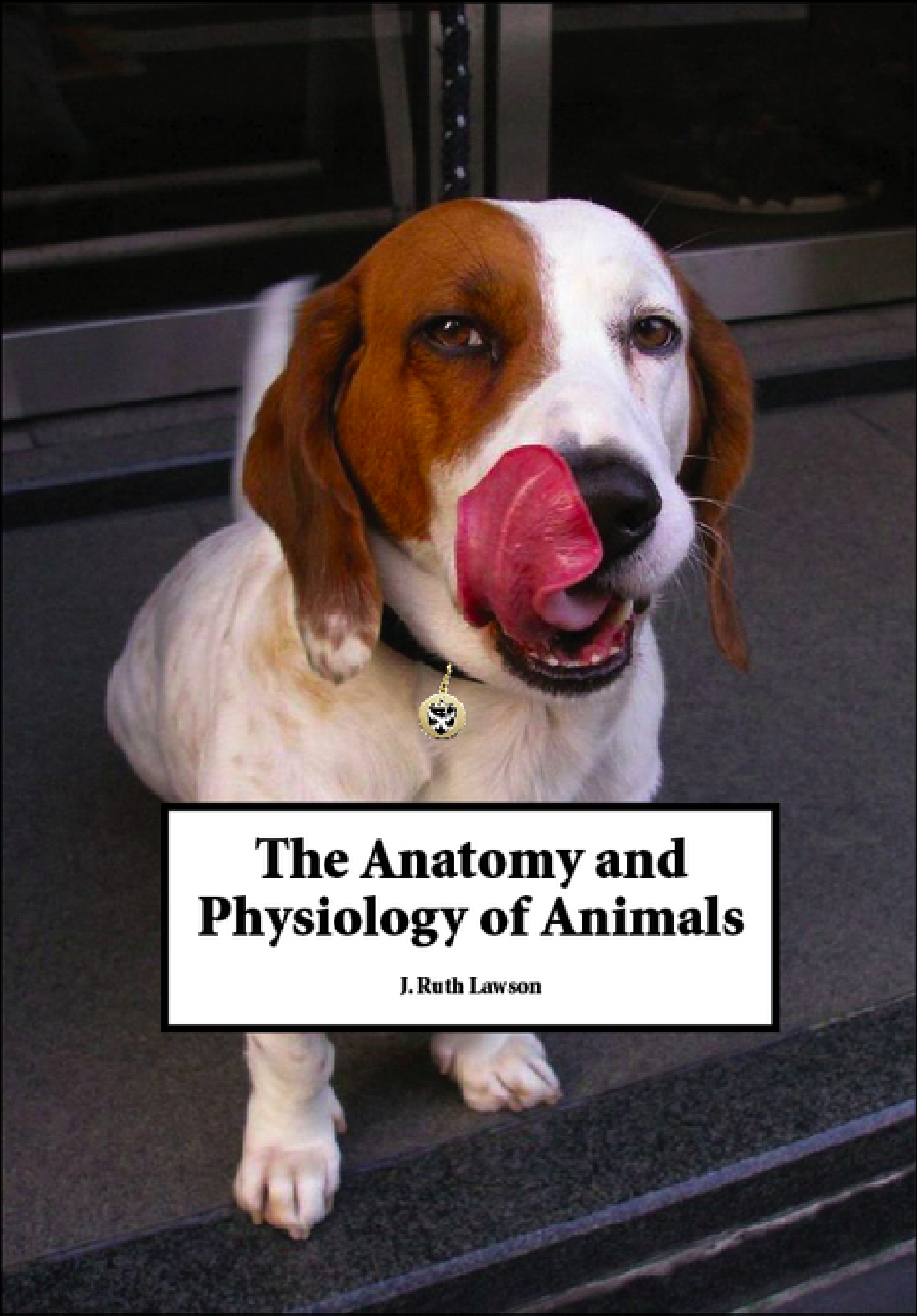

The Anatomy and Physiology of Animals

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Anatomy and Physiology of Animals

en.wikibooks.org

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Contents

1 Chemicals

Figure 1 original image by jurvetson[a] cc by

a http://flickr.com/photos/jurvetson/397768296/

1.1 Objectives

After completing this section, you should know the:

- symbols used to represent atoms;
- names of molecules commonly found in animal cells;
- characteristics of ions and electrolytes;
- basic structure of carbohydrates with examples;
- carbohydrates can be divided into mono- di- and poly-saccharides;
- basic structure of fats or lipids with examples;
- basic structure of proteins with examples;
- function of carbohydrates, lipids and proteins in the cell and animals' bodies;
- foods which supply carbohydrates, lipids and proteins in animal diets.

1.2 Elements And Atoms

The elements (simplest chemical substances) found in an animal's body are all made of basic building blocks or atoms. The most common elements found in cells are given in the table below with the symbol that is used to represent them.

Atom	Symbol
Calcium	Ca
Carbon	C
Chlorine	Cl
Copper	Cu
Iodine	I
Hydrogen	H
Iron	Fe
Magnesium	Mg
Nitrogen	N
Oxygen	O
Phosphorous	P

Atom	Symbol
Potassium	K
Sodium	Na
Sulfur	S
Zinc	Zn

1.3 Compounds And Molecules

A **molecule** is formed when two or more **atoms** join together. A compound is formed when two or than two different elements combine in a fixed ratio by mass. Note that some atoms are never found alone. For example **oxygen** is always found as molecules of 2 oxygen atoms (represented as O_2).

The table below gives some common compounds.

Compound	Symbol
Calcium carbonate	$CaCO_3$
Carbon dioxide	CO_2
Copper sulfate	$CuSO_4$
Glucose	$C_6H_{12}O_6$
Hydrochloric acid	HCl
Sodium bicarbonate (baking soda)	$NaHCO_3$
Sodium chloride (table salt)	NaCl
Sodium hydroxide	NaOH
Water	H_2O

1.4 Chemical Reactions

Reactions occur when atoms combine or separate from other atoms. In the process new products with different chemical properties are formed.

Chemical reactions can be represented by **chemical equations** . The starting atoms or compounds are usually put on the left-hand side of the equation and the products on the right-hand side.

For example

- $H_2O + CO_2$ gives H_2CO_3
- Water + Carbon dioxide gives Carbonic acid

1.5 Ionization

When some atoms dissolve in water they become charged particles called **ions** . Some become positively charged ions and others negatively charged. Ions may have one, two or sometimes three charges.

The table below shows examples of positively and negatively charged ions with the number of their charges.

Positive Ions		**Negative Ions**	
H+	Hydrogen	Cl-	Chloride
Ca^2+	Calcium	OH-	Hydroxyl
Na+	Sodium	HCO_3-	Bicarbonate
K+	Potassium	$CO_3{}^2$-	Carbonate
Mg^2+	Magnesium	$SO_4{}^2$-	Sulfate
Fe^2+	Iron (ferrous)	$PO_4{}^3$-	Phosphate
Fe^3+	Iron (ferric)	S^2-	Sulfide

Positive and negative ions attract one another to hold compounds together.

Ions are important in cells because they conduct electricity when dissolved in water. Substances that ionise in this way are known as **electrolytes** .

The molecules in an animal's body fall into two groups: **inorganic compounds** and **organic compounds** . The difference between these is that the first type does not contain **carbon** and the second type does.

1.6 Organic And Inorganic Compounds

Inorganic compounds include water, sodium chloride, potassium hydroxide and calcium phosphate.

Water is the most abundant inorganic compound, making up over 60% of the volume of cells and over 90% of body fluids like blood. Many substances dissolve in water and all the chemical reactions that take place in the body do so when dissolved in water. Other inorganic molecules help keep the **acid/base balance (pH**) and concentration of the blood and other body fluids stable (see Chapter 8).

Organic compounds include **carbohydrates, proteins** and **fats** . All organic molecules contain carbon atoms and they tend to be larger and more complex molecules than inorganic ones. This is largely because each carbon atom can link with four other atoms. Organic compounds can therefore consist of from one to many thousands of carbon atoms joined to form chains, branched chains and rings (see diagram below). All organic compounds also contain hydrogen and they may also contain other elements.

Figure 2

1.7 Carbohydrates

The name "carbohydrate" tells you something about the composition of these "hydrated carbon" compounds. They contain carbon, hydrogen and oxygen and like water (H_2O), there are always twice as many hydrogen atoms as oxygen atoms in each molecule. Carbohydrates are a large and diverse group that includes sugars, starches, glycogen and cellulose. Carbohydrates in the diet supply an animal with much of its energy and in the animal's body, they transport and store energy.

Carbohydrates are divided into three major groups based on size: **monosaccharides** (single sugars), **disaccharides** (double sugars) and **polysaccharides** (multi sugars).

Monosaccharides are the smallest carbohydrate molecules. The most important monosaccharide is glucose which supplies much of the energy in the cell. It consists of a ring of 6 carbon atoms with oxygen and hydrogen atoms attached.

Disaccharides are formed when 2 monosaccharides join together. Sucrose (table sugar), maltose, and lactose (milk sugar), are three important disaccharides. They are broken down to monosaccharides by digestive enzymes in the gut.

Polysaccharides like starch, glycogen and cellulose are formed by tens or hundreds of monosaccharides linking together. Unlike mono- and di-saccharides, polysaccharides are not sweet to taste and most do not dissolve in water.

UNKNOWN TEMPLATE multiple image

center Glucose Lactose Glucose Disaccharide (Lactose) Alpha-D-Glucopyranose.svg Lactose Haworth.svg 164 202

- **Starch** is the main molecule in which plants store the energy gained from the sun. It is found in grains like barley and roots like potatoes.
- **Glycogen** , the polysaccharide used by animals to store energy, is found in the liver and the muscles that move the skeleton.
- **Cellulose** forms the rigid cell walls of plants. Its structure is similar to glycogen, but it can't be digested by mammals. Cows and horses can eat cellulose with the help of bacteria which live in specialised parts of their gut.

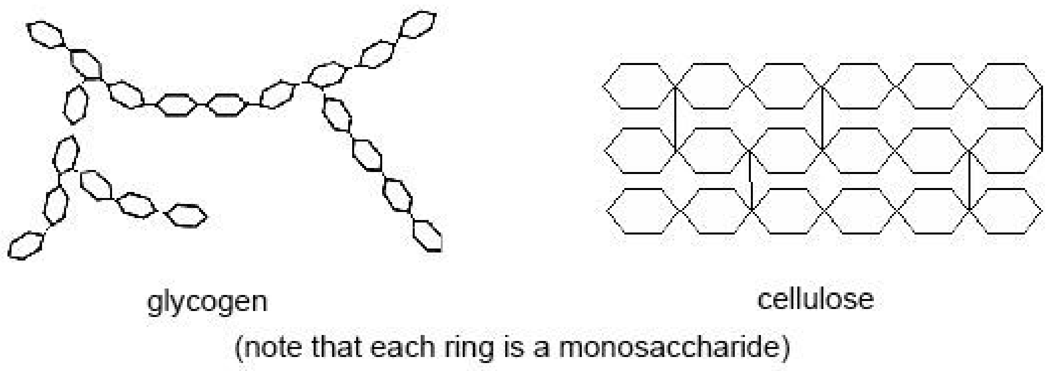

Figure 3

1.8 Fats

Fats or **lipids** are important in the plasma membrane around cells and form the insulating fat layer under the skin. They are also a highly concentrated source of energy, and when eaten in the diet provide more than twice as much energy per gram as either carbohydrates or proteins.

Like carbohydrates fats contain carbon, hydrogen and oxygen, but unlike them, there is no particular relationship between the number of hydrogen and oxygen atoms.

The fats and oils animals eat in their diets are called **triglycerides** or**neutral fats** . The building blocks of triglycerides are 3 **fatty acids** attached to a backbone of **glycerol** (**glycerine**). When fats are eaten the digestive enzymes break down the molecules into separate fatty acids and glycerol again.

Fatty acids are divided into two kinds: **saturated** and **unsaturated fatty acids** depending on how much hydrogen they contain. The fat found in animals bodies and in dairy products contains mainly saturated fatty acids and tends to be solid at room temperature. Fish and poultry fats and plant oils contain mostly unsaturated fatty acids and are more liquid at room temperature.

Phospholipids are lipids that contain a phosphate group. They are important in the plasma membrane of the cell.

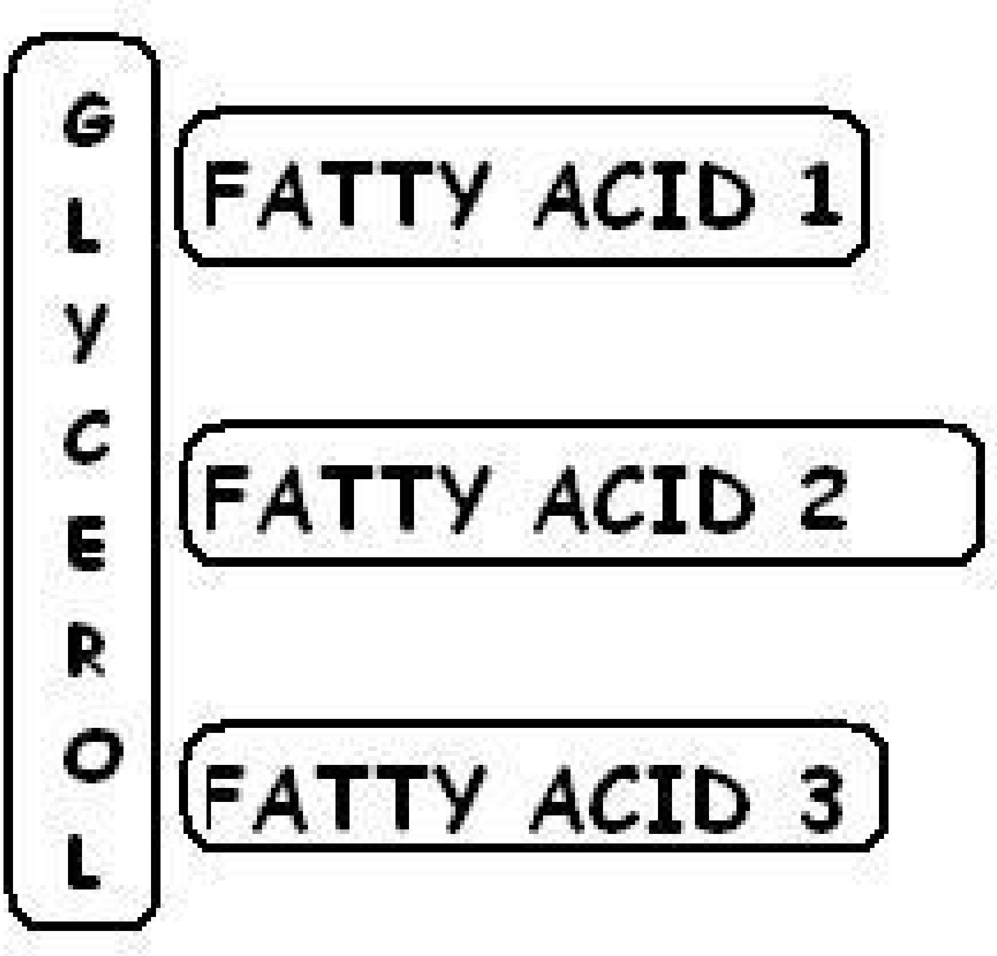

Figure 4

Figure 5

1.9 Proteins

Proteins are the third main group of organic compounds in the cell - in fact if you dried out a cell you would find that about 2/3 of the dry dust you were left with would consist of protein. Like carbohydrates and fats, proteins contain C, H and O but they all also contain **nitrogen** . Many also contain sulphur and phosphorus.

In the cell, proteins are an important part of the plasma membrane of the cell, but their most essential role is as **enzymes** . These are molecules that act as biological catalysts and are necessary for biochemical reactions to proceed. Protein is also found as **keratin** in the skin, feathers and hair, in muscles, as well as in antibodies and some hormones.

Proteins are built up of long chains of smaller molecules called **amino acids** . There are 20 common types of amino acid and different numbers of these arranged in different orders create the multitude of individual proteins that exist in an animal's body.

Long chains of amino acids often link with other amino acid chains and the resulting protein molecule may twist, spiral and fold up to make a complex 3-dimensional shape. As an example, see the diagram of the protein lysozyme below. Believe it or not, this is a small and relatively simple protein.

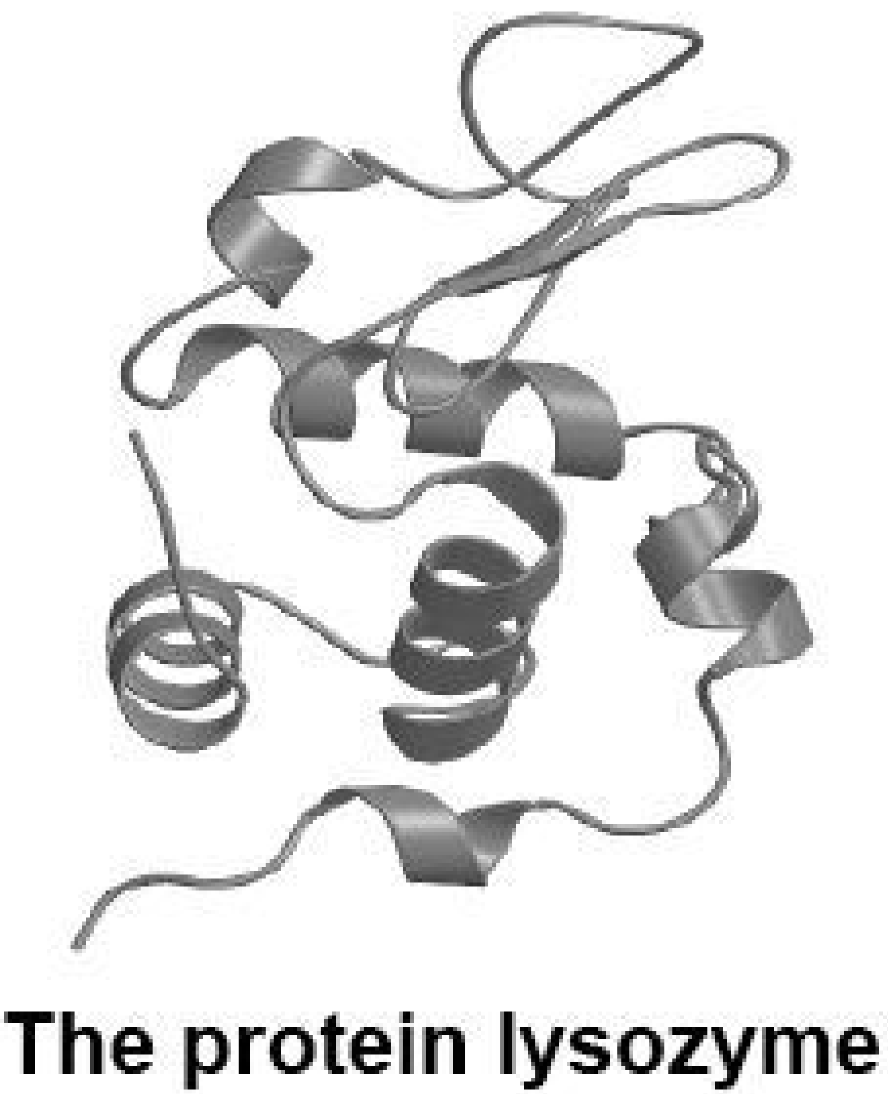

Figure 6

It is this shape that determines how proteins behave in cells, particularly when they are acting as enzymes. If for any reason this shape is altered, the protein stops working. This is what happens if proteins are heated or put in a solution that is too acidic or alkaline. Think what happens to the "white'" of an egg when it is cooked. The "white" contains the protein albumin, which is changed or "**denatured** " permanently by cooking. The catastrophic effect that heat has on enzymes is one of the reasons animals die if exposed to high temperatures.

In the animal's diet, proteins are found in meat (muscle), dairy products, seeds, nuts and legumes like soya. When the enzymes in the gut digest proteins they break them down into the separate amino acids, which are small enough to be absorbed into the blood.

1.10 Summary

- **Ions** are charged particles, and **electrolytes** are solutions of ions in water.
- **Carbohydrates** are made of carbon with hydrogen and oxygen (in the same ratio as water) linked together. The cell mainly uses carbohydrates for energy.
- **Fats** are also made of carbon, hydrogen and oxygen. They are a powerful energy source, and are also used for insulation.
- **Proteins** are the building materials of the body, and as **enzymes** make cell reactions happen. They contain nitrogen as well as carbon, hydrogen and oxygen.

1.11 Worksheet

Worksheet on Chemicals in the Cell[1]

1.12 Test Yourself

1. What is the difference between an atom and a molecule?
2. What is the chemical name for baking soda?

   And its formula?
3. Write the equation for carbonic acid splitting into water and carbon dioxide.
4. A solution of table salt in water is an example of an electrolyte.

   What ions are present in this solution?
5. What element is always present in proteins but not usually in fats or carbohydrates?
6. List three differences between glucose and glycogen.

   1.

1 http://www.wikieducator.org/Chemicals_Worksheet

2.

3.

7. Which will provide you with the most energy – one gram of sugar or one gram of butter?

/Test Yourself Answers/[2]

1.13 Website

- Survey of the living world organic molecules[3]

A good summary of carbohydrates, fats and proteins.

1.14 Glossary

- Link to Glossary[4]

[5]}}

2 https://en.wikibooks.org/wiki/%2FTest%20Yourself%20Answers%2F
3 http://darwin.baruch.cuny.edu/bio1003/organic_background.html
4 http://en.wikibooks.org/wiki/Anatomy_and_Physiology_of_Animals/Glossary
5 https://en.wikibooks.org/wiki/Category%3A

2 Classification

Figure 7 original image by R'Eyes[a] cc by

a http://flickr.com/photos/grrphoto/307172203

2.1 Objectives

After completing this section, you should know:

- how to write the scientific name of animals correctly
- know that animals belong to the Animal kingdom and that this is divided into phyla, classes, orders, families
- know the definition of a species
- know the phylum and class of the more common animals dealt with in this course

Classification is the process used by scientists to make sense of the 1.5 million or so different kinds of living organisms on the planet. It does this by describing, naming and placing them in different groups. As veterinary nurses you are mainly concerned with the Animal Kingdom but don't forget that animals rely on the Plant Kingdom for food to survive. Also many diseases that animals are affected by are members of the other Kingdoms -- fungi, bacteria and single celled animals.

2.2 Naming And Classifying Animals

There are more than 1.5 million different kinds of living organism on Earth ranging from small and simple bacteria to large, complex mammals. From the earliest time that humans have studied the natural world they have named these living organisms and placed them in different groups on the basis of their similarities and differences.

2.3 Naming Animals

Of course we know what a cat, a dog and a whale are but, in some situations using the common names for animals can be confusing. Problems arise because people in different countries, and even sometimes in the same country, have different common names for the same animals. For example a cat can be a chat, a Katze, gato, katt, or a moggie, depending on which language you use. To add to the confusion sometimes the same name is used for different animals. For example, the name 'gopher' is used for ground squirrels, rodents (pocket gophers), for moles and in the south-eastern United States for a turtle. This is the reason why all animals have been given an official **scientific** or **binomial name** . Unfortunately these names are always in Latin. For example:

- Common rat: *Rattus rattus*
- Human: *Homo sapiens*
- Domestic cat: *Felis domesticus*
- Domestic dog: *Canis familiaris*

As you can see from the above there are certain rules about writing scientific names:

- They always have **2 parts** to them.
- The first part is the **genus** name and is always written with a **capital** first letter.
- The second name is the **species** name and is always written in **lower case** .
- The name is always **underlined** or printed in **italics** .

The first time you refer to an organism you should write the whole name in full. If you need to keep referring to the same organism you can then abbreviate the genus name to just the initial. Thus "*Canis familiaris* " becomes "*C. familiaris* " the second and subsequent times you refer to it.

2.4 Classification Of Living Organisms

To make some sense of the multitude of living organisms they have been placed in different groups. The method that has been agreed by biologists for doing this is called the **classification system** . The system is based on the assumption that the process of evolution has, over the millennia, brought about slow changes that have converted simple one-celled organisms to complex multi-celled ones and generated the earth's incredible diversity of life forms. The classification system attempts to reflect the evolutionary relationships between organisms.

Initially this classification was based only on the appearance of the organism. However, the development of new techniques has advanced our scientific knowledge. The light microscope and later the electron microscope have enabled us to view the smallest structures, and now techniques for comparing DNA have begun to clarify still further the relationships between organisms. In the light of the advances in knowledge the classification has undergone numerous revisions over time.

At present most biologists divide the living world into 5 kingdoms, namely:

- bacteria
- protists
- fungi
- plants
- animal

We are concerned here almost entirely with the **Animal Kingdom** . However, we must not forget that bacteria, protists, and fungi cause many of the serious diseases that affect animals, and all animals rely either directly or indirectly on the plant world for their nourishment.

2.5 The Animal Kingdom

So what are animals? If we were suddenly confronted with an animal we had never seen in our lives before, how would we know it was not a plant or even a fungus? We all intuitively know part of the answer to this.

Animals:

- eat organic material (plants or other animals)
- move to find food
- take the food into their bodies and then digest it
- and most reproduce by fertilizing eggs by sperm

If you were tempted to add that animals are furry, run around on four legs and give birth to young that they feed on milk you were thinking only of mammals and forgetting temporarily that frogs, snakes and crocodiles, birds as well as fish, are also animals.

These are all members of the group called the **vertebrates** (or animals with a backbone) and mammals make up only about 8% of this group. The diagram on the next page shows the percentage of the different kinds of vertebrates.

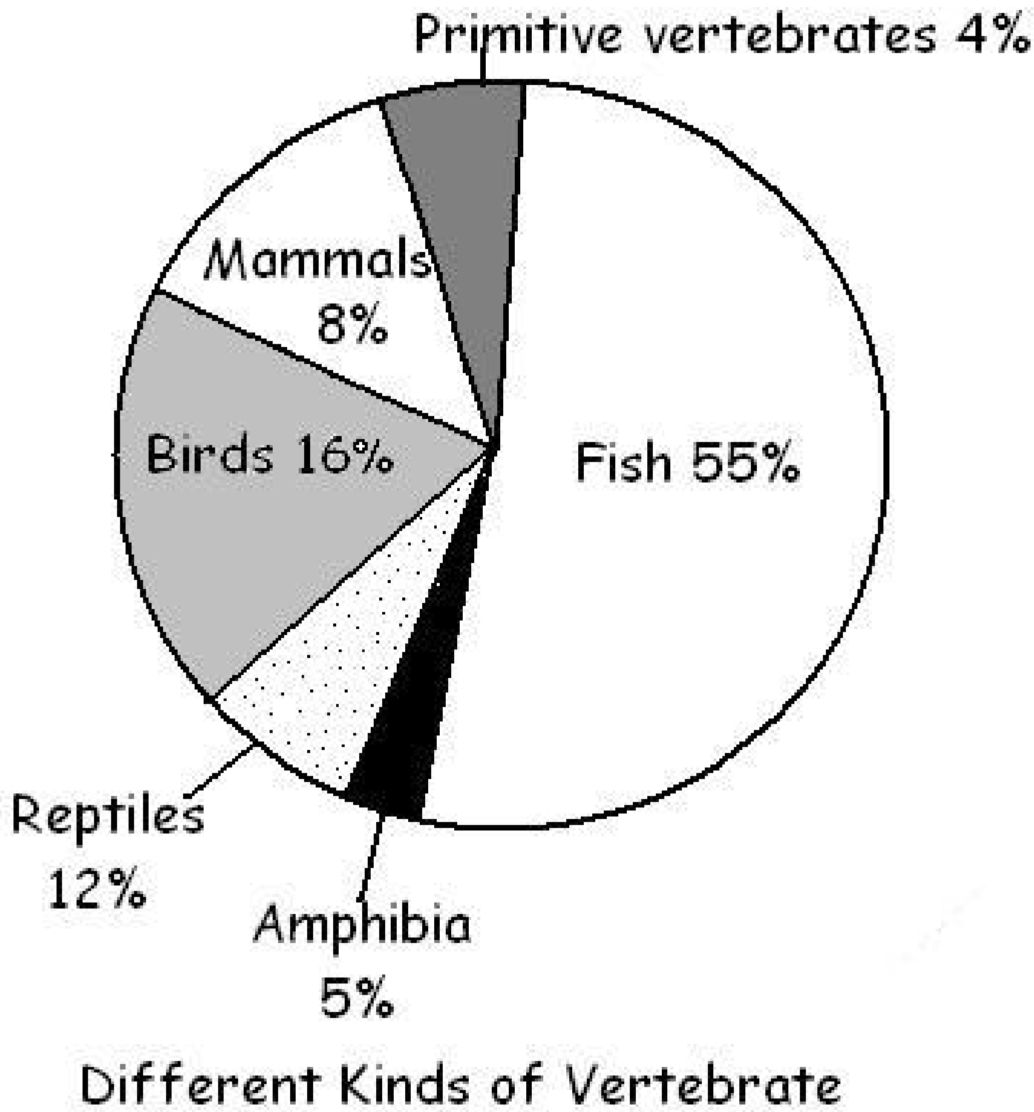

Figure 8

However, the term animal includes much more than just the Vertebrates. In fact this group makes up only a very small portion of all animals. Take a look at the diagram below, which shows the size of the different groups of animals in the Animal Kingdom as proportions of the total number of different animal species. Notice the small size of the segment representing vertebrates! All the other animals in the Animal Kingdom are animals with no backbone, or **invertebrates** . This includes the worms, sea anemones, starfish, snails, crabs, spiders and insects. As more than 90% of the invertebrates are insects, no wonder people worry that insects may take over the world one day!

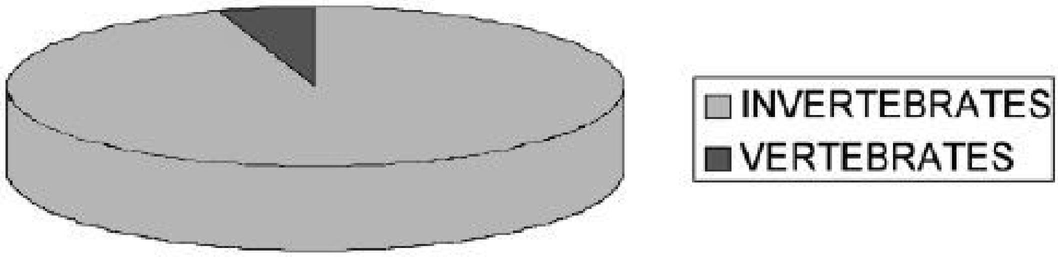

Figure 9

2.6 The Classification Of Vertebrates

As we have seen above the Vertebrates are divided into 5 groups or classes namely:

- Fish
- Amphibia (frogs and toads)
- Reptiles (snakes and crocodiles)
- Birds
- Mammals

These classes are all based on similarities. For instance all mammals have a similar skeleton, hair on their bodies, are warm bodied and suckle their young.

The class Mammalia (the mammals) contains 3 **subclasses** :

- Duck billed platypus and the spiny anteater
- **Marsupials** (animals like the kangaroo with pouches)
- **True mammals** (with a placenta)

Within the subclass containing the true mammals, there are groupings called **orders** that contain mammals that are more closely similar or related, than others. Examples of six mammalian orders are given below:

- Rodents (Rodentia) (rats and mice)
- Carnivores (Carnivora) (cats, dogs, bears and seals)
- Even-toed grazers (Artiodactyla) (pigs, sheep, cattle, antelopes)
- Odd-toed grazers (Perissodactyla) (horses, donkeys, zebras)
- Marine mammals (Cetacea) (whales, sea cows)
- Primates (monkeys, apes, humans)

Within each order there are various **families** . For example within the carnivore mammals are the families:

- Canidae (dog-like carnivores)
- Felidae (cat-like carnivores)

Even at this point it is possible to find groupings that are more closely related than others. These groups are called **genera** (singular genus). For instance within the cat family Felidae is the genus Felis containing the cats, as well as genera containing panthers, lynxes, and sabre toothed tigers!

The final groups within the system are the **species** . The definition of a species is a **group of animals that can mate successfully and produce fertile offspring** . This means that all domestic cats belong to the species *Felis domesticus* , because all breeds of cat whether Siamese, Manx or ordinary House hold cat can cross breed. However, domestic cats can not mate successfully with lions, tigers or jaguars, so these are placed in separate species, e.g. *Felis leo, Felis tigris and Felis onca* .

Even within the same species, there can be animals with quite wide variations in appearance that still breed successfully. We call these different **breeds, races** or **varieties** . For example there are many different breeds of dogs from Dalmatian to Chihuahua and of cats, from Siamese to Manx and domestic short-hairs, but all can cross breed. Often these breeds have been produced by**selective breeding** but varieties can arise in the wild when groups of animals are separated by a mountain range or sea and have developed different characteristics over long periods of time.

To summarise, the classification system consists of:

The **A** nimal **K** ingdom which is divided into

P hyla which are divided into

C lasses which are divided into

O rders which are divided into

F amilies which are divided into

G enera which are divided into

S pecies.

"**Kings Play Cricket On Flat Green Surfaces** " OR "**Kindly Professors Cannot Often Fail Good Students** " are just two of the phrases students use to remind themselves of the order of these categories - on the other hand you might like to invent your own.

2.7 Summary

- The **scientific name** of an animal has two parts, the **genus** and the **species** , and must be written in **italics** or **underlined** .
- Animals are divided into **vertebrates** and **invertebrates** .
- The classification system has groupings called **phyla** , **classes** , **orders** , **families** , **genera** and **species** .

- Furry, milk-producing animals are all in the class **Mammalia.**
- Members within a **species** can mate and produce fertile offspring.
- Sub-groups within a species include **breeds, races** and **varieties** .

2.8 Worksheet

Work through the exercises in this Classification Worksheet[1] to help you learn how to write scientific names and classify different animals.

2.9 Test Yourself

1a) True or False. Is this name written correctly? trichosurus Vulpecula.

1b) What do you need to change?

2. Rearrange these groups from the biggest to the smallest:

a) cars | diesel cars | motor vehicles | my diesel Toyota | transportation

b) Class | Species | Phylum | Genus | Order | Kingdom | Family

2.10 Websites

2.10.1 Classification

- `http://www.mcwdn.org/Animals/AnimalClassQuiz.html` Animal classification quiz

In fact much more than that. There is an elementary cell biology and classification quiz but the best thing about this website are the links to tables of characteristics of the different animal groups, for animals both with and without backbones.

- `http://animaldiversity.ummz.umich.edu/site/index.html` Animal diversity web

Careful! You could waste all day exploring this wonderful website. Chose an animal or group of animals you want to know about and you will see not only the classification but photos and details of distribution, behaviour and conservation status etc.

- `http://www.indianchild.com/animal_kingdom.htm` Indian child

Nice clear explanation of the different categories used in the classification of animals.

2.11 Glossary

- Link to Glossary[2]

1 `http://www.wikieducator.org/Classification_Worksheet`
2 `http://en.wikibooks.org/wiki/Anatomy_and_Physiology_of_Animals/Glossary`

[3]

3 https://en.wikibooks.org/wiki/Category%3A

3 The Cell

Figure 10 original image by pong[a] cc by

a http://flickr.com/photos/pong/13107953/

3.1 Objectives

After completing this section, you should know:

- that cells can be different shapes and sizes
- the role and function of the plasma membrane; cytoplasm, ribosomes, rough endoplasmic reticulum; smooth endoplasmic reticulum, mitochondria, golgi bodies, lysosomes, centrioles and the nucleus
- the structure of the plasma membrane
- that substances move across the plasma membrane by passive and active processes
- that passive processes include diffusion, osmosis and facilitated diffusion and active processes include active transport, pinocytosis, phagocytosis and exocytosis
- what the terms hypotonic, hypertonic isotonic and haemolysis mean
- that the nucleus contains the chromosomes formed from DNA
- that mitosis is the means by which ordinary cells divide
- the main stages of mitosis
- that meiosis is the process by which the chromosome number is halved when ova and sperm are formed

3.2 The Cell

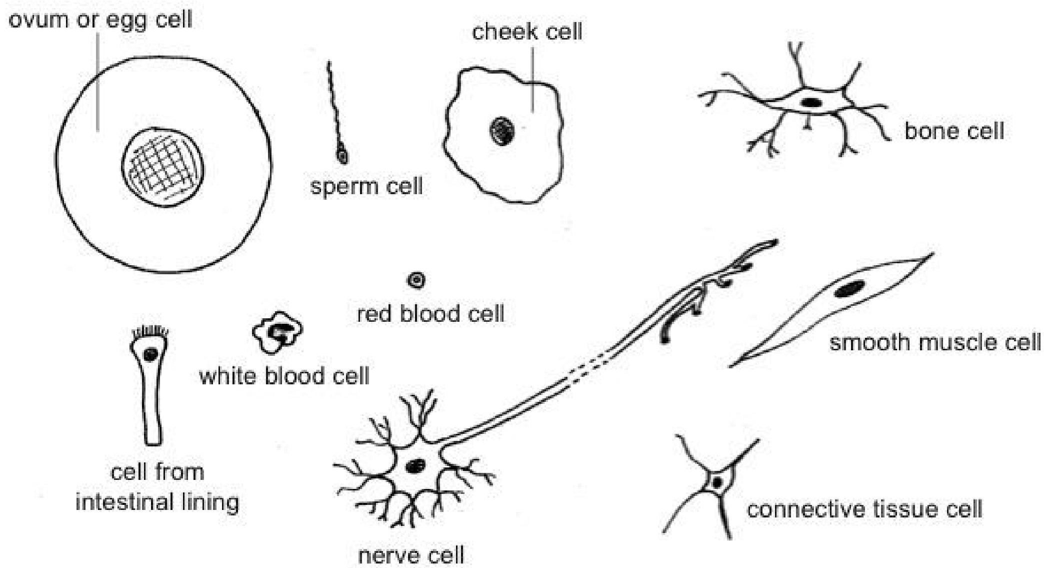

Figure 11 **Diagram 3.1** : A variety of animal cells

The cell is the basic building block of living organisms. Bacteria and the parasite that causes malaria consist of single cells, while plants and animals are made up of trillions of cells. Most cells are spherical or cube shaped but some are a range of different shapes (see diagram 3.1).

Most cells are so small that a microscope is needed to see them, although a few cells, e.g. the ostrich's egg, are so large that they could make a meal for several people.

A normal cell is about 0.02 of a millimetre (0.02mm) in diameter. (Small distances like this are normally expressed in micrometres or microns (µm). Note there are 1000 µms in every mm).

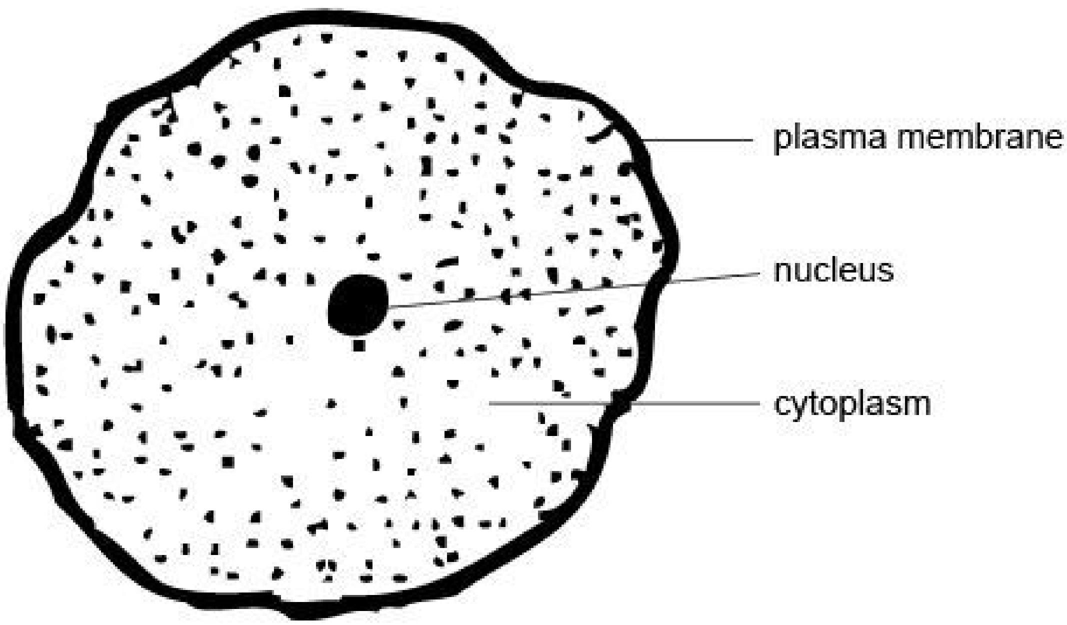

Figure 12 **Diagram 3.2** : An animal cell

When you look at a typical animal cell with a light microscope it seems quite simple with only a few structures visible (see diagram 3.2).

Three main parts can be seen:

- an outer cell membrane (plasma membrane),
- an inner region called the cytoplasm and
- the nucleus

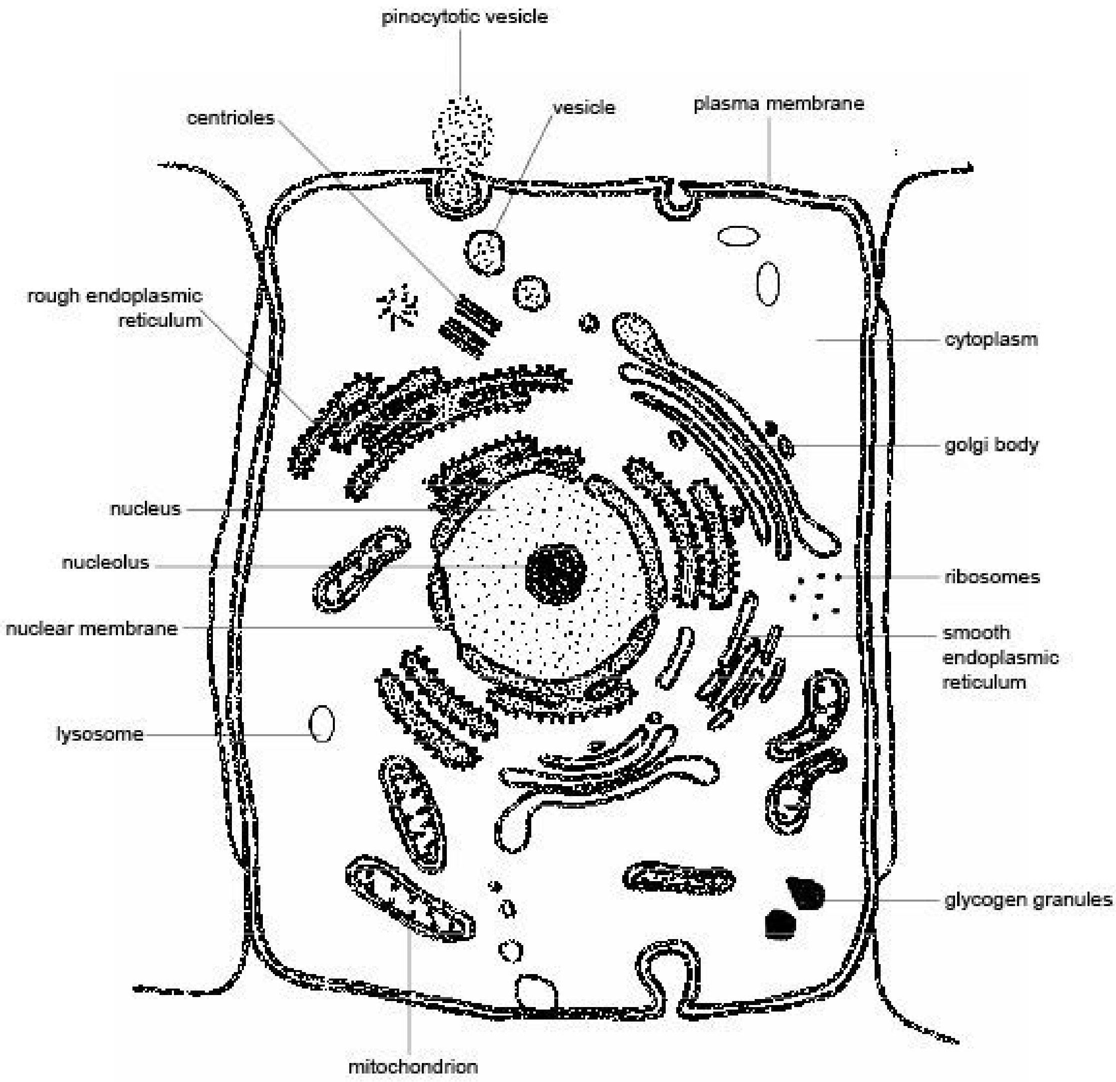

Figure 13 Diagram 3.3 : An animal cell as seen with an electron microscope

However, when you use an electron microscope to increase the magnification many thousands of times you see that these seemingly simple structures are incredibly complex, each with its own specialized function. For example the plasma membrane is seen to be a double layer and the cytoplasm contains many special structures called **organelles** (meaning little organs) which are described below. A drawing of the cell as seen with an electron microscope is shown in diagram 3.3.

3.3 The Plasma Membrane

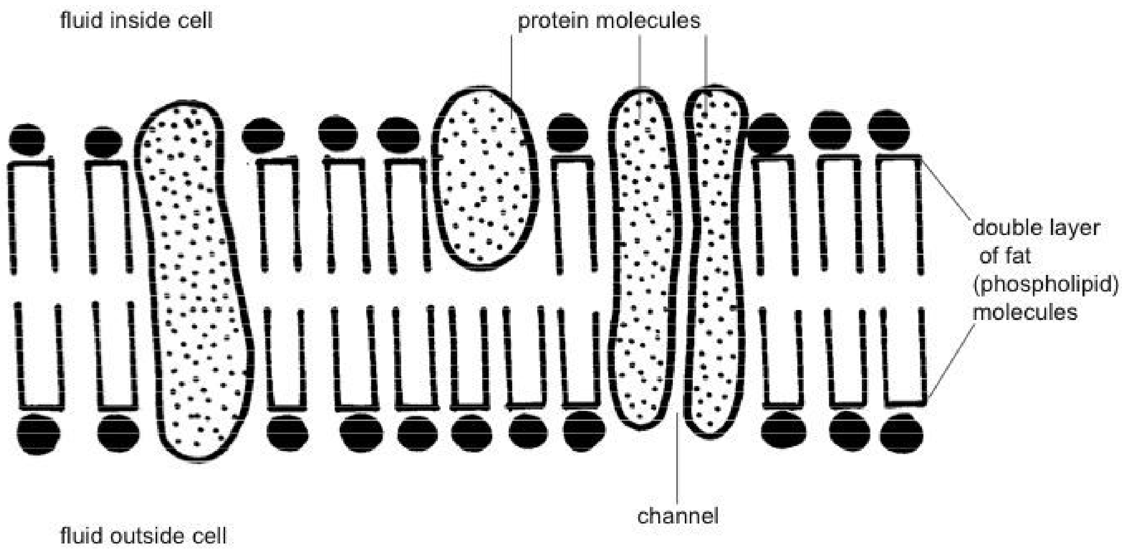

Figure 14 **Diagram 3.4** : The structure of the plasma membrane

The thin plasma membrane surrounds the cell, separating its contents from the surroundings and controlling what enters and leaves the cell. The plasma membrane is composed of two main molecules,phospholipids(fats) and proteins. The phospholipids are arranged in a double layer with the large protein molecules dotted about in the membrane (see diagram 3.4). Some of the protein molecules form tiny channels in the membrane while others help transport substances from one side of the membrane to the other.

3.3.1 How substances move across the Plasma Membrane

Substances need to pass through the membrane to enter or leave the cell and they do so in a number of ways. Some of these processes require no energy i.e. they are passive, while others require energy i.e. they are **active** .

Passive processes include: a) diffusion and b) osmosis, while active processes include: c) active transport, d) phagocytosis, e) pinocytosis and f) exocytosis. These will be described below.

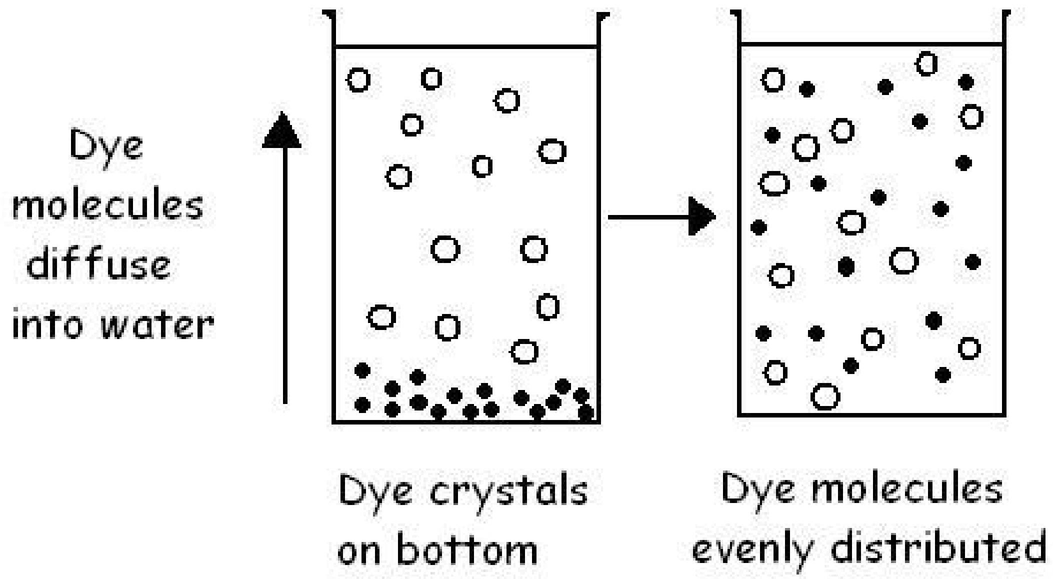

Figure 15 **Diagram 3.5** : Diffusion in a liquid

a) Diffusion

Although you may not know it, you are already familiar with the process of diffusion. It is diffusion that causes a smell (expensive perfume or smelly socks) in one part of the room to gradually move through the room so it can be smelt on the other side. Diffusion occurs in the air and in liquids.

Diagram 3.5 shows what happens when a few crystals of a dark purple dye called potassium permanganate are dropped into a beaker of water. The dye molecules diffuse into the water moving from high to low concentrations so they become evenly distributed throughout the beaker.

In the body, diffusion causes molecules that are in a high concentration on one side of the cell membrane to move across the membrane until they are present in equal concentrations on both sides. It takes place because all molecules have an in-built vibration that causes them to move and collide until they are evenly distributed. It is an absolutely natural process that requires no added energy.

Small molecules like oxygen, carbon dioxide, water and ammonia as well as fats, diffuse directly through the double fat layer of the membrane. The small molecules named above as well as a variety of charged particles (ions) also diffuse through the protein-lined channels. Larger molecules like glucose attach to a carrier molecule that aids their diffusion through the membrane. This is called **facilitated diffusion** .

In the animal's body diffusion is important for moving oxygen and carbon dioxide between the lungs and the blood, for moving digested food molecules from the gut into the blood and for the removal of waste products from the cell.

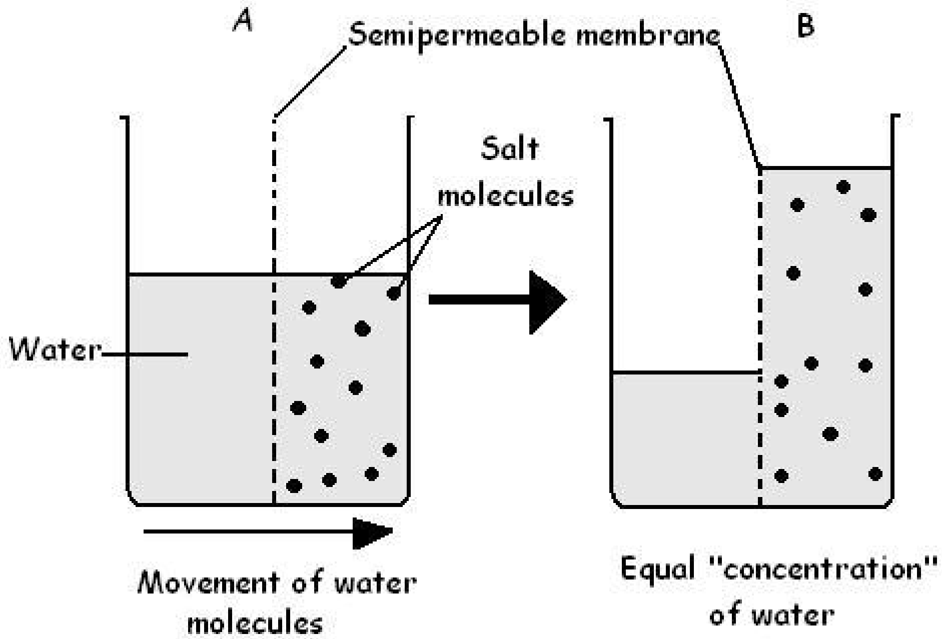

Figure 16 **Diagram 3.6** : Osmosis

b) Osmosis

Although the word may be unfamiliar, you are almost certainly acquainted with the effects of osmosis. It is osmosis that plumps out dried fruit when you soak it before making a fruit cake or makes that wizened old carrot look almost like new when you soak it in water. Osmosis is in fact the diffusion of water across a membrane that allows water across but not larger molecules. This kind of membrane is called a **semi-permeable membrane** .

Take a look at side **A** of diagram 3.6. It shows a container divided into two parts by an artificial semi-permeable membrane. Water is poured into one part while a solution containing salt is poured into the other part. Water can cross the membrane but the salt cannot. The water crosses the semi-permeable membrane by diffusion until there is an equal amount of water on both sides of the membrane. The effect of this would be to make the salt solution more diluted and cause the level of the liquid in the right-hand side of the container to rise so it looked like side **B** of diagram 3.6. This movement of water across the semi-permeable membrane is called osmosis. It is a completely natural process that requires no outside energy.

Although it would be difficult to do in practice, imagine that you could now take a plunger and push down on the fluid in the right-hand side of container **B** so that it flowed back across the semi-permeable membrane until the level of fluid on both sides was equal again. If you could measure the pressure required to do this, this would be equal to the **osmotic**

pressure of the salt solution. (This is a rather advanced concept at this stage but you will meet this term again when you study fluid balance later in the course).

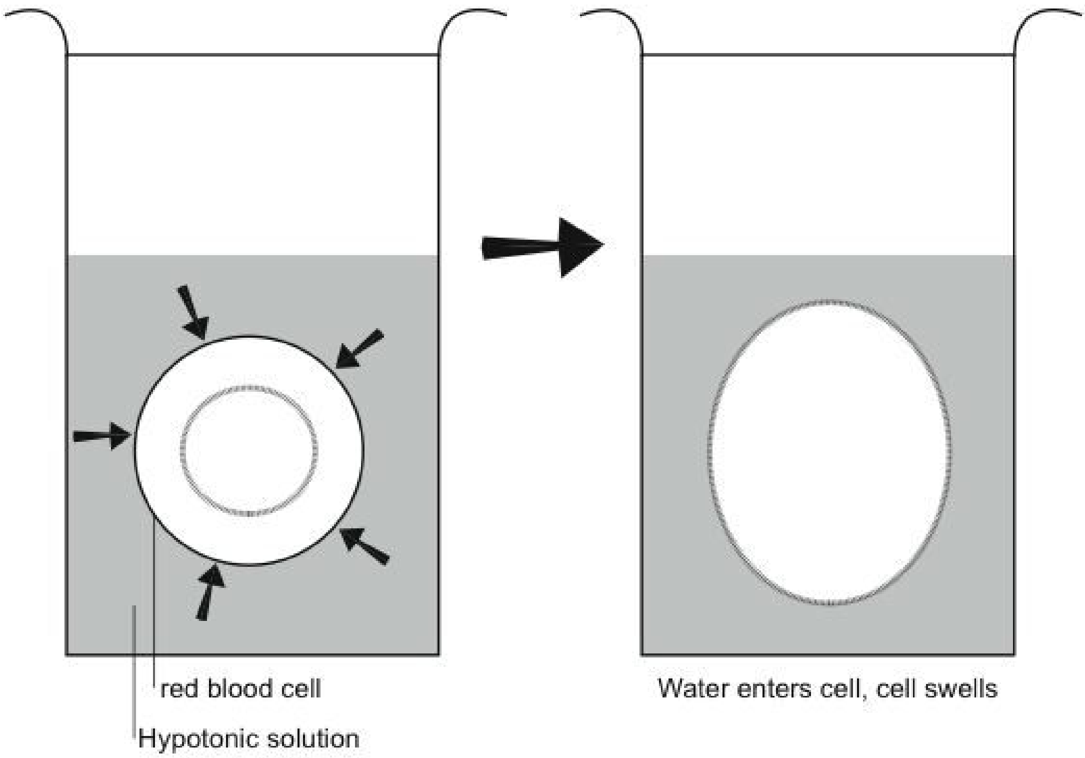

Figure 17 **Diagram 3.7** : Osmosis in red cells placed in a hypotonic solution

The plasma membrane of cells acts as a semi-permeable membrane. If red blood cells, for example, are placed in water, the water crosses the membrane to make the amount of water on both sides of it equal (see diagram 3.7). This means that the water moves into the cell causing it to swell. This can occur to such an extent that the cell actually bursts to release its contents. This bursting of red blood cells is called **haemolysis** . In a situation such as this when the solution on one side of a semi-permeable membrane has a lower concentration than that on the other side, the first solution is said to be **hypotonic** to the second.

Figure 18 **Diagram 3.8** : Osmosis in red cells placed in a hypertonic solution

Now think what would happen if red blood cells were placed in a salt solution that has a higher salt concentration than the solution within the cells (see diagram 3.8). Such a bathing solution is called a **hypertonic** solution. In this situation the “concentration” of water within the cells would be higher than that outside the cells. Osmosis (diffusion of water) would then occur from the inside of the cells to the outside solution, causing the cells to shrink.

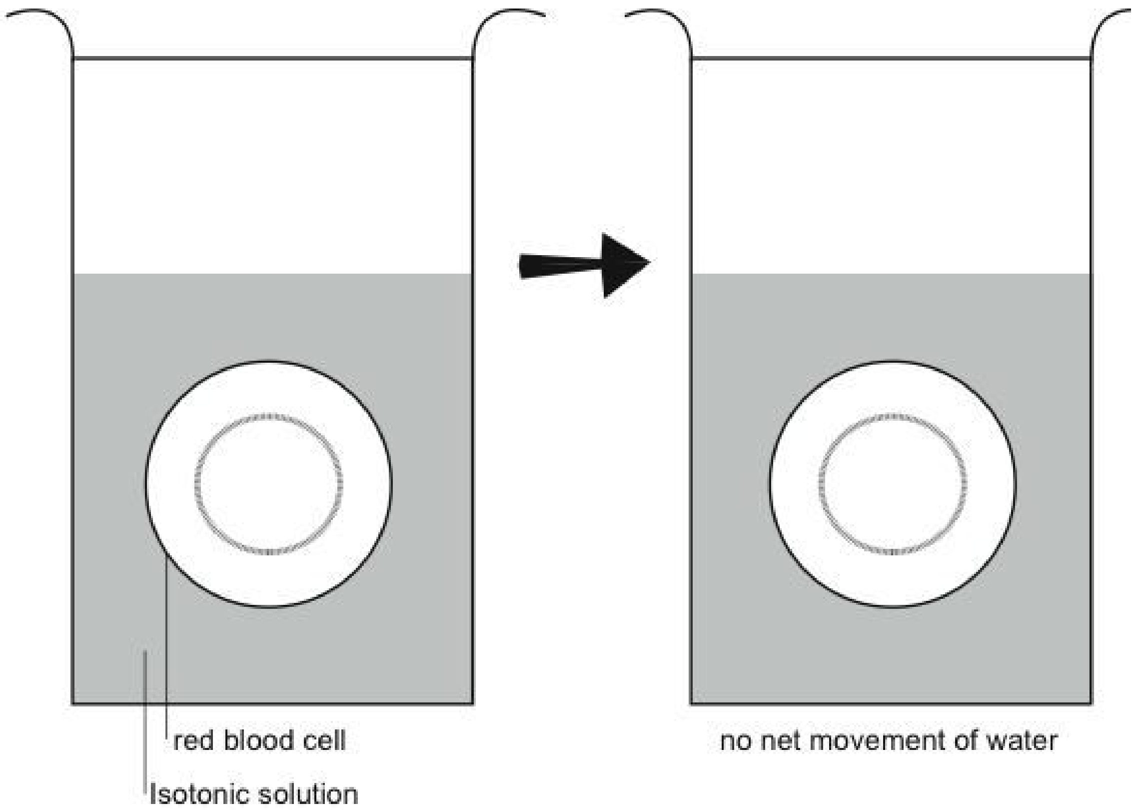

Figure 19 Diagram 3.9 : Red cells placed in an isotonic solution

A solution that contains 0.9% salt has the same concentration as body fluids and the solution within red cells. Cells placed in such a solution would neither swell nor shrink (see diagram 3.9). This solution is called an **isotonic** solution. This strength of salt solution is often called **normal saline** and is used when replacing an animal's body fluids or when cells like red blood cells have to be suspended in fluid.

Remember - osmosis is a special kind of diffusion. It is the diffusion of water molecules across a semi-permeable membrane. It is a completely passive process and requires no energy.

Sometimes it is difficult to remember which way the water molecules move. Although it is not strictly true in a biological sense, many students use the phrase **"SALT SUCKS"** to help them remember which way water moves across the membrane when there are two solutions of different salt concentrations on either side.

As we have seen water moves in and out of the cell by osmosis. All water movement from the intestine into the blood system and between the blood capillaries and the fluid around the cells (tissue or extra cellular fluid) takes place by osmosis. Osmosis is also important in the production of concentrated urine by the kidney.

c) Active transport

When a substance is transported from a low concentration to a high concentration i.e. uphill against the concentration gradient, energy has to be used. This is called **active transport** .

Active transport is important in maintaining different concentrations of the ions sodium and potassium on either side of the nerve cell membrane. It is also important for removing valuable molecules such as glucose, amino acids and sodium ions from the urine.

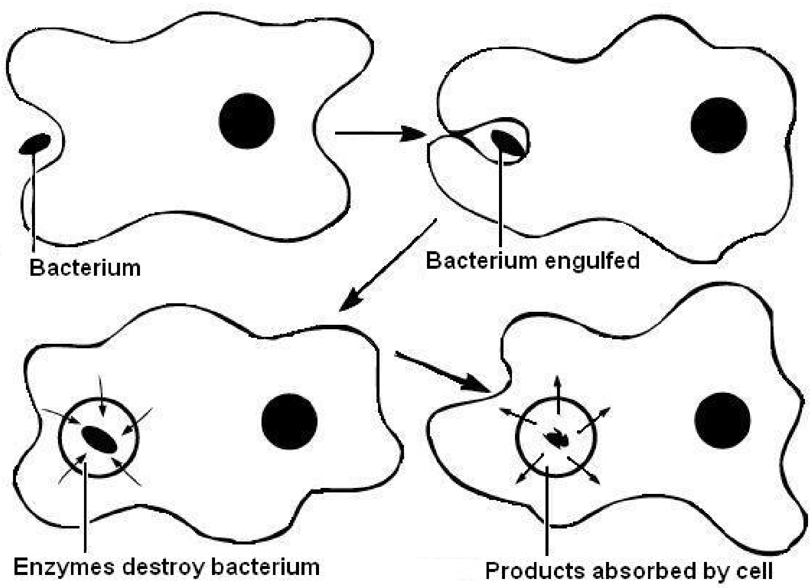

Figure 20 Diagram 3.10 : Phagocytosis

d) Phagocytosis

Phagocytosis is sometimes called "cell eating". It is a process that requires energy and is used by cells to move solid particles like bacteria across the plasma membrane. Finger-like projections from the plasma membrane surround the bacteria and engulf them as shown in diagram 3.10. Once within the cell, enzymes produced by the lysosomes of the cell (described later) destroy the bacteria.

The destruction of bacteria and other foreign substance by white blood cells by the process of phagocytosis is a vital part of the defense mechanisms of the body.

e) Pinocytosis

Pinocytosis or "cell drinking" is a very similar process to phagocytosis but is used by cells to move fluids across the plasma membrane. Most cells carry out pinocytosis (note the pinocytotic vesicle in diagram 3.3).

f) Exocytosis

Exocytosis is the process by means of which substances formed in the cell are moved through the plasma membrane into the fluid outside the cell (or extra-cellular fluid). It occurs in all cells but is most important in secretory cells (e.g. cells that produce digestive enzymes) and nerve cells.

3.4 The Cytoplasm

Within the plasma membrane is the **cytoplasm** . It consists of a clear jelly-like fluid called the a) **cytosol** or **intracellular fluid** in which b) **cell inclusions** , c) **organelles** and d) **microfilaments** and **microtubules** are found.

3.4.1 a) Cytosol

The cytosol consists mainly of water in which various molecules are dissolved or suspended. These molecules include proteins, fats and carbohydrates as well as sodium, potassium, calcium and chloride ions. Many of the reactions that take place in the cell occur in the cytosol.

3.4.2 b) Cell inclusions

These are large particles of fat, glycogen and melanin that have been produced by the cell. They are often large enough to be seen with the light microscope. For example the cells of adipose tissue (as in the insulating fat layer under the skin) contain fat that takes up most of the cell.

3.4.3 c) Organelles

Organelles are the "little organs" of the cell - like the heart, kidney and liver are the organs of the body. They are structures with characteristic appearances and specific "jobs" in the cell. Most can not be seen with the light microscope and so it was only when the electron microscope was developed that they were discovered. The main organelles in the cell are the **ribosomes, endoplasmic reticulum, mitochondrion, Golgi complex** and **lysosomes** . A cell containing these organelles as seen with the electron microscope is shown in diagram 3.3.

Ribosomes

Figure 21 **Diagram 3.11** : Rough endoplasmic reticulum

Ribosomes are tiny spherical organelles that make proteins by joining amino acids together. Many ribosomes are found free in the cytosol, while others are attached to the rough endoplasmic reticulum.

Endoplasmic reticulum

The **endoplasmic reticulum (ER)** is a network of membranes that form channels throughout the cytoplasm from the nucleus to the plasma membrane. Various molecules are made in the ER and transported around the cell in its channels. There are two types of ER: smooth ER and rough ER.

Smooth ER is where the fats in the cell are made and in some cells, where chemicals like alcohol, pesticides and carcinogenic molecules are inactivated.

The **Rough ER** has ribosomes attached to its surface. The function of the Rough ER is therefore to make proteins that are modified stored and transported by the ER (Diagram 3.11).

Mitochondria

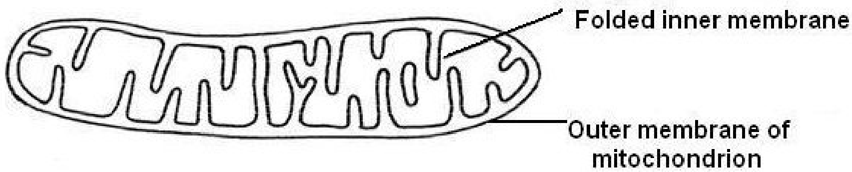

Figure 22 Diagram 3.12 : A mitochondrion

Mitochondria (singular mitochondrion) are oval or rod shaped organelles scattered throughout the cytoplasm. They consist of two membranes, the inner one of which is folded to increase its surface area. (Diagram 3.12)

Mitochondria are the "power stations" of the cell. They make energy by "burning" food molecules like glucose. This process is called **cellular respiration** . The reaction requires oxygen and produces carbon dioxide which is a waste product. The process is very complex and takes place in a large number of steps but the overall word equation for cellular respiration is-

Glucose + oxygen = carbon dioxide + water + energy

Note that cellular respiration is different from respiration or breathing. Breathing is the means by which air is drawn into and expelled from the lungs. Breathing is necessary to supply the cells with the oxygen required by the mitochondria and to remove the carbon dioxide produced as a waste product of cellular respiration.

Active cells like muscle, liver, kidney and sperm cells have large numbers of mitochondria.

Golgi Apparatus

Figure 23 Diagram 3.13 : A Golgi body

The **Golgi bodies** in a cell together make up the **Golgi apparatus** . Golgi bodies are found near the nucleus and consist of flattened membranes stacked on top of each other rather like a pile of plates (see diagram 3.13). The Golgi apparatus modifies and sorts the proteins and fats made by the ER, then surrounds them in a membrane as **vesicles** so they can be moved to other parts of the cell.

Lysosomes

Lysosomes are large vesicles that contain digestive enzymes. These break down bacteria and other substances that are brought into the cell by phagocytosis or pinocytosis. They also digest worn-out or damaged organelles, the components of which can then be recycled by the cell to make new structures.

3.4.4 d) Microfilaments And Microtubules

Some cells can move and change shape and organelles and chemicals are moved around the cell. Threadlike structures called **microfilaments** and **microtubules** that can contract are responsible for this movement.

These structures also form the projections from the plasma membrane known as **flagella** (singular flagellum) as in the sperm tail, and **cilia** found lining the respiratory tract and used to remove mucus that has trapped dust particles (see chapter 4).

Microtubules also form the pair of cylindrical structures called **centrioles** found near the nucleus. These help organise the spindle used in cell division.

3.5 The Nucleus

Figure 24 **Diagram 3.14** : A cell with an enlarged chromosome

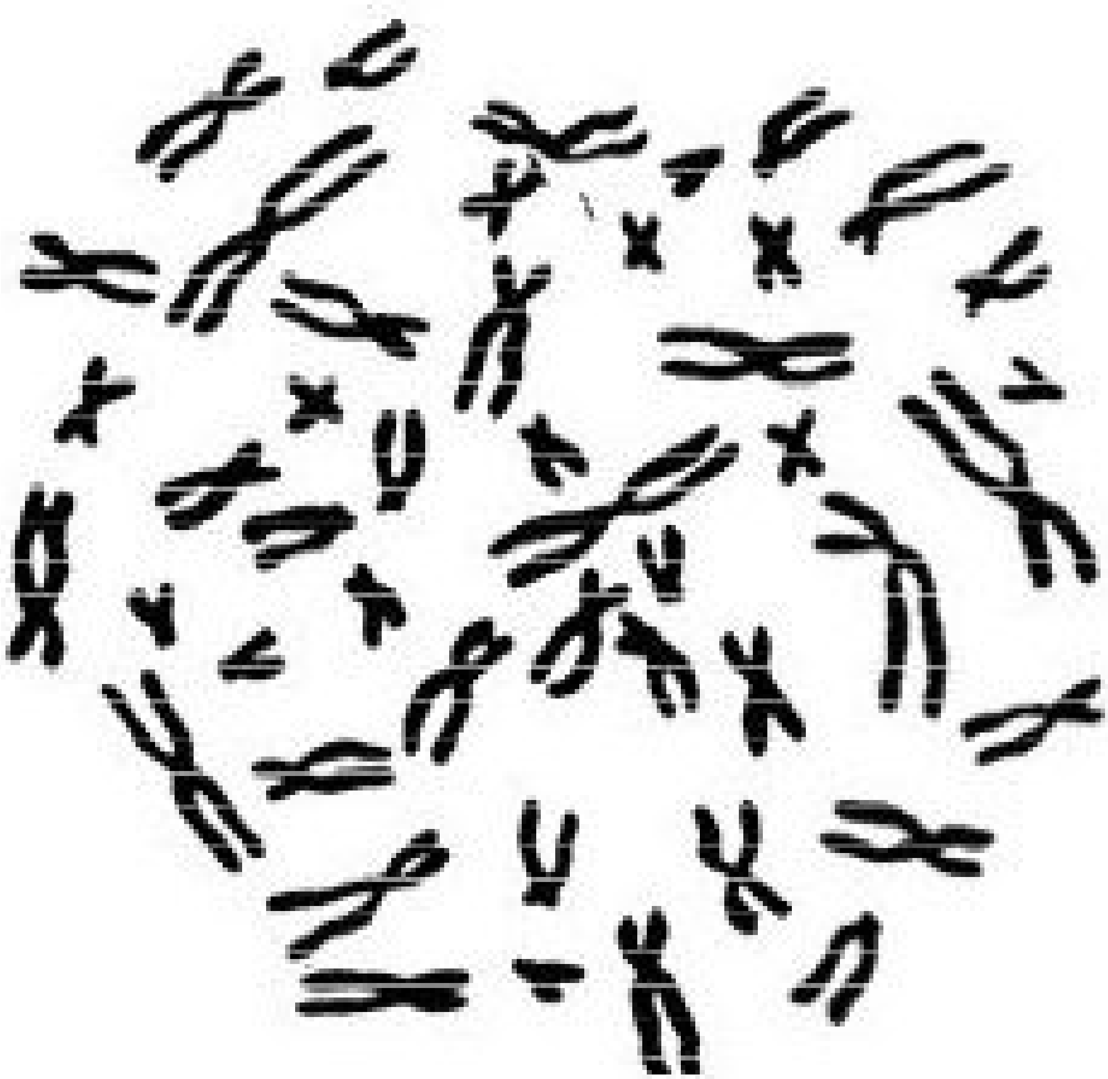

Figure 25 **Diagram 3.15** : A full set of human chromosomes

The **nucleus** is the largest structure in a cell and can be seen with the light microscope. It is a spherical or oval body that contains the **chromosomes** . The nucleus controls the development and activity of the cell. Most cells contain a nucleus although mature red blood cells have lost theirs during development and some muscle cells have several nuclei.

A double membrane similar in structure to the plasma membrane surrounds the nucleus (now called the nuclear envelope). Pores in this nuclear membrane allow communication between the nucleus and the cytoplasm.

Within the nucleus one or more spherical bodies of darker material can be seen, even with the light microscope. These are called **nucleoli** and are made of RNA. Their role is to make new ribosomes.

3.5.1 Chromosomes

Inside the nucleus are the chromosomes which:

- contain DNA;
- control the activity of the cell;
- are transmitted from cell to cell when cells divide;
- are passed to a new individual when sex cells fuse together in sexual reproduction.

In cells that are not dividing the chromosomes are very long and thin and appear as dark grainy material. They become visible just before a cell divides when they shorten and thicken and can then be counted (see diagram 3.14).

The number of chromosomes in the cells of different species varies but is constant in the cells of any one species (e.g. horses have 64 chromosomes, cats have 38 and humans 46). Chromosomes occur in pairs (i.e. 32 pairs in the horse nucleus and 19 in that of the cat). Members of each pair are identical in length and shape and if you look carefully at diagram 3.15, you may be able to see some of the pairs in the human set of chromosomes.

3.6 Cell Division

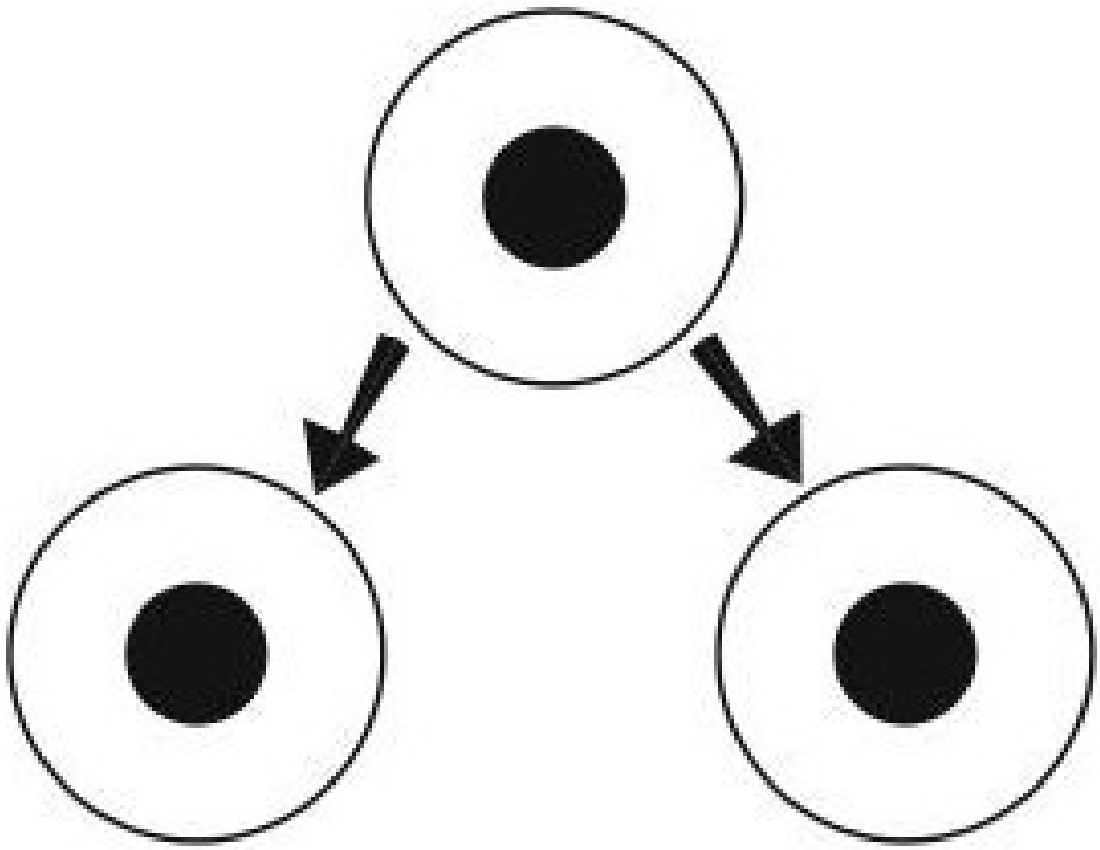

Figure 26 **Diagram 3.16** : Division by mitosis results in 2 new cells identical to each other and to parent cell

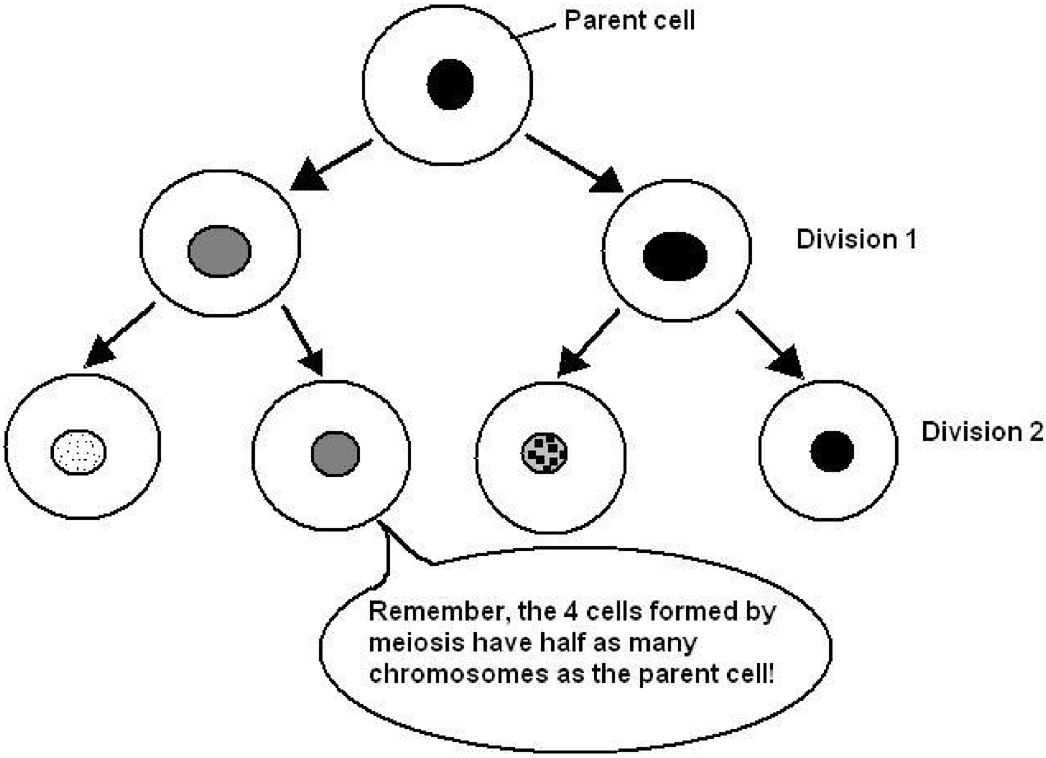

Figure 27 **Diagram 3.17** : Division by meiosis results in 4 new cells that are genetically different to each other

Cells divide when an animal grows, when its body repairs an injury and when it produces sperm and eggs (or ova). There are two types of cell division: **Mitosis** and **meiosis** .

Mitosis . This is the cell division that occurs when an animal grows and when tissues are repaired or replaced. It produces two new cells (daughter cells) each with a full set of chromosomes that are identical to each other and to the parent cell. All the cells of an animal's body therefore contain identical DNA.

Meiosis. This is the cell division that produces the ova and sperm necessary for sexual reproduction. It only occurs in the ovary and testis.

The most important function of meiosis it to halve the number of chromosomes so that when the sperm fertilises the ovum the normal number is regained. Body cells with the full set of chromosomes are called **diploid** cells, while **gametes** (sperm and ova) with half the chromosomes are called **haploid** cells.

Meiosis is a more complex process than mitosis as it involves two divisions one after the other and the four cells produced are all genetically different from each other and from the parent cell.

This fact that the cells formed by meiosis are all genetically different from each other and from the parent cell can be seen in litters of kittens where all the members of the litter are different from each other as well as being different from the parents although they display characteristics of both.

3.7 The Cell As A Factory

To make the function of the parts of the cell easier to understand and remember you can compare them to a factory. For example:

- The nucleus (1) is the managing director of the factory consulting the blueprint (the chromosomes) (2);
- The mitochondria (3) supply the power
- The ribosomes (4) make the products;
- The chloroplasts of plant cells (5) supply the fuel (food)
- The Golgi apparatus (6) packages the products ready for dispatch;
- The ER (7) modifies, stores and transports the products around the factory;
- The plasma membrane is the factory wall and the gates (8);
- The lysosomes dispose of the waste and worn-out machinery.

The cell compared to a factory[1]

3.8 Summary

- Cells consist of three parts: the **plasma membrane, cytoplasm** and **nucleus** .
- Substances pass through the plasma membrane by **diffusion** (gases, lipids), **osmosis** (water), **active transport** (glucose, ions), **phagocytosis** (particles), **pinocytosis** (fluids) and **exocytosis** (particles and fluids).
- **Osmosis** is the diffusion of **water** through a **semipermeable membrane** . Water diffuses from high water ”concentration” to low water ”concentration”.
- The cytoplasm consists of **cytosol** in which are suspended **cell inclusions** and **organelles** .
- organelles include **ribosomes, endoplasmic reticulum, mitochondria, Golgi bodies** and **lysosomes** .
- The **nucleus** controls the activity of the cell. It contains the **chromosomes** that are composed of **DNA** .
- The cell divides by **mitosis** and **meiosis**

3.9 Worksheets

There are several worksheets you can use to help you understand and learn about the cell.

Plasma Membrane Worksheet[2]

1 http://www.harunyahya.com/images_books/images_Dna/1.jpg
2 http://www.wikieducator.org/Plasma_Membrane_Worksheet

Diffusion and Osmosis Worksheet 1[3]

Diffusion and Osmosis Worksheet 2[4]

Cell Division Worksheet[5]

3.10 Test Yourself

You can then test yourself to see how much you remember.

1. Complete the table below:

3 http://www.wikieducator.org/Diffusion_and_Osmosis_Worksheet_1
4 http://www.wikieducator.org/Diffusion_and_Osmosis_Worksheet_2
5 http://www.wikieducator.org/Cell_Division_Worksheet

	Requires energy	**Requires a semi permeable membrane?**	**Is the movement of water molecules only?**	**Molecules move from high to low concentration?**	**Molecules move from low to high concentration?**
Diffusion	?	?	?	Yes	?
Osmosis	?	?	?	?	?
Active Transport	?	Yes	?	?	Yes

2. Red blood cells placed in a 5% salt solution would:

swell/stay the same/ shrink?

3. Red blood cells placed in a 0.9% solution of salt would be in a:

hypotonic/isotonic/hypertonic solution?

4. White blood cells remove foreign bodies like bacteria from the body by engulfing them. This process is known as ....

5. Match the organelle in the left hand column of the table below with its function in the right hand column.

Organelle	**Function**
a. Nucleus	1. Modifies proteins and fats
b. Mitochondrion	2. Makes, modifies and stores proteins
c. Golgi body	3. Digests worn out organelles
d. Rough endoplasmic reticulum	4. Makes fats
e. Lysosome	5. Controls the activity of the cell proteins
f. Smooth endoplasmic reticulum	6. Produces energy

6. The cell division that causes an organism to grow and repairs tissues is called:

7. The cell division that produces sperm and ova is called:

8. TWO important differences between the two types of cell division named by you above are:

a.

b.

/Test Yourself Answers/[6]

3.11 Websites

- `http://www.cellsalive.com/` Cells alive
  Cells Alive gives good animations of the animal cell.
- Cell[7] Wikipedia
  Wikipedia is good for almost anything you want to know about cells. Just watch as there is much more here than you need to know.
- `http://personal.tmlp.com/Jimr57/textbook/chapter3/chapter3.htm` Virtual cell
  The Virtual Cell has beautiful pictures of lots of (virtual?) cell organelles.
- `http://www.wisc-online.com/objects/index_tj.asp?objid=AP11403` Typical animal cell
  Great interactive animal cell.

6 https://en.wikibooks.org/wiki/%2FTest%20Yourself%20Answers%2F
7 https://en.wikipedia.org/wiki/Cell

- http://www.wiley.com/college/apcentral/anatomydrill/ Anatomy drill and practice
  Cell to test yourself on by dragging labels.
- http://www.maxanim.com/physiology/index.htm Max Animations
  Great animations here of diffusion, osmosis, facilitated diffusion, endo- and exocytosis and the development and action of lysosomes. A bit higher level than you need but still not to be missed.
- http://www.stolaf.edu/people/giannini/flashanimat/transport/diffusion.swf Diffusion
  Diffusion animation - good and clear.
- http://www.tvdsb.on.ca/westmin/science/sbi3a1/Cells/Osmosis.htm Osmosis
  Nice simple osmosis animation.
- http://zoology.okstate.edu/zoo_lrc/biol1114/tutorials/Flash/Osmosis_Animation.htm Osmosis
  Diffusion and osmosis. Watch what happens to the water and the solute molecules.
- http://www.wisc-online.com/objects/index_tj.asp?objid=NUR4004 Osmotic Pressure
  Do an online experiment to illustrate osmosis and osmotic pressure.
- http://www.stolaf.edu/people/giannini/flashanimat/transport/osmosis.swf Osmosis
  Even better osmosis demonstration - you get to add the salt.

3.12 Glossary

- Link to Glossary[8]

8 https://en.wikibooks.org/wiki/..%2FGlossary

4 Body Organisation

Figure 28 original image by grrphoto[a] cc by

a http://flickr.com/photos/grrphoto/282326570/

In this chapter, the way the cells of the body are organised into different tissues is described. You will find out how these tissues are arranged into organs, and how the organs form systems such as the digestive system and the reproductive system. Also in this chapter, the important concept of homeostasis is defined. You are also introduced to those pesky things -- directional terms.

4.1 Objectives

After completing this section, you should know:

- the "Mrs Gren" characteristics of living organisms
- what a tissue is
- four basic types of tissues, their general function and where they are found in the body
- the basic organisation of the body of vertebrates including the main body cavities and the location of the following major organs: thorax, heart, lungs, thymus, abdomen, liver, stomach, spleen, intestines, kidneys, sperm ducts, ovaries, uterus, cervix, vagina, urinary bladder
- the 11 body systems
- what homeostasis is
- directional terms including dorsal, ventral, caudal, cranial, medial, lateral, proximal, distal, rostral, palmar and plantar. Plus transverse and longitudinal sections

4.2 The Organisation Of Animal Bodies

Living organisms move, feed, respire (burn food to make energy), grow, sense their environment, excrete and reproduce. These seven characteristics are sometimes summarized by the words "MRS GREN". functions of:

M ovement

R espiration

S ensitivity

G rowth

R eproduction

E xcretion

N utrition

Living organisms are made from cells which are organised into tissues and these are themselves combined to form organs and systems.

Skin cells, muscle cells, skeleton cells and nerve cells, for example. These different types of cells are not just scattered around randomly but similar cells that perform the same function are arranged in groups. These collections of similar cells are known as **tissues** .

There are four main types of tissues in animals. These are:

- **Epithelial** tissues that form linings, coverings and glands,
- **Connective** tissues for transport and support
- **Muscle** tissues for movement and
- **Nervous** tissues for carrying messages.

4.2.1 Epithelial Tissues

Epithelium (plural epithelia) is tissue that covers and lines. It covers an organ or lines a tube or space in the body. There are several different types of epithelium, distinguished by the different shapes of the cells and whether they consist of only a single layer of cells or several layers of cells.

Simple Epithelia - with a single layer of cells

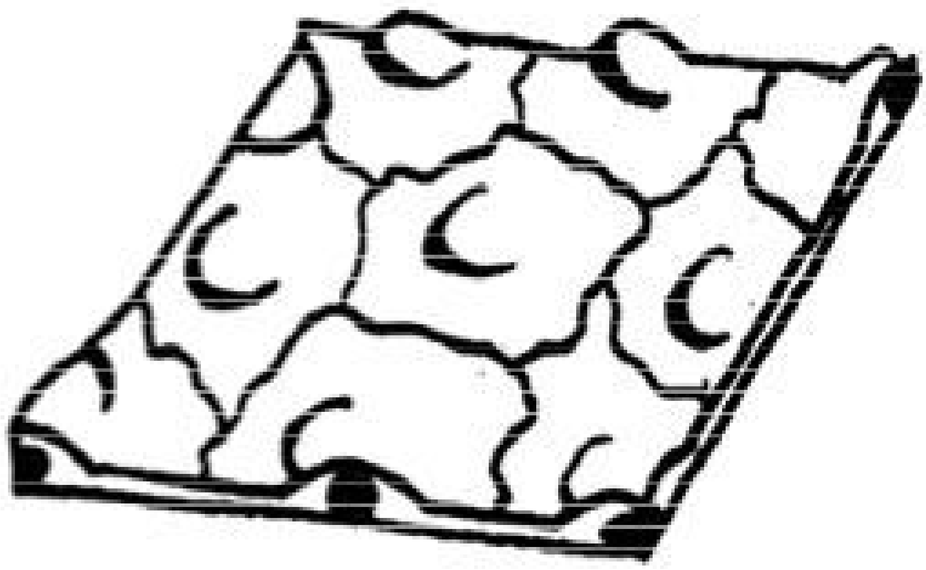

Figure 29 **Diagram 4.1** : Squamous epithelium

Squamous epithelium

Squamous epithelium consists of a single layer of flattened cells that are shaped rather like 'crazy paving'. It is found lining the heart, blood vessels, lung alveoli and body cavities (see diagram 4.1). Its thinness allows molecules to diffuse across readily.

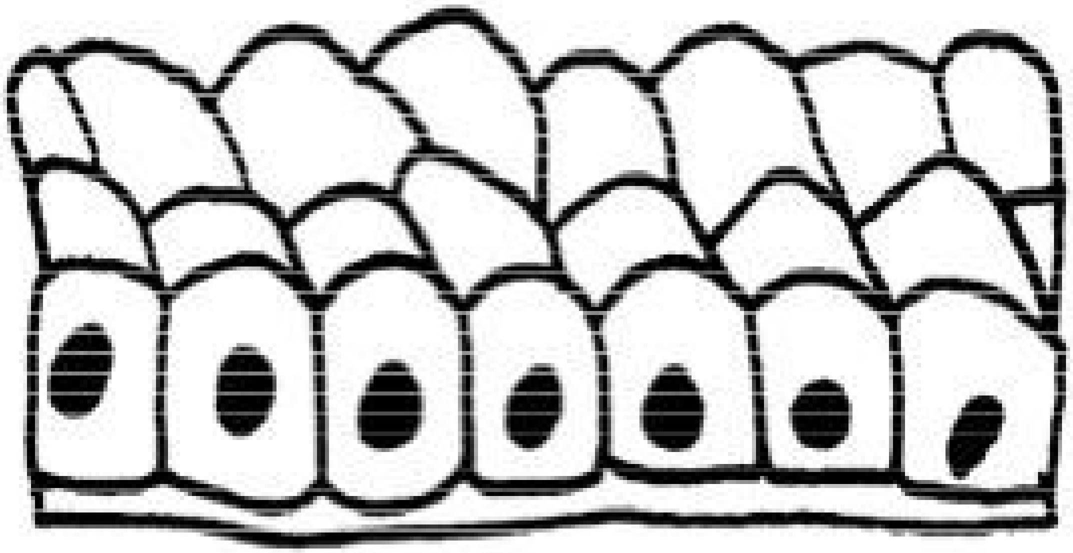

Figure 30 **Diagram 4.2** : Cuboidal epithelium

Cuboidal epithelium
Cuboidal epithelium consists of a single layer of cube shaped cells. It is rare in the body but is found lining kidney tubules (see diagram 4.2). Molecules pass across it by diffusion, osmosis and active transport.

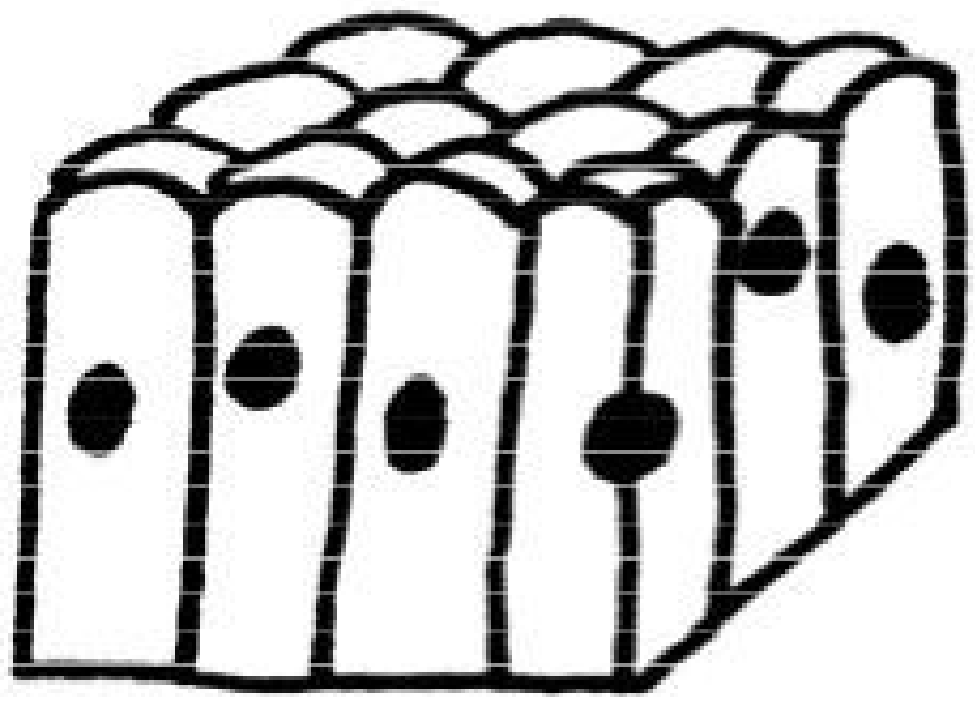

Figure 31 Diagram 4.3 : Columnar epithelium

Columnar epithelium

Columnar epithelium consists of column shaped cells. It is found lining the gut from the stomach to the anus (see diagram 4.3). Digested food products move across it into the blood stream.

Figure 32 Diagram 4.4 : Columnar epithelium with cilia

Columnar epithelium with cilia

Columnar epithelium with cilia on the free surface (also known as the apical side of the cell) lines the respiratory tract, fallopian tubes and uterus (see diagram 4.4). The cilia beat rhythmically to transport particles.

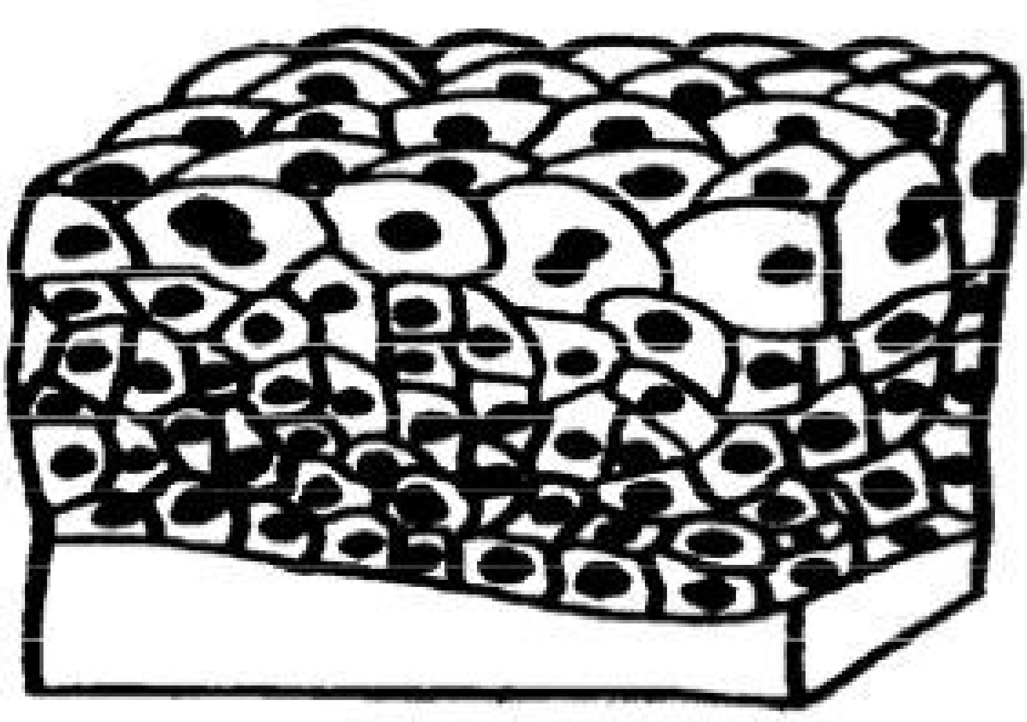

Figure 33 Diagram 4.5 : Transitional epithelium

Transitional epithelium - with a variable number of layers

The cells in transitional epithelium can move over one another allowing it to stretch. It is found in the wall of the bladder (see diagram 4.5).

Stratified epithelia - with several layers of cells

Figure 34 Diagram 4.6 : Stratified squamous epithelium

Epithelia with several layers of cells are found where toughness and resistance to abrasion are needed.

Stratified squamous epithelium
Stratified squamous epithelium has many layers of flattened cells. It is found lining the mouth, cervix and vagina. Cells at the base divide and push up the cells above them and cells at the top are worn or pushed off the surface (see diagram 4.6). This type of epithelium protects underlying layers and repairs itself rapidly if damaged.

Keratinised stratified squamous epithelium
Keratinised stratified squamous epithelium has a tough waterproof protein called **keratin**

deposited in the cells. It forms the skin found covering the outer surface of mammals. (Skin will be described in more detail in Chapter 5).

4.2.2 Connective Tissues

Blood, bone, tendons, cartilage, fibrous connective tissue and fat (adipose) tissue are all classed as connective tissues. They are tissues that are used for supporting the body or transporting substances around the body. They also consist of three parts: they all have cells suspended in a ground substance or **matrix** and most have **fibres** running through it.

Blood

Blood consists of a matrix - plasma, with several types of cells and cell fragments suspended in it. The fibres are only evident in blood that has clotted. Blood will be described in detail in chapter 8.

Lymph

Lymph is similar in composition to blood plasma with various types of white blood cell floating in it. It flows in lymphatic vessels.

Connective tissue 'proper'

Figure 35 Diagram 4.7 : Loose connective tissue

Connective tissue 'proper' consists of a jelly-like matrix with a dense network of collagen and elastic fibres and various cells embedded in it. There are various different forms of 'proper' connective tissue (see 1, 2 and 3 below).

Loose connective tissue
Loose connective tissue is a sticky whitish substance that fills the spaces between organs. It is found in the dermis of the skin (see diagram 4.7).

Dense connective tissue
Dense connective tissue contains lots of thick fibres and is very strong. It forms tendons, ligaments and heart valves and covers bones and organs like the kidney and liver.

Adipose tissue

Adipose tissue consists of cells filled with fat. It forms the fatty layer under the dermis of the skin, around the kidneys and heart and the yellow marrow of the bones.

Figure 36 Diagram 4.8 : Cartilage

Cartilage

Cartilage is the 'gristle' of the meat. It consists of a tough jelly-like matrix with cells suspended in it. It may contain collagen and elastic fibres. It is a flexible but tough tissue and is found at the ends of bones, in the nose, ear and trachea and between the vertebrae (see diagram 4.8).

Bone

Bone consists of a solid matrix made of calcium salts that give it its hardness. **Collagen** fibres running through it give it its strength. Bone cells are found in spaces in the matrix. Two types of bone are found in the skeleton namely **spongy** and **compact bone** . They differ in the way the cells and matrix are arranged. (See Chapter 6 for more details of bone).

4.2.3 Muscle Tissues

Muscle tissue is composed of cells that contract and move the body. There are three types of muscle tissue:

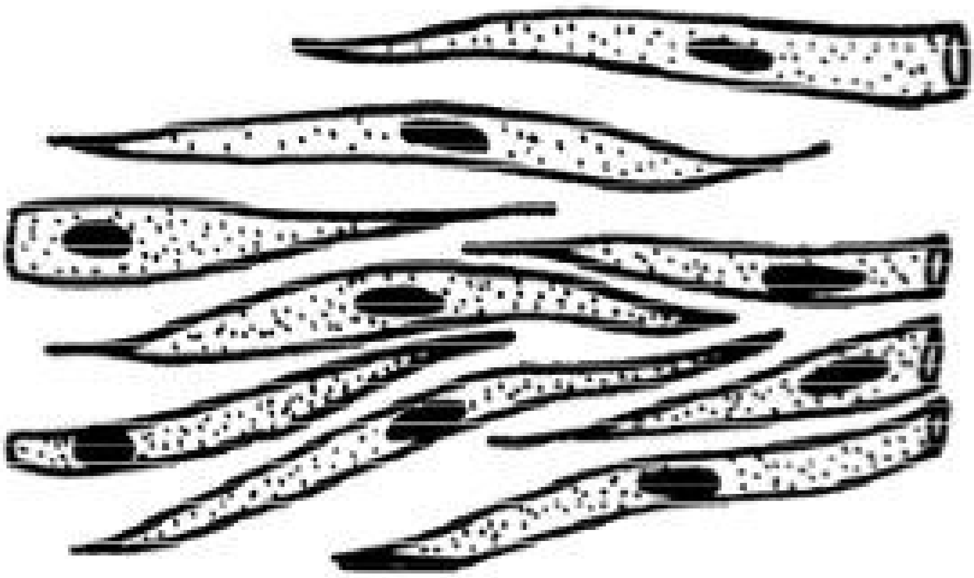

Figure 37 **Diagram 4.9** : Smooth muscle fibres

Smooth muscle

Smooth muscle consists of long and slender cells with a central nucleus (see diagram 4.9). It is found in the walls of blood vessels, airways to the lungs and the gut. It changes the size of the blood vessels and helps move food and fluid along. Contraction of smooth muscle fibres occurs without the conscious control of the animal.

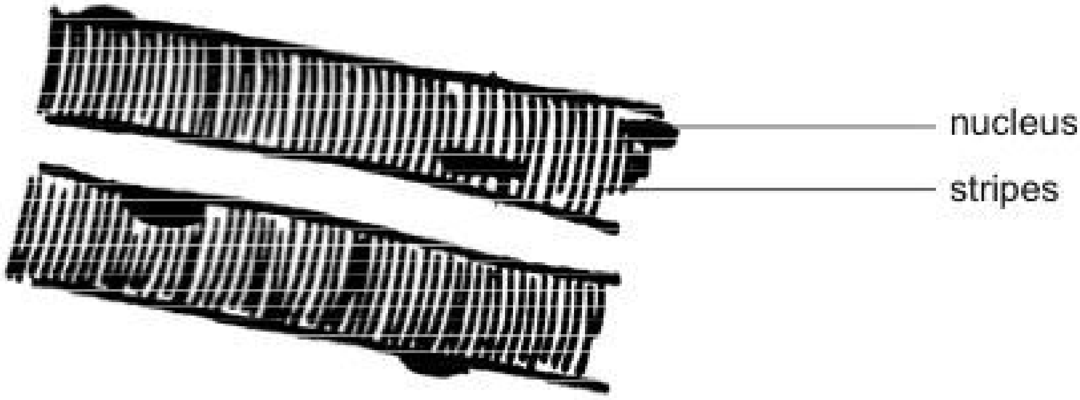

Figure 38 **Diagram 4.10** : Skeletal muscle fibres

Skeletal muscle

Skeletal muscle (sometimes called **striated** , **striped** or **voluntary muscle**) has striped fibres with alternating light and dark bands. It is attached to bones and is under the voluntary control of the animal (see diagram 4.10).

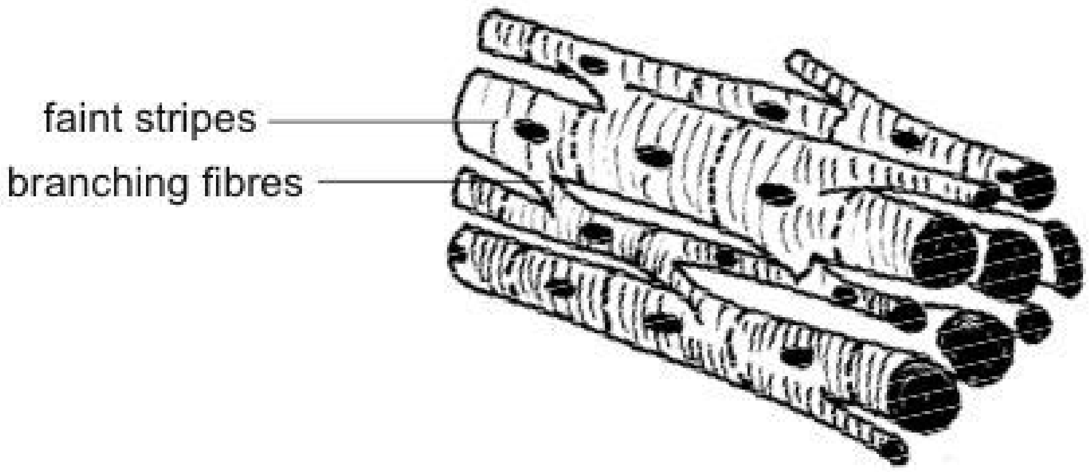

Figure 39 **Diagram 4.11** : Cardiac muscle fibres

Cardiac muscle

Cardiac muscle is found only in the walls of the heart where it produces the ‘heart beat’. Cardiac muscle cells are branched cylinders with central nuclei and faint stripes (see diagram 4.11). Each fibre contracts automatically but the heart beat as a whole is controlled by the **pacemaker** and the involuntary **autonomic nervous system** .

Figure 40 **Diagram 4.12** : A motor neuron

4.2.4 Nervous Tissues

Nervous tissue forms the nerves, spinal cord and brain. Nerve cells or **neurons** consist of a cell body and a long thread or axon that carries the nerve impulse. An insulating sheath of fatty material (**myelin**) usually surrounds the axon. Diagram 4.12 shows a typical motor neuron that sends messages to muscles to contract.

4.3 Vertebrate Bodies

We are so familiar with animals with backbones (i.e. vertebrates) that it seems rather unnecessary to point out that the body is divided into three sections. There is a well-defined **head** that contains the brain, the major sense organs and the mouth, a **trunk** that contains the other organs and a well-developed **tail** . Other features of vertebrates may be less apparent. For instance, vertebrates that live on the land have developed a flexible neck that is absent in fish where it would be in the way of the gills and interfere with streamlining. Mammals but not other vertebrates have a sheet of muscle called the **diaphragm** that divides the trunk into the chest region or **thorax** and the **abdomen** .

4.4 Body Cavities

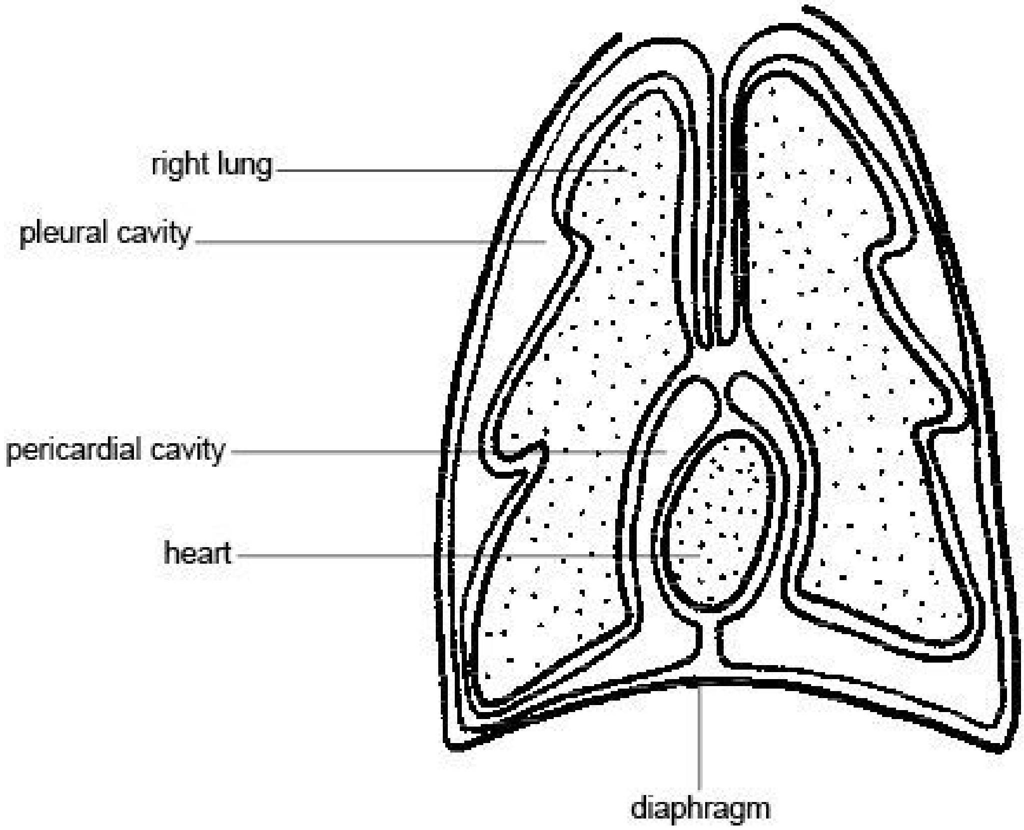

Figure 41 **Diagram 4.13** : The body cavities

In contrast to many primitive animals, vertebrates have spaces or **body cavities** that contain the body organs. Most vertebrates have a single body cavity but in mammals the diaphragm divides the main cavity into a **thoracic** and an **abdominal cavity** . In the thoracic cavity the heart and lungs are surrounded by their own membranes so that cavities are created around the heart - the **pericardial cavity** , and around the lungs – the **pleural cavity** (see diagram 4.13).

4.5 Organs

Figure 42 **Diagram 4.14** : Cells, tissues and organs forming the digestive system

Just as the various parts of the cell work together to perform the cell's functions and a large number of similar cells make up a tissue, so many different tissues can "cooperate" to form an organ that performs a particular function. For example, connective tissues, epithelial tissues, muscle tissue and nervous tissue combine to make the organ that we call the stomach. In turn the stomach combines with other organs like the intestines, liver and pancreas to form the digestive system (see diagram 4.14).

4.6 Generalised Plan Of The Mammalian Body

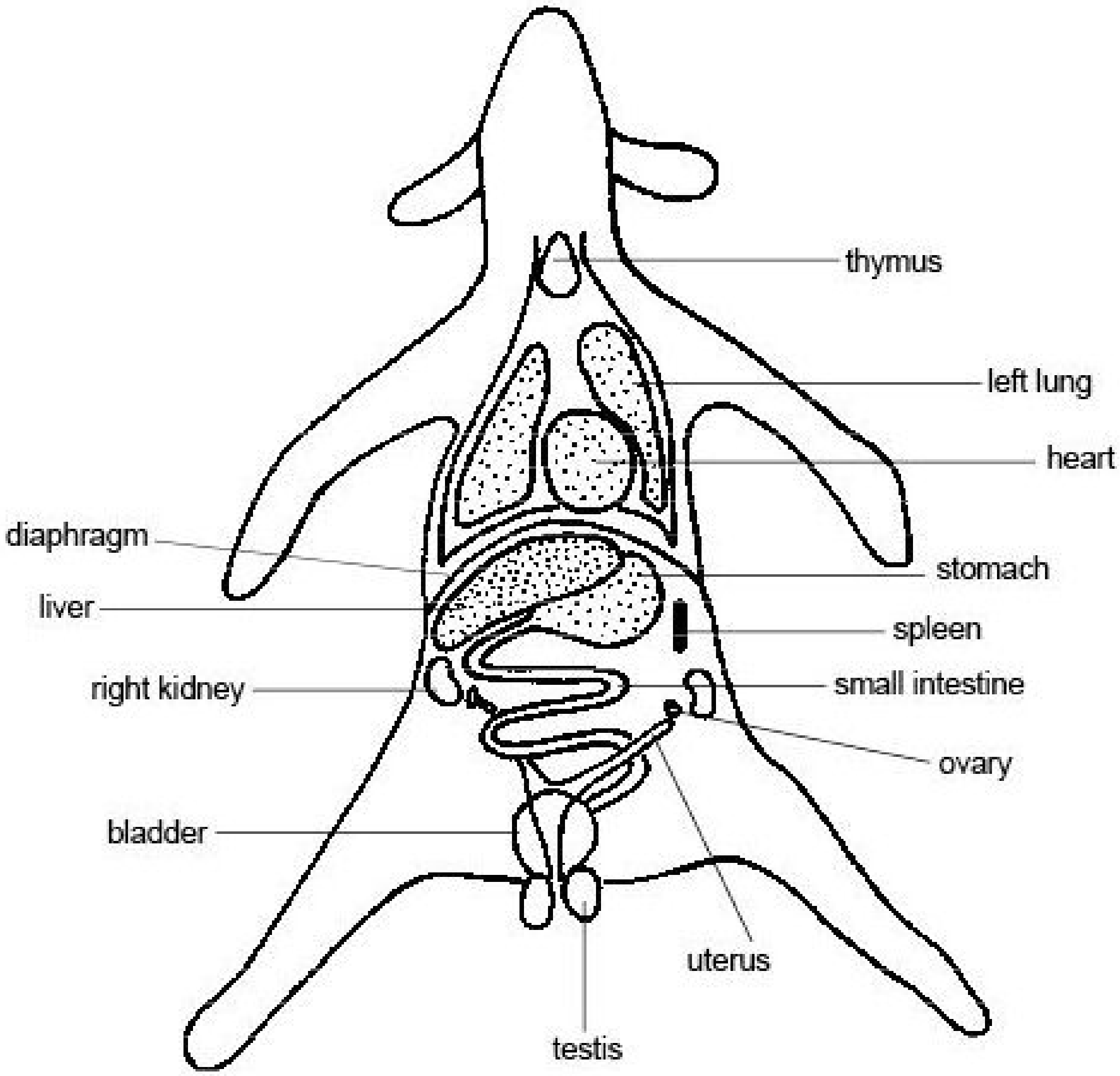

Figure 43 Diagram 4.15 : The main organs of the vertebrate body

At this point it would be a good idea to make yourself familiar with the major organs and their positions in the body of a mammal like the rabbit. Diagram 4.15 shows the main body organs.

4.7 Body Systems

Organs do not work in isolation but function in cooperation with other organs and body structures to bring about the MRS GREN functions necessary to keep an animal alive. For example the stomach can only work in conjunction with the mouth and oesophagus (gullet). These provide it with the food it breaks down and digests. It then needs to pass the food on to the intestines etc. for further digestion and absorption. The organs involved with the taking of food into the body, the digestion and absorption of the food and elimination of waste products are collectively known as the digestive system.

4.7.1 The 11 body systems

1. Skin
   The skin covering the body consists of two layers, the **epidermis** and **dermis** . Associated with these layers are hairs, feathers, claws, hoofs, glands and sense organs of the skin.
2. Skeletal System
   This can be divided into the bones of the skeleton and the joints where the bones move over each other.
3. Muscular System
   The muscles, in conjunction with the skeleton and joints, give the body the ability to move.
4. Cardiovascular System
   This is also known as the circulatory system. It consists of the heart, the blood vessels and the blood. It transports substances around the body.
5. Lymphatic System
   This system is responsible for collecting and "cleaning" the fluid that leaks out of the blood vessels. This fluid is then returned to the blood system. The lymphatic system also makes antibodies that protect the body from invasion by bacteria etc. It consists of lymphatic vessels, lymph nodes, the spleen and thymus glands.
6. Respiratory System
   This is the system involved with bringing oxygen in the air into the body and getting rid of carbon dioxide, which is a waste product of processes that occur in the cell. It is made up of the trachea, bronchi, bronchioles, lungs, diaphragm, ribs and muscles that move the ribs in breathing.
7. Digestive System
   This is also known as the **gastrointestinal system** , **alimentary system** or **gut** . It consists of the digestive tube and glands like the liver and pancreas that produce digestive secretions. It is concerned with breaking down the large molecules in foods into smaller ones that can be absorbed into the blood and lymph. Waste material is also eliminated by the digestive system.
8. Urinary System
   This is also known as the **renal system** . It removes waste products from the blood and is made up of the kidneys, ureters and bladder.
9. Reproductive System

This is the system that keeps the species going by making new individuals. It is made up of the ovaries, uterus, vagina and fallopian tubes in the female and the testes with associated glands and ducts in the male.

10. Nervous System
    This system coordinates the activities of the body and responses to the environment. It consists of the sense organs (eye, ear, semicircular canals, and organs of taste and smell), the nerves, brain and spinal cord.
11. Endocrine System
    This is the system that produces chemical messengers or hormones. It consists of various **endocrine glands** (ductless glands) that include the pituitary, adrenal, thyroid and pineal glands as well as the testes and ovary.

4.8 Homeostasis

All the body systems, except the reproductive system, are involved with keeping the conditions inside the animal more or less stable. This is called **homeostasis** . These constant conditions are essential for the survival and proper functioning of the cells, tissues and organs of the body. The skin, for example, has an important role in keeping the temperature of the body constant. The kidneys keep the concentration of salts in the blood within limits and the islets of Langerhans in the pancreas maintain the correct level of glucose in the blood through the hormone insulin. As long as the various body processes remain within normal limits, the body functions properly and is healthy. Once homeostasis is disturbed disease or death may result. (See Chapters 12 and16 for more on homeostasis).

4.9 Directional Terms

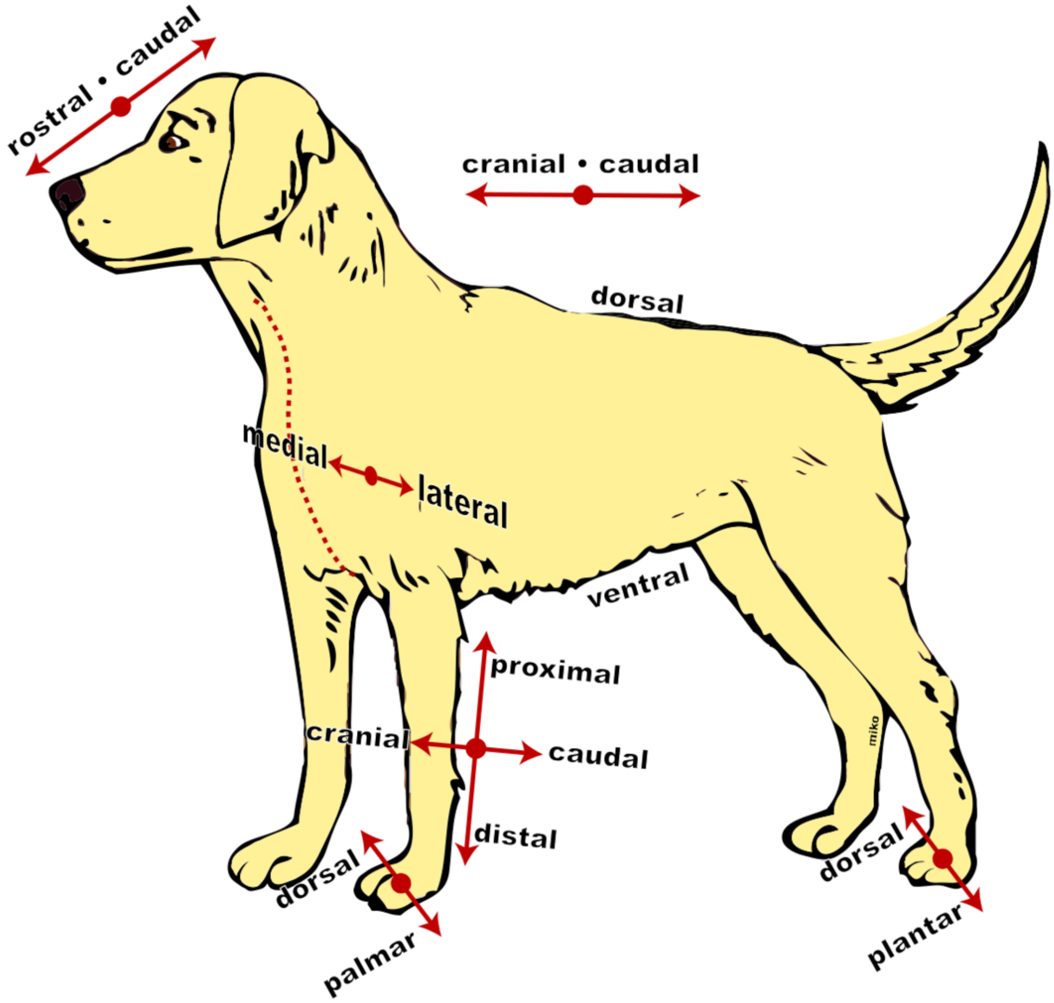

Figure 44 **Diagram 4.16** : The directional terms used with animals

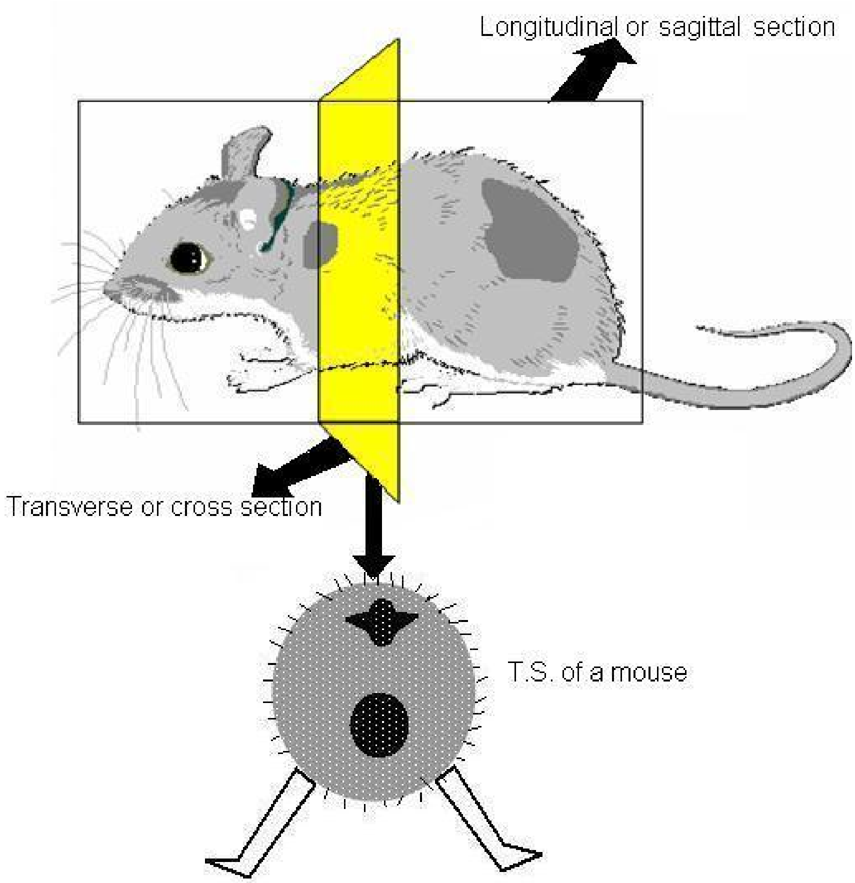

Figure 45 **Diagram 4.17** : Transverse and longitudinal sections of a mouse

In the following chapters the systems of the body in the list above will be covered one by one. For each one the structure of the organs involved will be described and the way they function will be explained.

In order to describe structures in the body of an animal it is necessary to have a system for describing the position of parts of the body in relation to other parts. For example it may be necessary to describe the position of the liver in relation to the diaphragm, or the heart in relation to the lungs. Certainly if you work further with animals, in a veterinary clinic for example, it will be necessary to be able to accurately describe the position of an injury. The terms used for this are called **directional terms** .

The most common directional terms are **right** and **left** . However, even these are not completely straightforward especially when looking at diagrams of animals. The convention is to show the left side of the animal or organ on the right side of the page. This is the view you would get looking down on an animal lying on its back during surgery or in a post-mortem. Sometimes it is useful to imagine 'getting inside' the animal (so to speak) to check which side is which. The other common and useful directional terms are listed below and shown in diagram 4.16.

Term	Definition	Example
Dorsal	Nearer the back of the animal than	The backbone is dorsal to the belly
Ventral	Nearer the belly of the animal than	The breastbone is ventral to the heart
Cranial (or anterior)	Nearer to the skull than	The diaphragm is cranial to the stomach
Caudal (or posterior)	Nearer to the tail than	The ribs are caudal to the neck
Proximal	Closer to the body than (only used for structures on limbs)	The shoulder is proximal to the elbow
Distal	Further from the body than (only used for structures on limbs)	The ankle is distal to the knee
Medial	Nearer to the midline than	The bladder is medial to the hips
Lateral	Further from the midline than	The ribs are lateral to the lungs
Rostral	Towards the muzzle	There are more grey hairs in the rostral part of the head
Palmar	The ”walking” surface of the front paw	There is a small cut on the left palmar surface
Plantar	The ”walking” surface of the hind paw	The pads are on the plantar side of the foot

Note that we don't use the terms **superior** and **inferior** for animals. They are only used to describe the position of structures in the human body (and possibly apes) where the upright posture means some structures are above or superior to others.

In order to look at the structure of some of the parts or organs of the body it may be necessary to cut them open or even make thin slices of them that they can be examined under the microscope. The direction and position of slices or sections through an animal's body have their own terminology.

If an animal or organ is sliced lengthwise this section is called a **longitudinal** or **sagittal section** . This is sometimes abbreviated to LS.

If the section is sliced crosswise it is called a **transverse** or **cross section** . This is sometimes abbreviated to TS or XS (see diagram 4.17).

4.10 Summary

- The characteristics of living organisms can be summarised by the words "**MRS GREN** ."
- There are 4 main types of tissue namely: **epithelial, connective, muscle** and **nervous tissues** .
- **Epithelial tissues** form the skin and line the gut, respiratory tract, bladder etc.
- **Connective tissues** form tendons, ligaments, adipose tissue, blood, cartilage and bone, and are found in the dermis of the skin.
- **Muscular tissues** contract and consist of 3 types: **smooth, skeletal and cardiac** .
- Vertebrate bodies have a **head, trunk** and **tail** . Body organs are located in **body cavities** . 11 body systems perform essential body functions most of which maintain a stable environment or **homeostasis** within the animal.
- **Directional terms** describe the location of parts of the body in relation to other parts.

4.11 Worksheets

Students often find it hard learning how to use directional terms correctly. There are two worksheets to help you with these and another on tissues.

Directional Terms Worksheet 1[1]

Directional Terms Worksheet 2[2]

Tissues Worksheet[3]

4.12 Test Yourself

1. Living organisms can be distinguished from non-living matter because they usually move and grow. Name 5 other functions of living organisms:

1.

2.

3.

4.

5.

2. What tissue types would you find...

a) lining the intestine:

b) covering the body:

1 http://www.wikieducator.org/Directional_Terms_Worksheet_1
2 http://www.wikieducator.org/Directional_Terms_Worksheet_2
3 http://www.wikieducator.org/Tissues_Worksheet

c) moving bones:

d) flowing through blood vessels:

e) linking the eye to the brain:

f) lining the bladder:

3. Name the body cavity in which the following organs are found:

a) heart:

b) bladder:

c) stomach:

d) lungs:

4. Name the body system that...

a) includes the bones and joints:

b) includes the ovaries and testes:

c) produces hormones:

d) includes the heart, blood vessels and blood:

5. What is homeostasis?

6. Circle which is correct:

a) The head is cranial | caudal to the neck

b) The heart is medial | lateral to the ribs

c) The elbow is proximal | distal to the fingers

d) The spine is dorsal | ventral to the heart

7. Indicate whether or not these statements are true.

a) The stomach is cranial to the diaphragm - true | false

b) The heart lies in the pelvic cavity - true | false

c) The spleen is roughly the same size as the stomach and lies near it - true | false

d) The small intestine is proximal to the kidneys - true | false

e) The bladder is medial to the hips - true | false

f) The liver is cranial to the heart - true | false

/Test Yourself Answers/[4]

4 https://en.wikibooks.org/wiki/%2FTest%20Yourself%20Answers%2F

4.13 Websites

- Animal organ systems and homeostasis

Overview of the different organ systems (in humans) and their functions in maintaining homeostasis in the body.

http://www.emc.maricopa.edu/faculty/farabee/biobk/BioBookANIMORGSYS.html

- Wikipedia

Directional terms for animals. A little more detail than required but still great.

http://en.wikipedia.org/wiki/Anatomical_terms_of_location

4.14 Glossary

- Link to Glossary[5]

[6]

5 http://en.wikibooks.org/wiki/Anatomy_and_Physiology_of_Animals/Glossary
6 https://en.wikibooks.org/wiki/Category%3A

5 The Skin

Figure 46 original image by Fran-cis-ca[a] cc by

[a] http://flickr.com/photos/alosojos/318955761/

The skin is the first of the eleven body systems to be described. Each chapter from now on will cover one body system.

The skin, sometimes known as the **Integumentary System** is, in fact, the largest organ of the body. It has a complex structure, being composed of many different tissues. It performs many functions that are important in maintaining homeostasis in the body. Probably the most important of these functions is the control of body temperature. The skin also protects the body from physical damage and bacterial invasion. The skin has an array of sense organs which sense the external environment, and also cells which can make **vitamin D** in sunlight.

The skin is one of the first systems affected when an animal becomes sick so it is important for anyone working with animals to have a sound knowledge of the structure and functioning of the skin so they can quickly recognise signs of disease.

5.1 Objectives

After completing this section, you should know:

- the general structure of the skin
- the function of the keratin deposited in the epidermis
- the structure and function of keratin skin structures including calluses, scales, nails, claws, hoofs and horns
- that antlers are not made either of keratin or in the epidermis
- the structure of hairs
- the structure of the different types of feathers and the function of preening
- the general structure and function of sweat, scent, preen and mammary glands
- the basic functions of the skin in sensing stimuli, temperature control and production of vitamin D
- the mechanisms by which the skin regulates body temperature

5.2 The Skin

Skin comes in all kinds of textures and forms. There is the dry warty skin of toads and crocodiles, the wet slimy skin of fish and frogs, the hard shell of tortoises and the soft supple skin of snakes and humans. Mammalian skin is covered with hair, that of birds with feathers, and fish and reptiles have scales. Pigment in the skin, hairs or feathers can make the outer surface almost any colour of the rainbow.

> Skin is one of the largest organs of the body, making up 6-8% of the total body weight. It consists of two distinct layers. The top layer is called the **epidermis** and under that is the **dermis'**

The epidermis is the layer that bubbles up when we have a blister and as we know from this experience, it has no blood or nerves in it. The cells at the base of the epidermis continually divide and push the cells above them upwards. As these cells move up they die and become the dry flaky scales that fall off the skin surface. The cells in the epidermis die because a special protein called **keratin** is deposited in them. Keratin is an extremely important substance for it makes the skin waterproof. Without it land vertebrates like reptiles, birds and mammals would, like frogs, be able to survive only in damp places.

5.3 Skin Structures Made Of Keratin

5.3.1 Claws, Nails and Hoofs

Reptiles, birds and mammals all have nails or claws on the ends of their toes. They protect the end of the toe and may be used for grasping, grooming, digging or in defense. They are continually worn away and grow continuously from a growth layer at their base (see diagram 5.2).

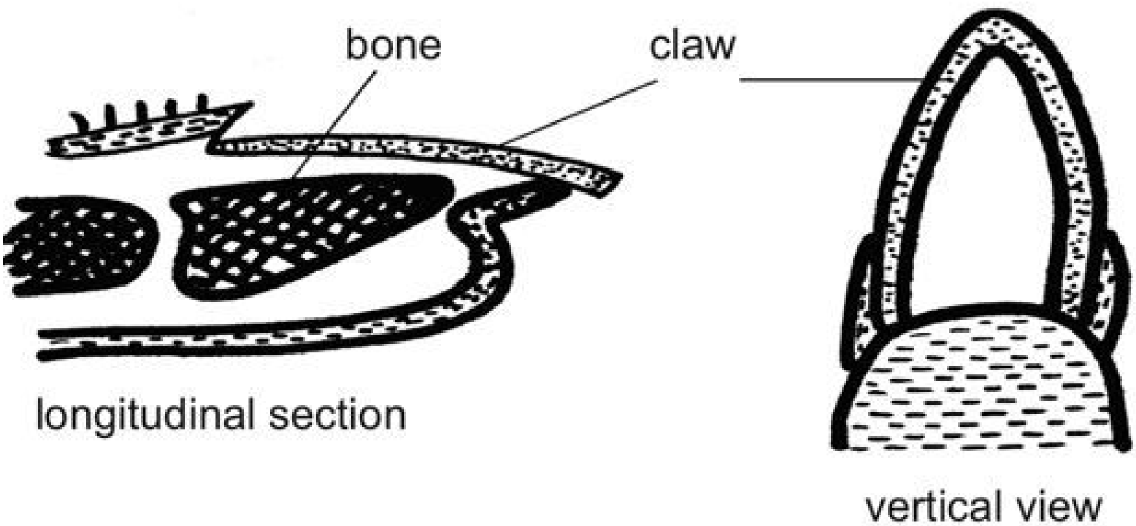

Figure 47

Diagram 5.2 - A carnivore's claw

Hoofs are found in sheep, cows, horses etc. otherwise known as **ungulate mammals** . These are animals that have lost toes in the process of evolution and walk on the "nails" of the remaining toes. The hoof is a cylinder of horny material that surrounds and protects the tip of the toe (see diagram 5.3).

Figure 48

Diagram 5.3 - A horse's hoof

5.3.2 Horns And Antlers

True horns are made of keratin and are found in sheep, goats and cattle. They are never branched and, once grown, are never shed. They consist of a core of bone arising in the dermis of the skin and are fused with the skull. The horn itself forms as a hollow cone-shaped sheath around the bone (see diagram 5.4).

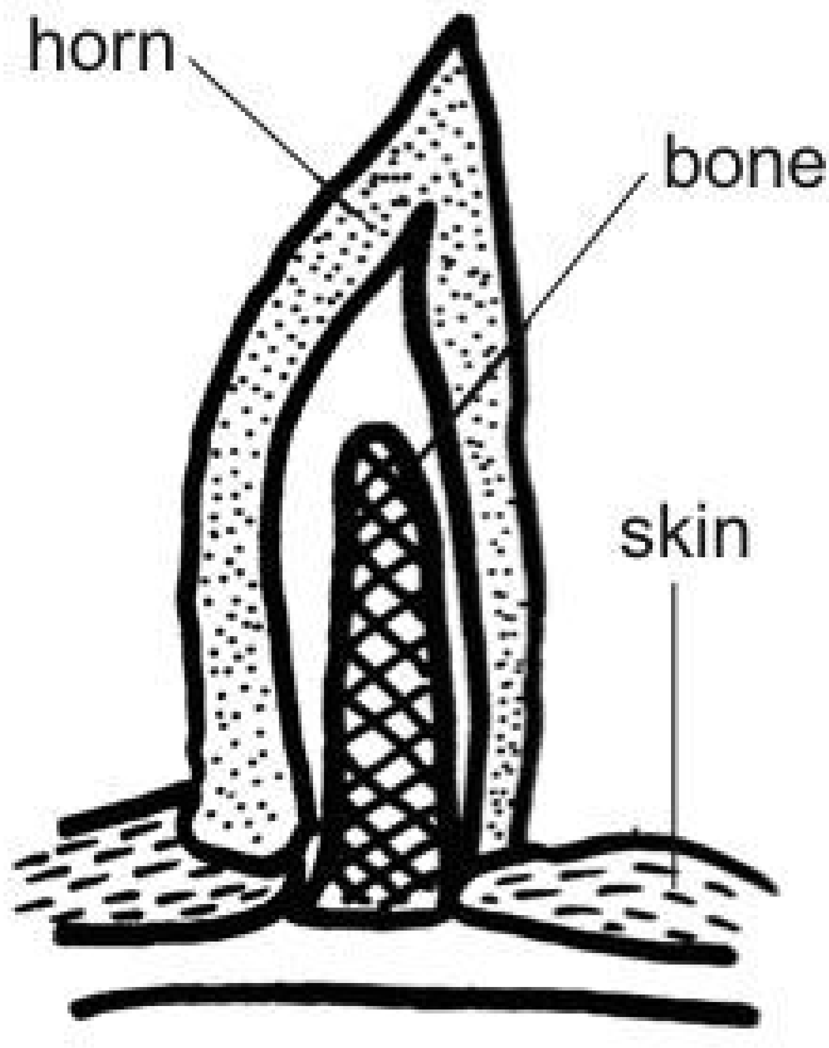

Figure 49

Diagram 5.4 - A horn

The **antlers** of male deer have quite a different structure. They are not formed in the epidermis and do not consist of keratin but are entirely of bone. They are shed each year and are often branched, especially in older animals. When growing they are covered in skin called **velvet** that forms the bone. Later the velvet is shed to leave the bony antler. The velvet is often removed artificially to be sold in Asia as a traditional medicine (see diagram 5.5).

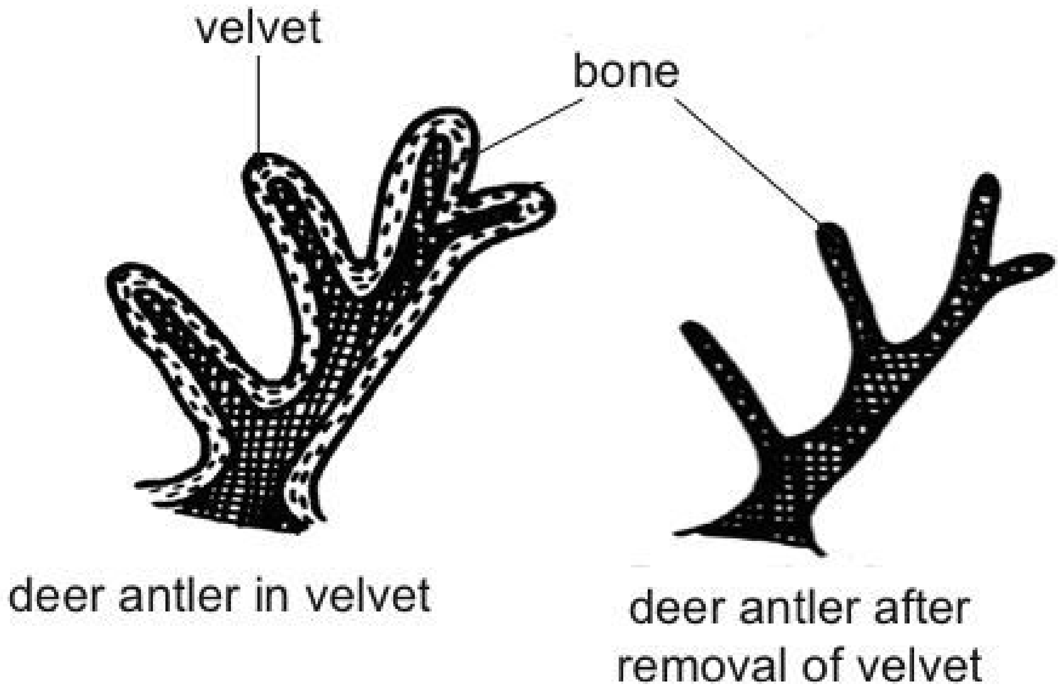

Figure 50

Diagram 5.5 - A deer antler

Other animals have projections on their heads that are not true horns either. The horns on the head of giraffes are made of bone covered with skin and hair, and the 'horn' of a rhinoceros is made of modified and fused hair-like structures.

5.3.3 Hair

Hair is also made of keratin and develops in the epidermis. It covers the body of most mammals where it acts as an insulator and helps to regulate the temperature of the body (see below). The colour in hairs is formed from the same pigment, **melanin** that colours the skin. Coat colour may help camouflage animals and sometimes acts to attract the opposite sex.

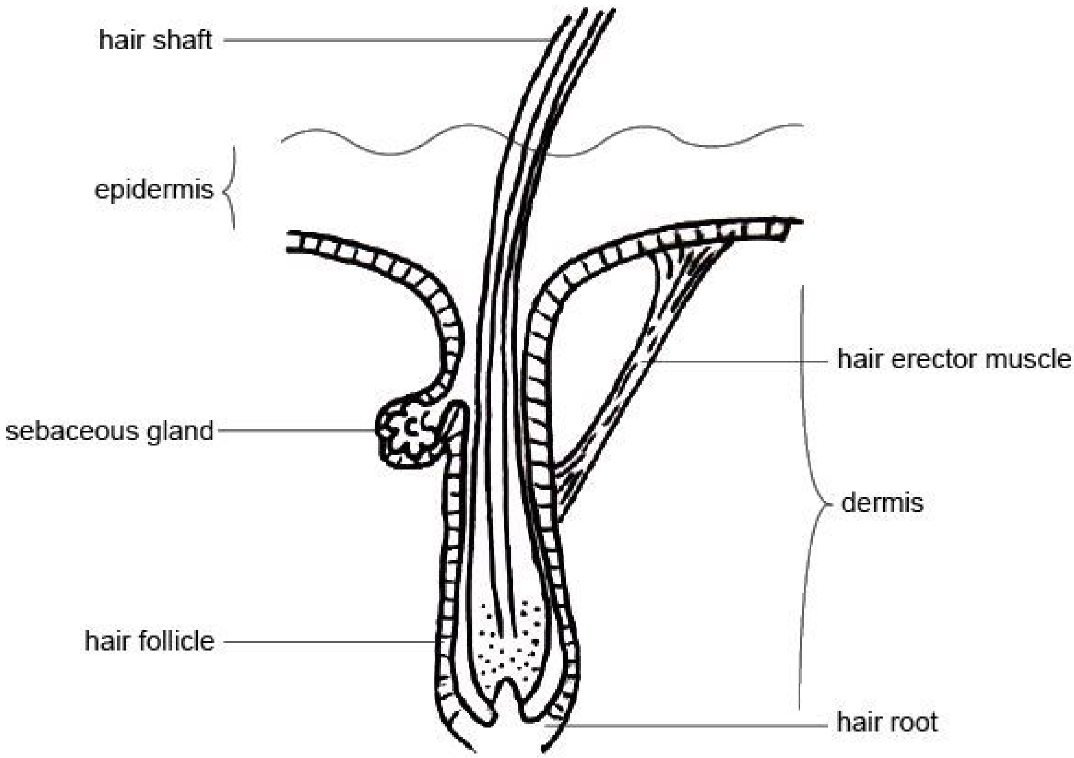

Figure 51

Diagram 5.6 - A hair

Hairs lie in a **follicle** and grow from a **root** that is well supplied with blood vessels. The hair itself consists of layers of dead keratin - containing cells and usually lies at a slant in the skin. A small bundle of smooth muscle fibres (the **hair erector muscle**) is attached to the side of each hair and when this contracts the hair stands on end. This increases the insulating power of the coat and is also used by some animals to make them seem larger when confronted by a foe or a competitor(see diagram 5.6).

The whiskers of cats and the spines of hedgehogs are examples of special types of hairs.

5.3.4 Feathers

The lightness and stiffness of keratin is also a key to bird flight. In the form of feathers it provides the large airfoils necessary for flapping and gliding flight. In another form, the light fluffy down feathers,also made of keratin, are some of the best natural insulators known. This superior insulation is necessary to help maintain the high body temperatures of birds.

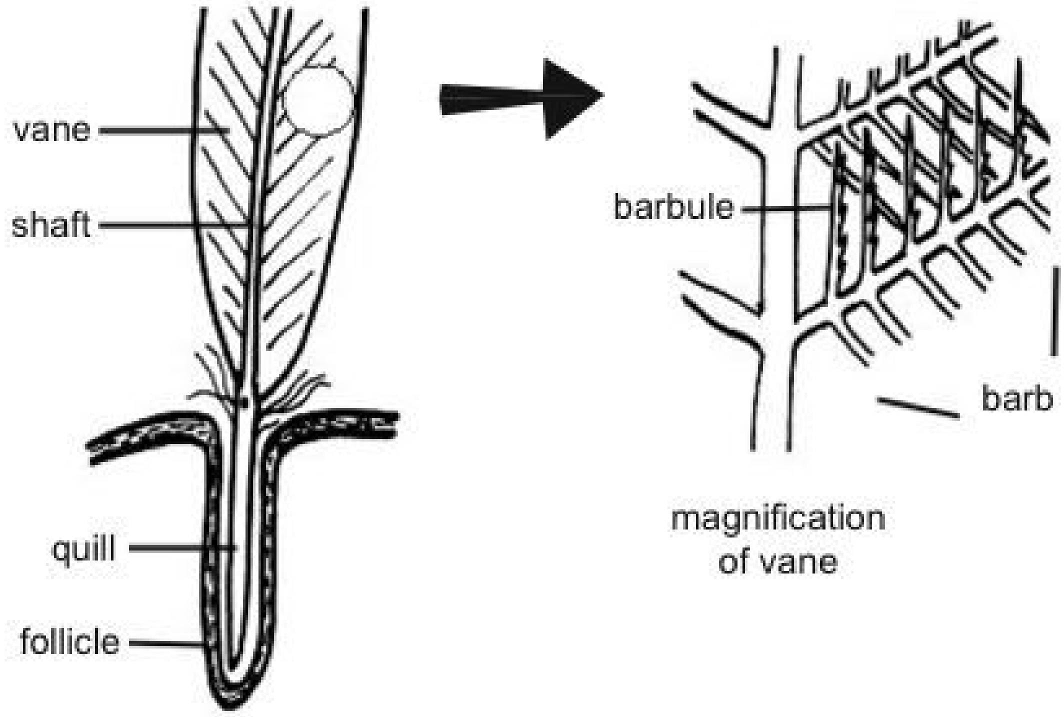

Figure 52

Diagram 5.7 - A Contour Feather

Countour feathers are large feathers that cover the body, wings and tail. They have an expanded **vane** that provides the smooth, continuous surface that is required for effective flight. This surface is formed by **barbs** that extend out from the central shaft. If you look carefully at a feather you can see that on either side of each barb are thousands of **barbules** that lock together by a complex system of hooks and notches. if this arrangement becomes disrupted, the bird uses its beak to draw the barbs and barbules together again in an action known as **preening** (see diagram 5.7).

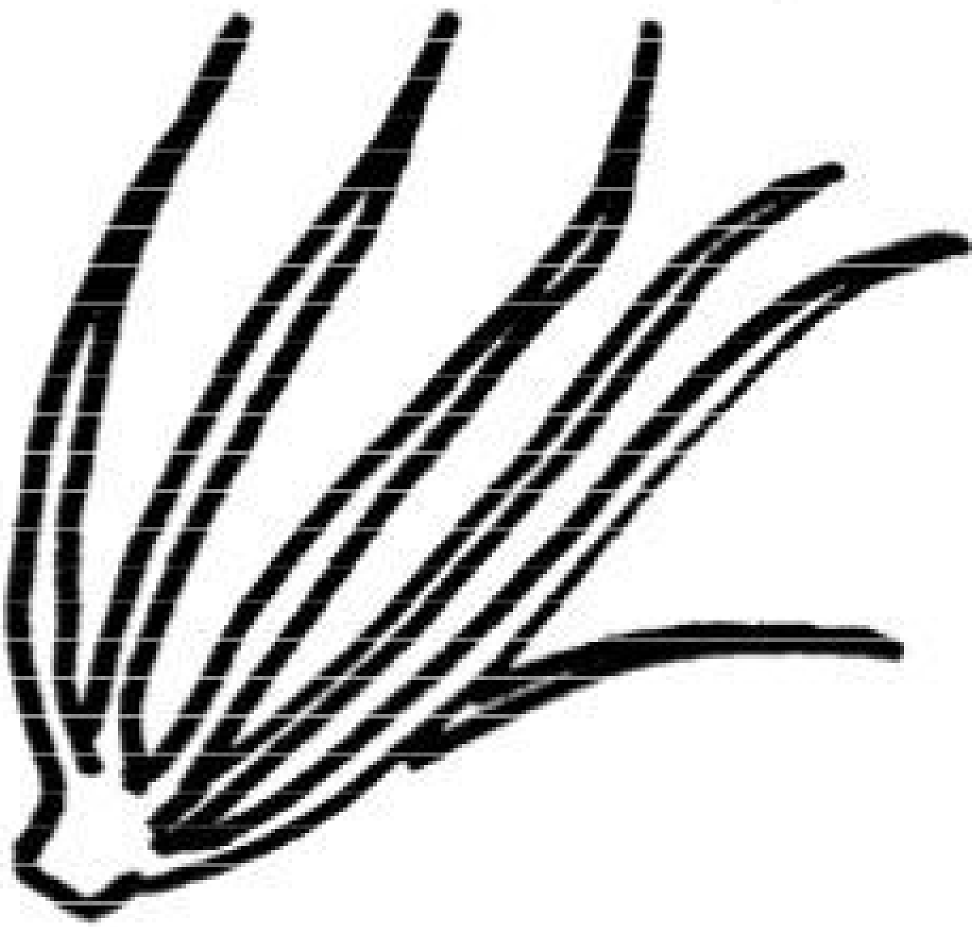

Figure 53

Diagram 5.8 - A Down Feather

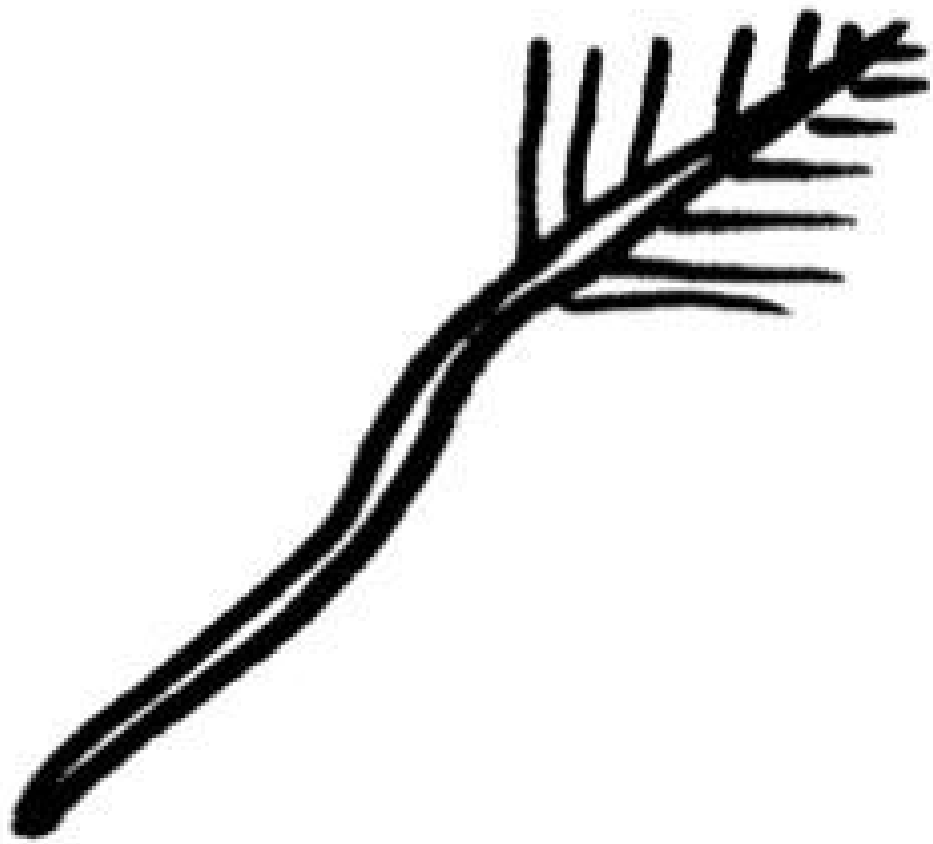

Figure 54

Diagram 5.9 - A Pin Feather

Down feathers are the only feathers covering a chick and form the main insulation layer under the contour feathers of the adult. They have no shaft but consist of a spray of simple, slender branches (see diagram 5.8).

Pin feathers have a slender hair-like shaft often with a tiny tuft of barbs on the end. They are found between the other feathers and help tell a bird how its feathers are lying (see diagram 5.9).

5.4 Skin Glands

Glands are organs that produce and secrete fluids. They are usually divided into two groups depending upon whether or not they have channels or ducts to carry their products away. Glands with ducts are called **exocrine glands** and include the glands found in the skin as well as the glands that produce digestive enzymes in the gut. **Endocrine glands** have no ducts and release their products (hormones) directly into the blood stream. The pituitary and adrenal glands are examples of endocrine glands.

Most vertebrates have exocrine glands in the skin that produce a variety of secretions. The slime on the skin of fish and frogs is **mucus** produced by skin glands and some fish and frogs also produce poison from modified glands. In fact the skin glands of some frogs produce the most poisonous chemicals known. Reptiles and birds have a dry skin with few glands. The **preen gland** , situated near the base of the bird's tail, produces oil to help keep the feathers in good condition. Mammals have an array of different skin glands. These include the wax producing, sweat, sebaceous and mammary glands.

Wax producing glands are found in the ears.

Sebaceous glands secrete an oily secretion into the hair follicle. This secretion, known as **sebum** , keeps the hair supple and helps prevent the growth of bacteria (see diagram 5.6).

Sweat glands consist of a coiled tube and a duct leading onto the skin surface. Their appearance when examined under the microscope inspired one of the first scientists to observe them to call them "fairies' intestines" (see diagram 5.1). Sweat contains salt and waste products like urea and the evaporation of sweat on the skin surface is one of the major mechanisms for cooling the body of many mammals. Horses can sweat up to 30 litres of fluid a day during active exercise, but cats and dogs have few sweat glands and must cool themselves by panting. Scent in the sweat of many animals is used to mark territory or attract the opposite sex.

Mammary glands are only present in mammals. They are thought to be modified sebaceous glands and are present in both sexes but are rarely active in males (see diagram 5.10). The number of glands varies from species to species. They open to the surface in well-developed nipples. Milk contains proteins, sugars, fats and salts, although the exact composition varies from one species to another.

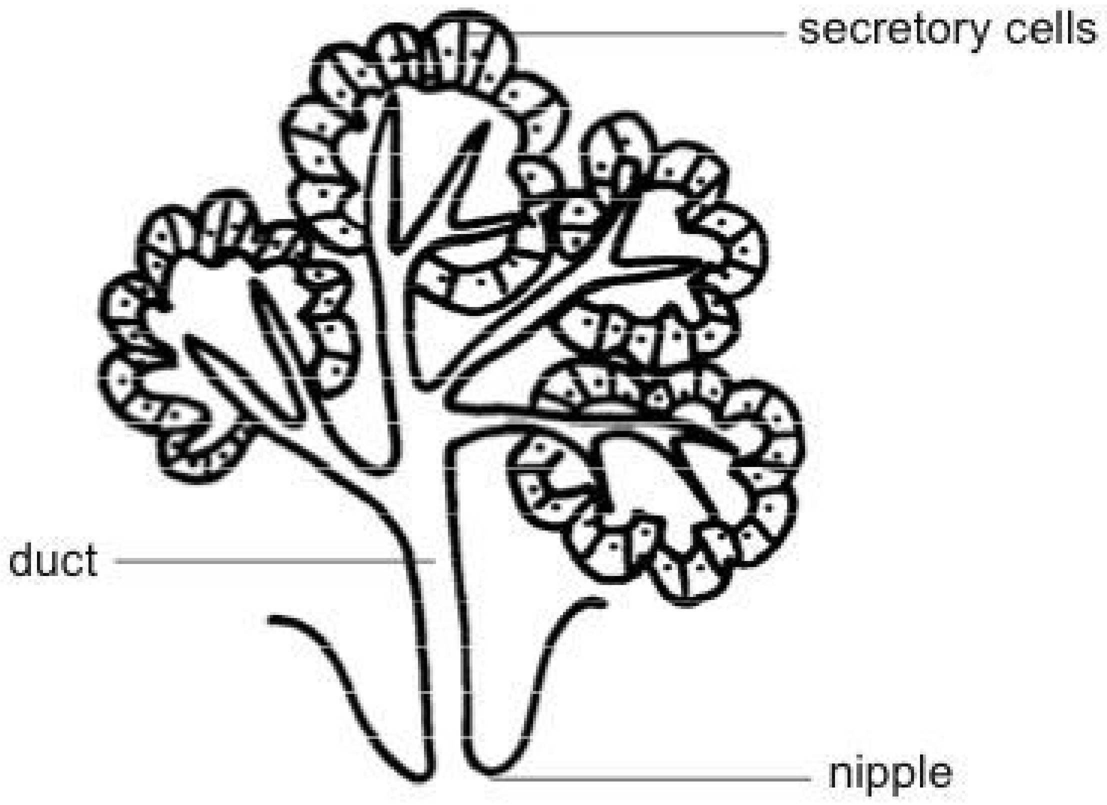

Figure 55

Diagram 5.10 - A Mammary Gland

5.5 The Skin And Sun

A moderate amount of UV in sunlight is necessary for the skin to form **vitamin D** . This vitamin prevents bone disorders like rickets to which animals reared indoors are susceptible. Excessive exposure to the UV in sunlight can be damaging and the pigment **melanin** , deposited in cells at the base of the epidermis, helps to protect the underlying layers of the skin from this damage. Melanin also colours the skin and variations in the amount of melanin produces colours from pale yellow to black.

5.5.1 Sunburn And Skin Cancer

Excess exposure to the sun can cause sunburn. This is common in humans, but light skinned animals like cats and pigs can also be sunburned, especially on the ears. Skin cancer can also result from excessive exposure to the sun. As holes in the ozone layer increase exposure to the sun's UV rays, so too does the rate of skin cancer in humans and animals.

5.6 The Dermis

The underlying layer of the skin, known as the dermis, is much thicker but much more uniform in structure than the epidermis (see diagram 5.1). It is composed of loose connective tissue with a felted mass of **collagen** and **elastic fibres** . It is this part of the skin of cattle and pigs etc. that becomes commercial leather when treated,. The dermis is well supplied with blood vessels, so cuts and burns that penetrate down into the dermis will bleed or cause serious fluid loss. There are also numerous nerve endings and touch receptors in the dermis because, of course, the skin is sensitive to touch, pain and temperature.

When looking at a section of the skin under the microscope you can see hair follicles, sweat and sebaceous glands dipping down into the dermis. However, these structures do not originate in the dermis but are derived from the epidermis.

In the lower levels of the dermis is a layer of fat or **adipose tissue** (see diagram 5.1). This acts as an energy store and is an excellent insulator especially in mammals like whales with little hair.

5.7 The Skin And Temperature Regulation

Vertebrates can be divided into two groups depending on whether or not they control their internal temperature. Amphibia (frogs) and reptiles are said to be"**cold blooded** " (**poikilothermic**) because their body temperature approximately follows that of the environment. Birds and mammals are said to be **warm blooded (homoiothermic**) because they can maintain a roughly constant body temperature despite changes in the temperature of the environment.

Heat is produced by the biochemical reactions of the body (especially in the liver) and by muscle contraction. Most of the heat loss from the body occurs via the skin. It is therefore not surprising that many of the mechanisms for controlling the temperature of the body operate here.

5.7.1 Reduction Of Heat Loss

When an animal is in a cold environment and needs to reduce heat loss the erector muscles contract causing the hair or feathers to rise up and increase the layer of insulating air trapped by them (see diagram 5.11a).

Figure 56

Diagram 5.11a) Hair muscle relaxed...............Diagram 5.11b) Hair muscle contracted

Heat loss from the skin surface can also be reduced by the contraction of the abundant blood vessels that lie in the dermis. This takes blood flow to deeper levels, so reducing heat loss and causing pale skin (see diagram 5.12a).

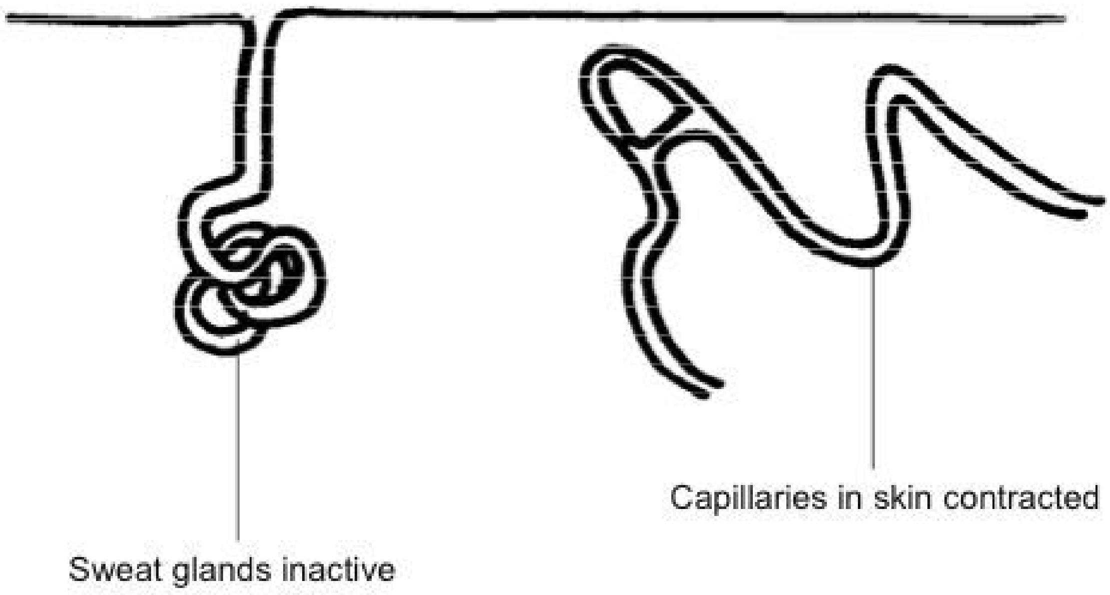

Figure 57

Diagram 5.12a) Reduction of heat loss by skin

Shivering caused by twitching muscles produces heat that also helps raise the body temperature.

5.7.2 Increase Of Heat Loss

There are two main mechanisms used by animals to increase the amount of heat lost from the skin when they are in a hot environment or high levels of activity are increasing internal heat production. The first is the expansion of the blood vessels in the dermis so blood flows near the skin surface and heat loss to the environment can take place. The second is by the production of sweat from the sweat glands (see diagram 5.12b). The evaporation of this liquid on the skin surface produces a cooling effect.

The mechanisms for regulating body temperature are under the control of a small region of the brain called the **hypothalamus** . This acts like a thermostat.

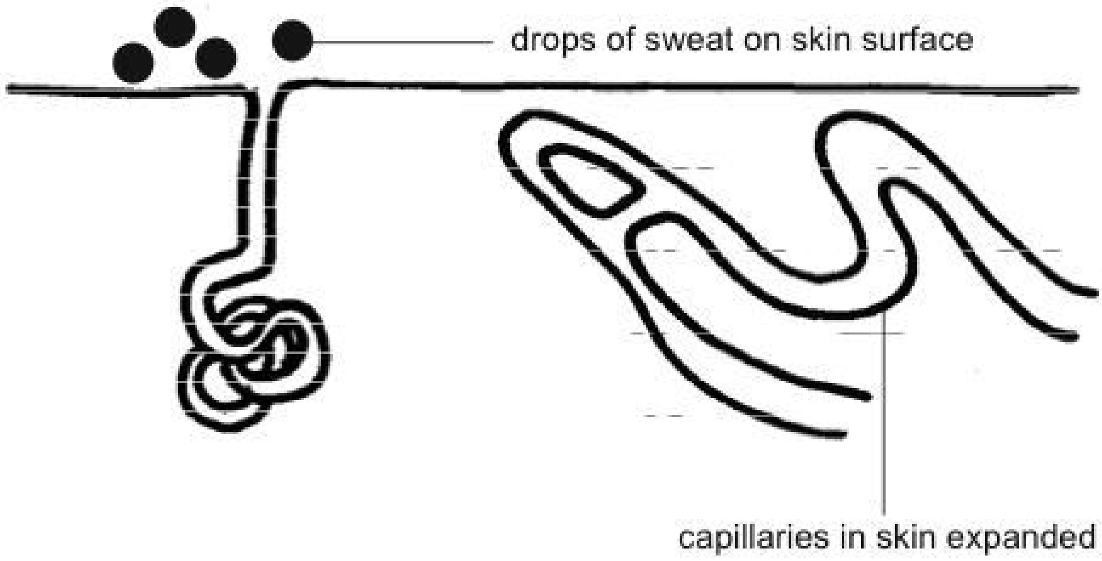

Figure 58

Diagram 5.12b) - Increase of heat loss by skin

5.7.3 Heat Loss And Body Size

The amount of heat that can be lost from the surface of the body is related to the area of skin an animal has in relation to the total volume of its body.

Small animals like mice have a very large skin area compared to their total volume. This means they tend to loose large amounts of heat and have difficulty keeping warm in cold weather. They may need to keep active just to maintain their body temperature or may hibernate to avoid the problem.

Large animals like elephants have the opposite problem. They have only a relatively small skin area in relation to their total volume and may have trouble keeping cool. This is one reason that these large animals tend to have sparse coverings of hair.

5.8 Summary

- Skin consists of two layers: the thin **epidermis** and under it the thicker **dermis.**
- The **Epidermis** is formed by the division of base cells that push those above them towards the surface where they die and are shed.
- **Keratin** , a protein, is deposited in the epidermal cells. It makes skin waterproof.
- Various skin structures formed in the epidermis are made of keratin. These include: claws, nails, hoofs, horn, hair and feathers.
- Various **Exocrine Glands** (with ducts) formed in the epidermis include sweat, sebaceous, and mammary glands.

- **Melanin** deposited in cells at the base of the epidermis protects deeper cells from the harmful effects of the sun.
- The **Dermis** is composed of loose connective tissue and is well supplied with blood.
- Beneath the dermis is insulating **adipose tissue** .
- Body Temperature is controlled by: sweat, hair erection, dilation and contraction of dermal capillaries and shivering.

5.9 Worksheet

Use the Skin Worksheet[1]to help you learn all about the skin.

5.10 Test Yourself

Now use this Skin Test Yourself to see how much you have learned and remember.

1. The two layers that form the skin are the a) ______ and b) ______

a)epidermis

b)dermis

2. The special protein deposited in epidermal cells to make them waterproof is:

keratin

3. Many important skin structures are made of keratin. These include:

hair,nails,foot pads,feathers,scales on reptiles

4. Sweat, sebaceous and mammary glands all have ducts to the outside. These kind of glands are known as:_______

exocrine

5. What is the pigment deposited in skin cells that protects underlying skin layers from the harmful effects of the sun?

melanin

6. How does the skin help cool an animal down when it is active or in a hot environment? Panting and secretion from sweat glands.

7. Name two mechanisms by means of which the skin helps prevent heat loss when an animal is in a cold environment.

a.shivering

b.contraction of blood vessels

/Test Yourself Answers/[2]

1 http://www.wikieducator.org/Skin_Worksheet
2 https://en.wikibooks.org/wiki/%2FTest%20Yourself%20Answers%2F

5.11 Websites

- http://www.auburn.edu/academic/classes/zy/0301/Topic6/Topic6.html Comparative anatomy

Good on keratin skin structures - hairs, feathers, horns etc.

- http://www.olympusmicro.com/micd/galleries/brightfield/skinhairymammal.html Hairy mammal skin

All about hairy mammalian skin.

- http://www.earthlife.net/birds/feathers.html The wonder of bird feathers

Fantastic article on bird feathers with great pictures.

- http://en.wikipedia.org/wiki/Skin Wikipedia

Wikipedia on (human) skin. Good as usual, but more information than you need.

5.12 Glossary

- Link to Glossary[3]

Skin[4]

3 http://en.wikibooks.org/wiki/Anatomy_and_Physiology_of_Animals/Glossary
4 https://en.wikibooks.org/wiki/Category%3A

6 The Skeleton

Figure 59 original image by heschong[a] cc by

[a] http://flickr.com/photos/heschong/154550215/

6.1 Objectives

After completing this section, you should know:

- the functions of the skeleton
- the basic structure of a vertebrae and the regions of the vertebral column
- the general structure of the skull
- the difference between 'true ribs' and 'floating ribs
- the main bones of the fore and hind limbs, and their girdles and be able to identify them in a live cat, dog, or rabbit

Fish, frogs, reptiles, birds and mammals are called **vertebrates** , a name that comes from the bony column of vertebrae (the spine) that supports the body and head. The rest of the skeleton of all these animals (except the fish) also has the same basic design with a skull that houses and protects the brain and sense organs and ribs that protect the heart and lungs and, in mammals, make breathing possible. Each of the four limbs is made to the same basic pattern. It is joined to the spine by means of a flat, broad bone called a **girdle** and consists of one long upper bone, two long lower bones, several smaller bones in the wrist or ankle and five digits (see diagrams 6.1 18,19 and 20).

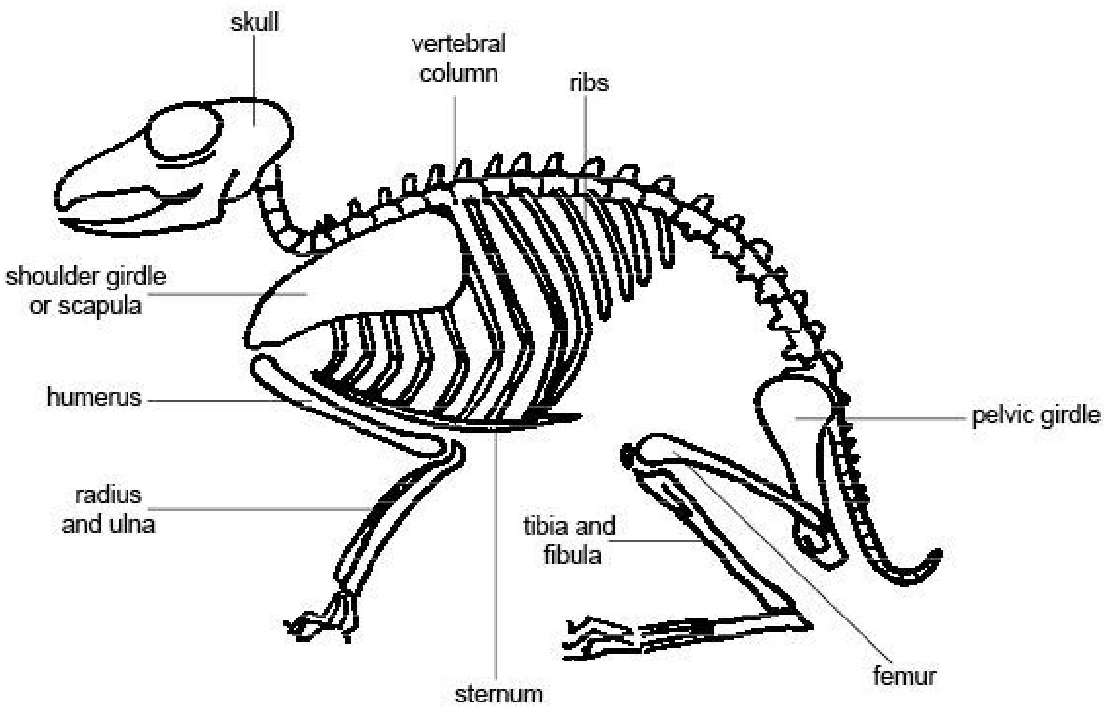

Figure 60

Diagram 6.1 - The mammalian skeleton

6.2 The Vertebral Column

The vertebral column consists of a series of bones called **vertebrae** linked together to form a flexible column with the skull at one end and the tail at the other. Each vertebra consists of a ring of bone with spines (spinous process) protruding dorsally from it. The spinal cord passes through the hole in the middle and muscles attach to the spines making movement of the body possible (see diagram 6.2).

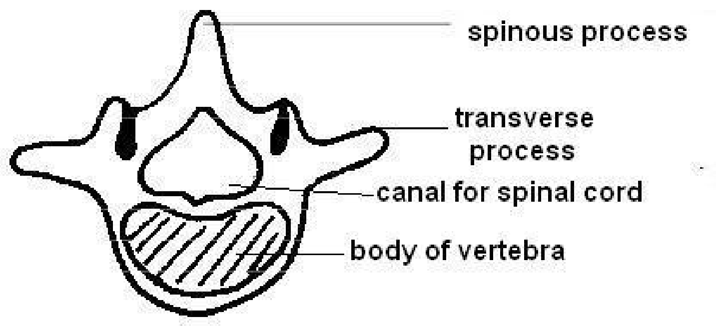

Figure 61

Diagram 6.2 - Cross section of a lumbar vertebre

The shape and size of the vertebrae of mammals vary from the neck to the tail. In the neck there are **cervical vertebrae** with the two top ones, the **atlas** and **axis** , being specialised to support the head and allow it to nod "Yes" and shake "No". **Thoracic vertebrae** in the chest region have special surfaces against which the ribs move during breathing. Grazing animals like cows and giraffes that have to support weighty heads on long necks have extra large spines on their cervical and thoracic vertebrae for muscles to attach to. **Lumbar vertebrae** in the loin region are usually large strong vertebrae with prominent spines for the attachment of the large muscles of the lower back. The **sacral vertebrae** are usually fused into one solid bone called the **sacrum** that sits within the **pelvic girdle** . Finally there are a variable number of small bones in the tail called the **coccygeal vertebrae** (see diagram 6.3).

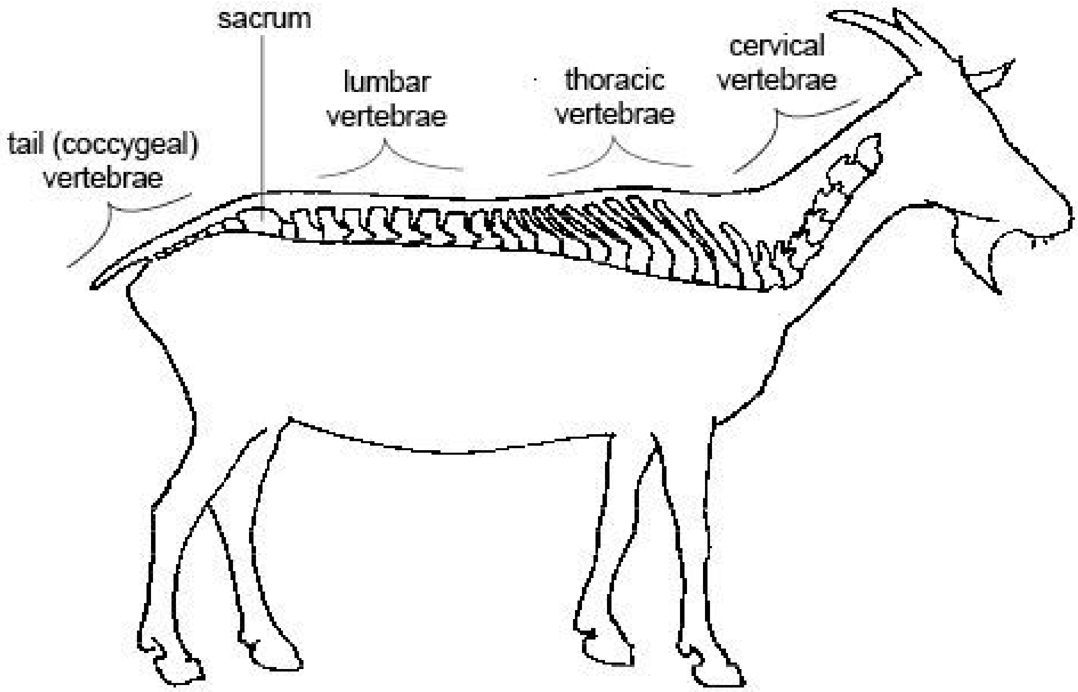

Figure 62

Diagram 6.3 - The regions of the vertebral column dik

6.3 The Skull

The skull of mammals consists of 30 separate bones that grow together during development to form a solid case protecting the brain and sense organs. The “box “enclosing and protecting the brain is called the **cranium** (see diagram 6.4). The bony wall of the cranium encloses the middle and inner ears, protects the organs of smell in the nasal cavity and the eyes in sockets known as **orbits** . The teeth are inserted into the upper and lower jaws (see Chapter 5 for more on teeth) The lower jaw is known as the **mandible** . It forms a joint with the skull moved by strong muscles that allow an animal to chew. At the front of the skull is the nasal cavity, separated from the mouth by a plate of bone called the **palate** . Behind the nasal cavity and connecting with it are the **sinuses** . These are air spaces in the bones of the skull which help keep the skull as light as possible. At the base of the cranium is the **foramen magnum** , translated as “big hole”, through which the spinal cord passes. On either side of this are two small, smooth rounded knobs or **condyles** that **articulate** (move against) the first or Atlas vertebra.

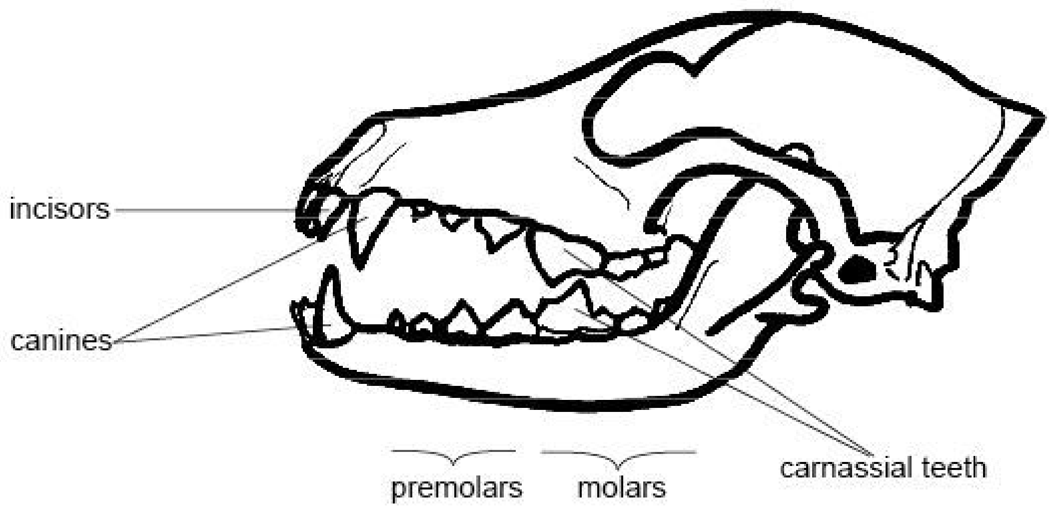

Figure 63

Diagram 6.4 - A dog's skull

6.4 The Rib

Paired ribs are attached to each thoracic vertebra against which they move in breathing. Each rib is attached ventrally either to the **sternum** or to the rib in front by cartilage to form the rib cage that protects the heart and lungs. In dogs one pair of ribs is not attached ventrally at all. They are called **floating ribs** (see diagram 6.5). Birds have a large expanded sternum called the **keel** to which the flight muscles (the 'breast" meat of a roast chicken) are attached.

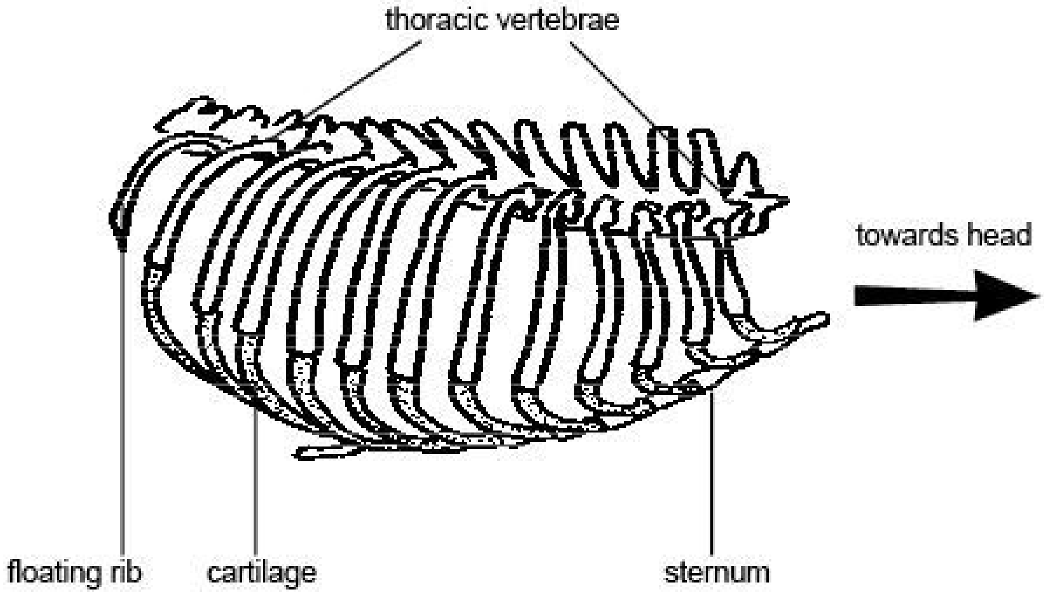

Figure 64

Diagram 6.5 - The rib

6.5 The Forelimb

The forelimb consists of: **Humerus, radius** and **ulna, carpals, metacarpals, digits** or **phalanges** (see diagram 6.6). The top of the humerus moves against (articulates with) the **scapula** at the shoulder joint. By changing the number, size and shape of the various bones, fore limbs have evolved to fit different ways of life. They have become wings for flying in birds and bats, flippers for swimming in whales, seals and porpoises, fast and efficient limbs for running in horses and arms and hands for holding and manipulating in primates (see diagram 6.8).

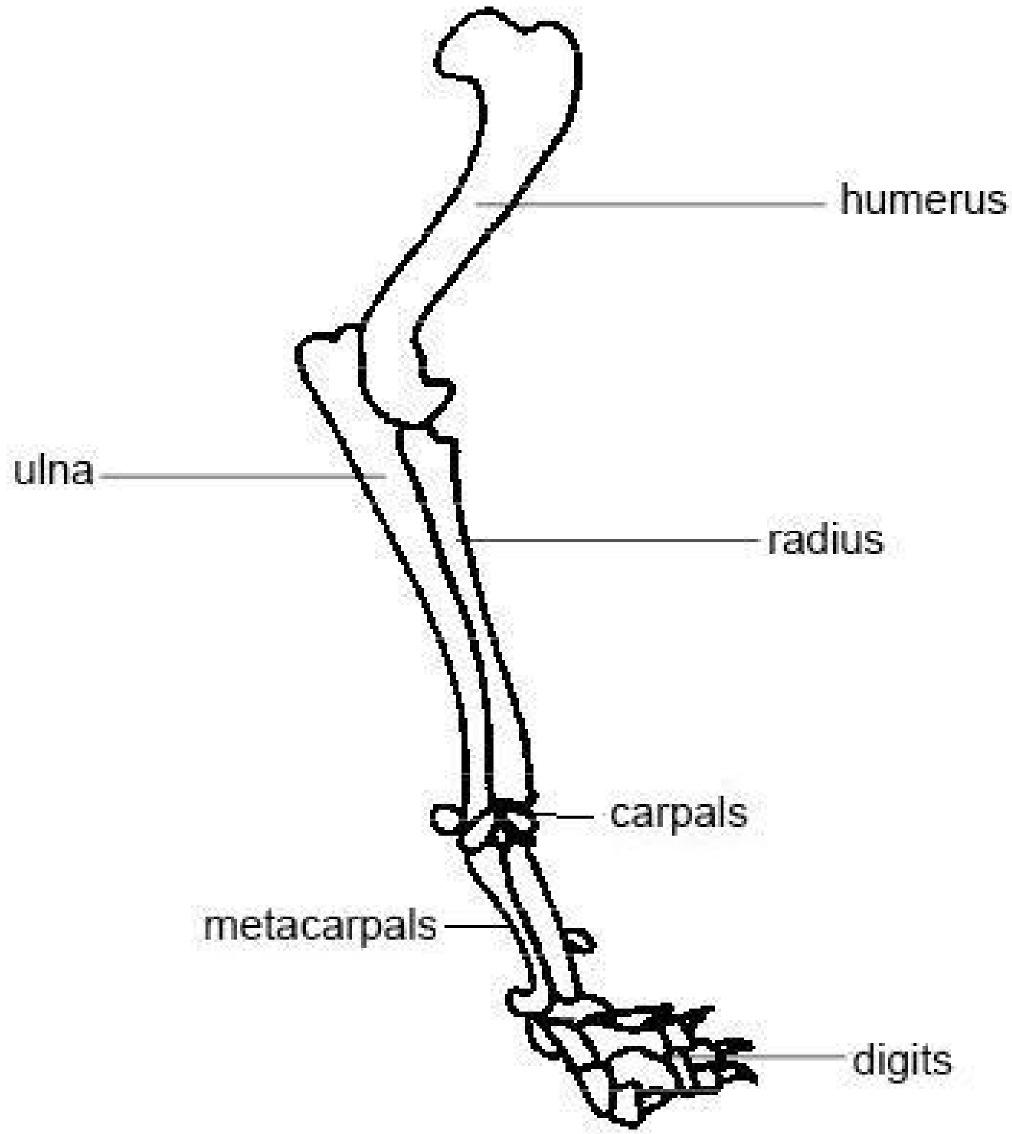

Figure 65

Diagram 6.6 - Forelimb of a dog

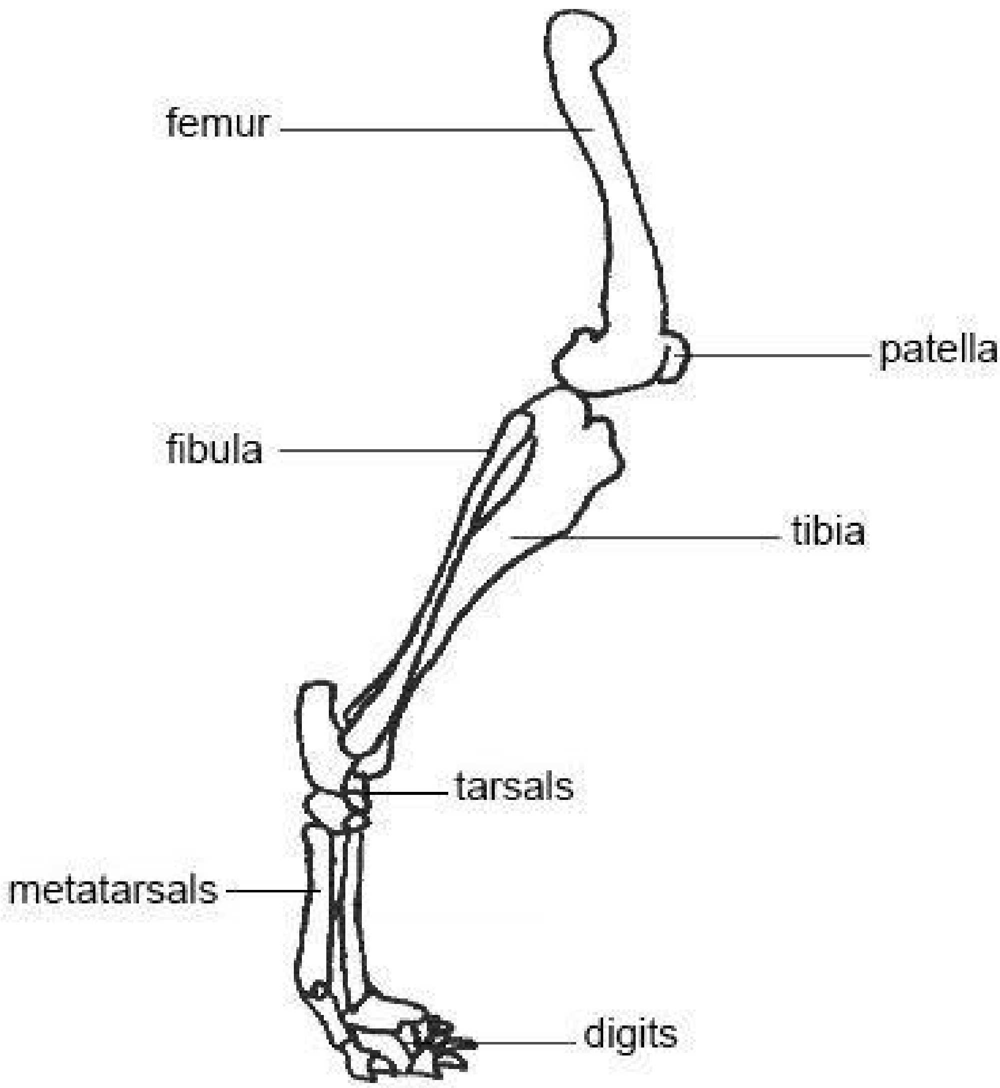

Figure 66

Diagram 6.7. Hindlimb of a dog

6.6 The Hind Limb

The hind limbs have a similar basic pattern to the forelimb. They consist of: **femur, tibia** and **fibula, tarsals, metatarsals, digits** or **phalanges** (see diagram 6.7). The top of the femur moves against (articulates with) the pelvis at the hip joint.

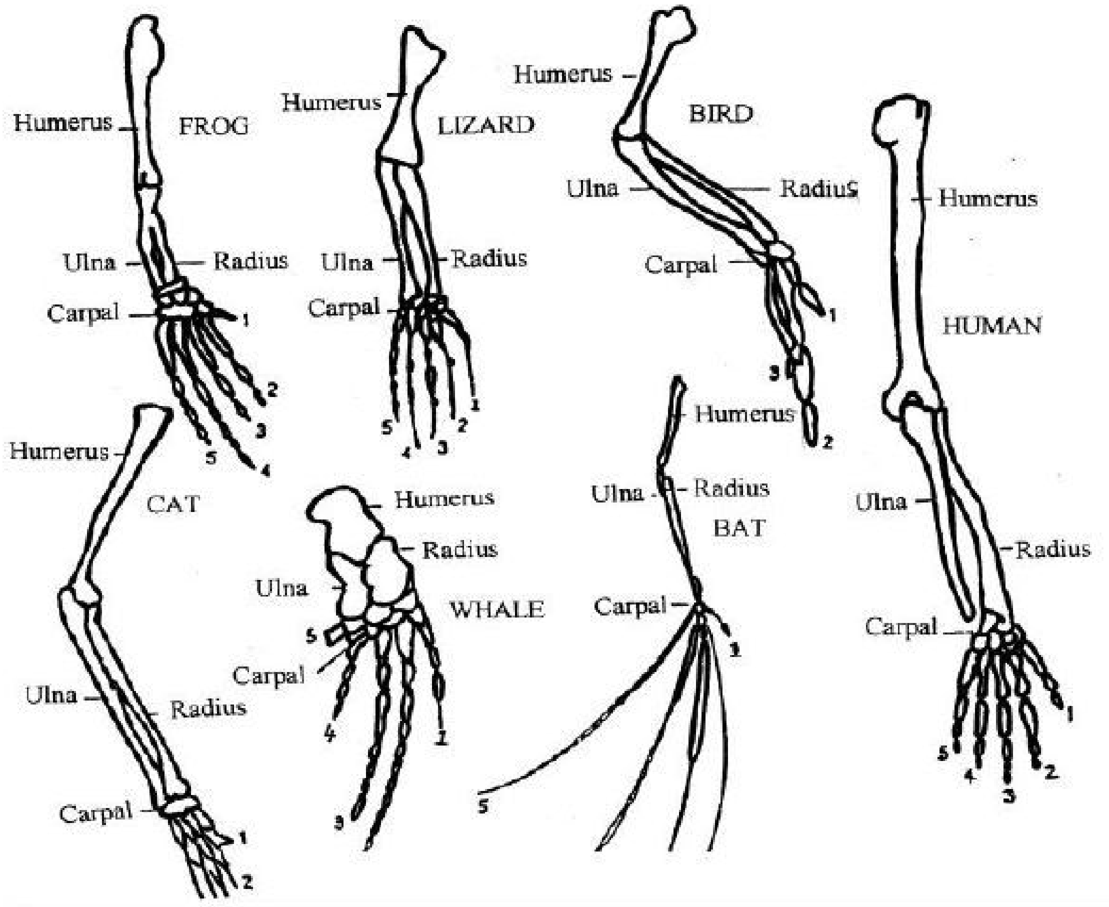

Figure 67

Diagram 6.8 - Various vertebrate limbs

Figure 68

Diagram 6.9 - Forelimb of a horse

This diagram is wrong. The Long pastern or proximal phalanx is P1, not P3. The distal phalanx or coffin bone (called hoof there) is the 3rd phalanges. The **patella** or kneecap is embedded in a large tendon in front of the knee. It seems to smooth the movements of the knee. The legs of the horse are highly adapted to give it great galloping speed over long distances. The bones of the leg, wrist and foot are greatly elongated and the hooves are actually the tips of the third fingers and toes, the other digits having been lost or reduced (see diagram 6.9).

6.7 The Girdles

The girdles pass on the "push" produced by the limbs to the body. The shoulder girdle or **scapula** is a triangle of bone surrounded by the muscles of the back but not connected directly to the spine (see diagram 6.1). This arrangement helps it to cushion the body when landing after a leap and gives the forelimbs the flexibility to manipulate food or strike at prey. Animals that use their forelimbs for grasping, burrowing or climbing have a well-developed **clavicle** or collar bone. This connects the shoulder girdle to the sternum. Animals like sheep, horses and cows that use their forelimbs only for supporting the body and locomotion have no clavicle. The **pelvic girdle** or hipbone attaches the sacrum and the hind legs. It transmits the force of the leg-thrust in walking or jumping directly to the spine (see diagram 6.10).

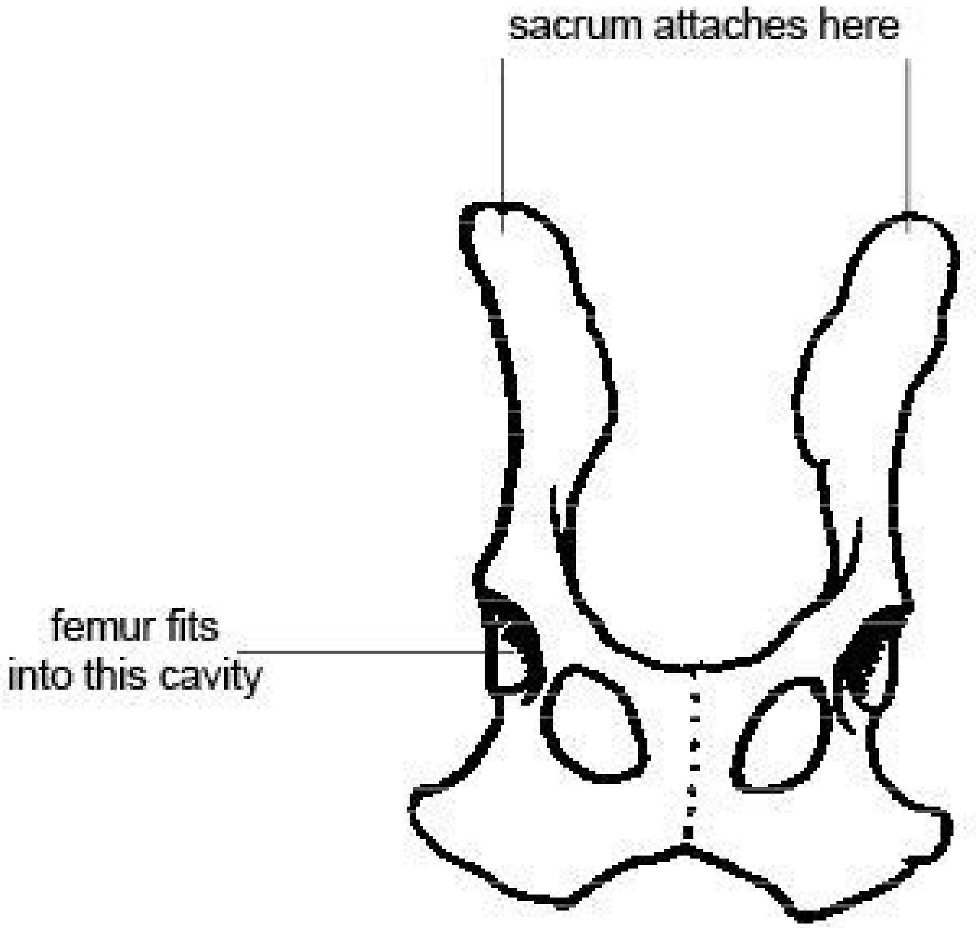

Figure 69

Diagram 6.10 - The pelvic girdle

6.8 Categories Of Bones

People who study skeletons place the different bones of the skeleton into groups according to their shape or the way in which they develop. Thus we have **long bones** like the femur, radius and finger bones, **short bones** like the ones of the wrist and ankle, **irregular bones** like the vertebrae and **flat bones** like the shoulder blade and bones of the skull. Finally there are bones that develop in tissue separated from the main skeleton. These include **sesamoid bones** which include bones like the patella or kneecap that develop in tendons and **visceral bones** that develop in the soft tissue of the penis of the dog and the cow's heart.

6.9 Bird Skeletons

Although the skeleton of birds is made up of the same bones as that of mammals, many are highly adapted for flight. The most noticeable difference is that the bones of the forelimbs are elongated to act as wings. The large flight muscles make up as much as 1/5th of the body weight and are attached to an extension of the sternum called the **keel** . The vertebrae of the lower back are fused to provide the rigidity needed to produce flying movements. There are also many adaptations to reduce the weight of the skeleton. For instance birds have a beak rather than teeth and many of the bones are hollow (see diagram 6.11).

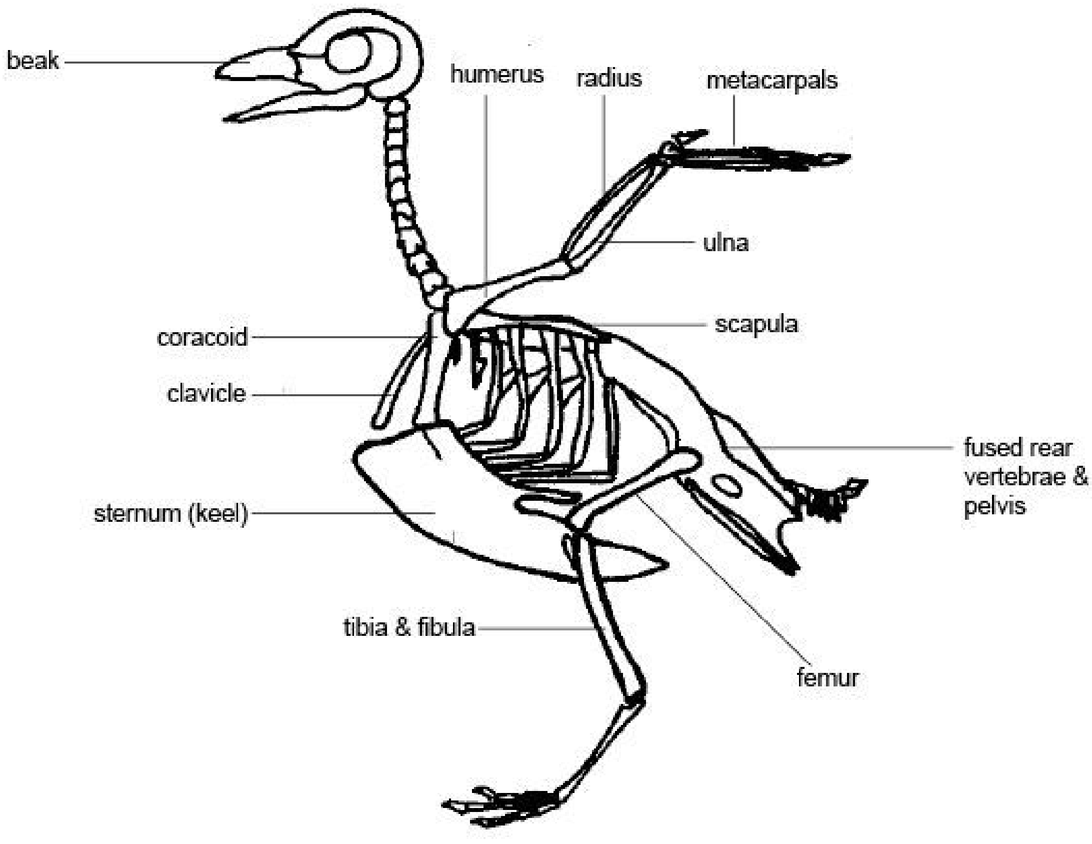

Figure 70

Diagram 6.11 - A bird's skeleton

6.10 The Structure Of Long Bones

A long bone consists of a central portion or **shaft** and two ends called **epiphyses** (see diagram 6.12). Long bones move against or articulate with other bones at joints and their ends have flattened surfaces and rounded protuberances (condyles) to make this possible. If you carefully examine a long bone you may also see raised or rough surfaces. This is where the muscles that move the bones are attached. You will also see holes (a hole is called a **foramen**) in the bone. Blood vessels and nerves pass into the bone through these. You may also be able to see a fine line at each end of the bone. This is called the **growth plate** or **epiphyseal line** and marks the place where increase in length of the bone occurred (see diagram 6.16).

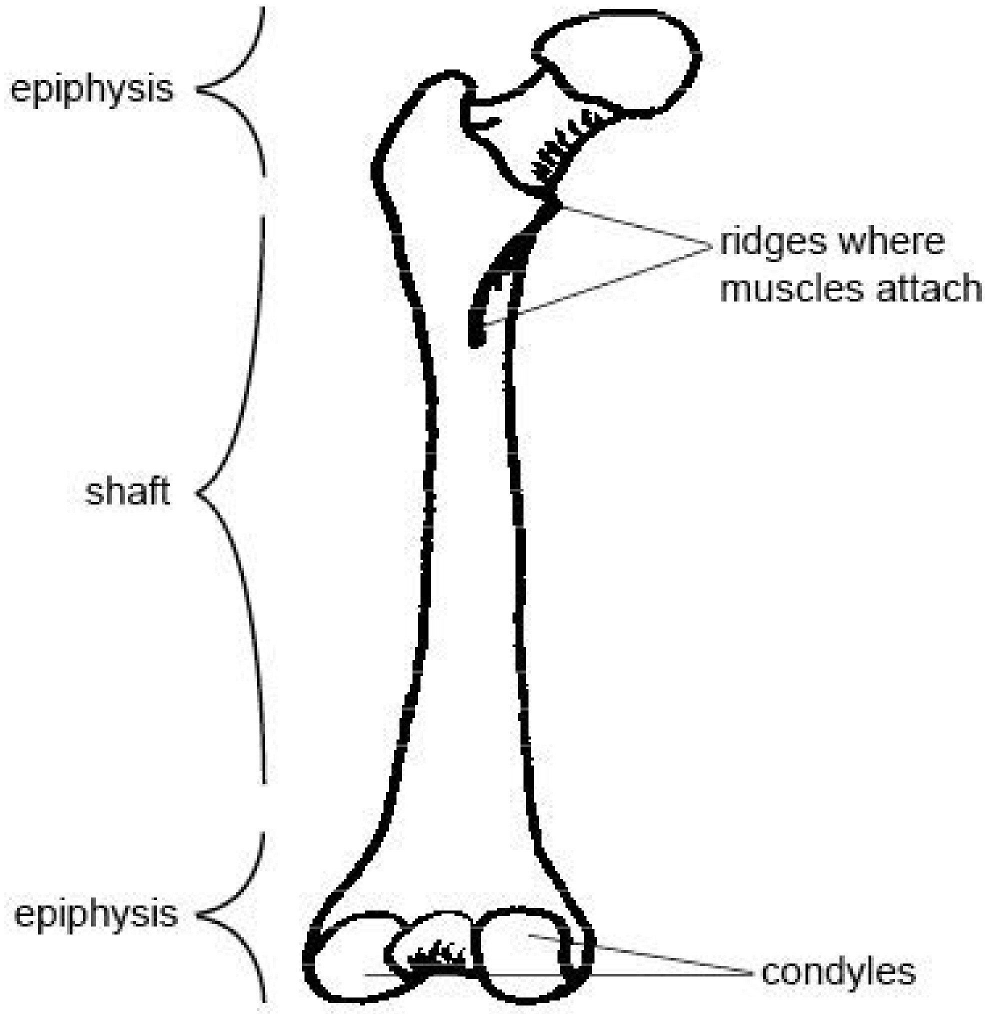

Figure 71

Diagram 6.12 - A femur

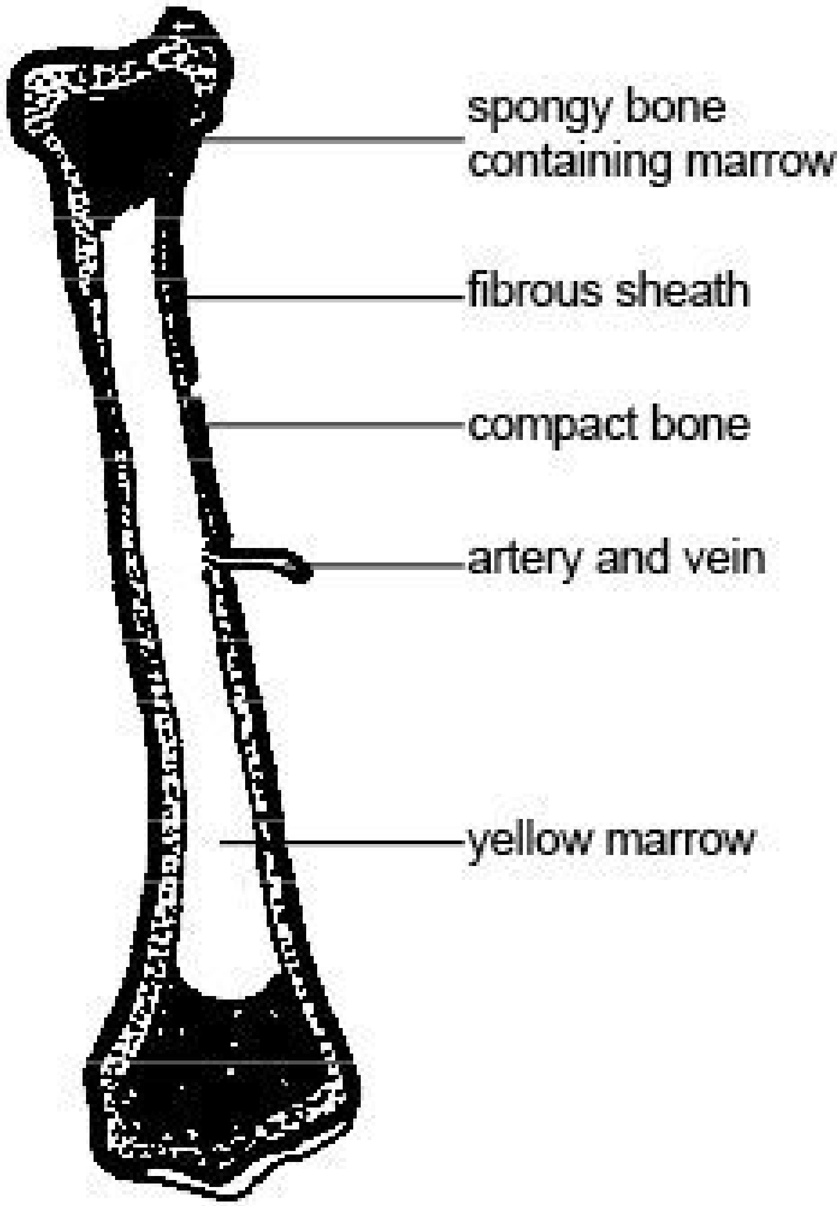

Figure 72

6.13 - A longitudinal section through a long bone

If you cut a long bone lengthways you will see it consists of a hollow cylinder (see diagram 6.13). The outer shell is covered by a tough fibrous sheath to which the tendons are attached. Under this is a layer of hard, dense **compact bone** (see below). This gives the bone its strength. The central cavity contains fatty **yellow marrow** , an important energy store for the body, and the ends are made from honeycomb-like bony material called **spongy bone** (see box below). Spongy bone contains **red marrow** where red blood cells are made.

6.11 Compact Bone

Compact bone is not the lifeless material it may appear at first glance. It is a living dynamic tissue with blood vessels, nerves and living cells that continually rebuild and reshape the bone structure as a result of the stresses, bends and breaks it experiences. Compact bone is composed of microscopic hollow cylinders that run parallel to each other along the length of the bone. Each of these cylinders is called a **Haversian system** . Blood vessels and nerves run along the central canal of each Haversian system. Each system consists of concentric rings of bone material (the **matrix**) with minute spaces in it that hold the bone cells. The hard matrix contains crystals of calcium phosphate, calcium carbonate and magnesium salts with collagen fibres that make the bone stronger and somewhat flexible. Tiny canals connect the cells with each other and their blood supply (see diagram 6.14).

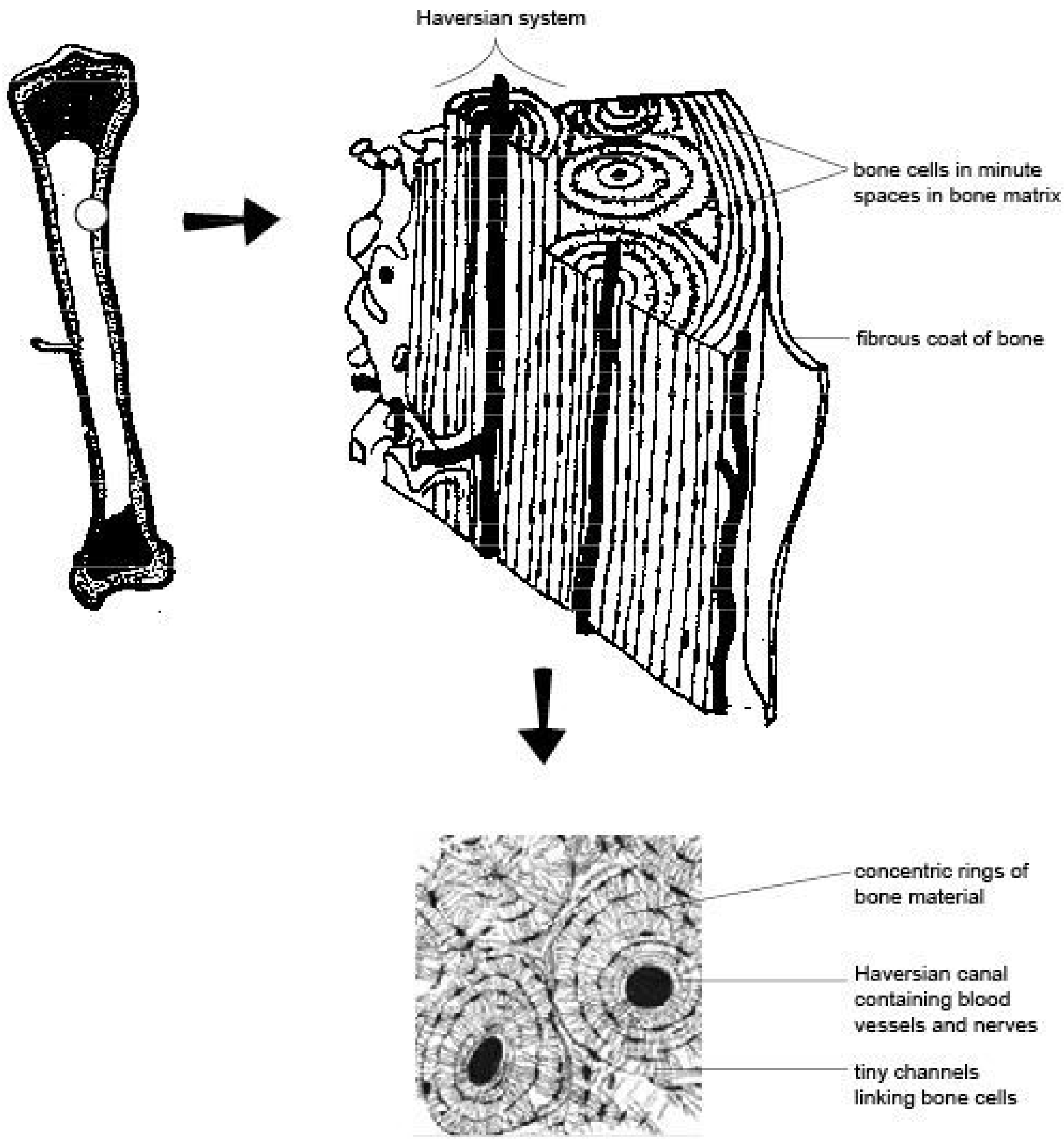

Figure 73

Diagram 6.14 - Haversian systems of compact bone

6.12 Spongy Bone

Spongy bone gives bones lightness with strength. It consists of an irregular lattice that looks just like an old fashioned loofah sponge (see diagram 6.15). It is found on the ends of long bones and makes up most of the bone tissue of the limb girdles, ribs, sternum, vertebrae and skull. The spaces contain red marrow, which is where red blood cells are made and stored.

Figure 74

Diagram 6.15 - Spongy bone

6.13 Bone Growth

The skeleton starts off in the foetus as either cartilage or fibrous connective tissue. Before birth and, sometimes for years after it, the cartilage is gradually replaced by bone. The long bones increase in length at the ends at an area known as the **epiphyseal plate** where new cartilage is laid down and then gradually converted to bone. When an animal is mature, bone growth ceases and the epiphyseal plate converts into a fine **epiphyseal line** (see diagram 6.16).

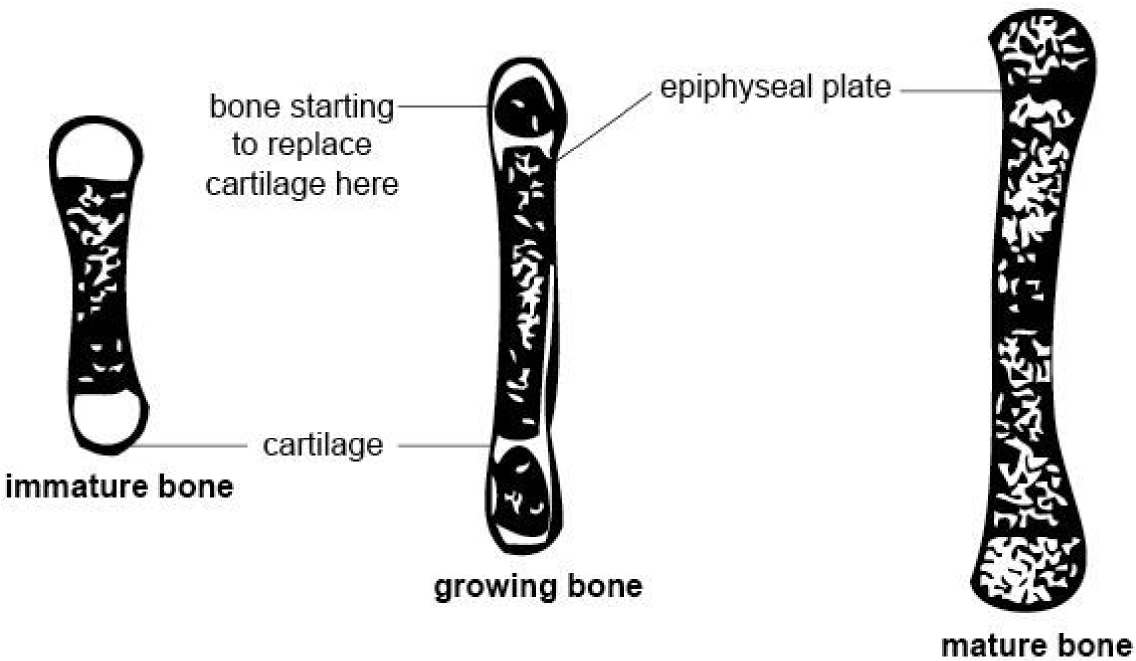

Figure 75

Diagram 6.16 - A growing bone

6.14 Broken Bones

A fracture or break dramatically demonstrates the dynamic nature of bone. Soon after the break occurs blood pours into the site and cartilage is deposited. This starts to connect the broken ends together. Later spongy bone replaces the cartilage, which is itself replaced by compact bone. Partial healing to the point where some weight can be put on the bone can take place in 6 weeks but complete healing may take 3-4 months.

6.15 Joints

Joints are the structures in the skeleton where 2 or more bones meet. There are several different types of joints. Some are **immovable** once the animal has reached maturity. Examples of these are those between the bones of the skull and the midline joint of the pelvic girdle. Some are **slightly moveable** like the joints between the vertebrae but most joints allow free movement and have a typical structure with a fluid filled cavity separating the articulating surfaces (surfaces that move against each other) of the two bones. This kind of joint is called a **synovial joint** (see diagram 6.17). The joint is held together by bundles of white fibrous tissue called **ligaments** and a fibrous **capsule** encloses the joint. The inner layers of this capsule secrete the **synovial fluid** that acts as a lubricant. The articulating surfaces of the bones are covered with **cartilage** that also reduces friction and some joints, e.g. the knee, have a pad of cartilage between the surfaces that articulate with each other.

The shape of the articulating bones in a joint and the arrangement of ligaments determine the kind of movement made by the joint. Some joints only allow a to and from **gliding movement** e.g. between the ankle and wrist bones; the joints at the elbow, knee and fingers are **hinge joints** and allow movement in two dimensions and the axis vertebra **pivots** on the atlas vertebra. **Ball and socket joints** , like those at the shoulder and hip, allow the greatest range of movement.

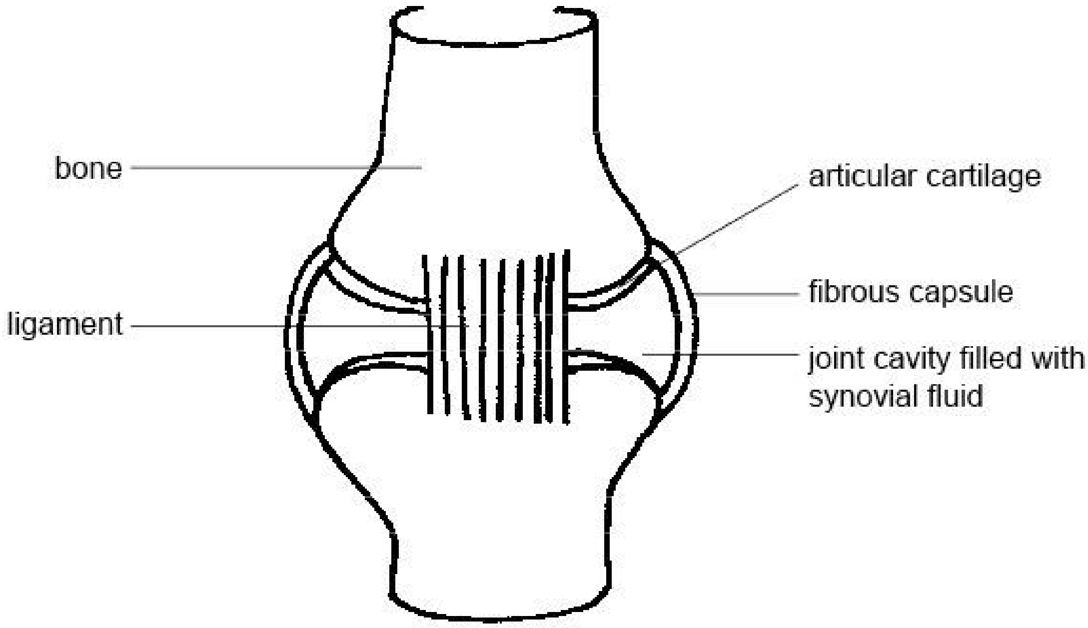

Figure 76

Diagram 6.17 - A synovial joint

6.16 Common Names Of Joints

Some joints in animals are given common names that tend to be confusing. For example:

1. The joint between the femur and the tibia on the hind leg is our knee but the **stifle** in animals.
2. Our ankle joint (between the tarsals and metatarsals) is the **hock** in animals
3. Our knuckle joint (between the metacarpals or metatarsals and the phalanges) is the **fetlock** in the horse.
4. The **"knee"** on the horse is equivalent to our wrist (ie on the front limb between the radius and metacarpals) see diagrams 6.6, 6.7, 6.8, 6.17 and 6.18.

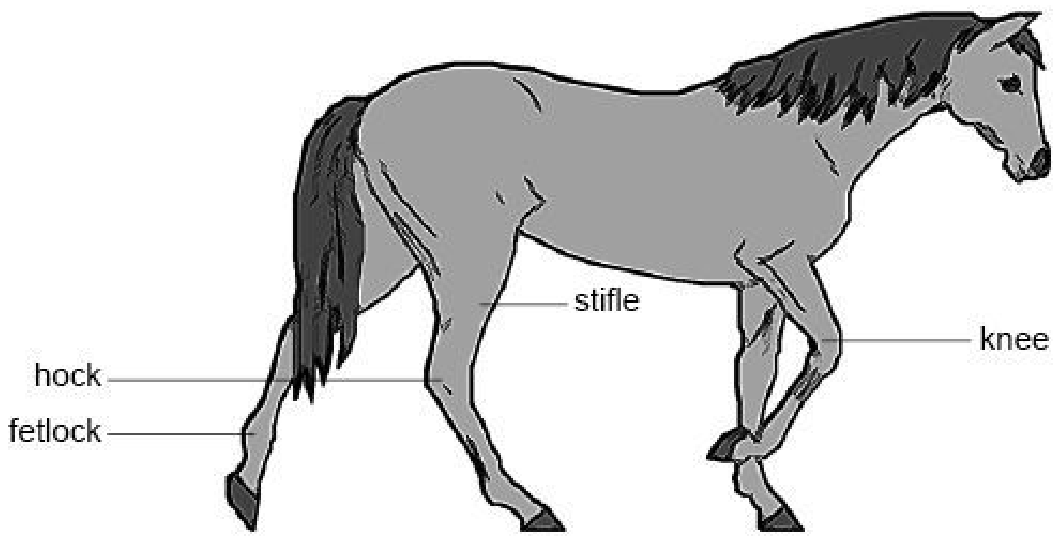

Figure 77

Diagram 6.18 - The names of common joints of a horse

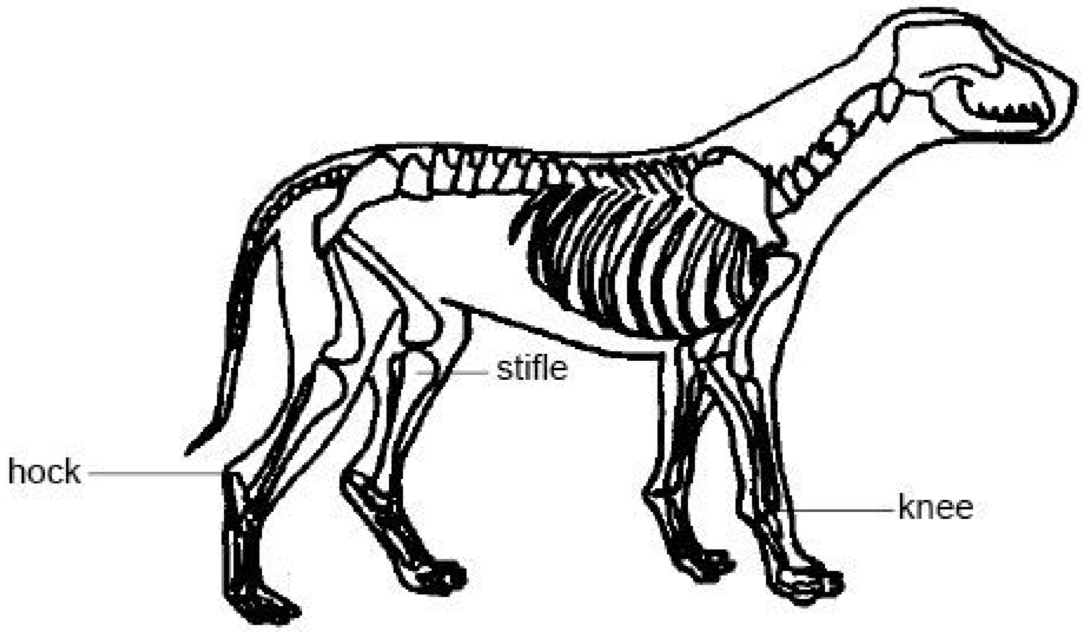

Figure 78

Diagarm 6.19 - The names of common joints of a dog

6.17 Locomotion

Different animals place different parts of the foot or forelimb on the ground when walking or running.

Humans and bears put the whole surface of the foot on the ground when they walk. This is known as **plantigrade locomotion** . Dogs and cats walk on their toes (**digitigrade locomotion**) while horses and pigs walk on their "toenails" or hoofs. This is called **unguligrade locomotion** (see diagram 6.20).

1. **Plantigrade locomotion** (on the "palms of the hand) as in humans and bears
2. **Digitigrade locomotion** (on the "fingers") as in cats and dogs
3. **Unguligrade locomotion** (on the "fingernails") as in horses

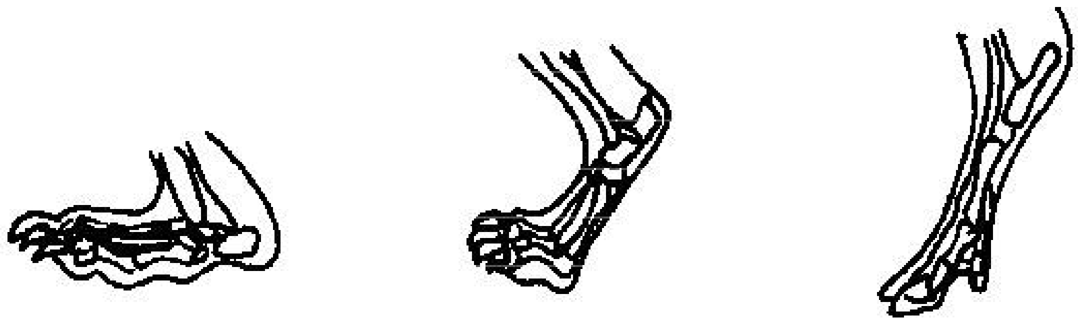

Figure 79

Diagram 6.20 - Locomotion

6.18 Summary

- The skeleton maintains the shape of the body, protects internal organs and makes locomotion possible.
- The **vertebrae** support the body and protect the spinal cord. They consist of: **cervical vertebrae** in the neck, **thoracic vertebrae** in the chest region which articulate with the ribs, **lumbar vertebrae** in the loin region, **sacral vertebrae** fused to the pelvis to form the sacrum and **tail** or **coccygeal vertebrae** .
- The **skull** protects the brain and sense organs. The **cranium** forms a solid box enclosing the brain. The **mandible** forms the jaw.
- The forelimb consists of the **humerus, radius, ulna, carpals, metacarpals** and **phalanges** . It moves against or **articulates** with the **scapula** at the shoulder joint.
- The hindlimb consists of the **femur, patella, tibia, fibula, tarsals, metatarsals** and **digits** . It moves against or articulates with the **pelvis** at the hip joint.
- Bones articulate against each other at **joints** .
- **Compact bone** in the shaft of long bones gives them their strength. **Spongy bone** at the ends reduces weight. Bone growth occurs at the **growth plate** .

6.19 Worksheet

Use the Skeleton Worksheet[1] to learn the main parts of the skeleton.

6.20 Test Yourself

1. Name the bones which move against (articulate with)...

a) the humerus:

b) the thoracic vertebrae:

c) the pelvis:

2. Name the bones in the forelimb:

3. Where is the patella found?

4. Where are the following joints located?

a) The stifle joint:

b) The elbow joint:

c) The hock joint:

d) The hip joint:

5. Attach the following labels to the diagram of the long bone shown below.

a) compact bone

b) spongy bone

c) growth plate

d) fibrous sheath

e) red marrow

f) blood vessel

Figure 80

6. Attach the following labels to the diagram of a joint shown below

a) bone

b) articular cartilage

c) joint cavity

d) capsule

1 http://www.wikieducator.org/Skeleton_Worksheet

e) ligament

f) synovial fluid.

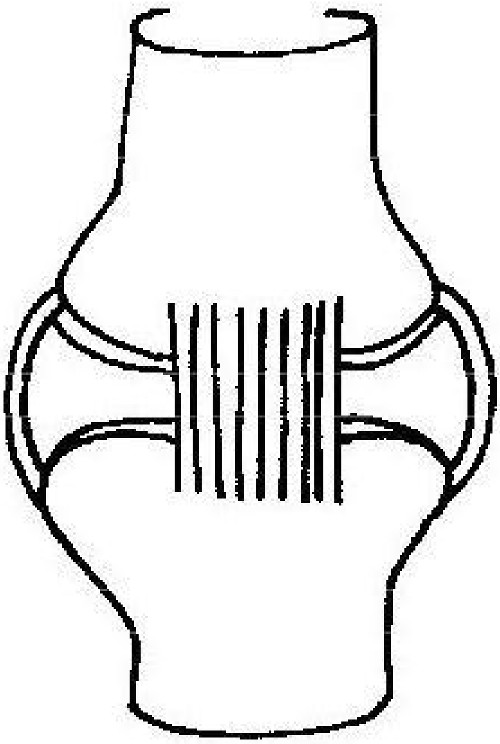

Figure 81

/Test Yourself Answers/[2]

6.21 Websites

- `http://www.infovisual.info/02/056_en.html` Bird skeleton

A good diagram of the bird skeleton.

2 `https://en.wikibooks.org/wiki/%2FTest%20Yourself%20Answers%2F`

- http://www.earthlife.net/mammals/skeleton.html Earth life

A great introduction to the mammalian skeleton. A little above the level required but it has so much interesting information it's worth reading it.

- http://www.klbschool.org.uk/interactive/science/skeleton.htm The human skeleton

Test yourself on the names of the bones of the (human) skeleton.

- http://www.shockfamily.net/skeleton/JOINTS.HTML The joints

Quite a good article on the different kinds of joints with diagrams.

- http://en.wikipedia.org/wiki/Bone Wikipedia

Wikipedia is disappointing where the skeleton is concerned. Most articles stick entirely to the human skeleton or have far too much detail. However this one on compact and spongy bone and the growth of bone is quite good although still much above the level required.

6.22 Glossary

- Link to Glossary[3]

Skeleton[4]

3 http://en.wikibooks.org/wiki/Anatomy_and_Physiology_of_Animals/Glossary
4 https://en.wikibooks.org/wiki/Category%3A

7 Muscles

Figure 82 original image by eclecticblogs[a] cc by

a http://flickr.com/photos/eclecticblogs/96179424/

7.1 Objectives

After completing this section, you should know:

- The structure of smooth, cardiac and skeletal muscle and where they are found.
- What the insertion and origin of a muscle is.
- What flexion and extension of a muscle means.
- That muscles usually operate as antagonistic pairs.
- What tendons attach muscles to bones.

7.2 Muscles

Muscles make up the bulk of an animal's body and account for about half its weight. The meat on the chop or roast is muscle and is composed mainly of protein. The cells that make up muscle tissue are elongated and able to contract to a half or even a third of their length when at rest. There are three different kinds of muscle based on appearance and function: smooth, cardiac and skeletal muscle.

7.2.1 Types of Muscle

- Smooth muscle

Smooth or Involuntary muscle carries out the unconscious routine tasks of the body such as moving food down the digestive system, keeping the eyes in focus and adjusting the diameter of blood vessels. The individual cells are spindle-shaped, being fatter in the middle and tapering off towards the ends with a nucleus in the centre of the cell. They are usually found in sheets and are stimulated by the non-conscious or autonomic nervous system as well as by hormones (see Chapter 3).

- Cardiac muscle

Cardiac muscle is only found in the wall of the heart. It is composed of branching fibres that form a three-dimensional network. When examined under the microscope, a central nucleus and faint stripes or striations can be seen in the cells. Cardiac muscle cells contract spontaneously and rhythmically without outside stimulation, but the sinoatrial node (natural pacemaker) coordinates the heart beat. Nerves and hormones modify this rhythm (see Chapter 3).

- Skeletal muscle

Skeletal muscle is the muscle that is attached to and moves the skeleton, and is under voluntary control. It is composed of elongated cells or fibres lying parallel to each other. Each cell is unusual in that it has several nuclei and when examined under the microscope appears striped or striated. This appearance gives the muscle its names of striped or striated muscle. Each cell of striated muscle contains hundreds, or even thousands, of microscopic fibres each one with its own striped appearance. The stripes are formed by two different sorts of protein that slide over each other making the cell contract (see diagram 7.1).

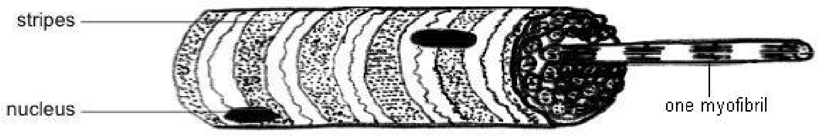

Figure 83

Diagram 7.1 - A striped muscle cell

7.2.2 Muscle contraction

Muscle contraction requires energy and muscle cells have numerous mitochondria. However, only about 15% of the energy released by the mitochondria is used to fuel muscle contraction. The rest is released as heat. This is why exercise increases body temperature and makes animals sweat or pant to rid themselves of this heat.

What we refer to as a muscle is made up of groups of muscle fibres surrounded by connective tissue. The connective tissue sheaths join together at the ends of the muscle to form tough white bands of fibre called **tendons** . These attach the muscles to the bones. Tendons are similar in structure to the **ligaments** that attach bones together across a joint (see diagrams 7.2a and b).

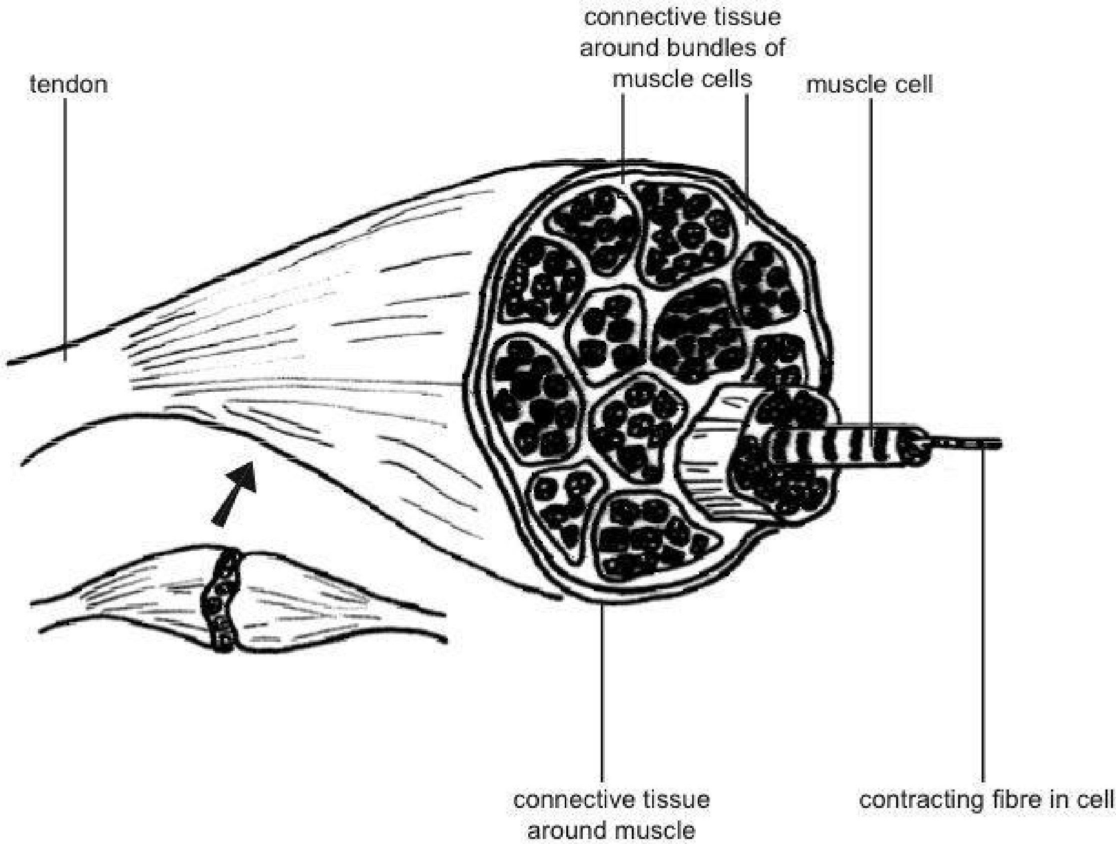

Figure 84

Diagram 7.2 a and b - The structure of a muscle

Remember:

Tendons Tie muscles to bones

and

Ligaments Link bones at joints

7.2.3 Structure of a muscle

A single muscle is fat in the middle and tapers towards the ends. The middle part, which gets fatter when the muscle contracts, is called the **belly** of the muscle. If you contract your biceps muscle in your upper arm you may feel it getting fatter in the middle. You may also notice that the biceps is attached at its top end to bones in your shoulder while at the bottom it is attached to bones in your lower arm. Notice that the bones at only one end move when you contract the biceps. This end of the muscle is called the **insertion** . The other end of the muscle, the **origin** , is attached to the bone that moves the least (see diagram 7.3).

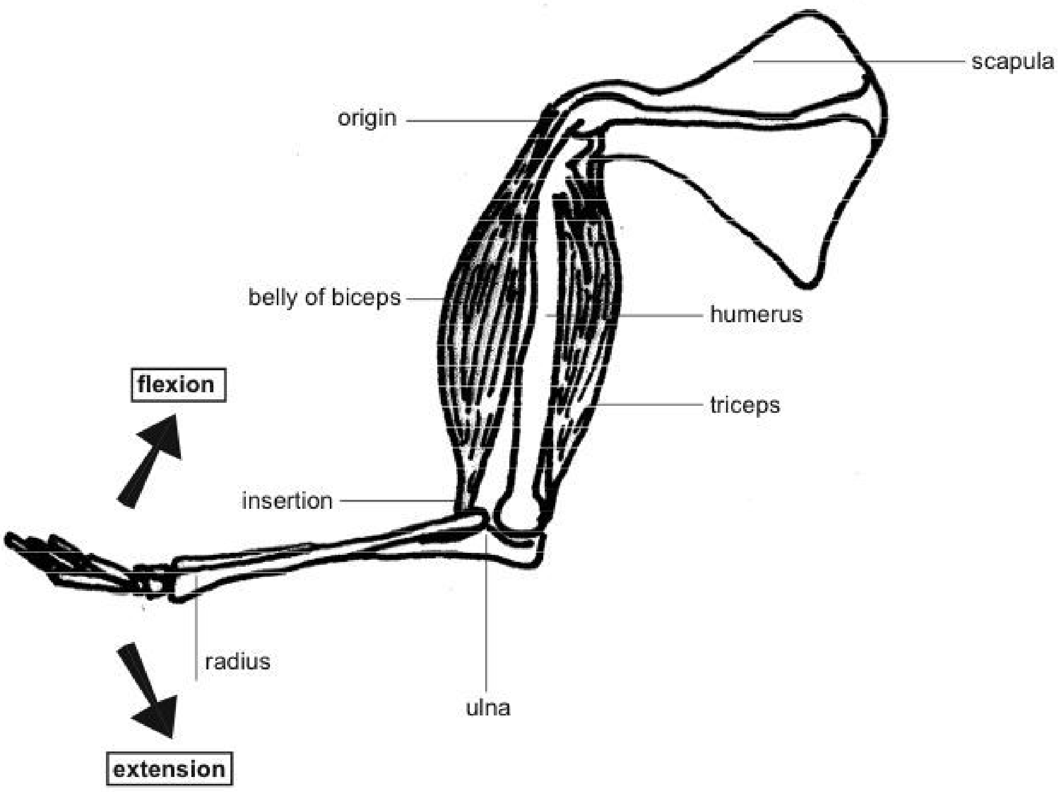

Figure 85

Diagram 7.3 - Antagonistic muscles, flexion and extension

7.2.4 Antagonistic muscles

Skeletal muscles usually work in pairs. When one contracts the other relaxes and vice versa. Pairs of muscles that work like this are called **antagonistic muscles** . For example the muscles in the upper forearm are the biceps and triceps (see diagram 7.3). Together they bend the elbow. When the biceps contracts (and the triceps relaxes) the lower forearm is raised and the angle of the joint is reduced. This kind of movement is called **flexion** . When the triceps is contracted (and the biceps relaxes), the angle of the elbow increases. The term for this movement is **extension** .

When you or animals contract skeletal muscle it is a voluntary action. For example, you make a conscious decision to walk across the room, raise the spoon to your mouth or smile. There is however, another way in which contraction of muscles attached to the skeleton happens that is not under voluntary control. This is during a **reflex action** , such as jerking your hand away from the hot stove you have touched by accident. This is called a **reflex arc** and will be described in detail in chapter 14-15.

7.3 Summary

- There are three different kinds of muscle tissue: **smooth muscle** in the walls of the gut and blood

vessels; **cardiac muscle** in the heart and **skeletal muscle** attached to the skeleton.

- **Tendons** attach skeletal muscles to the skeleton.
- **Ligaments** link bones together at a joint.
- Skeletal muscles work in pairs known as **antagonistic pairs.** As one contracts the other in the

pair relaxes.

- **Flexion** is the movement that reduces the angle of a joint. **Extension** increases the angle

of a joint.

7.4 Test Yourself

1. What kind of muscle tissue:

a) moves bones:

b) makes the heart pump blood:

c) pushes food along the intestine:

d) makes your mouth form a smile:

e) makes the hair stand up when cold:

f) makes the diaphragm contract for breathing in:

2. What structure connects a muscle to a bone?

3. What is the insertion of a muscle?

4. Which muscle is antagonistic to the biceps?

5. Name 3 other antagonistic pairs and tell what they do.

6. When you bend your knee what movement are you making?

7. When you straighten your ankle joint what movement happens?

8. What organelles provide the energy that muscles need?

9. State the difference between a tendon and a ligament.

10.In the section ”Skeletal Muscle” there are 2 proteins mentioned. Name these proteins, state their size difference, and tell what they actually do to help produce movement.

7.5 Website

- http://health.howstuffworks.com/muscle.htm How muscles work

Description of the three types of muscles and how skeletal muscles work.

7.6 Glossary

- Link to Glossary[1]

[2]

1 http://en.wikibooks.org/wiki/Anatomy_and_Physiology_of_Animals/Glossary
2 https://en.wikibooks.org/wiki/Category%3A

8 Cardiovascular System

Figure 86 original image by tuey[a] cc by

a http://flickr.com/photos/tuey/321163599

This chapter on the Cardiovascular system is divided into 3 sections. These are:

1. /Blood/[1]
2. /The Heart/[2]
3. /Blood circulation/[3]

1 https://en.wikibooks.org/wiki/%2FBlood%2F
2 https://en.wikibooks.org/wiki/%2FThe%20Heart%2F
3 https://en.wikibooks.org/wiki/%2FBlood%20circulation%2F

9 Respiratory System

Figure 87 original image by Zofia P[a] cc by

a http://flickr.com/photos/daisy2/661821348/

9.1 Objectives

After completing this section, you should know:

- why animals need energy and how they make it in cells
- why animals require oxygen and need to get rid of carbon dioxide
- what the term gas exchange means
- the structure of alveoli and how oxygen and carbon dioxide pass across their walls
- how oxygen and carbon dioxide are carried in the blood
- the route air takes in the respiratory system (i.e. the nose, pharynx, larynx, trachea, bronchus,

bronchioles, alveoli)

- the movements of the ribs and diaphragm to bring about inspiration
- what tidal volume, minute volume and vital capacity are
- how the rate of breathing is controlled and how this helps regulate the acid-base balance of the blood

9.2 Overview

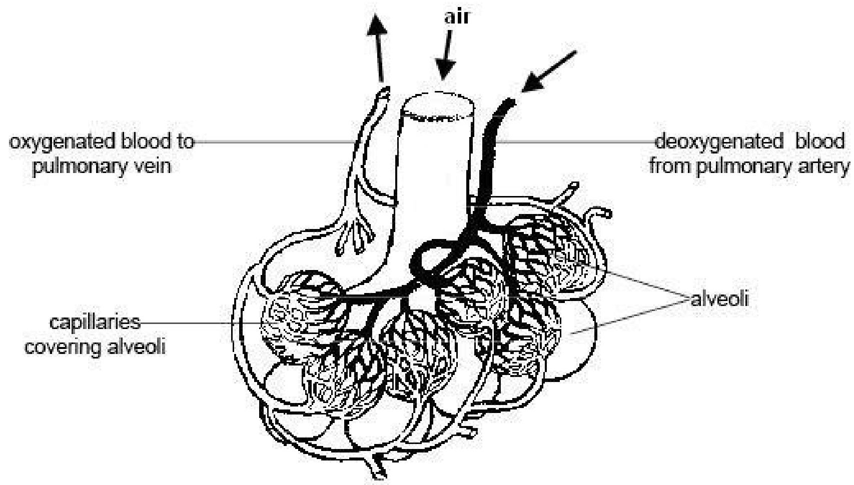

Figure 88 **Diagram 9.1** : Alveoli with blood supply

Animals require a supply of energy to survive. This energy is needed to build large molecules like proteins and glycogen, make the structures in cells, move chemicals through membranes and around cells, contract muscles, transmit nerve impulses and keep the body warm. Animals get their energy from the large molecules that they eat as food. Glucose is often the energy source but it may also come from other carbohydrates, as well as fats and protein. The energy is made by the biochemical process known as **cellular respiration** that takes place in the **mitochondria** inside every living cell.

The overall reaction can be summarised by the word equation given below.

Charbohydrate Food (glucose) + Oxygen = Carbon Dioxide + Water + energy

As you can see from this equation, the cells need to be supplied with **oxygen** and **glucose** and the waste product, **carbon dioxide** , which is poisonous to cells, needs to be removed. The way the digestive system provides the glucose for cellular respiration will be described in Chapter 11 ("The Gut and Digestion"), but here we are only concerned with the two gases, oxygen and carbon dioxide, that are involved in cellular respiration. These gases are carried in the blood to and from the tissues where they are required or produced.

Oxygen enters the body from the air (or water in fish)and carbon dioxide is usually eliminated from the same part of the body. This process is called **gas exchange** . In fish gas exchange occurs in the gills, in land dwelling vertebrates lungs are the gas exchange organs and frogs use gills when they are tadpoles and lungs, the mouth and the skin when adults.

Mammals (and birds) are active and have relatively high body temperatures so they require large amounts of oxygen to provide sufficient energy through cellular respiration. In order to take in enough oxygen and release all the carbon dioxide produced they need a very large surface area over which gas exchange can take place. The many minute air sacs or **alveoli** of the lungs provide this. When you look at these under the microscope they appear rather like bunches of grapes covered with a dense network of fine capillaries (see diagram 9.1). A thin layer of water covers the inner surface of each alveolus. There is only a very small distance -just 2 layers of thin cells - between the air in the alveoli and the blood in the capillaries. The gases pass across this gap by **diffusion** .

9.3 Diffusion And Transport Of Oxygen

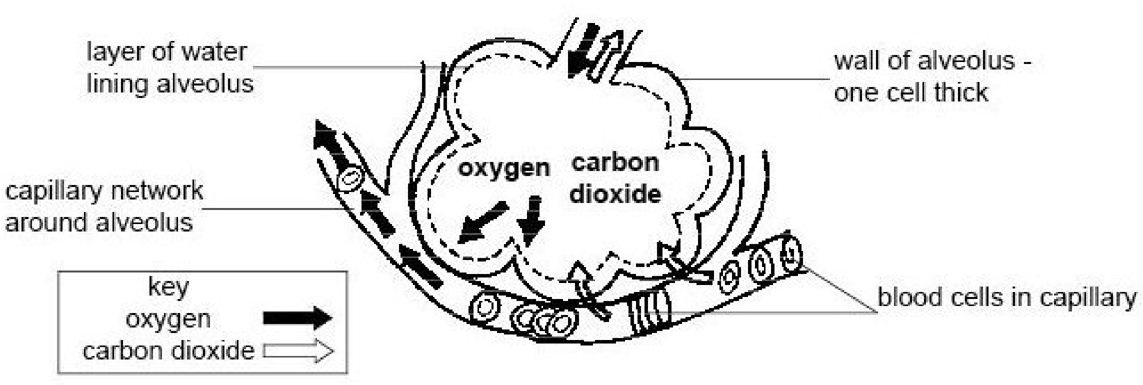

Figure 89 **Diagram 9.2** : Cross section of an alveolus

The air in the alveoli is rich in oxygen while the blood in the capillaries around the alveoli is deoxygenated. This is because the haemoglobin in the red blood cells has released all the oxygen it has been carrying to the cells of the body. Oxygen diffuses from high concentration to low concentration. It therefore crosses the narrow barrier between the alveoli and the capillaries to enter the blood and combine with the haemoglobin in the red blood cells to form **oxyhaemoglobin** .

The narrow diameter of the capillaries around the alveoli means that the blood flow is slowed down and that the red cells are squeezed against the capillary walls. Both of these factors help the oxygen diffuse into the blood (see diagram 9.2).

When the blood reaches the capillaries of the tissues the oxygen splits from the haemoglobin molecule. It then diffuses into the tissue fluid and then into the cells.

9.4 Diffusion And Transport Of Carbon Dioxide

Blood entering the lung capillaries is full of carbon dioxide that it has collected from the tissues. Most of the carbon dioxide is dissolved in the plasma either in the form of **sodium bicarbonate** or **carbonic acid** . A little is transported by the red blood cells. As the blood enters the lungs the carbon dioxide gas diffuses through the capillary and alveoli walls into the water film and then into the alveoli. Finally it is removed from the lungs during breathing out (see diagram 9.2). (See chapter 8 for more information about how oxygen and carbon dioxide are carried in the blood).

9.5 The Air Passages

When air is breathed in it passes from the nose to the alveoli of the lungs down a series of tubes (see diagram 9.3). After entering the nose the air passes through the **nasal cavity** , which is lined with a moist membrane that adds warmth and moisture to the air as it passes. The air then flows through the **pharynx** or throat, a passage that carries both food and air, to the **larynx** where the voice-box is located. Here the passages for food and air separate again. Food must pass into the oesophagus and the air into the windpipe or **trachea** . To prevent food entering this, a small flap of tissue called the **epiglottis** closes the opening during swallowing (see chapter 11). A reflex that inhibits breathing during swallowing also (usually) prevents choking on food.

The trachea is the tube that ducts the air down the throat. Incomplete rings of cartilage in its walls help keep it open even when the neck is bent and head turned. The fact that acrobats and people that tie themselves in knots doing yoga still keep breathing during the most contorted manoeuvres shows how effective this arrangement is. The air passage now divides into the two **bronchi** that take the air to the right and left lungs before dividing into smaller and smaller **bronchioles** that spread throughout the lungs to carry air to the alveoli. Smooth muscles in the walls of the bronchi and bronchioles adjust the diameter of the air passages.

The tissue lining the respiratory passages produces**mucus** and is covered with minute hairs or **cilia.** Any dust that is breathed into the respiratory system immediately gets entangled in the mucous and the cilia move it towards the mouth or nose where it can be coughed up or blown out.

9.6 The Lungs And The Pleural Cavities

Figure 90 **Diagram 9.3** : The respiratory system

The lungs fill most of the chest or **thoracic cavity** , which is completely separated from the abdominal cavity by the **diaphragm** . The lungs and the spaces in which they lie (called the **pleural cavities)** are covered with membranes called the **pleura** . There is a thin film of fluid between the two membranes. This lubricates them as they move over each other during breathing movements.

9.6.1 Collapsed Lungs

The pleural cavities are completely airtight with no connection with the outside and if they are punctured by accident (a broken rib will often do this), air rushes in and the lung collapses. Separating the two lungs is a region of tissue that contains the oesophagus, trachea, aorta, vena cava and lymph nodes. This is called the **mediastinum** . In humans and sheep it separates the cavity completely so that puncturing one pleural cavity leads to the collapse of only one lung. In dogs, however, this separation is incomplete so a puncture results in a complete collapse of both lungs.

9.7 Breathing

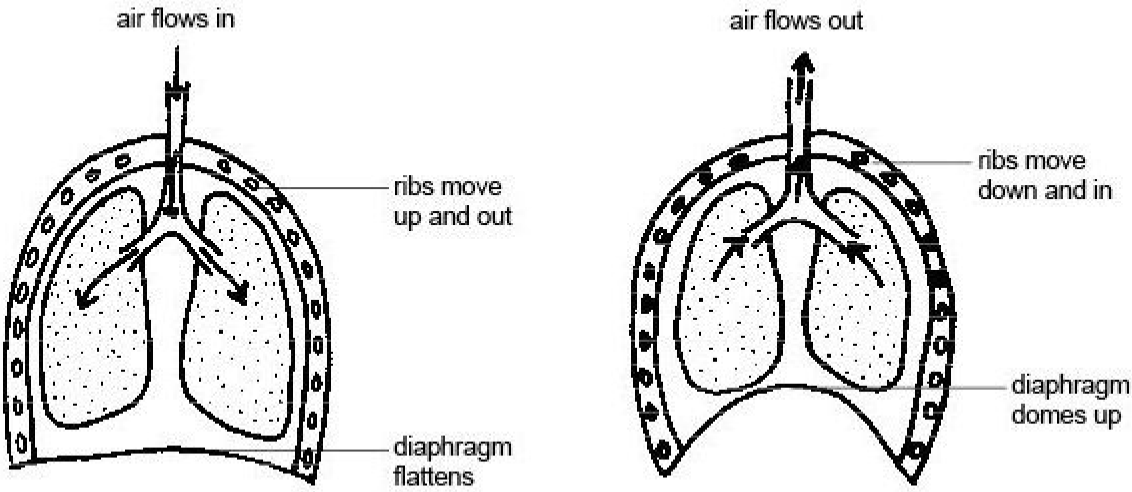

Figure 91 **Diagram 9.4a** : Inspiration; **Diagram 9.4b** : Expiration

The process of breathing moves air in and out of the lungs. Sometimes this process is called **respiration** but it is important not to confuse it with the chemical process, **cellular respiration** , that takes place in the mitochondria of cells. Breathing is brought about by the movement of the diaphragm and the ribs.

9.7.1 Inspiration

The diaphragm is a thin sheet of muscle that completely separates the abdominal and thoracic cavities. When at rest it domes up into the thoracic cavity but during breathing in or **inspiration** it flattens. At the same time special muscles in the chest wall move the ribs forwards and outwards. These movements of both the diaphragm and the ribs cause the volume of the thorax to increase. Because the pleural cavities are airtight, the lungs expand to fill this increased space and air is drawn down the trachea into the lungs (see diagram 9.4a).

9.7.2 Expiration

Expiration or breathing out consists of the opposite movements. The ribs move down and in and the diaphragm resumes its domed shape so the air is expelled (see diagram 9.4b). Expiration is usually passive and no energy is required (unless you are blowing up a balloon).

9.7.3 Lung Volumes

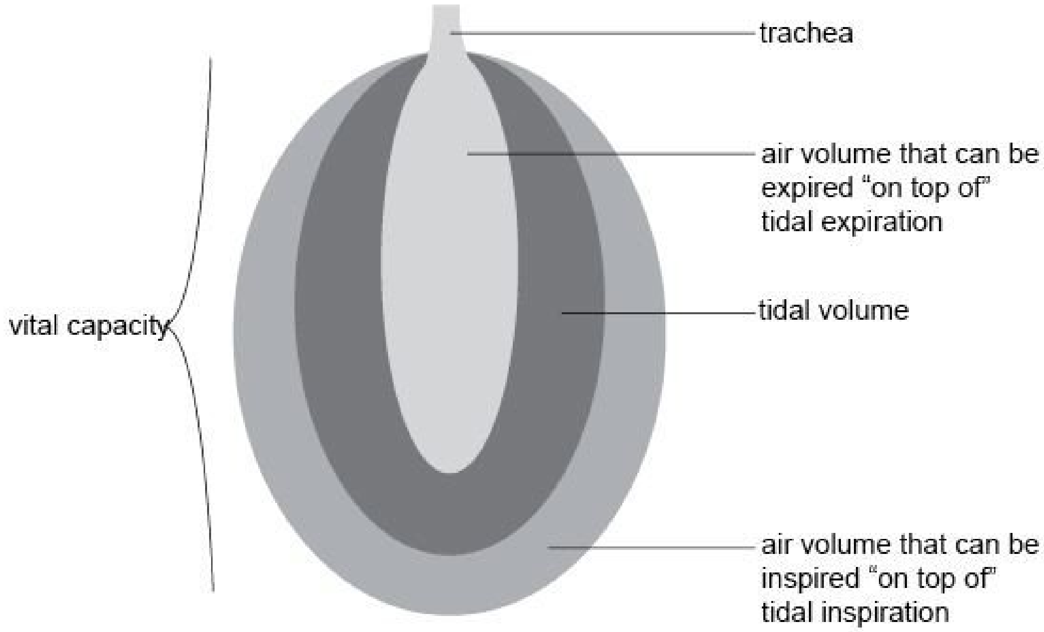

Figure 92 Diagram 9.5 : Lung volumes

As you sit here reading this just pay attention to your breathing. Notice that your in and out breaths are really quite small and gentle (unless you have just rushed here from somewhere else!). Only a small amount of the total volume that your lungs hold is breathed in and out with each breath. This kind of gentle "at rest" breathing is called **tidal breathing** and the volume breathed in or out (they should be the same) is the **tidal volume** (see diagram 9.5). Sometimes people want to measure the volume of air inspired or expired during a minute of this normal breathing. This is called the **minute volume** . It could be estimated by measuring the volume of one tidal breath and then multiplying that by the number of breaths in a minute. Of course it is possible to take a deep breath and breathe in as far as you can and then expire as far as possible. The volume of the air expired when a maximum expiration follows a maximum inspiration is called the **vital capacity** (see diagram 9.5).

9.7.4 Composition Of Air

The air animals breathe in consists of 21% oxygen and 0.04% carbon dioxide. Expelled air consists of 16% oxygen and 4.4% carbon dioxide. This means that the lungs remove only a quarter of the oxygen contained in the air. This is why it is possible to give someone (or an animal) artificial respiration by blowing expired air into their mouth.

Breathing is usually an unconscious activity that takes place whether you are awake or asleep, although, humans at least, can also control it consciously. Two regions in the hindbrain called the **medulla oblongata** and **pons** control the rate of breathing. These are called **respiratory centres** . They respond to the concentration of carbon dioxide in the blood. When this concentration rises during a bout of activity, for example, nerve impulses are automatically sent to the diaphragm and rib muscles that increase the rate and the depth of breathing. Increasing the rate of breathing also increases the amount of oxygen in the blood to meet the needs of this increased activity.

9.7.5 The Acidity Of The Blood And Breathing

The degree of acidity of the blood (the **acid-base balance)** is critical for normal functioning of cells and the body as a whole. For example, blood that is too acidic or alkaline can seriously affect nerve function causing a coma, muscle spasms, convulsions and even death. Carbon dioxide carried in the blood makes the blood acidic and the higher the concentration of carbon dioxide the more acidic it is. This is obviously dangerous so there are various mechanisms in the body that bring the acid-base balance back within the normal range. Breathing is one of these homeostatic mechanisms. By increasing the rate of breathing the animal increases the amount of dissolved carbon dioxide that is expelled from the blood. This reduces the acidity of the blood.

9.7.6 Breathing In Birds

Birds have a unique respiratory system that enables them to respire at the very high rates necessary for flight. The lungs are relatively solid structures that do not change shape and size in the same way as mammalian lungs do. Tubes run through them and connect with a series of air sacs situated in the thoracic and abdominal body cavities and some of the bones. Movements of the ribs and breastbone or sternum expand and compress these air sacs so they act rather like bellows and pump air through the lungs. The evolution of this extremely efficient system of breathing has enabled birds to migrate vast distances and fly at altitudes higher than the summit of Everest.

9.8 Summary

- Animals need to breathe to supply the cells with oxygen and remove the waste product c**arbon dioxide** .
- The lungs are situated in the **pleural cavities** of the **thorax** .
- **Gas exchange** occurs in the **alveoli** of the lungs that provide a large surface area. Here oxygen diffuses from the alveoli into the red blood cells in the capillaries that surround the alveoli. Carbon dioxide, at high concentration in the blood, diffuses into the alveoli to be breathed out.
- **Inspiration** occurs when muscle contraction causes the ribs to move up and out and the diaphragm to flatten. These movements increase the volume of the pleural cavity and draw air down the respiratory system into the lungs.
- The air enters the nasal cavity and passes to the **pharynx** and **larynx** where the **epiglottis** closes the opening to the lungs during swallowing. the air passes down the trachea kept open by rings of cartilage to the **bronchi** and **bronchioles** and then to the alveoli.
- **Expiration** is a passive process requiring no energy as it relies on the relaxation of the muscles and recoil of the elastic tissue of the lungs.

- The rate of breathing is determined by the concentration of carbon dioxide in the blood. As carbon dioxide makes blood acidic, the rate of breathing helps control the **acid/base balance** of the blood.
- The cells lining the respiratory passages produce mucus which traps dust particles, which are wafted into the nose by cilia.

9.9 Worksheet

Work through the Respiratory System Worksheet[1] to learn the main structures of the respiratory system and how they contribute to inspiration and gas exchange.

9.10 Test Yourself

Then use the Test Yourself below to see how much you remember and understand.

1. What is meant by the phrase “gas exchange”?

2. Where does gas exchange take place?

3. What is the process by which oxygen moves from the alveoli into the blood?

4. Why does this process occur?

5. How does the structure of the alveoli make gas exchange efficient?

6. How is oxygen carried in the blood?

7. List the structures that air passes on its way from the nose to the alveoli:

8. What is the function of the mucus and cilia lining the respiratory passages?

9. How do movements of the ribs and diaphragm bring about inspiration? Circle the correct statement below.

a) The diaphragm domes up into the thorax and ribs move in and down

b) The diaphragm flattens and ribs move up and out

c) The diaphragm domes up into the thorax and the ribs move up and out.

d) The diaphragm flattens and the ribs move in and down

10. What is the function of the epiglottis?

11. What controls the rate of breathing?

/Test Yourself Answers/[2]

1 http://www.wikieducator.org/Respiratory_System_Worksheet
2 https://en.wikibooks.org/wiki/%2FTest%20Yourself%20Answers%2F

9.11 Websites

- http://www.biotopics.co.uk/humans/resyst.html Bio topics

A good interactive explanation of breathing and gas exchange in humans with diagrams to label, animations to watch and questions to answer.

- http://www.schoolscience.co.uk/content/4/biology/abpi/asthma/asth3.html School Science

Although this is of the human respiratory system there is a good diagram that gives the functions of the various parts as you move your mouse over it. Also an animation of gas exchange and a quiz to test your understanding of it.

- http://en.wikipedia.org/wiki/Lung Wikipedia

Wikipedia on the lungs. Lots of good information on the human respiratory system with all sorts of links if you are interested.

9.12 Glossary

- Link to Glossary[3]

[4]

3 http://en.wikibooks.org/wiki/Anatomy_and_Physiology_of_Animals/Glossary
4 https://en.wikibooks.org/wiki/Category%3A

10 Lymphatic System

Figure 93 original image by Toms Bauģis [a] cc by

a http://flickr.com/photos/toms/111942949

10.1 Objectives

After completing this section, you should know:

- the function of the lymphatic system
- what the terms tissue fluid, lymph, lymphocyte and lymphatic mean
- how lymph is formed and what is in it
- the basic structure and function of a lymph node and the position of some important lymph nodes in the body
- the route by which lymph circulates in the body and is returned to the blood system
- the location and function of the spleen, thymus and lacteals

10.2 Lymphatic System

When **tissue fluid** enters the small blind-ended **lymphatic capillaries** that form a network between the cells it becomes **lymph** . Lymph is a clear watery fluid that is very similar to blood plasma except that it contains large numbers of white blood cells, mostly **lymphocytes** . It also contains protein, cellular debris, foreign particles and bacteria. Lymph that comes from the intestines also contains many fat globules following the absorption of fat from the digested food into the lymphatics (**lacteals**) of the villi (see chapter 11 for more on these). From the lymph capillaries the lymph flows into larger tubes called **lymphatic vessels.** These carry the lymph back to join the blood circulation (see diagrams 10.1 and 10.2).

Figure 94

Diagram 10.1 - A capillary bed with lymphatic capillaries

10.2.1 Lymphatic vessels

Lymphatic vessels have several similarities to veins. Both are thin walled and return fluid to the right hand side of the heart. The movement of the fluid in both is brought about by the contraction of the muscles that surround them and both have valves to prevent backflow. One important difference is that lymph passes through at least one **lymph node** or gland before it reaches the blood system (see diagram 10.2). These filter out used cell parts, cancer cells and bacteria and help defend the body from infection.

Lymph nodes are of various sizes and shapes and found throughout the body and the more important ones are shown in diagram 10.3. They consist of lymph tissue surrounded by a fibrous sheath. Lymph flows into them through a number of incoming vessels. It then trickles through small channels where white cells called **macrophages** (derived from **monocytes**) remove the bacteria and debris by engulfing and digesting them (see diagram 10.4). The lymph then leaves the lymph nodes through outgoing vessels to continue its journey towards the heart where it rejoins the blood circulation (see diagrams 10.2 and 10.3).

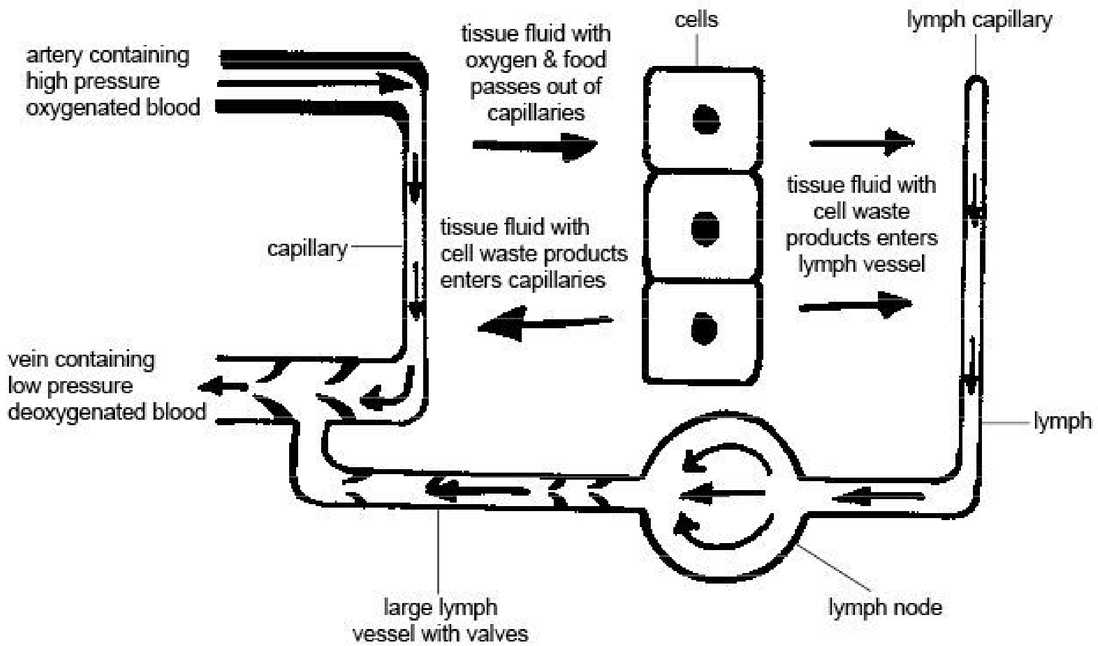

Figure 95

Diagram 10.2 - The lymphatic system

Figure 96

Diagram 10.3 - The circulation of lymph with major lymph nodes