# Anatomy & Physiology Level 3

## Student Training Guidelines

### Evaluation – Support – Feedback

* Evaluate your client’s experience to build confidence
* Collect feedback from client 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

### 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

### 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

### 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.

Blown Aesthetics would like to take time to thank you for training with us and we hope that 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

### 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 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 break down 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.

### Essay Question 1

**Please provide all answers on a separate answer sheet.**

1. What does ATP stand for and where in a cell is this produced?
2. In Detail explain what DNA is and what is its function.
3. In detail please explain the difference between rough and smooth Endoplasmic Reticulum.

### 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.

### 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

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.

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.

### 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 and Arterioles

**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. The endothelium acts as a filter to keep blood cells inside of the vessels while allowing liquids, dissolved gases, and other chemicals to diffuse along their concentration gradients into or out of tissues.

**Precapillary sphincters** are bands of smooth muscle found at the arteriole ends of capillaries. These sphincters regulate blood flow into the capillaries. Since there is a limited supply of blood, and not all tissues have the same energy and oxygen requirements, the precapillary sphincters reduce blood flow to inactive tissues and allow free flow into active 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 chemicals absorbed from food. 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: transportation of materials, protection from pathogens, and regulation of the body’s homeostasis.

* **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.
* **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.
* **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 solution.

### 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.

## 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.

### 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.

### 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.

### The 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.

## 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. 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.

### 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 bloodstream 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 break down 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.

## 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.

### Urinary System Anatomy

#### 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 **uretervesical 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 bloodstream. 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 break down 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.

### Divisions of the Skeletal System

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 along the body’s midline axis and is made up of 80 bones in the following regions:

* Skull
* Hyoid
* Auditory ossicles
* Ribs
* Sternum
* Vertebral column

The **appendicular skeleton** is made up of 126 bones in the following regions:

* Upper limbs
* Lower limbs
* Pelvic girdle
* Pectoral (shoulder) girdle

#### Skull

The skull is composed of 22 bones that are fused together except for the mandible. These 21 fused bones are separate in children to allow the skull and brain to grow, but fuse to give added strength and protection as an adult. The mandible remains as a movable jaw bone and forms the only movable joint in the skull with the temporal bone.

The bones of the superior portion of the skull are known as the **cranium** and protect the brain from damage. The bones of the inferior and anterior portion of the skull are known as **facial bones** and support the eyes, nose, and mouth.

#### Hyoid and Auditory Ossicles

The **hyoid** is a small, U-shaped bone found just inferior to the mandible. The hyoid is the only bone in the body that does not form a joint with any other bone—it is a floating bone. The hyoid’s function is to help hold the trachea open and to form a bony connection for the tongue muscles.

The **malleus, incus, and stapes**—known collectively as the **auditory ossicles**—are the smallest bones in the body. Found in a small cavity inside of the temporal bone, they serve to transmit and amplify sound from the eardrum to the inner ear.

#### Vertebrae

Twenty-six vertebrae form the vertebral column of the human body. They are named by region:

* **Cervical (neck)** - 7 vertebrae
* **Thoracic (chest)** - 12 vertebrae
* **Lumbar (lower back)** - 5 vertebrae
* **Sacrum** - 1 vertebra
* **Coccyx (tailbone)** - 1 vertebra

Except for the singular sacrum and coccyx, each vertebra is named for the first letter of its region and its position along the superior-inferior axis. For example, the most superior thoracic vertebra is called T1 and the most inferior is called T12.

#### Ribs and Sternum

The **sternum**, or breastbone, is a thin, knife-shaped bone located along the midline of the anterior side of the thoracic region of the skeleton. The sternum connects to the ribs by thin bands of cartilage called the **costal cartilage**.

There are 12 pairs of ribs that together with the sternum form the ribcage of the thoracic region. The first seven ribs are known as **“true ribs”** because they connect the thoracic vertebrae directly to the sternum through their own band of costal cartilage. Ribs 8, 9, and 10 all connect to the sternum through cartilage that is connected to the cartilage of the seventh rib, so we consider these to be **“false ribs.”** Ribs 11 and 12 are also false ribs, but are also considered to be **“floating ribs”** because they do not have any cartilage attachment to the sternum at all.

#### Pectoral Girdle and Upper Limb

The **pectoral girdle** connects the upper limb (arm) bones to the axial skeleton and consists of the left and right clavicles and left and right scapulae.

The **humerus** is the bone of the upper arm. It forms the ball and socket joint of the shoulder with the scapula and forms the elbow joint with the lower arm bones. The **radius** and **ulna** are the two bones of the forearm. The ulna is on the medial side of the forearm and forms a hinge joint with the humerus at the elbow. The radius allows the forearm and hand to turn over at the wrist joint.

The lower arm bones form the wrist joint with the **carpals**, a group of eight small bones that give added flexibility to the wrist. The carpals are connected to the five **metacarpals** that form the bones of the hand and connect to each of the fingers. Each finger has three bones known as **phalanges**, except for the thumb, which only has two phalanges.

#### Pelvic Girdle and Lower Limb

Formed by the left and right hip bones, the **pelvic girdle** connects the lower limb (leg) bones to the axial skeleton.

The **femur** is the largest bone in the body and the only bone of the thigh (femoral) region. The femur forms the ball and socket hip joint with the hip bone and forms the knee joint with the tibia and patella.

Commonly called the kneecap, the **patella** is special because it is one of the few bones that are not present at birth. The patella forms in early childhood to support the knee for walking and crawling.

The **tibia** and **fibula** are the bones of the lower leg. The tibia is much larger than the fibula and bears almost all the body’s weight. The fibula is mainly a muscle attachment point and is used to help maintain balance. The tibia and fibula form the ankle joint with the **talus**, one of the seven **tarsal** bones in the foot. The tarsals are a group of seven small bones that form the posterior end of the foot and heel. The tarsals form joints with the five long **metatarsals** of the foot. Then each of the metatarsals forms a joint with one of the set of **phalanges** in the toes. Each toe has three phalanges, except for the big toe, which only has two phalanges.

### Microscopic Structure of Bones

The skeleton makes up about 30-40% of an adult’s body mass. The skeleton’s mass is made up of non-living **bone matrix** and many tiny bone cells. Roughly half of the bone matrix’s mass is water, while the other half is collagen protein and solid crystals of calcium carbonate and calcium phosphate.

Living bone cells are found on the edges of bones and in small cavities inside of the bone matrix. Although these cells make up very little of the total bone mass, they have several very important roles in the functions of the skeletal system. The bone cells allow bones to:

* Grow and develop
* Be repaired following an injury or daily wear
* Be broken down to release their stored minerals

### Types of Bones

All the bones of the body can be broken down into five types: long, short, flat, irregular, and sesamoid.

* **Long:** Long bones are longer than they are wide and are the major bones of the limbs. Long bones grow more than the other classes of bone throughout childhood and so are responsible for the bulk of our height as adults. A hollow **medullary cavity** is found in the centre of long bones and serves as a storage area for bone marrow. Examples of long bones include the femur, tibia, fibula, metatarsals, and phalanges.
* **Short:** Short bones are about as long as they are wide and are often cubed or round in shape. The carpal bones of the wrist and the tarsal bones of the foot are examples of short bones.
* **Flat:** Flat bones vary greatly in size and shape, but have the common feature of being very thin in one direction. Because they are thin, flat bones do not have a medullary cavity like the long bones. The frontal, parietal, and occipital bones of the cranium—along with the ribs and hip bones—are all examples of flat bones.
* **Irregular:** Irregular bones have a shape that does not fit the pattern of the long, short, or flat bones. The vertebrae, sacrum, and coccyx of the spine—as well as the sphenoid, ethmoid, and zygomatic bones of the skull—are all irregular bones.
* **Sesamoid:** The sesamoid bones are formed after birth inside of tendons that run across joints. Sesamoid bones grow to protect the tendon from stresses and strains at the joint and can help to give a mechanical advantage to muscles pulling on the tendon. The patella and the pisiform bone of the carpals are the only sesamoid bones that are counted as part of the 206 bones of the body. Other sesamoid bones can form in the joints of the hands and feet, but are not present in all people.

### Parts of Bones

The long bones of the body contain many distinct regions due to the way in which they develop. At birth, each long bone is made of three individual bones separated by hyaline cartilage. Each end bone is called an **epiphysis** (epi = on; physis = to grow) while the middle bone is called a **diaphysis** (dia = passing through). The epiphyses and diaphysis grow towards one another and eventually fuse into one bone. The region of growth and eventual fusion in between the epiphysis and diaphysis is called the **metaphysis** (meta = after). Once the long bone parts have fused together, the only hyaline cartilage left in the bone is found as **articular cartilage** on the ends of the bone that form joints with other bones. The articular cartilage acts as a shock absorber and gliding surface between the bones to facilitate movement at the joint.

Looking at a bone in cross section, there are several distinct layered regions that make up a bone. The outside of a bone is covered in a thin layer of dense irregular connective tissue called the **periosteum**. The periosteum contains many strong collagen fibres that are used to firmly anchor tendons and muscles to the bone for movement.

Stem cells and osteoblast cells in the periosteum are involved in the growth and repair of the outside of the bone due to stress and injury. Blood vessels present in the periosteum provide energy to the cells on the surface of the bone and penetrate the bone itself to nourish the cells inside of the bone. The periosteum also contains nervous tissue and many nerve endings to give bone its sensitivity to pain when injured.

Deep to the periosteum is the **compact bone** that makes up the hard, mineralized portion of the bone. Compact bone is made of a matrix of hard mineral salts reinforced with tough collagen fibres. Many tiny cells called **osteocytes** live in small spaces in the matrix and help to maintain the strength and integrity of the compact bone.

Deep to the compact bone layer is a region of **spongy bone** where the bone tissue grows in thin columns called **trabeculae** with spaces for red bone marrow in between. The trabeculae grow in a specific pattern to resist outside stresses with the least amount of mass possible, keeping bones light but strong. Long bones have a spongy bone on their ends but have a hollow **medullary cavity** in the middle of the diaphysis. The medullary cavity contains red bone marrow during childhood, eventually turning into yellow bone marrow after puberty.

### Articulations

An **articulation**, or **joint**, is a point of contact between bones, between a bone and cartilage, or between a bone and a tooth.

* **Synovial joints** are the most common type of articulation and feature a small gap between the bones. This gap allows a free range of motion and space for synovial fluid to lubricate the joint.
* **Fibrous joints** exist where bones are very tightly joined and offer little to no movement between the bones. Fibrous joints also hold teeth in their bony sockets.
* Finally, **cartilaginous joints** are formed where bone meets cartilage or where there is a layer of cartilage between two bones. These joints provide a small amount of flexibility in the joint due to the gel-like consistency of cartilage.

### Skeletal System Physiology

#### Support and Protection

The skeletal system’s primary function is to form a solid framework that supports and protects the body’s organs and anchors the skeletal muscles. The bones of the axial skeleton act as a hard shell to protect the internal organs—such as the brain and the heart—from damage caused by external forces. The bones of the appendicular skeleton provide support and flexibility at the joints and anchor the muscles that move the limbs.

#### Movement

The bones of the skeletal system act as attachment points for the skeletal muscles of the body. Almost every skeletal muscle works by pulling two or more bones either closer together or further apart. Joints act as pivot points for the movement of the bones. The regions of each bone where muscles attach to the bone grow larger and stronger to support the additional force of the muscle. In addition, the overall mass and thickness of a bone increase when it is under a lot of stress from lifting weights or supporting body weight.

#### Haematopoiesis

Red bone marrow produces red and white blood cells in a process known as **haematopoiesis**. Red bone marrow is found in the hollow space inside of bones known as the medullary cavity. Children tend to have more red bone marrow compared to their body size than adults do, due to their body’s constant growth and development. The amount of red bone marrow drops off at the end of puberty, replaced by yellow bone marrow.

#### Storage

The skeletal system stores many different types of essential substances to facilitate growth and repair of the body. The skeletal system’s cell matrix acts as our calcium bank by storing and releasing calcium ions into the blood as needed. Proper levels of calcium ions in the blood are essential to the proper function of the nervous and muscular systems. Bone cells also release **osteocalcin**, a hormone that helps regulate blood sugar and fat deposition.

The yellow bone marrow inside of our hollow long bones is used to store energy in the form of lipids. Finally, red bone marrow stores some iron in the form of the molecule **ferritin** and uses this iron to form haemoglobin in red blood cells.

#### Growth and Development

The skeleton begins to form early in foetal development as a flexible skeleton made of hyaline cartilage and dense irregular fibrous connective tissue. These tissues act as a soft, growing framework and placeholder for the bony skeleton that will replace them. As development progresses, blood vessels begin to grow into the soft foetal skeleton, bringing stem cells and nutrients for bone growth. Osseous tissue slowly replaces the cartilage and fibrous tissue in a process called **calcification**. The calcified areas spread out from their blood vessels replacing the old tissues until they reach the border of another bony area. At birth, the skeleton of a new-born has more than 300 bones; as a person ages, these bones grow together and fuse into larger bones, leaving adults with only 206 bones.

Flat bones follow the process of **intramembranous ossification** where the young bones grow from a primary ossification centre in fibrous membranes and leave a small region of fibrous tissue in between each other. In the skull these soft spots are known as **fontanels**, and give the skull flexibility and room for the bones to grow. Bone slowly replaces the fontanels until the individual bones of the skull fuse together to form a rigid adult skull.

Long bones follow the process of **endochondral ossification** where the diaphysis grows inside of cartilage from a primary ossification centre until it forms most of the bone. The epiphyses then grow from secondary ossification centres on the ends of the bone. A small band of hyaline cartilage remains in between the bones as a **growth plate**. As we grow through childhood, the growth plates grow under the influence of growth and sex hormones, slowly separating the bones. At the same time the bones grow larger by growing back into the growth plates. This process continues until the end of puberty, when the growth plate stops growing and the bones fuse permanently into a single bone. The vast difference in height and limb length between birth and adulthood are mainly the result of endochondral ossification in the long bones.