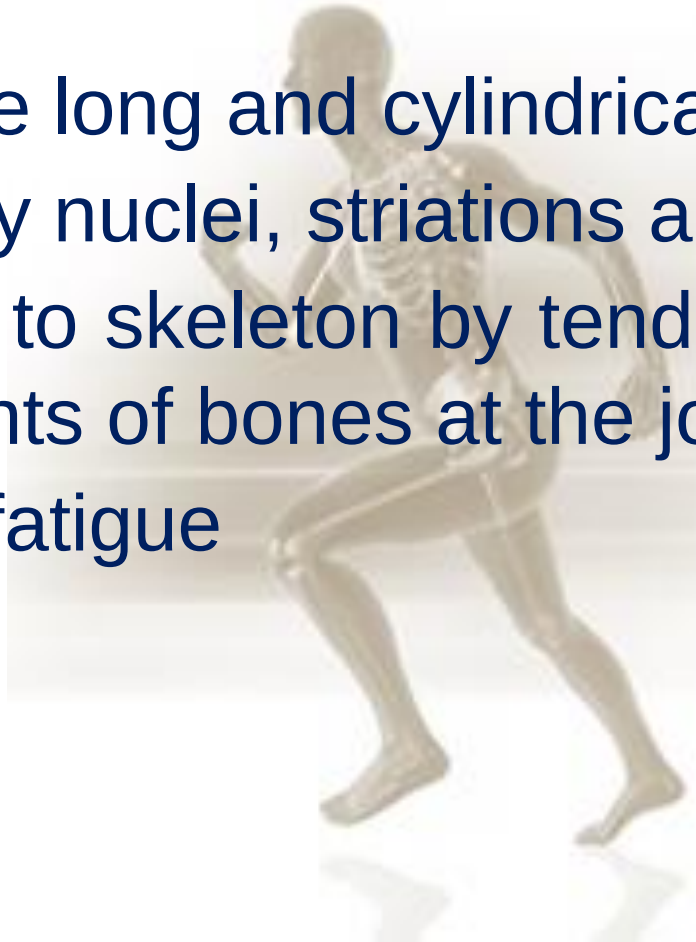
- Striated – have stripes across the fiber
- Smooth – no striations

Types of Muscles

A. Skeletal Muscles
B. Cardiac Muscles
C. Smooth Muscles



A. Skeletal Muscle



- Fibers are long and cylindrical.
- Has many nuclei, striations and voluntary
- Attached to skeleton by tendons and cause movements of bones at the joints
- They do fatigue

Functions of Skeletal muscles

A. **Movements** – muscles move bones by pulling not pushing

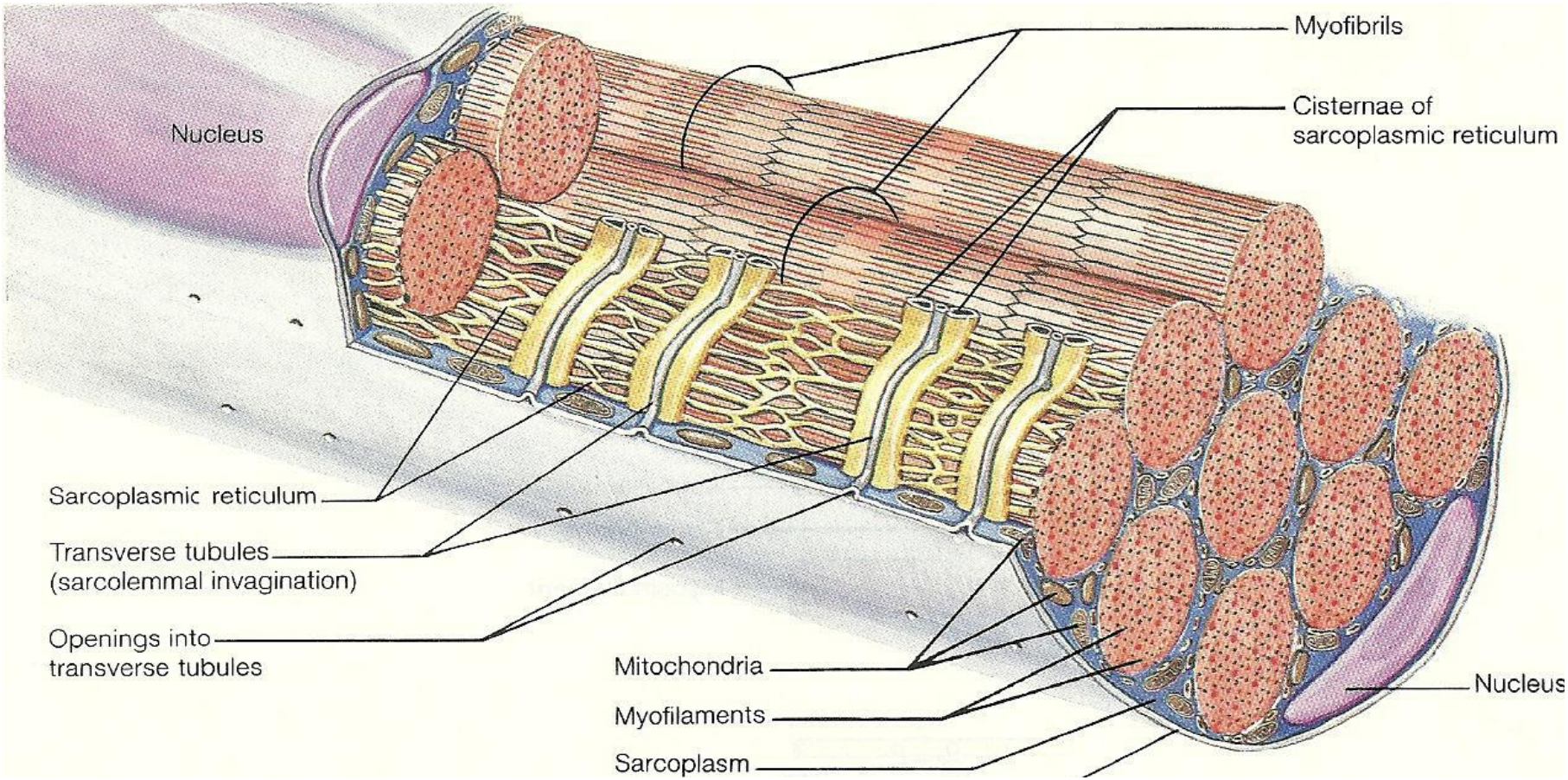
1. Synergists – any movement is generally accomplished by more than one muscle.
2. Agonist- most responsible for the movement.
3. Antagonist- muscles and muscle groups usually work in pairs. Biceps flex arm and its partner triceps extend arm. Two muscles are antagonists.
4. Levators - muscle that raise a body part.

Functions of Skeletal muscles

B. **Maintenance of posture or muscle tone** – We are able to maintain our body position because of tonic contractions in our skeletal muscles.

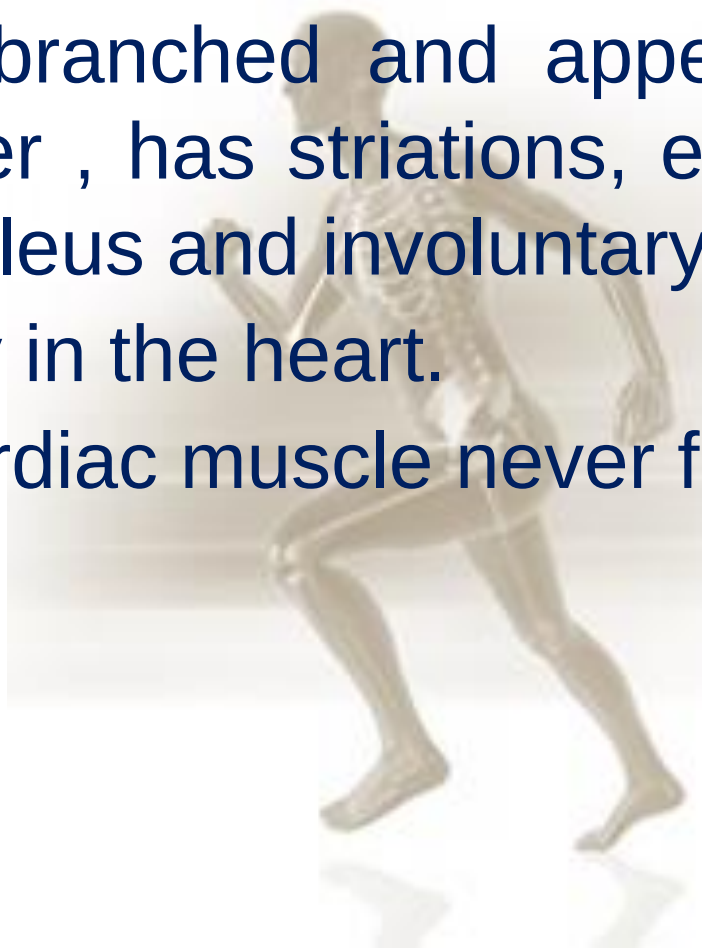
C. **Heat Production** – Contractions of muscles produce most of the heat required to maintain body temperature.

Structural Organization of Skeletal Muscle



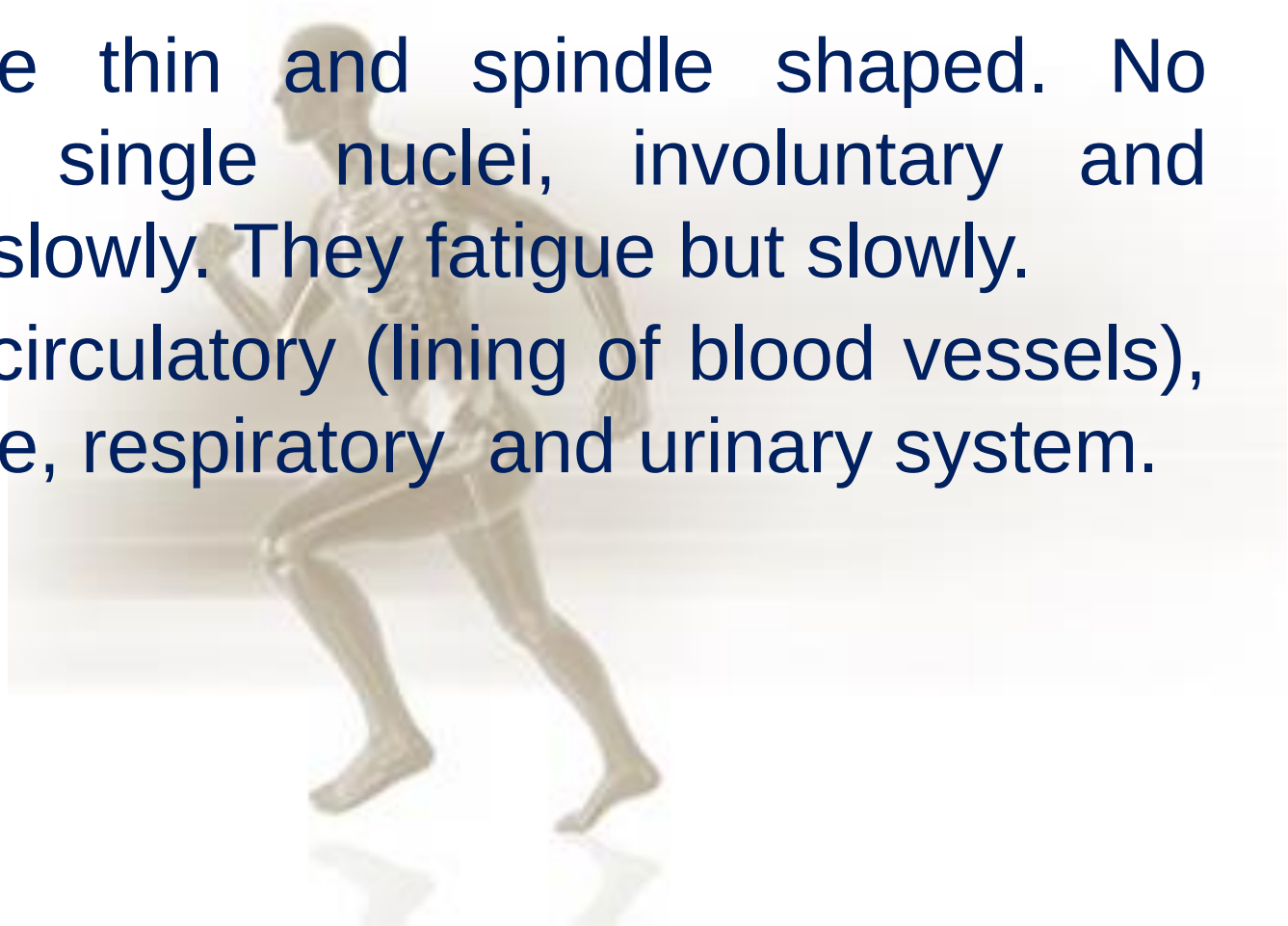
B. Cardiac Muscles

- Cells are branched and appear fused with one another , has striations, each cell has a central nucleus and involuntary.
- Found only in the heart.
- Healthy cardiac muscle never fatigue.



C. Smooth Muscle

- Fibers are thin and spindle shaped. No striations, single nuclei, involuntary and contracts slowly. They fatigue but slowly.
- Found in circulatory (lining of blood vessels), in digestive, respiratory and urinary system.



Skeletal System

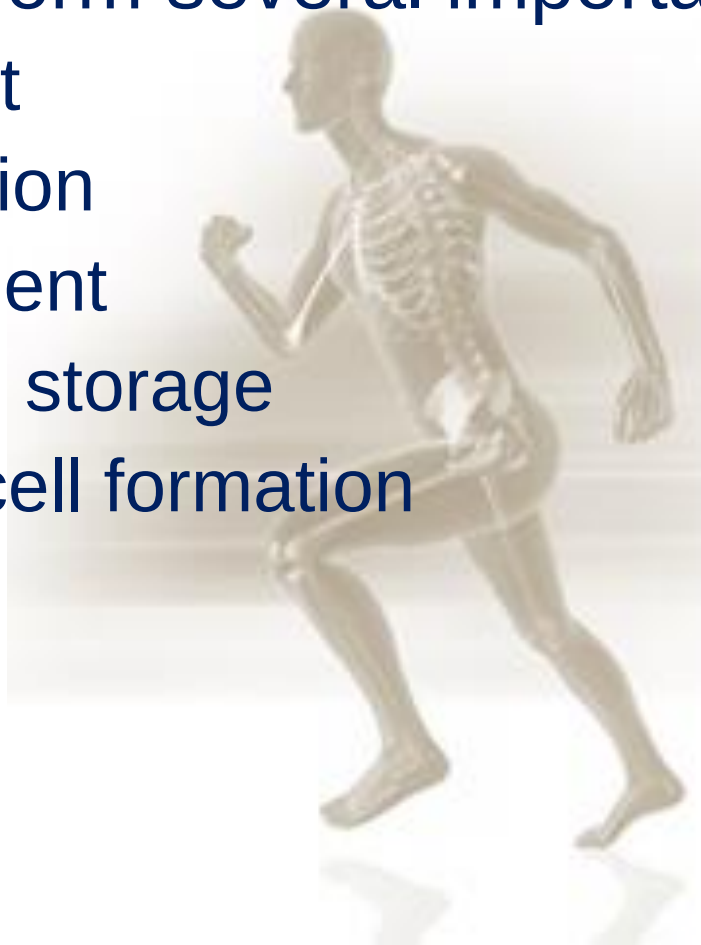
Bones

- Total Bones in human body are 206
- Bones of the skeleton are organs that contain several different tissues
- Bones are dominated by bone tissue but also contain:
  - Nervous tissue and nerves;
  - Blood tissue and vessels;
  - Cartilage in articular area;
  - Epithelial tissue lining the blood vessels.

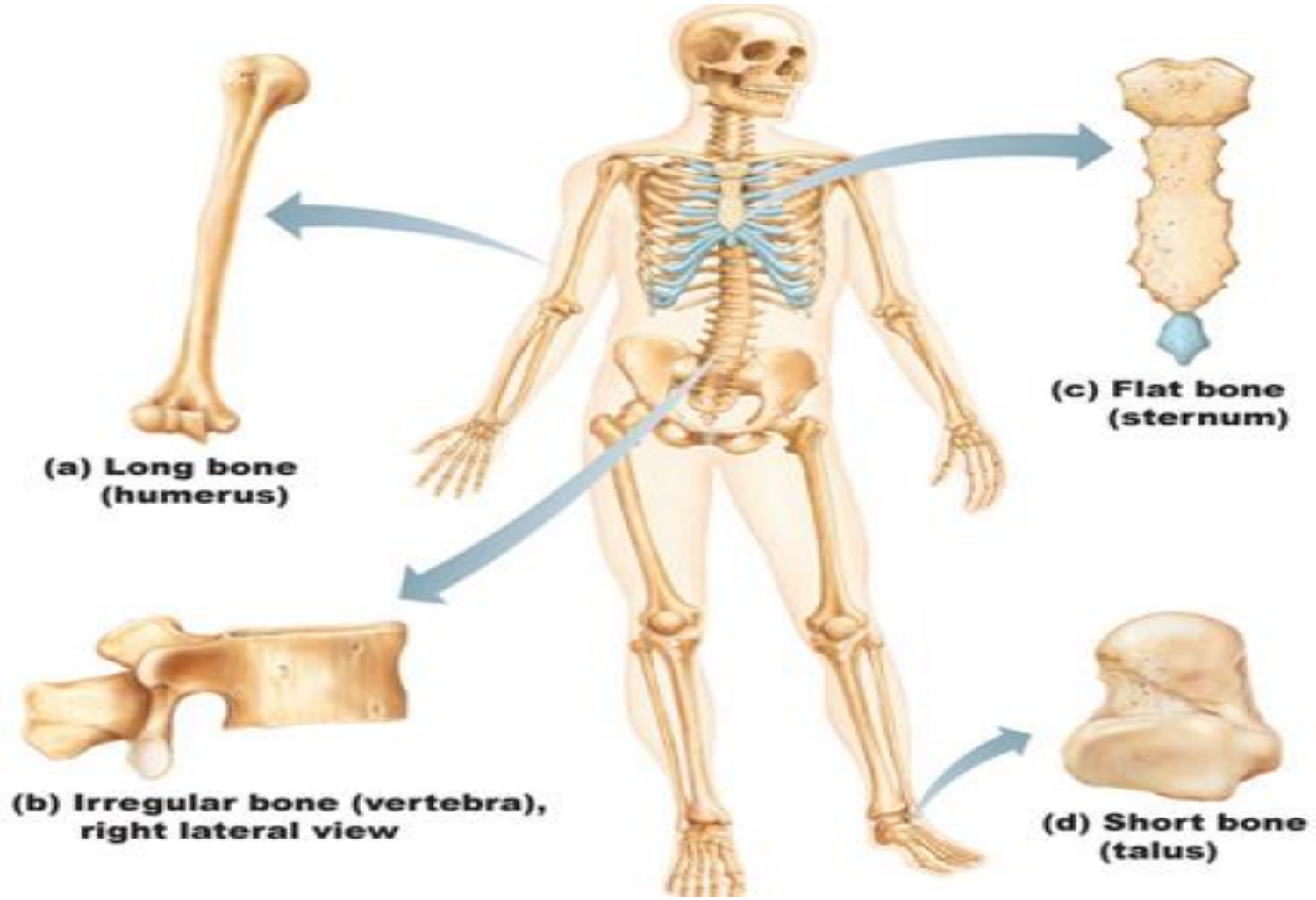
Functions of Bones

Bones perform several important functions:

- Support
- Protection
- Movement
- Mineral storage
- Blood cell formation



Classification of Bones

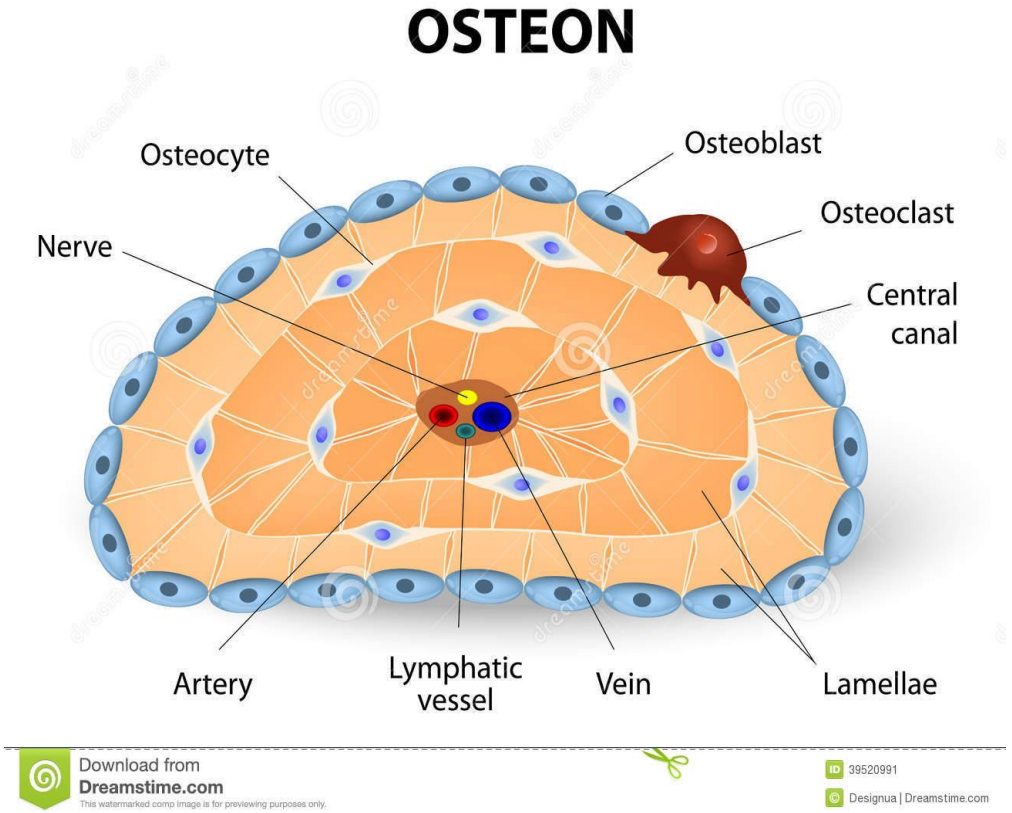


Types of Bones

1. **Compact Bones (Cortical)**
   - Compact bone appears very dense.
   - It actually contains canals and passageways that provide access for nerves, blood vessels, and lymphatic ducts.
   - The structural unit of compact bone is the osteon or Haversian system.
   - Each osteon is an elongated cylinder running parallel to the long axis of the bone.
   - Structurally each osteon represents a weight bearing pillar.

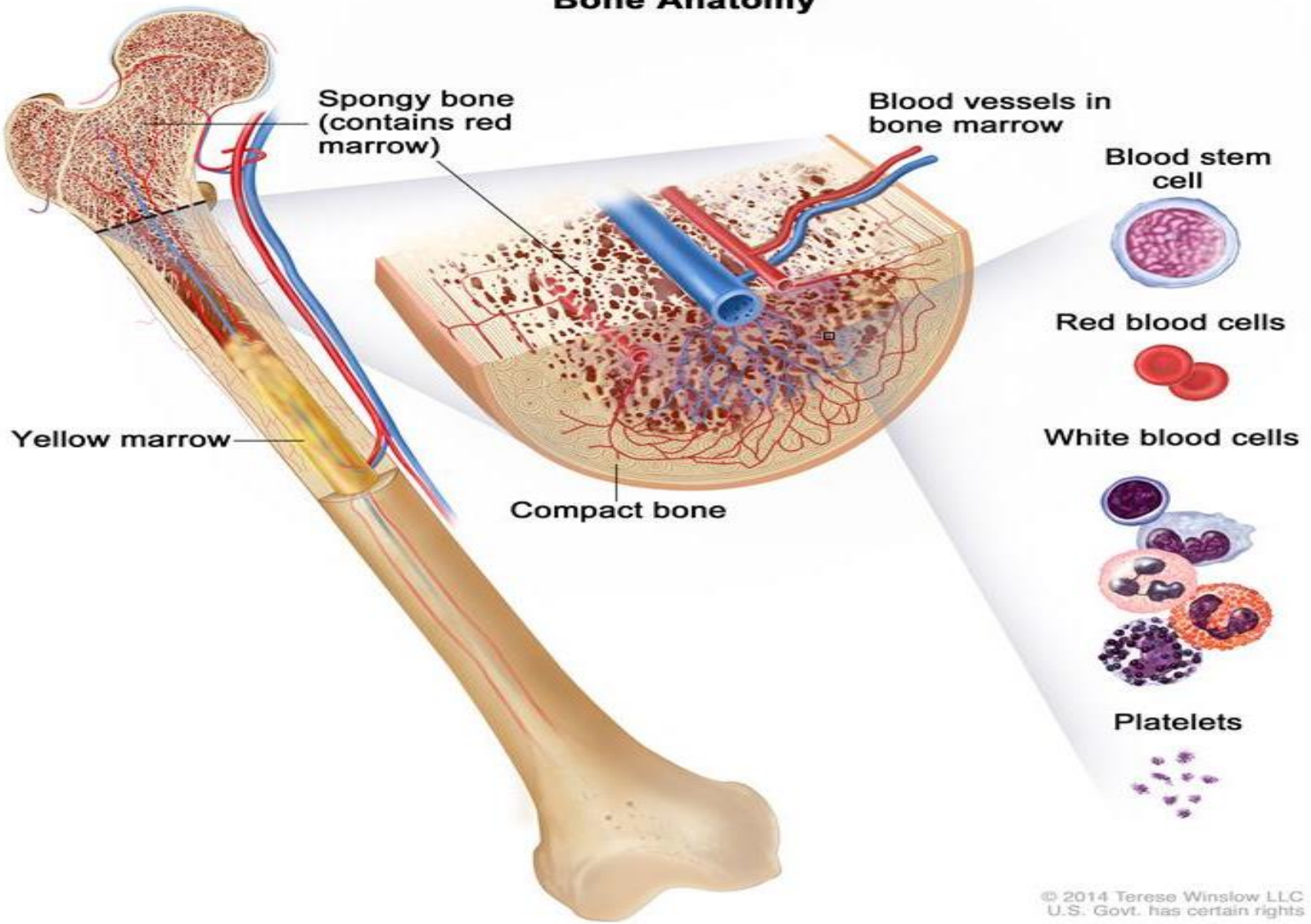
An Osteon

- Each osteon is a group of hollow tubes of bone matrix
- Each matrix tube is a lamella
- Collagen fibers in each layer run in opposite directions
- Resists torsion stresses



2. Spongy Bone (Cancellous):

- internal layer - latticework of bone tissue (haphazard arrangement).
- made of trabeculae (“little beams”)
- filled with red and yellow bone marrow
- osteocytes get nutrients directly from circulating blood.
- short, flat and irregular bone is made up of mostly spongy bone


Bone Anatomy
Spongy bone (contains red marrow)
Blood vessels in bone marrow
Blood stem cell
Red blood cells
White blood cells
Platelets
Yellow marrow
Compact bone
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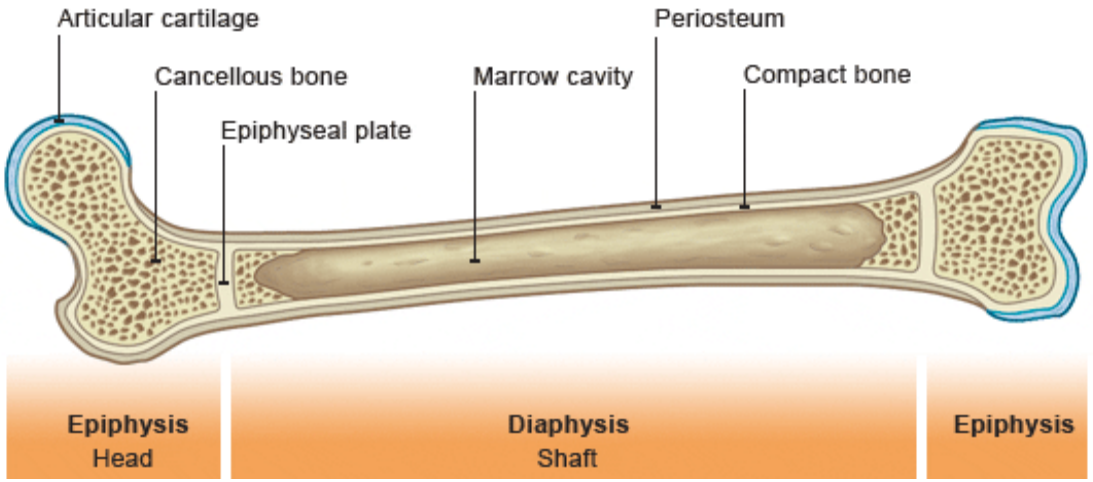
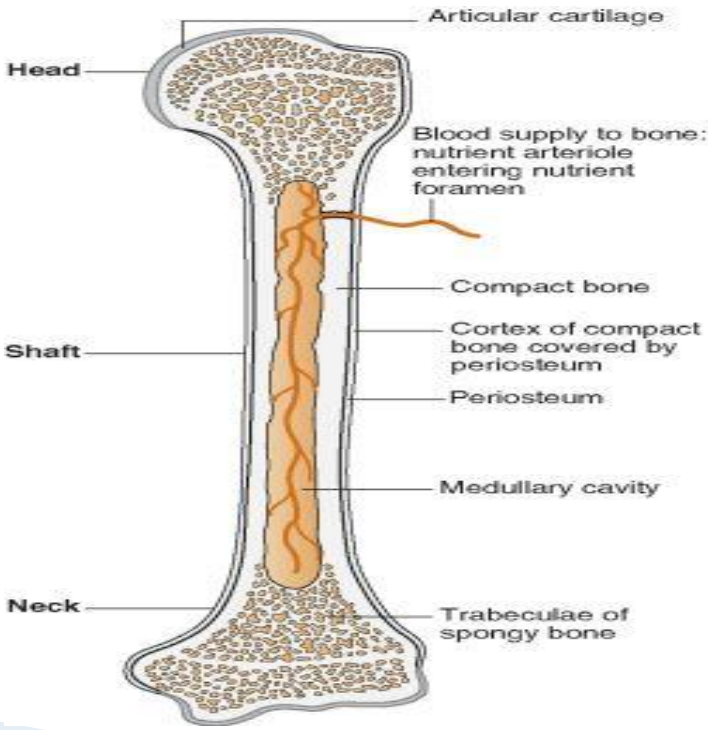
Gross Anatomy

- **Landmarks on a typical long bone**
  - Diaphysis
  - Epiphysis
  - Membranes
- **Membranes**
  - Periosteum
  - Endosteum

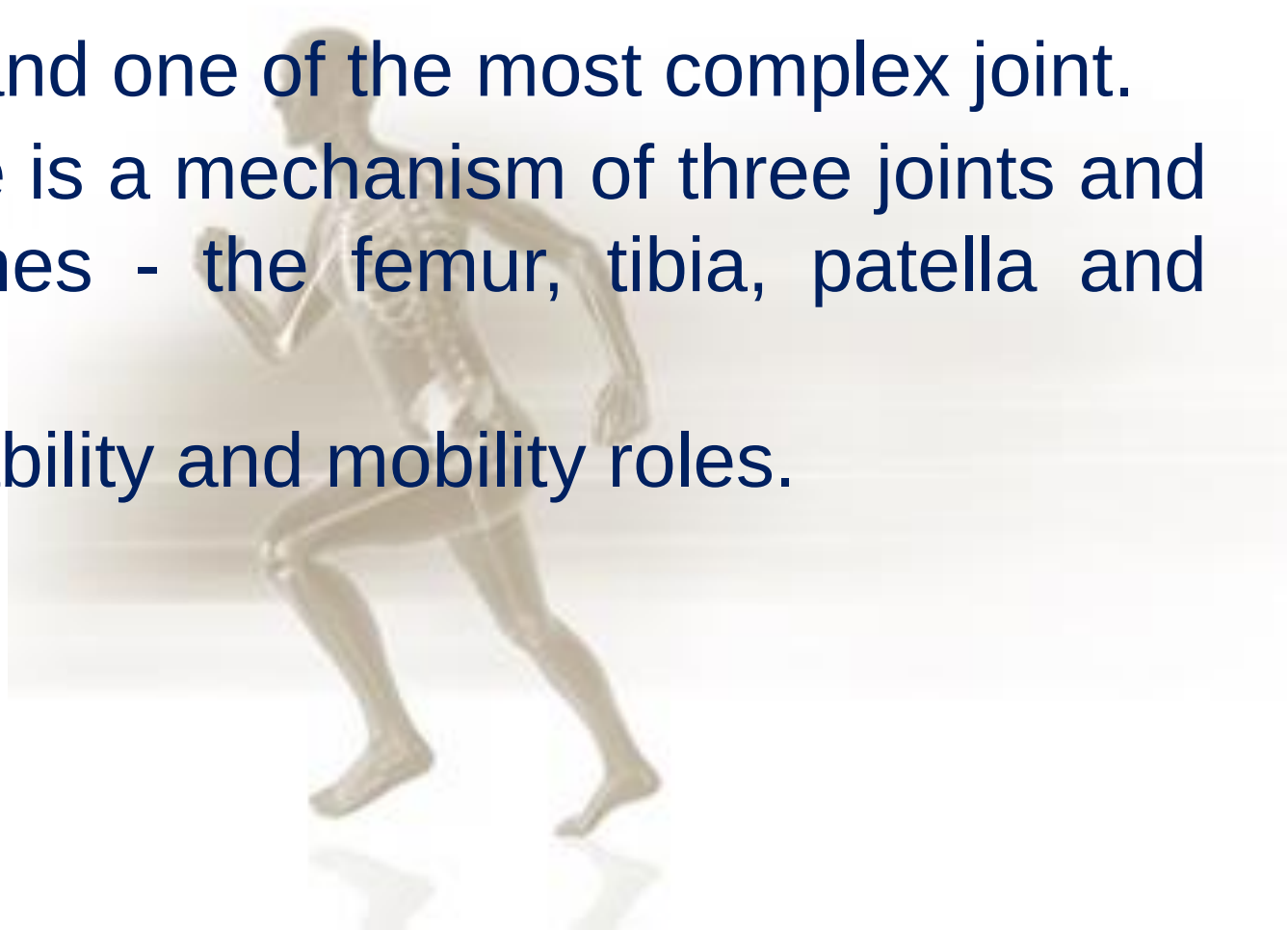




Anatomy of the Knee joint

Introduction of Knee Joint

- Largest and one of the most complex joint.
- The knee is a mechanism of three joints and Four bones - the femur, tibia, patella and fibula.
- Major stability and mobility roles.



Functions

1. Functional shortening and lengthening of the extremity by flexion and extension.
2. Supports body during dynamic and static activities.
3. Closed kinematic chain – support body weight in static erect posture.
4. Dynamically – moving and supporting body in sitting and squatting activities, supporting and weight transferring activity during locomotion.

- **Knee Complex**:

  Tibio-femoral and Patello- femoral
- **Type of Joint (Tibio- femoral):**

  Double Condyloid joint
- **Patello-femoral**

  Patella serves as pulley mechanism for quadriceps muscles
- **Degrees of freedom of motion!**
  1. Flexion/Extension
  2. Medial/Lateral rotation
  3. Adduction/abduction

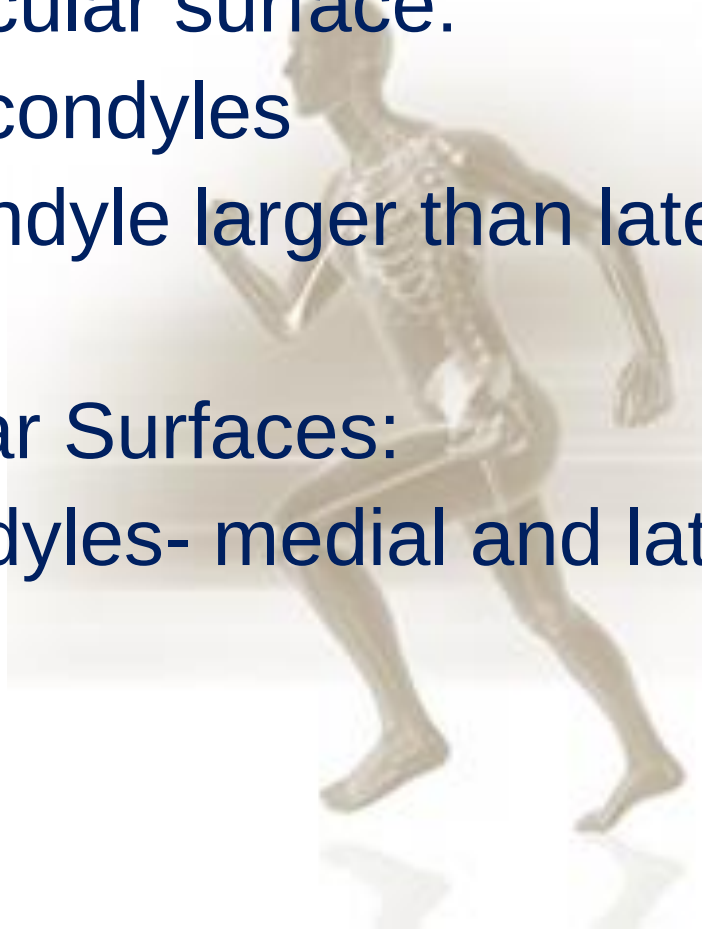
Articular Surfaces

Proximal Articular surface:

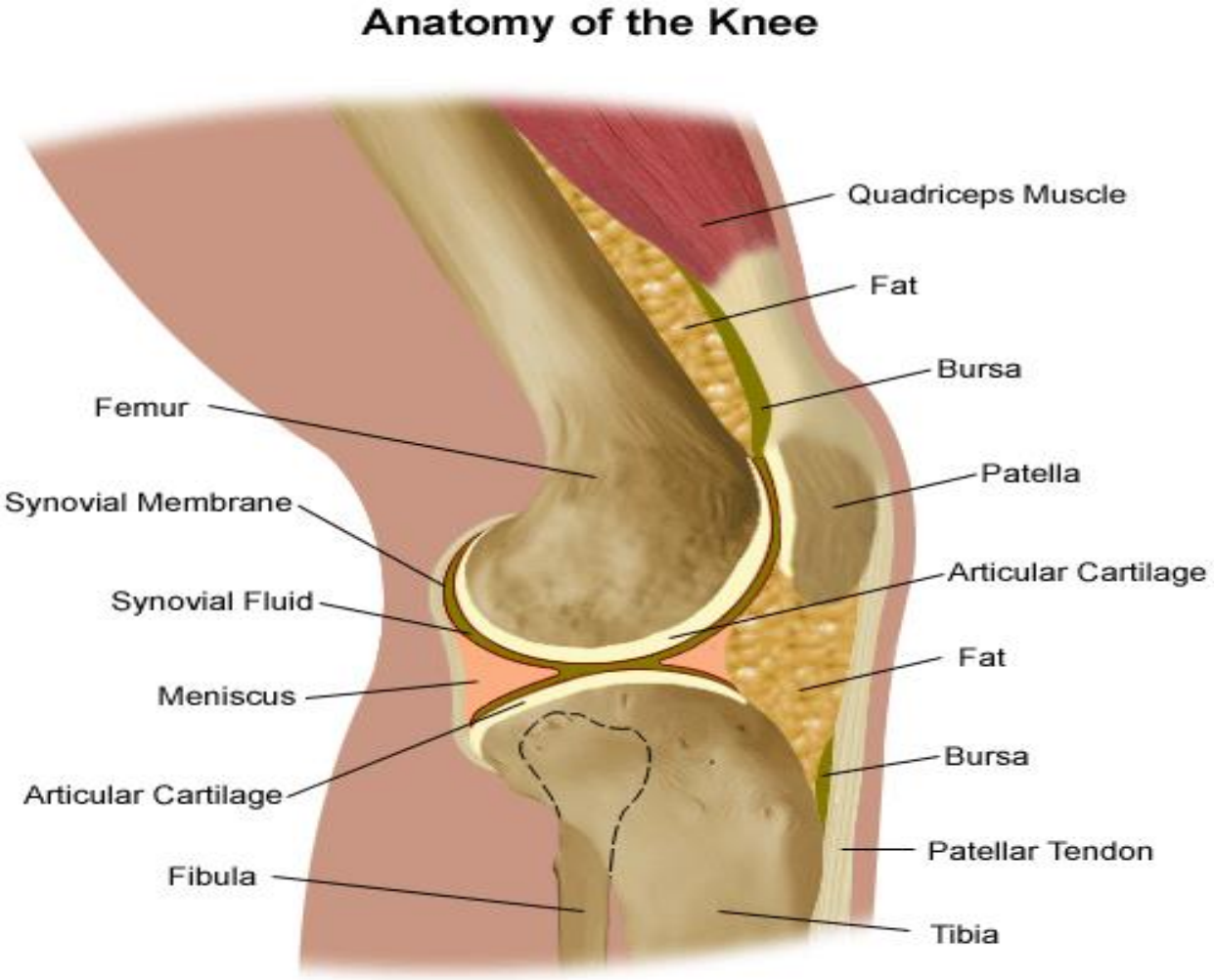
- Femoral condyles
- Medial condyle larger than lateral

Distal Articular Surfaces:

- Tibial condyles- medial and lateral



Structure of the Knee



Alignment of Knee

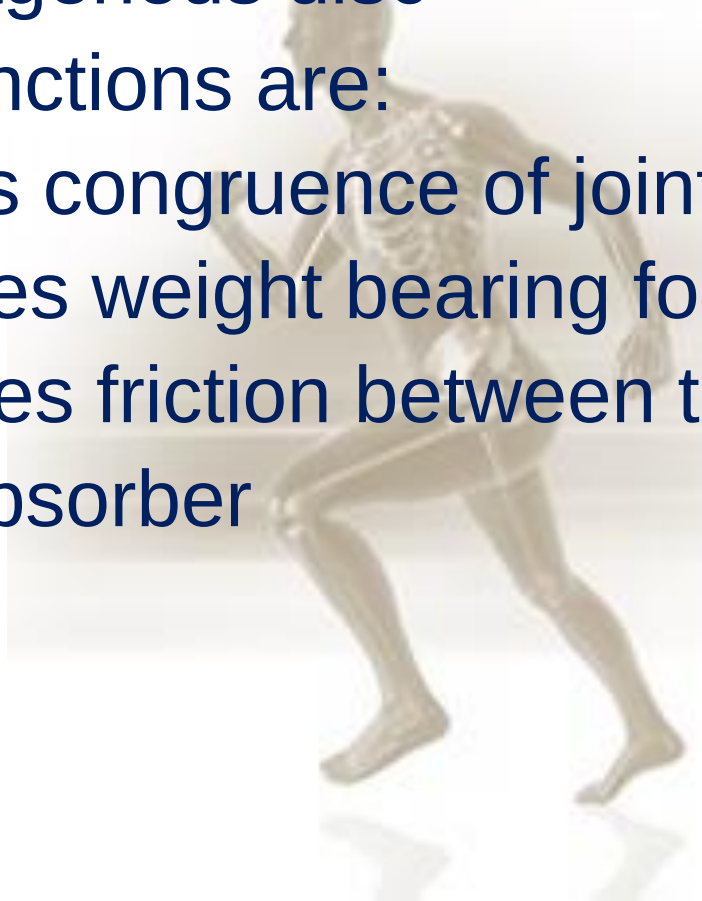
- The anatomical axis of femur is oblique directed inferiorly and medially
- Anatomical axis of tibia is vertical
- Normally knee forms lateral angle of 170- 175
- Variations
  1. Genu Valgum (knock knee)- lateral angle less than 170
  2. Genu Varum(bow leg)- angle is more than 180

Joint Menisci

- Fibrocartilagenous disc

  Menisci functions are:

1. Improves congruence of joint
2. Distributes weight bearing forces
3. Decreases friction between tibia and femur
4. Shock absorber



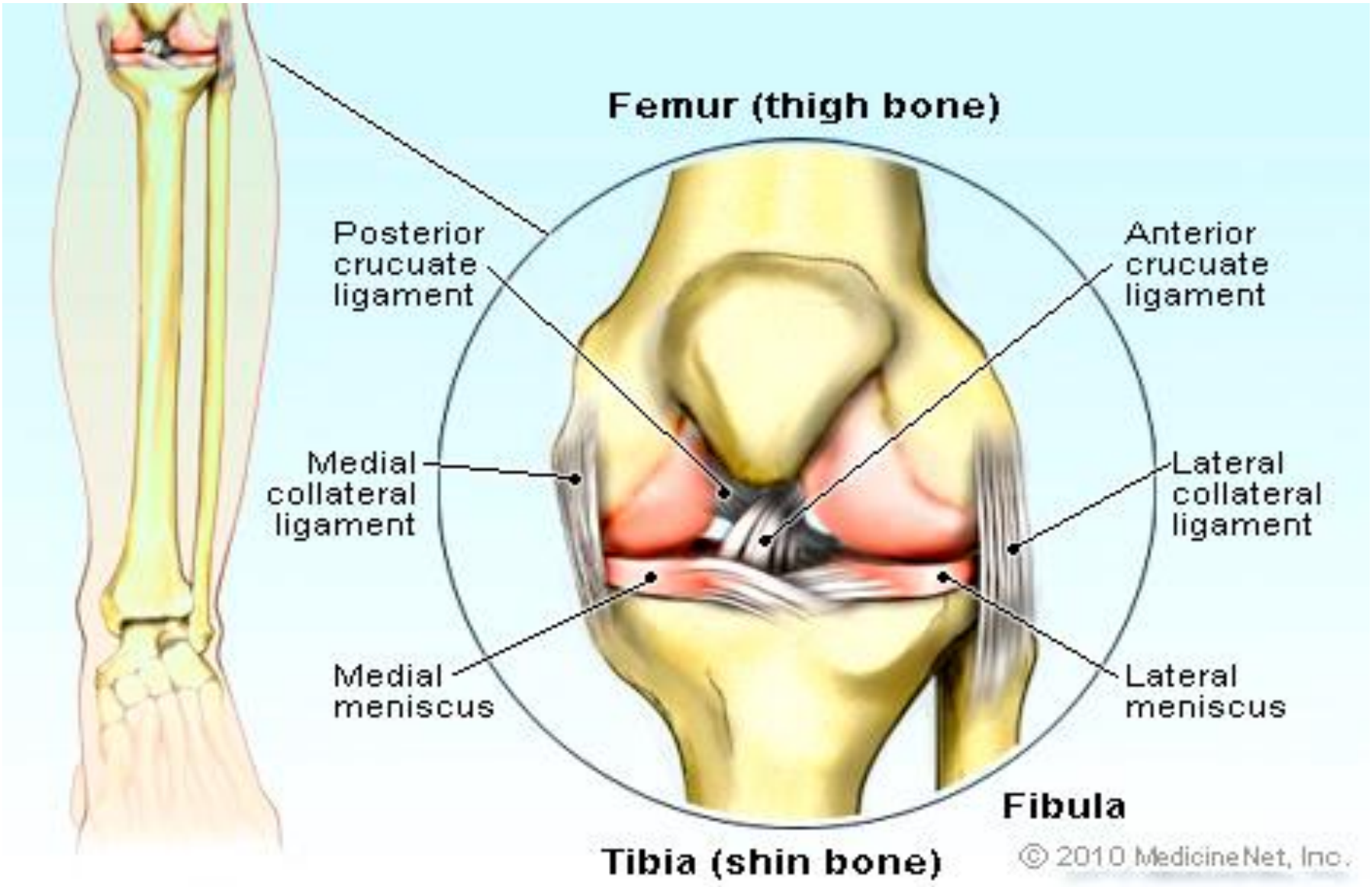
Capsule and Ligaments

- **Capsule** encloses medial and lateral tibio-femoral joint and patello- femoral joint.

Two layers of capsule:

- Fibrous layer and;
- Synovial layer

- **Collateral Ligament**
  1. Medial collateral ligament
  2. Lateral collateral ligament
- **Cruciate Ligament**
  1. Anterior Cruciate ligament
  2. Posterior Cruciate ligament


Femur (thigh bone)
Posterior crucuate ligament
Anterior crucuate ligament
Medial collateral ligament
Lateral collateral ligament
Medial meniscus
Lateral meniscus
Fibula
Tibia (shin bone)
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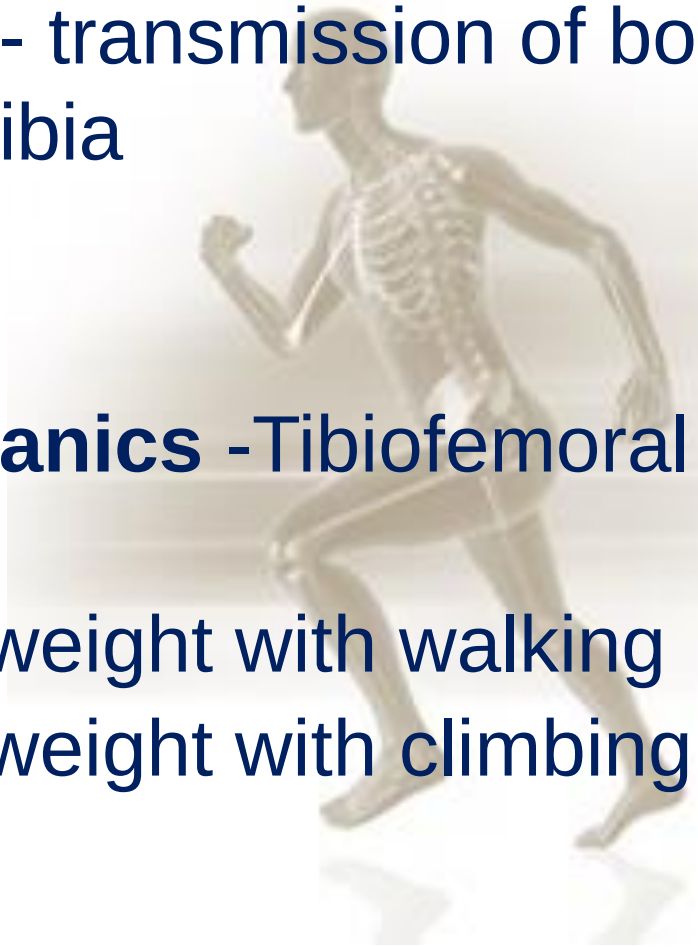
Tibiofemoral Articulation

- **Function**- transmission of body weight from femur to tibia

- **Biomechanics** -Tibiofemoral joint reaction force :

  3x body weight with walking

  4x body weight with climbing



Patellofemoral Articulation

- **Function**- transmits tensile forces generated by the quadriceps to the patellar tendon

- **Biomechanics**- patellofemoral joint reaction force:

  7x body weight with squatting

  2-3x body weight when descending stairs

Main Muscles and Bursae of the Knee Joint

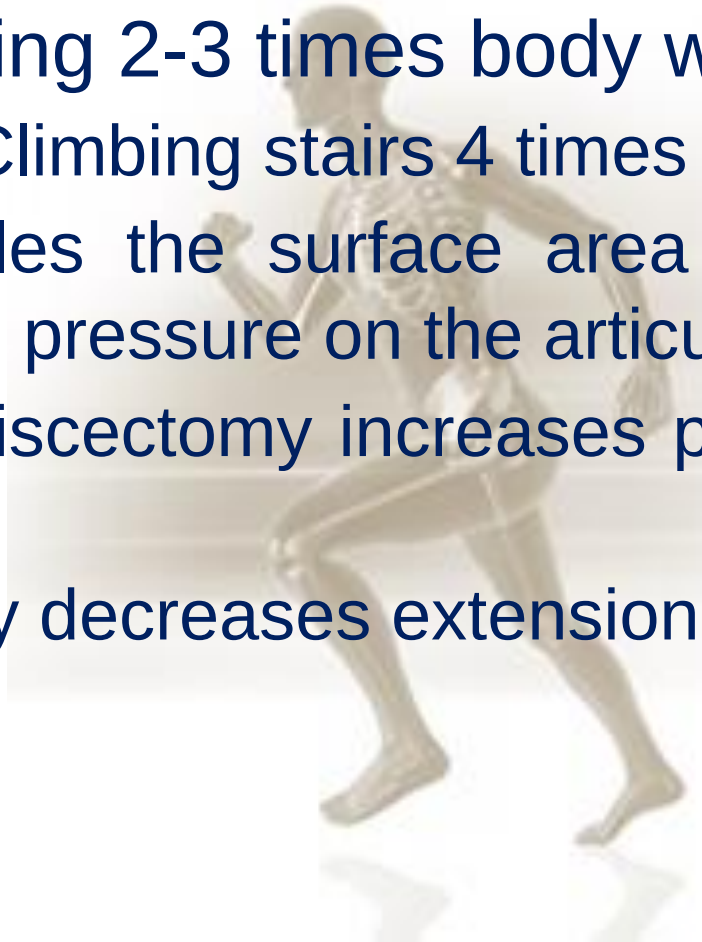
- Qudriceps
- Gastrocnemius
- Hamstrings
- Gracilis
- Sartorius
- Popliteus
- Soleus

Bursae

There are 14 Bursae at knee joint. They reduce friction between inter tissue during movement

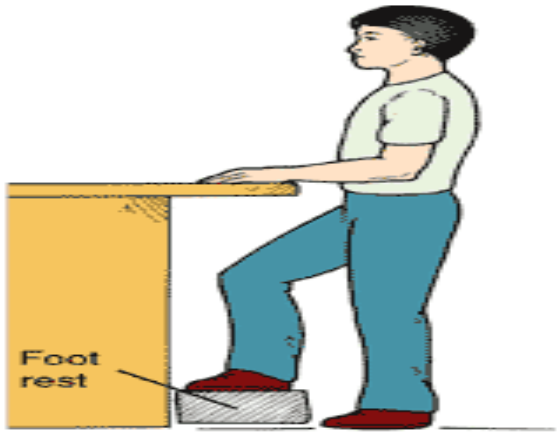
Compression forces at Knee

- While walking 2-3 times body weight
- Ascending/Climbing stairs 4 times body weight
- Menisci triples the surface area by significantly reducing the pressure on the articular cartilage
- Lateral meniscectomy increases pressure at knee by 230 %
- Patellectomy decreases extension force by 30%



Proper Sitting, Standing, and Lifting

Sitting



Standing

Lifting

1. Bend your knees and squat down to a comfortable level.

2. Lift the object and bring it close to your body.

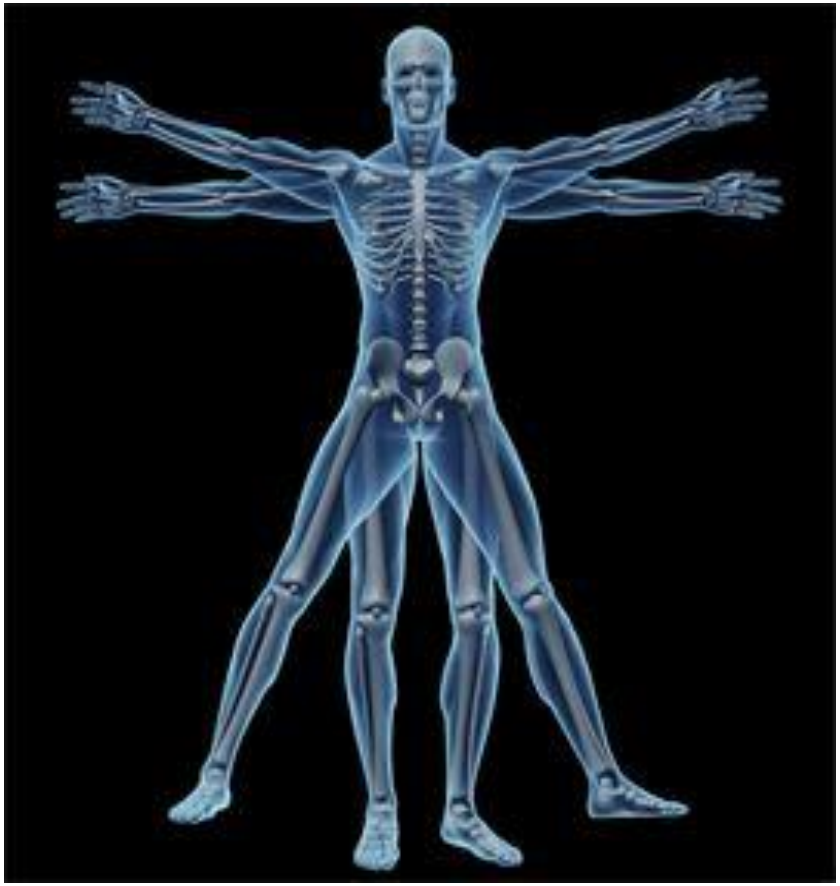
3. Return to an upright position by pushing up with your legs and buttocks.

Research

- Research of neuromuscular performance offers a unique possibility for integration of biomechanics, muscle physiology and neurophysiology. This integration especially desirable in situations where recording of neuromuscular function is made under normal movement conditions of the entire physiological range. This would improve the possibilities to investigate more exactly the interrelationship between structural aspects of the neuromuscular system and performance characteristics.

Areas of study, Research and Practice in Healthcare Biomechanics

- Sport and Exercise Science
- Coaching
- Ergonomics
- Equipment Design
- Gait & Locomotion
- Orthopedics - Rehabilitation - Physiotherapy, Occupational Therapy
- Prosthetics and Orthotics
- Motor Control
- Computer Simulation



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- **Peripheral Nervous System Anatomy;** Author: Jasvinder Chawla, MD, MBA; Chief Editor: Thomas R Gest, PhD
- **Medline**; David C. Dugdale, III, MD, Professor of Medicine, Division of General Medicine, Department of Medicine, University of Washington School of Medicine, Seattle, WA.
- **Merriem Webster**; anatomy and fuction of muscle
- **Gray's Anatomy**

Thank You!