# Anatomy & Physiology Level 4

## Student Training Guidelines

### Evaluation – Support – Feedback

* Evaluate your client's experience to build confidence.
* Collect feedback from clients to build knowledge.
* Learning to support yourself through head office.

### Certification Requirements

* Question and answer time must be completed.
* Answers must meet the pass criteria.
* Theory work completed and marked prior to physical training.

### Training Brief

* Rules and regulations
* Discrimination and equality
* Blown Aesthetics Code of conduct
* Training breakdown

### Practical assessments and evaluation

* Evaluation and question and answering
* Customer satisfaction

### What will we cover in theory training?

* Paper training manuals
* Paper documentation
* Skills and assessment ability
* Product evaluations and case studies

## Student Training Guidelines

### What will students gain from theory learning?

* Product knowledge - Science and factual evidence
* Industry knowledge
* Confidence
* Listening skills
* Professionalism
* How to approach a client
* How to deal with uneasy clients and the correct protocol
* Refund regulations on products
* Customer care
* Customer service
* Equality and discrimination
* Diversity
* Rules and regulations
* Codes of practise
* Laws and legislations

## Student Training Guidelines

### Conducting practical training

* Interaction
* Hands-on experience
* Evaluations
* Case studies
* Personal experiences
* Role play
* Health and safety
* Observational thinking
* Student input
* Allowing outspoken opinions.
* Showing the student how to complete customer disclaimers
* Demonstrations

## Student Training Guidelines

### What student benefits will they gain from practical learning?

* Data protection knowledge
* Record keeping
* Filling out disclaimers and filing procedures
* Practical application
* Health and safety
* Professionalism
* Customer objections
* Observational hazards
* Cross-contamination/infection

**Please note:** Students must be well presented and have their hair tied back. Students that arrive any later than ten minutes into a training session will not be able to enter the session. This is a distraction for others also attending training.

Leaesthetics would like to thank you for choosing me. I hope you enjoy your experience.

## Contents

1. Organisation of the body-cells, tissues, organs
2. Organ Systems
3. Cardiovascular System
4. Lymphatic/immune system
5. Digestive system
6. Endocrine system
7. Renal/urinary system
8. Skeletal system
9. Reproductive system
10. Nervous system
11. Muscular system
12. Integumentary system
13. The face

## Organisation of the Body

Many people have compared the human body to a machine. Each machine consists of many parts, each part then does a very specific job whilst working in tandem to perform a specific overall function. In Multicellular organisms such as the human body there are different levels of organisation. These levels of organisation co-ordinate and work together enabling the proper functioning of organisms such as the human body.

The human body is organized into 5 different levels of organisation. They comprise of:

* Cells
* Tissues
* Organs
* Organ systems
* The functioning Organism

It is convenient to consider the structures of the body in terms of fundamental levels of organization that increase in complexity: subatomic particles, atoms, molecules, organelles, cells, tissues, organs, organ systems, organisms and biosphere.

## Level 1 - Cells

Cells are the basic units of life and form the first level of organization. A cell is also the smallest unit of life. The name cell is Latin for cella, meaning "small room" is the basic structural, functional, and biological unit of all known living organisms. Cells are often called the "building blocks of life". Cells within the human body have specific functions, examples of this include nerve cells, blood cells, liver cells, and so on. Cells themselves are made of various macromolecules that form organelles. Each organelle in a cell has a defined role, which makes a cell capable of delivering what it is designed to do.

Cells consist of cytoplasm enclosed within a membrane, which contains many biomolecules such as proteins and nucleic acids. Organisms can be classified as unicellular (consisting of a single cell; including bacteria) or multicellular (including plants and animals). While the number of cells in plants and animals varies from species to species, humans contain more than 10 trillion cells. Most plant and animal cells are visible only under a microscope.

### The Cell

The cell contains various structural components to allow it to maintain life which are known as **organelles**. All the organelles are suspended within a gelatinous matrix, the **cytoplasm**, which is contained within the cell membrane. One of the few cells in the human body that lacks almost all organelles are the red blood cells.

The main organelles are as follows:

* cell membrane
* endoplasmic reticulum
* Golgi apparatus
* lysosomes
* mitochondria
* nucleus
* peroxisomes
* microfilaments and microtubules

On the following page I will add a human cell diagram.

### Cell Membrane

The cell membrane is the outer coating of the cell and contains the cytoplasm, substances within it and the organelle. It is a double-layered membrane composed of proteins and lipids. The lipid molecules on the outer and inner part (lipid bilayer) allow it to selectively transport substances in and out of the cell.

### Endoplasmic Reticulum

The endoplasmic reticulum (ER) is a membranous structure that contains a network of tubules and vesicles. Its structure is such that substances can move through it and be kept in isolation from the rest of the cell until the manufacturing processes conducted within are completed. There are two types of endoplasmic reticulum – **rough (granular)** and **smooth (agranular)**.

* The **rough endoplasmic reticulum (RER/granular ER)** contains a combination of proteins and enzymes. These parts of the endoplasmic reticulum contain many ribosomes giving it a rough appearance. Its function is to synthesize new proteins.
* The **smooth endoplasmic reticulum (SER/agranular ER)** does not have any attached ribosomes. Its function is to synthesize different types of lipids (fats). The smooth ER also plays a role in carbohydrate and drug metabolism.

### Golgi Apparatus

The Golgi apparatus is a stacked collection of flat vesicles. It is closely associated with the endoplasmic reticulum in that substances produced in the ER are transported as vesicles and fuses with the Golgi apparatus. In this way, the products from the ER are stored in the Golgi apparatus and converted into different substances that are necessary for the cell’s various functions.

### Lysosomes

Lysosomes are vesicles that break off from the Golgi apparatus. It varies in size and function depending on the type of cell. Lysosomes contain enzymes that help with the digestion of nutrients in the cell and break down any cellular debris or invading microorganisms like bacteria.

A structure that is similar to a lysosome is the **secretory vesicle**. It contains enzymes that are not used within the cell but emptied outside of the cell, for example the secretory vesicles of the pancreatic acinar cell release digestive enzymes which help with the digestion of nutrients in the gut.

### Peroxisomes

These organelles are very similar to the lysosomes and contain enzymes that act together in the form of hydrogen peroxide to neutralize substances that may be toxic to the cell. Peroxisomes are formed directly from the endoplasmic reticulum rather than from the Golgi apparatus like lysosomes.

### Mitochondria

These are the powerhouses of the cell and breakdown nutrients to yield energy. Apart from producing its own energy, it also produces a high-energy compound called **ATP (adenosine triphosphate)** which can be used as a simple energy source elsewhere. Mitochondria are composed of two membranous layers – an outer membrane that surrounds the structure and an inner membrane that provides the physical sites of energy production. The inner membrane has many infoldings that form shelves where enzymes attach and oxidize nutrients. The mitochondria also contain DNA which allows it to replicate where and when necessary.

### Nucleus

The nucleus is the master control of the cell. It contains genes, collections of DNA, which determines every aspect of human anatomy and physiology. The DNA which is arranged into chromosomes also contains the blueprint specific for each type of cell which allows for replication of the cell. Within the nucleus is an area known as the **nucleolus**. It is not enclosed by a membrane but is just an accumulation of RNA and proteins within the nucleus. The nucleolus is the site where the ribosomal RNA is transcribed from DNA and assembled.

### Microfilaments and Microtubules

Microfilaments and microtubules are rigid protein substances that form the internal skeleton of the cell known as the **cytoskeleton**. Some of these microtubules also make up the centrioles and mitotic spindles within the cell which are responsible for the division of the cytoplasm when the cell divides. The microtubules are the central component of cilia, small hair-like projections that protrude from the surface of certain cells. It is also the central component of specialized cilia like the tail of the sperm cells which beats in a manner to allow the cell to move in a fluid medium.

It is convenient to consider the structures of the body in terms of fundamental levels of organization that increase in complexity: subatomic particles, atoms, molecules, organelles, cells, tissues, organs, organ systems, organisms and biosphere.

All living cells are surrounded by a thin, complicated, flexible, waterproof, sensitive, and self repairing container that holds the cell together, allows it to grow, feeds it information and stops the contents from escaping. This is the **cell membrane**.

Although the major component of the membrane, and that which gives it many of its properties, is a double layer of phospholipid molecules, the **lipid bilayer**, almost all the highly specific functions and properties of membranes are the result of actions and properties of proteins.

The quantity of protein in the average cell membrane varies considerably. Highly specialized membranes, such as those found surrounding a mitochondrion, are more than 70% protein, whereas a human nerve cell in the arm or brain, has only slightly more than 20% protein in its structure.

### Hydrophobic and Hydrophilic

The interior and the exterior of cells is liquid, usually a solution or suspension of ions, small molecules and large molecules dissolved in water. Proteins must therefore be **hydrophilic** ("water loving") to be suspended in this environment.

The bilayer of molecules that surround cells, however, is mostly made up of phospholipids arranged in such a way that their hydrocarbon "tails" are all pointing into the centre of the structure.

Hydrocarbon molecules are strongly **hydrophobic** ("water fearing"), and it is this strongly hydrophobic layer of material that gives the cell membrane its "waterproof" nature and allows it to act as a container for the cell and its contents.

It would be useless to make a container of something that easily dissolved in water!

### Crossing the membrane

Some proteins associated with the cell membrane simply connect with one surface or other of the lipid bilayer. They may be attached by way of carbohydrate links, or be complexed with other proteins already embedded in the hydrophobic container.

However, many other proteins extend their structures completely though the bilayer, crossing from one side to another. These **transmembrane proteins** have regions that easily associate with water (i.e. hydrophilic) and other regions which associate easily with the hydrocarbon dominated centre of the bilayer (i.e. hydrophobic).

Other proteins have regions that are hydrophilic, which have no problems in the aqueous environment outside the cell, but also are linked to chains of carbohydrate (oligosaccharides) and then to a separate phospholipid, which has no difficulty fitting into the membrane.

These proteins, called **peripheral membrane proteins**, are only associated with one side of the membrane or the other - never both.

Only the transmembrane proteins can operate on both sides of the membrane at once, and they often serve to "signal" events taking place outside the cell, to vital functions inside the cell.

They also serve as exits and entrances, transporting vital materials from one side of the membrane to the other.

Those regions of the protein that must interact with the strongly hydrophobic centre of the lipid bilayer have sequences of polypeptide that are made up of amino acids with hydrophobic R-groups, such as alanine, leucine, glycine, serine and tyrosine.

It is thought that these hydrophobic lengths of polypeptide coil up into an alpha-helical shape.

Normal eukaryotic cells contain lots and lots of different proteins, making a study of just those proteins associated with the membranes quite difficult. This problem can be solved, however, if the plasma membranes of human red blood cells are used as a starting material.

**Prokaryotic cells** are the cells that do not have a true nucleus and membrane-bound organelles.

Such cells are available in very large numbers, they only have one membrane as part of their structure (the plasma membrane), and it is easy to prepare "ghosts" of these cells by bursting them open in very dilute salt solution and setting free their only contents - the protein haemoglobin.

The remaining, almost pure plasma membrane, can then be studied directly without the problems of contaminating cytoplasmic proteins.

Very often the sheets of pure membrane are resealed into tiny globule; tiny "cells" which can be studied for their membrane properties.

The study of plasma membrane proteins prepared in this way has shown that there are about 15 major proteins in or on the membrane, with three of them **spectrin**, **glycophorin**, and **band-III** accounting for about 60% of the total.

**Spectrin** is found on the inner, cytoplasmic, side of the cell membrane. It is a long, fibrous molecule that makes up about 30% of the total protein found there. It consists of two very large polypeptide chains that wind themselves into a complex that stretches between other protein molecules, such as actin, and several other proteins, including the band-III type and ankyrin.

Together, these proteins appear to form a mesh or network on the inner surface of the red blood cell, which may in turn be responsible for holding the cell in its typical biconcave shape, even as it squeezes through some very, very narrow capillaries in the blood stream.

### Essay Question 1

Please provide all answers on a separate answer sheet.

1. Explain in detail the difference between Hydrophilic and Hydrophobic cells.
2. In Detail explain what DNA is and what is its function.
3. What is the difference between a Eukaryotic and Prokaryotic cell.

## Level 2 - Tissues

A group of cells with similar structure and function is called a **tissue**. A tissue has a specific function which it accomplishes as a result of all its constituent cells working together. Different types of tissues can be found in different organs. In humans, there are four basic types of tissue: **epithelial**, **connective**, **muscular**, and **nervous tissue**. There may be various sub-tissues within each of the primary tissues.

**Epithelial tissue** covers the body surface and forms the lining for most internal cavities. The major function of epithelial tissue includes protection, secretion, absorption, and filtration. The skin is an organ made up of epithelial tissue which protects the body from dirt, dust, bacteria and other microbes that may be harmful. Cells of the epithelial tissue have different shapes These shapes range from thin and flat to cubic or elongated.

**Connective tissue** is the most abundant and the most widely distributed of the tissues. Connective tissues perform a variety of functions including support and protection. The following tissues are found in the human body, ordinary loose connective tissue, fat tissue, dense fibrous tissue, cartilage, bone, blood, and lymph, which are all considered connective tissue.

There are three types of **muscle tissue**: **skeletal**, **smooth**, and **cardiac**. Skeletal muscle is a voluntary type of muscle tissue that is used in the contraction of skeletal parts. Smooth muscle is found in the walls of internal organs and blood vessels. It is an involuntary type. The cardiac muscle is found only in the walls of the heart and is involuntary in nature.

**Nerve tissue** is composed of specialized cells which not only receive stimuli but also conduct impulses to and from all parts of the body. Nerve cells or neurons are long and string-like.

In tissues the simplest combination is called a **membrane**, or a sheet of tissues which cover or line the body surface or divide organs into parts. Examples include the mucous membrane which lines body cavities. Tissues combine to form organs. An organ is a part of the body which performs a definite function. The final units of organization in the body are called systems. A system is a group of organs each of which contributes its share to the function of the body.

### Connective Tissue

Connective tissue connects, supports, binds, or separates other tissues or organs, typically having relatively few cells embedded in an amorphous matrix, often with collagen or other fibres, and including cartilaginous, fatty, and elastic tissues. The connective tissues include several types of fibrous tissue that vary only in their density and cellularity. In the abdominal cavity, most organs are suspended from the abdominal wall by a membranous band known as the **mesentery**, which is supported by connective tissue; others are embedded in **adipose tissue**, a form of connective tissue in which the cells are specialized for the synthesis and storage of energy-rich reserves of fat, or lipid.

The entire body is supported from within by a skeleton composed of **bone**, a type of connective tissue endowed with great resistance to stress owing to its highly ordered laminated structure and to its hardness, which results from deposition of mineral salts in its fibres and amorphous matrix. The individual bones of the skeleton are held firmly together by **ligaments**, and muscles are attached to bone by **tendons**, both of which are examples of dense connective tissue in which many fibre bundles are associated in parallel array to provide great tensile strength.

At joints, the articular surfaces of the bones are covered with **cartilage**, a connective tissue with an abundant intercellular substance that gives it a firm consistency well adapted to permitting smooth gliding movements between the apposed surfaces. The **synovial membrane**, which lines the margins of the joint cavity and lubricates and nourishes the joint surfaces, is also a form of connective tissue.

### Epithelial Tissue

Epithetical tissue is a type of tissue made up of densely packed cells that rest on a basement membrane to act as a covering or lining of various bodily surfaces and cavities. Epithelial tissues line the outer surfaces of organs and blood vessels throughout the body, as well as the inner surfaces of cavities in many internal organs. An example is the epidermis, the outermost layer of the skin.

There are three principal shapes of epithelial cell: **squamous**, **columnar**, and **cuboidal**. These can be arranged in a single layer of cells as **simple epithelium**, either squamous, columnar, cuboidal, pseudo-stratified columnar or in layers of two or more cells deep as **stratified (layered)**, either squamous, columnar or cuboidal. All glands are made up of epithelial cells. Functions of epithelial cells include secretion, selective absorption, protection, transcellular transport, and sensing. Epithelial layers contain no blood vessels, so they must receive nourishment via diffusion of substances from the underlying connective tissue, through the basement membrane.

In general, epithelial tissues are classified by the number of their layers and by the shape and function of the cells.

The three principal shapes associated with epithelial cells are:

* **Squamous epithelium** has cells that are wider than their height (flat and scale-like).
* **Cuboidal epithelium** has cells whose height and width are approximately the same (cube shaped).
* **Columnar epithelium** has cells taller than they are wide (column-shaped).

By layer, epithelium is classed as either **simple epithelium**, only one cell thick (unilayered) or **stratified epithelium** as stratified squamous epithelium, stratified cuboidal epithelium, and stratified columnar epithelium that are two or more cells thick (multi-layered), and both types of layering can be made up of any of the cell shapes. However, when taller simple columnar epithelial cells are viewed in cross section showing several nuclei appearing at different heights, they can be confused with stratified epithelia. This kind of epithelium is therefore described as **pseudostratified columnar epithelium**.

**Transitional epithelium** has cells that can change from squamous to cuboidal, depending on the amount of tension on the epithelium.

#### Simple Epithelium

Simple epithelium is a single layer of cells with every cell in direct contact with the basement membrane that separates it from the underlying connective tissue. In general, it is found where absorption and filtration occur. The thinness of the epithelial barrier facilitates these processes.

In general, simple epithelial tissues are classified by the shape of their cells. The four major classes of simple epithelium are:

1. simple squamous
2. simple cuboidal
3. simple columnar
4. pseudostratified

* **Simple squamous;** which is found lining areas where passive diffusion of gases occur. e.g. skin, walls of capillaries, linings of the pericardial, pleural, and peritoneal cavities, as well as the linings of the alveoli of the lungs.
* **Simple cuboidal:** these cells may have secretory, absorptive, or excretory functions. examples include small collecting ducts of kidney, pancreas, and salivary gland.
* **Simple columnar;** cells can be secretory, absorptive, or excretory; Simple columnar epithelium can be ciliated or non-ciliated; ciliated columnar is found in the female reproductive tract and uterus. Non-ciliated epithelium can also possess microvilli. Some cells contain goblet cells and are referred to as simple glandular columnar epithelium. these secrete mucus and are found in stomach, colon and rectum.
* **Pseudostratified columnar epithelium;** can be ciliated or non-ciliated. The ciliated type is also called respiratory epithelium as it is almost exclusively confined to the larger respiratory airways of the nasal cavity, trachea and bronchi.

#### Stratified Epithelium

Stratified epithelium differs from simple epithelium in that it is multi-layered. It is therefore found where body linings must withstand mechanical or chemical insult such that layers can be abraded and lost without exposing sub epithelial layers. Cells flatten as the layers become more apical, though in their most basal layers the cells can be

### Muscle Tissue

Muscle tissue is a soft tissue that composes muscles in animal bodies, and gives rise to muscles' ability to contract. This is opposed to other components or tissues in muscle such as tendons or perimysium. It is formed during embryonic development through a process known as **myogenesis**.

Muscle tissue varies with function and location in the body. In mammals the three types are: **skeletal or striated muscle**; **smooth or non-striated muscle**; and **cardiac muscle**, which is sometimes known as semi-striated. Smooth and cardiac muscle contracts involuntarily, without conscious intervention. These muscle types may be activated both through interaction of the central nervous system as well as by receiving innervation from peripheral plexus or endocrine (hormonal) activation. Striated or skeletal muscle only contracts voluntarily, upon influence of the central nervous system.

Reflexes are a form of non-conscious activation of skeletal muscles, but nonetheless arise through activation of the central nervous system, albeit not engaging cortical structures until after the contraction has occurred.

The different muscle types vary in their response to neurotransmitters and endocrine substances such as acetylcholine, noradrenaline, adrenaline, nitric oxide and among others depending on muscle type and the exact location of the muscle.

Muscle cells (**myocytes**) are elongated cells ranging from several millimetres to about 10 centimetres in length and from 10 to 100 micrometres in width.

These cells are joined together in tissues that may be either striated or smooth, depending on the presence or absence, respectively, of organized, regularly repeated arrangements of myofibrillar contractile proteins called **myofilaments**. Striated muscle is further classified as either skeletal or cardiac muscle. Striated muscle is typically subject to conscious control, while smooth muscle is not. Thus, muscle tissue can be one of three different types:

* **Skeletal muscle**, striated in structure and under voluntary control, is anchored by tendons (or by aponeuroses at a few places) to bone and is used to effect skeletal movement such as locomotion and to maintain posture. (Though postural control is generally maintained as an unconscious reflex—see proprioception—the muscles responsible also react to conscious control like non-postural muscles.) An average adult male is made up of 42% of skeletal muscle and an average adult female is made up of 36% (as a percentage of body mass). It also has striations unlike smooth muscle.
* **Smooth muscle**, neither striated in structure nor under voluntary control, is found within the walls of organs and structures such as the oesophagus, stomach, intestines, bronchi, uterus, urethra, bladder, blood vessels, and the arrector pili in the skin (in which it controls erection of body hair).
* In vertebrates, there is a third muscle tissue recognized: **Cardiac muscle (myocardium)**, found only in the heart, is a striated muscle similar in structure to skeletal muscle but not subject to voluntary control.

Cardiac and skeletal muscles are "striated" in that they contain sarcomeres and are packed into highly regular arrangements of bundles; smooth muscle has neither. While skeletal muscles are arranged in regular, parallel bundles, cardiac muscle connects at

Striated muscle contracts and relaxes in short, intense bursts, whereas smooth muscle sustains longer or even near-permanent contractions.

### Nervous Tissue

Nervous tissue or nerve tissue is the main tissue component of the two parts of the nervous system; the **brain** and **spinal cord** of the central nervous system (CNS), and the branching **peripheral nerves** of the peripheral nervous system (PNS), which regulates and controls bodily functions and activity. Nervous tissue is made up of different types of nerve cells, all of which have an **axon**, the long stem-like part of the cell that sends action potential signals to the next cell. Bundles of axons make up the nerves.

Functions of the nervous system are sensory input, integration, control of muscles and glands, homeostasis, and mental activity.

Nervous tissue is composed of **neurons**, also called nerve cells, and **neuroglial cells**. Four types of neuroglia found in the CNS are **astrocytes**, **microglial cells**, **ependymal cells** and **oligodendrocytes**. Two types of neuroglia found in the PNS are **satellite cells** and **Schwann cells**. In the central nervous system (CNS), the tissue types found are **grey matter** and **white matter**. The tissue is categorized by its neuronal and neuroglial components. Neurons are cells with specialized features that allow them to receive and facilitate nerve impulses, or action potentials, across their membrane to the next neuron. They possess a large cell body (**soma**), with cell projections called **dendrites** and an **axon**. Dendrites are thin, branching projections that receive electrochemical signalling (neurotransmitters) to create a change in voltage in the cell. Axons are long projections that carry the action potential away from the cell body toward the next neuron.

The bulb-like end of the axon, called the **axon terminal**, is separated from the dendrite of the following neuron by a small gap called a **synaptic cleft**. When the action potential travels to the axon terminal, neurotransmitters are released across the synapse and bind to the post-synaptic receptors, continuing the nerve impulse.

## Level 3 - Organs

Two or more tissues organise to form **organs** which then serve a specific function. Examples are brain, heart, lungs, kidney, liver, and so on, each of which have definite functions. Most organs are made of all four types of tissue. The intestine, for example, is made of epithelial tissue as the inner lining, which helps in enzyme secretion and nutrient absorption. Epithelial tissue is covered by layers of muscle tissue, which help in peristaltic movements to move the food bolus. The intestine is also supplied by blood tissue (connective tissue) which helps in transporting nutrients absorbed by the intestine, and is connected to the brain through the nerve tissue, which conveys instructions from the brain.

## Level 4 - Organ Systems

A group of organs form the **organ system**, and together they perform a function. The heart and the blood vessels together make the **cardiovascular system**. Organs such as the nose, pharynx, trachea, lungs and the diaphragm work together as the **respiratory system**. The mouth, oesophagus, stomach, duodenum, and the intestines together form the **digestive system**. Other examples of organ system include the **endocrine system**, **integumentary system**, **muscular system**, **reproductive system**, **skeletal system**, **urinary system**, **immune system**, etc.

### Essay Question 2

Please complete on a separate answer sheet

Name the major tissues and organs that together make the organ systems stated below:

1. Cardiovascular system
2. Digestive system
3. Endocrine system
4. Integumentary system
5. Respiratory System
6. Nervous System

## Level 5: Organism

All the organ systems work together and carry out all life process’s in one single organism that is made up to be the human body. Life processes of the human body can now be maintained at several levels of structural organization due to the above levels we have discussed. They can eat, excrete, grow, reproduce, and respond to any environment.

## The Cardiovascular System

The cardiovascular system consists of the **heart**, **blood vessels**, and the approximately 5 litres of **blood** that the blood vessels transport. Responsible for transporting oxygen, nutrients, hormones, and cellular waste products throughout the body, the cardiovascular system is powered by the body’s hardest working organ — the heart, which is only about the size of a closed fist. Even at rest, the average heart easily pumps over 5 litres of blood throughout the body every minute.

The heart is a muscular pumping organ located medial to the lungs along the body’s midline in the thoracic region. The bottom tip of the heart, known as its **apex**, is turned to the left, so that about 2/3 of the heart is located on the body’s left side with the other 1/3 on right. The top of the heart, known as the heart’s **base**, connects to the great blood vessels of the body: the **aorta**, **vena cava**, **pulmonary trunk**, and **pulmonary veins**.

### Circulatory Loops

There are 2 primary circulatory loops in the human body: the **pulmonary circulation loop** and the **systemic circulation loop**.

* **Pulmonary circulation** transports deoxygenated blood from the right side of the heart to the lungs, where the blood picks up oxygen and returns to the left side of the heart. The pumping chambers of the heart that support the pulmonary circulation loop are the **right atrium** and **right ventricle**.
* **Systemic circulation** carries highly oxygenated blood from the left side of the heart to all the tissues of the body (except for the heart and lungs). Systemic circulation removes wastes from body tissues and returns deoxygenated blood to the right side of the heart. The **left atrium** and **left ventricle** of the heart are the pumping chambers for the systemic circulation loop.

The heart sits within a fluid-filled cavity called the **pericardial cavity**. The walls and lining of the pericardial cavity are a special membrane known as the **pericardium**. Pericardium is a type of serous membrane that produces serous fluid to lubricate the heart and prevent friction between the ever-beating heart and its surrounding organs. Besides lubrication, the pericardium serves to hold the heart in position and maintain a hollow space for the heart to expand into when it is full.

The pericardium has 2 layers—a **visceral layer** that covers the outside of the heart and a **parietal layer** that forms a sac around the outside of the pericardial cavity. The heart wall is made of 3 layers: **epicardium**, **myocardium** and **endocardium**.

* **Epicardium:** The epicardium is the outermost layer of the heart wall and is just another name for the visceral layer of the pericardium. Thus, the epicardium is a thin layer of serous membrane that helps to lubricate and protect the outside of the heart. Below the epicardium is the second, thicker layer of the heart wall: the myocardium.
* **Myocardium:** The myocardium is the muscular middle layer of the heart wall that contains the cardiac muscle tissue. Myocardium makes up most of the thickness and mass of the heart wall and is the part of the heart responsible for pumping blood. Below the myocardium is the thin endocardium layer.
* **Endocardium:** Endocardium is the simple squamous endothelium layer that lines the inside of the heart. The endocardium is very smooth and is responsible for keeping blood from sticking to the inside of the heart and forming potentially deadly blood clots.

The thickness of the heart wall varies in different parts of the heart. The atria of the heart have a very thin myocardium because they do not need to pump blood very far—only to the nearby ventricles. The ventricles, on the other hand, have a very thick myocardium to pump blood to the lungs or throughout the entire body. The right side of the heart has less myocardium in its walls than the left side because the left side must pump blood through the entire body while the right side only must pump to the lungs.

### Chambers of the Heart

The heart contains 4 chambers: the **right atrium**, **left atrium**, **right ventricle**, and **left ventricle**. The atria are smaller than the ventricles and have thinner, less muscular walls than the ventricles. The atria act as receiving chambers for blood, so they are connected to the veins that carry blood to the heart. The ventricles are the larger, stronger pumping chambers that send blood out of the heart. The ventricles are connected to the arteries that carry blood away from the heart.

The chambers on the right side of the heart are smaller and have less myocardium in their heart wall when compared to the left side of the heart. This difference in size between the sides of the heart is related to their functions and the size of the 2 circulatory loops. The right side of the heart maintains pulmonary circulation to the nearby lungs while the left side of the heart pumps blood all the way to the extremities of the body in the systemic circulatory loop.

### Valves of the Heart

The heart functions by pumping blood both to the lungs and to the systems of the body. To prevent blood from flowing backwards or “regurgitating” back into the heart, a system of one-way valves is present in the heart. The heart valves can be broken down into two types: **atrioventricular** and **semilunar valves**.

* **Atrioventricular (AV) valves:** The atrioventricular (AV) valves are located in the middle of the heart between the atria and ventricles and only allow blood to flow from the atria into the ventricles.
  + The AV valve on the right side of the heart is called the **tricuspid valve** because it is made of three cusps (flaps) that separate to allow blood to pass through and connect to block regurgitation of blood.
  + The AV valve on the left side of the heart is called the **mitral valve** or the **bicuspid valve** because it has two cusps.
  + The AV valves are attached on the ventricular side to tough strings called **chordae tendineae**. The chordae tendineae pull on the AV valves to keep them from folding backwards and allowing blood to regurgitate past them. During the contraction of the ventricles, the AV valves look like domed parachutes with the chordae tendineae acting as the ropes holding the parachutes taut.
* **Semilunar valves:** The semilunar valves, so named for the crescent moon shape of their cusps, are located between the ventricles and the arteries that carry blood away from the heart.
  + The semilunar valve on the right side of the heart is the **pulmonary valve**, so named because it prevents the backflow of blood from the pulmonary trunk into the right ventricle.
  + The semilunar valve on the left side of the heart is the **aortic valve**, named for the fact that it prevents the aorta from regurgitating blood back into the left ventricle.
  + The semilunar valves are smaller than the AV valves and do not have chordae tendineae to hold them in place. Instead, the cusps of the semilunar valves are cup shaped to catch regurgitating blood and use the blood’s pressure to snap shut.

### Conduction System of the Heart

The heart is able to both set its own rhythm and to conduct the signals necessary to maintain and coordinate this rhythm throughout its structures. About 1% of the cardiac muscle cells in the heart are responsible for forming the conduction system that sets the pace for the rest of the cardiac muscle cells.

The conduction system starts with the pacemaker of the heart—a small bundle of cells known as the **sinoatrial (SA) node**. The SA node is located in the wall of the right atrium inferior to the superior vena cava. The SA node is responsible for setting the pace of the heart as a whole and directly signals the atria to contract. The signal from the SA node is picked up by another mass of conductive tissue known as the **atrioventricular (AV) node**.

The AV node is located in the right atrium in the inferior portion of the interatrial septum. The AV node picks up the signal sent by the SA node and transmits it through the **atrioventricular (AV) bundle**. The AV bundle is a strand of conductive tissue that runs through the interatrial septum and into the interventricular septum. The AV bundle splits into left and right branches in the interventricular septum and continues running through the septum until they reach the apex of the heart. Branching off from the left and right bundle branches are many **Purkinje fibers** that carry the signal to the walls of the ventricles, stimulating the cardiac muscle cells to contract in a coordinated manner to efficiently pump blood out of the heart.

### Physiology of the Heart

#### Coronary Systole and Diastole

At any given time, the chambers of the heart may be found in one of two states:

* **Systole:** During systole, cardiac muscle tissue is contracting to push blood out of the chamber.
* **Diastole:** During diastole, the cardiac muscle cells relax to allow the chamber to fill with blood.

Blood pressure increases in the major arteries during ventricular systole and decreases during ventricular diastole. This leads to the 2 numbers associated with blood pressure—systolic blood pressure is the higher number and diastolic blood pressure is the lower number. For example, a blood pressure of 120/80 describes the systolic pressure (120) and the diastolic pressure (80).

#### The Cardiac Cycle

The cardiac cycle includes all the events that take place during one heartbeat. There are 3 phases to the cardiac cycle: **atrial systole**, **ventricular systole**, and **relaxation**.

1. **Atrial systole:** During the atrial systole phase of the cardiac cycle, the atria contract and push blood into the ventricles. To facilitate this filling, the AV valves stay open and the semilunar valves stay closed to keep arterial blood from re-entering the heart. The atria are much smaller than the ventricles, so they only fill about 25% of the ventricles during this phase. The ventricles remain in diastole during this phase.
2. **Ventricular systole:** During ventricular systole, the ventricles contract to push blood into the aorta and pulmonary trunk. The pressure of the ventricles forces the semilunar valves to open and the AV valves to close. This arrangement of valves allows for blood flow from the ventricles into the arteries. The cardiac muscles of the atria repolarize and enter the state of diastole during this phase.
3. **Relaxation phase:** During the relaxation phase, all 4 chambers of the heart are in diastole as blood pours into the heart from the veins. The ventricles fill to about 75% capacity during this phase and will be filled only after the atria enter systole. The cardiac muscle cells of the ventricles repolarize during this phase to prepare for the next round of depolarization and contraction. During this phase, the AV valves open to allow blood to flow freely into the ventricles while the semilunar valves close to prevent the regurgitation of blood from the great arteries into the ventricles.

## Blood Vessels

Blood vessels are the body’s highways that allow blood to flow quickly and efficiently from the heart to every region of the body and back again. The size of blood vessels corresponds with the amount of blood that passes through the vessel. All blood vessels contain a hollow area called the **lumen** through which blood can flow through Around the lumen is the wall of the vessel, which may be thin in the case of capillaries or very thick in the case of arteries.

All blood vessels are lined with a thin layer of simple squamous epithelium known as the **endothelium** that keeps blood cells inside of the blood vessels and prevents clots from forming. The endothelium lines the entire circulatory system, all the way to the interior of the heart, where it is called the **endocardium**.

There are three major types of blood vessels: **arteries**, **capillaries** and **veins**. Blood vessels are often named after either the region of the body through which they carry blood or for nearby structures. For example, the **brachiocephalic artery** carries blood into the brachial (arm) and cephalic (head) regions. One of its branches, the **subclavian artery**, runs under the clavicle; hence the name subclavian. The subclavian artery runs into the axillary region where it becomes known as the **axillary artery**.

### Arteries

Arteries are blood vessels that carry blood away from the heart. Blood carried by arteries is usually highly oxygenated, having just left the lungs on its way to the body’s tissues. The pulmonary trunk and arteries of the pulmonary circulation loop provide an exception to this rule — these arteries carry deoxygenated blood from the heart to the lungs to be oxygenated.

Arteries face high levels of blood pressure as they carry blood being pushed from the heart under great force. To withstand this pressure, the walls of the arteries are thicker, more elastic, and more muscular than those of other vessels. The largest arteries of the body contain a high percentage of elastic tissue that allows them to stretch and accommodate the pressure of the heart.

Smaller arteries are more muscular in the structure of their walls. The smooth muscles of the arterial walls of these smaller arteries contract or expand to regulate the flow of blood through their lumen. In this way, the body controls how much blood flows to different parts of the body under varying circumstances. The regulation of blood flow also affects blood pressure, as smaller arteries give blood less area to flow through and therefore increases the pressure of the blood on arterial walls.

**Arterioles** are narrower arteries that branch off from the ends of arteries and carry blood to capillaries. They face much lower blood pressures than arteries due to their greater number, decreased blood volume, and distance from the direct pressure of the heart. Thus, arteriole walls are much thinner than those of arteries. Arterioles, like arteries, can use smooth muscle to control their aperture and regulate blood flow and blood pressure.

### Capillaries

Capillaries are the smallest and thinnest of the blood vessels in the body and the most common. They can be found running throughout almost every tissue of the body and border the edges of the body’s avascular tissues. Capillaries connect to arterioles on one end and venules on the other.

Capillaries carry blood very close to the cells of the tissues of the body to exchange gases, nutrients, and waste products. The walls of capillaries consist of only a thin layer of endothelium so that there is the minimum amount of structure possible between the blood and the tissues.

### Veins and Venules

Veins are the large return vessels of the body and act as the blood return counterparts of arteries. Because the arteries, arterioles, and capillaries absorb most of the force of the heart’s contractions, veins and venules are subjected to very low blood pressures. This lack of pressure allows the walls of veins to be much thinner, less elastic, and less muscular than the walls of arteries.

Veins rely on gravity, inertia, and the force of skeletal muscle contractions to help push blood back to the heart. To facilitate the movement of blood, some veins contain many one-way valves that prevent blood from flowing away from the heart. As skeletal muscles in the body contract, they squeeze nearby veins and push blood through valves closer to the heart.

When the muscle relaxes, the valve traps the blood until another contraction pushes the blood closer to the heart. **Venules** are like arterioles as they are small vessels that connect capillaries, but unlike arterioles, venules connect to veins instead of arteries. Venules pick up blood from many capillaries and deposit it into larger veins for transport back to the heart.

### Coronary Circulation

The heart has its own set of blood vessels that provide the myocardium with the oxygen and nutrients necessary to pump blood throughout the body. The **left and right coronary arteries** branch off from the aorta and provide blood to the left and right sides of the heart. The **coronary sinus** is a vein on the posterior side of the heart that returns deoxygenated blood from the myocardium to the vena cava.

### Hepatic Portal Circulation

The veins of the stomach and intestines perform a unique function: instead of carrying blood directly back to the heart, they carry blood to the liver through the **hepatic portal vein**. Blood leaving the digestive organs is rich in nutrients and other The liver removes toxins, stores sugars, and processes the products of digestion before they reach the other body tissues. Blood from the liver then returns to the heart through the inferior vena cava.

## Blood

The average human body contains about 4 to 5 litres of blood. As a liquid connective tissue, it transports many substances through the body and helps to maintain homeostasis of nutrients, wastes, and gases. Blood is made up of **red blood cells**, **white blood cells**, **platelets**, and liquid **plasma**.

### Red Blood Cells

Red blood cells, also known as **erythrocytes**, are by far the most common type of blood cell and make up about 45% of blood volume. Erythrocytes are produced inside of red bone marrow from stem cells at the astonishing rate of about 2 million cells every second. The shape of erythrocytes is biconcave—disks with a concave curve on both sides of the disk so that the centre of an erythrocyte is its thinnest part.

The unique shape of erythrocytes gives these cells a high surface area to volume ratio and allows them to fold to fit into thin capillaries. Immature erythrocytes have a nucleus that is ejected from the cell when it reaches maturity to provide it with its unique shape and flexibility. The lack of a nucleus means that red blood cells contain no DNA and are not able to repair themselves once damaged.

Erythrocytes transport oxygen in the blood through the red pigment **haemoglobin**. Haemoglobin contains iron and proteins joined to greatly increase the oxygen carrying capacity of erythrocytes. The high surface area to volume ratio of erythrocytes allows oxygen to be easily transferred into the cell in the lungs and out of the cell in the capillaries of the systemic tissues.

### White Blood Cells

White blood cells, also known as **leukocytes**, make up a very small percentage of the total number of cells in the bloodstream, but have important functions in the body’s immune system. There are two major classes of white blood cells: **granular leukocytes** and **agranular leukocytes**.

* **Granular Leukocytes:** The three types of granular leukocytes are **neutrophils**, **eosinophils**, and **basophils**. Each type of granular leukocyte is classified by the presence of chemical-filled vesicles in their cytoplasm that give them their function.
  + **Neutrophils** contain digestive enzymes that neutralize bacteria that invade the body.
  + **Eosinophils** contain digestive enzymes specialized for digesting viruses that have been bound to by antibodies in the blood.
  + **Basophils** release histamine to intensify allergic reactions and help protect the body from parasites
* **Agranular Leukocytes:** The two major classes of agranular leukocytes are **lymphocytes** and **monocytes**.
  + **Lymphocytes** include T cells and natural killer cells that fight off viral infections and B cells that produce antibodies against infections by pathogens.
  + **Monocytes** develop into cells called macrophages that engulf and ingest pathogens and the dead cells from wounds or infections.

### Platelets

Also known as **thrombocytes**, platelets are small cell fragments responsible for the clotting of blood and the formation of scabs. Platelets form in the red bone marrow from large **megakaryocyte** cells that periodically rupture and release thousands of pieces of membrane that become the platelets. Platelets do not contain a nucleus and only survive in the body for up to a week before macrophages capture and digest them.

### Plasma

Plasma is the non-cellular or liquid portion of the blood that makes up about 55% of the blood’s volume. Plasma is a mixture of water, proteins, and dissolved substances. Around 90% of plasma is made of water, although the exact percentage varies depending upon the hydration levels of the individual. The proteins within plasma include **antibodies** and **albumins**. Antibodies are part of the immune system and bind to antigens on the surface of pathogens that infect the body. Albumins help maintain the body’s osmotic balance by providing an isotonic solution for the cells of the body.

Many different substances can be found dissolved in the plasma, including glucose, oxygen, carbon dioxide, electrolytes, nutrients, and cellular waste products. The plasma functions as a transportation medium for these substances as they move throughout the body.

### Functions of the Cardiovascular System

The cardiovascular system has three major functions:

1. **Transportation:** The cardiovascular system transports blood to almost all the body’s tissues. The blood delivers essential nutrients and oxygen and removes wastes and carbon dioxide to be processed or removed from the body. Hormones are transported throughout the body via the blood’s liquid plasma.
2. **Protection:** The cardiovascular system protects the body through its white blood cells. White blood cells clean up cellular debris and fight pathogens that have entered the body. Platelets and red blood cells form scabs to seal wounds and prevent pathogens from entering the body and liquids from leaking out. Blood also carries antibodies that provide specific immunity to pathogens that the body has previously been exposed to or has been vaccinated against.
3. **Regulation:** The cardiovascular system is instrumental in the body’s ability to maintain homeostatic control of several internal conditions. Blood vessels help maintain a stable body temperature by controlling the blood flow to the surface of the skin. Blood vessels near the skin’s surface open during times of overheating to allow hot blood to dump its heat into the body’s surroundings. In the case of hypothermia, these blood vessels constrict to keep blood flowing only to vital organs in the body’s core. Blood also helps balance the body’s pH due to the presence of bicarbonate ions, which act as a buffer solution. Finally, the albumins in blood plasma help to balance the osmotic concentration of the body’s cells by maintaining an isotonic environment.

### Essay question 3

Please complete on a separate answer sheet.

1. Describe the 3 functions of the cardiovascular system.
2. In detail explain the difference between veins and arteries including the function.
3. What is the SA node?
4. In detail explain the cardiac cycle
5. Name the 4 chambers of the heart

## Lymphatic / Immune System

The lymphatic system is a network of tissues and organs that help rid the body of toxins, waste and other unwanted materials. The primary function of the lymphatic system is to transport **lymph**, a fluid containing infection-fighting white blood cells, throughout the body.

The lymphatic system is part of the vascular system and an important part of the immune system, the lymphatic system helps keep the body healthy by eliminating infections and diseases.

The lymphatic system primarily consists of **lymphatic vessels**, which are like the circulatory system's veins and capillaries. The vessels are connected to **lymph nodes**, where the lymph is filtered. The **tonsils**, **adenoids**, **spleen** and **thymus** are all part of the lymphatic system.

There are hundreds of lymph nodes in the human body. They are located deep inside the body, such as around the lungs and heart, or closer to the surface, such as under the arm or groin. The lymph nodes are found from the head to around the knee area.

The **spleen**, which is located on the left side of the body just above the kidney, is the largest lymphatic organ. The spleen acts as a blood filter; it controls the amount of red blood cells and blood storage in the body, and helps to fight infection. If the spleen detects potentially dangerous bacteria, viruses, or other microorganisms in the blood, the spleen along with the lymph nodes create white blood cells called **lymphocytes**, which act as defenders against invaders. The lymphocytes produce antibodies to kill the foreign microorganisms and stop infections from spreading.

Humans can live without a spleen, although people who have lost their spleen to disease or injury are more prone to infections.

The **thymus** is in the chest just above the heart. This small organ stores immature lymphocytes (specialized white blood cells) and prepares them to become active T cells, which help destroy infected or cancerous cells.

**Tonsils** are large clusters of lymphatic cells found in the pharynx. They are the bodies first line of defence as part of the immune system. They sample bacteria and viruses that enter the body through the mouth or nose.

## The Digestive System

The digestive system is a group of organs working together to convert food into energy and basic nutrients to feed the entire body. Food passes through a long tube inside the body known as the **alimentary canal** or the **gastrointestinal tract (GI tract)**. The alimentary canal is made up of the **oral cavity**, **pharynx**, **oesophagus**, **stomach**, **small intestines**, and **large intestines**. In addition to the alimentary canal, there are several important accessory organs that help your body to digest food but do not have food pass through them. Accessory organs of the digestive system include the **teeth**, **tongue**, **salivary glands**, **liver**, **gallbladder**, and **pancreas**. To achieve the goal of providing energy and nutrients to the body, six major functions take place in the digestive system:

1. Ingestion
2. Secretion
3. Mixing and movement
4. Digestion
5. Absorption
6. Excretion

### Mouth

Food begins its journey through the digestive system in the mouth, also known as the **oral cavity**. Inside the mouth are many accessory organs that aid in the digestion of food—the tongue, teeth, and salivary glands. Teeth chop food into small pieces, which are moistened by saliva before the tongue and other muscles push the food into the pharynx.

### Teeth

The teeth are 32 small, hard organs found along the anterior and lateral edges of the mouth. Each tooth is made of a bone-like substance called **dentin** and covered in a layer of **enamel**—the hardest substance in the body. Teeth are living organs and contain blood vessels and nerves under the dentin in a soft region known as the **pulp**. The teeth are designed for cutting and grinding food into smaller pieces.

### Tongue

The tongue is located on the inferior portion of the mouth just posterior and medial to the teeth. It is a small organ made up of several pairs of muscles covered in a thin, bumpy, skin-like layer. The outside of the tongue contains many rough **papillae** for gripping food as it is moved by the tongue’s muscles. The **taste buds** on the surface of the tongue detect taste molecules in food and connect to nerves in the tongue to send taste information to the brain. The tongue also helps to push food toward the posterior part of the mouth for swallowing.

### Salivary Glands

Surrounding the mouth are 3 sets of salivary glands. The salivary glands are accessory organs that produce a watery secretion known as **saliva**. Saliva helps to moisten food and begins the digestion of carbohydrates. The body also uses saliva to lubricate food as it passes through the mouth, pharynx, and oesophagus.

* The two **parotid glands** are major salivary glands wrapped around the mandibular ramus in humans. These are largest of the salivary glands, secreting saliva to facilitate mastication and swallowing, and amylase to begin the digestion of starches. It is the serous type of gland which secretes ptyalin. It enters the oral cavity via the parotid duct (Stensen duct). The glands are located posterior to the mandibular ramus and anterior to the mastoid process of the temporal bone. They are clinically relevant in dissections of facial nerve branches while exposing the different lobes, since any iatrogenic lesion will result in either loss of action or strength of muscles involved in facial expression. They produce 20% of the total salivary content in the oral cavity. Mumps is a viral infection, caused by infection in the parotid gland.
* The **submandibular glands** (previously known as submaxillary glands) are a pair of major salivary glands located beneath the lower jaws, superior to the digastric muscles. The secretion produced is a mixture of both serous fluid and mucus, and enters the oral cavity via the submandibular duct or Wharton duct. Approximately 65-70% of saliva in the oral cavity is produced by the submandibular glands, even though they are much smaller than the parotid glands. This gland can usually be felt via palpation of the neck, as it is in the superficial cervical region and feels like a rounded ball. It is located about two fingers above the Adam's apple (laryngeal prominence) and about two inches apart under the chin.
* The **sublingual glands** are a pair of major salivary glands located inferior to the tongue, anterior to the submandibular glands. The secretion produced is mainly mucous in nature; however, it is categorized as a mixed gland. Unlike the other two major glands, the ductal system of the sublingual glands does not have intercalated ducts and usually does not have striated ducts either, so saliva exits directly from 8-20 excretory ducts known as the Rivinus ducts. Approximately 5% of saliva entering the oral cavity comes from these glands.

### Pharynx

The pharynx, or throat, is a funnel-shaped tube connected to the posterior end of the mouth. The pharynx is responsible for the passing of masses of chewed food from the mouth to the oesophagus. The pharynx also plays an important role in the respiratory system, as air from the nasal cavity passes through the pharynx on its way to the larynx and eventually the lungs. Because the pharynx serves two different functions, it contains a flap of tissue known as the **epiglottis** that acts as a switch to route food to the oesophagus and air to the larynx.

### Oesophagus

The oesophagus is a muscular tube connecting the pharynx to the stomach that is part of the upper gastrointestinal tract. It carries swallowed masses of chewed food along its length. At the inferior end of the oesophagus is a muscular ring called the **lower oesophageal sphincter** or **cardiac sphincter**. The function of this sphincter is to close of the end of the oesophagus and trap food in the stomach.

In much of a digestive tract such as the human gastrointestinal tract, smooth muscle tissue contracts in sequence to produce a **peristaltic wave**, which propels a ball of food (called a **bolus** while in the oesophagus and upper gastrointestinal tract and **chyme** in the stomach) along the tract.

### Stomach

The stomach is a muscular sac that is located on the left side of the abdominal cavity, just inferior to the diaphragm. In an average person, the stomach is about the size of their two fists placed next to each other. This major organ acts as a storage tank for food so that the body has time to digest large meals properly. The stomach also contains hydrochloric acid and digestive enzymes that continue the digestion of food that began in the mouth.

### Small Intestine

The small intestine is a long, thin tube about 1 inch in diameter and about 10 feet long that is part of the lower gastrointestinal tract. It is located just inferior to the stomach and takes up most of the space in the abdominal cavity. The entire small intestine is coiled like a hose and the inside surface is full of many ridges and folds. These folds are used to maximize the digestion of food and absorption of nutrients. By the time food leaves the small intestine, around 90% of all nutrients have been extracted from the food that entered it.

### Liver and Gallbladder

The **liver** is a roughly triangular accessory organ of the digestive system located to the right of the stomach, just inferior to the diaphragm and superior to the small intestine. The liver weighs about 3 pounds and is the second largest organ in the body. The liver has many different functions in the body, but the main function of the liver in digestion is the production of **bile** and its secretion into the small intestine. The **gallbladder** is a small, pear-shaped organ located just posterior to the liver. The gallbladder is used to store and recycle excess bile from the small intestine so that it can be reused for the digestion of subsequent meals.

### Pancreas

The pancreas is a large gland located just inferior and posterior to the stomach. It is about 6 inches long and shaped like short, lumpy snake with its “head” connected to the duodenum and its “tail” pointing to the left wall of the abdominal cavity. The pancreas secretes digestive enzymes into the small intestine to complete the chemical digestion of foods.

### Large Intestine

The large intestine is a long, thick tube about 2.5 inches in diameter and about 5 feet long. It is located just inferior to the stomach and wraps around the superior and lateral border of the small intestine. The large intestine absorbs water and contains many symbiotic bacteria that aid in the breaking down of wastes to extract some small amounts of nutrients. Faeces in the large intestine exit the body through the anal canal.

### Functions of the Digestive System

1. **Ingestion:** The first function of the digestive system is ingestion, or the intake of food. The mouth is responsible for this function, as it is the orifice through which all food enters the body. The mouth and stomach are also responsible for the storage of food as it is waiting to be digested. This storage capacity allows the body to eat only a few times each day and to ingest more food than it can process at one time.
2. **Secretion:** During a day, the digestive system secretes around 7 litres of fluids. These fluids include saliva, mucus, hydrochloric acid, enzymes, and bile. Saliva moistens dry food and contains salivary amylase, a digestive enzyme that begins the digestion of carbohydrates. Mucus serves as a protective barrier and lubricant inside of the GI tract. Hydrochloric acid helps to digest food chemically and protects the body by killing bacteria present in our food. Enzymes are like tiny biochemical machines that disassemble large macromolecules like proteins, carbohydrates, and lipids into their smaller components. Finally, bile is used to emulsify large masses of lipids into tiny globules for easy digestion.
3. **Mixing and Movement:** The digestive system uses 3 main processes to move and mix food:
   * **Swallowing:** Swallowing is the process of using smooth and skeletal muscles in the mouth, tongue, and pharynx to push food out of the mouth, through the pharynx, and into the oesophagus.
   * **Peristalsis:** Peristalsis is a muscular wave that travels the length of the GI tract, moving partially digested food a short distance down the tract. It takes many waves of peristalsis for food to travel from the oesophagus, through the stomach and intestines, and reach the end of the GI tract.
   * **Segmentation:** Segmentation occurs only in the small intestine as short segments of intestine contract like hands squeezing a toothpaste tube. Segmentation helps to increase the absorption of nutrients by mixing food and increasing its contact with the walls of the intestine.
4. **Digestion:** Digestion is the process of turning large pieces of food into its component chemicals.
   * **Mechanical digestion** is the physical breakdown of large pieces of food into smaller pieces. This mode of digestion begins with the chewing of food by the teeth and is continued through the muscular mixing of food by the stomach and intestines. Bile produced by the liver is also used to mechanically break fats into smaller globules.
   * While food is being mechanically digested it is also being **chemically digested** as larger and more complex molecules are being broken down into smaller molecules that are easier to absorb. Chemical digestion begins in the mouth with salivary amylase in saliva splitting complex carbohydrates into simple carbohydrates. The enzymes and acid in the stomach continue chemical digestion, but the bulk of chemical digestion takes place in the small intestine thanks to the action of the pancreas. The pancreas secretes an incredibly strong digestive cocktail known as pancreatic juice, which is capable of digesting lipids, carbohydrates, proteins and nucleic acids. By the time food has left the duodenum, it has been reduced to its chemical building blocks—fatty acids, amino acids, monosaccharides, and nucleotides.
5. **Absorption:** Once food has been reduced to its building blocks, it is ready for the body to absorb. Absorption begins in the stomach with simple molecules like water and alcohol being absorbed directly into the bloodstream. Most absorption takes place in the walls of the small intestine, which are densely folded to maximize the surface area in contact with digested food. Small blood and lymphatic vessels in the intestinal wall pick up the molecules and carry them to the rest of the body. The large intestine is also involved in the absorption of water and vitamins B and K before faeces leave the body.
6. **Excretion:** The final function of the digestive system is the excretion of waste in a process known as **defecation**. Defecation removes indigestible substances from the body so that they do not accumulate inside the gut. The timing of defecation is controlled voluntarily by the conscious part of the brain, but must be accomplished on a regular basis to prevent a backup of indigestible materials.

### Essay question 4

Please place your answer on a separate answer sheet.

1. In detail please explain the process of absorption which occurs within the digestive system?
2. Please name the organs which make up the digestive system.
3. Explain what peristalsis is

## The Endocrine System

The endocrine system is a series of glands that produce and secrete **hormones** that the body uses for a wide range of functions. The group of glands of an organism that carry those hormones directly into the circulatory system to be carried towards distant target organs, and the feedback loops of homeostasis that the hormones drive. In humans, the major endocrine glands are the **thyroid gland** and the **adrenal glands**.

In vertebrates, the **hypothalamus** is the neural control centre for all endocrine systems. Special features of endocrine glands are, in general, their ductless nature, their vascularity, and commonly the presence of intracellular vacuoles or granules that store their hormones.

In contrast, **exocrine glands**, such as salivary glands, sweat glands, and glands within the gastrointestinal tract, tend to be much less vascular and have ducts or a hollow lumen. A number of glands that signal each other in sequence are usually referred to as an **axis**.

These control many different bodily functions, including:

* Respiration
* Metabolism
* Reproduction
* Sensory perception
* Movement
* Sexual development
* Growth

The endocrine system works alongside of the nervous system to form the control systems of the body. The nervous system provides a very fast and narrowly targeted system to turn on specific glands and muscles throughout the body. The endocrine system, on the other hand, is much slower acting, but has very widespread, long lasting, and powerful effects. Hormones are distributed by glands through the bloodstream to the entire body, affecting any cell with a receptor for a particular hormone. Most hormones affect cells in several organs or throughout the entire body, leading to many diverse and powerful responses.

In addition to the specialized endocrine organs mentioned above, many other organs that are part of other body systems, such as bone, kidney, liver, heart and gonads, have secondary endocrine functions. For example, the kidney secretes endocrine hormones such as **erythropoietin** and **renin**. Hormones can consist of either amino acid complexes, steroids, eicosanoids, leukotrienes, or prostaglandins.

The endocrine system contrasts with the exocrine system, which secretes its hormones to the outside of the body using ducts. As opposed to endocrine factors that travel considerably longer distances via the circulatory system, other signalling molecules, such as paracrine factors involved in paracrine signalling diffuse over a relatively short distance.

### Anatomy of the Endocrine System

#### Hypothalamus

The hypothalamus is a part of the brain located superior and anterior to the brain stem and inferior to the thalamus. It serves many different functions in the nervous system, and is also responsible for the direct control of the endocrine system through the pituitary gland. The hypothalamus contains special cells called **neurosecretory cells**—neurons that secrete hormones:

* Thyrotropin-releasing hormone (TRH)
* Growth hormone-releasing hormone (GHRH)
* Growth hormone-inhibiting hormone (GHIH)
* Gonadotropin-releasing hormone (GnRH)
* Corticotropin-releasing hormone (CRH)
* Oxytocin
* Antidiuretic hormone (ADH)

All the releasing and inhibiting hormones affect the function of the anterior pituitary gland. TRH stimulates the anterior pituitary gland to release thyroid-stimulating hormone. GHRH and GHIH work to regulate the release of growth hormone—GHRH stimulates growth hormone release, GHIH inhibits its release. GnRH stimulates the release of follicle stimulating hormone and luteinizing hormone while CRH stimulates the release of adrenocorticotropic hormone. The last two hormones—oxytocin and antidiuretic hormone—are produced by the hypothalamus and transported to the posterior pituitary, where they are stored and later released

#### Pituitary Gland

The pituitary gland, also known as the **hypophysis**, is a small pea-sized lump of tissue connected to the inferior portion of the hypothalamus of the brain.

Many blood vessels surround the pituitary gland to carry the hormones it releases throughout the body. Situated in a small depression in the sphenoid bone called the **Sella turcica**, the pituitary gland is made of 2 separate structures: the **posterior** and **anterior pituitary glands**.

* **Posterior Pituitary:** The posterior pituitary gland is not glandular tissue at all, but nervous tissue instead. The posterior pituitary is a small extension of the hypothalamus through which the axons of some of the neurosecretory cells of the hypothalamus extend. These neurosecretory cells create 2 hormones in the hypothalamus that are stored and released by the posterior pituitary:
  + **Oxytocin** triggers uterine contractions during childbirth and the release of milk during breastfeeding.
  + **Antidiuretic hormone (ADH)** prevents water loss in the body by increasing the re-uptake of water in the kidneys and reducing blood flow to sweat glands.
* **Anterior Pituitary:** The anterior pituitary gland is the true glandular part of the pituitary gland. The function of the anterior pituitary gland is controlled by the releasing and inhibiting hormones of the hypothalamus. The anterior pituitary produces 6 important hormones:
  + **Thyroid stimulating hormone (TSH)**, as its name suggests, is a tropic hormone responsible for the stimulation of the thyroid gland.
  + **Adrenocorticotropic hormone (ACTH)** stimulates the adrenal cortex, the outer part of the adrenal gland, to produce its hormones.
  + **Follicle stimulating hormone (FSH)** stimulates the follicle cells of the gonads to produce gametes—ova in females and sperm in males.
  + **Luteinizing hormone (LH)** stimulates the gonads to produce the sex hormones—oestrogens in females and testosterone in males.
  + **Human growth hormone (HGH)** affects many target cells throughout the body by stimulating their growth, repair, and reproduction.
  + **Prolactin (PRL)** has many effects on the body, chief of which is that it stimulates the mammary glands of the breast to produce milk.

#### Pineal Gland

The pineal gland is a small pinecone-shaped mass of glandular tissue found just posterior to the thalamus of the brain. The pineal gland produces the hormone **melatonin** that helps to regulate the human sleep-wake cycle known as the **circadian rhythm**. The activity of the pineal gland is inhibited by stimulation from the photoreceptors of the retina. This light sensitivity causes melatonin to be produced only in low light or darkness. Increased melatonin production causes humans to feel drowsy at night-time when the pineal gland is active.

#### Thyroid Gland

The thyroid gland is a butterfly-shaped gland located at the base of the neck and wrapped around the lateral sides of the trachea. The thyroid gland produces 3 major hormones:

* **Calcitonin**
* **Triiodothyronine (T3)**
* **Thyroxine (T4)**

Calcitonin is released when calcium ion levels in the blood rise above a certain set point. Calcitonin functions to reduce the concentration of calcium ions in the blood by aiding the absorption of calcium into the matrix of bones. The hormones T3 and T4 work together to regulate the body’s metabolic rate. Increased levels of T3 and T4 lead to increased cellular activity and energy usage in the body.

#### Parathyroid Glands

The parathyroid glands are 4 small masses of glandular tissue found on the posterior side of the thyroid gland. The parathyroid glands produce the hormone **parathyroid hormone (PTH)**, which is involved in calcium ion homeostasis. PTH is released from the parathyroid glands when calcium ion levels in the blood drop below a set point. PTH stimulates the osteoclasts to break down the calcium containing bone matrix to release free calcium ions into the bloodstream. PTH also triggers the kidneys to return calcium ions filtered out of the blood back to the blood stream so that it is conserved.

#### Adrenal Glands

The adrenal glands are a pair of roughly triangular glands found immediately superior to the kidneys. The adrenal glands are each made of 2 distinct layers, each with their own unique functions: the outer **adrenal cortex** and inner **adrenal medulla**.

* **Adrenal Cortex:** The adrenal cortex produces many cortical hormones in 3 classes: **glucocorticoids**, **mineralocorticoids**, and **androgens**.
  + **Glucocorticoids** have many diverse functions, including the breakdown of proteins and lipids to produce glucose. Glucocorticoids also function to reduce inflammation and immune response.
  + **Mineralocorticoids**, as their name suggests, are a group of hormones that help to regulate the concentration of mineral ions in the body.
  + **Androgens**, such as testosterone, are produced at low levels in the adrenal cortex to regulate the growth and activity of cells that are receptive to male hormones. In adult males, the number of androgens produced by the testes is many times greater than the amount produced by the adrenal cortex, leading to the appearance of male secondary sex characteristics.
* **Adrenal Medulla:** The adrenal medulla produces the hormones **epinephrine** and **norepinephrine** under stimulation by the sympathetic division of the autonomic nervous system. Both hormones help to increase the flow of blood to the brain and muscles to improve the “fight-or-flight” response to stress. These hormones also work to increase heart rate, breathing rate, and blood pressure while decreasing the flow of blood to and function of organs that are not involved in responding to emergencies.

#### Pancreas

The pancreas is a large gland located in the abdominal cavity just inferior and posterior to the stomach. The pancreas is a heteroaryne gland as it contains both endocrine and exocrine tissue. The endocrine cells of the pancreas make up just about 1% of the total mass of the pancreas and are found in small groups throughout the pancreas called **islets of Langerhans**. Within these islets are 2 types of cells—**alpha** and **beta cells**.

* The **alpha cells** produce the hormone **glucagon**, which is responsible for raising blood glucose levels. Glucagon triggers muscle and liver cells to breakdown the polysaccharide glycogen to release glucose into the bloodstream.
* The **beta cells** produce the hormone **insulin**, which is responsible for lowering blood glucose levels after a meal. Insulin triggers the absorption of glucose from the blood into cells, where it is added to glycogen molecules for storage.

#### Gonads

The gonads—**ovaries** in females and **testes** in males—are responsible for producing the sex hormones of the body. These sex hormones determine the secondary sex characteristics of adult females and adult males.

* **Testes:** The testes are a pair of ellipsoid organs found in the scrotum of males that produce the androgen **testosterone** in males after the start of puberty. Testosterone has effects on many parts of the body, including the muscles, bones, sex organs, and hair follicles. This hormone causes growth and increases in strength of the bones and muscles, including the accelerated growth of long bones during adolescence. During puberty, testosterone controls the growth and development of the sex organs and body hair of males, including pubic, chest, and facial hair. In men who have inherited genes for baldness testosterone triggers the onset of androgenic alopecia, commonly known as male pattern baldness.
* **Ovaries:** The ovaries are a pair of almond-shaped glands located in the pelvic body cavity lateral and superior to the uterus in females. The ovaries produce the female sex hormones **progesterone** and **oestrogens**. Progesterone is most active in females during ovulation and pregnancy where it maintains appropriate conditions in the human body to support a developing foetus. Oestrogens are a group of related hormones that function as the primary female sex hormones. The release of oestrogen during puberty triggers the development of female secondary sex characteristics such as uterine development, breast development, and the growth of pubic hair. Oestrogen also triggers the increased growth of bones during adolescence that lead to adult height and proportions.

#### Thymus

The thymus is a soft, triangular-shaped organ found in the chest posterior to the sternum. The thymus produces hormones called **thymosins** that help to train and develop T-lymphocytes during foetal development and childhood. The T-lymphocytes produced in the thymus go on to protect the body from pathogens throughout a person’s entire life. The thymus becomes inactive during puberty and is slowly replaced by adipose tissue throughout a person’s life.

#### Other Hormone Producing Organs

In addition to the glands of the endocrine system, many other non-glandular organs and tissues in the body produce hormones as well.

* **Heart:** The cardiac muscle tissue of the heart can produce the hormone **atrial natriuretic peptide (ANP)** in response to high blood pressure levels. ANP works to reduce blood pressure by triggering vasodilation to provide more space for the blood to travel through. ANP also reduces blood volume and pressure by causing water and salt to be excreted out of the blood by the kidneys.
* **Kidneys:** The kidneys produce the hormone **erythropoietin (EPO)** in response to low levels of oxygen in the blood. EPO released by the kidneys travels to the red bone marrow where it stimulates an increased production of red blood cells. The number of red blood cells increases the oxygen carrying capacity of the blood, eventually ending the production of EPO.
* **Digestive System:** The hormones **cholecystokinin (CCK)**, **secretin**, and **gastrin** are all produced by the organs of the gastrointestinal tract. CCK, secretin, and gastrin all help to regulate the secretion of pancreatic juice, bile, and gastric juice in response to the presence of food in the stomach. CCK is also instrumental in the sensation of satiety or “fullness” after eating a meal.
* **Adipose:** Adipose tissue produces the hormone **leptin** that is involved in the management of appetite and energy usage by the body. Leptin is produced at levels relative to the amount of adipose tissue in the body, allowing the brain to monitor the body’s energy storage condition. When the body contains a sufficient level of adipose for energy storage, the level of leptin in the blood tells the brain that the body is not starving and may work normally. If the level of adipose or leptin decreases below a certain threshold, the body enters starvation mode and attempts to conserve energy through increased hunger and food intake and decreased energy usage. Adipose tissue also produces very low levels of oestrogens in both men and women. In obese people the large volume of adipose tissue may lead to abnormal oestrogen levels.
* **Placenta:** In pregnant women, the placenta produces several hormones that help to maintain pregnancy. **Progesterone** is produced to relax the uterus, protect the foetus from the mother’s immune system, and prevent premature delivery of the foetus. **Human chorionic gonadotropin (HCG)** assists progesterone by signalling the ovaries to maintain the production of oestrogen and progesterone throughout pregnancy.

#### Local Hormones

**Prostaglandins** and **leukotrienes** are produced by every tissue in the body (except for blood tissue) in response to damaging stimuli. These two hormones mainly affect the cells that are local to the source of damage, leaving the rest of the body free to function normally.

* **Prostaglandins** cause swelling, inflammation, increased pain sensitivity, and increased local body temperature to help block damaged regions of the body from infection or further damage. They act as the body’s natural bandages to keep pathogens out and swell around damaged joints like a natural cast to limit movement.
* **Leukotrienes** help the body heal after prostaglandins have taken effect by reducing inflammation while helping white blood cells to move into the region to clean up pathogens and damaged tissues.

### Hormone Properties

Once hormones have been produced by glands, they are distributed through the body via the bloodstream. As hormones travel through the body, they pass through cells or along the plasma membranes of cells until they encounter a receptor for that hormone. Hormones can only affect **target cells** that have the appropriate receptors. This property of hormones is known as **specificity**. Hormone specificity explains how each hormone can have specific effects in widespread parts of the body.

Many hormones produced by the endocrine system are classified as **tropic hormones**. A tropic hormone is a hormone that can trigger the release of another hormone in another gland. Tropic hormones provide a pathway of control for hormone production as well as a way for glands to be controlled in distant regions of the body. Many of the hormones produced by the pituitary gland, such as TSH, ACTH, and FSH are tropic hormones.

### Hormonal Regulation

The levels of hormones in the body can be regulated by several factors. The nervous system can control hormone levels through the action of the hypothalamus and its releasing and inhibiting hormones. For example, TRH produced by the hypothalamus stimulates the anterior pituitary to produce TSH. Tropic hormones provide another level of control for the release of hormones. For example, TSH is a tropic hormone that stimulates the thyroid gland to produce T3 and T4. Nutrition can also control the levels of hormones in the body. For example, the thyroid hormones T3 and T4 require 3 or 4 iodine atoms, respectively, to be produced. In people lacking iodine in their diet, they will fail to produce sufficient levels of thyroid hormones to maintain a healthy metabolic rate. Finally, the number of receptors present in cells can be varied by cells in response to hormones. Cells that are exposed to high levels of hormones for extended periods of time can begin to reduce the number of receptors that they produce, leading to reduced hormonal control of the cell.

### Classes of Hormones

Hormones are classified into 2 categories depending on their chemical make-up and solubility: **water-soluble** and **lipid-soluble** hormones. Each of these classes of hormones has specific mechanisms for their function that dictate how they affect their target cells.

* **Water-soluble hormones:** Water-soluble hormones include the peptide and amino-acid hormones such as insulin, epinephrine, HGH, and oxytocin. As their name indicates, these hormones are soluble in water. Water-soluble hormones are unable to pass through the phospholipid bilayer of the plasma membrane and are therefore dependent upon receptor molecules on the surface of cells. When a water-soluble hormone binds to a receptor molecule on the surface of a cell, it triggers a reaction inside of the cell. This reaction may change a factor inside of the cell such as the permeability of the membrane or the activation of another molecule. A common reaction is to cause molecules of **cyclic adenosine monophosphate (cAMP)** to be synthesized from **adenosine triphosphate (ATP)** present in the cell. cAMP acts as a second messenger within the cell where it binds to a second receptor to change the function of the cell’s physiology.
* **Lipid-soluble hormones:** Lipid-soluble hormones include the steroid hormones such as testosterone, oestrogens, glucocorticoids, and mineralocorticoids. Because they are soluble in lipids, these hormones can pass directly through the phospholipid bilayer of the plasma membrane and bind directly to receptors inside the cell nucleus. Lipid-soluble hormones can directly control the function of a cell from these receptors, often triggering the transcription of genes in the DNA to produce “messenger RNAs (mRNAs)” that are used to make proteins that affect the cell’s growth and function.

### Essay question 5

Please place your answer on a separate answer sheet.

1. In details please describe the difference in the Endocrine system in males and females including the hormones produced.
2. Name 3 of the hormones produced, where are they come from and their function

## The Renal /Urinary System

The urinary system, also known as the **renal system** or **urinary tract**. The purpose of the urinary system is to eliminate waste from the body, regulate blood volume and blood pressure, control levels of electrolytes and metabolites, and regulate blood ph.

The urinary system consists of the **kidneys**, **ureters**, **urinary bladder**, and **urethra**. The kidneys filter the blood to remove wastes and produce urine. The ureters, urinary bladder, and urethra together form the urinary tract, which acts as a plumbing system to drain urine from the kidneys, store it, and then release it during urination. Besides filtering and eliminating wastes from the body, the urinary system also maintains the homeostasis of water, ions, pH, blood pressure, calcium and red blood cells.

The urinary tract is the body's drainage system for the eventual removal of urine. The kidneys have an extensive blood supply via the **renal arteries** which leave the kidneys via the **renal vein**. Each kidney consists of functional units called **nephrons**. Following filtration of blood and further processing, wastes (in the form of urine) exit the kidney via the ureters, tubes made of smooth muscle fibres that propel urine towards the urinary bladder, where it is stored and subsequently expelled from the body by urination (voiding). The female and male urinary system are very similar, differing only in the length of the urethra.

Urine is formed in the kidneys through a filtration of blood. The urine is then passed through the ureters to the bladder, where it is stored. During urination, the urine is passed from the bladder through the urethra to the outside of the body.

800–2,000 millilitres (mL) of urine are normally produced every day in a healthy human. This amount varies according to fluid intake and kidney function.

### Urinary System Anatomy

#### Kidneys

The kidneys are a pair of bean-shaped organs found along the posterior wall of the abdominal cavity. The left kidney is located slightly higher than the right kidney because the right side of the liver is much larger than the left side. The kidneys, unlike the other organs of the abdominal cavity, are located posterior to the peritoneum and touch the muscles of the back.

The kidneys are surrounded by a layer of adipose that holds them in place and protects them from physical damage. The kidneys filter metabolic wastes, excess ions, and chemicals from the blood to form urine.

#### Ureters

The ureters are a pair of tubes that carry urine from the kidneys to the urinary bladder. The ureters are about 10 to 12 inches long and run on the left and right sides of the body parallel to the vertebral column. Gravity and peristalsis of smooth muscle tissue in the walls of the ureters move urine toward the urinary bladder. The ends of the ureters extend slightly into the urinary bladder and are sealed at the point of entry to the bladder by the **ureter vesical valves**. These valves prevent urine from flowing back towards the kidneys.

#### Urinary Bladder

The urinary bladder is a sac-like hollow organ used for the storage of urine. The urinary bladder is located along the body’s midline at the inferior end of the pelvis. Urine entering the urinary bladder from the ureters slowly fills the hollow space of the bladder and stretches its elastic walls. The walls of the bladder allow it to stretch to hold anywhere from 600 to 800 millilitres of urine.

#### Urethra

The urethra is the tube through which urine passes from the bladder to the exterior of the body. The female urethra is around 2 inches long and ends inferior to the clitoris and superior to the vaginal opening. In males, the urethra is around 8 to 10 inches long and ends at the tip of the penis. The urethra is also an organ of the male reproductive system as it carries sperm out of the body through the penis.

The flow of urine through the urethra is controlled by the **internal** and **external urethral sphincter muscles**. The internal urethral sphincter is made of smooth muscle and opens involuntarily when the bladder reaches a certain set level of distention. The opening of the internal sphincter results in the sensation of needing to urinate. The external urethral sphincter is made of skeletal muscle and may be opened to allow urine to pass through the urethra or may be held closed to delay urination.

### Urinary System Physiology

#### Maintenance of Homeostasis

The kidneys maintain the homeostasis of several important internal conditions by controlling the excretion of substances out of the body.

* **Ions:** The kidney can control the excretion of potassium, sodium, calcium, magnesium, phosphate, and chloride ions into urine. In cases where these ions reach a higher than normal concentration, the kidneys can increase their excretion out of the body to return them to a normal level. Conversely, the kidneys can conserve these ions when they are present in lower than normal levels by allowing the ions to be reabsorbed into the blood during filtration.
* **pH:** The kidneys monitor and regulate the levels of hydrogen ions (H+) and bicarbonate ions in the blood to control blood ph. H+ ions are produced as a natural by-product of the metabolism of dietary proteins and accumulate in the blood over time. The kidneys excrete excess H+ ions into urine for elimination from the body. The kidneys also conserve bicarbonate ions, which act as important pH buffers in the blood.
* **Osmolarity:** The cells of the body need to grow in an isotonic environment to maintain their fluid and electrolyte balance. The kidneys maintain the body’s osmotic balance by controlling the amount of water that is filtered out of the blood and excreted into urine. When a person consumes a large amount of water, the kidneys reduce their reabsorption of water to allow the excess water to be excreted in urine. This results in the production of dilute, watery urine. In the case of the body being dehydrated, the kidneys reabsorb as much water as possible back into the blood to produce highly concentrated urine full of excreted ions and wastes. The changes in excretion of water are controlled by **antidiuretic hormone (ADH)**. ADH is produced in the hypothalamus and released by the posterior pituitary gland to help the body retain water.
* **Blood Pressure:** The kidneys monitor the body’s blood pressure to help maintain homeostasis. When blood pressure is elevated, the kidneys can help to reduce blood pressure by reducing the volume of blood in the body. The kidneys can reduce blood volume by reducing the reabsorption of water into the blood and producing watery, dilute urine. When blood pressure becomes too low, the kidneys can produce the enzyme **renin** to constrict blood vessels and produce concentrated urine, which allows more water to remain in the blood.

#### Filtration

Inside each kidney are around a million tiny structures called **nephrons**. The nephron is the functional unit of the kidney that filters blood to produce urine.

Arterioles in the kidneys deliver blood to a bundle of capillaries surrounded by a capsule called a **glomerulus**.

As blood flows through the glomerulus, much of the blood’s plasma is pushed out of the capillaries and into the capsule, leaving the blood cells and a small amount of plasma to continue flowing through the capillaries. The liquid filtrate in the capsule flows through a series of tubules lined with filtering cells and surrounded by capillaries. The cells surrounding the tubules selectively absorb water and substances from the filtrate in the tubule and return it to the blood in the capillaries. At the same time, waste products present in the blood are secreted into the filtrate. By the end of this process, the filtrate in the tubule has become urine containing only water, waste products, and excess ions. The blood exiting the capillaries has reabsorbed all the nutrients along with most of the water and ions that the body needs to function.

#### Storage and Excretion of Wastes

After urine has been produced by the kidneys, it is transported through the ureters to the urinary bladder. The urinary bladder fills with urine and stores it until the body is ready for its excretion. When the volume of the urinary bladder reaches anywhere from 150 to 400 millilitres, its walls begin to stretch and stretch receptors in its walls send signals to the brain and spinal cord.

These signals result in the relaxation of the involuntary internal urethral sphincter and the sensation of needing to urinate. Urination may be delayed if the bladder does not exceed its maximum volume, but increasing nerve signals lead to greater discomfort and desire to urinate.

Urination is the process of releasing urine from the urinary bladder through the urethra and out of the body. The process of urination begins when the muscles of the urethral sphincters relax, allowing urine to pass through the urethra. While the sphincters relax, the smooth muscle in the walls of the urinary bladder contract to expel urine from the bladder.

#### Production of Hormones

The kidneys produce and interact with several hormones that are involved in the control of systems outside of the urinary system.

* **Calcitriol:** Calcitriol is the active form of vitamin D in the human body. It is produced by the kidneys from precursor molecules produced by UV radiation striking the skin. Calcitriol works together with **parathyroid hormone (PTH)** to raise the level of calcium ions in the blood stream. When the level of calcium ions in the blood drops below a threshold level, the parathyroid glands release PTH, which in turn stimulates the kidneys to release calcitriol. Calcitriol promotes the small intestine to absorb calcium from food and deposit it into the bloodstream. It also stimulates the osteoclasts of the skeletal system to breakdown bone matrix to release calcium ions into the blood.
* **Erythropoietin:** Erythropoietin, also known as **EPO**, is a hormone that is produced by the kidneys to stimulate the production of red blood cells. The kidneys monitor the condition of the blood that passes through their capillaries, including the oxygen-carrying capacity of the blood. When the blood becomes hypoxic, meaning that it is carrying deficient levels of oxygen, cells lining the capillaries begin producing EPO and release it into the bloodstream. EPO travels through the blood to the red bone marrow, where it stimulates hematopoietic cells to increase their rate of red blood cell production. Red blood cells contain haemoglobin, which greatly increases the blood’s oxygen-carrying capacity and effectively ends the hypoxic conditions.
* **Renin:** Renin is not a hormone itself, but an enzyme that the kidneys produce to start the **renin-angiotensin system (RAS)**. The RAS increases blood volume and blood pressure in response to low blood pressure, blood loss, or dehydration. Renin is released into the blood where it catalyses angiotensinogen from the liver into angiotensin I. Angiotensin I is further catalysed by another enzyme into Angiotensin II. Angiotensin II stimulates several processes, including stimulating the adrenal cortex to produce the hormone aldosterone. Aldosterone then changes the function of the kidneys to increase the reabsorption of water and sodium ions into the blood, increasing blood volume and raising blood pressure. Negative feedback from increased blood pressure finally turns off the RAS to maintain healthy blood pressure levels.

## The Skeletal System

The adult human skeletal system consists of 206 bones, as well as a network of tendons, ligaments and cartilage that connects them. The skeletal system performs vital functions—support, movement, protection, blood cell production, calcium storage and endocrine regulation — that enable us to survive.

The amount of bones a person is born with isn't the final tally later. Human infants are born with about 300 bones, some of which fuse together as the body develops. By the time humans reach adulthood, they have 206 bones.

The skeletal system includes all the bones and joints in the body. Each bone is a complex living organ that is made up of many cells, protein fibres, and minerals. The skeleton acts as a scaffold by providing support and protection for the soft tissues that make up the rest of the body. The skeletal system also provides attachment points for muscles to allow movements at the joints. New blood cells are produced by the red bone marrow inside of our bones. Bones act as the body’s warehouse for calcium, iron, and energy in the form of fat. Finally, the skeleton grows throughout childhood and provides a framework for the rest of the body to grow along with it.

The skeletal system in an adult body is made up of 206 individual bones. These bones are arranged into two major divisions: the **axial skeleton** and the **appendicular skeleton**. The axial skeleton runs