Cells and Tissues

Lesson Aim

To explain the human body at a microscopic level, including the structure and function of cells, tissues and membranes.

THE CELL

All living matter is composed of functional units called cells. At one end of the scale in the animal kingdom, there are unicellular organisms composed of a single cell (e.g. Protozoa or Amoeba). In an amoeba all the vital processes of the animal take place inside a single cell. Cells are capable of digesting food, growing, respiring, excreting, secreting, reproducing and responding to stimuli. All these things happen in a single-celled animal.

At the other end of the scale, there are the multi-cellular organisms such as the higher animals and humans. In these organisms, there is a vast colony of individual cells that have become specialised to perform specific functions. Cells can differ vastly in their shapes and functions; however, they are all fundamentally similar in their chemical make-up, and the way they operate.

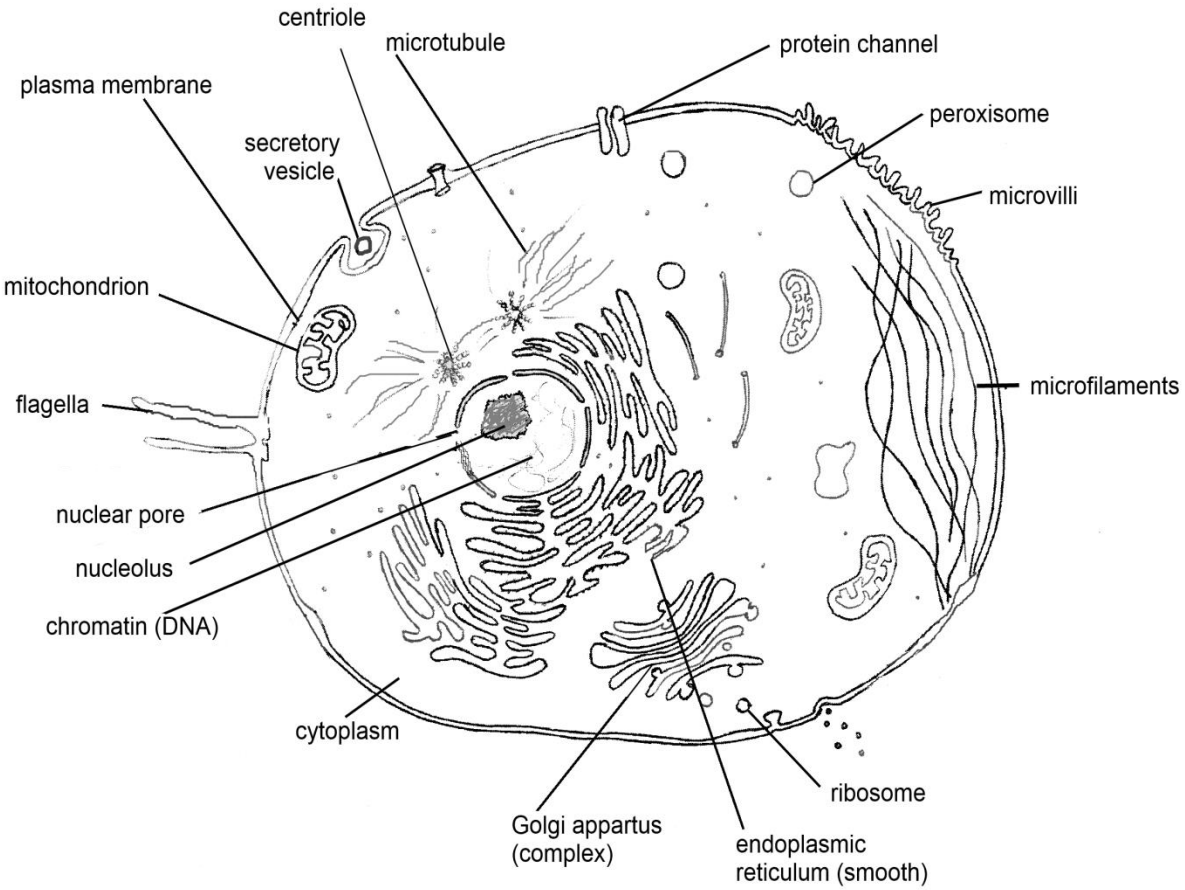
There are two basic types of cells – prokaryotic cells, and eukaryotic cells. **Prokaryotic cells** live as single-celled organisms such as bacteria. Prokaryotic cells do not contain a nucleus but have a cell wall and a plasma membrane surrounding a single compartment that contains the cytoplasm and DNA. Prokaryotic cells reproduce by dividing into two. They are less organised and less dynamic than eukaryotic cells.

Eukaryotic cells are generally bigger and more complex than prokaryotic cells. All multi-cellular organisms are formed from eukaryotic cells (although eukaryotic cells may also live as single-celled organisms). Eukaryotic cells contain a nucleus, as well as a variety of other organelles and structures that perform specialised functions. The various parts of the eukaryotic cell and its functions are: (also see diagram below)

- *Cell membrane*. This is the outer layer of the cell. It gives the cell its shape and holds the liquid inside the cell. It is semi-permeable which means it allows certain things to pass in and out of the cell. The membrane itself is a phospholipid bilayer which means that it is composed of two layers of phosphate and lipid molecules.
- *Nucleus.* This is the part of the cell which holds the genetic material, the chromosomes and chromatin which are concerned with reproduction of the cell. Inside the nucleus is the suborganelle known as the nucleolus, which functions to make and assemble ribosomes.
- *Cytoplasm.* This is the water-based fluid inside the cell which contains salts and other ions and molecules suspended in solution. Within the cytoplasm you will find filaments, proteins, organelles and vesicles.
- *Cytoskeleton.* A network of protein filaments in the cytoplasm that provide a structural framework for the cell, and it is responsible for cell movements.
- *Golgi apparatus.* This is essentially a large folding membrane. It serves as a processing factory within the cell, primarily working on proteins and lipids. It also packages macromolecules for transport to other regions of the cell, or for secretion.
- *Lysosomes.* These organelles contain powerful enzymes known as hydrolases that break down food molecules, old or unwanted organelles and even invading pathogens.
- *Ribosomes.* Ribosomes are tiny, roughly spherical structures attached to the rough endoplasmic reticulum. They are involved in the synthesis of proteins. They also occur free in the cytoplasm.

- *Centriole.* This is concerned with cell division, the reproduction of the cell and the movement of cell chromosomes.
- *Mitochondrion.* Mitochondria (plural of mitochondrion = mitochondria) are concerned with the respiration of the cell. Respiration produces energy for the cell. These are the cell's powerhouses.
- *Endoplasmic reticulum.* Another membrane organelle that associates with the nuclear membrane. Serves a variety of functions, the most important being protein synthesis and folding. Some proteins move on to the Golgi for more modification and final packaging.
- *Peroxisomes.* These organelles contain peroxides that digest lipids and some other foods.
- *Fibrils.* These are concerned with nervous responses.
- *Glycogen.* A complex polymer of glucose that acts as a storage/supply of glucose in the liver and muscle cells.
- *Microfilament.* Protein filaments that give shape, support and movement in non-muscle cells, and form the contractile units of muscle cells.
- *Secretory vesicle.* A tiny sac inside the cell that contain molecules for secretion to the outside environment. These may be waste materials, or hormones, or other molecules with important function outside of the cell that produced them.

Although the cell is very, very small, you can see that it contains many different parts and can carry out an array of functions.



Labelled diagram of a generic eukaryotic (cell with membrane bound organelles)

FROM CELLS TO BODIES

Humans are multi-cellular organisms. The single cells, many of which are specialised so that they can perform a particular function, are grouped together to form tissues. These tissues in turn form special groups called organs (such as the stomach, heart, liver, and so on). The groups of organs make up a system (such as the

respiratory system, reproductive system, cardiovascular system and so on), and the systems join together to form a living body.

HUMAN TISSUES

There are five basic types of tissue found in humans:

- Epithelial tissues
- Connective tissues
- Fluid tissues
- Muscle tissues
- Nervous tissues

Epithelial Tissues

These are formed from cells which join together side by side to form multi-cellular covering layers, for example, the skin covering the body. This type of tissue also forms the covering layers of various organs in the body; the lining of the body cavities and the active parts of the glands of the body. Epithelial tissues are made up of specialised cells of various shapes and are joined in different ways. In some areas they exist in many layers (stratified), and in others there may be just one layer (simple). Epithelial cells form a barrier by keeping some molecules in, and other molecules out. Other functions epithelial cells may carry out include absorbing nutrients, secreting products such as hormones, excreting wastes, receiving sensation, and protecting the interior of the organism from harmful microorganisms.

Connective Tissues

This is the tissue which joins other tissues together. Connective tissues give form and strength to many organs, and often serve for protection and leverage. It can vary vastly, from being hard tissue, such as bone, to being soft like the substance in the eye. In connective tissue, the bulk of the tissue is composed of an extracellular matrix, with cells that produce the matrix interspersed throughout. The tensile strength of the connective tissue is primarily determined by the collagen that makes up the extracellular matrix. Examples of connective tissue are: bones; tendons; ligaments; cartilage and fat.

Fluid Tissues

These tissues transport food nutrients and waste products around the body. Blood is a good example of a fluid tissue; it is also an example of a connective tissue.

Muscle Tissues

Muscle tissue is characterised by its ability to contract when stimulated. The contraction movement is produced when protein filaments actin and myosin slide past each other. There are three types of muscle tissues:

- **Striated or voluntary muscle tissue** which is the type found in your arms and legs and which you can rest as you wish. Skeletal muscle is made up of striated muscle fibres supported by connective tissues attached to bone by tendons or an aponeurosis, and stimulated by nerves. Striated muscle is made up of elongated fibres that has transverse light and dark bands.
- **Smooth or involuntary muscle tissue** works automatically and cannot be controlled by you. Involuntary muscle tissue would be found in the muscle in the intestine which moves food along though the gut.
- **Cardiac muscle tissue** is also involuntary and cannot be controlled by you. This type of muscle tissue is found in the heart.

Muscle tissue is made so that it can expand and contract. You contract (shorten) the muscles of your arm when you pick up a brick and expand (lengthen) them when you stretch out your arm. The involuntary muscles of the body expand and contract on their own (think how your heart beats without your control).

Nervous Tissue

Nervous tissue includes the tissue which makes up the brain, spinal cord and peripheral nerves which transmit messages around the body. The nerve cells which make up this tissue are sensitive to stimuli, such as heat and

touch. They can link up charges and transmit impulses through the nervous system. Nociceptors sense pain, thermoreceptors sense heat and cold, mechanoreceptors sense movement, Meissner's corpuscles sense touch and Pacinian corpuscles sense pressure. Proprioceptors are found in the muscle tissue and sense muscle tension and joint angle.

These are the different types of tissues, but remember that, although they are different from each other because they perform different functions, they are all made up of cells. These cells are the basic units of life. They take in food or nutrients, utilise the nutrients and produce energy and waste products. That is the basic process of living - the breakdown of food into energy and waste products. This process goes on in plants, fungi and animals (including humans) as well as single celled micro-organisms such as bacteria.

CELL DIVISION

Cell growth occurs by a single cell dividing to reproduce two cells. This process can occur by either of two different methods - mitosis or meiosis.

Mitosis is a process involving one parent cell, where the new cells are identical copies of the cell which they came from (i.e. the parent cell). This process is involved in normal growth processes of an organism such as:

- An organism growing bigger throughout its life.
- An organism replacing dead or discarded cells (rejuvenation).

Before the process of mitosis (during the cell cycle) a cell duplicates its DNA. During mitosis the paired chromosomes are separated into opposite ends of the cells, so each half is exactly the same. Two daughter nuclei are formed within the cell encasing the chromosomes. The cytoplasm divides in two, producing two identical daughter cells.

Meiosis is a process of cell division that occurs only in the ovaries and testes for reproduction. Meiosis produces gamete cells (sperm and egg cells), which contain half of the DNA of the parent cell (23 chromosomes) so therefore when the cells come together in fertilisation they form a complete set of 46 chromosomes. The process is similar to mitosis, however in meiosis there is a shuffling process that produces a different genetic combination in each gamete. Also, in meiosis there are four genetically different haploid cells produced (compared to two genetically identical diploid cells in mitosis).

The cell provided by the male and the female undergo meiosis to generate cells with only half the normal DNA complement. When the cells meet during conception the two half sets of DNA are added together in one cell to give a full DNA complement and a cell that has a mix of paternal and maternal genes.

CELL PROCESSES

Cells are enclosed by a semi-permeable membrane. The word permeable means porous or penetrable. Semi-permeable means that the membrane only allows certain things to pass through it. The membrane around cells allows water and other items in solution (i.e. dissolved in water) to pass into or out of the cell.

Some molecules, such as small polar (hydrophilic) molecules (e.g. water) and non-polar (hydrophobic) molecules e.g. oxygen and carbon dioxide, can pass through the cell membrane passively. Passive transport means that the molecules pass through cell membranes without the need for chemical energy. There are different types of passive transport including osmosis, diffusion, facilitated diffusion and filtration.

Other molecules, such as charged ions and large molecules (e.g. proteins and sugars) cannot move passively through the cell membrane but, using chemical energy, can move through pores in the cell membrane, a process known as active transport.

Osmosis and Filtration

OSMOSIS is the process whereby water can pass through a semi-permeable membrane from a weak solution to a stronger solution.

EXAMPLE:

A and B are two liquids separated by a semi-permeable membrane such as a cell wall. Liquid A is a solution of sugar and contains dissolved sugar particles (or molecules as very small particles are called). Liquid B is pure water, which is called distilled water, and this does not contain any dissolved matter at all. The movement which takes place is of water from Solution B through the semi-permeable membrane to Solution A. This causes Solution A to increase in volume and Solution B to decrease in volume. The pressure exerted by this movement is called osmotic pressure**.** As Solution B gets less and Solution A increases, this osmotic pressure will increase until water starts being forced back through the membrane from Solution A to Solution B. This counter pressure is called the FILTRATION pressure.

The movement with osmosis is always of water, from a weak to a stronger solution. If Solution A was a strong sugar solution and Solution B was a weak sugar solution, the water movement would go on until both solutions were of equal strength. At this point, equilibrium is reached.

THE OBJECT OF OSMOSIS IS TO HAVE SOLUTIONS OF EQUAL IONIC STRENGTH ON EACH SIDE OF THE SEMI-PERMEABLE MEMBRANE.

Filtration

Filtration refers to the movement of very small particles of matter, or molecules across a semi permeable cell membrane due to hydrostatic pressure that is where the pressure on one side of the membrane is much greater than the pressure on the other side of the membrane. A good example of this force is the blood pressure of the body which is caused by the heart pumping blood around the system. This causes the pressure inside the capillaries to be higher than that in the surrounding fluid. This higher pressure forces particles through the capillary walls.

Active transport

In contrast to passive transport where substances move across a semi permeable membrane from where they are most concentrated to where they are less concentrated, substances can also move in the opposite direction from where they are less concentrated to where they are more concentrated through a process known as active transport. This movement of particles or molecules across a semi-permeable membrane is against the force exerted by osmotic pressure or hydrostatic pressure and requires energy before it can take place as it overcomes existing forces. It involves large membrane bound protein complexes that use energy to exchange ions against the osmotic or electrochemical gradient.

There are two main types of active transport- exocytosis which involves sending molecules out of the cell and endocytosis which involves sending molecules into a cell. There are two main types of endocytosis- Phagocytosis and Pinocytosis. Phagocytosis comes from the Greek, "phagos" means eat. Phagocytosis is the action of a cell extends its cell membrane out, surrounds a molecule or microorganism, and brings it inside the cell where it can then be digested. With pinocytosis, the molecule attaches itself to the cell membrane. It is then drawn into the body of the cell although it is still surrounded by a part of the cell membrane. The gap is repaired by the cell membrane growing together.

ELECTRO-CHEMICAL GRADIENT

Some substances form ions when they are dissolved in water. An ion is a particle that has become electrically charged. For example, when common salt (which is called sodium chloride - NaCl for short) is dissolved in water it splits into sodium ions (positively charged) and chlorine ions (negatively charged)

Where there are an unequal number of positive and negative ions on either side of a semi-permeable membrane, the ions will move across the membrane until balance is reached. Balance occurs when there are equal numbers of positive and negative ions on either side of the membrane. The movement occurs because the attraction of the positive and negative ions sets up an electrical force.

NUTRIENT AND WASTE EXCHANGE IN CELLS

Having looked at the special properties of cells, we can now consider how nutrients pass from the arteries into the cells and how the waste products pass from the cells into the veins.

Both arteries and veins begin at the heart and spread throughout the body. To begin with, they are large tubes about the width of a little finger. They have thick walls. As they spread out, they divide into branches and get progressively smaller and narrower until finally they become very fine, thread-like tubes called capillaries.

Capillaries have very thin walls. The arterial system and the venous system connect up with each other through these capillaries.

Notice that between the capillaries and the cells to which they carry nutrients, there is a fluid called interstitial fluid. (Interstitial means "intervening space"). This fluid surrounds the cells and capillaries and acts as a connecting link.

The nutrients carried by the arteries pass through the walls of the artery capillaries; travel through the interstitial fluid and pass through the walls of the cells. Waste products pass in a similar way but in the opposite direction! They travel through the cell walls; into the interstitial fluid and through the venous capillary walls.

Although this sounds a simple procedure, it is a complex operation that makes use of all the special properties of cells (such as osmosis, hydrostatic pressure and the electro-chemical gradient).

SET TASK

Research the processes of Mitosis and Meiosis. If possible, search the internet for animations or illustrations of the process, otherwise look at text books or similar. Spend about 30 minutes doing this.