1

Cells and Basic Tissues

Learning goals

In this chapter, the learning goals are:

- To identify the essential functions required to sustain life
- To identify the structure and function of animal cells and tissues
- To explain the diversity of animal cells and tissues in existence
- To explain how animal cells work in partnership to form systems

What Is Biology?

Biology is the study of life and living organisms

How do we define life?

To be considered a living organism, an organism must be able to perform all the following essential functions of life:

- *Movement* – The organism can move itself or a part of itself.
- *Reproduction* – The organism can reproduce itself so that the species doesn't die out.
- *Sensitivity* – The organism can react to stimuli in its surroundings to avoid life-threatening events in its environment.
- *Growth* – The organism can sustain growth from within itself via processes that involve taking in new materials from the outside and incorporating them into its internal structure.
- *Release of energy from respiration* – The organism can use nutritional sources to release a usable form of energy in a controlled way to sustain life.
- *Excretion* – The organism can excrete waste metabolic products from itself.
- *Nutrition* – The organism can ingest nutritional materials that provide energy to maintain life and growth.

A cell is the simplest functional unit of all tissues. Each cell can individually perform all the essential life functions identified previously. Organisms may be single-celled or multi-celled. Within multicellular organisms, the component cells show a wide range of specialisations, thereby contributing to cell diversity within an organism.

Cells can therefore be deemed to be the building blocks of the body, and therefore, the following can be stated:

Animal Biology and Care, Fourth Edition. Emily Jewell.

Companion Website: https://www.wiley.com/go/animal/biology4e/jewell

- *Cells* form …
- *Tissues*, and tissues form …
- *Organs* – organs work together to form *systems* within the body.
- *Systems* have a specific function to perform in living organisms using the diverse range of cell specialisations.

Cell Diversity

Animal cells are not all identical (Figure 1.1), but they all have the same basic structure because they are all derived from a type of cell called a *Stem Cell*. Stem cells have the potential to become any type of cell within the body, and once they become specialised, they are said to have *differentiated*. Cells become specialised so that they are more efficient in the role that they have within the body. Stem cells are not only found in the embryo but can also be found in a range of locations across the adult mammalian body, e.g. bone marrow, liver, heart, brain, muscles, and skin.

Individual components of animal cells are called *organelles*, and each organelle is described in the following section:

- *Cell/Plasma membrane* – All animal cells are surrounded by a membrane which contains all the other organelles of the cell as without it, the cell contents would spill out. This membrane can be referred to as either the cell membrane or the plasma membrane.

  Cell/plasma membranes are approximately 0.00001 mm (10 nm) in thickness. The cell/plasma membrane is the boundary keeping the cytoplasm of the cell contained.

  The role of the cell/plasma membrane is to be a barrier that separates the external environment of the cell from the internal environment, along with controlling what enters/exits the cell (cell exchange). The cell/plasma membrane allows certain chemicals to pass in and out of the cell by the exchange processes of *diffusion, osmosis*, or *active transport*. The cell/plasma membrane is *selectively permeable*, i.e. it chooses what can/can't come in/out of the cell according to the needs of the cell.
- *Nucleus* – There is usually one nucleus in the cell, which is located near the centre of the cell. Its role is to be the brain of the cell and control its activities. The nucleus is surrounded

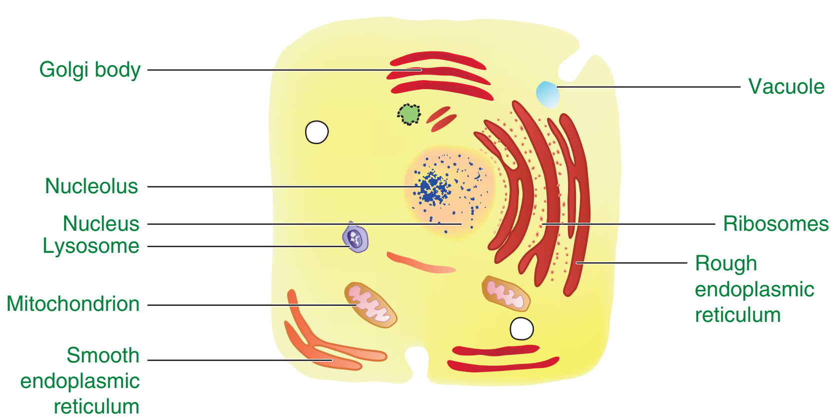


Figure 1.1 Basic cell structure.

by a double membrane called the *nuclear envelope*. Inside the nucleus is an area called the *nucleolus*, which contains the genetic material [deoxyribonucleic acid (DNA) and ribonucleic acid (RNA)] of the cell, which is important for cell reproduction. *Chromatin* is found in the nucleus and condenses to form *chromosomes*. The nuclear envelope is interspersed with *nuclear pores*, which allow material in/out of the nucleus itself. It is important to note here that red blood cells do not contain a nucleus.

- *Cytoplasm* – A gel-like material that supports the organelles within the cell between the cell/plasma membrane and the nucleus. Cytoplasm is where chemical reactions occur within the cell for metabolic purposes. Cytoplasm also allows the organelles to move around and move molecules between them.
- *Chromosomes* – These are rod-shaped components that contain the hereditary information of an organism. This hereditary material is called DNA and it controls the characteristics that an organism inherits from its parents. Chromosomes exist as thin strands of DNA and are usually found in pairs. Chromosomes are subdivided into genes.
- *Mitochondria* – These are energy-producing organelles where cell respiration takes place. Energy is generated from nutritional sources such as carbohydrates, fats, and proteins to create a usable form of energy. Mitochondria are often called the powerhouses of the cell. Mitochondria are surrounded by a double membrane. The outer membrane is the surface of the mitochondrion. The inner membrane has many folds called *cristae*, which increase the surface area to maximise the energy produced by cell respiration. Due to the energy that they need to swim, sperm cells contain many mitochondria. This is an example of cell specialisation. It is important to note that a single mitochondria is called a *mitochondrion*.
- *Endoplasmic reticulum* (ER) – ER is a series of tubules acting as a transport and packaging system in the cell. ER may be rough ER or smooth ER. Rough ER has ribosomes attached to it where proteins are synthesised. This protein can be used by the cell to synthesise enzymes, hormones, antibodies, and muscle. Smooth ER has no ribosomes and is used to synthesise and transport lipids (fats) and steroids made within the body.
- *Ribosomes* – *Ribosomes* build proteins within the cell. These proteins then join to form amino acids which are essential for growth and repair in the body. Ribosomes are found in the cell's cytoplasm. Ribosomes contain RNA.
- *Centrosome* – The centrosome is an area found near the nucleus in animal cells that helps with the ability of the cell to change its shape such as in cell division and during phagocytosis (cell eating). It is responsible for the organisation of microtubules in the cell. The centrosome is made up of two *centrioles*. Centrioles are important during cell division and the formation of the *cilia* and *flagella* of certain cells (the slender projecting hairs responsible for movement of single-celled organisms). Centrioles can only be seen during cell division; otherwise, the centrosome is seen.
- *Lysosomes* – *Lysosomes* are small vesicles (fluid-filled spheres) in cells that contain numerous types of enzymes responsible for splitting complex chemical compounds into simpler ones (known as *lysis*, meaning 'to break up') followed by digestion. They help to destroy worn-out organelles within the cell and recycle them for further use. Lysosomes are created by the *Golgi apparatus*, and the enzymes within them are produced in the endoplasmic reticulum.
- *Golgi apparatus* – The Golgi apparatus is a series of flattened sacs that extend from the endoplasmic reticulum throughout the cytoplasm of the cell. The sacs are where different chemical reactions occur. It is responsible for moving molecules from the ER to elsewhere in the cell. The Golgi apparatus is also involved in labelling some vesicles with proteins or

carbohydrates complexes so that they are transported to the correct locations. The Golgi apparatus is also referred to as the Golgi body/Golgi complex.

- *Peroxisomes* – Peroxisomes are mainly involved in breaking down lipids and toxic molecules, such as hydrogen peroxide, made during digestion into safer molecules. Peroxisomes are similar to lysosomes but have a slightly different structure and contain different lysing enzymes.
- *Cilia* – Cilia are hair-like projections on a cell, which aid absorption or movement of fluids away from a cell. Cilia are only found in animal cells and are made up of microtubules. They are usually found in groups or as a border on cell surfaces.
- *Flagella* – Flagella are long whip-like structures that can be found as part of microbial and animal cell structures. They tend to be longer and less dense than cilia. Sperm cells have a flagellum for movement.

Most of the organelles listed are common to virtually all cells, but the shape, form, and contents of individual cells be differentiated according to its intended function, as previously explained. The structural characteristics of a particular cell are closely related to its functions (Figure 1.2).

Types of cells found in the animal body

- *Epithelial cells* – These cells line the surface of the body, body organs, and cavities within it. Their shape and structural form reflect this role, e.g. tightly packed together, flattened where abrasion occurs, and ciliated where absorption occurs. Epithelial cells are often described according to their shape, e.g. squamous, cuboidal, columnar, ciliated, or stratified.
- *Endothelial cells* – These are a type of epithelial cell with a specific role to line the inside surfaces of blood vessels and lymphatic vessels.

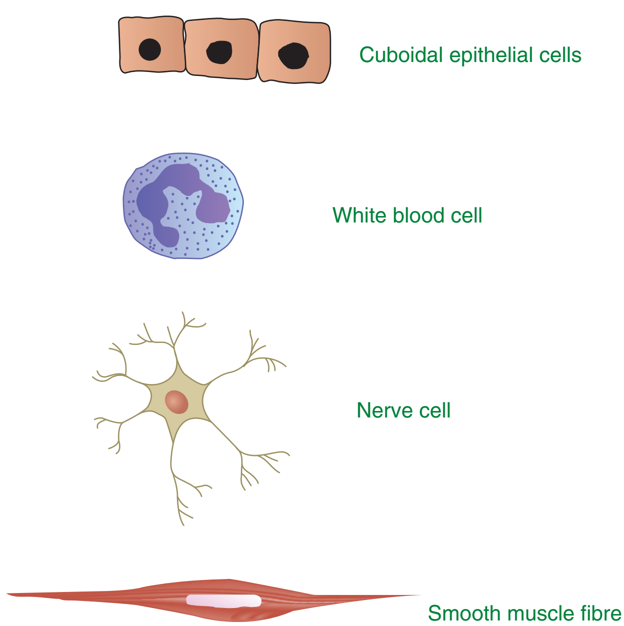


Figure 1.2 Examples of cell diversity.

- *Glandular cells* – These are a type of epithelial cell, but they make and release secretions either inside the body or onto the body surface. They can be found in a range of locations throughout the body, and examples of secretions include sweat, saliva, enzymes, hormones, and mucus.
- *Osteoblasts* – They produce bone tissue. They form new bone and contribute to growth and repair of bone. Osteoblasts can develop into osteocytes.
- *Osteocytes* – These are mature bone cells that maintain the health of the bone. They have a role to play in maintaining calcium balance within the bone. Osteocytes have a much longer life span than osteoblasts or osteoclasts.
- *Osteoclasts* – They break down bone tissue that is old or damaged.
- *Erythrocytes (red blood cells)* – These are designed to contain the red pigment haemoglobin, which carries oxygen around the body. They have a biconcave disc shape and are one of the few cells in the body that do not have a nucleus.
- *Nerve cells* – Nerve cells or neurones have fine projections that transmit electrical impulses through the nervous system to reach the whole body.
- *Muscle cells* – These are found in cardiac muscle, smooth muscle, and skeletal muscle. They contain protein filaments that slide over each other to cause contractions once they have been stimulated by the electrical impulse from nerve cells. Muscle cells contain high numbers of mitochondria to provide energy.
- *Fat cells* – These are also called adipose cells/adipocytes. They are specialised to have a role in energy storage and metabolism. There are different types of fat cells, and they are a type of connective tissue.
- *Sperm cells* – These are the male sex cells. They have a tail for swimming and only contain half the number of chromosomes.
- *Ova* – These are the female sex cells. They contain only half the number of chromosomes of other cells in the body and once combined with a sperm cell, the resulting embryonic cell has a full set of chromosomes.
- *Stem cells* – These are cells that have not become specialised to a particular function. They are also called undifferentiated cells. Stem cells are found in early embryos following rapid division and are known as *embryonic stem cells*. They can develop into any type of cell. Stem cells can also be found throughout the adult body – *adult stem cells*. Stem cells are now used in medical treatments of certain conditions in animals such as osteoarthritis and torn ligaments. An infusion of stem cells into the affected area can improve repair and regeneration of damaged tissues. Treatments involving stem cells are known as *stem cell therapy*.
- *Cancer cells* – Cancer cells are cells that behave abnormally due to mutations in genetic DNA. These mutations can either be inherited, due to external factors (e.g. ultraviolet rays from the sun) or completely random. Cancer cells can invade surrounding healthy tissues. Cancer cells don't repair themselves or die, so they keep growing and can break off the original growth (tumour) to move to other locations in the body, known as *metastasis*. Cancer cells can be given different names according to where they are found in the body, e.g. *carcinomas* are found in epithelial tissues; *sarcomas* are found in connective tissues such as bone, fat, and muscle; and *leukaemia* and *lymphomas* are found in white blood cells.

Summary of cells

No matter what the type of cell found in an organism, cells have needs that must be met to survive:

- Food for energy
- Water (body fluid) to hydrate the cells

- Oxygen to all cells
- A suitable temperature in which to live

Cells are differentiated according to the role that they have in the body, but they are all derived from embryonic stem cells.

Animal Tissues

Tissues are a collection of cells and their products that have a common fundamental function, in which one cell type is dominant:

- *Epithelial tissue* – forms a protective layer both inside and on the surface of the body. Examples of this tissue are the skin, glands, and linings of the various body systems.
- *Connective tissue* – supports body tissues and acts as a transport system to move materials vital to tissue cells around the body. Examples of this tissue are as follows:
  - *Loose connective tissue* that surrounds organs.
  - *Dense connective tissue* that has great strength and is found as tendons and ligaments.
  - *Blood* that transports essential nutrients, gases, waste products, hormones, and enzymes to and from all body cells.
  - *Cartilage* and *bone* that provide shape and protection for organs and allow movement.
  - *Adipose* tissue is mainly found around internal organs *(visceral)* and under the surface of the skin *(subcutaneous)*. As well as storing and releasing energy, adipose tissue also plays an active part in the endocrine system to maintain homeostasis in the body.
- *Muscle/muscular tissue* – It is concerned with movement of the skeleton, the organ systems, and the heart. There are three types of muscle tissues in the body:
  - Skeletal
  - Smooth
  - Cardiac
- *Nervous tissue* – It is concerned with transporting messages to tissues and connecting body tissues for the required response.

Epithelial tissue

Epithelial tissue covers all surfaces of the body, both inside and out, whether it is a surface, a cavity, or a tube. Epithelial tissue is made up of cells arranged in a continuous sheet as either single or multiple layers. Epithelial tissues are involved in a wide range of activities, such as secretion of fluids, protection, and absorption.

Epithelial tissue varies in shape, structure, and thickness according to function and location in the body. Epithelial tissues are classified according to appearance:

- *Number of layers* – a single layer of these cells is called *simple* epithelium; more than one layer is called *stratified* epithelium.
- *Shape of the cells* involved – e.g. *squamous* (thin and flat), *columnar* (column), and *cuboidal* (cube).
- *Specialisations* – e.g. covered in tiny hairs called *cilia* or thickened surface tissue called *keratin*, which covers the nose and pads of paws/feet.
- *Glandular* – means that it is involved in secretion. Secretions that go directly into the bloodstream are called *hormones* and are produced by glands of the *endocrine* system. Some

secretions are produced by glands that have ducts onto the surface of a cell. Glands with ducts belong to the *exocrine* system, e.g. enzymes that are produced by the pancreas.

Note: Epithelial tissues always have a basement membrane as part of their structure.

Types of epithelial tissue

Epithelial tissue has many different functions, and therefore, there are different types. There are different types of epithelial tissues, which are as follows:

- *Simple squamous (Pavement epithelium)* – can be found lining the surfaces involved in the transport of gases (lungs) or fluids (walls of blood vessels) (Figure 1.3a).
- *Cuboidal* – can be found lining small ducts and tubes such as those of the kidney, pancreas, and salivary glands of the mouth (Figure 1.3b).
- *Columnar* – located on highly absorbing surfaces like the small intestine for the uptake of nutrients (Figure 1.3c).
- *Ciliated* – has tiny hair-like projections in parallel rows on the surface of the cell, which beat in a wave-like manner, moving films of mucus or fluid in a particular direction. For example, in the respiratory airway (trachea), they remove unwanted inhaled materials (Figure 1.4a).
- *Glandular* – which produce secretions containing hormones, enzymes, or sweat (Figure 1.4b).
- *Stratified* – This type of epithelium has two or more layers of cells. Its function is mostly one of protection and it is found where there is more wear on the epithelial surface, e.g. in the mouth or as skin (Figure 1.4c).
- *Pseudo-stratified* – This is only one layer in thickness but appears to be more when microscopically examined, as the nuclei of the cells are at different heights. It is found in the male reproductive system, the male urinary system, and upper respiratory tract.
- *Transitional* – This is so called as its appearance varies according to its state. It is found in the bladder and male reproductive tract. In an unstretched sample of transitional epithelium (i.e. less fluid in the bladder), the cells appear to be stratified cuboidal, but once the sample is stretched (i.e. bladder is full), the cells appear to be simple squamous.

Connective tissue

Connective tissue connects all the other body tissues together. Connective tissue comprises different cell types, which work together to provide support, bonds, and organisation to provide a matrix

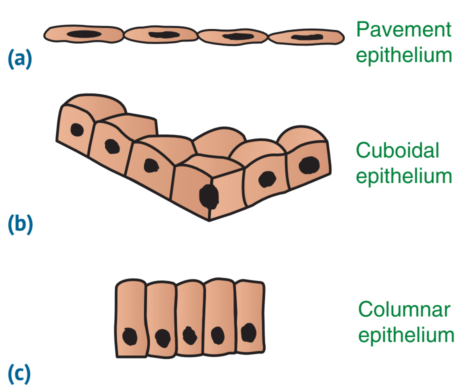


Figure 1.3 (a) Pavement, (b) cuboidal, and (c) columnar tissues.

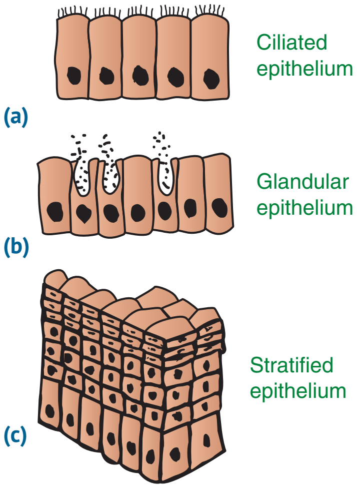


Figure 1.4 (a) Ciliated, (b) glandular, and (c) stratified tissues.

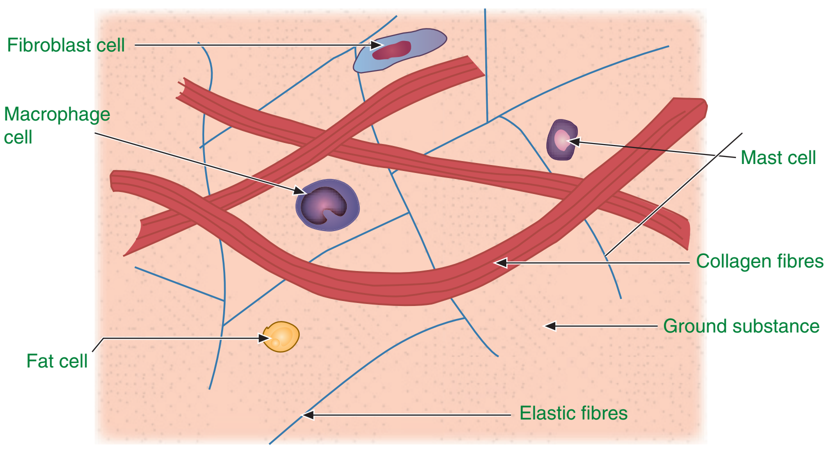


Figure 1.5 Connective tissue.

for metabolic exchange of nutrients and waste products between tissues to form organs. The different types of connective tissue vary according to their density, cell components, and specialisms.

The basic structure of connective tissue is a ground extracellular matrix, which contains cells and protein fibres (Figure 1.5). Connective tissues need a good blood supply due to the exchange of nutrients and waste products that occur within them.

Structure of connective tissue

As already mentioned, the basic structure of connective tissue is an extracellular matrix containing protein fibres and cells.

Ground/extracellular matrix

The ground matrix is a thick, clear, and colourless fluid that fills up the space between the cells and the protein fibres. It acts as a sieve for molecules that can travel between the blood and the cells, therefore aiding the exchange of nutrients, oxygen, and waste products.

There are three protein fibres that could be present in the ground matrix:

- *Collagen* – produced by fibroblasts. Not very elastic but has great tensile strength and flexibility. Tendons by which muscles are attached to the bones are composed of collagen fibres.
- *Elastic* – It is found where the tissue is regularly required to stretch and bend. Can be found in ligaments which hold the bones of the skeleton together, the walls of large blood vessels, and in the skin.
- *Reticular* – It is found where greater support is needed, such as in the walls of blood vessels, smooth muscle cells, and nerve fibres.

There are two types of cells (split into subtypes) that can be present in the ground matrix:

- *Fixed/resident* cells – permanent residents of connective tissue.
- *Fibroblasts* – most common type of connective tissue cell.
- *Adipose* – present in smaller numbers except in adipose tissue.
- *Transient/Wandering* cells – can move through extracellular space.
- *Macrophages* – phagocytic cells that remove dead cells and tissue.
- *Mast cells* – containing secretory granules in their cytoplasm that release their contents when the cell is damaged.
- *Plasma cells* – antibody-producing cells derived from lymphocytes that are present in small numbers.
- *Leucocytes* – present in small numbers for a short time. Their quantity is higher if the animal has an infection.

Types of connective tissue

The proportion, density, and type of protein fibres and cells contained in the ground matrix determine the type of connective tissue.

Loose connective tissue fills layers between the epithelial tissue of other organs almost like a packing material. As the name suggests, the protein fibres are arranged loosely within this type of tissue. It is quite fragile and not very resistant to stress. There are three types of loose connective tissue:

- *Areolar tissue* – there is a high distribution of this type of tissue across the body, and it is predominantly comprised of collagen fibres and fibroblasts with equal amounts of ground matrix, fibres, and cells. Can be found in subcutaneous and dermal layers of skin, in mucous membranes, and around blood vessels.
- *Adipose tissue* – comprised of many adipocytes that store lipid droplets. It is a source of stem cells for repair of cells and tissues. White adipose tissue is predominant and found across the body and is a site of storage for fat droplets. Brown adipose tissue is so called as it is darker in colour and is more energy dense. It is spread between mitochondria and releases heat to maintain body temperature. There is a high proportion of brown adipose tissue in newborn animals (neonates) as they are not yet able to maintain their own body temperature.
- *Reticular tissue* – contains a greater proportion of reticular fibres throughout. Reticular tissue can be found in places such as the liver, spleen, lymph nodes, and bone marrow.

Dense connective tissue provides tough support in the skin. It contains a greater number of protein fibres that are thicker and more densely packed than in loose connective tissue. It is found where strength is required in the tissues but little flexibility such as in tendons, ligaments, large blood vessels, and the lungs. There are three types of dense connective tissue:

- *Dense regular* – provides strength and strong attachments, e.g. tendons and ligaments.
- *Dense irregular* – provides resistance against stress, e.g. dermal layer of the skills and surrounding capsules of body organs.
- *Elastic* – contains a high number of elastic fibres which provide stretch and expansion as needed, e.g. in lungs and large blood vessels.

Specialised connective tissue – There are several specialised connective tissue types in the body:

- *Bone* – a connective tissue made up of cells called osteocytes, osteoblasts, and osteoclasts embedded in an extracellular matrix that becomes calcified for strength. Bone can either be compact or spongy. Compact bone is the strongest. Spongy bone has spaces in its structure that are filled with red bone marrow, which is responsible for producing and destroying blood cells.
- *Cartilage* – a strong and resilient supportive tissue that has some degree of flexibility. It has no direct blood or nerve supply; nutrients are obtained from surrounding capillaries through diffusion. The only cells in cartilage tissue are *chondrocytes*. There are three types of cartilage:
  - *Hyaline cartilage*
  - *Elastic cartilage*
  - *Fibrocartilage*
- *Blood* – Blood is a fluid connective tissue that contains a range of cells and an extracellular material called *plasma*. Blood cells are formed from stem cells in bone marrow. Plasma makes up approximately 55% of the total volume of blood. The primary function of blood is to transfer nutrients and respiratory gases (oxygen and carbon dioxide) to and from the right locations. Blood is classified as a connective tissue because it connects all the cells in the body together.
- *Fibrous connective tissue* – It is like dense connective tissue. It is involved in the repair of damaged tissues, and it is often called scar tissue but can also be found in the covering of organs such as the kidney and the brain, as well as in ligaments.
- *Lymphoid tissue* – It is a specialised form of reticular connective tissue. It makes up the lymphatic system and is therefore found in bone marrow, the thymus, spleen, and lymph nodes.

Blood

Blood is a highly specialised connective tissue consisting of different types of cells held in an aqueous fluid called *plasma* (Figure 1.6). Plasma makes up 55% of total blood volume, and the cellular components therefore make up 45%. The main blood cells are:

- Red blood cells (*erythrocytes*)
- White blood cells (*leucocytes*)
- Platelets (*thrombocytes*)

It is important to note that the proportions of cells in blood can vary according to the physiological state of the body. For example, an animal with an infection will have a higher proportion of white blood cells and an animal with a wound will have a higher proportion of platelets in the injured area. Some illnesses are caused by a change in blood cells in the body. For example, *anaemia* is a lack of healthy red blood cells in the body.

Blood performs a wide range of functions, but its key role is as a transportation system. Living animals continuously take in valuable substances such as respiratory gases (oxygen) and nutrients,

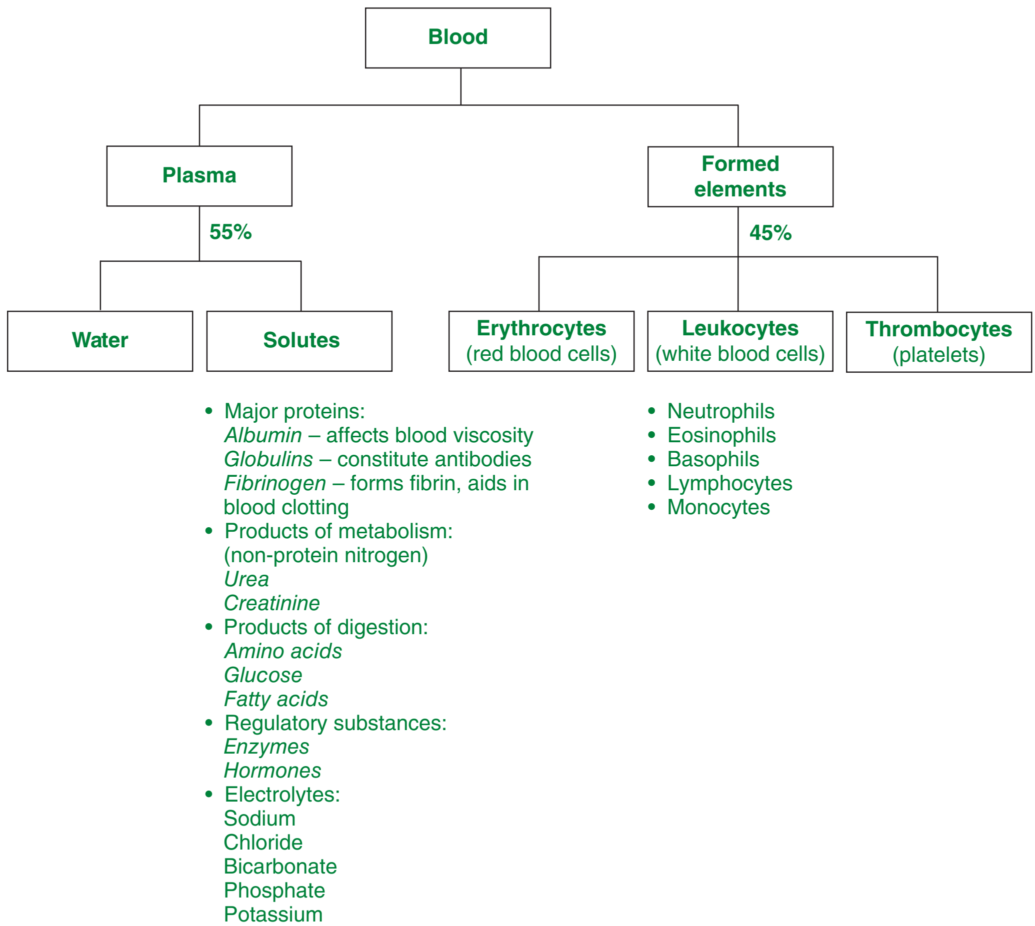


Figure 1.6 Components of blood.

which need to be distributed throughout their bodies. They produce an endless stream of waste materials, such as carbon dioxide, which must be removed from their bodies before they reach harmful levels. These distribution and waste removal processes are performed by blood.

Composition of blood

Plasma makes up about 55% of blood. Cells and other components make up the remaining 45%. The amount of blood in an animal is known as *total blood volume*. The amount varies according to the size of the animal and its physiological state. Blood volume can be affected by metabolic conditions, illnesses, cardiac function, sex (usually higher in males than females), and weight. Blood sample analysis gives a good indicator of what is happening in the body at any one time.

To analyse a blood sample, it is mixed with an *anticoagulant* (stops clotting) and placed into a *centrifuge*, which spins at high speed. This centrifugal force causes the components within the blood to separate out into layers. The plasma is at the top of the tube, followed by the platelets, and then the white blood cells with the red blood cells at the bottom (Figure 1.7). The white blood cells and platelets may be referred to in combination as the *buffy coat*.

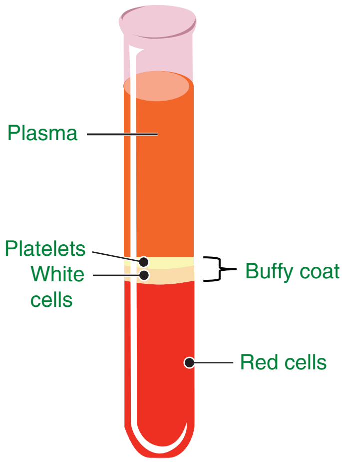


Figure 1.7 Blood separated into layers.

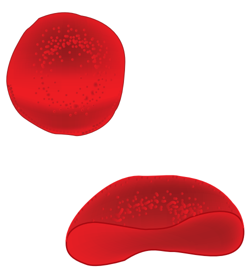


Figure 1.8 Cross-section of a red blood cell showing its biconcave shape.

Components of blood

Plasma – It is approximately 92% water and contains a variety of dissolved substances such as plasma proteins (6–7%) and salts/glucose (1%), which are transported from one part of the body to another. For example, nutrients from food breakdown (glucose, lipids, and amino acids) are taken from the small intestine to the liver where they are metabolised. The resulting waste product of urea is transported from the liver to the kidneys to be excreted. Another example is when hormones are transported from their various production sites in endocrine glands to their target organ location. There is a continuous exchange taking place in the body between blood and cells.

Three key plasma proteins carried in blood are called *albumin, globulin*, and *fibrinogen*. Fibrinogen plays an important role in the process of blood clotting. When fibrinogen has been used up by clot formation at the site of injury, then the fluid part of blood seen is called *serum*. Serum is simply plasma with fibrinogen removed.

Plasma	Serum
Fibrinogen (protein for clotting) plus water, protein, glucose, lipids, amino acids, salts, enzymes, hormones, and waste products	Contains water, protein, glucose, lipids, amino acids, salts, enzymes, hormones, and waste products but no proteins for clotting (these have been used up)

About 92% of blood is made of water, and the water can be forced into the tissues where it is then called *tissue fluid* because of its location. Both plasma and tissue fluid are the environments that keep body cells alive.

Imagine it as a fish tank where the plasma/tissue fluid is the water, and the cells are the fish that get their nutrients and oxygen from that water and subsequently excrete their waste products into the same water, which is then filtered to remove them. The filters in the body are the kidneys, which are discussed in Chapter 3.

Red blood cells (erythrocytes)

Red blood cells (RBC) are produced from stem cells in red bone marrow. Their main function is to carry oxygen from the respiratory organs to the tissues. To do this effectively, their structure is adapted, and they have no nucleus. Due to this, red blood cells are biconcave discs in shape with a surrounding thin elastic membrane (Figure 1.8). RBC are filled with the red pigment *haemoglobin*. Haemoglobin combines with oxygen to form the molecule *oxyhaemoglobin* and carries the oxygen to the tissues. Haemoglobin also combines with carbon dioxide to carry this waste product away from the tissues. The quantities of red blood cells present are what give blood its red colour. When combined with oxygen, it is a brighter red but duller without. The lifespan of a red blood cell is approximately 120 days in the body.

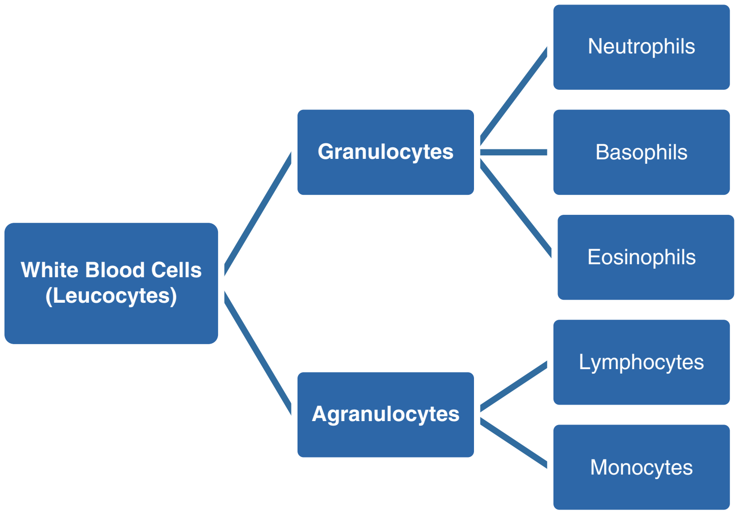


Figure 1.9 Categorisation of white blood cells.

White blood cells (leucocytes)

White blood cells (WBC) exist in lower quantities in the blood (approximately 1% of total blood volume), and their key role is to protect the body from infection and disease, as well as aiding repair from injury. All white blood cells have a nucleus. WBC are produced in the bone marrow and are categorized into two key groups (Figure 1.9).

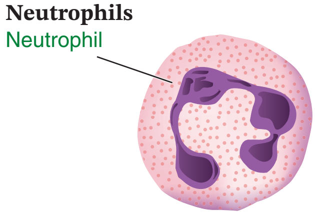
Functions of WBC

The term *phagocyte* or *phagocytic* means 'cell eater'. Phagocytic cells eat/engulf and destroy other cells that can be harmful to the body, e.g. pathogens, toxic materials. WBC are transported via the blood stream where they push through the walls of capillaries into the tissue spaces. Phagocytic WBC will gather areas where there are injury and damage to the body to destroy bacteria, viruses, and other harmful materials. They are one of the first lines of defence the body has in fighting infection.

Granulocytes

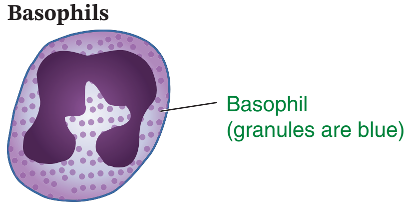
- Have granules in their cytoplasm that contain enzymes to protect from pathogens.
- The proportion present in the blood increases during times of infection as they are the first line of defence.

Neutrophils

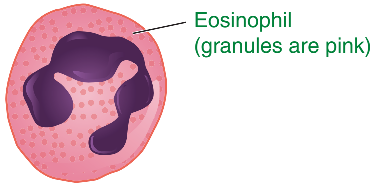
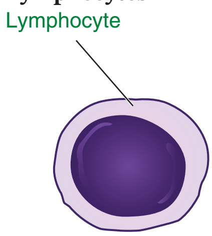
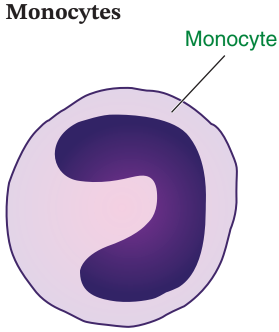


- Make up 40–60% of WBC
- Lifespan of 12–20 days
- *Phagocytic* cells that remove and destroy pathogens

Basophils



- Make up 1–3% of WBC
- Life span of 1–2 days
- Fight parasite infection
- Prevent blood clotting as they contain *heparin*
- Respond to allergic reactions

	Eosinophils 	• Make up 1–4% of WBC • Lifespan of 5–6 days • Eliminate parasites • Respond to histamine released during allergic reactions • Help dissolve blood clots as contain *plasminogen* • Sustain an inflammatory response
Agranulocytes Have no granules in their cytoplasm Integral part of the animal's immune system	**Lymphocytes** 	• 18–40% of WBC • Lifespan of a few weeks to years • Large nucleus • Recognise and respond to foreign *antigens* • 3 main types – T Cells, B cells, and NK cells (natural killer cells)
	Monocytes 	• 2–10% of WBC • Lifespan 2–3 days • Largest of the WBC • Mature into macrophages and dendritic cells • Part of the innate and adaptive immune system

Bone and Cartilage

There are two kinds of specialised skeletal connective tissue: bone and cartilage.

Bone

Bone is a connective tissue made up of cells called osteocytes, osteoblasts, and osteoclasts that are embedded in an extracellular matrix that becomes calcified for strength.

Bone can either be compact or spongy. Compact bone is the strongest. Spongy bone has spaces in its structure that are filled with red bone marrow, which is responsible for producing and destroying blood cells.

Cartilage

Cartilage is a dense, clear, blue/white material found mainly in skeletal joints that provides support for the body. Cartilage can be elastic or rigid. Cartilage has no blood vessels or nerve supply but is covered by a membrane called the *perichondrium* from which it receives its blood supply. The cells of cartilage are called *chondroblasts*.

There are three types of cartilage that have been previously identified:

- *Hyaline cartilage* – It contains many collagen fibres and is found in mobile articular joints, ribs, and the C-shaped rings of cartilage that keep the trachea open for air passage into the lungs. Hyaline cartilage also forms the embryonic skeleton until it is replaced by bone.
- *Elastic cartilage* – This has a high number of elastic fibres and is found where flexibility is needed in the structure, e.g. the ear pinna, the external ear canal, the epiglottis, and larynx and the upper respiratory tract.
- *Fibrocartilage* – It is found where strength is required for support in the body such as the intervertebral discs, the hip joints, and tendons. Its collagen fibres tend to be thicker than those of hyaline cartilage. The knee joint contains thick pads of fibrocartilage called menisci.

Muscle tissue

Muscle cells are usually long, thin cells known as *myocytes*. Individual myocytes combine to form bunches of cells called *muscle fibres*. Groups of muscle fibres are joined together by connective tissue to form muscles. The structure of the muscle fibres gives muscles the ability to contract as the cells are excitable and elastic in their nature. These characteristics enable movement of the skeleton and the function of organs and systems within the body.

The cell membrane of muscle cells is called the *sarcolemma* and as with all other cell membranes, it is selectively permeable and controls the movement of substances in and out of the cell. The cytoplasm of muscle cells may be referred to as *sarcoplasm*.

There are three main types of muscle tissue:

- *Skeletal* (also called voluntary and striated) (Figure 1.10)
- *Smooth* (also called involuntary, non-striated, and visceral) (Figure 1.11)
- *Cardiac* (Figure 1.12)

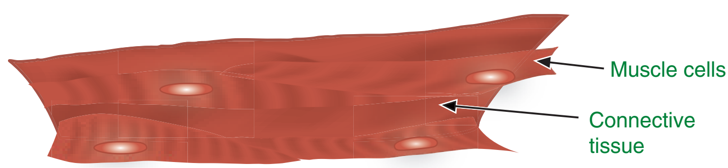


Figure 1.10 Skeletal (striated) muscle fibre.

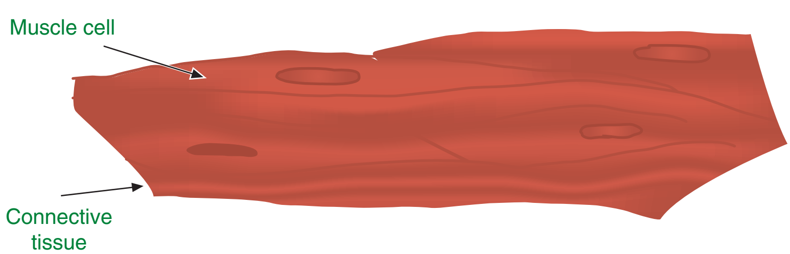


Figure 1.11 Smooth (non-striated) muscle fibre.

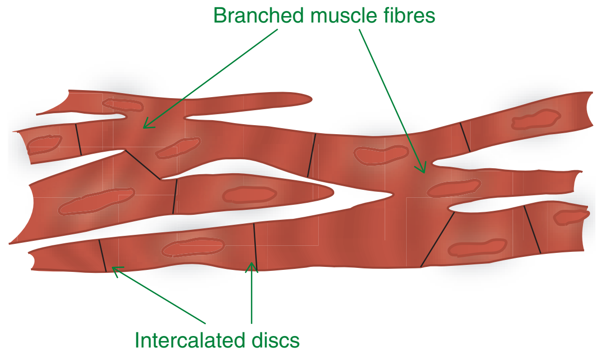


Figure 1.12 Cardiac muscle fibre.

Skeletal muscle tissue

Skeletal muscle tissue is found in the muscles attached to the skeleton by tendons. The cells are cylindrical and vary from 1 mm to 5 cm in length. Skeletal muscles are also called *voluntary muscle* as most of the time, they move due to thought processes of the animal. As well as enabling movement in an animal, skeletal muscles also support body posture and contribute towards the regulation of body temperature.

Skeletal muscles are constructed from parallel muscle fibres being held together in small bundles by connective tissue. These are collected into larger groups, which ultimately form the muscle and are surrounded by more connective tissue called the *muscle sheath*. When muscles are close to one another, the muscle sheaths may thicken to form *intermuscular septa*.

Skeletal muscle appears striped when viewed under the microscope. These stripes are known as striations leading to skeletal muscle tissue being called *striated* muscle. The striped appearance is due to the arrangement of two proteins called *actin* and *myosin*, which form muscle units called *sarcomeres*. These sarcomere units are repeated throughout the muscle fibre. Actin and myosin are the key proteins referred to in the most widely accepted theory of muscle contraction called the *sliding filament theory*. This theory states that a muscle contracts due to the thinner actin filaments sliding over the thicker myosin filaments within muscle cells to cause contraction.

Skeletal muscle cells are cylindrical in shape and have more than one nucleus (multi-nucleated). These cells contain many mitochondria due to their role in energy production. Their endoplasmic reticulum is more specialised *(sarcoplasmic reticulum)* as it stores and releases calcium ions that are needed for muscle contraction to take place.

While skeletal muscle can be quickly stimulated to respond, and can contract rapidly, it becomes tired easily (fatigued). Muscle fibres may be categorised as fast twitch and slow twitch fibres. Twitch refers to the process of contraction. Slow twitch fibres move more slowly but do not tire as easily, whereas fast twitch fibres help fast movement over a shorter time frame but are easily fatigued.

Tendons

At either end of a muscle, the muscle sheath continues into the connective tissue of the structure to which the muscle is attached, i.e. bone. In most cases for skeletal muscles, the connective tissue leaves the muscle as a fibrous band called a *tendon*. Tendons connect muscle to bone and do not stretch very easily. They help with supporting the body structure. Tendons have little blood supply and so, if damaged, they heal very slowly.

Examples of tendons:

- *Achilles tendon* – connects the calf muscle to the heel bone to enable walking
- *Superficial flexor tendon* – helps transfer energy from the upper leg to the lower leg through flexion of the joint in animals

In some areas of the body, fibrous sheets called *aponeurosis* connect muscles to bones and contribute to the body's strength and stability. Aponeuroses are also responsible for absorbing energy when the body moves in stabilising posture. Examples of aponeurosis are as follows:

- *Epicranial aponeurosis* – found in the skull. Works with the skin and other connective tissue to support the muscles of the skull that control facial expression
- *Plantar aponeurosis* – found in the foot. Works to support the foot when running and walking

Ligaments

Ligaments hold bones together across a joint to give it more protection and stability. They stop bones from over-twisting or moving too far apart.

Examples of ligaments:

- *Anterior cruciate ligament* – found around the *stifle* (knee) joint. The common site of injury causing lameness in dogs.
- *Nuchal ligament* – found in the neck from the skull to the vertebral joints at the base of the neck. The nuchal ligament helps to support the weight of the head in species such as cows, horses, and dogs.

Smooth Muscle

Smooth muscle cells are spindle shaped and usually no longer than 0.5 mm in length. When viewed under the microscope, they look smooth (not striated) and contain a single nucleus (Figure 1.11). Smooth muscle cells contain fewer mitochondria than skeletal muscle cells as they do not produce rapid bursts of energy, but they appear to contain more Golgi bodies and endoplasmic reticulum. Within smooth muscle, there are layers known as circular muscle and longitudinal muscle, and these layers work together to move objects through the relevant tract, e.g. digestive, reproductive.

Smooth muscle is specialised for continuous low-force contractions that are applied over a greater section of muscle tissue. Smooth muscle may also be called *involuntary* muscle as their movement is involuntary, i.e. the animal does not need to think about moving them. For example, smooth muscle is found in the intestinal walls of the digestive tract, where it contracts in a continuous rhythm, to move food through the tract by *peristalsis*. Peristalsis occurs when the circular muscle layer contracts and the longitudinal muscle relaxes behind the food bolus to move it along. The longitudinal muscles contract and the circular muscles relax at the other side of the bolus to enable it to move further down the digestive tract.

Smooth muscle can be found in the respiratory tract, the urinary and the reproductive systems, where they are responsible for changing the size of blood vessels and organs. They form a supportive lining and can also be called visceral muscles due to this.

Cardiac Muscle

Cardiac muscle is only found in the heart. Cardiac muscle helps to pump blood through the body to ensure that nutrients and oxygen are delivered to all cells, tissues, and organs.

Cardiac muscle produces continuous forceful contractions that use a lot of energy. For continuous contraction to take place, the muscle fibres are branched and have specialised junctions with the surrounding fibres. These specialised junctions are called *intercalated discs*, and they allow rapid electrical signalling between the cells to enable rapid contraction of nearby tissue. Cardiac myocytes are elongated and striated in appearance with only one nucleus per cell unlike skeletal muscle (Figure 1.12). They contain many mitochondria for a constant energy supply. They are held together by very small amounts of connective tissue.

Nervous Tissue

The function of nervous tissue is to receive, transmit, and coordinate electrical messages from one part of the body to another to effect a change. Nervous tissue is therefore complex. Individual nerve cells can transmit and sometimes store information because of this complexity.

Nerve cells are called *neurones* (Figure 1.13). Neurones connect and communicate to form pathways so that the body can respond to information received from stimuli. Neurones vary in size and shape depending on where they are in the nervous system. However, all neurones have the same basic structure:

- A large *cell body (soma)* containing the nucleus surrounded by cytoplasm, with two types of processes extending from the cell body: a single axon and one or more dendrites. The cell body maintains the nerve cell and is involved in its growth and development.
- *Dendrites* are processes like tree branches that receive electrical impulses from specialised *sense receptors* (information) and convert them into electrical impulses to transfer the information into the cell body.
- *Axons* extend from the cell body as a tube-like structure of variable length, carrying the electrical signal away to the next nerve cell at their *terminal ending*. The point at which the axon leaves the cell body is called the *axon hillock*.

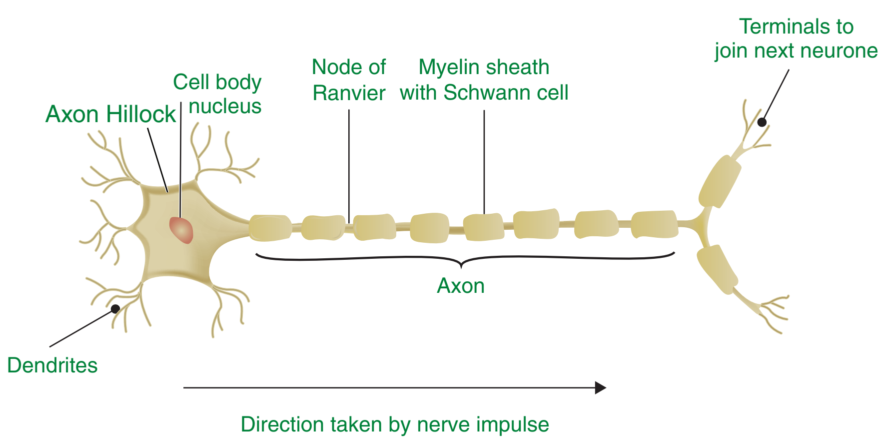


Figure 1.13 A neurone.

- The primary function of the axon is to transmit electrical signals at the *axon terminal* to other neurones, muscles and glands or form junctions (*synapses*) with adjoining neurones from which they receive electrical stimuli, which are passed to the cells beyond.

Additional structures

- Along the axon, most neurones have a protective layer called the *myelin sheath*, which aids in speeding up the transmission of the electrical impulses. The myelin sheath is formed by structures called *glial cells*. The myelin sheath is comprised of individual segments called *Schwann cells*. In between the Schwann cells are gaps called nodes of Ranvier. The structures aid transmission of the electrical impulse through a process called *saltatory conduction*.

While the basic structure is the same, neurones can be classified into three types:

1. **Sensory neurones**
   Receive information from the *external environment* via specialised tissues called sensory receptors and transmit electrical impulses to the central nervous system (CNS) for processing. Because they transmit information towards the CNS, sensory neurones are also called *afferent* neurones. Sensory neurones detect external stimuli such as touch, taste, smell, pain, and temperature.
2. **Motor neurones**
   Receive information from the CNS and transmit electrical impulses to voluntary (skeletal) and involuntary (cardiac and smooth) muscles. Because they transmit information away from the CNS, sensory neurones are also called e*fferent* neurones.
3. **Interneurones**
   Interneurones are the connecting cells between the sensory neurones and the motor neurones. There may be several interneurones involved in the transfer of electrical impulses from stimuli receipt to muscle movement. They are the most abundant type of nerve cells, and they are only found in the CNS.

The point at which neurones meet each other to transfer information is called a *synapse* or synaptic gap. The neurone that is sending the signal is called the *presynaptic neurone* and the neurone receiving the signal is called the *post-synaptic neurone*. Transmission across the synapse may be electrical or chemical. Chemical transmission is via chemicals called *neurotransmitters*.

Summary of Tissues

There are many different tissue types within the body with their own specialised function reflected in the diversity of cells that the tissues contain. The four main tissue types are as follows:

- Epithelial
- Connective
- Muscle
- Nervous

All tissue types work together to form organ systems that integrate and collaborate to enable functioning of the animal body and respond to its external environment.