Week 1 Introducing Biomacromolecules….

The Objectives

By the end of this week you should be able to:

- Distinguish between an atom, an element, a molecule, an ion and a compound
- List the elements found in living organisms
- Distinguish between organic and inorganic molecules
- Describe the roles of biologically important inorganic molecules
- Outline the properties of water that are important to life
- Write a hypothesis

Question 15
What are the four main types of macromolecules found in all organism?

Question 16
Where are phospholipids located in a cell?

Question 17
Cholesterol is an important lipid molecule. What is its function?

Question 18
Relate the structure of glycolipids to their function in the cell.

Words that should be in your yellow book.

Plasma membrane, cytoplasm eukaryote, prokaryote, organelle, atom, element, molecule, ion, compound, inorganic compounds, organic compounds, covalent bonds, ionic bonds, polarity, cohesion hydrophobic, hydrophilic pH.

Week 2 Chemical Nature of Cells

The Objectives

By the end of this week you should be able to:

- Describe the basic structures of carbohydrates, proteins, nucleic acids and lipids
- Make a model of a protein

Question 1
Which macromolecules are polymers?

Question 2
Distinguish between autotrophs and heterotrophs in sourcing nutrients to build their macromolecules.

Question 4
Describe the chemical composition of a carbohydrate.

Question 5
What distinguishes the three classes of carbohydrates from each other?

Question 6
Glycogen and starch are called storage polysaccharides. In what organisms would you find?

a) glycogen
b) starch

Question 7
Explain why there are so many different kinds of protein.

Question 8
Where in a protein molecule would you find a hydrophilic amino acid? Explain why some amino acids are hydrophilic.

Question 9
What level of protein structure determines its function?

Question 10
What have you learnt from doing this activity?

Question 11
Explain how your model of a protein is different from the real thing.

Question 12
How could you improve your models?

Question 13

a) Describe, by means of a simple annotated (labels and notes) diagram, the structure of a nucleotide.
b) What distinguishes one nucleotide from another?

Question 14
Where is DNA located in a cell? Describe its function and explain its significance.

Question 14
Describe using an example what is meant by the 'base-pairing' rule.

Question 15
Have a go at the following animation
http://learn.genetics.utah.edu/content/begin/dna/transcribe/
(a) Write down the RNA strand you created
(b) Name the amino acids you created.

Question 16
Draw a table comparing DNA to RNA.

- Macromolecules (polymers) are large organic molecules formed by joining together many smaller molecules.
- The four main types of organic molecules are carbohydrates, lipids, proteins and nucleic acids.
- Carbohydrates are the most abundant organic compounds in nature. Their general formula is $Cn(H_2O)n$. They are grouped into monosaccharides, disaccharides and polysaccharides and have many different properties.
- Proteins are more complex molecules than carbohydrates or lipids, and make up more than 50% of the dry weight of cells. All proteins contain carbon, hydrogen, oxygen and nitrogen; many also contain sulphur, phosphorus and other elements.
- Proteins are chains of amino acids known as polypeptides. The properties of proteins are determined by their shape, which is determined by their amino acid sequence.
- The nucleic acids DNA and RNA are the genetic materials of organisms and they determine inherited features.
- Lipids are non-polar hydrophobic molecules and can form an effective barrier between two watery environments. They have a much smaller proportion of oxygen than carbohydrates, and often contain other elements, such as phosphorus and nitrogen.
- Lipids include fats and oils (important as energy-storing molecules), phospholipids (the important component of cell membranes) and steroids (hormones and vitamins).

Key Terms

Carbohydrate, protein, nucleic acid, lipid, phospholipid, macromolecules, autotroph, heterotroph, chemotroph, polymer, monosaccharide, disaccharide, polysaccharide, glucose, glycogen, amino acids, polypeptide, hydrophilic, hydrophobic, DNA, RNA, nucleotide genes, genome

Week 3 Chemical Nature of Cells

The Objectives

By the end of this week you should be able to:

- Describe the molecular structure of cell membranes.
- Outline the particular role of phospholipids in membranes.
- Describe the different ways that molecules cross membranes.
- Describe the role of the nucleus, ribosomes, endoplasmic reticulum, Golgi apparatus and lysosomes in protein production, handling and export.
- Describe the roles of the endoplasmic reticulum and Golgi apparatus in the synthesis of other biomolecules.
- Make a model of the cell membrane.

Question 1
What are the functions of cell membranes?
Explain why the structure of the membrane can be described as a 'fluid mosaic'?

Question 2
Explain how the following affect the ability of a molecule to pass across a cell membrane:
(a) size
(b) charge (e.g. ions, polar or non-polar)
(c) solubility (e.g. in lipids)

Question 3
Where are the signals for cell to cell recognition located?

Question 4
a) What is meant by the label 'partially permeable' in reference to the plasma membrane?
b) What is the definition of osmosis?

Question 5
Which of the following is an energy-requiring process?

a) osmosis
b) diffusion
c) active transport
d)facilitated diffusion

Question 6
True or false? Briefly explain your choice:

a) A nucleus from a plant cell would be expected to have a nuclear membrane.
b) Bacterial cells do not have any DNA.
c) A mature red blood cell is an example of a prokaryote cell.

Question 7
Suggest why the nucleus is sometimes called 'the control centre' of a cell.

Question 8
Is the major site of ATP production the same in a plant cell as in an animal cell?

Question 9
A scientist wishes to examine ribosomes in pancreatic cells. Where should the scientist look – in the membrane or in the cytoplasm?

Question 10
A substance such as a protein, made in a cell is moved outside the cell. Outline a possible pathway for this substance starting from where it is made to how it leaves the cell.

Question 11
Lysosomes are sometimes called 'suicide bags'. Suggest why this name is given.

Question 12
Next week, in Week 4, you will have to complete a practical exercise for your SAC (School Assessed Coursework). Have you worked out where and how you will complete it and do you have some one to act as your supervisor?

Question 13
In question 10 earlier you answered the following question:

A substance such as a protein, made in a cell is moved outside the cell. Outline a possible pathway for this substance starting from where it is made to how it leaves the cell.

Following are three different responses from three different students to the same question:

i. Protein is made inside the cell, sometimes it is moved outside a cell. These cells have a structure known as the 'Golgi complex'. It consists of several layers of membranes. The Golgi complex packages the proteins into membrane-bound bags, or vesicles for export outside the cell.

ii. A protein would be made in a ribosome, often found in the rough endoplasmic reticulum. From here the protein will be transported to the Golgi apparatus to be 'packaged' in a vesicle. This vesicle will probably merge with the cell membrane (as it is made of the same material) and the protein would be excreted from the cell - the process is called exocytosis.

iii. The ribosome's create a protein, that protein is then moved to the golgi complex through the endoplasmic reticulum, the protein is then packed into a vesicle and is then transported out of the cell.

Read carefully through each of the above responses and then answer the following questions:

a) Which student shows the best understanding of protein production? Why do you think so?

b) Have another look at your answer to question 10. State what changes, if any, you would make to your earlier answer.

c) What else could you do to ensure that you fully understand the protein production pathway?

d) Do you think that this question (question 13) has added to your understanding of protein production?

Key Summary Points Copy these notes into your book.

- *Lipid-soluble substances* of various sizes, such as chloroform and alcohol, are able to simply dissolve into the phospholipid bilayer and pass easily through membranes.
- *Tiny molecules*, such as water and urea, can pass between the phospholipids molecules.
- *Small uncharged molecules*, such as oxygen and carbon dioxide, can also go through the phospholipids bilayer.
- *Large water-soluble substances*, including amino acids and simple sugars, pass through channels made from protein molecules. Protein channels may be selective for particular substances, and they may require the expenditure of energy for transport to occur.
- The plasma membrane forms the boundary of each living cell.
- Several different processes exist whereby substances may cross plasma membranes
- Glycoproteins on plasma membranes are part of a system of 'self' and 'non-self' recognition.
- Cell walls lie outside the plasma membrane of plant, fungal and bacterial cells.
- The nucleus contains the nucleic acid DNA, which is the genetic material within a cell.
- The nucleus of eukaryote cells is enclosed within a nuclear envelope.
- Living cells use energy all the time, principally as chemical energy present in ATP.
- Mitochondria are the major sites of ATP production in eukaryotic cells.
- Prokaryote cells do not have mitochondria.
- Ribosomes are tiny organelles where proteins are produced
- The endoplasmic reticulum (ER) is a series of membrane-bound channels.
- The ER functions in the transport of substances within a cell.
- The Golgi complex packages substances into vesicles for export.
- Lysosomes are membrane-bound sacs containing dissolved digestive enzymes.
- Lysosomes can digest material brought into their sacs.
- Lysosomes play a role in organised cell death.

Key words: These will need to go into your yellow book.

Prokaryotic, eukaryotic, cytosol, organelle, nucleus, endoplasmic reticulum, mitochondria, chloroplasts, lysosome, vacuoles, cytoplasm, phospholipids, cholesterol, diffusion, Osmosis, glycoprotein, glycolipids, hydrophobic, hydrophilic, lipophilic, facilitated diffusion, Active transport, endocytosis, exocytosis, deoxyribonucleic acid, ATP (adenosine triphosphate).

Week 4 Chemical Nature of Cells

Week 5 Chemical Nature of Cells

You should be able to do:

- Describe the ATP/ADP cycle and role of ATP
- Give the general equation for aerobic respiration
- Describe glycolysis, aerobic respiration and fermentation
- Compare anaerobic and aerobic respiration
- Outline the process of photosynthesis, including light-dependent and light- independent (dark) reactions
- Compare the roles of chloroplasts and mitochondria in energy transformations
- Compare products of anaerobic and aerobic respiration in plants and animals

Questions

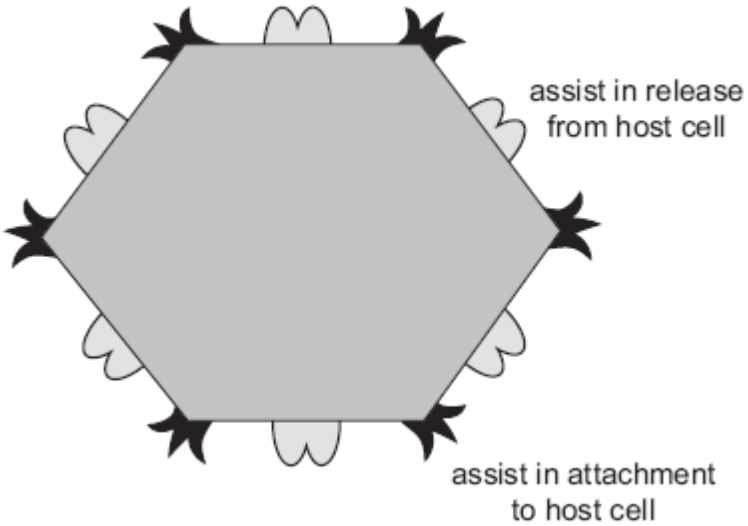
1. Define the term "biotechnology".
2. What is gene therapy?
3. How is gene therapy likely to help diabetics?
4. How are mass produced antibodies used in modern medicine?
5. How is it hypothesised that monoclonal antibodies will help in the treatment of cancer?
6. **6.** What are ribozymes and what substrate do they catalyse?
7. **7.** How does the hammerhead ribozyme work?
8. **8**. The HIV virus is a retrovirus. Why is this important for the use of hammerhead ribozymes in HIV/AIDS therapy?
9. **9.** How are scientists hoping to use synthetic ribozymes in cancer therapy?

- For immediately usable energy, all cells use the chemical energy carried in the terminal phosphate bond of ATP.
- ATP in cells is replenished through the ATP/ADP cycle.
- The energy used to make ATP can be obtained by releasing the chemical energy stored in the bonds of glucose molecules in a series of enzyme-controlled chemical steps generally referred to as cellular respiration.
- Glycolysis takes place in the cytosol and generates two ATP molecules and two molecules of pyruvate per molecule of glucose. It does not require oxygen.
- If no oxygen is available, pyruvate is fermented anaerobically in the cytosol to lactic acid (in animals) or alcohol and carbon dioxide (in plants and micro-organisms), with no ATP produced.
- Lactic acid is recycled back into glucose in the liver when oxygen becomes available again. The amount of oxygen required for this is the oxygen debt.

- Other substrates, such as lipids and proteins, can also enter these cell respiration pathways at various places and be broken down to produce ATP.
- Organisms *obtain* glucose in different ways.
- Autotrophs make glucose by combining carbon dioxide from air with water, using energy from the physical environment.
- Heterotrophs acquire the organic compounds they need, including glucose, by eating other organism or their products.
- Green plants trap light energy and transform it into the chemical energy by the process of photosynthesis.
- Photosynthesis occurs in chloroplasts in two stages:
  - light-dependent reactions occur on the membranes of the chloroplast where chlorophyll traps light energy and uses it to produce ATP and split water into hydrogen ions and oxygen gas.
  - light-independent reactions occur in the fluid matrix of the chloroplasts where ATP from the first stage provides energy to combine carbon dioxide with hydrogen ions (also from the first stage) to form glucose and water.
- C4 and CAM plants show adaptations of the light-independent pathway that was more efficient for plants in the hot dry climates.
- Carbon dioxide levels, light intensity, temperature, and certain other factors affect rates of photosynthesis.
- The main energy storage component in plants is starch, and many seeds store oil.
- Animals have a limited capacity to store carbohydrates (as glycogen). The majority of their energy reserves are stored as fats.
- Radiant energy from the Sun is the ultimate source of virtually all the energy used by living organisms.

Week 6 Applications of Molecular Biology

By the end of this week you should be able to:

- Complete SAC 2 for outcome 1
- Understand the importance of biotechnology in medicine
- Apply your knowledge to new situations
- Investigate the use of biotechnology
- Complete a practice exam
- **1.** What is meant by 'rational drug design'?
-
- **2.** What problems did Australian scientists have to overcome before they
- designed the drug Relenza that was effective against the influenza virus?
-
- **Application question**
- **3.** Scientists aim to develop a drug against a particular virus that infects humans. The virus has a protein coat and different parts of the coat play different roles in the infective cycle. Some sites assist in the attachment of the virus to a host cell, others are important in the release from a host cell. The structure is represented in the following diagram.
- 

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- The virus reproduces by attaching itself to the surface of a host cell and injecting its DNA into the host cell. The viral DNA then uses the components of the host cell to reproduce its parts and hundreds of new viruses bud off from the host cell. Ultimately the host cell dies.
-

- Design a drug that will be effective against the virus shown above. In your answer, outline the important aspects you would need to consider. Outline how your drug would prevent continuation of the cycle of reproduction of the virus particle. Use diagrams in your answer.
-
- **4.** Before a drug is used for human treatment it is usually tested on animals. This is because results for animals often give some indication of how effective a drug may be in humans. In this case the virus under investigation (see above) also infects mice.
-
- **Design** an experiment (**you don't have to actually do it!),** using mice, to test the effectiveness of the drug you have designed. You may wish to revise your understanding of how to carry out a controlled experiment – See the interactive titled 'A Fair Test', found online in the biology course material. See also the background information to Week 4's SAC experiment. Ring your teacher to get further help.
-

Key Summary Points

-
- • Early work in molecular biology involved investigating metabolic pathways and the roles played by proteins and enzymes.
- • Discovery of the structure of DNA in 1953 became a pivotal point for the current and ongoing developments that exist in molecular biology today.
- • Gene therapy is a procedure with the potential to correct some genetic defects.
- • Gene therapy involves inserting a functional piece of DNA into the cells of an individual with a genetic defect.
- • Virus vectors are commonly used to carry DNA into other cells.
- • Different genetic conditions can develop at different ages in individuals.
- • Tests exist to distinguish functional from non-functional segments of DNA in an individual.
- • In these tests, the DNA of one individual is often compared with the DNA of other family members.
- • If we understand the mechanism by which an infective organism or agent causes disease, we may be able to design a drug to prevent it occurring.
- • One of the proteins, an enzyme, on the outer layer of the influenza virus has a non-variable active site that is important for the continuation of their life cycle.
- • Vaccinations contain antigens from disease-causing organisms that stimulate the immune system to develop antibodies for future protection from the disease.
- • It is difficult to make vaccines against some parasites because of the complexity of the life cycle and knowing which of their antigens are most important in their disease-causing capacity.

Week 7 Coordination and Regulation

THE OBJECTIVES

By the end of this week you should have completed the SAC (School Assessed Coursework) practical activity.

You should also be able to:

- define homeostasis
- list the types at signals and cues that organisms can detect and respond to
- describe two ways that hormone signals are received and transduced by receptors
- draw a stimulus-response model
- give the difference between positive and negative feedback
- explain the different roles of nerves and hormones in communicating messages to bring about appropriate responses.

1. Using an example of an external signal, draw a flow chart to illustrate the five principles of cell communication.

2. What is homeostasis and why is it important?

3. What is the role of the nervous system?

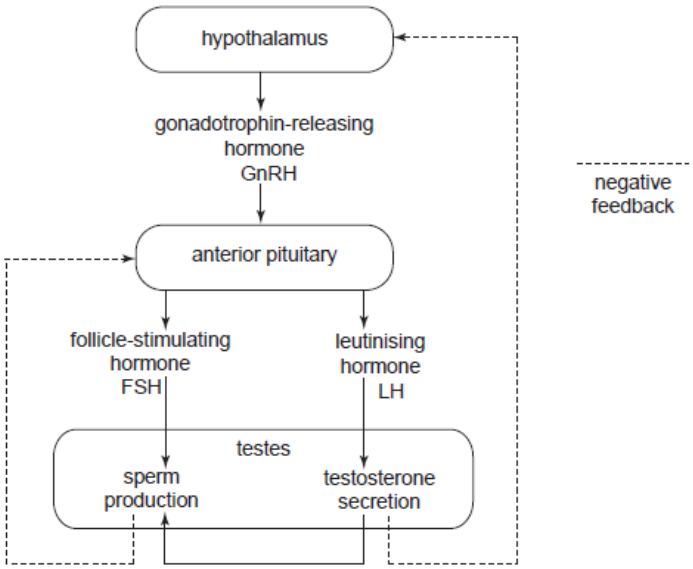
4. What is the role of the hormonal (endocrine) system?

5. How are positive and negative feedback different? Why is positive feedback not associated with homeostasis?

6. By means of labelled diagrams, compare a stimulus-response model with a negative feedback model. Give one named example of each kind of model.

7. Draw a stimulus-response model to illustrate how the principles of communication can be applied at a cellular level.

8. The following diagram outlines the hormonal control of the testes.



Key Summary Points

- Living organisms survive, grow and reproduce because they are able to detect and respond to environmental changes
- Both internal and external environmental factors act as stimuli for animals in the maintenance of homeostasis.
- Communication between cells is usually chemical in nature, involving signalling molecules such as neurotransmitters and hormones.
- Signalling molecules act only on target cells, which are cells that have the appropriate receptor molecules.
- Receptors are specialised molecules capable of receiving and responding to specific stimuli, such as signalling molecules, or other environmental stimuli.
- Signal transduction refers to the ways that receptors convert incoming signals into information in a form that leads to an appropriately coordinated response.
- The way that a cell 'reads' a hormonal message depends on the structure of the hormone molecule; in particular, whether the hormone can pass through the cell membrane or not.

1. What is a signalling molecule?
2. What are the 2 main types of hormones? What similarities are there in their mode of action?
3. Two students had a disagreement. One said that nerves acted electrically but hormones acted chemically. The other claimed that both acted chemically. How would you respond to these claims? Explain.
4. Draw a flow diagram to illustrate the sequence of events that occurs when blood glucose levels rise after drinking a can of cola. Include details of how the signal of the hormone(s) involved is relayed through the target cells.
5. Construct a table summarising the effects of prostaglandins in the body.

6. Draw an annotated diagram to show the events occurring at the synapse of a neuron junction. Identify the substances involved at the synapse. Identify the effect of nerve poisons on these.
7. Give one example of a pheromone and explain how it benefits one organism.

Week 8 Coordination and Regulation

By the end of this week you should be able to:

- Explain what a signalling molecule is.
- Describe examples of the chemical factors and signalling molecules to which organisms respond.
- Explain the differing roles of nerves and hormones in communicating messages to bring about appropriate responses.
- Give some examples of illness and disease due to disruption of detection and signalling pathways.
- Explain how plant regulation pathways differ from those in animals.
- List the environmental factors to which plants respond.
- Describe the types and roles of plant growth regulators (hormones).

1. What is the difference between phototropism and geotropism?

2. Why do plant cells need to communicate?

3. What is a plant growth regulator? List five plant growth regulators. See the five plant hormones given in the animation section of the online biology course environment.

4. The fruits available to us at supermarkets are often out of season in our local area. We rely on having them transported long distances, often from as far away as Queensland. For example, apples may have been harvested many weeks, even months ago, yet they appear fresh and ripe on supermarket shelves. Use your knowledge of "ripening hormones" and a little research to find out how such fruits are managed between picking and purchasing. (Hint: When are they harvested? In what kind of environment are they stored? For how long? How can fruit merchants ensure their fruits are ripe at the time of sale to supermarkets?)

- Many complex animals use a variety of chemical and electrical signals in a communication network involving two systems - the nervous system and the endocrine system. These systems are integrally related.
- Signalling molecules are chemicals that are released by cells such as neurotransmitters and hormones.
- Most of the chemical signals produced by animal cells are hormones
- There are two main types of hormones - steroid hormones and amino acid and polypeptide-based hormones.
- Hormones travel throughout the body via the bloodstream.

- Hormones bind to specific receptor proteins found only in target cells.
- Integrated responses to environmental change usually involve a large amount of sensory information received from different parts of the body.
- Glands in the endocrine system secrete hormones which are important in homeostasis, such as regulating blood glucose levels in the bloodstream, in growth and development and many other processes.
- The nervous system is composed of specialised cells called neurons, which are organised in the central nervous system (CNS) - the brain and spinal cord- and the peripheral nervous system - which extends out to the rest of the body. The CNS coordinates the information received from stimuli and coordinates the best response.
- Neurones transmit messages between receptor organs effector organs and the CNS in the form of electrical impulses.
- A neurotransmitter is a chemical substance that can control and coordinate responses.
- Many physiological disorders can be attributed to a breakdown at some stage in these regulatory mechanisms and some novel technologies are being developed to treat them.
- Pheromones are chemicals emitted by living organisms to send messages to individuals of the same species.
- Plants have no nervous system; internal coordination is controlled by hormones (or growth regulators)
- Plant growth and reproduction are synchronised with seasonal changes, and with local physical and climatic conditions. Plants also respond to light, gravity and temperature.
- Plants are sensitive to a number of environmental factors, both physical and chemical, that contribute to hormonal regulation.
- Directionality is often an important aspect in plant sensing and responding, particularly of light (phototropism) and gravity (geotropism).
- Photoperiodism is a plant's ability to measure seasonal changes by the length of day and night. Short -day plants require long nights to trigger flowering. Long-day plants flower if the nights are short or if the plants are continuously illuminated.
- Many commercially available synthetic substances that mimic natural plant hormones have been developed to control the development and growth of plants.

Week 9 Detecting 'Self' and 'Non-self'

By the end of this week you should be able to:

- Explain the difference between pathogenicity and virulence
- Understand the difference between non-cellular and cellular agents
- Distinguish between a fungal and a bacterial pathogen
- Understand how pathogens may be transmitted to a new host
- Explain why it is important to understand the life cycle of parasites
- Create a visual summary of the main points covered in this week.

Questions

2. Define the term disease.

3. What is the difference between an infectious disease and a non-infectious disease? Give an example of each.

4. Explain the difference between pathogenicity and virulence.

5. Use the following terms in their correct order to construct a flow chart to summarise the events in the disease process: recovery, infection, symptoms, incubation, immune system is activated, death, immune system overwhelmed, medical treatment.

6. Explain why viruses target specific host cells.

7. What is one structural difference between a virus and a viroid?

8. What is the unique feature of a prion that distinguishes it from other non-cellular infectious agents?

9. List three ways that a bacterial pathogen could cause harm to its host.

10. Bacteria that have a capsule are often more virulent. Explain.

11. What methods can be used to identify different strains of bacteria?

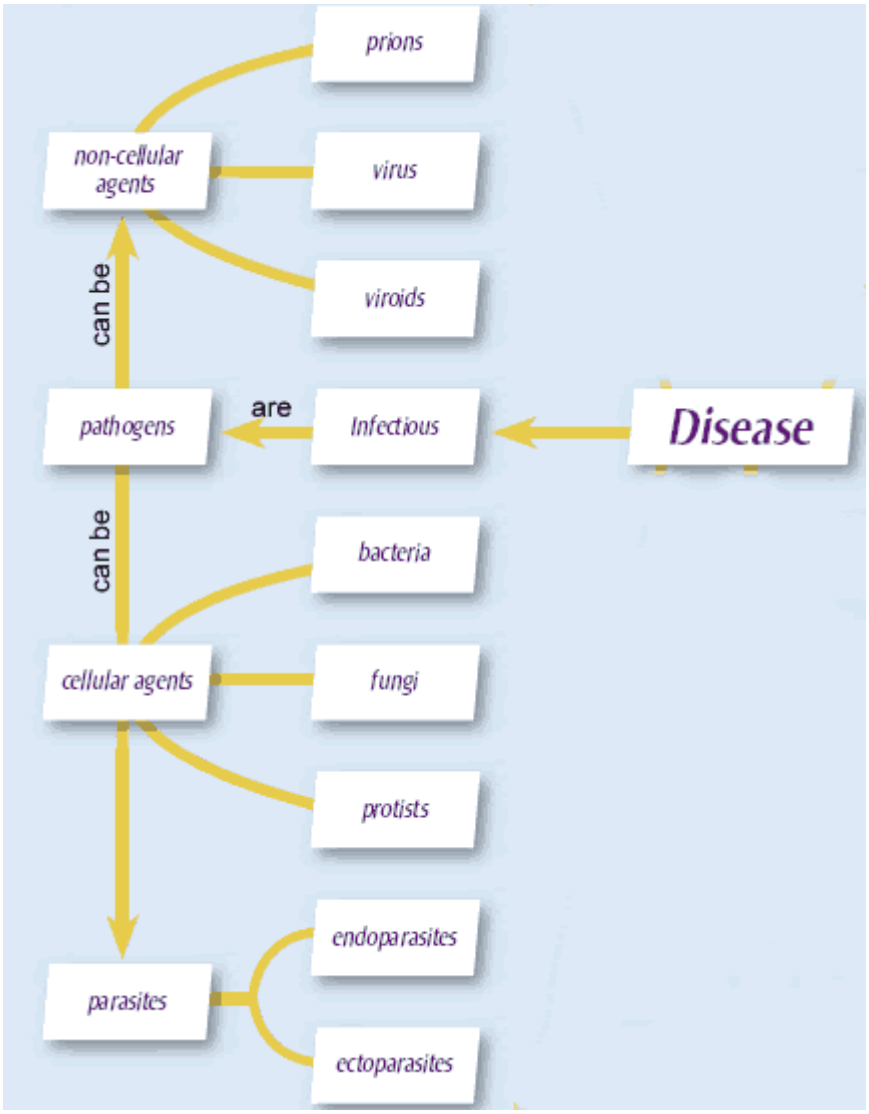
12. Distinguish between a fungal pathogen and a bacterial pathogen.

13. Describe two ways that a fungal pathogen may be transmitted to a new host.

14. Explain how a fungus may cause disease in its host.

15. Why is understanding of a parasite's life cycle essential in limiting the spread of the parasite? Use an example to justify your answer.

16. Below is a section of the visual summary given on page 167 of your text book. I've added the words 'are' and 'can be' to make the connecting lines more meaningful for example **'pathogens <u>are</u> infectious'**. Complete the rest of the connecting lines by adding one or more words and write down the sentences that they represent as shown in my example above.



Questions

17. Antiseptics, disinfectants and antibiotics are all chemicals that are used to destroy pathogenic microbes. Outline the difference between these products.

18. Outline a challenge presented to modern medicine in relation to the use of antibiotics, their effect on bacteria and the subsequent effect on patients.

19. Explain why it is difficult to treat viral infections.

20. Vaccines and drugs have been effective in preventing the spread of many different bacterial and viral pathogens. However, organisms like the liver fluke, *Plasmodium* and *Trypanosoma* have been more difficult to control. Explain why.

- Disease is any condition where normal activities are impaired.
- Many diseases are infectious – they are caused by an agent that can be passed from one organism to another.

- A pathogen is an infectious agent that causes disease in other organisms.
- Viruses are non-cellular infectious agents that can infect all types of organisms.
- They consist of either DNA or RNA, a protein coat and perhaps a membrane envelope.
- Viruses are completely parasitic on living cells and the interaction between a virus and a host cell is specific.
- Some viruses exit the cell by lysis of the cell.
- Enveloped virus particles are released slowly by budding, and result in a persistent infection of cells.
- A number of viruses appear to be able to cause normal cells to become cancerous.
- Viroids are tiny disease-causing RNA molecules.
- Prions are disease-causing proteins (they contain no DNA or RNA)
- Parasites are adapted to particular host species.
- Many bacteria are parasites, and some are major pathogens of humans, crops and animals.
- A person who is infected with a micro-organism but shows no symptoms of a disease is known as a carrier. They are asymptomatic.
- Protozoans that are pathogenic to animals cause diseases such as sleeping sickness, diarrhoea, malaria and amoebic dysentery.
- Fungi are important pathogens of plants, causing diseases such as rusts, smuts, ergot and Dutch elm disease. In humans, fungi cause athlete's foot, ringworm and thrush. A number of fungi are insect-killers.
- Parasitic worms such as tapeworms, flukes, roundworms and hookworms cause serious disease in animals.
- Insects are major vectors of disease.
- Agents used to kill pathogenic micro-organisms include disinfectants, antiseptics and fungicides.
- Treating viral infections is difficult.

KEY POINTS FOR GREEN BOOK.

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