Chapter 1

Cells and Basic Tissues

Summary

In this chapter, the learning outcomes are:

- To understand the essential functions required to sustain life – MRS GREN
- To be able to identify the structure and function of animal cells and tissues
- To be able to recognize the diversity of animal cells and tissues in existence

What is Biology?

Biology is the study of life and living organisms

What is life?

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

- *Movement* – the organism is capable of moving itself or a part of itself.
- *Reproduction* – the organism is capable of reproducing itself so that the species doesn't die out.
- *Sensitivity* – to stimuli in its surroundings in order to avoid life-threatening occurrences in the environment.
- *Growth* – sustained growth from within by a process which involves the intake of new materials from the outside and their incorporation into the internal structure of the organism.
- *Release of energy from respiration* – in a controlled manner and in a form usable by the organism. The process of respiration releases energy from food to sustain life.
- *Excretion* – the removal of the waste products of metabolism from the organism.
- *Nutrition* – taking in food materials which provide energy to maintain life and growth.

Animal Biology and Care, Third Edition. Sue Dallas and Emily Jewell.

Companion Website: www.wiley.com/go/dallas/animal-biology-care

The cell is the simplest functional unit of all tissues and has the ability to perform individually all the essential life functions. Organisms may be single-celled or multi-celled. Within the multicellular organisms, the constituent cells show a wide range of specialisations. Cells can be viewed as the building blocks of the body, and so the following can be said:

- *Cells* form…
- *Tissues*, and tissues form…
- *Organs*, and organs… join together to form *systems* within the body.
- Systems have a specific function to perform in the living organism.

The diversity of cells

Cells are not all identical (Fig. 1.1) but all have the same basic structure. Each component of a cell is known as an organelle:

- *Cell membrane* – the surrounding membrane of the cell which encloses the cytoplasm and is only 0.00001 mm in thickness. The cell membrane is the outer boundary that controls all exchanges between the cell and its surrounding environment. The cell membrane allows certain chemicals to pass in and out of the cell either by *diffusion, osmosis* or *active transport*. The cell membrane is described as being *selectively permeable*.

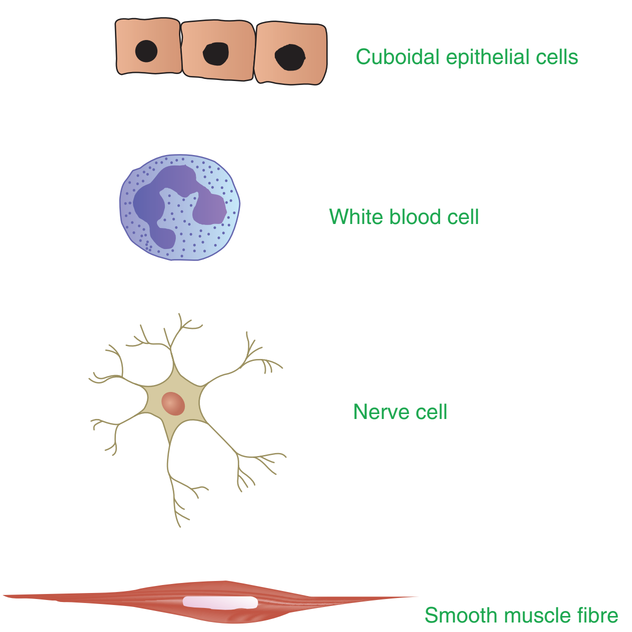

Fig. 1.1 Diversity of cells from their basic form.

- *Nucleus* – acts as the cell's brain and controls the cell's activities and there is usually only one nucleus in the cell. The nucleus also contains the chromosomes.
- *Cytoplasm* – a jelly-like material that supports the organelles within the cell. It contains enzymes and many other chemicals that aid cell metabolism.
- *Chromosomes* – rod-shaped components that contain the hereditary information of the organism. Chromosomes contain deoxyribonucleic acid (DNA) which controls the characteristics that an organism inherits from its parents.
- *Mitochondria* – the energy-producing organelles where cell respiration takes place.
- *Endoplasmic reticulum* (ER) – is a series of tubules acting as a transport and packaging system. ER may be rough ER or smooth ER. Rough ER has ribosomes attached to it where proteins are synthesized. This protein can be used by the cell to synthesize enzymes and hormones. Smooth ER has no ribosomes and is used to synthesize and transport lipids (fats) and steroids made within the body.
- *Ribosomes* – build proteins within the cell which are then joined to form amino acids which are essential to growth. Ribosomes contain *ribonucleic acid* (RNA).
- *Centrosome* – an area found near the nucleus and 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 for movement of single-celled organisms). Centrioles can only be seen during cell division; otherwise, a dark area known as the centrosome is observed.
- *Lysosomes* – are dark round bodies containing enzymes responsible for splitting complex chemical compounds into simpler ones (known as *lysis*, meaning 'to break up') followed by digestion. They also destroy worn-out organelles within the cell. These destructive enzymes are packaged in an area of the cell called the *Golgi complex* or *Golgi body*.
- *Peroxisomes* – are similar to lysosomes but they contain a different type of enzyme that breaks down toxic materials in the cell. Peroxisomes are good at breaking down fatty acids, alcohol and hydrogen peroxide made during digestion.

The organelles listed earlier are common to virtually all cells, but the shape, form and contents of individual cells show much variation. The structural characteristics of a particular cell are closely related to its functions (Fig. 1.2).

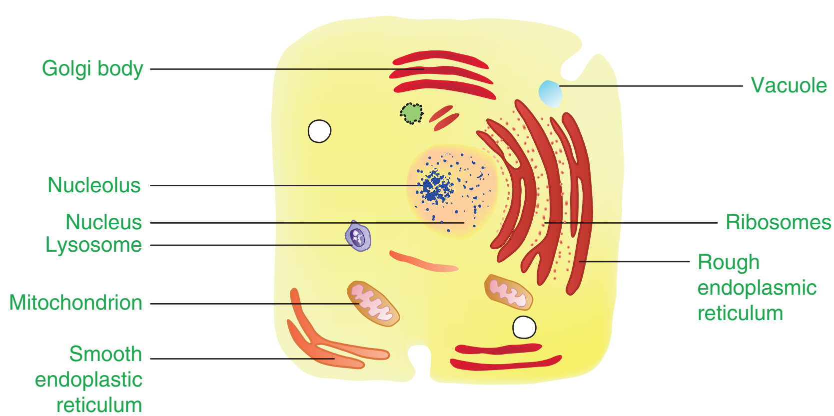

Fig. 1.2 Basic cell structure.

Types of cell found in the animal body

- *Epithelial cells* – have a shape and form that make them most suitable for lining the surface of the body and the organs and cavities within it.
- *Glandular cells* – are responsible for producing some kind of secretion, for example, mucus, to lubricate between tissues.
- *Osteoblasts* – produce bone tissue.
- *Erythrocytes* (*red blood cells*) – have a shape designed to hold the red pigment haemoglobin which conveys oxygen around the body. In order to do this, they are one of the few cells in the body which no longer contain a nucleus.
- *Nerve cells* – or neurones have slender armlike processes which will transmit electrical impulses through the nervous system to reach the whole body.
- *Muscle cells* – are also capable of electrical activity accompanied by a muscle contraction for body movement.
- *Sperm cells* – are the male sex cells. They have a tail for swimming and only contain half the amount of chromosomes.
- *Ova* – are the female sex cells. They contain only half the amount of chromosomes of other cells in the body.

Cells

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

- Food for energy
- Water (body fluid) to hydrate the cells
- Oxygen to all cells
- A suitable temperature in which to live

Animal Tissues

Tissues are a collection of cells and their products which have a common fundamental function and in which one particular type of cell predominates:

- *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:
  - *loose connective tissue* which surrounds organs
  - *dense connective tissue* which has great strength and is found as tendons and ligaments
  - *blood* which transports essential nutrients, gases, waste products, hormones and enzymes to and from all body cells
  - *cartilage* and *bone* which provide shape and protection for organs and allow movement.

- *Muscular tissue* – are concerned with movement of the skeleton, the organ systems and the heart.
- *Nervous tissue* – is concerned with transporting messages to tissues and connecting the body as a whole for the required response.

Epithelial tissue

This tissue covers all surfaces of the body, both inside and out, whether it is a surface, a cavity or a tube. It is made up of a diverse group of tissues which are involved in a wide range of activities such as secretion of a special fluid, protection and absorption.

Depending on their function, the cells of this tissue will have varied shape, structure and thickness. 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.
- *Specialisations*, such as tiny hairs called cilia or special thickened surface tissue called keratin, which covers the nose and pads of the feet.
- *Glandular* – means that it is involved in secretion. Secretions which go directly into the bloodstream are called *hormones* and are produced by glands of the *endocrine* or *ductless system*. Some secretions are produced by glands that have ducts. The secretion is released through the duct onto the surface of the cell. Glands with ducts belong to the exocrine system and an example of this is when enzymes are produced by the pancreas.

Types of epithelial tissue

Epithelial tissue has many different functions, and this therefore reflects in the different forms that can be found. There are six main types of epithelial tissue:

- *Pavement* – can be found lining the surfaces involved in the transport of gases (lungs) or fluids (walls of blood vessels) (Fig. 1.3a).
- *Cuboidal* – can be found lining small ducts and tubes such as those of the kidney, pancreas and salivary glands of the mouth (Fig. 1.3b).
- *Columnar* – located on highly absorbing surfaces like the small intestine for the uptake of nutrients (Fig. 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 (Fig. 1.4a).
- *Glandular* – which secrete a special fluid containing hormones or enzymes (Fig. 1.4b).
- *Stratified* – this type of epithelium has two or more layers of cells. Its function is mostly protection. It can be found lining the mouth or as skin (Fig. 1.4c).

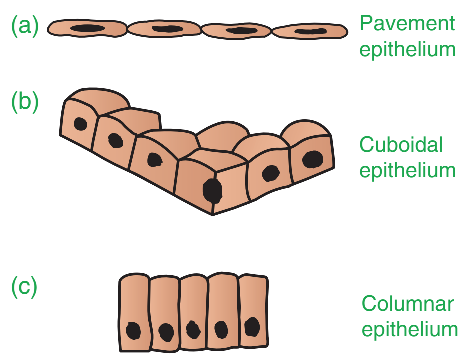

Fig. 1.3 Pavement, cuboidal and columnar tissue.

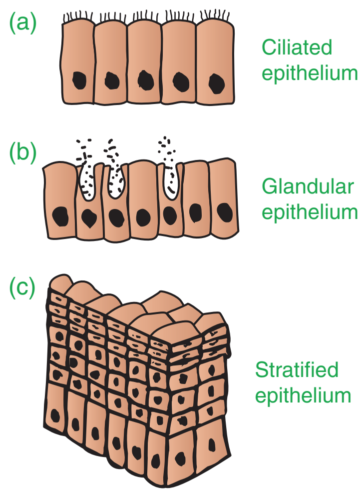

Fig. 1.4 Ciliated, glandular and stratified tissues.

Connective tissue

Connective tissue binds all the other body tissues together. It supports them and acts as a transport system for the exchange of nutrients, metabolites and waste products between tissues and the circulatory system (Fig. 1.5).

Connective tissues occur in many different forms with a wide range of physical properties:

- *Loose connective tissue* acts as a type of packing material between other tissues with specific functions.
- *Dense connective tissue* provides tough support in the skin.
- *Rigid* forms of connective tissue, like cartilage and bone, support the skeleton.

Connective tissue also has functions including the storage of fat in adipose tissue, fighting infection and tissue repair.

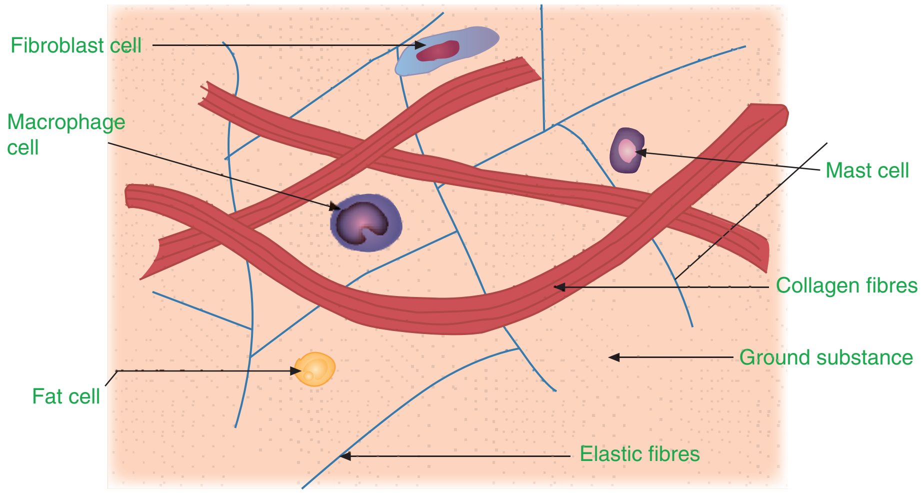

Fig. 1.5 Connective tissue.

Connective tissue has two components:

(1) *Cells*:
 (a) fibroblasts for repair and maintenance of the tissue
 (b) fat-storing cells
 (c) defence and immune function cells called *macrophages*.
(2) *Ground substance* – a material which holds together other materials to make up tissue and looks like a semi-fluid gel.

Connective tissue can be described as a mixture of fibres in different proportions. Its efficiency in binding structures together is achieved by the special grouping of proteins in the ground substance. The particular type and abundance of fibre present depend on the stresses and strains to which the tissue is normally subjected.

Connective tissue is composed of two types of fibre:

- *Collagen* – produced by the fibroblasts and is not elastic but has great tensile strength. Tendons by which muscles are attached to the bones are composed of collagen fibres.
- *Elastin* – has great elasticity and is found in ligaments which bind the bones of the skeleton together.

Blood

Blood is a highly specialised tissue consisting of several types of cell suspended in a fluid medium called *plasma* (Fig. 1.6). The cellular constituents consist of:

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

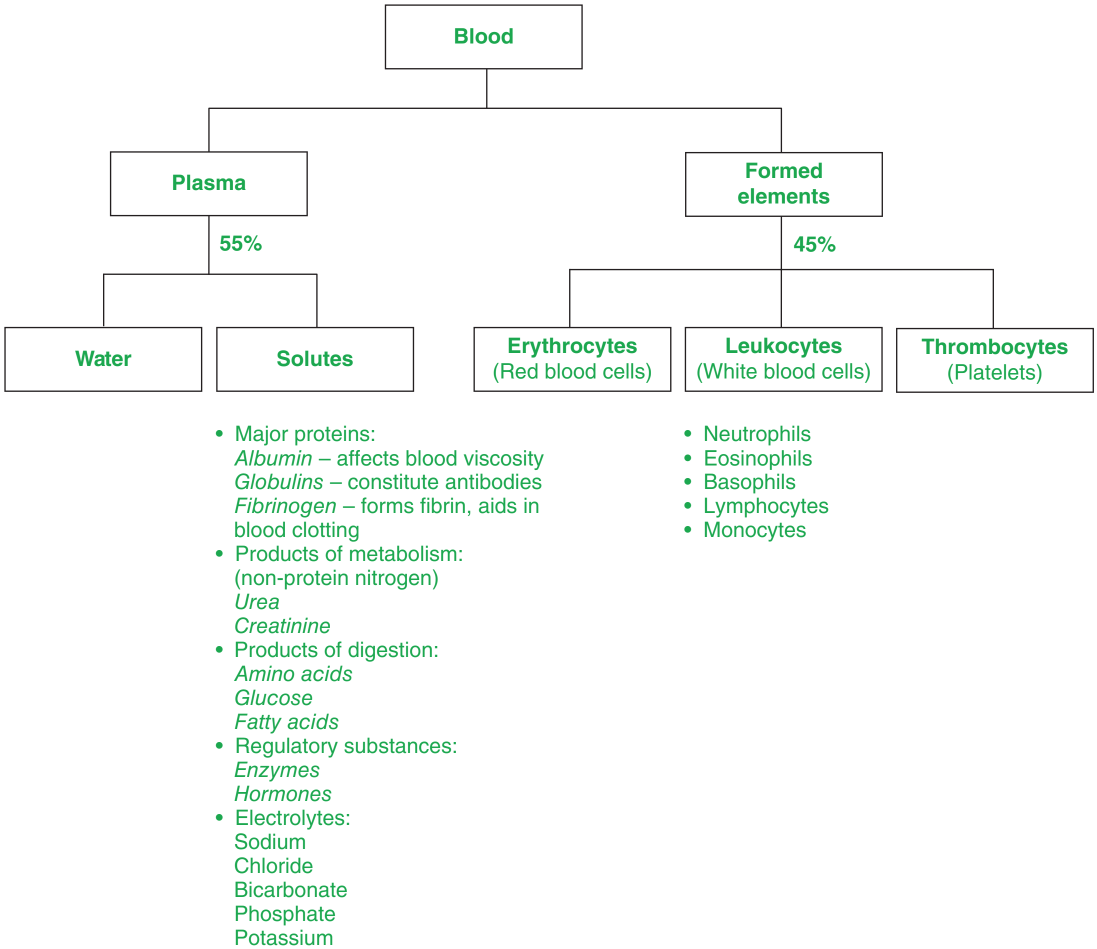

Fig. 1.6 Blood components.

Blood has a varied structure and performs a wide range of functions. One of its main functions is the transportation of red blood cells and all materials in the plasma around the body. Blood is considered a tissue because it connects all the cells in the body together.

Living animals constantly absorb useful substances like oxygen and food, which must then be distributed throughout their bodies. They produce a continuous stream of waste materials, such as carbon dioxide, which must be removed from their bodies before they reach harmful levels. The distribution of food, oxygen and other substances throughout the body and the removal of any wastes are performed by this transport system tissue.

Composition of the blood

Fluid called *plasma* makes up about 60%. Cells and other material in transit make up the remaining 40%.

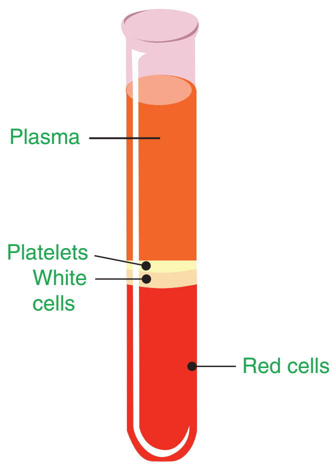

Fig. 1.7 Blood separated into layers.

If a sample of blood (mixed with an anticoagulant to stop it from clotting) was put into a centrifuge and spun to separate out the component parts, it would show at the top of the tube the fluid part (plasma), then the platelets (cell fragments), then the white blood cells and finally the red cells (Fig. 1.7).

Plasma – is mainly water containing a variety of dissolved substances which are transported from one part of the body to another. To give a few examples, food materials (glucose, lipids and amino acids) are conveyed from the small intestine to the liver, urea from the liver to the kidneys and hormones from various ductless glands to their target organs. Cells are constantly shedding materials into the blood which flows past them and removing materials from it. Plasma provides the medium through which this continual exchange takes place.

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)

Plasma carries many more products than the diagram shows, including the plasma proteins called albumin, globulin and fibrinogen. Fibrinogen plays an important role in the process of blood clotting. When it has been used up by clot formation, then the fluid part of blood seen at the site of injury is called *serum*. Therefore, the serum is plasma with the fibrinogen removed. About 92% of blood is made of water, and this same water can be forced into the tissues. It is then called *tissue fluid* because of its location.

It is important to realise that plasma and the tissue fluid derived from it form the environment which keeps body cells alive. In a sense, these fluids are equivalent to a pond or fish

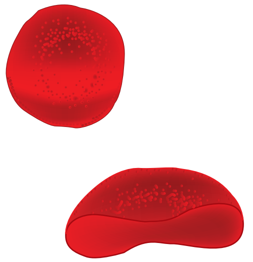

Fig. 1.8 Cross section of a red blood cell showing its biconcave shape.

tank in which both single-celled organisms and multi-celled organisms live and are supplied with their food and oxygen and into which they excrete waste.

Red blood cells (erythrocytes)

These are produced in the red or active bone marrow. The main function of red blood cells is to carry oxygen from the respiratory organ to the tissues, and their structure is modified accordingly. These cells have had their nucleus removed, with the result that the cell is sunk in on each side, giving it the shape of a biconcave disc. It is surrounded by a thin elastic membrane, and the interior of the cell is filled with the red pigment haemoglobin which combines with and carries oxygen (Fig. 1.8).

White blood cells (leucocytes)

The white cells are fewer in number and have a very different role to play. They fall into two groups (Fig. 1.9):

- *Granulocytes (granules in the cytoplasm)*. These are produced in the bone marrow.
  - *Neutrophils* – phagocytic cells
  - *Eosinophils* – respond to allergies
  - *Basophils* – promote inflammation for healing of tissue
- *Agranulocytes (no granules in their cytoplasm)*. Produced in the bone marrow or lymph system.
  - *Lymphocytes* – support the immune system
  - *Monocytes* – phagocyte cells

Phagocyte or phagocytic means 'cell eater'. These cells eat or engulf other cells/materials that may be harmful and destroy them. Red cells will remain in the bloodstream to perform their role of oxygen carrier, but white cells will only use the bloodstream as a transporter from their site of origin to the capillaries where they will push through the wall of the blood vessel and into the tissue spaces. Those that are phagocytic will gather in and around wounds and destroy bacteria and any other harmful materials. In this manner, the cells assist in 'fighting infection'.

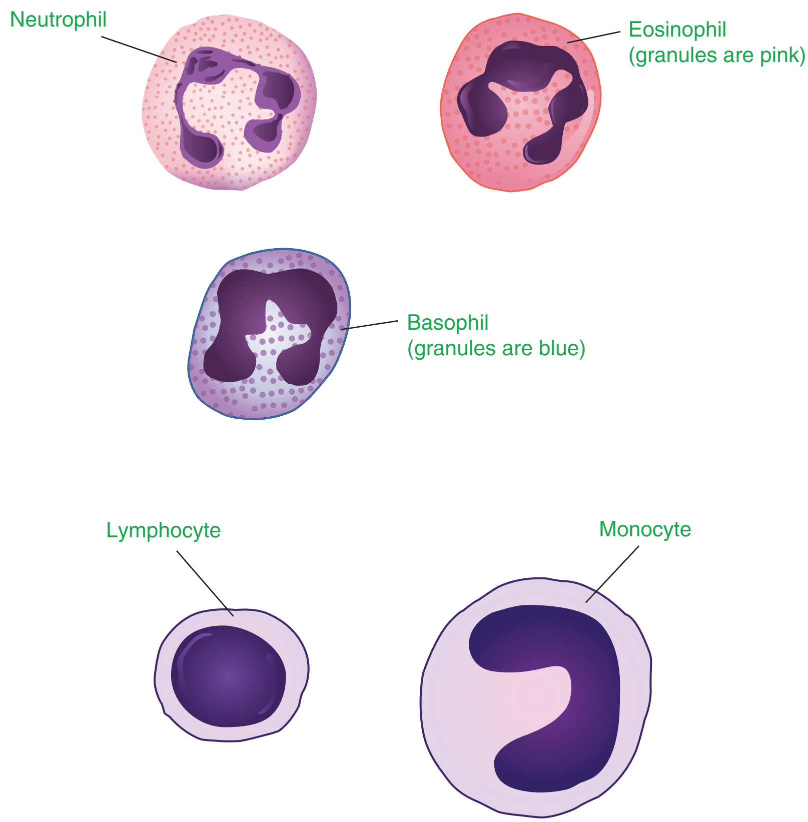

Fig. 1.9 White blood cells.

Bone and cartilage

There are two kinds of skeletal tissue, bone and cartilage.

Bone

Bone tissue is closely related to connective tissue in that it consists of cells embedded in an organic matrix (ground substance). However, this matrix is comparatively hard. The cells of the bone are called *osteoblasts* and *osteoclasts*.

Cartilage

Cartilage is a dense, clear, blue/white material which provides support for the body and can be elastic or rigid. Found mainly in the joints, it has no blood vessels 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:

(1) *Hyaline cartilage* – the cells for hyaline production are called *chondrocytes*. They lie within a hyaline matrix with collagen fibres running through. Hyaline is a smooth tissue and forms articular joint surfaces for the bones and the C-shaped rings of cartilage that keep the trachea open for air passage into the lungs.
(2) *Fibrocartilage* – this is stronger than hyaline but with a similar base structure that contains more collagen fibres. It surrounds the articular surface of some bones, for example, in the hip joint (acetabulum) and the shoulder joint (glenoid cavity), and is also found in the stifle or knee joint as pads of cartilage called *menisci*.
(3) *Elastic* – this has a hyaline matrix and many elastic fibres which provide its elastic properties. It is found in the ear flap (pinna) and in the larynx area of the throat.

Muscular tissue

Muscular tissue has a well-developed ability to contract due to its structure. Muscle cells are usually long, thin and thread-like and are often called *fibres*. There are three main types of fibres:

- *Skeletal* (also called voluntary and striated) (Fig. 1.10)
- *Smooth* (also called involuntary, nonstriated and visceral) (Fig. 1.11)
- *Cardiac* (Fig. 1.12)

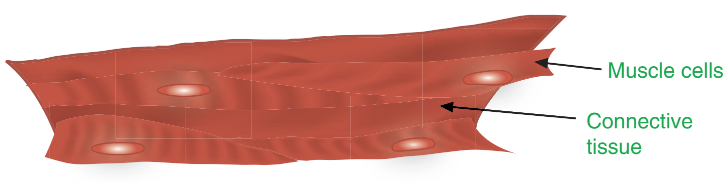

Fig. 1.10 Skeletal (striated) muscle fibre.

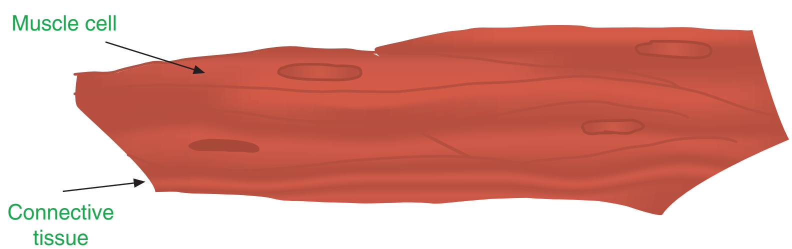

Fig. 1.11 Smooth (non-striated) muscle fibre.

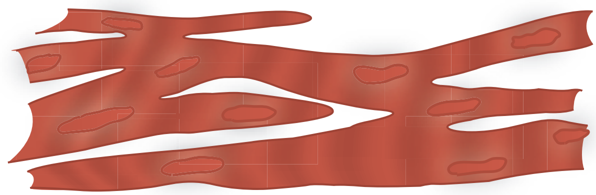

Fig. 1.12 Cardiac muscle fibre.

Skeletal muscle

Skeletal muscle is located in muscles attached to the skeleton. The cells are cylindrical and vary from about 1 mm to 5 cm in length. Since skeletal muscles respond to the will of the animal, the cells are also called *voluntary* muscle cells.

Skeletal muscles are formed of parallel muscle cells (*fibres*) held together in small bundles by connective tissue. These are collected into larger groups, enclosed in connective tissue which ultimately form the muscle and are surrounded by yet more connective tissue commonly called the *muscle sheath*.

When muscles are close to one another, the sheaths may thicken to form *intermuscular septa*.

All the connective tissue within and around the muscles continues into the connective tissue of the structure to which the muscle is attached, i.e. bone. Sometimes, the muscle appears to attach directly, but usually, the connective tissue leaves the muscle as a fibrous band known as a *tendon* (i.e. Achilles tendon on the point of the hock) or as a fibrous sheet called an *aponeurosis* (i.e. the sheet of muscle and connective tissue called the diaphragm).

Some muscles are named according to their shape, some according to their functions and others according to their position in the body.

Under the microscope, skeletal muscle cells look striped (they have *striations*), and so, this type of muscle tissue may also be referred to as striated muscle.

Smooth muscle

Smooth muscle is specialized for continuous contractions of little force but over a greater section of muscle tissue. This is in direct contrast to skeletal muscle, which is specialized for relatively forceful contractions of short duration and under voluntary control. Smooth muscle, for example, is found in the intestinal wall and contracts in continuous rhythm, moving food through the tract by *peristaltic action*.

Smooth muscle fibres are spindle shaped and about 0.5 mm in length or shorter. Under the microscope, they look smooth. Only small amounts of connective tissue bind them together to form sheets or layers of muscle tissue. They may also be called *involuntary* muscles because they are not controlled by the will of the animal. These fibres are found in the muscle of organs, hence the alternative name of *visceral* muscle.

Cardiac muscle

Cardiac muscle is only found in the heart. It produces strong contractions using a lot of energy but its contractions are continuous. In order for continuous contraction to take place, the fibres have junctions or connections with the surrounding fibres which allow very rapid contractions of all nearby tissue. The cells are elongated and are the only muscle cells which frequently branch. They are held together by very small amounts of connective tissue.

Nervous tissue

The function of nervous tissue is to transmit electrical messages from one part of the body to another. As a result of this, nerve cells are interconnected in a very complex way. The cells can transmit and sometimes store information because of this complex link-up with each other.

Nerve cells are called *neurones* (Fig. 1.13), and they connect and communicate to form pathways so that the body can respond to information received. Neurones vary in size and shape depending on where they are in the nervous system. However, all neurones have the same basic structure. They consist of a large cell body containing the nucleus surrounded by cytoplasm, with two types of processes extending from the cell body: a single axon and one or more dendrites:

- *Dendrites* are branched, tapering processes which either end in specialized *sense receptors* (information) or form junctions (*synapses*) with neighbouring neurones from which they receive electrical stimuli, which are passed to the cells beyond.
- *Axons* extend from the cell body as a tube-like structure of variable length, carrying stimuli or messages away to the next nerve cell.

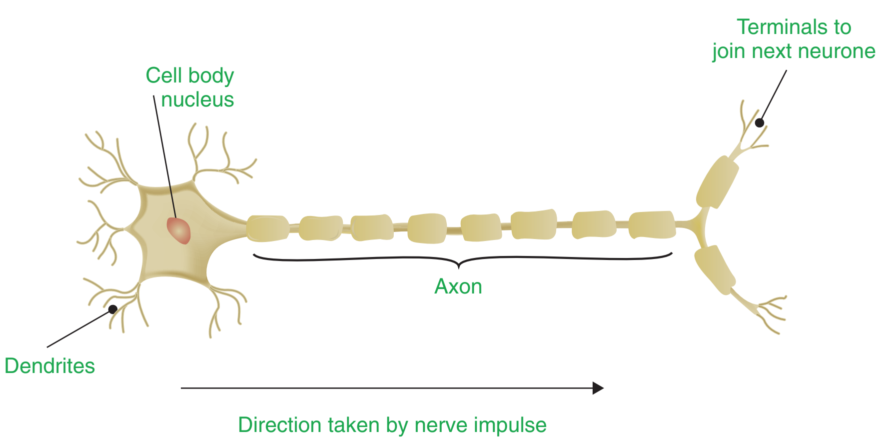

Fig. 1.13 A neurone.