Table of Contents

1. Introduction
2. Types of Movement
3. Muscle
4. Skeletal Muscles
5. Cardiac Muscles
6. Smooth Muscles
7. Structure of Skeletal System
8. Structure of Contractile Proteins
9. Mechanism of Muscle Contraction
10. Additional Muscle Concepts
11. Joints
12. Disorders of Muscular and Skeletal System
13. Osteoporosis
14. Muscular Dystrophy
15. Myasthenia Gravis
16. Osteomalacia or Rickets
17. Arthritis
18. Gout
19. Tetany
20. Human Skeletal System

Introduction

Overview of Movement

- **Movement** is a basic feature of living beings.
- Animals and plants show various movements; unicellular organisms like *Amoeba* move by protoplasmic streaming.
- Movement types include cilia, flagella, and tentacles; humans move limbs, jaws, eyelids, tongue, etc.
- **Locomotion** is voluntary movement causing change in place: walking, running, climbing, flying, swimming.
- All locomotion is movement, but not all movement is locomotion.
- Examples: *Paramecium* uses cilia for food movement and locomotion; *Hydra* uses tentacles for prey capture and locomotion; humans use limbs for posture and locomotion.
- Locomotion helps in searching food, shelter, mates, breeding grounds, favorable climate, or escaping predators.

Memory Aids

- Locomotion = movement with change in place.
- *Amoeba* moves by streaming; *Paramecium* and *Hydra* use cilia/tentacles.
- Humans move limbs for posture and locomotion.

Quick Checkpoints

- What distinguishes locomotion from general movement?
- How do unicellular organisms move?
- Examples of locomotion in different organisms?
- Purpose of locomotion in animals?

Types of Movement

Cellular Movement Types

- **Amoeboid/Pseudopodial movement:** Movement by pseudopodia via cytoplasmic streaming; seen in *Amoeba*, macrophages, leucocytes; involves microfilaments.
- **Ciliary movement:** Movement by cilia in internal organs; clears microbes/dust in respiratory tract; transports ova in fallopian tubes and sperm in vasa efferentia.
- **Muscular movement:** Movement of limbs, jaws, tongue by alternate muscle contraction and relaxation.
- **Flagellar movement:** Movement by tail and middle piece propulsion; seen in human sperm, sponges' water current, and protozoans like *Euglena*.

Locomotion requires coordinated muscular, skeletal, and neural activity.

Memory Aids

- Amoeboid = pseudopodia + cytoplasmic streaming.
- Cilia clear and transport in body tubes.
- Muscles contract-relax for movement.
- Flagella propel sperm and protozoans.

Quick Checkpoints

- What causes amoeboid movement?
- Where is ciliary movement found in humans?
- How do muscles produce movement?
- Examples of flagellar movement?
- What systems coordinate locomotion?

Muscle

Overview

- Specialised tissue of **mesodermal** origin.
- Contributes 40-50% of adult human body weight.
- Properties: excitability, contractility, extensibility, elasticity.
- Three types based on location: Skeletal, Smooth, Cardiac.

Memory Aids

- Muscle = Mesoderm origin + Movement + Multiple types.
- Excitability and contractility are key muscle traits.

Quick Checkpoints

- What is the origin of muscle tissue?
- Name the three types of muscles.
- List special properties of muscles.

Skeletal Muscles

Characteristics

- Associated with skeleton; also called striped or striated muscles.
- Located in limbs, body wall, tongue, pharynx, upper oesophagus.
- Voluntary control by nervous system.
- Functions: locomotion, posture changes.

Memory Aids

- Skeletal = Striated + Voluntary + Attached to bones.

Quick Checkpoints

- Where are skeletal muscles found?
- Are skeletal muscles voluntary or involuntary?
- What actions do skeletal muscles perform?

Cardiac Muscles

Characteristics

- Found in heart walls and large veins entering heart (pulmonary veins, superior vena cava).
- Cylindrical, striated, branched, uninucleate fibers.
- Involuntary control.
- Intercalated discs transmit contraction waves between fibers.

Memory Aids

- Cardiac = Heart muscle + Involuntary + Intercalated discs.

Quick Checkpoints

- Where are cardiac muscles located?
- Describe the structure of cardiac muscle fibers.
- What is the function of intercalated discs?

Smooth Muscles

Characteristics

- Also called visceral, unstriped, or non-striated muscles; spindle-shaped.
- Located in walls of hollow visceral organs: posterior oesophagus, stomach, intestine, lungs, urinary and genital tracts, bladder, blood vessels, iris, dermis.

- Not attached to skeleton.
- Involuntary control by autonomic nervous system.
- Functions: transport of food in digestive tract, movement of gametes in genital tract.

Memory Aids

- Smooth = Spindle shape + Visceral organs + Involuntary.

Quick Checkpoints

- What shape are smooth muscle fibers?
- Where are smooth muscles found?
- Are smooth muscles voluntary or involuntary?

Structure of Skeletal System

Organization

- Muscle made of bundles called fascicles, held by connective tissue called **fascia**.
- Fascicles contain muscle fibers; fibers are long, cylindrical cells surrounded by **sarcolemma**.
- Muscle fiber cytoplasm = **sarcoplasm**, contains many nuclei (syncytium), mitochondria (sarcosomes), and **sarcoplasmic reticulum** storing calcium ions.
- Muscle fibers contain parallel filaments called **myofilaments** or **myofibrils** with alternating dark and light bands.

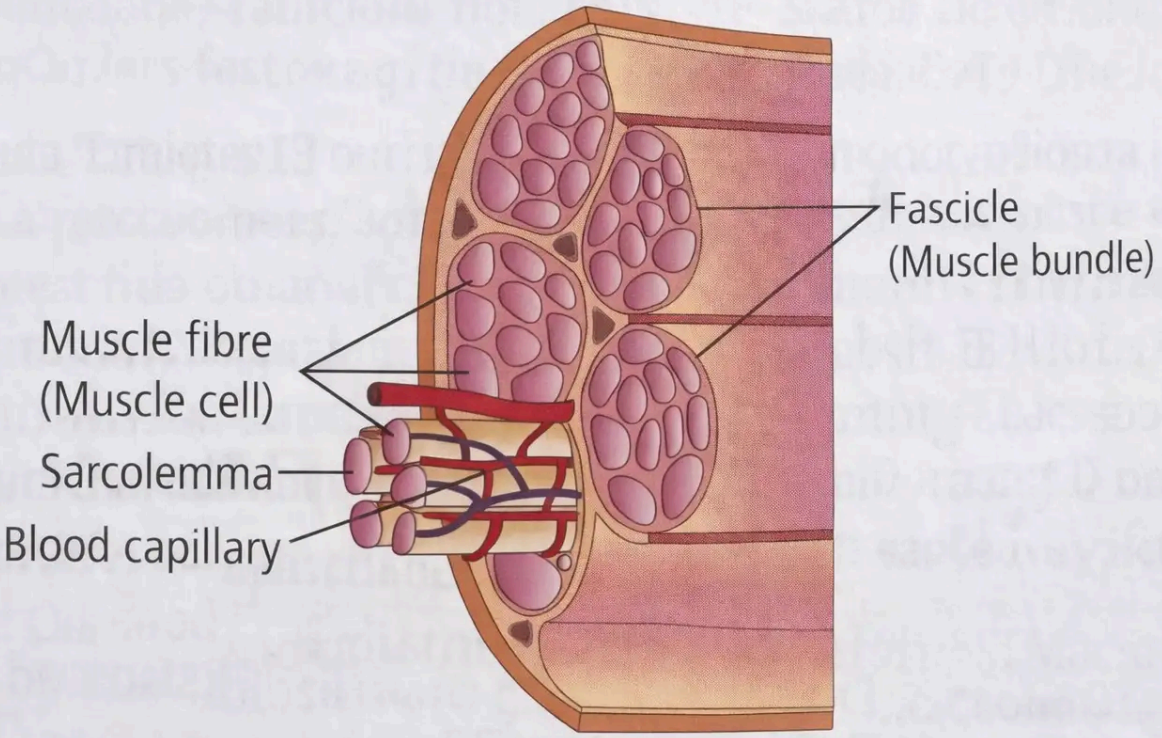


Fig.: Diagrammatic cross sectional view of a muscle showing muscle bundles and muscle fibres

Striation and Bands

- Striations due to actin (thin) and myosin (thick) protein arrangement.
- Light band = **'I'-band** (isotropic) with actin; dark band = **'A'-band** (anisotropic) with myosin.
- Thin and thick filaments arranged rod-like, parallel to myofibril axis.
- Center of 'I' band has elastic **'Z' line** (Z disc) where thin filaments attach.
- Thick filaments held at center of 'A' band by **'M' line**.
- Segment between two Z lines = **sarcomere**, functional contractile unit.
- Resting sarcomere has overlapping thin filaments on thick filaments edges; central thick filament region without overlap = **'H' zone**.

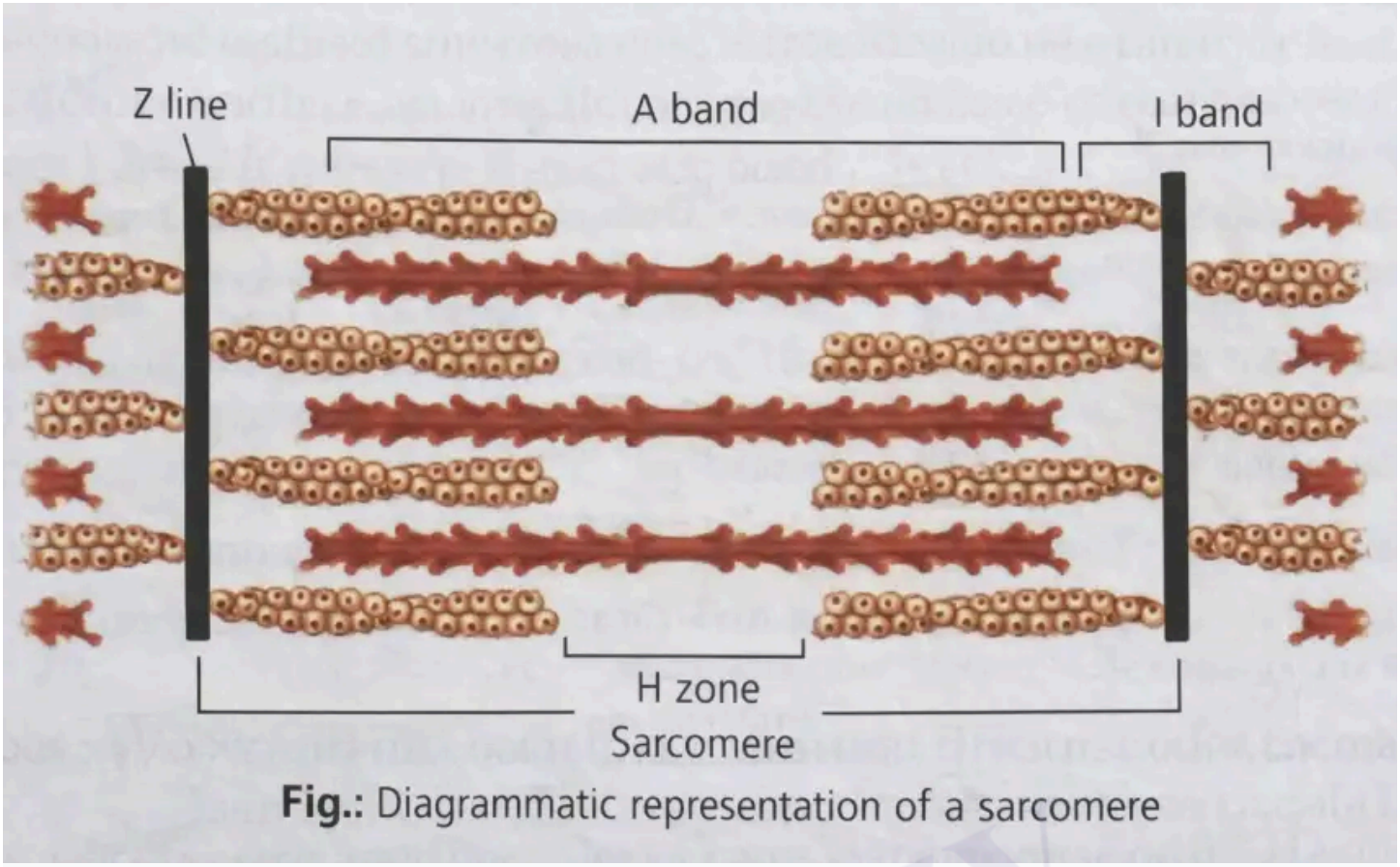


Fig.: Diagrammatic representation of a sarcomere

Memory Aids

- Striations = Actin (I-band) + Myosin (A-band).
- Sarcomere = Z line to Z line segment.
- H zone = Thick filament center without thin filament overlap.

Quick Checkpoints

- What causes muscle striations?
- Define sarcomere.
- What is the 'H' zone?

Structure of Contractile Proteins

Protein Components

- Four contractile proteins: myosin, actin, troponin, tropomyosin.

- **Thin myofilament** proteins:
  - **Actin:** Double-stranded F-actin helix made of G-actin monomers.
  - **Tropomyosin:** Double-stranded a-helical rod on F-actin; blocks active sites in resting state.
  - **Troponin:** Complex protein on tropomyosin; masks myosin binding sites on actin in resting state.
- **Thick myofilament** mainly myosin:
  - Myosin has two heavy and four light polypeptide chains forming two globular heads and a long tail.
  - Heads form crossbridges; split by trypsin into heavy meromyosin (HMM) and light meromyosin (LMM).
  - HMM heads have ATP and actin binding sites.

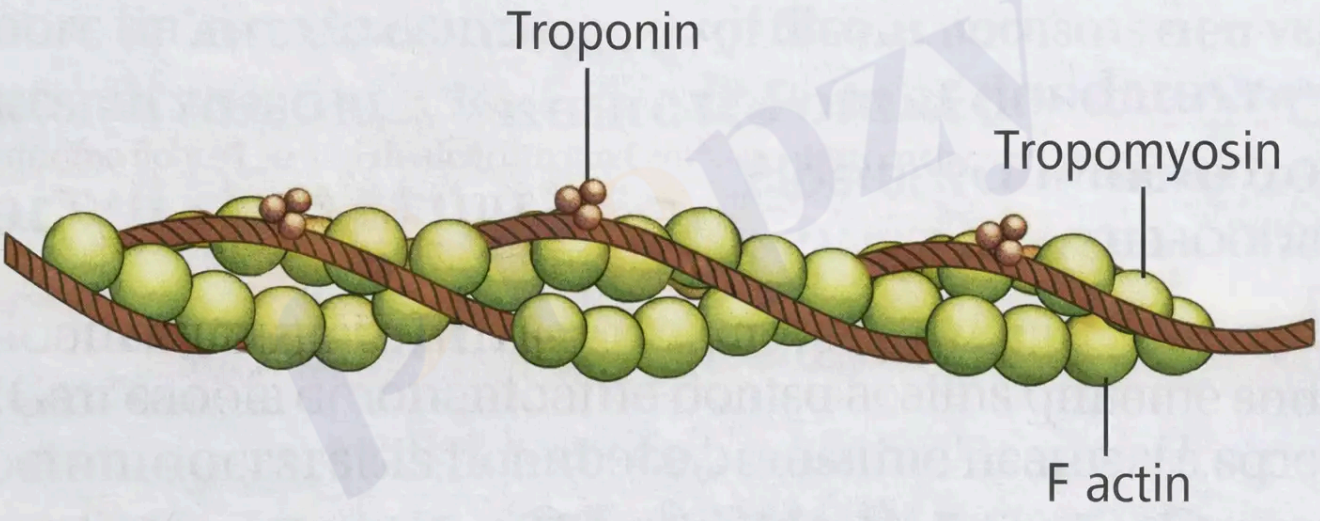


Fig.: An actin (thin) filament

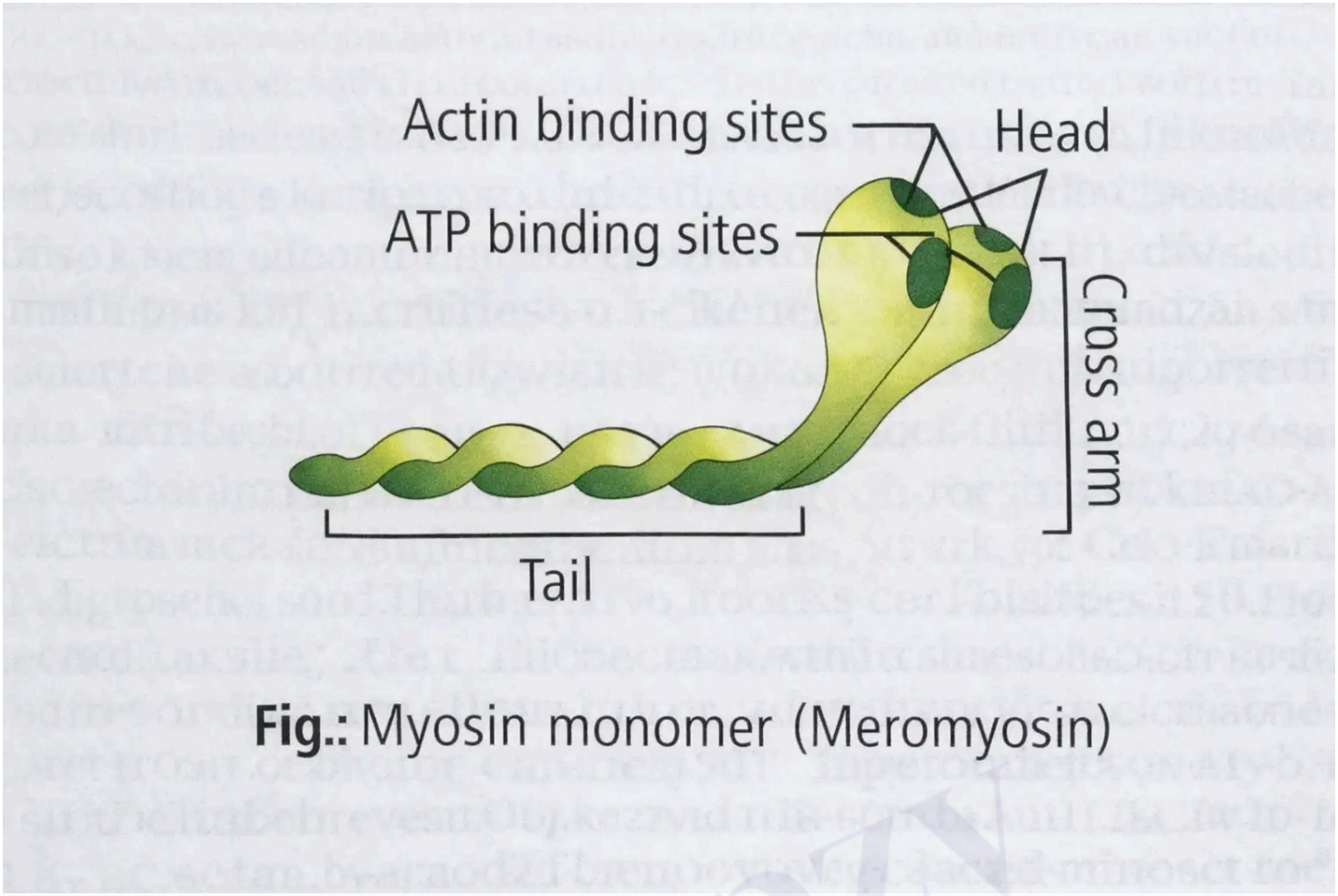


Fig.: Myosin monomer (Meromyosin)

Memory Aids

- Thin filament = Actin + Tropomyosin + Troponin.
- Thick filament = Myosin with heads for ATP and actin binding.

Quick Checkpoints

- What proteins form thin myofilaments?
- Describe the structure of myosin.
- What is the role of troponin?

Mechanism of Muscle Contraction

Sliding Filament Theory

- Contraction by sliding of thin filaments over thick filaments.

- Proposed by A. F. Huxley & Ralph Niedergerke, and H.E. Huxley & Jean Hanson (1954).
- Initiated by CNS signal via motor neuron; motor unit = motor neuron + connected muscle fibers.
- Neuromuscular junction (motor end plate) releases acetylcholine, generating action potential in sarcolemma.
- Action potential causes Ca^{2+} release into sarcoplasm.
- Ca^{2+} binds troponin, exposing myosin binding sites on actin.
- Myosin heads bind actin using ATP energy, forming cross bridges.
- Myosin heads pivot, pulling actin towards sarcomere center, shortening sarcomere (contraction).
- 'I' bands shorten; 'A' bands remain constant length.
- ADP and phosphate released; ATP binds myosin head, breaking cross bridge.
- ATP hydrolyzed; cycle repeats until Ca^{2+} pumped back, masking actin sites (relaxation).
- Repeated contraction causes lactic acid buildup, leading to fatigue.

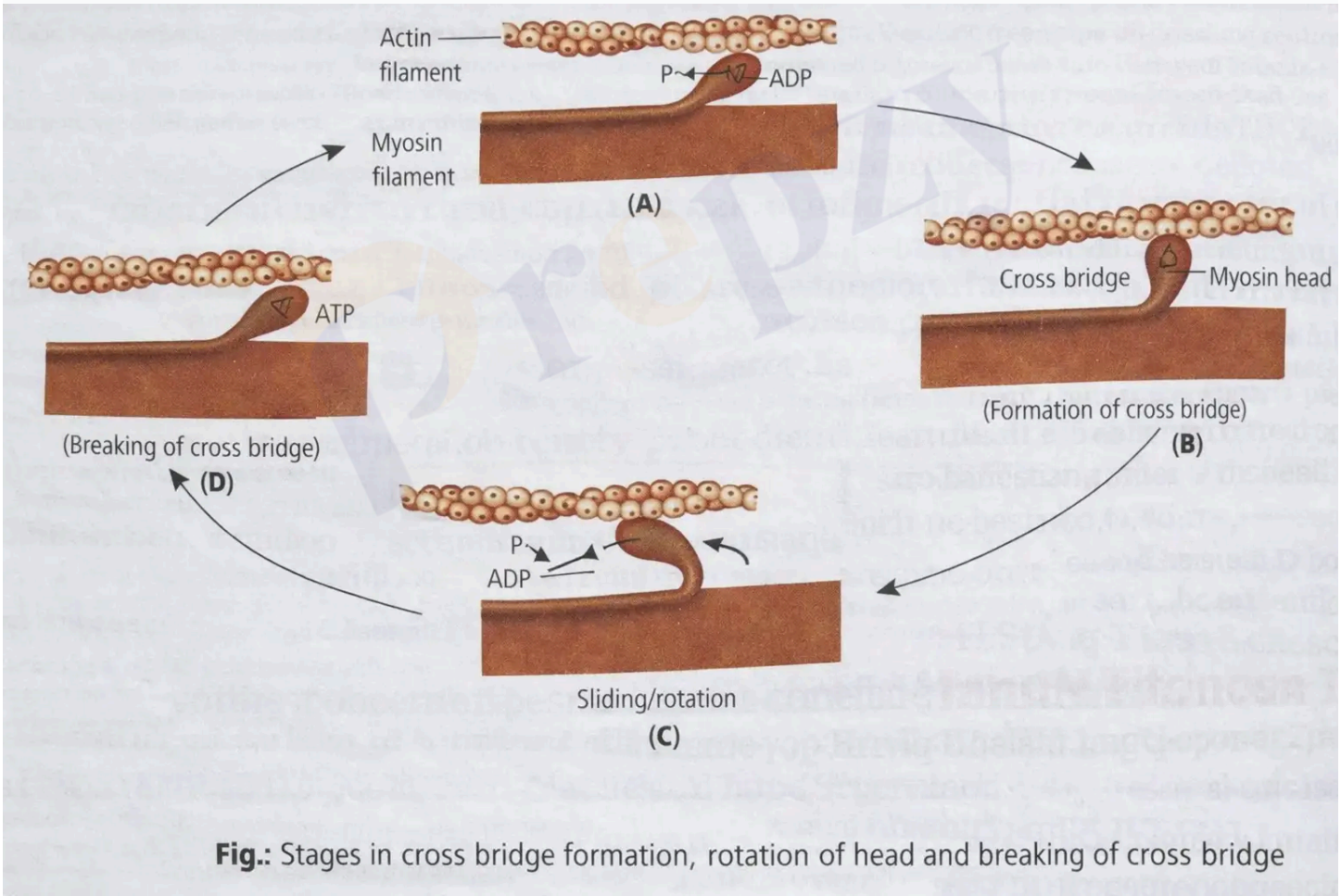


Fig.: Stages in cross bridge formation, rotation of head and breaking of cross bridge

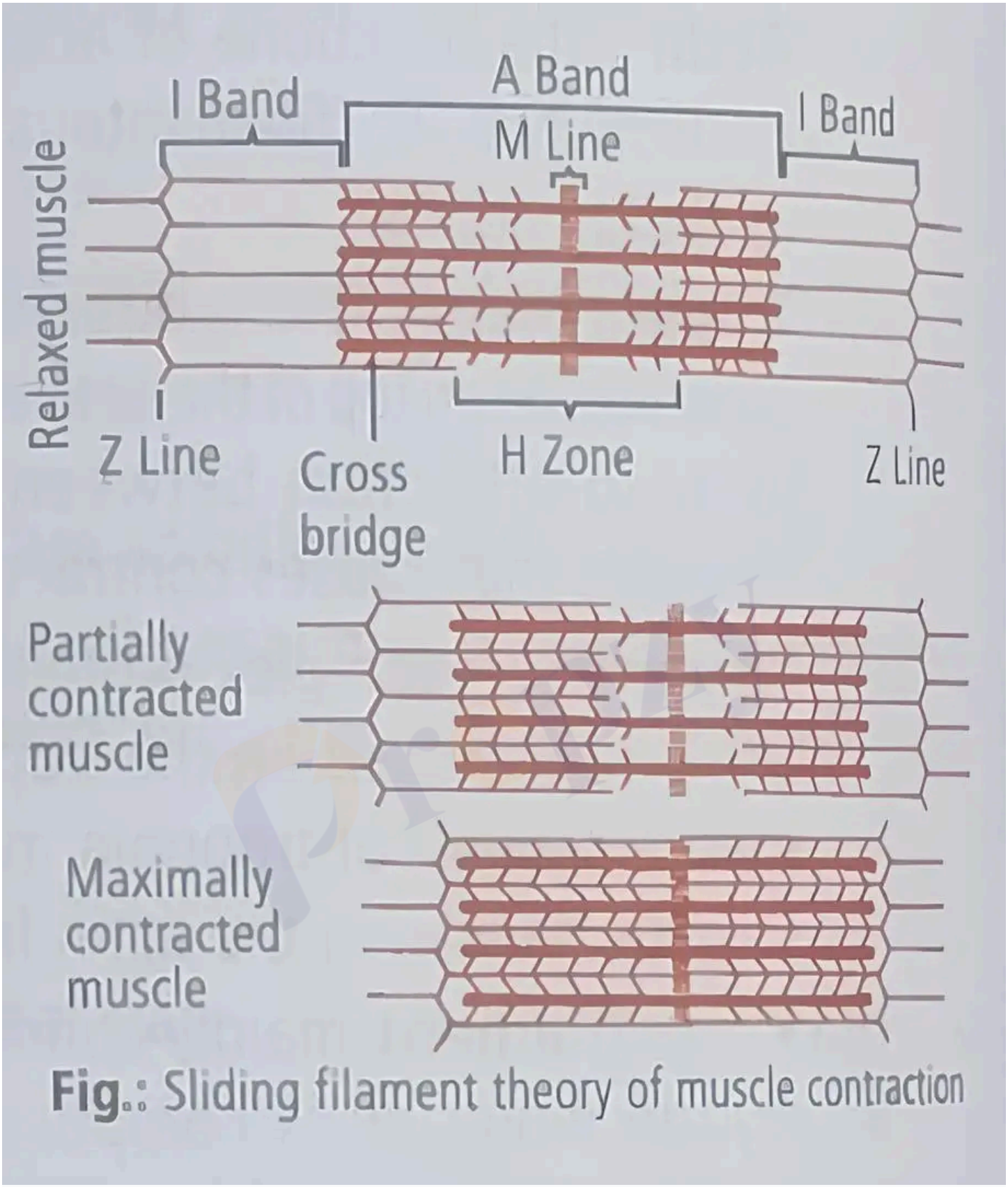


Fig.: Sliding filament theory of muscle contraction

Memory Aids

- Sliding filament = Thin filaments slide over thick filaments.
- Ca^{2+} triggers exposure of myosin binding sites.
- ATP powers cross bridge cycling.

Quick Checkpoints

- What triggers muscle contraction at molecular level?
- Describe the role of ATP in contraction.
- What happens to sarcomere bands during contraction?

Additional Muscle Concepts

Key Points

- All-or-none law: muscle fiber contracts fully or not at all.
- Oxygen debt: anaerobic respiration during vigorous exercise produces lactic acid causing fatigue; extra oxygen needed to oxidize lactic acid.
- Rigor mortis: post-death muscle stiffening due to lack of ATP preventing actin-myosin separation.
- Antagonistic muscles: muscles acting in opposition, e.g., biceps (flexor) and triceps (extensor).

Memory Aids

- All-or-none: full contraction or none.
- Oxygen debt = lactic acid buildup + fatigue.
- Rigor mortis = no ATP, muscles stiffen after death.
- Antagonistic muscles = opposite actions.

Quick Checkpoints

- What is the all-or-none law?
- Explain oxygen debt in muscles.
- What causes rigor mortis?
- Define antagonistic muscles with example.

Joints

Structure and Function

- Joints connect bones or bones to cartilage, enabling movement.
- Ligaments connect bones; tendons connect bones to muscles.
- Muscle force acts on joints, which serve as fulcrums for movement.
- Joint mobility varies by structure and type.
- Three main types: fibrous, cartilaginous, synovial.

Types of Joints

- **Fibrous joints:** No movement; bones joined by dense fibrous tissue. Example: skull sutures, teeth to maxilla/mandible.
- **Cartilaginous joints:** Bones joined by cartilage; allow limited movement. Example: vertebral joints, pubic symphysis.
- **Synovial joints:** Have fluid-filled synovial cavity; allow free movement. Examples:
  - Ball and socket (humerus and pectoral girdle)
  - Hinge (knee joint)
  - Pivot (atlas and axis)
  - Gliding (carpals)
  - Saddle (carpal and metacarpal of thumb)

Memory Aids

- Fibrous = Fixed (no movement)
- Cartilaginous = Cartilage connects, allows some movement
- Synovial = Synovial fluid allows free movement
- Examples: Ball & Socket = Shoulder; Hinge = Knee; Pivot = Neck; Gliding = Wrist; Saddle = Thumb

Quick Checkpoints

- What connects bones and muscles?

- Which joint type allows no movement?
- Where is synovial fluid found?
- Name a joint that permits limited movement.
- Identify examples of synovial joints.

Disorders of Muscular and Skeletal System

Overview

- Includes diseases affecting bones and muscles.
- Common disorders involve mineral loss, genetic mutations, autoimmune issues, and metabolic defects.

Memory Aids

- Disorders = Bone + Muscle problems.
- Focus on mineral loss, gene mutation, immunity, metabolism.

Quick Checkpoints

- What causes mineral loss in bones?
- How do gene mutations affect muscles?
- What is the role of immunity in muscle disorders?

Osteoporosis

Key Points

- Age-related bone disease with loss of minerals and fibers from bone matrix.
- Major causes: hormone imbalances (calcitonin, parathormone, estrogen) and deficiencies of calcium and vitamin D.

Memory Aids

- Osteo = bone, porosis = porous (weak bones).
- Think: Hormone + mineral deficiency = weak bones.

Quick Checkpoints

- Which hormones regulate bone minerals?
- How does vitamin D deficiency affect bones?

Muscular Dystrophy

Key Points

- Caused by mutated gene on X-chromosome.
- Mutation leads to absence of dystrophin protein in skeletal muscles.
- Dystrophin deficiency prevents calcium release from muscle cells, blocking muscle contraction.

Memory Aids

- Muscular Dystrophy = X-linked gene mutation.
- Dystrophin missing = no muscle contraction.

Quick Checkpoints

- What is the role of dystrophin?
- Why does muscle contraction fail?

Myasthenia Gravis

Key Points

- Autoimmune disorder affecting neuromuscular junction.
- Leads to fatigue, weakening, and paralysis of skeletal muscles.

Memory Aids

- Myasthenia = muscle weakness.
- Autoimmune attack blocks nerve-muscle communication.

Quick Checkpoints

- What part of muscle function is affected?
- How does immunity cause muscle weakness?

Osteomalacia or Rickets

Key Points

- Occurs in childhood (rickets) or adults (osteomalacia).
- Bones have insufficient calcium and phosphorus.

Memory Aids

- Rickets = childhood bone softening.
- Low calcium/phosphorus = weak bones.

Quick Checkpoints

- What minerals are deficient?
- How does deficiency affect bone strength?

Arthritis

Key Points

- Inflammation of joints.
- Types: rheumatoid arthritis, osteoarthritis, infectious arthritis.

Memory Aids

- Arthritis = joint inflammation.
- Remember types by cause: autoimmune, wear & tear, infection.

Quick Checkpoints

- What causes joint inflammation?
- How do types differ?

Gout

Key Points

- Defect in purine metabolism.
- Excess uric acid and salts accumulate in joints.

Memory Aids

- Gout = uric acid buildup.
- Think purine metabolism defect → joint pain.

Quick Checkpoints

- What metabolic defect causes gout?
- Where does uric acid accumulate?

Tetany

Key Points

- Rapid muscle spasms due to low calcium (Ca^{++}) in body fluids.

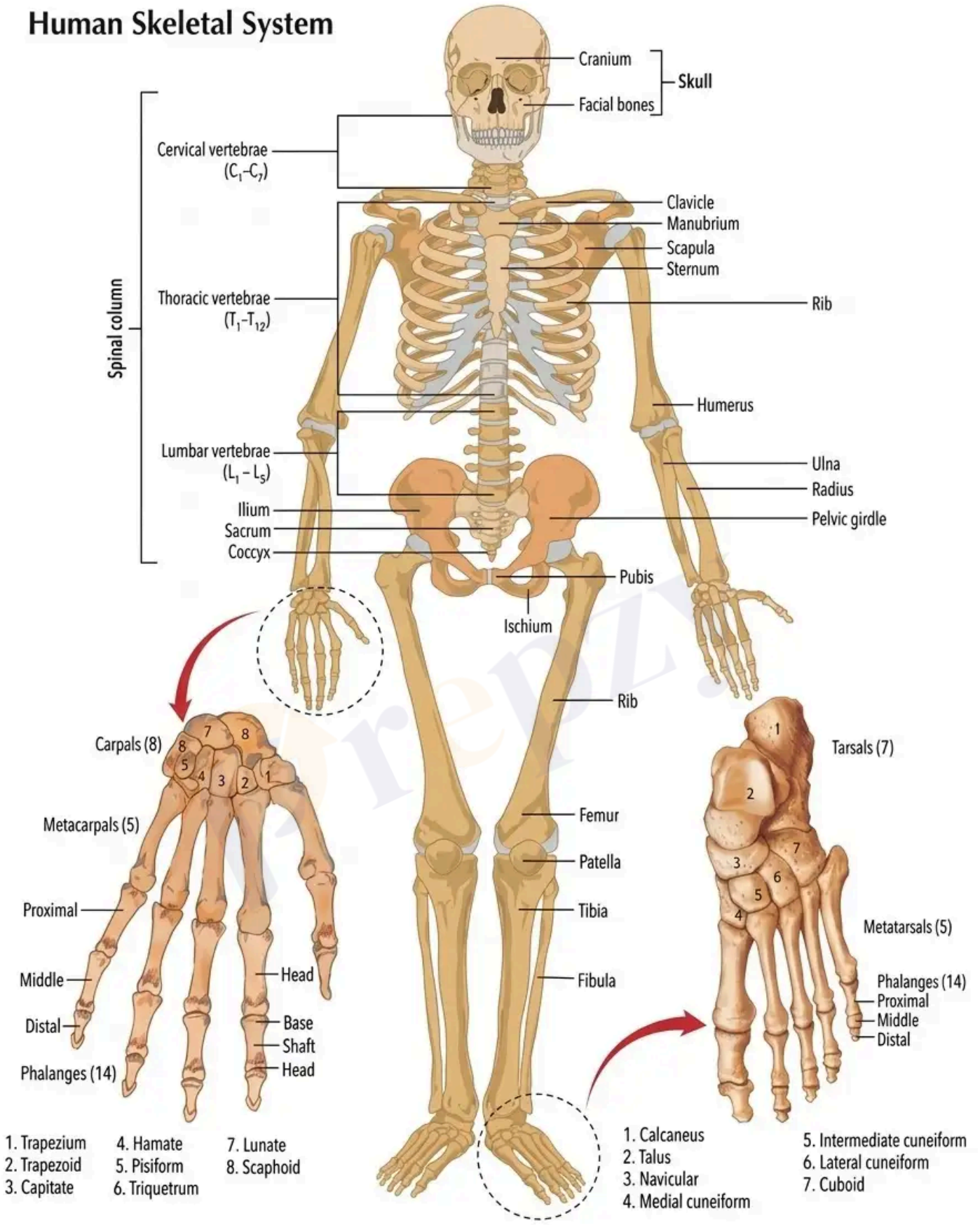
Memory Aids

- Tetany = muscle spasms from low Ca^{++}.

Quick Checkpoints

- What ion deficiency causes tetany?
- How does low calcium affect muscles?

Human Skeletal System



Human Skeletal System

Key Points

- Divided into skull, spinal column, rib cage, arms, pelvis, and legs.
- Skull: cranium and facial bones protect brain and shape face.
- Spinal column: cervical, thoracic, lumbar vertebrae support body and protect spinal cord.
- Rib cage: ribs, sternum, clavicle, scapula protect chest organs.
- Arms: humerus, radius, ulna bones.
- Pelvic girdle: ilium, pubis, ischium connect spine to legs.
- Legs: femur, patella, tibia, fibula bones.
- Hand bones: carpals, metacarpals, phalanges.
- Foot bones: tarsals, metatarsals, phalanges.

Memory Aids

- Skeleton parts: Head, Spine, Chest, Limbs, Pelvis.
- Hand and foot bones have carpals/tarsals, metacarpals/metatarsals, phalanges.

Quick Checkpoints

- What are the main parts of the skeleton?
- Which bones protect the brain?
- How are hand and foot bones classified?