# B.Pharmacy Notes - HAP Human Anatomy And Physiology - Unit 2 - Free PDF Download

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## The Integumentary System: Your Body's Protective Shield

Let's begin with the **Integumentary System**, which is basically your skin – and it's a lot more than just a covering!

**Introduction: Did** you know that your skin is actually the **largest organ** in your entire body? It's part of something called the integumentary system, and its main job is to act as a **protective shield**, covering your body and separating your internal organs from the outside world. Your skin also plays a super important role in **regulating your body temperature**. It's made up of two main layers: the **outer layer** called the **epidermis** and the **inner layer** called the **dermis**.

**Structure of Skin**

1. **Epidermis** The epidermis is the very outer layer of your skin. It's made up of several layers of a special type of tissue called stratified squamous epithelium. This epidermis is further divided into five distinct layers, starting from the outermost to the innermost:

    - **Stratum Corneum**: This is the most superficial, or outermost, layer. It's primarily made of cells containing a tough protein called **keratin**, which helps make your skin strong and waterproof. What's interesting is that the cells in this layer **don't have nuclei**.
    - **Stratum Lucidum**: This is a thin, clear, and glistening layer. It's often described as being more or less transparent and its cells contain cytoplasm.
    - **Stratum Granulosum**: This layer contains distinctive **spindle-shaped cells**. Both the **cytoplasm and nucleus are present** in these cells.
    - **Stratum Spinosum**: Here, you'll find **polyhedral cells**, which means they have many sides.
    - **Stratum Germinativum (also known as Stratum Basale)**: This is the deepest layer of the epidermis. It's made of a single layer of **columnar or cuboidal cells**. This crucial layer is directly

**connected to the dermis** and is where **melanin pigments** (which determine your skin colour) are produced.

2. **Dermis:** Beneath the epidermis lies the dermis. This layer is composed of **connective tissue** and is **highly vascular**, meaning it has a rich blood supply. It's primarily made up of **fibroelastic tissue**, which is what gives your skin its **texture** and elasticity. The dermis is also home to several important structures:

    - **Sebaceous glands**: These are flask-shaped glands that secrete an oily substance called **sebum**. Sebum travels through a duct that opens into a **hair follicle**. Its main function is to **prevent excess evaporation of water** from the skin and keep your skin from drying out. You'll find these glands in most parts of your body, except for the palms of your hands and the soles of your feet.
    - **Sweat glands**: There are two main types: **Eccrine glands** and **Apocrine glands**.
        - **Eccrine glands** are found all over your body and produce **watery sweat**.
        - **Apocrine glands** are located in specific areas like the armpits (axilla), female genitalia, and around the nipples, and they secrete **milky sweat**.
    - **Ceruminous glands**: These glands are responsible for secreting **wax in the external ear**.
    - **Hair roots and erector pili muscles**: The **contraction of these tiny muscles** causes your hair to straighten, which is what gives you goosebumps!

**Functions of Skin** Your skin does so much more than just cover you. Here are its key functions:

1. **Protection**: It protects your body against **injury** and **bacterial invasion**.
2. **Temperature Regulation**: It plays a crucial role in **regulating your body temperature**.
3. **Sensation**: Your skin acts as a medium for **receiving sensations** like touch, pressure, and temperature.
4. **Excretion**: It **excretes sodium chloride and metabolites** like urea.
5. **Fluid Balance**: It helps **maintain water and electrolyte balance**.
6. **Vitamin D Synthesis**: Your skin **synthesises vitamin D** from ergosterol when exposed to ultraviolet rays from sunlight.
7. **Melanin Synthesis**: It **synthesises melanin** from tyrosine, which protects against UV radiation.
8. **Sebum and Sweat Secretion**: It **secretes sweat and sebum**, which helps keep the skin soft.
9. **Storage**: It **stores fat, water, chlorides, and sugar**.

**Regulation of Body Temperature** Maintaining a stable body temperature is vital. The normal body temperature is around **37°C (98.4°F)**. This temperature is kept constant through a delicate balance between **heat production** and **heat loss**. Body temperature is controlled by a special **heat regulating centre** located in the **hypothalamus** of your brain.

- **Heat Production**: Your body produces heat in several ways:

    1. During **severe exercise**, due to increased activity of muscles.
    2. By increased activity of your liver and other glands in the body.
    3. From an increased intake of food, particularly **proteins**.
    4. Through increased **metabolism**, such as the oxidation of food substances and the burning of fat.
    5. From endocrine secretions like **adrenaline and noradrenaline**.
- **Heat Loss**: Your body loses heat to the environment through various mechanisms:

    1. **Radiation**: Heat is lost directly to the surrounding air.
    2. **Conduction**: Heat is lost through direct contact with cooler objects, like clothing or bedding.
    3. **Convection**: Hot air around your body moves upwards and is replaced by cooler air, carrying heat away.
    4. **Sweating**: When you sweat, your skin becomes cool, leading to heat loss.
    5. **Evaporation**: Water evaporating from your skin, mucous membranes, and respiratory passages also helps to cool your body and lose heat.

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## Joints: Connecting Your Bones for Movement

Now, let's explore how your bones come together to allow for movement.

**Introduction** A **joint**, also known as an **articulation**, is simply the **connection made between bones** in your body. Joints link the entire **skeletal system** together, making it a functional whole. They are specifically designed to allow for different **degrees and types of movement**.

**Classification of Joints and Their Function**

1. **Fixed or Fibrous Joints**

    - These joints **do not have a synovial cavity** (a fluid-filled space) and are fixed tightly together by tough **sutures** or ligaments.
    - **No movement** occurs in these joints; they are **immovable**.
    - **Examples**: The **bones of your skull** and the bones of your **pelvic girdle**.
    - **Functions**: Fibrous joints strongly **unite adjacent bones** and are crucial for **providing protection** for internal organs, giving **strength to body regions**, and offering **weight-bearing stability**. They provide stability to certain areas of the body, even though they don't move.

2. **Cartilaginous or Slightly Movable Joints**

    - In these joints, bones are separated by **cartilage**, and there is **no synovial cavity**.
    - They are also called **imperfect joints** because they only allow **little movements**.
    - **Examples**: Joints found **between two vertebrae**, between the **ribs and the sternum**.
    - **Function**: Cartilage in these joints is a **tough, elastic connective tissue** that helps to **reduce friction** between the bones, absorbing shock and allowing limited movement.

3. **Freely Movable or Synovial Joints**

    - These are considered **perfect joints** because they allow **free movements in one or more directions**.

4. **Freely movable or synovial joints are classified into six types:**

    - **(a) Ball and Socket Joints**: In this type, the **rounded surface of one bone** fits into a **depression** on another bone, allowing for **greater freedom of movement** than any other joint.
        - **Example**: **Hip joints**.
    - **(b) Gliding Joints**: This is a common type of synovial joint built between bones that have **flat or nearly flat articular surfaces**, meaning they can slide past each other.
        - **Example**: Joints between **vertebra, wrist, and ankle bones**.
    - **(c) Hinge Joints**: These joints function much like the **hinge on a door**, allowing bones to **move in one direction** (back and forth) with limited motion along other planes.
        - **Example**: **Knee and elbow joints**.

- **(d) Pivot Joints**: Pivot joints permit **rotatory movement** of bones around a **single axis**. It's a synovial joint where the ends of two bones connect to allow this rotation.
    - **Example**: Joints between the **radius and ulna** (in your forearm) and the **atlas and axis vertebrae** (in your neck).
- **(e) Ellipsoid (Condyloid) Joints**: A synovial joint where an **oval-shaped process of one bone** fits into an **elongated or ellipsoidal cavity of the other**. This allows movements such as **flexion, extension, abduction, and adduction**.
    - **Example**: **Wrist or radio carpal joints**.
- **(f) Saddle Joints**: This is a type of synovial joint where the **opposing surfaces are reciprocally concave and convex**, fitting into each other like a saddle and rider.
    - **Example**: The **carpo-metacarpal joint of the human thumb**.

**Movements of Joints** Joints allow for a variety of movements:

1. **Flexion**: A **bending movement**, usually forwards but sometimes backwards.
2. **Extension**: A **straightening or bending backwards** movement.
3. **Abduction**: Moving a limb **away from the midline** of the body.
4. **Adduction**: Moving a limb **towards the midline** of the body.
5. **Circumduction**: A circular movement that is a combination of **flexion, extension, abduction, and adduction**.
6. **Rotation**: Movement of a bone **round its long axis**. This can be **Medial rotation** (towards the midline) or **Lateral rotation** (away from the midline).
7. **Pronation**: Turning the **palm of the hand down**.
8. **Supination**: Turning the **palm of the hand up**.
9. **Inversion**: Turning the **sole of the foot inwards**.
10. **Eversion**: Turning the **sole of the foot outwards**.

**Joints of the Upper Limb** Here are some key joints in your upper limb:

1. **Sterno-clavicular joint**: This is a **gliding joint** between the **sternum** (breastbone) and the **clavicle** (collarbone). A pad of cartilage is present in the joint cavity between these bones.
2. **Acromio-clavicular joint**: This joint is formed by the **outer end of the clavicle** articulating with the **acromion process of the scapula** (shoulder blade).

3. **Shoulder joint**: This is a **ball and socket type of joint**. It occurs between the **head of the humerus** (upper arm bone) and the **glenoid cavity of the scapula**.
    - **Movements of the shoulder joint**: All types of movements are possible here, including **flexion, extension, adduction, abduction, rotation, and circumduction**.
4. **Elbow joint**: This is a **hinge joint** formed by the **humerus** (above) and the **radius and ulna** (below).
    - **Movements of the elbow joint**: Primarily **flexion and extension**.
5. **Radio-ulnar joint**: This joint is formed by the articulation of the **radius and ulna** at their upper and lower extremities.
    - **Movements of the radio-ulnar joint**: **Pronation and supination**.
6. **Wrist joint**: This is a **condyloid joint**. It is formed by the lower end of the **radius** and three **carpal bones** (bones of the wrist).
    - **Movements of the wrist joint**: **Flexion, extension, adduction, and abduction** are the movements possible here.
7. **Metacarpo-phalangial joint**: These occur between the **metacarpal** bones (palm) and **phalangial bones** (finger bones).
    - **Movements**: **Flexion, extension, adduction, and abduction** are possible.
8. **Inter-phalangial joints**: These occur between the **phalangial bones of the same finger**.
    - **Movements**: Primarily **flexion and extension**.

**Joints of the Lower Limb** Let's look at the important joints in your lower limb:

1. **Hip joint**: This is a **ball and socket type of joint**. It occurs between the **acetabulum** (a socket in the innominate bone) and the **head of the femur** (thigh bone). The joint capsule is strengthened by three important ligaments:
    - "Ilio-femoral ligament" in the front.
    - "Pubo-femoral ligament" below.
    - "Ischio-femoral ligament" at the back.
    - **Movements of the hip joint**: Similar to the shoulder, it allows **flexion, extension, adduction, abduction, rotation, and circumduction**.
2. **Knee joint**: This is a **hinge joint** formed by:
    - Two **condyles of the femur** articulating with the **condyles of the tibia** (shin bone).
    - The **patella** (kneecap).

    - **Movements of the knee joint**: Primarily **flexion and extension**.
3. **Ankle joint**: This is another **hinge joint** formed by:
    - The **tibia** and its medial malleolus.
    - The **lateral malleolus of fibula**.
    - Both articulate with a socket for the **talus** (an ankle bone) below.
    - **Movements of the ankle joint**: **Dorsi flexion** (lifting the foot) and **plantar flexion** (pointing the toes).
4. **Joints of the foot**: These include:
    - Tarsal joints
    - Tarso-metatarsal joints
    - Metatarso-phalangial joints
    - Inter-phalangial joints

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## The Skeletal System: Your Body's Framework

Now, let's delve into the bones that give your body its shape and allow you to move.

**Introduction** The **skeletal system** is made up of all the **bones and joints** in your body. It's a complex **living organ** composed of many cells, protein fibers, and minerals. This system **supports and protects** your body, giving it its **shape and form**. It’s composed of various **connective tissues**, including bone, cartilage, tendons, and ligaments.

**Functions of the Skeleton System** Your skeleton is much more than just a frame; it performs many vital tasks:

- **Support**: It acts as the **structural framework** of your body, supporting soft tissues and providing **attachment points** for the tendons of skeletal muscles.
- **Protection**: It **protects your internal organs** from injury. For example, your skull protects your brain.
- **Assistance in Movement**: Most skeletal muscles are attached to bones. When these muscles contract, they **pull the attached bones to produce movement**.
- **Blood Cell Production**: **Blood cells are produced in the bone marrow**.
- **Triglyceride Storage**: **Yellow bone marrow** primarily consists of adipose cells, which are used to **store triglycerides** (fats).

- **Mineral Homeostasis**: Bone tissue stores several important minerals, especially **calcium and phosphorus**. These minerals contribute to the **strength of bone** and are also vital for many bodily functions.

**Divisions of Skeletal System** The human skeleton is divided into two major parts:

1. **Axial skeletal system**
2. **Appendicular skeletal system**

**1. Axial Skeleton** This part of your skeleton forms the central axis of your body and includes the skull, vertebral column, and thoracic cage.

- **I. Skull** The skull sits on top of your vertebral column and its bony structure is divided into two main parts: the **cranium** and the **face**.

    - **A. Cranium** The cranium is formed by flat and irregular bones that provide strong **bony protection to your brain**. It forms a base on which the brain rests and a vault that surrounds and covers it. In adults, the sutures (joints) between the cranial bones are **immovable**. The cranium consists of eight bones:

        - 1 Frontal bone
        - 2 Parietal bones
        - 2 Temporal bones
        - 1 Occipital bone
        - 1 Sphenoid bone
        - 1 Ethmoid bone
    - **B. Face** Your face is formed by 13 bones in addition to the frontal bone. These include:

        - 2 Cheek bones (Zygomatic)
        - 1 Maxilla
        - 2 Nasal bones
        - 2 Lacrimal bones
        - 1 Vomer
        - 2 Palatine bones

        - 2 Inferior conchae
        - 1 Mandible (lower jaw bone)
- **II. Vertebral Column** Your vertebral column, or spine, is made up of a series of bones called **vertebrae**. Together with the sternum and ribs, it forms the skeleton of your trunk. The vertebral column houses and protects the **spinal cord**. It also supports your head and provides attachment points for the ribs, pelvic girdle, and muscles of your back and upper limbs. The adult vertebral column consists of **26 vertebrae**:
    - **7 cervical vertebrae**: These are in your **neck region**.
    - **12 thoracic vertebrae**: These are located behind your **thoracic cavity**.
    - **5 lumbar vertebrae**: These support your **lower back**.
    - **1 sacrum**: This consists of **five fused** sacral vertebrae.
    - **1 coccyx**: This consists of **four fused** coccygeal vertebrae.
    - **Functions of Vertebral Column**:
        - Provides strong bony **protection for the spinal cord**.
        - The pedicles of adjacent vertebrae form intervertebral openings, providing access for spinal nerves, blood vessels, and lymph vessels.
        - **Supports the skull**.
        - The intervertebral discs act as **shock absorbers**, protecting the brain during movement.
        - Forms the axis of the trunk, providing attachment to the ribs, shoulder girdle, upper limbs, the pelvic girdle, and lower limbs.
    - **Parts of a Typical Vertebra**: A typical vertebra has a body, vertebral arch, vertebral foramen, pedicles, and processes (spinous and transverse). Specific types of vertebrae also include the Atlas and Axis vertebrae in the neck.

- **Types of Vertebrae Details**:

    - **Cervical Vertebrae**: These vertebrae have a smaller body and larger vertebral arches. They have three openings: one vertebral foramen and two transverse foramina, through which the vertebral artery, vein, and nerve fibers pass. Their processes are split into two parts.
    - **Lumbar Vertebrae**: These are the **largest and strongest** vertebrae of the vertebral column. They have short and thick projections. Their superior articular processes are directed medially, while the inferior ones are directed laterally. The spinous processes are quadrilateral in shape, thick, broad, and project straight.
    - **Thoracic Vertebrae**: These are **larger and stronger** than cervical vertebrae. Their spinous processes are long and flattened. Thoracic vertebrae have longer and larger transverse processes. The bodies of these vertebrae have facets for articulation with the **head of the ribs**.
    - **Sacrum**: This consists of **five vertebrae fused** to form a triangular bone. The upper part articulates with the **5th lumbar vertebra**. On each side, it articulates with the ilium to form a **sacroiliac joint**, and its lower tip articulates with the coccyx.
    - **Coccyx**: This consists of **four terminal vertebrae fused** to form a small triangular bone, which is the broad base of the sacrum's tip.

- **III. Thoracic Cage** The thoracic cage is composed of:

    - 1 **Sternum** (breastbone)
    - 12 pairs of **ribs**
    - 12 **thoracic vertebrae**

**2. Appendicular Skeleton** The appendicular skeleton consists of the bones that make up your limbs and the girdles that attach them to the axial skeleton.

- **Pectoral Girdles (Shoulder girdle)** The pectoral girdle connects the bones of your **upper limbs to the axial skeleton**. Each pectoral girdle consists of two bones:

    - 1 **Clavicle** (collarbone)

- 1 **Scapula** (shoulder blade)

- **Clavicle**: The clavicle is located between the **ribcage** (sternum) and the **shoulder blade** (scapula). It connects your **arm to your body** and lies above several important nerves and blood vessels.

- **Scapula**: Also called the **shoulder blade**, it is one of two large bones forming the shoulder girdle. In humans, it is **triangular** and lies on the upper back, between the levels of the **second and eighth ribs**.

- **Upper Limbs (Upper extremity)** Your upper extremity, or arm, is a functional unit of your upper body. It has three main sections: the **upper arm, forearm, and hand**. It extends from the shoulder joint to the fingers and contains **30 bones**.

  - **Humerus**: This is the bone in your **upper arm**, located between your **elbow and your shoulder**. Its main function is to **support your shoulder** and provide a wide variety of **movements for your arm**.
  - **Ulna**: The ulna is one of two bones that make up your **forearm**, the other being the radius. It forms the **elbow joint with the humerus** and articulates with the radius both proximally (closer to the body) and distally (further from the body). The main function of the ulna, along with the radius, is to assist with **rotation**.
  - **Radius**: Also known as the **radial bone**, it is the other of the two forearm bones. It's crucial for the **shaping and use of your hands**.
  - **Carpals**: These are the wrist bones that **connect the distal aspects of the radial and ulnar bones of the forearm** to the bases of the **five metacarpal bones** of the hand. They consist of a proximal row and a distal row.
  - **Metacarpus (palm)**: This consists of **five bones** called metacarpals, forming the palm of your hand. Each metacarpal has a proximal base, an intermediate shaft, and a distal head.
  - **Phalanges (finger bones)**: These are the bones that make up the **fingers of your hand and the toes of your foot**. There are **56 phalanges** in the human body, with **fourteen on each hand and foot**. Each finger and toe typically has three phalanges, except for the thumb and big toe, which have two.

- **Pelvic Girdle (Pelvis)** The pelvis is the area of the body **below the abdomen** that is located between your **hip bones** and contains the **bladder and rectum**. In females, it also contains the vagina, cervix, uterus, fallopian tubes, and ovaries. It consists of three fused bones:
    - Ilium
    - Pubis
    - Ischium
- **Lower Limb (Lower extremity)** Each lower limb consists of **30 bones** distributed in four locations:
    - **Femur** (thigh bone)
    - **Patella** (kneecap)
    - **Tibia and fibula** (in the leg)
    - **7 tarsals** (in the tarsus/ankle)
    - **5 metatarsals** (in the metatarsus)
    - **14 phalanges** (bones of the digits in the foot)
    - **Femur**: The femur is the **largest and strongest bone** in the human body, commonly known as the **thigh bone**. It reaches from your **hip to your knee**. Its main function is **weight bearing** and providing **stability of gait** (how you walk). It's an essential part of the lower kinetic chain.
    - **Patella (knee cap)**: The patella is a **small bone** located in front of the **knee joint** where the **thighbone (femur)** and **shinbone (tibia)** meet. It **protects the knee** and connects the muscles in the front of the thigh to the tibia.
    - **Tibia and Fibula**: The tibia and fibula are the two long bones located in your lower leg. The **tibia is a larger bone** on the inside of your leg, and the **fibula is a smaller bone** on the outside. The **tibia is**

**much thicker than the fibula**.

- **Tarsals**: The tarsal bones consist of **seven short bones** located at the **proximal region of the foot** (the ankle area). They are arranged in proximal and distal rows. The **Calcaneus bone** is the largest tarsal bone that projects posteriorly as the heel.

- **Metatarsals**: The metatarsal bones, or metatarsus, are a group of **five long bones in the foot**, located between the tarsal bones of the hind- and mid-foot and the phalanges of the toes.

- **Phalanges**: The **14 bones** that are found in the fingers of your hand are also found in the **toes of each foot**.

**Disorders of the Skeletal System** The skeletal system can be affected by various conditions:

1. **Herniated (Slipped) Disc**: This occurs if the anterior and posterior ligaments of the discs (cushions between vertebrae) become injured. The pressure developed in the nucleus pulposus (the jelly-like centre of the disc) can become great enough to **rupture the surrounding fibrocartilage**.
2. **Abnormal Curves of the Vertebral Column**: Various conditions can exaggerate the normal curves of the vertebral column, or the spine may acquire a lateral bend, resulting in abnormal curves.
3. **Scoliosis**: This is a **lateral bending of the vertebral column**, most commonly seen in the **thoracic region**.
4. **Kyphosis**: This is an **increase in the thoracic curve** of the vertebral column, often leading to a 'hunchback' appearance.
5. **Lordosis**: This is an **increase in the lumbar curve** of the vertebral column, often causing an exaggerated inward curve of the lower back.
6. **Spina Bifida**: This is a **congenital defect** (meaning present from birth) of the vertebral column. It happens when the laminae of the L5 (fifth lumbar vertebra) and/or S1 (first sacral vertebra) fail to develop normally and unite at the midline.

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## Skeletal Muscle: The Powerhouse of Movement

Finally, let's explore the muscles that allow you to move your skeleton.

**Skeletal Muscle** A muscle is connected to your skeleton to form part of the **mechanical system** that moves your limbs and other parts of your body. These muscles play an essential role in **respiratory mechanics** (breathing) and help in **maintaining posture and balance**. They also **protect your vital organs** in the body.

**Structure of Muscle** Each skeletal muscle is a complex organ made up of various **integrated tissues**. These tissues include **skeletal muscle fibers, blood vessels, nerve fibers, and connective tissue**.

- Each muscle is wrapped in a sheath of dense, irregular connective tissue called the **epimysium**. This allows the muscle to contract and move powerfully while maintaining its **structural integrity**.
- Inside each skeletal muscle, **muscle fibers** are organised into bundles called **fascicles**. These fascicles are surrounded by a middle layer of connective tissue called the **perimysium**.
- Inside each fascicle, each muscle fiber is encased in a thin connective tissue layer of collagen and reticular fibers called the **endomysium**.
- The endomysium surrounds the **extracellular matrix** of the cells and plays a role in **transferring force** produced by the **muscle fibers to the tendons**.
- In skeletal muscles, they work with **tendons** to pull on **bones**. The collagen in the three connective tissue layers (epimysium, perimysium, endomysium) intertwines with the collagen of a tendon, creating a strong link.

**Function of Muscle** Your muscles are responsible for many crucial actions:

- **Move the skeleton**: Allowing you to walk, run, and lift.
- **Maintain body posture**: Keeping you upright.
- **Support soft tissues**: Like your abdominal organs.
- **Guard body entrances/exits**: Such as those of the digestive and urinary tracts.
- **Maintain body temperature**: Through shivering and metabolic heat production.
- **Store nutrients**: Glycogen and protein can be used for energy.

**Physiology of Muscle Contraction** Muscle contraction is a complex process that involves several steps:

**Step 1: Motor Neuron Sends Message to Muscle to Contract**

- A **motor neuron** sends an electrical signal, an **impulse**, in the form of a **neurotransmitter** to the muscle, telling it to contract.
- The specific neurotransmitter involved in muscle contraction is **acetylcholine**. It floats in the space between the nerve and muscle, called the **synaptic cleft**.

**Step 2: Muscle Depolarizes**

- Acetylcholine, present in the synaptic cleft, travels across to the **motor end plate** (the part of the muscle fibre that receives the nerve signal).
- It then attaches to special **receptors on transport proteins** on the motor end plate.
- When acetylcholine attaches to these transport proteins, it causes them to **open and let sodium into the cell**.
- The rushing of **sodium** inside the muscle cell changes its electrical potential, making it **positively charged** (depolarisation).
- This change in cell potential makes the cell less negative.

**Step 3: Release of Calcium by the Sarcoplasmic Reticulum**

- The muscle cell membrane, called the **sarcolemma**, contains tube-like structures called **T-tubules**.
- Inside the muscle cell, the **sarcoplasmic reticulum** (SR) stores calcium. The calcium concentration inside the SR is very high, about 2000 times greater than outside the muscle cell.
- When the muscle cell depolarises (due to sodium influx), the sarcoplasmic reticulum responds by **opening the calcium channels** in its terminal cisternae (parts of the SR).
- This opening of calcium channels results in a rush of **calcium into the sarcoplasm** (the cytoplasm of the muscle cell).
- This entire process is known as **excitation-contraction coupling** because the electrical excitation leads to muscle contraction.

**Step 4: Calcium Binds to the Troponin on the Actin**

- **Calcium** that has rushed into the sarcoplasm attaches to a protein called **troponin**. Troponin is part of a complex (the troponin-tropomyosin complex) wrapped around the **actin** (thin) filaments of the muscle.
- This binding of calcium to troponin causes a change in the **position of troponin**. This change then **exposes the myosin binding site on the actin** filament.

- With the binding site now exposed, the **myosin** (thick filament) can now attach to the actin, forming what is known as a **cross-bridge**.

**Step 5: Myosin Pulls Actin Along**

- Once a cross-bridge is formed, the **myosin** can move at its hinge region and then **pull the actin filament along**. This causes the actin and myosin to slide past each other, shortening the muscle.
- The cycle of movement ends when the **myosin releases from actin** and returns to its original position.
- The energy required for just one cross-bridge cycle (the attachment, pulling, and detachment of myosin from actin) is supplied by one **ATP molecule**.
- **ATP binds with the myosin head**, which has an enzyme called **ATPase activity**.
- The ATP then breaks down into **ADP (adenosine diphosphate) and a phosphate group**.
- Calcium binding to troponin exposes the binding site on actin, and then myosin binds to actin and releases the phosphate, extracting energy from that phosphate bond.
- When myosin pulls actin along, the **ADP is released from the myosin head**.
- Finally, the **myosin head releases from the actin** and returns to its resting position, with ADP and phosphate still attached.
- The energy released from ATP is now stored in the myosin heads, ready for the next contraction.
- In resting muscles, energy from ATP is stored in the myosin heads while they wait for another contraction signal.
- Muscle contraction usually **stops when signalling from the motor neuron ends**. This causes the sarcolemma to repolarise (return to its resting electrical state) and closes the voltage-gated calcium channels in the sarcoplasmic reticulum.
- Calcium ions (Ca++) are then **pumped back into the sarcoplasmic reticulum**, which causes the **tropomyosin** (another protein on actin) to re-shield the binding sites on the actin strands, preventing further myosin attachment.
- A muscle can also **stop contracting if it runs out of ATP** and becomes fatigued.

**Neuromuscular Junction**

- The **neuromuscular junction** is the specific **junction or connection between a nerve ending and the skeletal muscle**.
- At this site, the nerve loses its **myelin sheath** (an insulating layer) and spreads out into nerve endings.

- These nerve endings pierce the **sarcolemma** (muscle cell membrane) and come into contact with the **sarcoplasm** (muscle cell cytoplasm).
- **Acetylcholine** (the neurotransmitter) is produced and stored in small sacs called vesicles within the nerve ending.
- The **motor end plate** is the part of the muscle surface that faces the expanded nerve terminal.
- The surface of the motor end plate is convoluted (folded) and contains the enzyme **Acetylcholinesterase**.
- Acetylcholine is quickly **inactivated by this enzyme** if it is produced in excess, ensuring that the muscle contraction is precisely controlled and doesn't last too long.