



UNIT FIVE

THE HUMAN BODY SYSTEM

- 
- The human body is a biological machine made of body systems and groups of organs that work together to produce and sustain life.

□ Human Organ Systems

IntegumentarySystem

- Includes skin, hair, nails; protects the body and regulates temperature.

SkeletalSystem

- Made up of bones; supports the body and protects internal organs.

MuscularSystem

- Works with the skeleton to allow movement and maintain posture.

LymphaticSystem

- Helps defend the body against infection and removes waste fluids.

RespiratorySystem

- Brings oxygen into the body and removes carbon dioxide

DigestiveSystem

- Breaks down food into nutrients the body can use.

NervousSystem

- Controls body activities through brain, spinal cord, and nerves.

EndocrineSystem

- Produces hormones that regulate growth, metabolism, and mood.

CardiovascularSystem

- Circulates blood and delivers oxygen and nutrients throughout the body.

UrinarySystem

- Removes waste products and controls water balance.

ReproductiveSystems

- Enables reproduction and includes male and female reproductive organs.

5.1 Human Musculoskeletal System

The musculoskeletal system enables **movement, supports the body, and protects organs.**

□ **Functions of the Musculoskeletal System**

Movement – Allows the body to perform physical actions.

Shape and Form – Gives the body structure.

Protection – Shields internal organs like the heart and lungs.

Binding Organs – Connects parts of the body together.

Stability – Maintains posture and balance.

Blood Cell Production – Bone marrow produces red and white blood cells.

Mineral Storage – Stores calcium and phosphorus in bones.

Components of the Musculoskeletal System

Muscles

- Control bone movement and help maintain body position.

Joints and Cartilages

- Joints allow flexibility; cartilages cushion bones and prevent friction.

Tendons

- Tough bands connecting muscles to bones, enabling motion.

Connective Tissues

- Provide support, allow alignment, and help movement of body parts.

Ligaments

- Strong connective tissues that link bones to other bones at joints.

Types of Muscles

- The human muscular system has around 700 muscles, making up about 50% of body weight.
- These muscles are responsible for body movement.
- Each muscle is a discrete organ made of **skeletal muscle tissue, blood vessels, tendons, and nerves.**
- Muscles are typically attached to bones of the skeletal system

Three Types of Muscles in the Human Body

1. Cardiac Muscle

- Found only in the heart.
- Forms the middle layer of the heart wall called the **myocardium**, between the **pericardium** (outer) and **endocardium** (inner).
- Blood circulates through it via the coronary circulation.
- It is an involuntary, striated muscle.
- Made of cardiac muscle cells joined by intercalated discs.
- Surrounded by collagen fibers forming the extracellular matrix.

Skeletal Muscle

- Attached to bones and arranged around joints in opposing pairs.
- Makes up about 30–40% of total body mass.
- Responsible for voluntary movement and controlled actions.
- A motor unit consists of skeletal muscle fibers innervated by a single motor neuron (axon)

Smooth Muscles

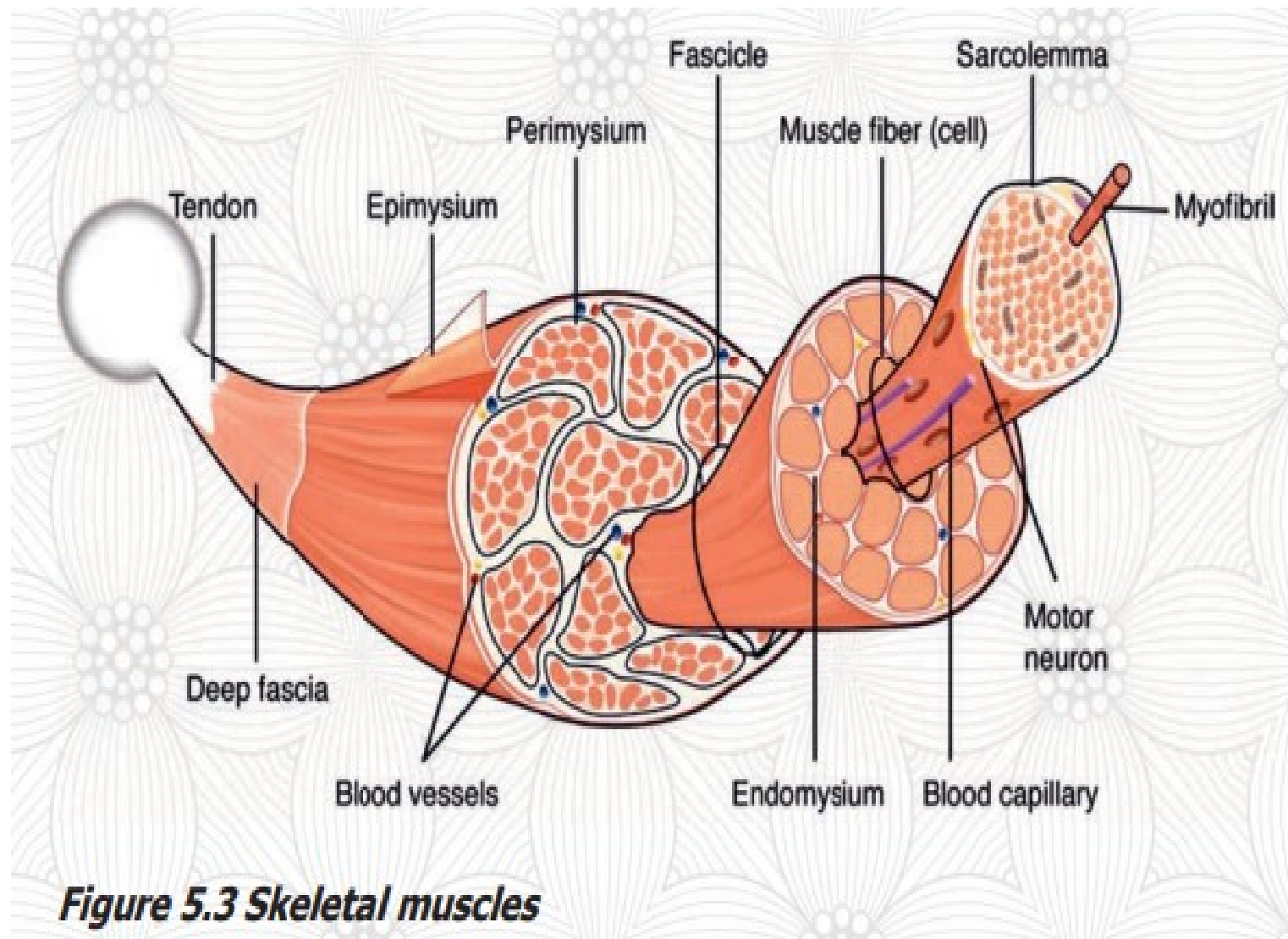
- involuntary ,non-striated muscles controlled unconsciously
- *Regulate the flow of substances inside hollow organs and vessels.*

Location

- Found in **the walls of stomach, intestine, bladder, uterus, blood vessels, lymph vessels, respiratory, urinary, and reproductive tracts, eyes, and ciliary muscles.**
- *Control internal movements like digestion, blood flow, and pupil size.*

Special Function in Skin

- Smooth muscles like erector pili in skin raise body hairs.
- *React to cold, heat, or fear, causing "goosebumps".*



Muscle Structures and Their Functions

Tendon

- Tough, fibrous connective tissue that connects muscle to bone.

- *Transmits force from muscle contraction to bones, enabling movement.*

DeepFascia

- Dense connective tissue surrounding entire muscle groups.

- *Supports structure, separates muscles, and helps muscles glide smoothly.*

Epimysium

- Outer connective tissue layer around a whole muscle.

- *Protects muscle from friction and assists in force transmission.*

Perimysium

- Connective tissue surrounding bundles (fascicles) of muscle fibers.

- *Provides pathways for nerves and blood vessels to reach fibers.*

Fascicle

- A bundle of muscle fibers grouped together by perimysium.

□ *Organizes fibers into functional units for efficient muscle action.*

Endomysium

-Thin connective tissue around each individual muscle fiber.

□ *Provides support and allows access for capillaries and nerves.*

MuscleFiber(Cell)

-Long, cylindrical, multinucleated cell of skeletal muscle.

□ *Main contractile unit containing machinery for muscle contraction.*

Sarcolemma

-Cell membrane of a muscle fiber

□ *Maintains internal environment and carries electrical signals (action potentials).*

Myofibril

- Threadlike structures inside muscle fibers made of sarcomeres.

□ *Contain actin and myosin filaments responsible for contraction.*

MotorNeuron

-Nerve cell connected to muscle fibers.

□ *Carries signals from the brain/spinal cord to stimulate contraction.*

Blood Capillary

- Tiny blood vessels that surround muscle fibers.

□ *Supply oxygen and nutrients, remove waste products from muscles.*

Mechanism of Actions of Skeletal Muscles

General Mechanism

- Muscle action is the activation of muscle cells to generate tension or contraction, leading to movement.

Structure of Skeletal Muscles

- Composed of bundles of muscle fibers, which are large cells formed by the fusion of many cells during development.

Myofibrils and Filaments

- The cytoplasm is mainly filled with myofibrils, made of thick myosin and thin actin filaments.
 - These are organized into repeated units called sarcomeres—the contractile units of the muscle.

Actin and Myosin Proteins

- Both are contractile proteins present in all types of muscles.
 - They work together to generate contractions and movement.

Role of Myosin

- Myosin is a molecular motor that converts ATP (chemical energy) into mechanical energy, pulling actin filaments and causing contraction.

Role of Actin

- Actin filaments, along with myosin, are involved in cell and muscle movement.
- They slide past each other during contraction.

Troponin

- A complex of three regulatory proteins essential for controlling skeletal muscle contraction.

Tropomyosin (in relaxed muscle)

- In a relaxed state, tropomyosin blocks the myosin binding sites on actin, preventing contraction.

Cross Bridge Formation

- When myosin binds to actin, it forms a cross bridge, which triggers muscle contraction

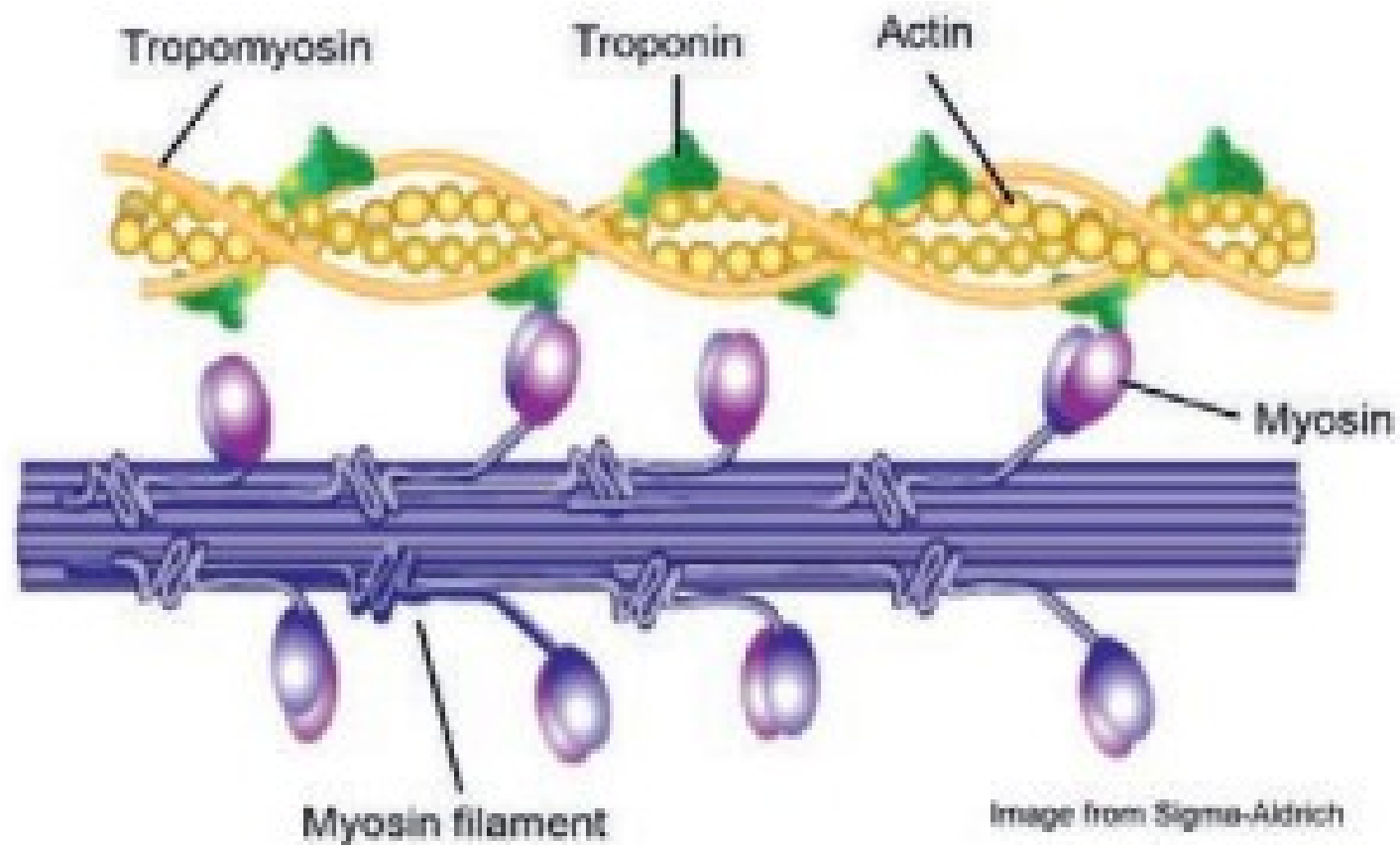


Figure 5.5 Actin and myosin in action

Key Proteins and Structures in Muscle Contraction

Actin

- A thin filament found in sarcomeres.
- *Acts as the attachment site for myosin during contraction; is pulled inward to shorten the sarcomere.*

Myosin

- A thick filament with projecting heads.
- *Myosin heads bind to actin, form cross-bridges, and pull actin inward using energy from ATP to cause contraction.*

Tropomyosin

- A protein that wraps around actin filaments.
- *Blocks myosin-binding sites on actin when the muscle is relaxed, preventing contraction.*

Troponin

- A protein complex located on tropomyosin.
- *Binds calcium ions, causing tropomyosin to shift and expose binding sites on actin for myosin attachment.*

Myosin Filament

- The thick filament made of bundles of myosin molecules.
- *Engages in cross-bridge cycling to pull actin filaments through a power stroke during muscle contraction.*

How Actin and Myosin Work Together

Resting State

- Tropomyosin blocks the binding sites on actin.
- *Prevents myosin heads from attaching; muscle stays relaxed.*

Activation

- Calcium ions bind to troponin.
- *This causes tropomyosin to shift, exposing binding sites on actin.*
- *Myosin heads can now attach to actin, forming cross-bridges.*

Contraction

- Myosin heads use ATP to pivot and pull actin filaments inward.
- *This shortens the sarcomere, resulting in muscle contraction.*

Relaxation

- Calcium ions are removed, and tropomyosin returns to its blocking position.
- *Myosin detaches from actin, and the muscle returns to its resting state.*

Muscle action involves the following steps:

Muscle Activation: A motor nerve transmits an action potential to the neuromuscular junction, stimulating the release of calcium from the sarcoplasmic reticulum into the muscle cell.

Muscle Contraction: Calcium binds to troponin on actin filaments, allowing myosin to bind to actin. ATP provides the energy for the actin-myosin cross-bridges to contract the muscle.

Recharging: ATP is re-synthesized, maintaining the actin-myosin binding for continued contraction.

Relaxation: Nerve stimulation stops, calcium is pumped back into the sarcoplasmic reticulum, breaking the link between actin and myosin, leading to relaxation.

Muscle contractions occur in three types:

Isometric: No change in muscle length.

Concentric: Muscle shortens as it contracts.

Eccentric: Muscle lengthens while contracting.

- 
- The human skeletal system is divided into two parts: the **axial** and **appendicular skeletons**.
 - Humans are born with over 300 bones, but by adulthood, this number reduces to 206 due to fusion.

Bones have three layers:

Periosteum: The outer membrane with osteoblasts (bone-forming cells) aiding growth and repair.

Compact Bone: The dense middle layer, providing strength, containing osteocytes (mature bone cells).

Spongy Bone: The inner, porous layer with osteoclasts (bone-resorbing cells) that regulate calcium and facilitate remodeling.

➤ Bones are made from **collagen and calcium phosphate**, giving them strength and lightness.

➤ The four bone cell types are:

Osteoblasts: Involved in new bone formation.

Osteocytes: Mature bone cells helping in bone maturation.

Osteoclasts: Break down bone tissue.

Osteoprogenitor cells: Important for fracture repair.

There are five bone types based on shape:

Long Bones: Long and thin (e.g., femur, humerus).

Short Bones: Squat and cubed (e.g., carpals, tarsals).

Flat Bones: Flattened and broad (e.g., skull bones, sternum).

Irregular Bones: Unique shapes (e.g., vertebrae, pelvis).

Sesamoid Bones: Small, flat, seed-shaped (e.g., patella, pisiform)

Functions of Bones

- **Support and Movement:** Bones support body structure, maintain posture, and enable movement.
- **Protection:** Bones protect internal organs (e.g., skull protects the brain, ribs protect heart and lungs).
- **Blood Cell Production:** Bones produce red blood cells, white blood cells, and platelets in bone marrow.
- **Fat Storage and Release:** Some bones store fat and release it when the body needs energy.
- **Mineral Storage and Release:** Bones store minerals like calcium, phosphorus, and vitamin D, releasing them as needed.

Axial Skeleton

- The axial skeleton includes **the skull, trunk, and pelvis**, forming the body's central core.
- The skull consists of **cranium bones** joined by sutures and **facial bones** forming cavities for the eyes, ears, nose, and mouth.
- Key facial bones: **mandible** (lower jaw), **maxilla** (upper jaw), **zygomatic** (cheekbone), and nasal bone.
- **The rib cage** (thoracic cage) includes 12 pairs of **ribs, costal cartilage, and the sternum**, forming the chest (thorax)

Table 5.2 Parts of the axial skeleton parts

Parts of the axial skeleton	Number of bones	Functions
Skull (Cranium 8+Facial 14)	22	It holds and protects the brain.
Ossicles (both ears, 3+3)	6	Auditory
Hyoid (neck)	1	Holds the head
Thoracic (rib cage)	24	It protects the heart and lungs.
Thorax (sternum)	1	Bind and handle the abdomen
Vertebral column	26	Holds up human body
Total bones	80	

Appendicular Skeleton

- The appendicular skeleton includes 126 bones out of the total 206.
- It consists of limbs, pectoral girdle (shoulders), pelvic girdle, and attached appendages.
- It enables movement (locomotion of lower limbs) and manipulation (upper limbs).

It is divided into six major regions.

Table 5.3 Parts of the appendicular skeleton

Appendicular skeleton parts	Number of bones
Shoulder girdles	4
Pelvis	2
Arms and forearms	6
Thighs and legs	8
Hands	54
Feet and ankles	52
Sum	126

Total number of bones in the human body = axial + appendicular = 80 + 126 = 206

The following figure shows both axial and appendicular skeleton (Figure 5.7).

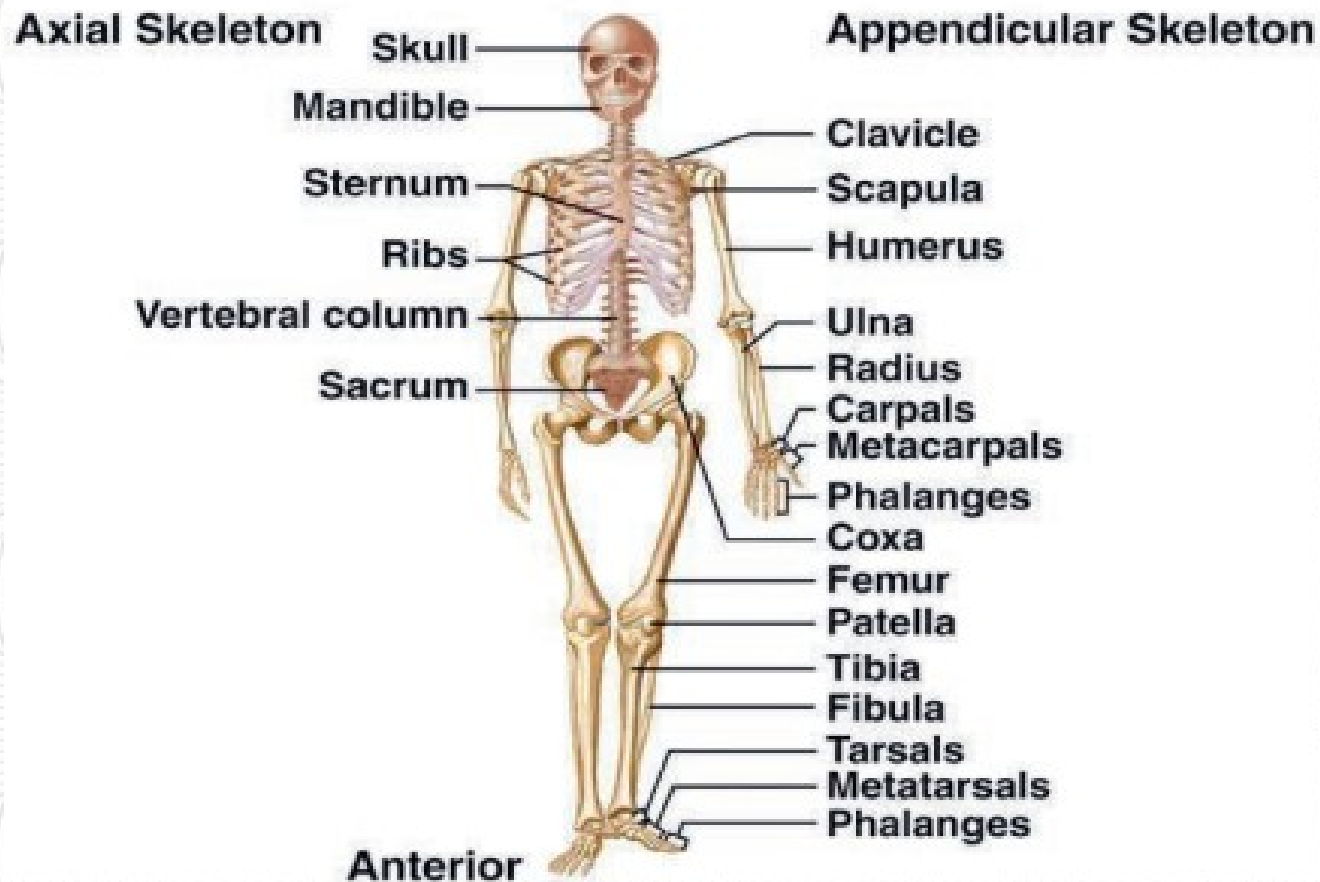


Figure 5.7 Axial and appendicular skeletons

Joints

Joints are where two or more bones meet, connected by binding tissues, allowing body movement.

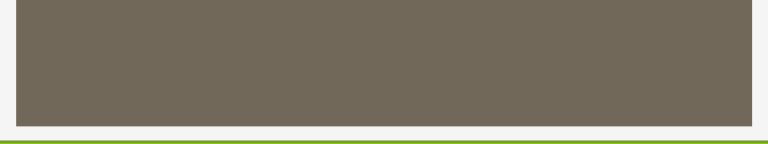
Types of Joints:

- **Ball and Socket Joint:** Allows movement in all directions (e.g., shoulder, hip).
- **Hinge Joint:** Moves in one direction like a door (e.g., elbow, knee).
- **Condylloid Joint:** Allows movement but not rotation (e.g., fingers, jaw).
- **Pivot Joint:** One bone swivels in a ring (e.g., neck, between ulna and radius).
- **Gliding Joint:** Limited sliding movement (e.g., wrist).
- **Saddle Joint:** Moves back and forth, side to side, but no rotation (e.g., thumb base).

The Male Reproductive System

The male reproductive system includes **external organs** (penis, testes, scrotum) and **internal organs** (prostate gland, vas deferens, urethra). These organs work together to produce **sperm, male sex hormones**, and **semen**.

- **Penis** – The male copulatory organ.
- Made of soft, spongy tissue, muscles, fibrous tissue, veins, arteries, and urethra.
- Has two sexual functions: **erection** and **ejaculation**.
- **Erection** is the stiffening of the penis due to sexual arousal or physical stimulation.
- Blood flows into the **corpus cavernosa** and **corpus spongiosum**, causing the penis to fill with blood.
- The veins are compressed, trapping the blood and maintaining the erection.

- 
- **Urethra** - is a tube that connects the urinary bladder to the urinary meatus for the removal of urine from the body.

Urethra allows for the passage of urine to the outside of the body and for the expulsion of sperm during ejaculation.

- **The scrotum** - is a sack of thick skin that protects the testes and controls the temperature of the testes.

It contains seminal vesicles, vas deferens, testicles (testes), and prostate gland.

- **Testes** - are oval pair bodies found in the scrotum with two primary functions:

Production of testosterone or male sex hormones and sperm (spermatogenesis).

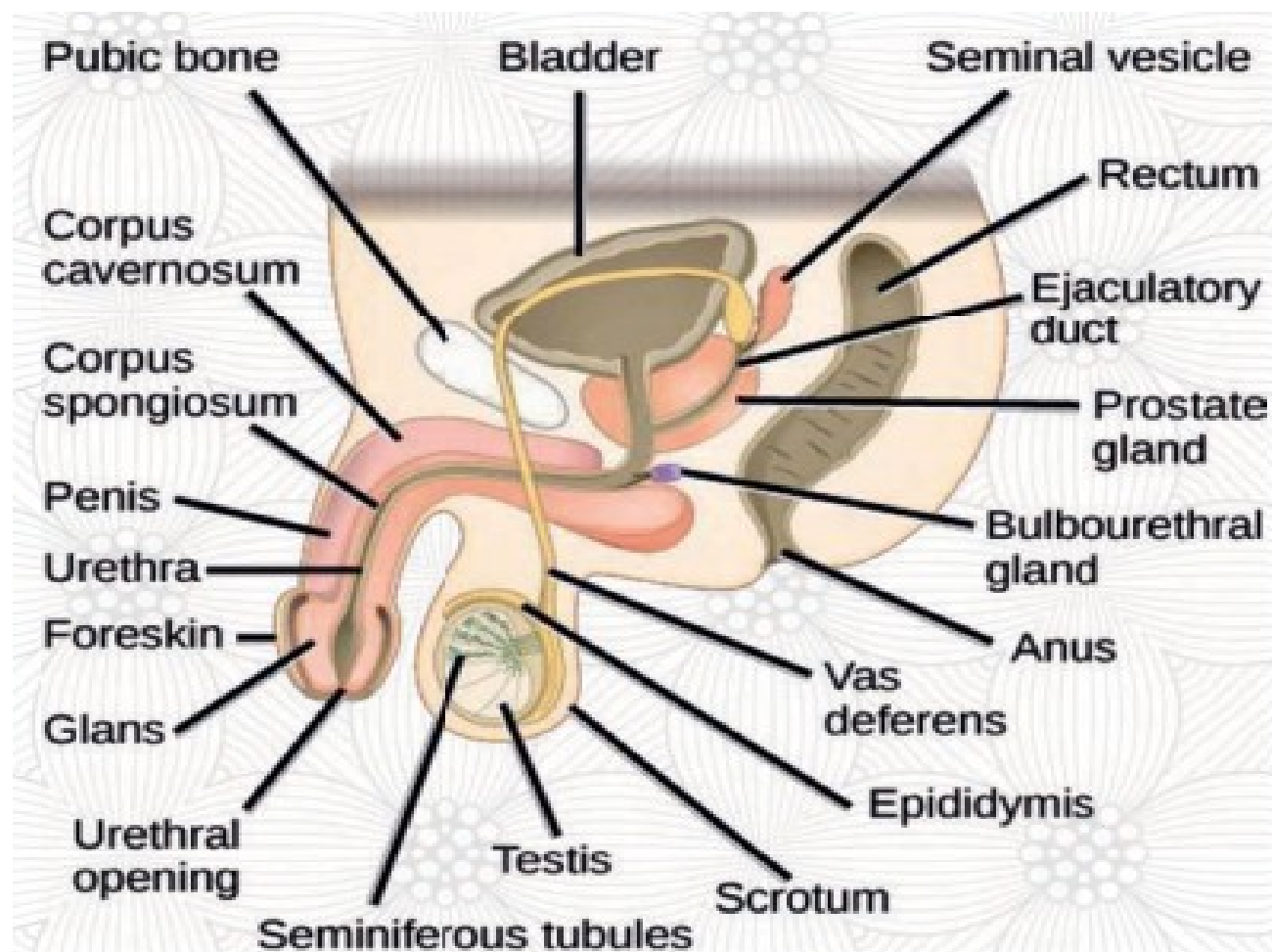


Figure 5.9 Male reproductive systems

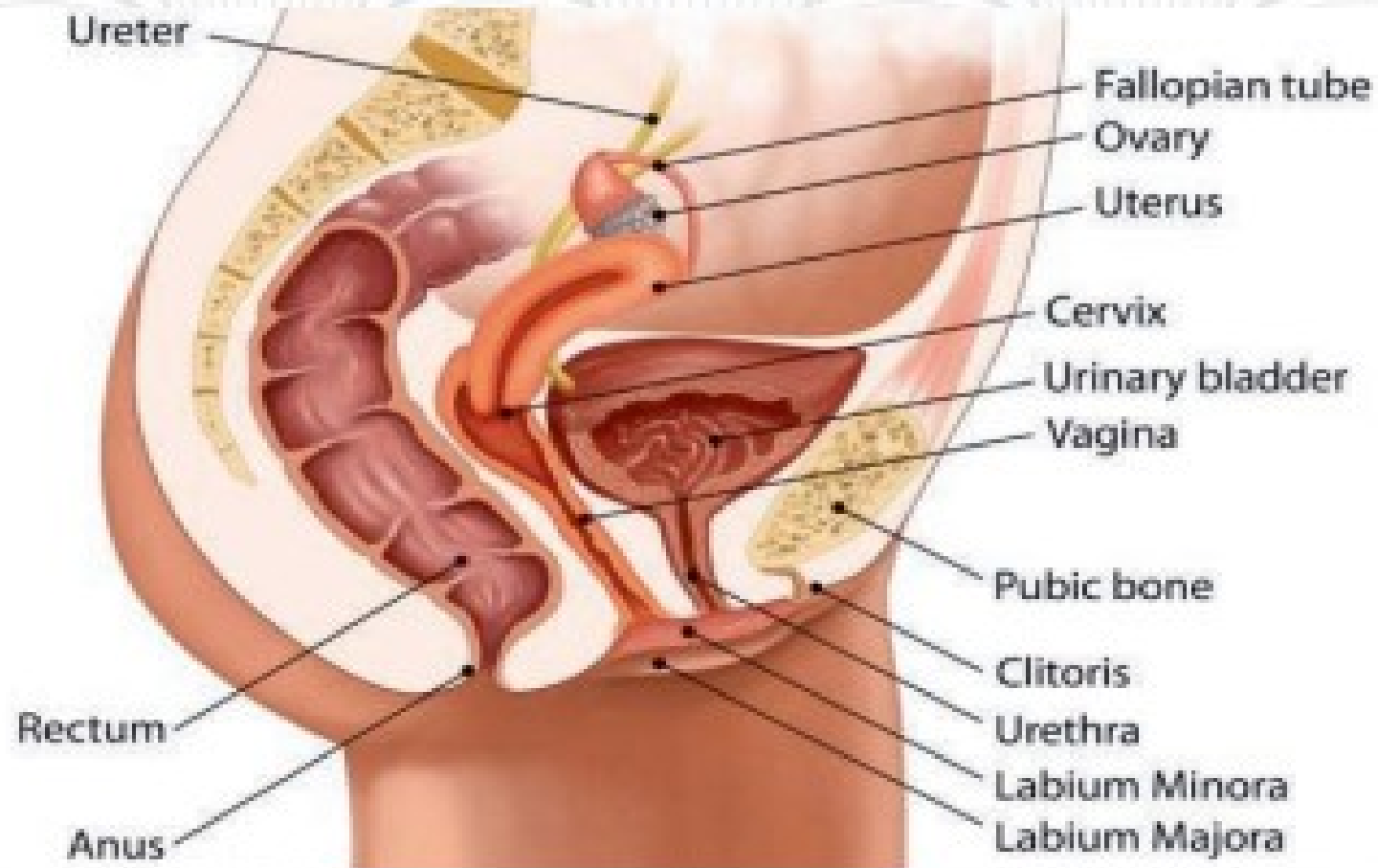


Figure 5.10 Female reproductive system organs

The Female Reproductive System

- The female reproductive system consists of the **ovaries, fallopian tubes, uterus, vagina, accessory glands, and external genital organs.**

Its main functions are:

- Producing **eggs** (female gametes),
- Secreting **sex hormones** (like estrogen),
- Providing a site for **fertilization**,
- **Gestating** a fetus if fertilization occurs,
- **Giving birth** to a baby.

External Reproductive Organs:

Labia majora (“large lips”)

Enclose and protect other external reproductive organs.

During **puberty**, hair grows on their skin, which contains **sweat** and **oil-secreting glands**.

Labia minora (“small lips”)

Vary in size and shape.

Located inside the labia majora.

Surround the **vaginal** and **urethral openings**.

Very delicate and can become **irritated** or **swollen**.

Bartholin’s glands

Located on either side of the vaginal opening.

Produce **mucus (fluid)** for lubrication

Clitoris

- Formed where the two labia minora meet.
- A small, **sensitive** protrusion comparable to the **penis**.
- Covered by a fold of skin called the **prepuce** (similar to the foreskin in males).
- Sensitive to stimulation and can become **erect**.

Internal Reproductive Organs:

Vagina

A **canal** that connects the **cervix** (lower uterus) to the outside.

Also known as the **birth canal**.

Uterus (Womb)

- A **hollow, pear-shaped** organ where a fetus develops.

Two parts:

- **Cervix** – lower part that opens into the vagina.
- **Corpus** – main body that **expands** to hold a baby.
- A **canal** through the cervix allows **sperm** to enter and **menstrual blood** to exit.

Ovaries

- Small, **oval-shaped glands** on each side of the uterus.
- Produce **eggs** and **hormones**.

Fallopian Tubes

- Narrow tubes connected to the **upper uterus**.
- Pathways for **egg cells** (ova) to travel from **ovaries to uterus**.
- **Fertilization** usually occurs here.
- The **fertilized egg** travels to the uterus and implants in the **uterine lining**.

Gametogenesis

- Gametogenesis is the process by which specialized generative cells, **gametes** (sperm or oocytes), are formed from **bipotential primordial germ cells (PGCs)**.
- It involves the transformation of a **diploid ($2n$)** mother cell into a **haploid (n)** daughter cell through **meiosis**.
- In males, this process is called **spermatogenesis**, producing **spermatozoa**.
- In females, it is called **oogenesis**, producing **ova (egg cells)**.

Spermatogenesis

- Occurs in the **seminiferous tubules** of the testis, beginning at **puberty**.
- The **testes** also produce **androgens** (testicular hormones).
- The **germinal epithelium** lines the seminiferous tubules and contains:
- **Cuboidal primordial germ cells (PGCs)** – divide mitotically and meiotically to form sperm.
- **Sertoli cells (tall somatic cells)** – act as **nurse cells**, nourishing developing sperms.
- **Spermatogonia (2n)**: Formed by mitotic division of PGCs.

- Spermatogonia divide to produce **primary spermatocytes** ($2n$), which undergo **meiosis I** to form two **secondary spermatocytes** (n).
- Meiosis II** of secondary spermatocytes produces **four haploid spermatids**.
- Spermiogenesis** transforms spermatids into **spermatozoa (sperm cells)**.
- Final maturation occurs in the **epididymis**, where sperm is secreted as **semen**.

Oogenesis

- Occurs in the **outer layer of ovaries**, starting from **oogonia (germ cells)**.
- By **embryogenesis**, 1–2 million cells are present.
- Oogonia develop into **primary oocytes**, which enter **meiosis** but arrest in division.
- As development continues, the oocyte gives rise to a **haploid oocyte (n)** and a **small polar body**, completing **oogenesis**.

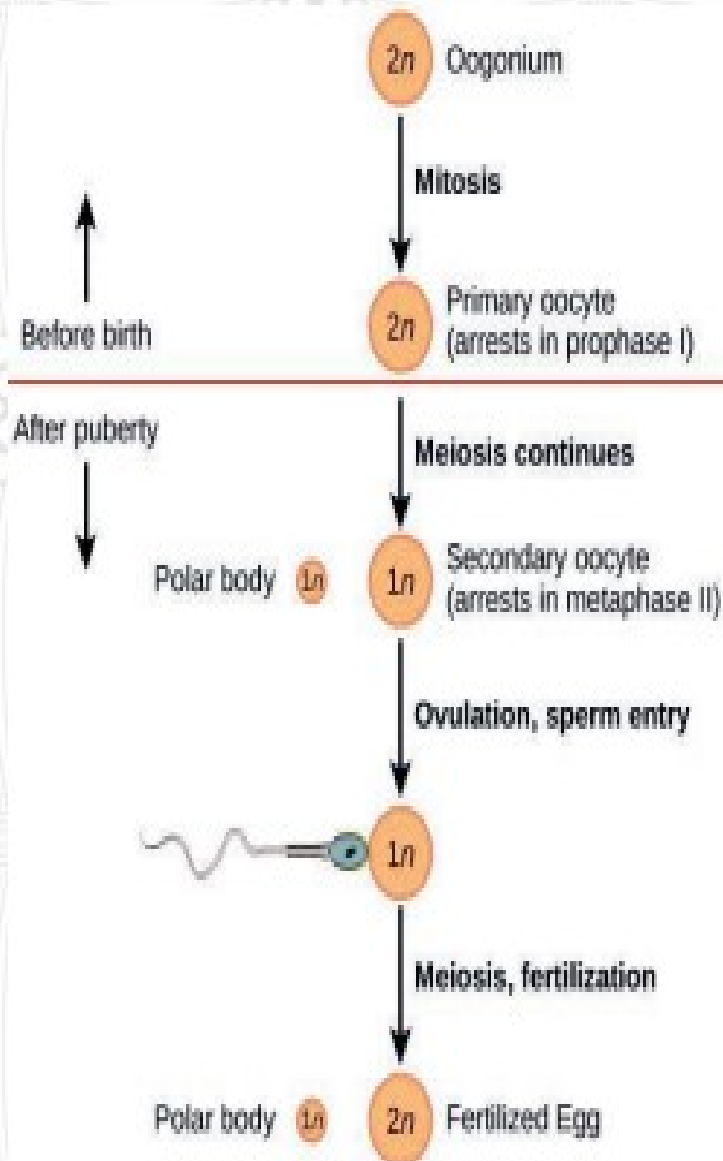
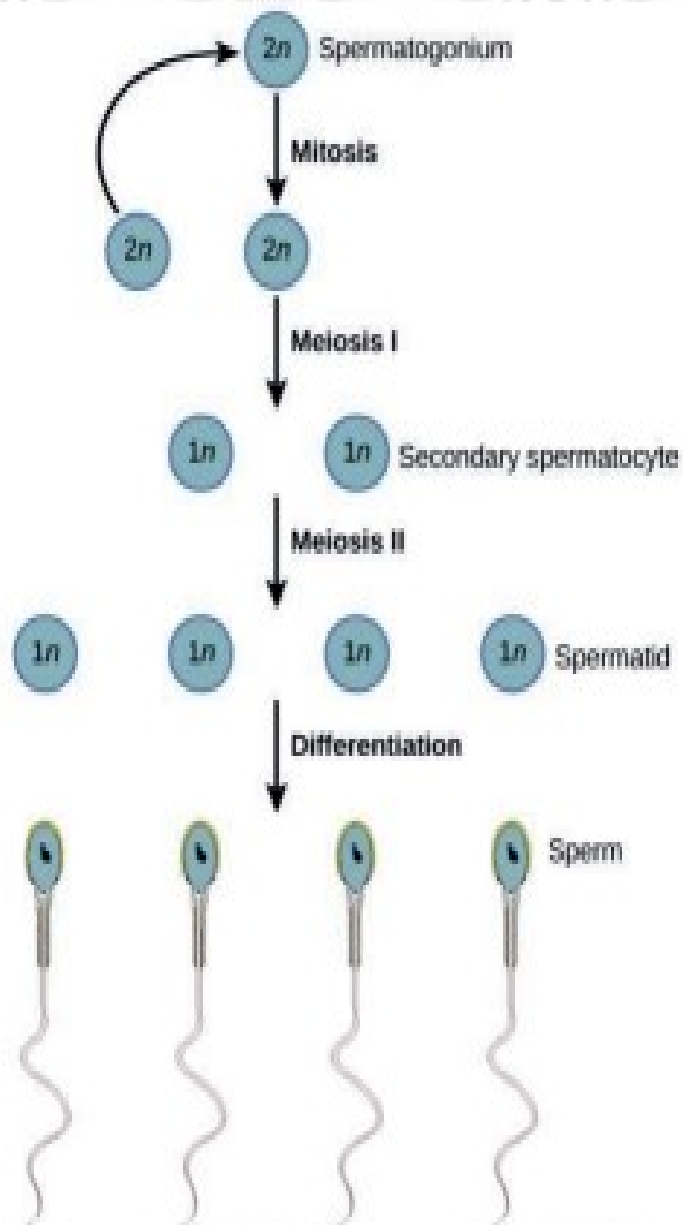


Figure 5.11 Spermatogenesis and oogenesis

Phases of the Menstrual Cycle

- The **menstrual cycle** is a natural, periodical process occurring monthly from **puberty to menopause**, excluding pregnancy.
- It involves the **discharge of blood and other substances** through the vagina.
- It is essential for **pregnancy**.

Two key events occur:

- **Release of an ovum** (egg) from an ovary.
- **Preparation of the uterine endometrium** for implantation of a fertilized egg.
- If the ovum is **not fertilized**, the uterine lining is shed, resulting in **menstruation**.
- The average cycle length is **28 days**.

The menstrual cycle includes **four main phases**:

Follicular Phase

- The **pituitary gland** produces and secretes **follicle-stimulating hormone (FSH)**.
- FSH stimulates the growth of **follicles** and **estrogen** production.

Estrogen provides **negative feedback** to inhibit the growth of other follicles.

Ovulation Phase

- Occurs around **days 12-14** of the cycle.

Estrogen levels rise and provide **positive feedback** to the anterior pituitary.

This triggers a **surge of luteinizing hormone (LH)**.

LH causes the **release of an egg (secondary oocyte)** — this is **ovulation**.

Luteal Phase

- The **ruptured follicle** becomes the **corpus luteum**, which slowly degenerates.
- It secretes high levels of **progesterone** and lower levels of **estrogen**.
- These hormones **thicken the endometrial lining** to prepare for pregnancy.
- They also **inhibit FSH and LH** to prevent development of new follicles.

Menstruation Phase

- If **fertilization occurs**, the embryo implants into the endometrium and releases hormones to **sustain the corpus luteum**.
- If **fertilization does not occur**, the corpus luteum degenerates into **corpus albicans** after about **two weeks**.
- **Estrogen and progesterone levels drop**, leading to shedding of the endometrial lining as **menstrual blood**.

Feedback Mechanisms in the Menstrual Cycle

- **Estrogen** stimulates ovulation and positively feeds back to the **hypothalamus and pituitary** (especially around days 12–14).
- **Progesterone** maintains the **endometrium** and supports gestation (fetal development).
- During pregnancy, **uterine wall dilation and contractions** continue until childbirth.

Table 5.6 Menstrual cycle

Phases	Days	Events
Menstrual Phase	1- 4	Menstruation occurs
Follicular Phase	5-13	Follicle matures and endometrium develops
Ovulation phase	14	Ovary releases an egg
Luteal Phase	15-28	Follicle becomes the corpus luteum and endometrium prepares for an egg

Positive and Negative Feedbacks in the Menstrual Cycle

- A **feedback mechanism** is a physiological regulation system that helps the body maintain **homeostasis**.
- In feedback loops, hormone levels are adjusted to regulate body processes.

Positive Feedback

- **Positive feedback** occurs when the end product of a process **enhances or accelerates** that process.
- In the **menstrual cycle (days 12-14)**, **estrogen** stimulates the **hypothalamus** to release **Gonadotropin Releasing Hormone (GnRH)**.
- GnRH then stimulates the **anterior pituitary gland** to secrete **Luteinizing Hormone (LH)** and **Follicle Stimulating Hormone (FSH)**.
- These hormones work to **trigger ovulation** and prepare the body for potential pregnancy.

Hormonal Roles in Feedback Mechanisms

Luteinizing Hormone (LH)

- **LH** is a **gonadotropic hormone** regulating testes in men and ovaries in women.
- **In men:** Stimulates **testosterone** production to support sperm production.
- **In women:**
 - In **weeks 1-2**, stimulates **ovarian follicles** to produce **estradiol**.
 - Around **day 14**, a surge in LH causes the **follicle to rupture**, releasing a **mature oocyte** – **ovulation**.
 - In **weeks 3-4**, the ruptured follicle becomes the **corpus luteum**, which produces **progesterone** to support early pregnancy.
 - A **rise in LH** acts as **negative feedback**, and **high LH** levels may signal **infertility**.

Follicle Stimulating Hormone (FSH)

- **FSH** plays a role in **sexual development and reproduction**, affecting both ovaries and testicles.

Women are born with **1-2 million eggs**, but only **400,000** reach puberty, and about **400** ovulate during reproductive years. The **brain releases FSH** at the start of each cycle to stimulate **follicle and egg development**.

- **Progesterone** maintains the **uterine lining**, preparing for pregnancy.
- A **rise in FSH** stimulates **follicular growth**, increasing **estradiol** and reducing **GnRH** via **negative feedback**. In the **first half** of the cycle (**follicular phase**), FSH rises, promoting follicle development leading to **ovulation**.
- The **ruptured follicle** becomes a **corpus luteum**, producing **progesterone** (**luteal phase**).
- If **fertilization does not occur**, the **corpus luteum breaks down**, **progesterone drops**, and a **new cycle** begins as FSH rises again.
- In **negative feedback**, if the **egg isn't fertilized**, the **corpus luteum dies**, **progesterone levels fall**, the **uterine lining breaks down**, and **menstruation** occurs.