

Chapter 17: Locomotion and Movement

Comprehensive Study Notes

Class 11 Biology - NCERT Based

EXAM SPRINT - Complete Coverage for NEET and Board Examinations

Introduction

Movement is a fundamental characteristic of living organisms, ranging from simple to complex forms:

Simple Forms:

- Protoplasmic streaming in Amoeba
- Ciliary and flagellar movements
- Tentacle movements in Hydra

Complex Forms:

- Limb movements in humans
- Locomotory movements (walking, running, swimming, flying)

Key Distinction:

- **Movement:** Any change in position of body parts
- **Locomotion:** Voluntary movement resulting in change of place/location
- **Relationship:** All locomotions are movements, but all movements are not locomotions

Purpose of Locomotion: Search for food, shelter, mates, breeding grounds, favorable climate, escape from predators

17.1 TYPES OF MOVEMENT

Human body cells exhibit three main types of movement:

1. Amoeboid Movement

Cells involved: Macrophages, leucocytes in blood **Mechanism:**

- Formation of pseudopodia
- Streaming of protoplasm (similar to Amoeba)
- Involvement of cytoskeletal elements (microfilaments) **Function:** Cellular locomotion and phagocytosis

2. Ciliary Movement

Location: Internal tubular organs lined by ciliated epithelium **Examples:**

- Trachea: Coordinated cilia remove dust and foreign particles
- Female reproductive tract: Facilitate passage of ova
- Spermatozoa: Flagellar movement for swimming **Mechanism:** Coordinated beating of cilia/flagella

3. Muscular Movement

Examples: Limb movements, jaw movements, tongue movements **Requirement:** Perfect coordination of muscular, skeletal, and neural systems **Importance:** Primary mechanism for locomotion in multicellular organisms

17.2 MUSCLE

General Characteristics

Origin: Specialized tissue of mesodermal origin **Proportion:** 40-50% of adult human body weight

Properties:

1. **Excitability:** Ability to respond to stimuli
2. **Contractility:** Ability to shorten and generate force
3. **Extensibility:** Ability to be stretched
4. **Elasticity:** Ability to return to original shape

Classification of Muscles

Based on Location and Structure:

1. Skeletal Muscles

Location: Closely associated with skeletal components **Appearance:** Striped/striated under microscope **Control:** Voluntary (controlled by nervous system) **Function:** Locomotion and body posture changes **Also called:** Striated muscles, voluntary muscles

2. Visceral Muscles

Location: Inner walls of hollow visceral organs (alimentary canal, reproductive tract) **Appearance:** Smooth, non-striated **Control:** Involuntary (not under voluntary nervous control) **Function:** Transportation of food, gametes **Also called:** Smooth muscles, involuntary muscles

3. Cardiac Muscles

Location: Heart **Appearance:** Striated, branched **Control:** Involuntary (not directly controlled by nervous system) **Function:** Pumping blood **Structure:** Many cardiac muscle cells in branching pattern

Structure of Skeletal Muscle

Organizational Hierarchy

1. Muscle Organization

Muscle → **Fascicles** → **Muscle Fibers** → **Myofibrils** → **Myofilaments**

Fascia: Common collagenous connective tissue layer holding muscle bundles **Fascicles:** Muscle bundles containing multiple muscle fibers

2. Muscle Fiber Structure

Sarcolemma: Plasma membrane lining the muscle fiber **Sarcoplasm:** Cytoplasm containing many nuclei (syncytium) **Sarcoplasmic Reticulum:** ER storing calcium ions **Myofibrils:** Parallely arranged filaments in sarcoplasm

Myofibril Structure

Band Pattern

I-band (Isotropic): Light band containing actin (thin filaments) **A-band (Anisotropic):** Dark band containing myosin (thick filaments) **Z-line:** Elastic fiber bisecting I-band, attachment point for thin filaments **M-line:** Thin fibrous membrane holding thick filaments in A-band center **H-zone:** Central part of A-band not overlapped by thin filaments

Sarcomere: Functional unit of contraction between two successive Z-lines

17.2.1 Structure of Contractile Proteins

Actin (Thin Filament)

Structure:

- Two F-actin (filamentous) helically wound
- Each F-actin: polymer of G-actin (globular) monomers
- **Tropomyosin:** Two filaments running along F-actin
- **Troponin:** Complex protein at regular intervals on tropomyosin

Resting State: Troponin subunit masks myosin binding sites on actin

Myosin (Thick Filament)

Structure:

- Polymerized protein of meromyosin monomers
- Each meromyosin has two parts:
 - **Heavy Meromyosin (HMM):** Globular head with short arm
 - **Light Meromyosin (LMM):** Tail portion

Cross Arms: HMM components projecting outward at regular intervals **Globular Head Functions:**

- Active ATPase enzyme
- ATP binding sites
- Actin binding sites

17.2.2 Mechanism of Muscle Contraction

Sliding Filament Theory

Principle: Muscle contraction occurs by sliding of thin filaments over thick filaments

Step-by-Step Process:

1. Neural Stimulation:

- Signal from CNS via motor neuron
- **Motor Unit:** Motor neuron + connected muscle fibers
- **Neuromuscular Junction/Motor End Plate:** Junction between neuron and sarcolemma

2. Action Potential Generation:

- Neurotransmitter (Acetylcholine) released
- Action potential generated in sarcolemma
- Spreads through muscle fiber

3. Calcium Release:

- Ca^{2+} ions released from sarcoplasmic reticulum into sarcoplasm
- Increased Ca^{2+} levels activate the contraction mechanism

4. Cross Bridge Formation:

- Ca^{2+} binds to troponin subunit on actin
- Removes masking of myosin binding sites on actin
- ATP hydrolysis provides energy
- Myosin head binds to exposed active sites on actin
- Forms cross bridge

5. Power Stroke:

- Cross bridge pulls actin filaments toward center of A-band
- Z-lines pulled inward
- Sarcomere shortens (contraction)
- I-bands reduce, A-bands retain length

6. Cross Bridge Breaking:

- Myosin releases ADP and P_i , returns to relaxed state
- New ATP binds, cross bridge breaks
- Cycle repeats for continued contraction

7. Relaxation:

- Ca^{2+} ions pumped back to sarcoplasmic cisternae
- Actin filaments masked again
- Z-lines return to original position
- Muscle relaxes

Energy and Fatigue

Energy Source: ATP hydrolysis **Fatigue Cause:** Lactic acid accumulation from anaerobic glycogen breakdown **Oxygen Storage:** Myoglobin (red pigment in muscles)

Muscle Fiber Types

Red Fibers (Slow-twitch)

Characteristics:

- High myoglobin content (reddish appearance)
- Plenty of mitochondria
- High oxygen storage capacity
- Aerobic ATP production
- Fatigue-resistant **Also called:** Aerobic muscles

White Fibers (Fast-twitch)

Characteristics:

- Low myoglobin content (pale/whitish appearance)
 - Few mitochondria
 - High sarcoplasmic reticulum
 - Anaerobic energy production
 - Fast contraction, quick fatigue
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17.3 SKELETAL SYSTEM

Overview

Components: Framework of bones and cartilages **Total bones:** 206 bones in adult humans

Functions: Support, protection, movement facilitation **Tissue types:**

- **Bone:** Hard matrix due to calcium salts
- **Cartilage:** Slightly pliable matrix due to chondroitin salts

Divisions of Skeletal System

1. Axial Skeleton (80 bones)

Definition: Bones distributed along main body axis **Components:** Skull, vertebral column, sternum, ribs

Skull (22 bones total)

Cranial bones: 8 bones forming cranium (brain protection) **Facial bones:** 14 bones forming front part of skull **Additional:**

- **Hyoid bone:** U-shaped bone at base of buccal cavity

- **Ear ossicles:** 3 tiny bones per middle ear (Malleus, Incus, Stapes)
- **Occipital condyles:** 2 condyles for skull-vertebral column articulation (dicondylic skull)

Vertebral Column (26 vertebrae)

Structure: Serially arranged vertebrae with central neural canal **Regions and counts:**

- **Cervical:** 7 vertebrae (consistent across most mammals)
- **Thoracic:** 12 vertebrae
- **Lumbar:** 5 vertebrae
- **Sacral:** 1 (fused) vertebrae
- **Coccygeal:** 1 (fused) vertebrae

First vertebra: Atlas (articulates with occipital condyles) **Functions:** Spinal cord protection, head support, attachment point for ribs and back muscles

Ribs and Sternum

Sternum: Flat bone on ventral midline of thorax **Ribs:** 12 pairs of thin flat bones **Rib characteristics:**

- **Bicephalic:** Two articulation surfaces on dorsal end
- Dorsal attachment: Thoracic vertebrae
- Ventral attachment: Sternum (via hyaline cartilage)

Rib Classifications:

- **True ribs:** First 7 pairs (directly attached to sternum)
- **Vertebrochondral (False) ribs:** 8th, 9th, 10th pairs (indirectly attached via 7th rib)
- **Floating ribs:** 11th and 12th pairs (no ventral attachment)

Rib cage: Thoracic vertebrae + ribs + sternum

2. Appendicular Skeleton

Definition: Bones of limbs and their girdles **Limb bones:** 30 bones per limb

Upper Limb (Forelimb) Bones

Arm bones:

- **Humerus:** Upper arm bone
- **Radius and Ulna:** Forearm bones

Hand bones:

- **Carpals:** 8 wrist bones
- **Metacarpals:** 5 palm bones
- **Phalanges:** 14 digit bones

Lower Limb (Hindlimb) Bones

Leg bones:

- **Femur:** Thigh bone (longest bone in body)
- **Tibia and Fibula:** Lower leg bones
- **Patella:** Cup-shaped knee cap bone

Foot bones:

- **Tarsals:** 7 ankle bones
- **Metatarsals:** 5 foot bones
- **Phalanges:** 14 digit bones

Girdles

Pectoral Girdle

Function: Articulates upper limbs with axial skeleton **Structure:** Two halves, each containing:

- **Clavicle:** Long slender bone with two curvatures (collar bone)
- **Scapula:** Large triangular flat bone (shoulder blade)

Scapula features:

- **Spine:** Slightly elevated ridge on dorsal surface
- **Acromion:** Flat expanded process projecting from spine
- **Glenoid cavity:** Depression below acromion (shoulder joint formation)

Pelvic Girdle

Function: Articulates lower limbs with axial skeleton **Structure:** Two coxal bones **Each coxal bone:**
Fusion of three bones:

- **Ilium:** Upper portion
- **Ischium:** Lower posterior portion
- **Pubis:** Lower anterior portion

Key features:

- **Acetabulum:** Cavity at fusion point (hip joint formation)
 - **Pubic symphysis:** Ventral meeting point of two halves (contains fibrous cartilage)
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17.4 JOINTS

Definition and Function

Joints: Points of contact between bones or between bones and cartilages **Function:** Enable movement with joint acting as fulcrum **Movement mechanism:** Muscle force applied through joints

Classification of Joints

1. Fibrous Joints

Mobility: No movement allowed **Structure:** Dense fibrous connective tissue **Example:** Skull bone sutures forming cranium **Also called:** Immovable joints

2. Cartilaginous Joints

Mobility: Limited movement **Structure:** Bones joined by cartilages **Example:** Adjacent vertebrae in vertebral column **Also called:** Slightly movable joints

3. Synovial Joints

Mobility: Considerable movement **Structure:** Fluid-filled synovial cavity between articulating surfaces **Function:** Locomotion and complex movements **Also called:** Freely movable joints

Types of Synovial Joints

Joint Type	Example	Movement Type
Ball and Socket	Humerus-Pectoral girdle	Multi-directional
Hinge	Knee joint	Uni-directional
Pivot	Atlas-Axis vertebrae	Rotational
Gliding	Between carpals	Sliding

Joint Type	Example	Movement Type
Saddle	Carpal-Metacarpal of thumb	Bi-directional

17.5 DISORDERS OF MUSCULAR AND SKELETAL SYSTEM

Muscular Disorders

Myasthenia Gravis

Type: Autoimmune disorder **Affected area:** Neuromuscular junction **Symptoms:** Fatigue, muscle weakening, paralysis of skeletal muscles **Cause:** Immune system attacks acetylcholine receptors

Muscular Dystrophy

Type: Genetic disorder (mostly) **Process:** Progressive degeneration of skeletal muscles

Characteristics: Muscle weakness, loss of muscle mass **Inheritance:** Often X-linked recessive

Tetany

Cause: Low Ca^{2+} levels in body fluid **Symptoms:** Rapid spasms (wild contractions) in muscles

Mechanism: Insufficient calcium for proper muscle relaxation

Skeletal Disorders

Arthritis

Definition: Inflammation of joints **Types:** Rheumatoid arthritis, osteoarthritis **Symptoms:** Joint pain, stiffness, reduced mobility **Causes:** Autoimmune, wear and tear, infection

Osteoporosis

Definition: Decreased bone mass and density **Characteristics:** Increased fracture risk **Common cause:** Decreased estrogen levels (especially post-menopause) **Demographics:** Age-related disorder, more common in women

Gout

Cause: Accumulation of uric acid crystals in joints **Process:** Inflammation of joints due to crystal deposits **Commonly affected:** Big toe joint, knee, ankle **Risk factors:** High purine diet, genetics, kidney dysfunction

NEET-Specific Important Points

High-Yield Topics for NEET:

1. Muscle Structure and Function:

- Types of muscles and their characteristics
- Sarcomere structure (A-band, I-band, Z-line, H-zone)
- Contractile proteins (actin, myosin, troponin, tropomyosin)
- Sliding filament theory mechanism

2. Muscle Contraction Process:

- Role of calcium ions
- Cross-bridge formation and breaking
- ATP involvement in muscle contraction
- Neuromuscular junction function

3. Skeletal System:

- Bone count (206 total, 80 axial, 126 appendicular)
- Vertebral column regions and counts
- Rib classifications
- Girdle structures and functions

4. Joint Classifications:

- Types and examples of joints
- Synovial joint varieties
- Movement patterns

5. Disorders:

- Muscle and bone disorders
- Causes and symptoms

Common NEET Question Patterns:

1. Structure-Function Questions:

- Identify muscle types from characteristics
- Sarcomere band identification
- Bone and joint classifications

2. Process Questions:

- Muscle contraction mechanism steps
- Calcium role in contraction
- Cross-bridge cycle

3. Numerical Questions:

- Bone counts in different regions
- Vertebrae numbers in each region
- Rib pair classifications

4. Disorder-Based Questions:

- Symptoms and causes matching
 - Disease identification from characteristics
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Memory Aids and Mnemonics

Muscle Types:

"Skeletal Soldiers Voluntarily Strike, Visceral Villains Involuntarily Invade, Cardiac Commandos Involuntarily Inspire"

- **Skeletal:** Striated, Voluntary
- **Visceral:** Smooth, Involuntary
- **Cardiac:** Striated, Involuntary

Sarcomere Bands:

"A Dark Band Always Includes Myosin, I Light Band Is Actin"

- **A-band:** Dark, contains myosin (thick filaments)
- **I-band:** Light, contains actin (thin filaments)

Vertebral Column:

"Cervical Children Thoroughly Love Soft Candies"

- **Cervical:** 7
- **Thoracic:** 12
- **Lumbar:** 5
- **Sacral:** 1 (fused)
- **Coccygeal:** 1 (fused)

Rib Classifications:

"True ribs Touch The Sternum (1-7), False ribs Fake The Connection (8-10), Floating ribs Find Freedom (11-12)"

Joint Types Movement:

"Fibrous = Fixed, Cartilaginous = Cautious, Synovial = Super mobile"

Contractile Proteins:

"Actin Acts Thin, Myosin Makes Thick"

- **Actin:** Thin filaments
- **Myosin:** Thick filaments

Practice Questions for NEET

Multiple Choice Questions:

1. The functional unit of muscle contraction is: a) Myofibril b) Sarcomere c) Myofilament d) Muscle fiber
2. Which of the following is NOT a property of muscles? a) Excitability b) Contractility c) Conductivity d) Extensibility

3. The total number of bones in axial skeleton is: a) 206 b) 126 c) 80 d) 64
4. Ca^{2+} ions in muscle contraction are stored in: a) Sarcolemma b) Sarcoplasm c) Sarcoplasmic reticulum d) Myofibrils

Short Answer Questions:

1. Define sliding filament theory.
2. Distinguish between red and white muscle fibers.
3. What is the role of calcium in muscle contraction?
4. Name the three types of joints with examples.

Long Answer Questions:

1. Describe the mechanism of muscle contraction with the role of various proteins involved.
2. Explain the organization of skeletal system in humans.
3. Describe the structure of sarcomere with a neat diagram.

Summary Table: Key Comparisons

Muscle Types Comparison:

Feature	Skeletal	Visceral	Cardiac
Appearance	Striated	Smooth	Striated, Branched
Control	Voluntary	Involuntary	Involuntary
Location	Attached to bones	Visceral organs	Heart
Function	Locomotion	Organ function	Blood circulation

Skeletal Divisions:

Division	Bone Count	Major Components
Axial	80	Skull, vertebral column, ribs, sternum
Appendicular	126	Limb bones, girdles
Total	206	Complete skeleton

Joint Types:

Joint Type	Mobility	Structure	Examples
Fibrous	Immovable	Dense fibrous tissue	Skull sutures
Cartilaginous	Slightly movable	Cartilage connection	Vertebrae
Synovial	Freely movable	Synovial cavity	Ball-socket, Hinge

Muscle Fiber Types:

Feature	Red Fibers	White Fibers
Myoglobin	High	Low
Mitochondria	Abundant	Few
Contraction	Slow, sustained	Fast, brief
Fatigue	Resistant	Quick fatigue
Metabolism	Aerobic	Anaerobic

Evolutionary Significance

Locomotion Evolution:

1. **Simple → Complex:** Amoeboid → Muscular locomotion
2. **Efficiency improvement:** Development of skeletal support
3. **Specialization:** Different muscle types for specific functions
4. **Coordination:** Integration of muscular, skeletal, and nervous systems

Adaptive Advantages:

- **Predator avoidance:** Rapid escape mechanisms
- **Resource acquisition:** Efficient foraging and hunting
- **Reproduction:** Mate finding and territorial behavior
- **Environmental adaptation:** Migration and habitat selection

EXAM SPRINT - Master Locomotion and Movement with focused study on muscle contraction mechanism, skeletal system organization, joint classifications, and movement types. Regular practice of structure-function relationships and process explanations is key to NEET success.

Source: NCERT Biology Class 11, Chapter 17 - Comprehensive coverage for NEET preparation