Edexcel Biology GCSE

Topic 5: Health, Disease and the Development of Medicines

Notes

(Content in **bold** is for higher tier only)

CONTENTS

5.1. 5.2, 5.3 - Definitions of Health, Disease and Susceptibility

The definition of health given by the World Health Organisation (WHO) is:

"A state of complete physical, mental and social well-being and not merely the absence of disease or infirmity."

Therefore, there are multiple different aspects to health that need to be considered - we need to take into account social and lifestyle factors too.

Communicable and non-communicable disease

Communicable diseases are those which can be transferred between individuals. This might be through air particles from coughing (known as **droplet infection**), from parasites in faeces (the **faecal-oral route**) or through bodily fluids including blood, semen and breast milk. These include viral infections such as flu, bacterial infections such as the common cold, and parasitic infections.

Non-communicable diseases are those which cannot be transferred between individuals. These are usually conditions with a genetic component or conditions acquired due to lifestyle factors. Some examples are cardiovascular disease, asthma, and diabetes.

Susceptibility to disease

Often, the presence of one disease can lead to increased susceptibility to other diseases. For example:

- Having HIV means that your immune system is impaired, leaving you at risk to many other 'opportunistic' infections, caused by bacteria, viruses and fungi.
- Having a particular virus called HPV can increase a woman's risk of developing cervical cancer.

5.4 - Pathogens

The definition of a pathogen is **an organism which causes disease.** They can infect plants or animals, spreading through either direct contact, by water or by air. Most pathogens fall into one of several types:

Viruses

- Very small
- They move into cells and use the biochemistry of it to make many copies of itself
- This leads to the cell bursting and releasing all of the copies into the bloodstream
- The damage and the destruction of the cells makes the individual feel ill

Bacteria

- Small

- They multiply very quickly through dividing by a process called **binary fission**
- They produce toxins that can damage cells

Fungi

- They can either be single celled or have a body made of **hyphae** (thread-like structures)
  They can produce **spores** which can be spread to other organisms

Protists

- Some are **parasitic**, meaning they use humans and animals as their hosts (live on and inside, causing damage)

5.5 - Common Infections and their Pathogens

Name of Disease	Category of Pathogen	Name of Pathogen	Effects	Method of Spread
Cholera	Bacteria	*Vibrio cholerae*	Diarrhoea	Water
Tuberculosis	Bacteria	*Mycobacterium tuberculosis*	Lung damage, coughing	Airborne
Chalara ash dieback	Fungi	*Hymenoscyphus fraxineus*	Leaf loss, bark lesions	Airborne
Malaria	Protists	*Plasmodium falciparum (and others)*	Damage to blood and liver	Animal vector (mosquito)
HIV	Virus	Human Immunodeficiency Virus	Destroys white blood cells, leads to onset of AIDS	Body fluids
Helicobacter	Bacteria	*Helicobacter pylori*	Can lead to stomach ulcers	Oral transmission
Ebola	Virus	*B. ebolavirus* (and others)	Causes hemorrhagic fever (fever accompanied by severe bleeding)	Body fluids

The ways that pathogens are spread include:

- **Direct contact**- touching contaminated surfaces
  Examples: kissing, contact with bodily fluids, direct skin to skin, microorganisms from faeces, infected plant material left in field
- **By water**- drinking or coming into contact with dirty water
- **By air**- pathogens can be carried in the air and then breathed in (a common example is the **droplet infection**, which is when sneezing, coughing or talking expels pathogens in droplets which can be breathed in)

The damage that disease causes to populations can be reduced by limiting the spread of the pathogens.

- **Improving hygiene**: Hand washing, using disinfectants, isolating raw meat, using tissues and handkerchiefs when sneezing
- **Reducing contact** with infected individuals
- **Removing vectors:** Using **pesticides or insecticides** and removing their habitat
- **Vaccination**: By injecting a small amount of a harmless pathogen into an individual's body, they can become immune to it so it will not infect them. This means they cannot pass it on to other individuals.

5.7B **Biology Only** - Lifecycle of a Virus

Viruses can 'survive' outside of a host - however, they require host cells to reproduce. This can be done in two ways:

Lytic pathway

1. Using host cell machinery, the virus **replicates its DNA**.
2. Next, these are **assembled** to form new virus particles.
3. Once the host cell is full of virus particles, it **bursts** in a process called **lysis**
4. The process is then repeated with nearby cells.

Lysogenic pathway

1. The virus uses restriction enzymes to **insert its DNA into the host cell DNA** - or it can insert small circular fragments of DNA called **plasmids** into the host cell cytoplasm.
2. The host cell replicates, and the **viral DNA is also copied in this process**.
3. The **lytic cycle** (see above) **begins at this point**, starting with the assembly of new viral particles

5.8 - Sexually Transmitted Infections

Sexually transmitted infections (STIs) are infections which can be spread through **sexual contact**, including oral and vaginal sex. They are carried in bodily fluids such as **semen** and **vaginal fluid**. Two examples are:

Name of STI	Category of Pathogen	Symptoms
Chlamydia	Bacteria	Often symptomless but if there are symptoms these can include painful urination or pelvic pain. Left untreated it can lead to infertility.
HIV	Virus	Increased susceptibility to other infections, severe illness and death if untreated

The spread of STIs can be reduced by using **barrier methods of contraception** (e.g **condoms**) or abstaining from sexual activity.

5.9B, 5.10B **Biology Only** - Plant Barriers against Disease

Plants have several methods of guarding their cells and tissues against pathogens that cause disease. Some of these methods involve having **physical** barriers against disease, whereas others use **chemicals** to defend against attack from pests and pathogens

Physical barriers

- A thick **cellulose cell wall**, which is impermeable to many pathogens
- A thick **waxy cuticle** on the surface of the leaf, which acts as a barrier to most pathogens
- Some plants are also covered in a **layer of bark** (e.g trees) which prevents pathogens from reaching the **cells and tissues inside**.
- Leaves can often close their **stomata** (pores) to stop pathogens entering the plant.

Chemical barriers

- Cells of some plants can produce antimicrobial chemicals, proteins and enzymes
- Some plants can release compounds that attract larger insects than the pests, which feed on the pests and stop them eating the plant.
- Often, we can extract antimicrobial compounds from these plants for use in drugs such as antibiotics.

5.11B **Higher Only** - Detecting and Identifying Plant Disease

There is a wide variety of pathogens that cause plant diseases, with an equally large variety of symptoms. Detecting and identifying these diseases in the lab and in the field is important, as it helps prevent the spread of disease across an entire crop.

Identifying disease in the field

Plants affected by disease often have a number of visible clues allowing us to identify it in the field:

- **Chalara dieback of ash causes malformations and browning of leaves**
- **Tobacco mosaic virus causes discolouration of leaves**
- **Bacterial canker on fruit trees causes loss of leaves, stunted growth and formation of pus-filled lesions on trunk.**
- **Aphids can cause serious structural damage to plants**

Identifying disease in the lab

Sometimes, laboratory techniques are needed to accurately identify a disease. Plant virologists use a specific method to do so:

1. **Cuttings are taken from the diseased plant.**
2. **The virus/bacterium causing the disease is grown on a culture medium/agar plate.**
3. **The pathogen is tested and identified using a monoclonal antibody testing kit (known as an ELISA kit).**

5.12 - Human Barriers against Disease

The human body, like plants, has a wide variety of **physical barriers** and **chemical defences** to provide protection from pathogens.

Physical barriers

Barrier	Associated with	Function
Mucus	Goblet cells in the airway (produce mucus)	Produced by goblet cells in the airway, mucus traps bacteria and other pathogens before they reach the lungs and cause infection.
Cilia	Ciliated epithelial cells (have cilia on their surface)	Wafts away mucus that has trapped pathogens, to be killed by stomach acid.

Skin	Skin cells	Provides a physical barrier against pathogens, protecting the tissues and cells beneath it from infection.

Chemical barriers

Barrier	Found in	Function
Lysozymes	White blood cells	Used by white blood cells to kill and digest bacteria
Hydrochloric acid	Stomach	Used to kill bacteria in food reaching the stomach - to prevent infection

5.13 - The Specific Immune Response

Mode of action	How it protects you
Phagocytosis (white blood cells engulfing and consuming pathogens)	This destroys them, meaning they can no longer make you feel ill.
Producing **antibodies**	Each pathogen has an **antigen** on their surface, which is a structure which a specific **complementary antibody** can bind to. Once antibodies begin to bind to the pathogen, the pathogens start to clump together, resulting in it being easier for white blood cells to find them and engulf them in **phagocytosis.** During this process, the antigens also trigger production of **memory lymphocytes** (lymphocytes are a special type of white blood cell). If you become infected again with the same pathogen, the specific complementary antibodies will be produced at a faster rate. The individual will not feel the symptoms of the illness. They are said to be **immune**.
Producing **antitoxins**	They neutralise the toxins released by the pathogen by binding to them.

5.14 and 5.15B - Immunisation

Vaccinations involve making an individual immune to a certain disease- they are protected against it before they have been infected. By immunising a large proportion of the population, the spread of the pathogen is reduced as there are less people to catch the disease from (called **herd immunity**).

Naturally, when you are infected with a pathogen, you feel ill until white blood cells manufacture the correct specific antibody to combat it. Upon a secondary infection, the antibodies can be produced much quicker, so the pathogen can be destroyed and the symptoms are not felt. Vaccinations replicate the first infection so that when the person is exposed to the real disease they do not feel any symptoms, just like in a secondary infection.

- The vaccine contains a dead or inactivated form of the pathogen
- This stimulates white blood cells to produce antibodies complementary to the antigens on the pathogen

Biology Only

Advantages of vaccination	Disadvantages of vaccination
They have eradicated many diseases so far (e.g smallpox) and reduced the occurrence of many (e.g rubella).	They are not always effective in providing immunity.
Epidemics (lots of cases in an area) can be prevented through herd immunity.	Bad reactions (such as fevers) can occur in response to vaccines (although very rare).

5.16 - Antibiotics

Antibiotics can only be used to treat **bacterial infections**, and not those caused by **viruses, fungi** or **other pathogens**.
Bacteria are susceptible to antibiotics because **antibiotics inhibit cell processes in the bacterium. However, viruses and other pathogens often use** cell machinery in host cells to reproduce, and these are **unaffected by antibiotics**.

5.17B **Biology Only** - Aseptic Technique

Microorganisms are very small, so in order for scientists to study them they need to grow many of them in the lab using nutrients (culturing them).

The culture medium contains **carbohydrates** for energy, **minerals**, **proteins** and **vitamins**.

There are two ways to grow microorganisms in the lab:

1. In **nutrient broth solution**- involves making a suspension of bacteria to be grown and mixing with sterile nutrient broth (the **culture medium**), stoppering the flask with cotton wool to prevent air from contaminating it and shaking regularly to provide oxygen for the growing bacteria.
2. On an **agar gel plate**- the agar acts as the culture medium, and bacteria grown on it form colonies on the surface.
   Making the plate:
   - Hot sterilised agar jelly is poured into a sterilised **Petri dish**, which is left to cool and set
   - Sterilised wire loops called **inoculating loops** are dipped in a solution of the microorganism and spread over the agar evenly
   - A lid is taped on and the plate is **incubated** for a few days so the microorganisms can grow (stored upside down)

The reasons why we follow certain steps in this procedure need to be understood.

Step	Why?
Petri dishes and culture media must be sterilised before use, often done by an **autoclave** (an oven) or UV light.	If this step does not take place, they are likely to be contaminated with other microorganisms. These could be harmless but will compete with the desired bacteria for nutrients and space, or they could be harmful (for example through a mutation taking place), potentially producing a new pathogen.
Inoculating loops must be sterilised by passing them through a flame.	This kills unwanted microorganisms, which is needed for reasons above.
The lid of the Petri dish should be sealed (but not completely) with tape.	Sealing stops airborne microorganisms from contaminating the culture, but it should not be sealed all the way around as this would result in harmful anaerobic bacteria growing (due to no oxygen entering).
The Petri dish should be stored upside down.	This is to prevent condensation from the lid landing on the agar surface and disrupting

	growth.
The culture should be incubated at 25 degrees.	If it were incubated at a higher temperature, nearer 37 degrees (human body temperature), it would be more likely that bacteria that could be harmful to humans would be able to grow as this is their optimum temperature. At lower temperatures, colonies of such bacteria would not be able to grow.

5.18B **Biology Only** - *Core Practical: Investigating the effects of antiseptics and antibiotics and* 5.19B **Biology Only** - Calculations with Bacterial Cultures

It is possible to calculate the cross sectional area of a bacterial culture using the formula for the area of a circle. If we apply an antibiotic to the agar plate, this is a useful calculation - as it allows us to **determine the effectiveness of the antibiotic**. In Part 1 of this experiment, we will grow the bacterial culture, and in Part 2 we will use πr2 to examine how effective the antibiotic is:

Growing the bacterial culture

1. Take a Petri dish that has been pre-poured with agar gel, and sterilise it in an **autoclave** before use. Use a inoculating loop (**sterilised in a Bunsen Burner**) to apply the bacteria being tested to the agar. Seal the top of the plate using tape. (**but not completely - see section 5.17**) Incubate the culture at 25 degrees C for 3 days.
2. Apply a filter paper disc soaked in antibiotic solution to the centre of the agar plate and wait for 24 hours, **or until there is no further change**.

Calculating the effectiveness of the antibiotic

3. Use a ruler to measure the **diameter of the circle taken up by the bacterial culture** and record this measurement. **Repeat for the diameter of the clear agar jelly in the centre**, where the antibiotic has killed the bacteria.
4. Divide both diameters by 2 to get the **radius** of both these circles. Use the formula for the area of a circle (**πr2**) to calculate the area of these circles.
5. **Divide the area of the smaller circle by the larger, and multiply by 100.** This is the percentage of the bacterial culture that has been destroyed by the antibiotic. The higher the percentage, the more effective the antibiotic.

We can repeat these calculations for multiple antibiotics and bacteria, in order to determine the effectiveness of **different bacteria/antibiotic combinations**. This is useful as it allows doctors and scientists to work out which antibiotics are most effective for **particular bacterial infections**.

5.20 - Developing New Medicines

Many drugs were initially discovered in plants and microorganisms. New drugs today are mainly synthesised by chemists. They need to be tested for **toxicity**, **efficacy** (how well they carry out their **role**) and dose, using **preclinical testing** and **clinical trials**.

Plants

The chemicals that plants use to kill pests and pathogens can be used to treat symptoms or human diseases.

Examples:

- **Aspirin** is used as a painkiller (originates from willow)
- **Digitalis** is used to treat heart problems (originates from foxgloves)

Microorganisms

- Penicillin
    - Alexander Fleming was growing bacteria on plates
    - He found mould (*Penicillium* **mould**) on his culture plates, with clear rings around the mould indicating there was no longer any bacteria there
    - He found that the mould was producing a substance called penicillin, which killed bacteria

Any new drugs being developed need to be tested to ensure they are safe and effective.

Preclinical testing: using cells, tissues and live animals

Clinical testing: using volunteers and patients

- It is first tested on healthy volunteers with a low dose to ensure there are no harmful side effects
- The drugs are then tested on patients to find the most effective dose
- To test how well it works, patients are split into two groups with one group receiving the drug and one receiving a **placebo** (appears to look like the drug but has no active ingredient so no effect) so the effect of the new drug can be observed
- These can be **single-blind** (only the doctor knows whether the patient is receiving the drug) or **double blind** (neither the patient or doctor knows whether they are receiving the drug, removing any biases the doctor may have when they are recording the results).

The results then need to be **peer reviewed** by other scientists to check for **repeatability**.

5.21B **Higher and Biology Only** - Production of Monoclonal Antibodies

Monoclonal antibodies are identical antibodies, that have been produced from the same immune cell. As a result of their ability to bind to only one protein antigen, they can be used to target chemicals and cells in the body and so have many different medical uses, e.g. in pregnancy testing.

How are they produced:

1. **Scientists obtain mice lymphocytes (a type of white blood cell that make antibodies but cannot divide), which have been stimulated to produce a specific antibody.**
2. **They are combined with tumour cells (do not make antibodies but divide rapidly), to form a cell called a hybridoma.**
3. **The hybridoma can divide to produce clones of itself, which all produce the same antibody.**
4. **The antibodies are collected and purified.**

5.22B **Higher and Biology Only** - Uses of Monoclonal Antibodies

Examples of the uses of monoclonal antibodies include in pregnancy tests, in laboratories to measure the levels of hormones or chemicals, in research and in the treatment of some diseases.

1. **Pregnancy tests**
   A hormone called human chorionic gonadotrophin (hCG) is present in the urine of women who are pregnant.
   - **There are two sections of the stick.**
   - **The first section has mobile antibodies complementary to the hCG hormone- these antibodies are also attached to blue beads.**
   - **The second section has stationary antibodies complementary to the hCG hormone which are stuck down to the stick.**
   - **The individual urinates on the first section, and if hCG is present it binds to the mobile antibodies attached to blue beads to form hCG/antibody complexes.**
   - **They are carried in the flow of liquid to the second section.**
   - **The stationary antibodies then bind to the HCG/antibody complexes.**
   - **As they are each bound to a blue bead, results in a blue line.**
   - **This indicates that you are pregnant.**

2. **In laboratories to analyse blood**
   - **They can be used to measure and monitor levels of hormones or chemicals in the blood.**

- **The monoclonal antibodies are modified so that they will bind to the molecule you are looking for.**
- **The antibodies are also bound to a fluorescent dye.**
- **If the molecules are in the sample then the antibodies bind to it, and the dye can be observed.**
- **An example is screening donated blood for HIV infections.**

3. **In research to find or identify certain molecules on a cell or tissue**
    - **The same method as above is applied, and scientists look for a build up of the fluorescence.**

4. **In the treatment of disease, e.g. cancer**
   Cancer cells have antigens on their cell membranes known as tumour markers (not found on normal body cells), which can be targeted. There are three main ways to treat cancers using monoclonal antibodies.
    a) **Producing monoclonal antibodies that bind to the tumour markers in order to stimulate the immune system to attack the cell.**
    b) **Using monoclonal antibodies to bind to receptor sites on the cell surface membrane of the cancer cells. This means growth-stimulating molecules cannot bind, stopping the cell from dividing.**
    c) **Using monoclonal antibodies to transport toxic drugs, chemicals or radioactive substances as they can only bind to cancer cells.**

Advantages of using monoclonal antibodies	Disadvantages of using monoclonal antibodies
They only bind to specific cells, meaning healthy cells are not affected.	It is difficult to attach monoclonal antibodies to drugs.
They can be engineered to treat many different conditions.	They are expensive to develop.
We are now able to produce mouse-human hybrid cells to reduce the chance of triggering an immune response.	As they were produced from mice lymphocytes, they often triggered an immune response when used in humans.

5.23 - Factors affecting Non-Communicable Disease

Non-communicable human diseases - for example cardiovascular disease, asthma, and diabete, are caused by the **interaction of a number of different factors**.

- **Cardiovascular diseases** such as coronary heart disease can be caused by high dietary intake of saturated fat, combined with a **sedentary** (inactive) lifestyle.

- **Several forms of cancer** can be contributed to by various factors - for example, **smoking** greatly increases the risk of lung cancer, whereas the risk of developing breast cancer is largely due to a combination of **age** and **genetics.**

- **Lung and liver diseases** are made more likely by smoking and high alcohol intake respectively. However, other factors can play a part - especially **age** and **genetics.** As an individual gets older, they are more likely to suffer from these conditions.

- **Vitamin and nutritional deficiencies** are common in anorexic patients, as well as those who **can't absorb or use nutrients properly** (including patients with coeliac disease and anaemia). **Obesity,** on the other hand, is caused by excess caloric intake (food intake), and can again be heavily influenced by genetics - some people are more likely to gain weight than others.

5.24 - Lifestyle Factors and Disease

Lifestyle factors (diet, exercise etc.) play a vital role in determining whether people will develop non-communicable diseases.

Obesity

- **Eating more calories than you burn** from physical activity (and everyday metabolism) causes us to **put on weight**.
- Eating a very large excess of calories, especially if a high proportion of these calories come from **saturated fat**, can lead to obesity and related illnesses.
- Obesity is an important problem worldwide, but especially in **developed countries** such as the UK.
- Obesity can lead to developing **cardiovascular disease** and **high blood pressure**, as fat (lipid) deposits form inside blood vessels.
- Obesity can also contribute to developing Type 2 diabetes, as the body cannot use **insulin** as effectively when there is a **high proportion of body fat**.
- Government programs such as the 'sugar tax' are aimed at reducing obesity across the country. Eating fewer **processed foods**, less **sugar**, **saturated fat** and **high calorie foods** can help reduce the risk of becoming obese.

Malnutrition

- Equally, **eating significantly fewer calories than we use** can lead to malnutrition, as the body will not be receiving adequate amounts of **nutrients and vitamins**.
- The symptoms can be different depending on the vitamin or nutrient that is deficient.
- Malnutrition is less of a problem in developed countries like the UK, but more of an issue in **underdeveloped countries** where many people do not have enough money to eat.

$$\text{BMI} = \frac{\text{mass (kg)}}{(\text{height (m)})^2}$$

We can work out BMI (Body Mass Index) to determine whether someone is **underweight**, of a **healthy weight**, **obese** or **morbidly** (severely) **obese**.
If someone's BMI is **over 30**, they are classified as obese.

We can also use the **waist-hip ratio**, calculated by dividing waist circumference (cm) by hip circumference (cm). Obesity is classified as a waist-hip ratio of more than **0.85 for women,** or **more than 1.0 in men.**

Liver disease

- A high alcohol intake can lead to liver disease.
- A type of liver disease called fatty liver is common in alcoholics. It can lead to liver cancer and impaired liver function.
- Alcoholics often also have vitamin deficiencies (particularly vitamin B6, thiamine)
- The recommended weekly allowance for men and women is 14 units a week. Drinking less than this significantly reduces the risk of developing liver disease.

Lung disease

- Smoking dramatically increases the risk of developing several lung diseases
- These include COPD (chronic obstructive pulmonary disease), bronchitis, pneumonia and lung cancer.
- Cigarette smoke contains over 40 different chemicals, all of which have different effects on the body - for example, tar can cause lung cancer and nicotine can cause high blood pressure and heart failure.
- The UK government provide services to help and encourage smokers to quit smoking.

5.25 - Evaluating Treatments for Cardiovascular Disease

There are several treatment options available for cardiovascular disease, including life-long medication, surgery and lifestyle changes:

Life-long medication

- There are several medications that will either **reduce cholesterol** or **reduce blood pressure.**
- People with very high blood pressure may have to take **multiple medications** to reduce it.
- They will most likely have to take these **for the rest of their life**.

Surgical procedures

- Sometimes medication does not work effectively, and **surgery** may be required.
- Coronary arteries supply the heart muscle with oxygen, and cover the heart
- If these are blocked, a **coronary artery bypass** can be performed, where the blocked sections of the coronary artery are 'bypassed'.
- Another method involves using a metal **stent** to widen arteries that have been narrowed by fat deposits (**atherosclerosis**)

Lifestyle changes

- Lifestyle changes (changes to exercise, diet and other habits) are very important in **preventing** and **treating** cardiovascular disease.
- Reducing the amount of saturated fat we eat can reduce the risk of developing **atherosclerosis** (fat deposits in the arteries) and **high cholesterol**.
- Maintaining a **healthy BMI** can reduce strain on the heart.
- Taking **regular exercise** ensures that we remain at a healthy weight
- Reducing the amount of **salt** in the diet, and managing **stress levels,** can prevent high blood pressure from developing.