Physiotherapy Department

# PT201: Biomechanics

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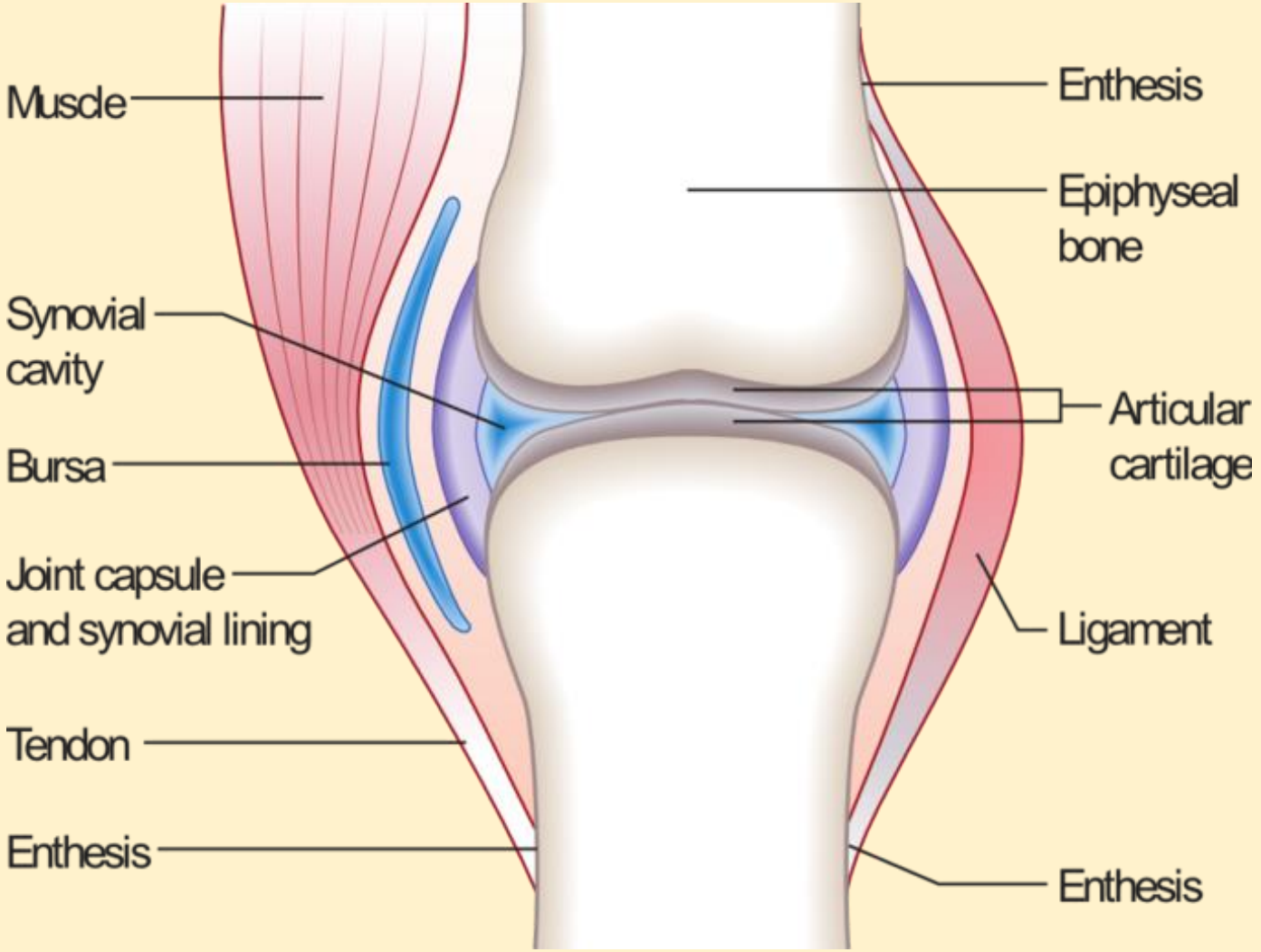
# Biomechanics of Joints



# Lecture 4
# Biomechanics of Joints

***31-10-2023***

# Synopsis

- Overview
- Typology
- Structure
- Motion
- Kinematics
- Lever system

# Objectives

- By the end of this lecture, students should understand and be able to describe basic biomechanics of joints based on the following headings:
  - Functional classification
  - Structure
  - Motion
  - Kinematics
  - Lever system

# Overview

- Joint is the junction or fulcrum between two or more bones
- Movement of the body occurs primarily via rotation of bones around individual joints (pivots)
- Joints transfer and disperse forces produced by gravity and muscle activation
- Type and extent of the movement possible at a joint depends on the structure and function of the joint

# Joint

**Typology**

- Joints can be classified based on their structure or movement potential

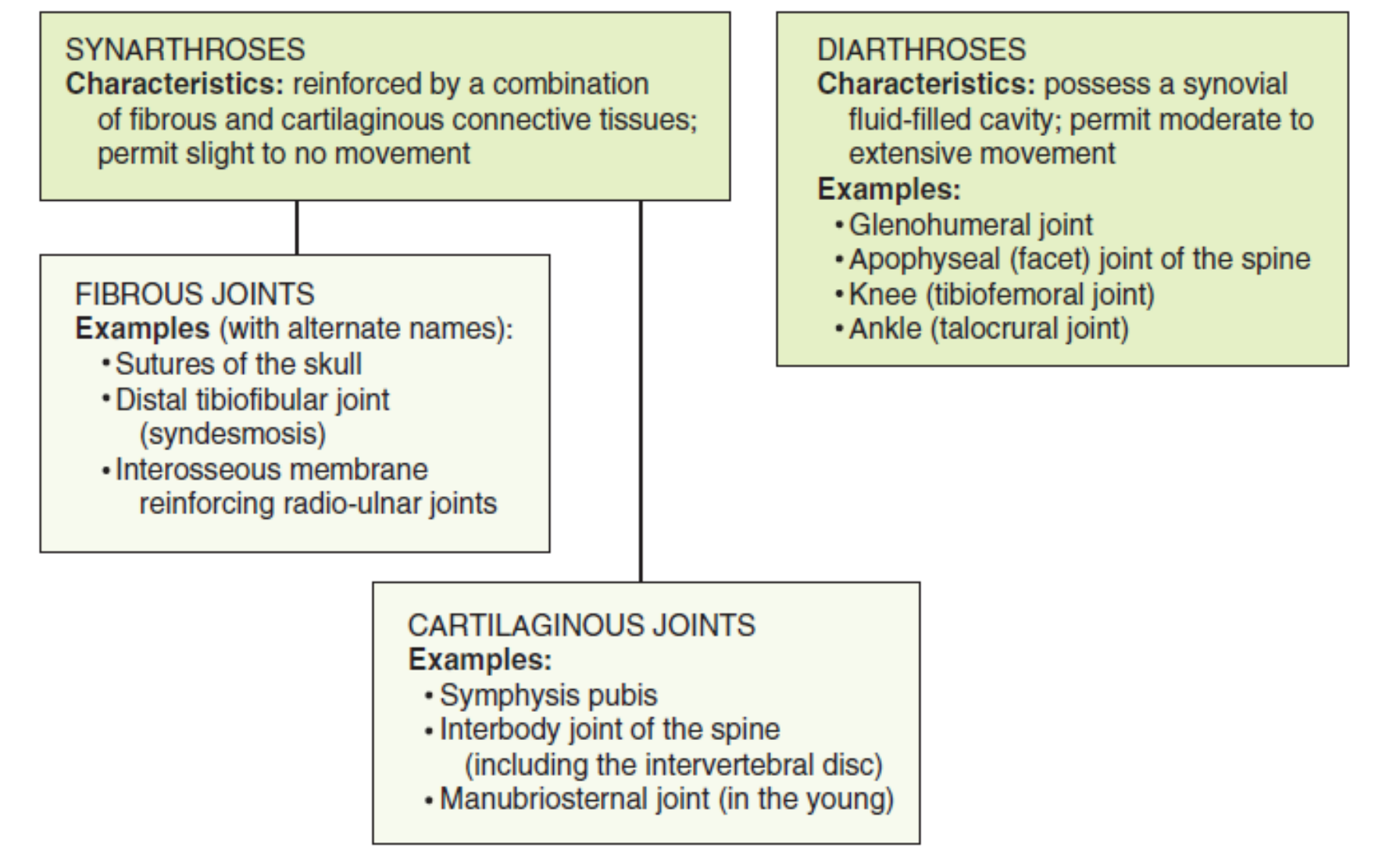
- Joint classification based on structure:
  - Fibrous (suture, gomphosis, and syndesmosis)
  - Cartilaginous (synchondrosis and symphysis)
  - Synovial (plane, saddle, hinge, pivot, ball and socket, and condyloid [ellipsoidal])

# Joint

- Joint classification based on the amount of movement possible
  - Diarthroses (permit free bone movement)
  - Synarthroses (permit very limited or no movement at all)

- Diarthroses are synovial joints, e.g., shoulder

- Synarthroses are further sub-divided into:
  - Synostoses  (bone is connected to bone by bone) e.g., sutures
  - Synchondroses (bone is connected to bone by cartilage) e.g., costosternal
  - Syndesmoses (bone is connected to bone by fibrous tissue) e.g., distal tibiofibular




Functional Classification of Human Joints

# Joint

**Structure**

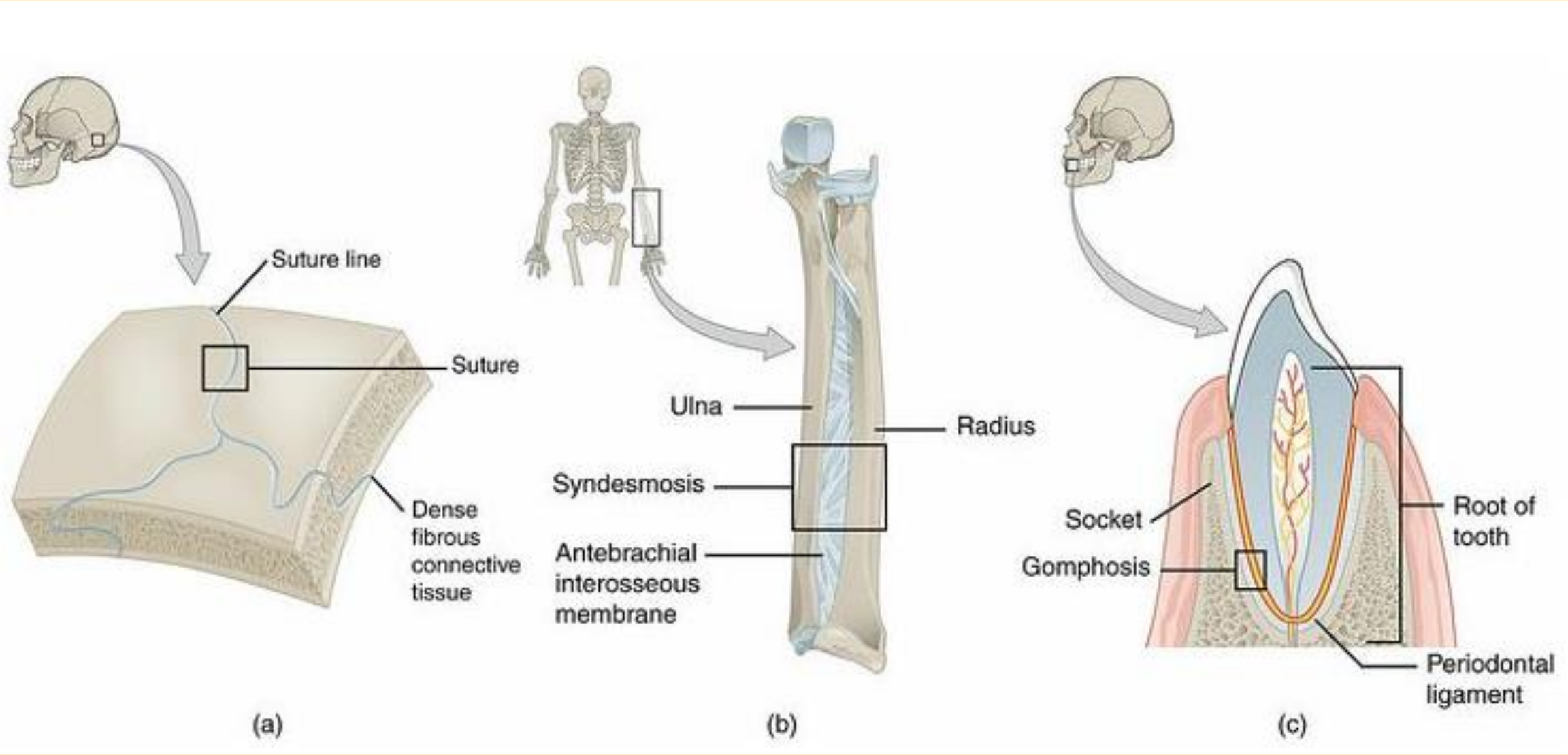
- Synarthrodial joints are specialized for stability and may permit little to no movement.

- Depending on the type, synarthrodial joints may exhibit the following features:
  - Cartilage (hyaline or fibrocartilage)
  - Strong fibrous connective tissue
  - Specialized dense connective tissue
  - Periarticular connective tissue
  - Interosseous membrane
  - Dense collagen

# Joint

- Diarthrodial joints are specialized for movement and always exhibit seven elements
  - Synovial fluid
  - Articular cartilage
  - Joint capsule
  - Synovial membrane
  - Ligaments
  - Blood vessels
  - Sensory nerves

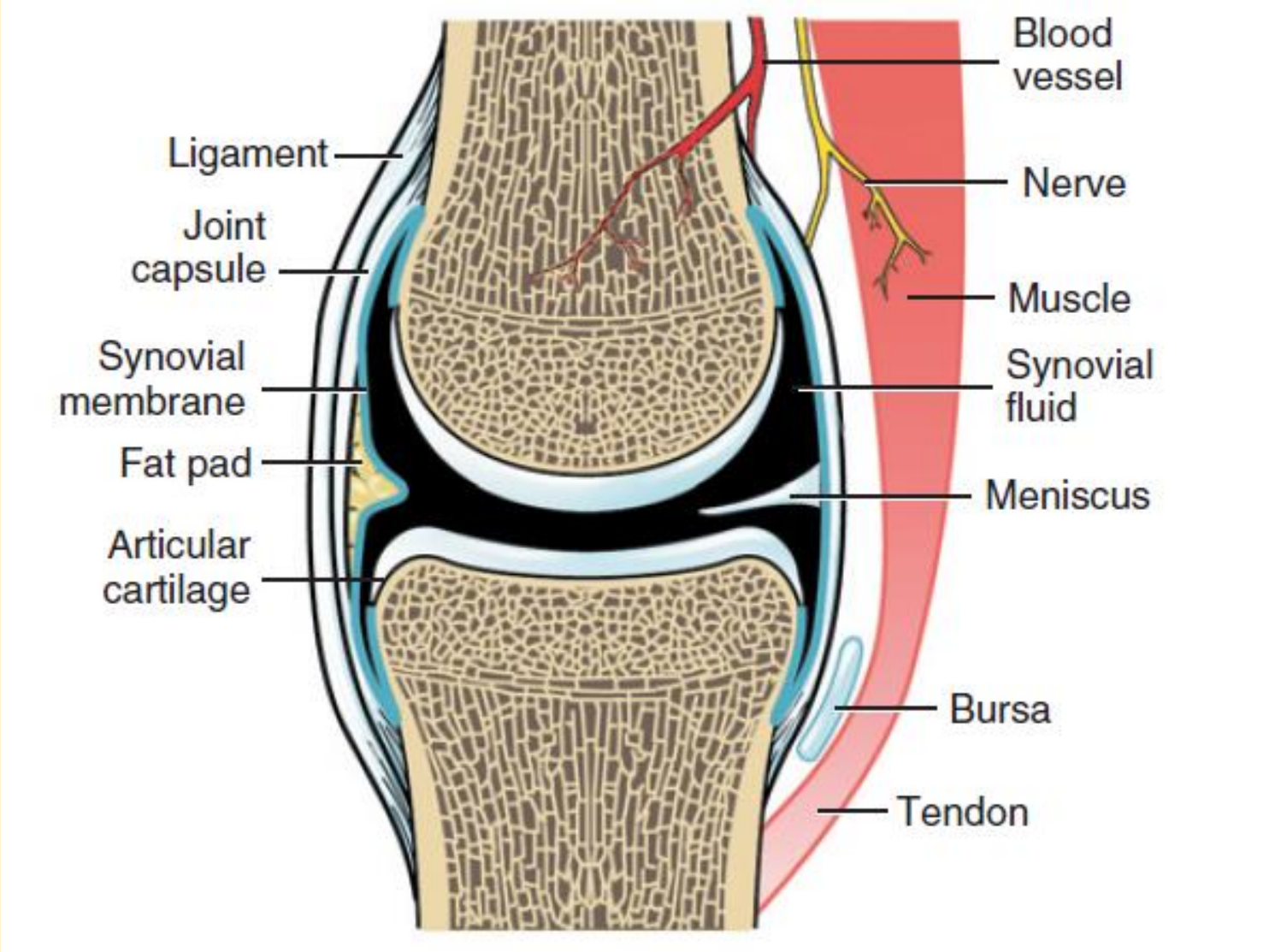
- Diarthrodial joints are sometimes associated with the following elements:
  - Intra-articular discs or menisci
  - Peripheral labrum
  - Fat pads
  - Bursa
  - Synovial plicae



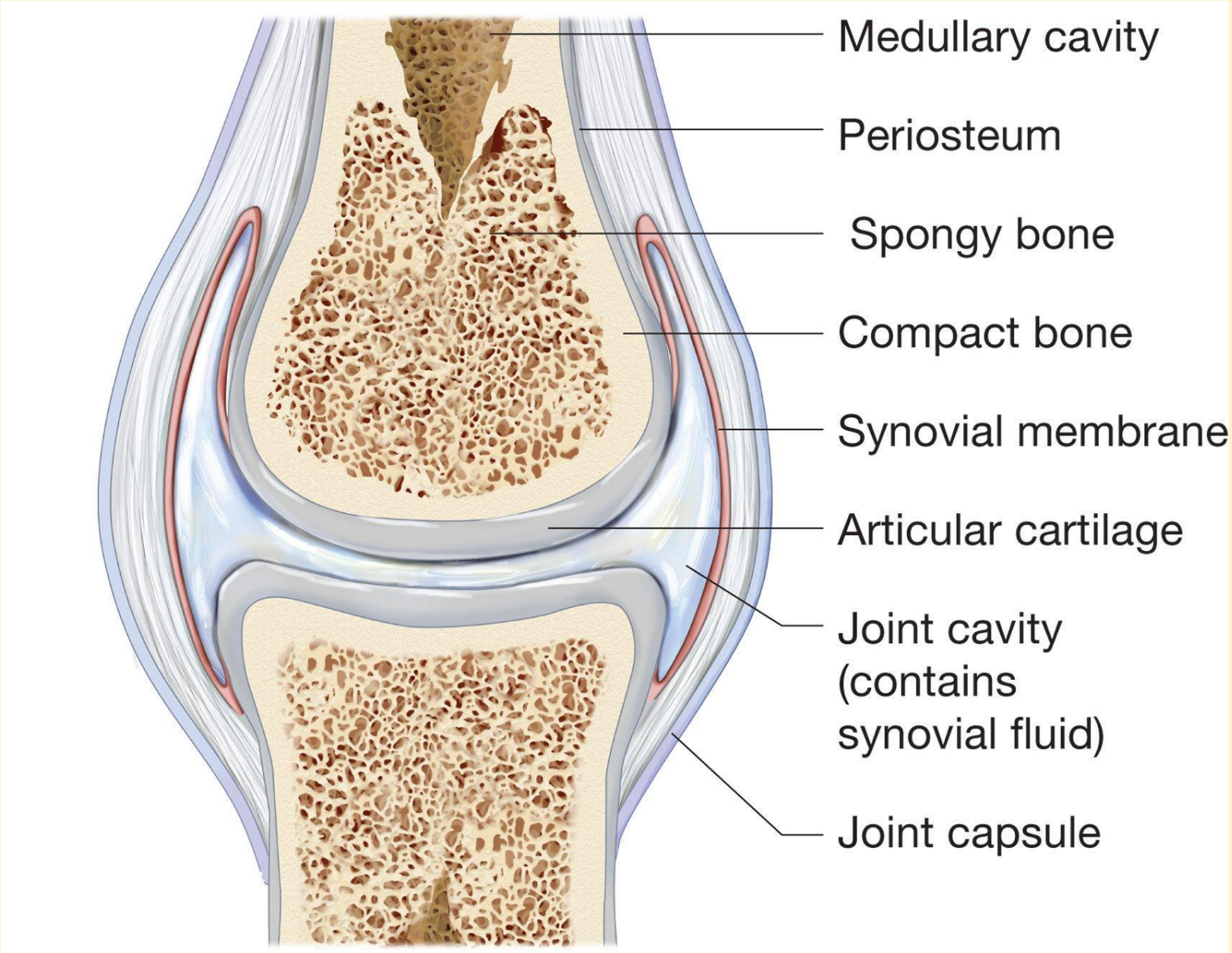

A. Synostosis B. Syndesmosis C. Gomphosis

**TABLE 2.1 Classification of Synovial Joints Based on Mechanical Analogy**

| | Primary Angular Motions | Mechanical Analogy | Anatomic Examples |
|---|---|---|---|
| Hinge joint | Flexion and extension only | Door hinge | Humero-ulnar joint<br>Interphalangeal joint |
| Pivot joint | Spinning of one member around a single axis of rotation | Doorknob | Humeroradial joint<br>Atlanto-axial joint |
| Ellipsoid joint | Biplanar motion (flexion-extension and abduction-adduction) | Flattened convex ellipsoid paired with a concave trough | Radiocarpal joint |
| Ball-and-socket joint | Triplanar motion (flexion-extension, abduction-adduction, and internal-external rotation) | Spherical convex surface paired with a concave cup | Glenohumeral joint<br>Coxofemoral (hip) joint |
| Plane joint | Typical motions include slide (translation) or combined slide and rotation | Relatively flat surfaces apposing each other, like a book on a table | Intercarpal or intertarsal joints<br>Carpometacarpal joints of digits II–V (often called modified plane joints) |
| Saddle joint | Biplanar motion; spin between bones is possible but may be limited by the interlocking nature of the joint | Each member has a reciprocally curved concave and convex surface oriented at right angles to the other, like a horse rider and a saddle | Carpometacarpal joint of the thumb<br>Sternoclavicular joint |
| Condyloid joint | Biplanar motion; either flexion-extension and abduction-adduction, or flexion-extension and axial rotation (internal-external rotation) | Mostly spherical convex surface that is enlarged in one dimension like a knuckle; paired with a shallow concave cup | Metacarpophalangeal joint<br>Tibiofemoral (knee) joint |




Generic Structure of Diarthroidial Joints




Generic Structure of Diarthroidial Joints

## Intra-Articular Discs (Menisci) Found in Several Synovial Joints of the Body

- Tibiofemoral (knee)
- Distal radio-ulnar
- Sternoclavicular
- Acromioclavicular
- Temporomandibular
- Apophyseal (variable)

# Joint

***Joint motion***

- Movements occurring between articular surfaces can be complex; the following terms are used to describe them
  - Spin (form of rotation)
  - Roll (form of rotation)
  - Slide (also called glide/translation)

- Spin: one surface spins relative to the other, which occurs about a fixed central axis

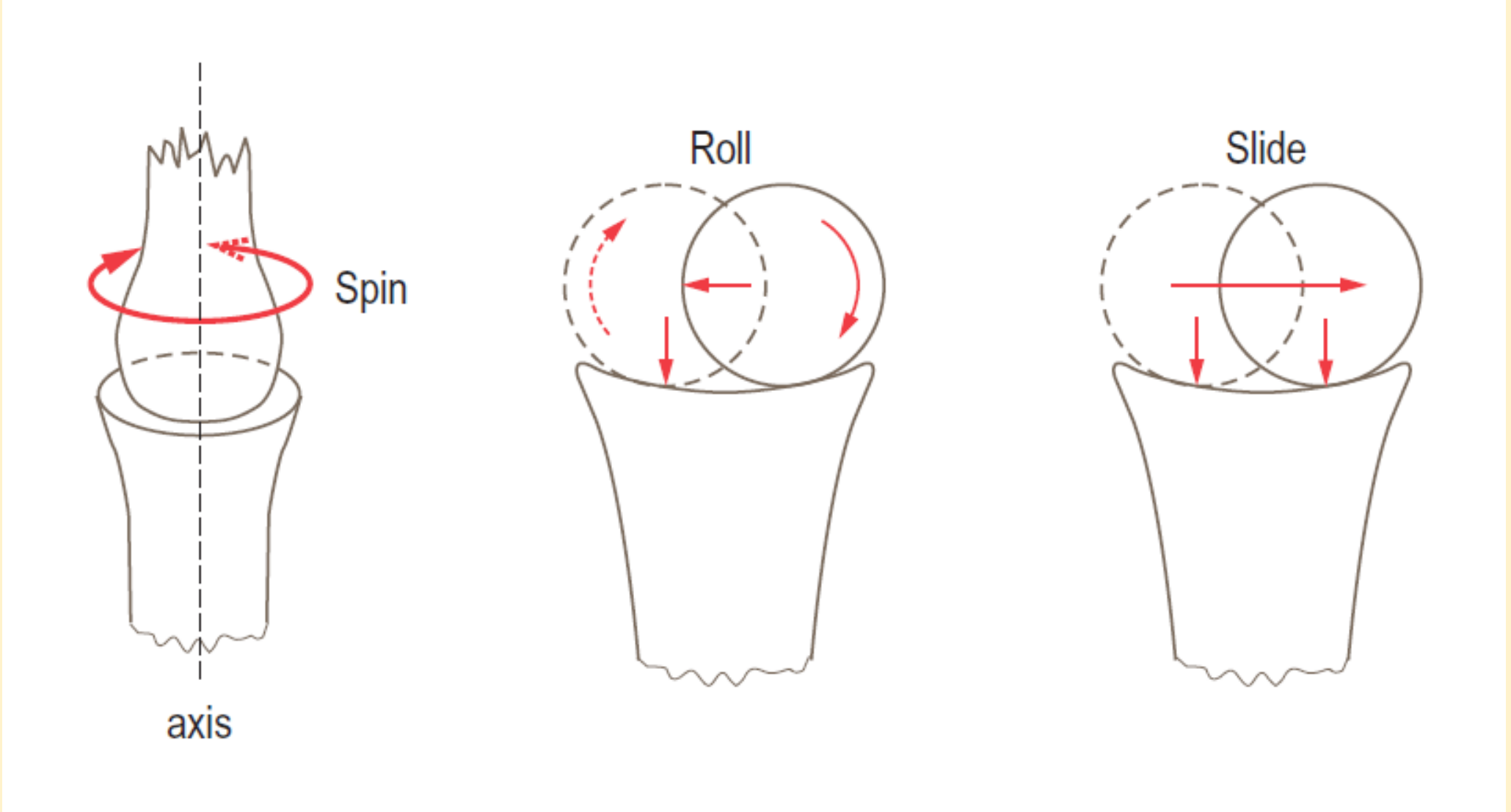
- Roll: one surface rolls across the other so that new parts of both surfaces are continually coming into contact with each other, as in a wheel rolling along the ground

# Joint

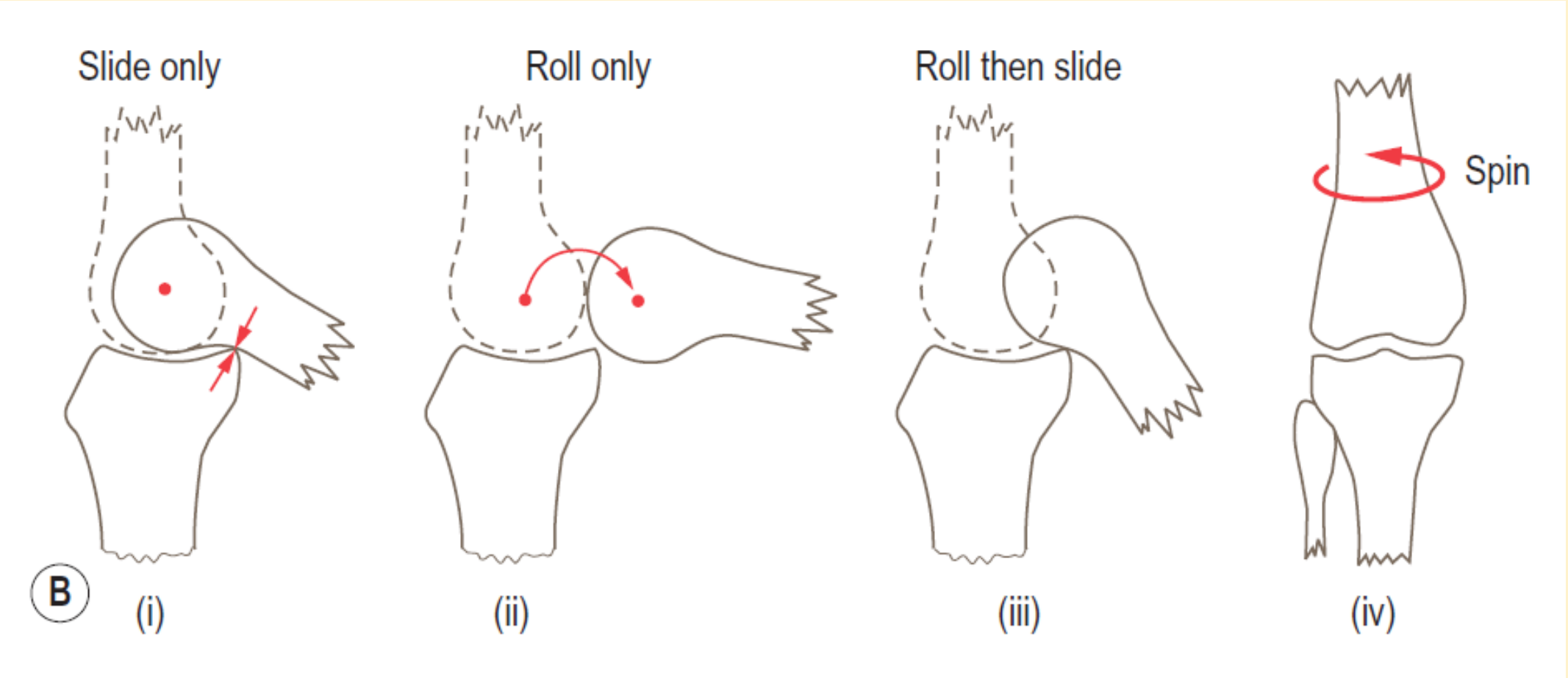
- Slide: occurs when one surface slides over the other so that new points on one surface continually make contact with the same point on the other surface

- Normally, spin, roll and slide do not occur separately as they complement one another to facilitate the complex movements available at joints

- Combinations of spin, roll, and slide (rotation and translation) are, therefore the basic components underlying movement at all joints




**S**pin, Roll and Slide between articular surfaces




(B) the effect of pure sliding (i) or rolling (ii) and a combination of rolling then sliding at the knee (iii), together with the spin that accompanies full extension (iv)

# Joint

- Kaltenborn concave-convex rule describes arthrokinematic movement in terms of role and glide in a joint

- When a **convex** joint surface is moving, the roll and glide occur in the **opposite direction**

- When a **concave** joint surface is moving, the roll and the glide occur in the **same direction**

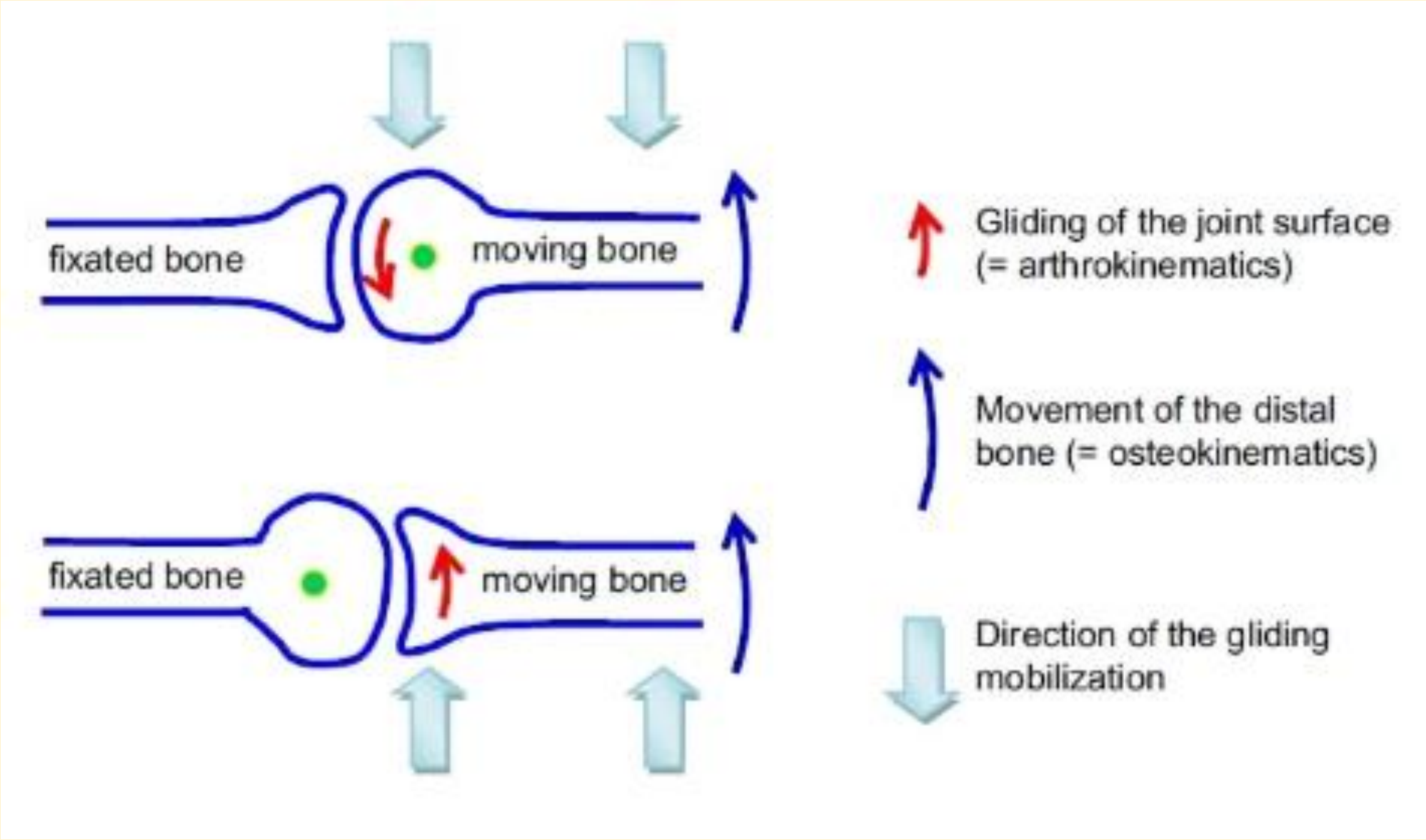
# Joint

- The direction in which sliding occurs depends on whether the moving surface is concave or convex

  - Concave = hollowed or rounded inward
  - Convex = curved or rounded outward

- If the moving joint surface is CONVEX, sliding is in the OPPOSITE direction of the angular movement of the bone

- If the moving joint surface is CONCAVE, sliding is in the SAME direction as the angular movement of the bone.




Kaltenborn concave-convex rule

# Joint

***Kinematics***

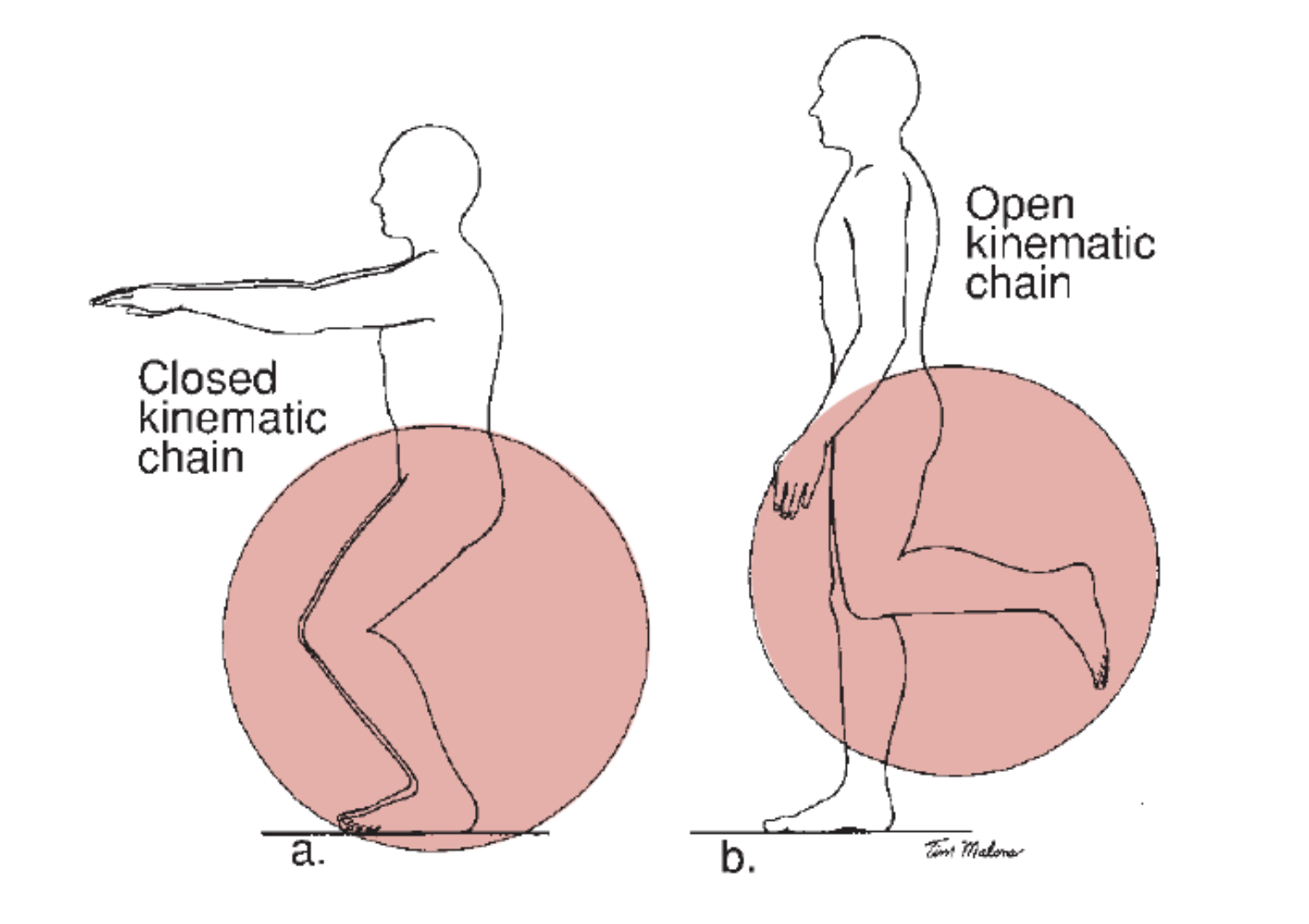
- Rotation is a motion about an axis, causing points on the rotating body to travel different distances depending upon their distance from the point of rotation

- Translation produces a linear movement in which all points in the body travel the same distance regardless of their location in the body

- System of joints and links is constructed so that motion of one link at one joint will produce motion at all of the other joints in the system in a predictable manner, a phenomenon called a '**kinematic chain**'

# Joint

- Kinematic chain can either be open or closed
- Open kinematic chain is when one joint can move independently of others in the chain
- Closed kinematic chain, here one end of the chain is closed, thus, movement at one joint automatically creates movement in other joints in the chain




**A.** Knee flexion accompanied by hip flexion **B.** Knee flexion exclusively

# Joint

- Range of motion (ROM) refers to the amount of motion available to a joint within the anatomic limits of the joint structure
- Active ROM is the movement that can be achieved when opposing muscles contract and relax
- Passive ROM is the movement achieved when an outside force, such as a therapist, causes movement of a joint

# Joint

- Hypermobility is excessive joint movement beyond what is physiologically allowed by the joint
- Hypomobility refers to reduced joint movement below the physiological limit of the joint
- Close-packed is a position in which the joint surfaces are maximally congruent, and the ligaments and capsule are maximally taut, usually at the end of the ROM
- Loose-packed position of a joint is when the articular surfaces are relatively free to move in relation to one another

# Joint

- Joint play/arthrokinematics are accessory joint movements which cannot be performed by the individual such as roll, spin, and slide, which accompany physiological movements of a join

- Arthrokinematics refers to the movements of joint surfaces on one another, they accompany voluntary movement but cannot be independently produced voluntarily

- Osteokinematics refers to the movement of the bones in space during physiologic joint motion

# Joint

- Osteokinematics are typically described by the plane in which they occur, the axis about which they occur, and the direction of movement

- Joint end feels are the sensation experienced by the examiner performing passive physiologic movements at each joint

- Type of joint end feels is determined by the type of structure that limits the joint ROM

## Normal joint end feels

| End-Feel | Description | Example |
|---|---|---|
| Soft | Soft tissue approximation | Knee flexion (contact between soft tissue of posterior leg and posterior thigh) |
| Firm | Muscular stretch | Hip flexion with the knee straight (passive tension of hamstring muscles) |
| | Capsular stretch | Extension of metacarpophalangeal joints of fingers (tension in the anterior capsule) |
| | Ligamentous stretch | Forearm supination (tension in the palmar radioulnar ligament of the inferior radioulnar joint, interosseous membrane, oblique cord) |
| Hard | Bone contacting bone | Elbow extension (contact between the olecranon process of the ulna and the olecranon fossa of the humerus) |

| End-Feel | Description | Example |
|---|---|---|
| Soft | Occurs sooner or later in the ROM than is usual or in a joint that normally has a firm or hard end-feel. Feels boggy. | Soft tissue edema<br>Synovitis |
| Firm | Occurs sooner or later in the ROM than is usual or in a joint that normally has a soft or hard end-feel. | Increased muscular tonus<br>Capsular, muscular, ligamentous, and fascial shortening |
| Hard | Occurs sooner or later in the ROM than is usual or in a joint that normally has a soft or firm end-feel. A bony grating or bony block is felt. | Chondromalacia<br>Osteoarthritis<br>Loose bone fragments in joint<br>Myositis ossificans<br>Fracture |
| Empty | No real end-feel because pain prevents reaching end of ROM. No resistance is felt except for individual's protective muscle splinting or muscle spasm. | Acute joint inflammation<br>Bursitis<br>Abscess<br>Fracture<br>Psychogenic disorder |

**Abnormal joint end feels**

# Joint

*Lever*

- A lever is a rigid rod (usually a length of a bone) that turns about a pivot (usually a joint)

- Levers provide a mechanical advantage by moving a larger load with a small force/effort

- Three classes of lever are found within the body
  - First class
  - Second class
  - Third class

# Joint

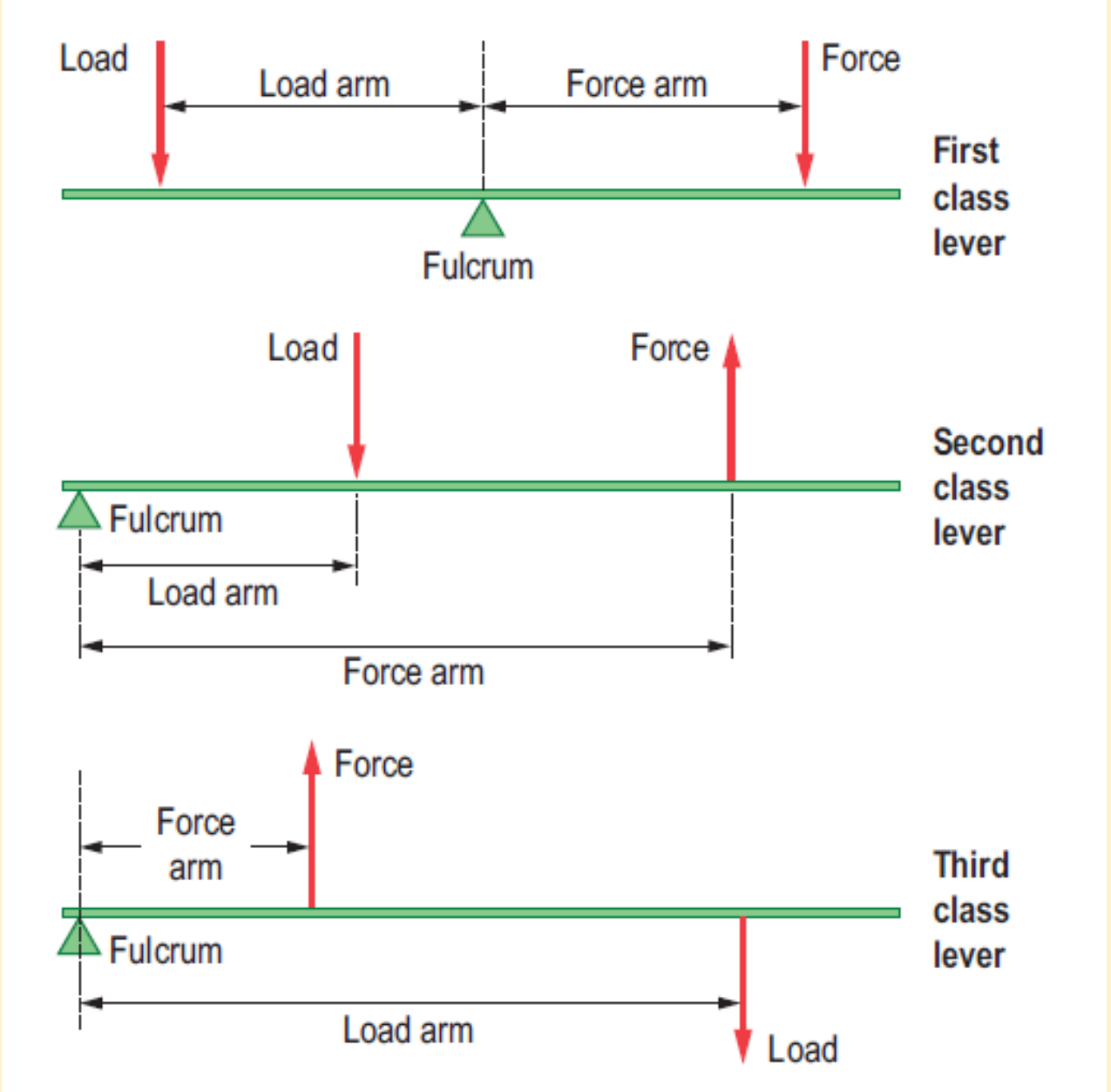
- First class levers have the load and muscle action on opposite sides of the joint (fulcrum) i.e., fulcrum at the center, e.g., standing on one limb
- First class lever is used in balancing weight and/or changing the direction of pull. There is usually no gain in mechanical advantage
- Second class levers have the load between the joint and the muscle attachment i.e., load at the center, e.g., tip toeing
- Second class lever provides mechanical advantage, thereby allowing large loads to be moved, but with a loss of speed

# Joint

- Third class levers have the muscle attachment (effort) between the load and the joint (being the most common in human body) i.e., effort at the center, e.g., Biceps brachii acting across the elbow joint

- Third class lever is the most commonly found within the body

- Third class lever works at a mechanical disadvantage moving less weight but often at great speed



# Summary points

- Connective tissue structures made movement possible at a joint
- Joint movement is produced by the collective actions of muscles, tendons, ligaments, bones, and cartilages
- Derangement from normal biomechanical behaviors of the articular connective tissues produces abnormal joint function
- Osteokinematics and arthrokinematics are the movements that take place around joint articulations

# Contributions and Questions

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