WJEC (England) Biology GCSE

Topic 3: Health, Disease and the Development of Medicine

Notes

('Higher Tier only' in **bold**)

3.1 Health and disease

Health is the state of being free from disease, both physical and mental. Diseases can reduce both mental and physical health by infecting and damaging tissues and organs within an organism. This can be by destroying cells, producing toxins or inhibiting cells from carrying out their usual function, causing harm to the infected organism. This usually causes symptoms to appear, although not all diseases have visible symptoms.

Types of diseases

Diseases can be communicable and non-communicable. Non-communicable diseases are usually associated with genetic, environmental and lifestyle factors and cannot be spread directly between different organisms. This includes diseases such as diabetes, cancer and cardiovascular diseases. Communicable diseases, in contrast, are diseases that can be passed between organisms. Communicable diseases include influenza, salmonella and HIV.

Interactions between diseases

Different diseases interact with each other, and some diseases can trigger others:

- Autoimmune diseases such as lupus weaken the immune system, making it more likely for other diseases to infect the body.
- Viruses can be a trigger for cancers, for example HIV increases the risk of developing skin cancer.
- Some diseases make others more likely, e.g. there is an increased risk of cardiovascular disease in patients with diabetes.
- Some diseases can prevent another from developing, for example, sickle cell anaemia prevents malaria by distorting the shape of red blood cells.

3.2 Communicable disease

Communicable disease transmission

Communicable diseases are caused by infection from a virus, bacteria, fungi or protist. These pathogens can be passed between organisms, meaning that the disease can be spread throughout a population. The most common ways of transmission are direct contact with an infected organism, airborne microorganisms, indirect contact (e.g. through infected surfaces), and through contaminated food and water. Reducing the spread of communicable diseases is important in human, animal and plant populations as diseases can result in loss of life, destruction of habitats and ecosystems, and loss of food sources.

Examples of communicable diseases:

	Name of disease	Name of pathogen	Transmission	Effects	How to limit spreading
Human diseases	Influenza	Influenza viruses (viral)	Direct transmission and airborne.	Fever, coughing, muscle pains, headache, sore throat	Wash hands, cover mouth and nose when coughing and sneezing, avoid close contact with others.
	Chlamydia	*Chlamydia* (bacteria)	Sexually transmitted	Can cause symptoms such as: pain when urinating, discoloured discharge (men and women) and, if left untreated, can lead to infertility.	Use condoms and dental dams. Get tested regularly.
	Malaria	*Plasmodium falciparum (and others)* (protist)	Through a **vector*** in the form of a female mosquito	Damage to blood and liver.	Minimise areas where mosquitoes may breed, such as standing water. Use repellents and mosquito nets. Take anti-malarial drugs before travelling to countries where malaria is common.
	HIV	Human Immunodeficiency Virus (viral)	Bodily fluids	Destroys white blood cells, leads to AIDS.	Use condoms and dental dams. Avoid contact with infected bodily fluids (does not include saliva).
Plant diseases	Ash dieback	*Hymenoscyphus fraxineus* (fungal)	Airborne, movement of diseased ash plants and infected logs, on people or animals.	Leaf loss, bark lesions.	Do not move infected plants. Wash animals, cars and boots when leaving an infected area to prevent spread. Burn infected trees.

* a vector is an organism that can carry a disease without being infected itself.

Defences against infection

The human body has a range of different non-specific defence systems to protect itself from foreign pathogens. These defences include:

- Mechanical barriers - e.g. hairs in the nose and skin. This also includes the barrier formed by blood clotting, which seals wounds to prevent microorganisms from entering.
- Chemical barriers - includes mucus, stomach acid and tears.
- Bacterial barriers - bacteria (e.g. in the gut) help to kill foreign pathogens.

These defences are present constantly and are not triggered as a response to a specific pathogen, unlike an immune response which is triggered once the pathogen has infected the body.

The human immune system

The immune system is a system that works to protect the body from disease by destroying foreign pathogens once they have entered the body. These pathogens are destroyed by white blood cells. White blood cells detect pathogens by using receptors found on their cell surface to identify antigens on pathogens. There are two main types of white blood cell which carry out the immune response once a pathogen is identified:

- Lymphocytes - lymphocytes release chemicals which trigger the release of antibodies to disable the pathogen and activate phagocytes. They can also release antitoxins to kill it directly.
- Phagocytes - phagocytes attack pathogens by ingesting them into the cell and then digesting them using enzymes to make the pathogen harmless. This process is called phagocytosis.

Antibodies

Antibodies are Y-shaped proteins that are released once a pathogen has been identified by a white blood cell. They travel to the site of the pathogen through the blood and bind to the antigens on the surface to neutralise it. Antibodies clump foreign cells together (agglutination), making them easier to be destroyed by the immune system.

Each antibody is specific to a particular antigen, meaning that it will only bind to one type of antigen. When a pathogen infects the body, the body produces a complementary antibody in order to neutralise it. After the infection, a small number will remain as memory cells so that if the same pathogen enters the body again, it can be killed more quickly.

Monoclonal antibodies and diagnostic testing

Monoclonal antibodies are identical antibody clones made from one parent lymphocyte cell. These activated lymphocyte cells are able to divide continuously. Each of the monoclonal antibodies produced is specific to the same antigen.

Producing monoclonal antibodies:

1. **A specific antigen is injected into an animal, such as a mouse.**
2. **The animal has an immune reaction to the antigens, and lymphocyte cells are taken from the animal. These produce antibodies that are complementary to the antigen.**
3. **The lymphocyte cells are fused with tumour cells to make hybridoma cells. Tumour cells do not produce antibodies but will divide indefinitely. This means that the new cells will both divide continuously and make monoclonal antibodies.**
4. **The hybridoma cells divide to produce more monoclonal antibodies. Cells producing the correct antibody are selected and cultured.**

Large numbers of monoclonal antibodies can be cultured this way in a laboratory. They can then be used in a range of ways, including:

- **Diagnostic tests, such as those for HIV and Chlamydia - in these tests, the monoclonal antibody is used to indicate the presence of a certain molecule that is only present when the patient is positive for that disease. Consequently, the test for each disease uses a different monoclonal antibody which is complementary to that specific molecule. Tests using monoclonal antibodies are much easier and faster to carry out, and also give more accurate results.**

- **Tissue typing for transplants - monoclonal antibodies can be used to match donor organs to patients before transplantation. This reduces the chance of the new organ being rejected.**

- **Cancer treatments - monoclonal antibodies can be made to bind to antigens on specific cancer cells whilst carrying chemotherapy drugs.**

- **Monitoring malaria - monoclonal antibodies can be used to test for malaria. This can help to monitor the spread of malaria and can also be used to test the effectiveness of treatments.**

Plant defences

Plants also have barriers to prevent foreign pathogens from entering the organism, as well as to protect against damage from insects and herbivores. This includes:

- Physical barriers - examples of physical barriers include the waxy cuticle, specialised hardened cells and the cellulose cell wall, which can be strengthened using chemical substances. These act as barriers to prevent damage from insects and herbivores, which could allow pathogens to enter the plant. Some plants also have specialised defences, such as stinging cells and trichomes, as a defence against herbivores.

- Antimicrobial substances - some plants, such as garlic and ginger, use antimicrobial agents to prevent pathogens which are not stopped by their physical barriers. These can also be

produced in response to an infection in order to destroy the pathogen, as plants do not have circulating immune cells or produce antibodies.

There are a range of ways to detect plant disease:

- **Abnormal growth or changes in leaf colour.**
- **Visible signs - the disease-causing organism may be visible or leave behind signs such as bacterial slime or eggs from insects.**
- **Samples can be taken to a laboratory and tested. Pathogens such as bacteria and viruses can be grown in cultures.**

3.3 Treating, curing and preventing disease

Vaccines

Vaccines allow people to become immune to a disease without ever being infected with a harmful pathogen. Vaccination is used to control the spread of a disease and leads to herd immunity. This is where a large amount of the population is vaccinated and are thus immune to the pathogen, so the disease cannot spread. The people that cannot be vaccinated, for example due to medical reasons, are therefore also protected against the disease.

How vaccination works:

1. A dead or attenuated version of a pathogen is given to the patient.
2. The antigens evoke an immune response, in which antibodies are produced.
3. Memory cells are produced which stay in the body, giving long-term immunity.

Vaccination can be a contentious issue and some parents choose not to vaccinate their children in fear that the vaccine could be harmful. Before making a decision on whether vaccination is a good idea, it is important to weigh up the costs and benefits, as well as getting reliable information on the subject. Each vaccine contains different substances and has different success rates and associated risks. Therefore, for some vaccines and some people, the risks may outweigh the benefits. For example, those with weak immune systems due to disease may choose not to have a vaccine as triggering an immune response to the vaccine could be harmful to them. This is why it is important for other people to be vaccinated to provide herd immunity.

It is important to consider the effects of the media and the spread of false information when researching vaccinations:

- It is essential to get information from sound scientific evidence that has been backed up by multiple peer-reviewed studies, rather than opinions. The media may present bias information as they primarily exist to sell stories rather than present scientific facts. False information also spreads quickly on social media platforms as there is no policing of information.

Antibiotics and antibiotic resistance

Antibiotic drugs, such as penicillin, are used to treat bacterial infections. Some antibiotics kill bacteria by destroying their cell wall, leading to the cell bursting, whilst others inhibit the growth of the bacteria. Viruses cannot be killed by antibiotics as they do not grow and reproduce in the same way as bacteria, and do not have the same structure.

Some bacterial strains become resistant to antibiotics as a result of natural selection:

1. A mutation occurs in a bacterial cell which makes it resistant to an antibiotic.
2. When that antibiotic is administered, this cell is not killed, whereas cells which have not become resistant are killed.
3. The resistant cell can therefore survive and reproduce, producing more resistant bacteria.
4. Antibiotic resistance then spreads throughout the population of bacteria.

Resistance to antibiotics results in antibiotic-resistant bacterial infections in hospitals, such as MRSA. It is therefore important to try and slow the development of resistant bacterial strains. This can be done by only using antibiotics for serious infections, and always completing the full course of antibiotics to make sure that all of the bacteria are killed.

Aseptic techniques

When handling samples and carrying out identification tests, aseptic techniques must be used to avoid contamination, which may influence the test results and misdiagnose the patient. These techniques also prevent the spread of pathogens by keeping microorganisms from a sample contained.

Aseptic techniques include:

- Wiping down surfaces with antibacterial cleaner both before and after handling the sample.
- Flaming or sterilising any equipment before using it to transfer the sample.
- Flaming culture bottle necks before use to prevent airborne bacteria entering the vessel.
- Keeping all vessels containing the sample open for a minimum amount of time.
- Closing windows and doors to limit air currents.
- No eating or drinking near the sample.
- Washing hands before and after handling the sample.

Developing new medicines

New potential drugs are being discovered all the time, and the advancement of technology and microbiology has brought huge improvements to drug discovery and development; more substances can now be tested, and the genomes and proteins of pathogens can be studied in detail to find potential medicines that target them specifically. Any potential drugs must be rigorously trialled to find their potential side effects, effectiveness at targeting the disease, and the dosage needed. This is a lengthy and costly process with many stages. Lots of drugs are discarded during this if they have no effect or damage human cells.

The stages of drug development:

1. Screening - To begin with, large varieties of substances can be screened to see their effect on a target chemical or pathogen. Those that show a positive reaction are taken for further testing and modifying, as it is unlikely that a perfect medicine will be found at this stage.
2. Pre-clinical trials - Once a potential medicine is selected, pre-clinical trials begin. The drug is first tested using computer programs to predict how it will interact with human cells, before being tested on cultures of human tissue grown in a laboratory to assess whether there is any harmful effect on the tissue. Drugs that pass this stage are then used in animal trials to determine a safe dose for humans and to look for any side effects.
3. Clinical trials - If a drug passes the pre-clinical trial stages, it can be used on healthy humans in clinical trials to make sure that it is safe. After this, it is tested on people with the disease to measure its effectiveness.

3.4 Non-communicable diseases in humans

Risk factors

Non-communicable diseases can develop due to a range of both lifestyle and genetic factors. Factors that may increase the risk of one or many diseases are known as risk factors. Risk factors increase the likelihood of a person developing a disease but do not directly cause it, and people can still develop a disease even if they have a healthy lifestyle with a low level of risk. Risk factors include:

- Unhealthy diet - eating a high amount of saturated fat can cause high blood pressure and lead to fatty deposits in arteries, which increases the risk of developing cardiovascular disease. A high sugar diet can lead to type-2 diabetes, where the body becomes resistant to insulin and cannot regulate blood-sugar levels.
- Lack of exercise - an inactive lifestyle can lead to obesity, which increases the risk of cardiovascular disease, cancer and diabetes. People who exercise regularly have a lower pulse and recovery rate which puts less strain on the heart and blood vessels.
- Age - generally, as age increases so does the risk of developing diseases. Some diseases, however, are more common in lower age groups.
- Environmental risk factors - some environmental factors can increase the risk of certain diseases. For example, UV radiation can increase the risk of skin cancer by causing DNA mutations.
- Drugs and smoking - smoking increases the risk of lung cancer and coronary heart disease, among many other diseases. It damages the lining of blood vessels, reduces the amount of oxygen in the blood, raises blood pressure and increases the likeliness of blood clots which lead to heart attacks and strokes. Other drugs including alcohol can increase the risk of heart disease, cancers and liver diseases.

Cardiovascular disease treatments

There are a range of different treatments that can be used to treat cardiovascular disease. Each patient is assessed and treated differently depending on how severe the disease is and the costs and benefits for the patient.

1. Altering the patient's lifestyle - this includes altering the diet, increasing physical activity levels and quitting smoking and drinking. This treatment is cheap and often effective, however it is not enough to treat more severe cases.

2. Use of drugs - statins are drugs that lower cholesterol. People with cardiovascular disease can take these to decrease the risk of heart attacks and strokes by reducing the amount of fatty deposits in their arteries. There are also other types of drugs that help by reducing blood pressure, widening blood vessels and thinning the blood to prevent clots. These drugs must be taken daily, are often required for life and can also have negative side effects.

3. Stents - stents are small, hollow tubes that can be inserted into blood vessels to widen them. This improves blood flow and prevents the risk of vessels being blocked. Stents involve no major incisions, making the operation much less risky than a heart transplant or bypass surgery. There is also a shorter recovery time and no risk of rejection.

4. Heart transplant - in some cases medicine is not effective and the heart becomes irreparably damaged, meaning that it cannot pump blood around the body. This means that the heart must be replaced by a healthy heart. This process requires major surgery and has the risk of the new heart being rejected. Donor hearts are also difficult to source as they must be the right size and have a similar blood and tissue type to the patient.

As all of these treatments are difficult to implement and come with risks, it is much better to reduce the risk of a disease before it develops. Treatments may also affect patients differently. For example, a drug may have no effect on some patients, whilst others may have an adverse reaction to the same drug.