KSQUARE CAREER INSTITUTE

LOCOMOTION AND MOVEMENT

Class 11 Biology • Muscles, Muscle Contraction, Skeleton & Joints • NEET Notes

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Topics Covered

1. Types of movement — amoeboid, ciliary, muscular
2. Muscle — properties, types (skeletal, visceral, cardiac)
3. Structure of skeletal muscle & the sarcomere; contractile proteins (actin, myosin)
4. Mechanism of muscle contraction — sliding filament theory; red & white fibres
5. Skeletal system — axial & appendicular skeleton (206 bones)
6. Joints — fibrous, cartilaginous, synovial (5 types)
7. Disorders of muscular & skeletal system • 15 NEET MCQs • Quick revision

NEET Point / PYQ Alert

NEET asks **2–3 questions** — favourites: **bands of sarcomere during contraction**, **role of Ca^{2+} & troponin**, **bone counts (ribs, vertebrae, skull)**, **types of synovial joints with examples**, **disorders**.

MOVEMENT & LOCOMOTION

- **Movement** is a significant feature of living beings — e.g. streaming of protoplasm (Amoeba), movement of cilia/flagella, tentacles, limbs, jaws, eyelids, tongue.
- **Locomotion** = voluntary movements that result in a **change of place or location** (walking, running, climbing, flying, swimming).
- **All locomotions are movements, but all movements are not locomotions.**
- In **Paramoecium**, cilia help in movement of food through the cytopharynx **and** in locomotion. **Hydra** uses tentacles for capturing prey and for locomotion.

TYPES OF MOVEMENT

Type	Mechanism	Examples in humans
Amoeboid	Streaming of protoplasm forms **pseudopodia**; cytoskeletal elements like **microfilaments** are involved	**Macrophages, leucocytes** (WBCs) in blood
Ciliary	Coordinated beating of **cilia** on internal tubular organs lined by ciliated epithelium	Trachea (removes dust particles & foreign substances); passage of **ova through the female reproductive tract** (fallopian tube)

Type	Mechanism	Examples in humans
Muscular	Contractile property of **muscles**	Movement of limbs, jaws, tongue; locomotion

Locomotion requires a perfect **coordinated activity of muscular, skeletal and neural systems**.

MUSCLE

- Specialised tissue of **mesodermal origin**; about **40–50% of the body weight** of an adult human.
- Special properties: **excitability, contractility, extensibility and elasticity**.

Feature	Skeletal	Visceral (smooth)	Cardiac
Location	Attached to **bones** (biceps)	Inner walls of **hollow visceral organs** — alimentary canal, reproductive tract, blood vessels	**Heart**
Appearance	**Striated**	**Non-striated (smooth)**	**Striated**, branched
Control	**Voluntary**	**Involuntary**	**Involuntary**
Cells	Long, cylindrical, multinucleate (syncytium)	Spindle-shaped, uninucleate	Branched, uninucleate, joined by **intercalated discs**
Function	Locomotion, change of body posture	Transport of food (peristalsis), gametes	Pumping blood; does not fatigue

STRUCTURE OF SKELETAL MUSCLE

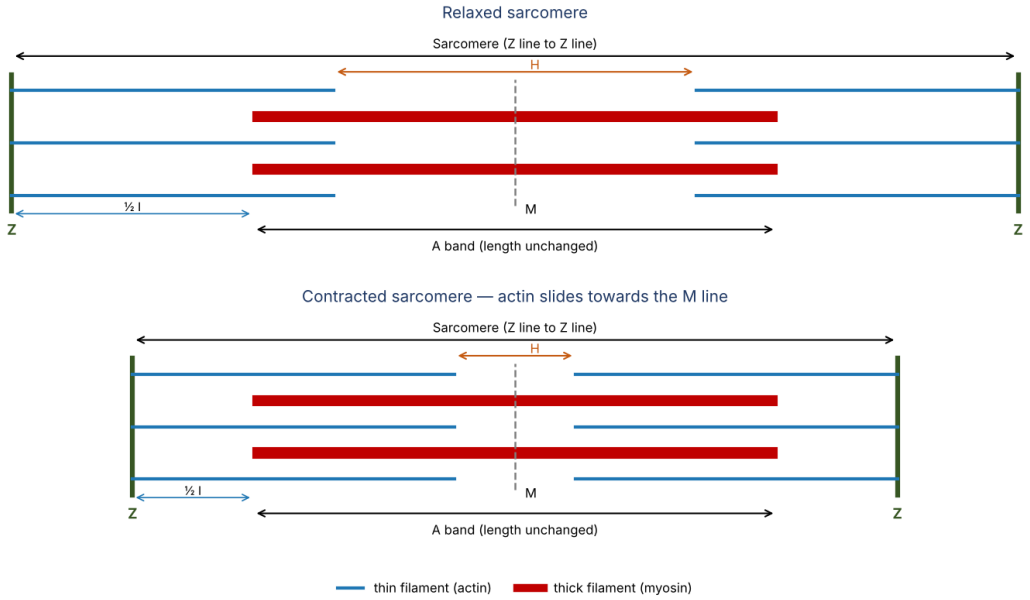
- Each skeletal muscle is made of many **muscle bundles (fascicles)** held together by a collagenous connective tissue layer called **fascia**.
- Each bundle contains many **muscle fibres**. Each fibre is lined by the plasma membrane — **sarcolemma** — enclosing the **sarcoplasm**.
- A muscle fibre is a **syncytium** (sarcoplasm contains many nuclei).
- The endoplasmic reticulum — **sarcoplasmic reticulum** — is the **store house of calcium ions**.
- Sarcoplasm contains a large number of parallel filaments — **myofilaments or myofibrils**.

▸ Light & Dark Bands

- Striated appearance is due to the distribution of two proteins — **actin** and **myosin**.
- **Light band (I band — isotropic):** contains **actin** (thin filaments).
- **Dark band (A band — anisotropic):** contains **myosin** (thick filaments).
- In the centre of each I band is an elastic fibre — the **Z line** — to which thin filaments are attached. Thick filaments in the A band are held together by a thin fibrous membrane — the **M line**.
- The central part of the thick filament **not overlapped by thin filaments** is the **H zone**.

Sarcomere

Portion of the myofibril **between two successive Z lines** — the **functional (contractile) unit of contraction**.



CONTRACTILE PROTEINS

Actin (thin filament)

- Each actin filament is made of **two 'F' (filamentous) actins** helically wound to each other.
- Each F-actin is a **polymer of monomeric 'G' (globular) actins**.
- Two filaments of **tropomyosin** run close to the F-actins throughout the length.
- **Troponin** (a complex protein) is distributed at regular intervals on tropomyosin; in the resting state a subunit of troponin **masks the active binding sites for myosin** on the actin filaments.

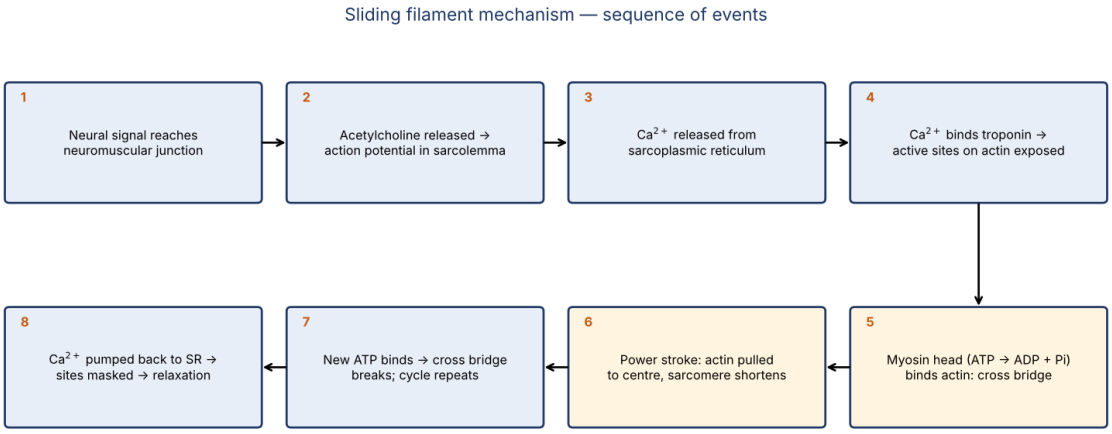
Myosin (thick filament)

- Also a **polymerised protein**; many monomeric proteins called **meromyosins** constitute one thick filament.
- Each meromyosin has two parts: a **globular head with a short arm** (**heavy meromyosin, HMM**) and a **tail** (**light meromyosin, LMM**).
- The HMM component (head + short arm) projects outwards at regular distance and angle — the **cross arm**.
- The globular head is an **active ATPase enzyme** and has **binding sites for ATP and active sites for actin**.

MECHANISM OF MUSCLE CONTRACTION

Sliding filament theory

Contraction of a muscle fibre takes place by the **sliding of thin filaments over thick filaments** — the filaments themselves do **not** shorten.



1. Contraction is initiated by a **signal from the CNS via a motor neuron**. A **motor neuron + the muscle fibres connected to it = motor unit**.
2. The junction between a motor neuron and the sarcolemma is the **neuromuscular junction (motor-end plate)**.
3. A neural signal releases the neurotransmitter **acetylcholine**, which generates an **action potential in the sarcolemma**.
4. This spreads through the fibre and causes release of **Ca^{2+} into the sarcoplasm** (from the sarcoplasmic reticulum).
5. Increased Ca^{2+} leads to binding of calcium with a subunit of **troponin**, removing the masking of **active sites for myosin**.
6. Using energy from **ATP hydrolysis**, the myosin head binds to the exposed active sites on actin, forming a **cross bridge**.
7. The cross bridge pulls the attached actin filaments towards the **centre of the A band**; the Z lines are also pulled inwards → **sarcomere shortens (contraction)**.
8. The myosin releases **ADP and Pi** and goes back to its relaxed state; a **new ATP binds** and the **cross bridge is broken**.
9. ATP is again hydrolysed by the myosin head and the cycle of cross-bridge formation and breakage repeats, causing further sliding.
10. The process continues until **Ca^{2+} is pumped back** to the sarcoplasmic cisternae → actin filaments are masked again → Z lines return to their original position → **relaxation**.

Band / zone	During contraction
I band	**Shortens**
A band	**Retains its length (no change)**
H zone	**Shortens / disappears**

Band / zone	During contraction
Sarcomere	**Shortens**
Actin & myosin filaments	Do **not** change in length

NEET Point / PYQ Alert

Contraction needs **Ca^{2+} + ATP**. Ca^{2+} binds **troponin** (not tropomyosin); ATP is hydrolysed by the **myosin head**.

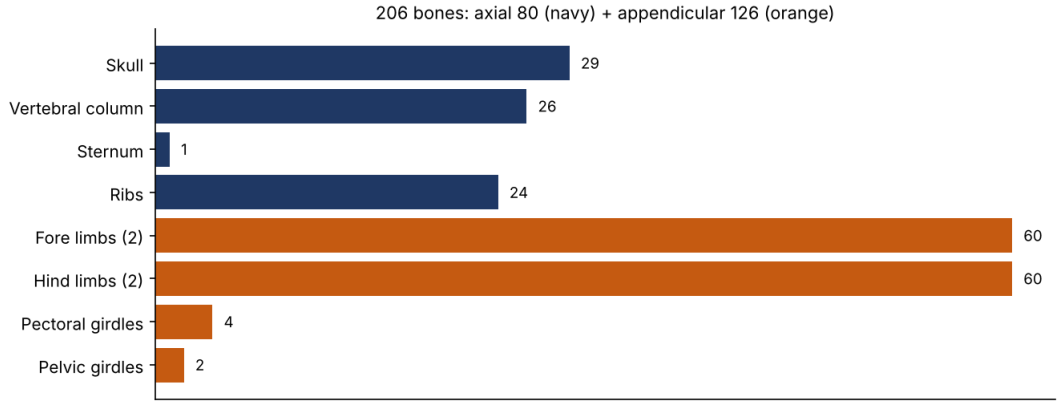
Repeated activation → **anaerobic breakdown of glycogen → accumulation of lactic acid → fatigue**.

Red & White Muscle Fibres

Feature	Red fibres	White fibres
Myoglobin (red O_2-storing pigment)	**High**	**Low** (pale/whitish)
Mitochondria	**Plenty**	**Few**
Sarcoplasmic reticulum	Less	**High**
Energy	**Aerobic** (use stored O_2)	**Anaerobic**

SKELETAL SYSTEM

- Consists of a framework of **bones and a few cartilages**; plays a significant role in movement.
- **Bone** has a very hard matrix due to **calcium salts**; **cartilage** has a slightly pliable matrix due to **chondroitin salts**.
- Human skeleton = **206 bones** + a few cartilages, grouped into the **axial skeleton (80)** and **appendicular skeleton (126)**.



Axial Skeleton (80 bones)

Skull (29 bones)

Part	Number
Cranial bones (hard protective outer covering — cranium for the brain)	**8**

Part	Number
Facial bones (front part of skull)	**14**
Hyoid (U-shaped, at the base of the buccal cavity)	**1**
Ear ossicles — malleus, incus, stapes (3 in each middle ear)	**6**

- The skull joins the vertebral column with the help of **two occipital condyles** → **dicondylic skull**.

Vertebral Column (26 vertebrae)

- Formed by **26 serially arranged units — vertebrae**; **dorsally** placed, extends from the base of the skull and forms the main framework of the trunk.
- Each vertebra has a central hollow portion — **neural canal** — through which the **spinal cord** passes.
- **First vertebra = atlas**; it articulates with the occipital condyles.

Region	Number
Cervical (neck)	**7** (same in almost all mammals, including humans)
Thoracic	**12**
Lumbar	**5**
Sacral	**1** (fused)
Coccygeal	**1** (fused)

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Vertebral formula: **C_7 T_{12} L_5 S_1 Co_1**. The vertebral column protects the spinal cord, supports the head and serves as the point of attachment for ribs and musculature of the back.

Sternum & Ribs

- **Sternum:** flat bone on the **ventral midline** of the thorax.
- **Ribs: 12 pairs.** Each rib is a thin flat bone connected **dorsally to the vertebral column** and **ventrally to the sternum**; it has **two articulation surfaces** on its dorsal end → **bicephalic**.

Ribs	Pairs	Attachment
True ribs	**1st–7th** (7 pairs)	Directly to the **sternum** with the help of hyaline cartilage
False ribs (vertebrochondral)	**8th, 9th, 10th** (3 pairs)	Do not articulate directly with sternum; join the **7th rib** with hyaline cartilage
Floating ribs	**11th, 12th** (2 pairs)	Not connected ventrally

- **Thoracic vertebrae + ribs + sternum = rib cage**.

▸ Appendicular Skeleton (126 bones)

Bones of the **limbs** along with their **girdles**.

Fore limb (each — 30)	Hind limb (each — 30)
Humerus (1)	**Femur** (1) — thigh bone, **longest bone** of the body
Radius & ulna (2)	**Tibia & fibula** (2)
Carpals — wrist bones (8)	**Tarsals** — ankle bones (7)
Metacarpals — palm bones (5)	**Metatarsals** (5)
Phalanges — digits (14)	**Phalanges** (14)
—	**Patella** — cup-shaped bone covering the knee ventrally (knee cap) (1)

Pectoral Girdle (each half: clavicle + scapula)

- **Scapula:** large triangular flat bone in the dorsal part of the thorax between the **2nd and 7th ribs**. Its dorsal flat triangular body has a slightly elevated ridge — the **spine** — which projects as a flat, expanded process, the **acromion**; the **clavicle articulates with the acromion**.
- Below the acromion is a depression — the **glenoid cavity** — which articulates with the **head of the humerus** to form the **shoulder joint**.
- **Clavicle (collar bone):** long slender bone with **two curvatures**.

Pelvic Girdle (two coxal bones)

- Each **coxal bone** is formed by fusion of **three bones — ilium, ischium and pubis**.
- At their point of fusion is a cavity — **acetabulum** — to which the **thigh bone (femur)** articulates.
- The two halves meet ventrally to form the **pubic symphysis** containing fibrous cartilage.

JOINTS

- Joints are **points of contact between bones, or between bones and cartilages**. Force generated by muscles is used to carry out movement through joints, where the joint acts as a **fulcrum**.
- Classified on the basis of structure/movability into three types:

Type	Features	Examples
Fibrous	**No movement**; bones fused end-to-end by dense fibrous connective tissue (sutures)	Flat skull bones (sutures) forming the cranium
Cartilaginous	Bones joined by **cartilage**; **limited movement**	Between adjacent **vertebrae**
Synovial	Fluid-filled **synovial cavity** between articulating surfaces; **considerable movement** — locomotion	See below

▸ Types of Synovial Joints

Joint	Example
Ball and socket	Between **humerus and pectoral girdle** (shoulder); femur and pelvic girdle (hip)
Hinge	**Knee** joint, elbow
Pivot	Between **atlas and axis**

Joint	Example
Gliding	Between the **carpals**
Saddle	Between **carpal and metacarpal of thumb**

DISORDERS OF MUSCULAR & SKELETAL SYSTEM

Disorder	Cause / feature
Myasthenia gravis	**Auto-immune** disorder affecting the **neuromuscular junction** → fatigue, weakening and paralysis of skeletal muscle
Muscular dystrophy	Progressive **degeneration of skeletal muscle**, mostly due to a **genetic disorder**
Tetany	Rapid **spasms (wild contractions)** in muscle due to **low Ca^{2+}** in body fluid
Arthritis	**Inflammation of joints**
Osteoporosis	**Age-related**; decreased bone mass and increased chances of fractures; **decreased levels of oestrogen** is a common cause
Gout	Inflammation of joints due to **accumulation of uric acid crystals**

BEYOND THE LECTURE (ADDITIONAL TOPIC)

Topic	Key point
Muscle twitch / tetanus	Single stimulus → single twitch (latent, contraction, relaxation). Rapid repeated stimuli → sustained contraction = **tetanus** (physiological, different from the disease tetany)
All-or-none law	A single muscle fibre contracts fully or not at all above the threshold stimulus
Rigor mortis	Stiffening after death — no ATP, so cross bridges cannot detach
Oxygen debt	Extra O_2 needed after exercise to oxidise lactic acid (in liver → glucose by Cori cycle)
Smallest / largest bones	Smallest: **stapes** (middle ear); largest/longest: **femur**
Cartilage types	Hyaline (rib ends, trachea), elastic (pinna, epiglottis), fibrous (pubic symphysis, intervertebral discs)
Tendon vs ligament	Tendon: muscle → bone; ligament: bone → bone
Sliding filament theory	Proposed by **A. F. Huxley & H. E. Huxley** (1954)

PRACTICE MCQS (NEET PATTERN)

Q1. During muscle contraction, which band does NOT change in length?

(a) I band
(b) A band
(c) H zone

(d) Sarcomere

Answer: (b) — A band = length of myosin, which does not shorten.

Q2. Calcium ions released during muscle contraction bind to

(a) Actin
(b) Myosin
(c) Troponin
(d) Tropomyosin

Answer: (c)

Q3. The functional unit of contraction in a skeletal muscle is

(a) Myofibril
(b) Sarcomere
(c) Fascicle
(d) Sarcolemma

Answer: (b)

Q4. The store house of Ca^{2+} in a muscle fibre is

(a) Sarcolemma
(b) Sarcoplasm
(c) Sarcoplasmic reticulum
(d) Mitochondria

Answer: (c)

Q5. The globular head of myosin has activity of

(a) Kinase
(b) ATPase
(c) Phosphatase
(d) Hydrolase only for GTP

Answer: (b)

Q6. Number of true ribs in humans (pairs)

(a) 5
(b) 7
(c) 3
(d) 2

Answer: (b)

Q7. The joint between atlas and axis is

(a) Hinge joint
(b) Saddle joint
(c) Pivot joint
(d) Gliding joint

Answer: (c)

Q8. Which of the following is a ball and socket joint?

(a) Knee
(b) Shoulder
(c) Elbow
(d) Between carpals

Answer: (b) — Humerus with glenoid cavity of pectoral girdle.

Q9. Total number of bones in the human skull is

(a) 22
(b) 29
(c) 8
(d) 14

Answer: (b) — 8 cranial + 14 facial + 1 hyoid + 6 ear ossicles.

Q10. An auto-immune disorder affecting the neuromuscular junction is

(a) Muscular dystrophy
(b) Tetany
(c) Myasthenia gravis
(d) Gout

Answer: (c)

Q11. Tetany is caused by

(a) Low Ca^{2+} in body fluid
(b) High uric acid
(c) Low oestrogen
(d) Lactic acid accumulation

Answer: (a)

Q12. Which statement about red muscle fibres is correct?

(a) Low myoglobin, few mitochondria
(b) High myoglobin, many mitochondria
(c) Anaerobic
(d) High sarcoplasmic reticulum

Answer: (b)

Q13. Acetabulum is formed by the fusion of

(a) Ilium, ischium, pubis
(b) Scapula, clavicle
(c) Tibia, fibula
(d) Femur, patella

Answer: (a)

Q14. Which of the following is NOT a property of muscle?

(a) Excitability
(b) Contractility
(c) Rigidity
(d) Elasticity

Answer: (c) — Properties: excitability, contractility, extensibility, elasticity.

Q15. Movement of ova through the female reproductive tract is an example of

(a) Amoeboid movement
(b) Ciliary movement
(c) Muscular movement only
(d) Flagellar movement

Answer: (b)

QUICK REVISION

1. Muscle: mesodermal, 40–50% body weight; skeletal (striated, voluntary), visceral (smooth, involuntary), cardiac (striated, involuntary).
2. I band = actin; A band = myosin; Z line in I band; M line in A band; sarcomere = Z to Z.
3. Contraction: ACh → action potential → Ca^{2+} from SR → binds troponin → cross bridge (ATP) → sliding.
4. Contraction: I band & H zone shorten, A band constant.
5. 206 bones = axial 80 (skull 29, vertebrae 26, sternum 1, ribs 24) + appendicular 126.
6. Ribs: true 1–7, false 8–10, floating 11–12; vertebrae $C_7T_{12}L_5S_1Co_1$.
7. Synovial: ball & socket (shoulder), hinge (knee), pivot (atlas–axis), gliding (carpals), saddle (thumb).

Bones give the frame, muscles give the motion — and practice gives the marks!

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