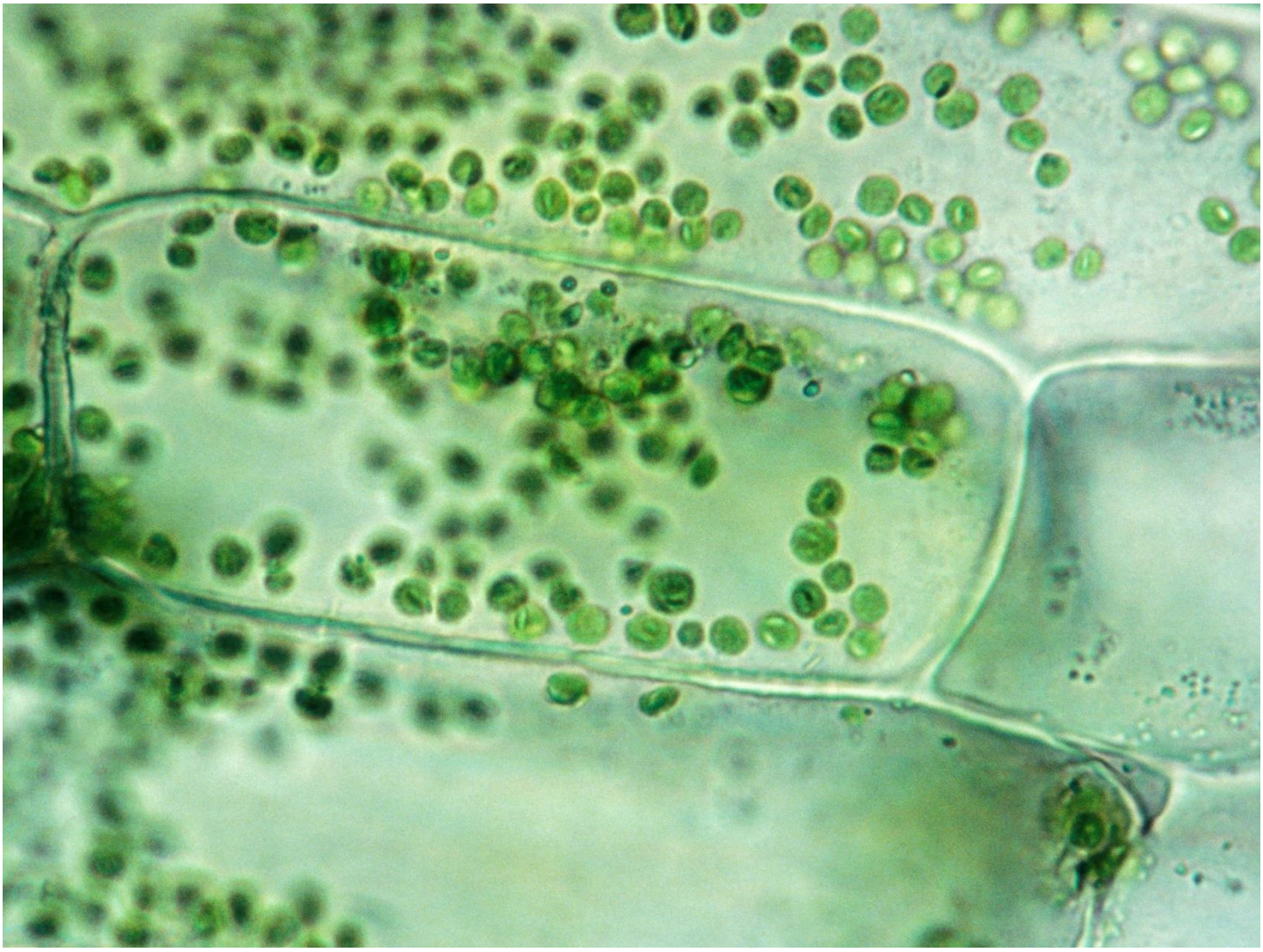
A-level Biology



Bridging Course - Week 4

Entry Requirements for Studying A-level Biology?

- Students who are expected to achieve at least a grade 7 in GCSE Biology Separate Science or a grade 7 in Combined Science.
- Students who have enjoyed their GCSE Biology course, and who enjoy extra reading and research.
- Students should be competent in both Mathematics and Chemistry.

What to expect from A-level Biology?

The study of A Level Biology compliments a large number of university courses such as Medicine, Dentistry, Biomedical Science, Genetic Engineering, Environmental Science along with many others. It can also provide academic credentials for unrelated courses such as Law and Architecture.
The course covers both animal, plant and environmental Biology, which will be taught through a combination of theory and practical work. This is a demanding A level, and students will need to be competent in both Maths and Chemistry.

This bridging course will provide you with a mixture of information about A-level Biology, and what to expect from the course, as well as key work to complete. Students who are expecting to study Biology at A-level, and are likely to meet the entry requirements, must complete the bridging course fully and thoroughly, to the best of their ability. You should complete all work digitally if possible, so it is available to print and place in your file at the start of the course. You will submit it to your teacher in September. All of the work will be reviewed and selected work will be assessed, and you will be given feedback on it. This work will be signalled to you. If you do not have access to the internet, please contact the school and appropriate resources will be sent to you. If you are thinking about studying Biology at A-level you should attempt this work to see whether or not you think studying a subject like this is right for you. If you later decide to study Biology, you must ensure you complete this work in full. This work should be completed after you have read and completed the Study Skills work that all of Year 12 should complete.

Course Outline

Paper 1	Paper 2	Paper 3
What's assessed • Any content from topics 1–4, including relevant practical skills	**What's assessed** • Any content from topics 5–8, including relevant practical skills	**What's assessed** • Any content from topics 1–8, including relevant practical skills
Assessed • written exam: 2 hours • 91 marks • 35% of A-level	**Assessed** • written exam: 2 hours • 91 marks • 35% of A-level	**Assessed** • written exam: 2 hours • 78 marks • 30% of A-level
Questions • 76 marks: a mixture of short and long answer questions • 15 marks: extended response questions	**Questions** • 76 marks: a mixture of short and long answer questions • 15 marks: comprehension question	**Questions** • 38 marks: structured questions, including practical techniques • 15 marks: critical analysis of given experimental data • 25 marks: one essay from a choice of two titles

The topics that you will study over the two years are as follows.

Year 12
Topic 1 - Biological molecules
Topic 2 – Cells
Topic 3 – Organisms exchange substances with their environment
Topic 4 – Genetic information, variation and relationships between organisms
Topic 5 – Energy transfers between organisms - Respiration and photosynthesis

Year 13
Topic 5 - Energy transfers between organisms – Energy and ecosystems
Topic 6 - Organisms respond to changes in their environment
Topic 7 - Genetics, populations, evolution and ecosystems
Topic 8 - The control of gene expression

The following work will introduce key aspects of the Year 12 content along with some of the skills required during the A-level Biology course. This week we will be looking at the immune system.

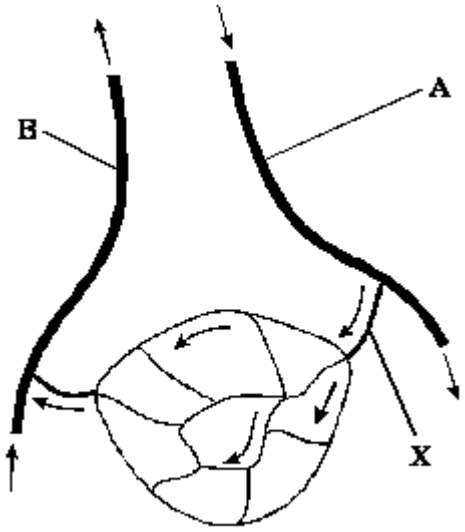
Recap Task

So far we have looked at cell structure, the structure of some of the biological molecules that make up cells, and the circulatory system that supplies cells with the chemicals they need. This week will bring together knowledge from these areas in looking at specialised cells in our immune system, and how particular proteins, antiibodies and antigens, are involved in this process.

To recap and assess your knowledge answer the following questions.

Q1.

The diagram shows some blood vessels in muscle tissue.



Not drawn to scale

(a) (i) Which type of blood vessel is **X**?

_____

(1)

(ii) Name **two** substances which are at a higher concentration in the blood at **A** than in the blood at **B**.

1. _____

2. _____

(1)

(b) The table shows the mean diameter of the lumen and the rate of blood flow in some types of human blood vessel.

Type of blood vessel	Mean diameter of lumen / μm	Rate of blood flow / cm s^{-1}
Artery	400	10 – 40
Arteriole	30	0.1 – 10
Capillary	8	less than 0.1

Using information in the table, explain what causes the rate of blood flow to be slower in capillaries than in other vessels.

_____

_____

_____

_____

(2)

(c) (i) Which type of blood vessel has most elastic tissue in its wall?

_____

(1)

(ii) How does this elastic tissue help to smooth out the flow of blood in the blood vessel?

_____

_____

_____

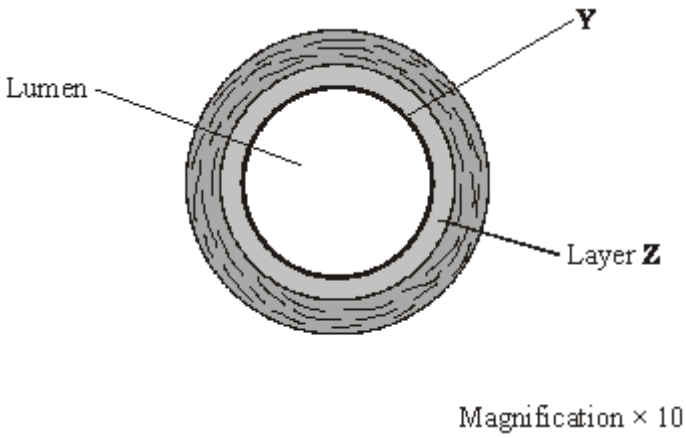
_____

(2)

(Total 7 marks)

Q2.

The diagram shows a cross-section of an artery.



Magnification × 10

(a) Name the layer labelled **Y**.

_____

(1)

(b) Layer **Z** contains a high proportion of elastic tissue.

Describe the advantage of having elastic tissue in the wall of an artery.

_____

_____

_____

_____

(2)

(c) Calculate the cross-sectional area of the lumen of the artery shown in the diagram. Show your working.

The area of a circle is given by πr^2, where r is the radius of a circle ($\pi = 3.14$).

Answer _____ mm^2

(3)

(Total 6 marks)

Mark schemes

Q1.

(a) (i) arteriole;

1

(ii) *any two*
oxygen / glucose / amino acids / fatty acids / glycerol / minerals.

1

(b) small diameter / lumen / small mean cross-sectional area / increase in (total) cross sectional area;
more surface in contact with blood / greater friction / resistance;

2

(c) (i) artery.

1

(ii) stretches / expands to accommodate increase in blood volume / when ventricle contracts / increase in blood pressure;
recoils when blood volume decreases / when ventricle relaxes / blood pressure decreases.

2

[7]

Q2.

(a) endothelium / tunica intima *(accept endothelial cells)*;

1

(b) elastic tissue allows recoil
(*reject if wording implies a muscle e.g. contract / relax) (ignore expand)*;
maintains blood pressure / constant / smooth blood flow
(not increases blood pressure).

2

(c) measuring radius / 12 mm / 12.5 mm / 1.2 cm / 1.25 cm;
correct calculation / 3.14 × 12 x 12 = 452 / 3.14 x 12.5 x 12.5 = 490 / 491.
allow for magnification ÷100 = 4.52 / 4.9.
(allow 1 mark for correct calculation using incorrect radius)

3

[6]

The Immune System

Students will build on their knowledge of the human immune system.
Students will investigate the relationship between antibodies and antigens.
Students will plan an essay linking the areas they have studied.
Students will produce an essay the areas they have studied.

Recap Previous Knowledge

Review your GCSE notes and revision material on the immune system, and then answer the following questions;

1. Describe how a phagocyte helps to fight disease.
2. Describe how a lymphocyte helps to fight disease.
3. What is an antigen?
4. What is an antibody?
5. Covid-19 is a virus. It is currently uncertain if humans will develop lasting immunity to Covid-19 after infection. (i) Explain why it was initially assumed that if someone had Covid-19 they would not get it again. (ii) Explain why it might be the case that someone who had previously had Covid-19 might not have lasting immunity. (iii) Explain how a vaccination for Covid-19 might be developed.

1. Antibodies and Antigens

The human immune system is one of the more challenging topics covered in Year 12 (so don't worry if you don't understand all of this), and here we are just going to look an antibodies and antigens, which are examples of proteins. The following video covers details of the human immune system, which will give you an overview of what we will be studying but may also be confusing. Just concentrate on the sections on antigens and antibodies.

Read the following information from the text book.

5.3 T lymphocytes and cell-mediated immunity

Learning objectives

- State the definition of an antigen.
- Describe the two main types of lymphocyte.
- Explain the role of T cells (T lymphocytes) in cell-mediated immunity.

Specification reference: 3.2.4

The initial response of the body to infection is non-specific (see Topic 5.2). The next phase is the primary immune response that confers immunity. Immunity is the ability of organisms to resist infection by protecting against disease-causing microorganisms or their toxins that invade their bodies. It involves the recognition of foreign material (antigens).

Antigens

An antigen is any part of an organism or substance that is recognised as non-self (foreign) by the immune system and stimulates an immune response. Antigens are usually proteins that are part of the cell-surface membranes or cell walls of invading cells, such as microorganisms, or abnormal body cells, such as cancer cells. The presence of an antigen triggers the production of an antibody as part of the body's defence system (see Topic 5.4).

Lymphocytes

Immune responses such as phagocytosis are **non-specific** (see Topic 5.2) and occur whatever the infection. The body also has **specific** responses that react to specific antigens. These are slower in action at first, but they can provide long-term immunity. This specific immune response depends on a type of white blood cell called a **lymphocyte**. Lymphocytes are produced by stem cells in the bone marrow. There are two types of lymphocyte, each with its own role in the immune response:

- **B lymphocytes (B cells)** are so called because they mature in the bone marrow. They are associated with humoral immunity, that is, immunity involving antibodies that are present in body fluids, or 'humour' such as blood plasma. This is described in more detail in Topic 5.5.
- **T lymphocytes (T cells)** are so called because they mature in the thymus gland. They are associated with cell-mediated immunity, that is immunity involving body cells.

Cell-mediated immunity

Lymphocytes respond to an organism's own cells that have been infected by non-self material from a different species, for example a virus. They also respond to cells from other individuals of the same species because these are genetically different. These therefore have different antigens on their cell-surface membrane from the antigens on the organism's own cells. T lymphocytes can distinguish these invader cells from normal cells because:

- phagocytes that have engulfed and hydrolysed a pathogen present some of a pathogen's antigens on their own cell-surface membrane
- body cells invaded by a virus present some of the viral antigens on their own cell-surface membrane.

Study tip

It is always necessary to describe events in detail using the appropriate scientific terms. For example, in immunity questions vague references to 'cells fighting disease' should be avoided.

5.4 B lymphocytes and humoral immunity

We saw in Topic 5.3 that the first phase of the specific response to infection is the mitotic division of specific T cells to form a clone of the relevant T cells to build up their numbers. Some of these T cells produce factors that stimulate B cells to divide. It is these B cells that are involved in the next phase of the immune response: humoral immunity.

Learning objectives

- Explain the role of B cells (B lymphocytes) in humoral immunity.
- Explain the roles of plasma cells and antibodies in the primary immune response.
- Explain the role of memory cells in the secondary immune response.
- Explain how antigenic variation affects the body's response to infection.

Specification reference: 3.2.4

Humoral immunity

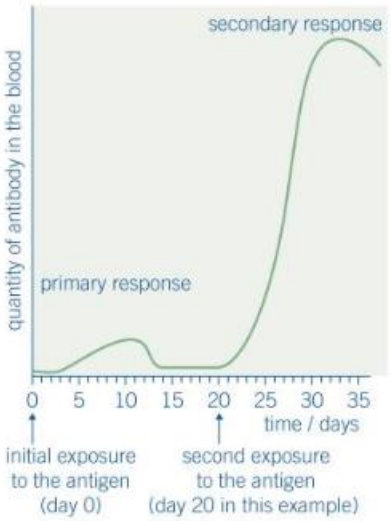
Humoral immunity is so called because it involves **antibodies** (see Topic 5.5), and antibodies are soluble in the blood and tissue fluid of the body. An old-fashioned word for body fluids is 'humour'. There are many different types of B cell, possibly as many as ten million, and each B cell starts to produce a specific antibody that responds to one specific antigen. When an **antigen**, for example, a protein on the surface of a pathogen, foreign cell, toxin, damaged or abnormal cell, enters the blood or tissue fluid, there will be one B cell that has an antibody on its surface whose shape exactly fits the antigen, that is, they are complementary. The antibody therefore attaches to this complementary antigen. The antigen enters the B cell by **endocytosis** and gets presented on its surface (processed). T_H cells bind to these processed antigens and stimulate this B cell to divide by mitosis (see Topic 3.7) to form a clone of identical B cells, all of which produce the antibody that is specific to the foreign antigen. This is called **clonal selection** and accounts for the body's ability to respond rapidly to any of a vast number of antigens.

In practice, a typical pathogen has many different proteins on its surface, all of which act as antigens. Some pathogens, such as the bacterium that causes cholera, also produce toxins. Each toxin molecule also acts as an antigen. Therefore many different B cells make clones, each of which produces its own type of antibody. As each clone produces one specific antibody these antibodies are referred to as **monoclonal antibodies** (see Topic 5.5). In each clone, the cells produced develop into one of two types of cell:

- **Plasma cells** secrete antibodies usually into blood plasma. These cells survive for only a few days, but each can make around 2000 antibodies every second during its brief lifespan. These antibodies lead to the destruction of the antigen. The plasma cells are therefore responsible for the immediate defence of the body against infection. The production of antibodies and memory cells (see below) is known as the **primary immune response**.
- **Memory cells** are responsible for the **secondary immune response.** Memory cells live considerably longer than plasma cells, often for decades. These cells do not produce antibodies directly, but circulate in the blood and tissue fluid. When they encounter the same antigen at a later date, they divide rapidly and develop into plasma cells and more memory cells. The plasma cells produce the antibodies needed to destroy the pathogen, while the new memory cells circulate in readiness for any future infection. In this way, memory cells provide long-term immunity against the original infection. An increased quantity of antibodies is secreted at a faster rate than in the primary immune response. It ensures that a new infection is destroyed before it can cause any harm – and individuals

Hint

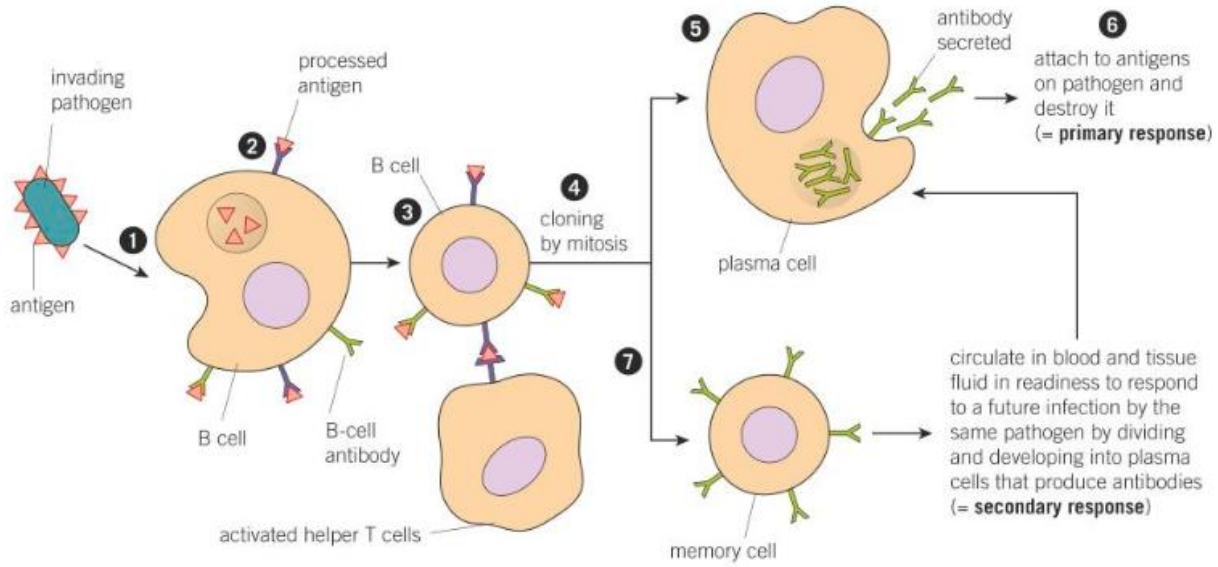
Remember that B cells with the appropriate antibody to bind to antigens of a pathogen are not produced in response to the pathogen. They are present from birth. Being present, they simply *multiply* in response to the pathogen.



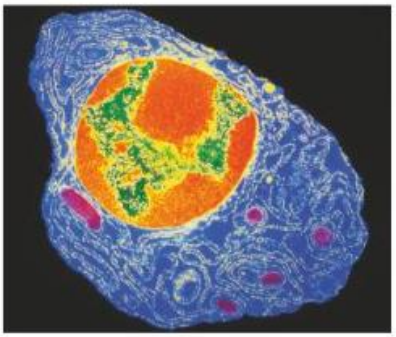
▲ **Figure 1** *Primary and secondary responses to an antigen*

are often totally unaware that they have ever been infected. Figure 1 illustrates the relative amounts of antibody produced in the primary and secondary immune responses.

The role of B cells in immunity is explained below and summarised in Figure 2.



▲ **Figure 2** *Summary of role of B cells in humoral immunity*



▲ **Figure 3** *False-colour TEM of a plasma cell. Plasma cells are mature B lymphocytes that secrete antibodies. Note the well-developed rough endoplasmic reticulum (yellow dotted lines) where the antibodies are synthesised.*

1 The surface antigens of an invading pathogen are taken up by a B cell.
2 The B cell processes the antigens and presents them on its surface.
3 Helper T cells (activated in the process described in Topic 5.3) attach to the processed antigens on the B cell thereby activating the B cell.
4 The B cell is now activated to divide by **mitosis** to give a clone of plasma cells.
5 The cloned plasma cells produce and secrete the specific antibody that exactly fits the antigen on the pathogen's surface.
6 The antibody attaches to antigens on the pathogen and destroys them (see Topic 5.5).
7 Some B cells develop into memory cells. These can respond to future infections by the same pathogen by dividing rapidly and developing into plasma cells that produce antibodies. This is the secondary immune response.

Summary questions

1 Explain why the secondary immune response is much more rapid than the primary one.
2 Contrast the cell-mediated and humoral responses to a pathogen.
3 Plasma cells can produce around 2000 protein antibodies each second. Suggest **three** cell organelles that you might expect to find in large quantities in a plasma cell, and explain why.

5.5 Antibodies

In Topic 5.4 we saw how B cells respond to **antigens** by producing antibodies. Let us now look at antibodies and how they work in more detail.

Learning objectives

- Describe the structure of an antibody.
- Describe the functions of antibodies.
- Describe the nature of a monoclonal antibody.
- Explain how monoclonal antibodies are produced.
- Explain how monoclonal antibodies are used to target specific substances and cells.

Specification reference: 3.2.4

Antibodies

Antibodies are proteins with specific binding sites synthesised by B cells. When the body is infected by non-self material, a B cell produces a specific antibody. This specific antibody reacts with an antigen on the surface of the non-self material by binding to them. Each antibody has two identical binding sites. The antibody binding sites are complementary to a specific antigen. The massive variety of antibodies is possible because they are made of proteins – molecules that occur in an almost infinite number of forms.

Antibodies are made up of four polypeptide chains. The chains of one pair are long and are called **heavy chains**, while the chains of the other pair are shorter and are known as **light chains**. Each antibody has a specific binding site that fits very precisely onto a specific antigen to form what is known as an **antigen–antibody complex**. The binding site is different on different antibodies and is therefore called the **variable region**. Each binding site consists of a sequence of amino acids that form a specific 3-D shape that binds directly to a specific antigen. The rest of the antibody is known as the **constant region**. This binds to receptors on cells such as B cells. The structure of an antibody is illustrated in Figure 1.

Hint

One molecule fitting neatly with another is a recurring theme throughout biology. We met it with enzymes (see Topic 1.7) and with T cells (see Topic 5.3) and it features again here. While the 'lock and key' image is helpful, remember that, with the induced fit model of enzyme action, the molecules are flexible rather than rigid. This is the same for antibodies. The image of a hand fitting a glove is therefore perhaps a better one when it comes to understanding the process.

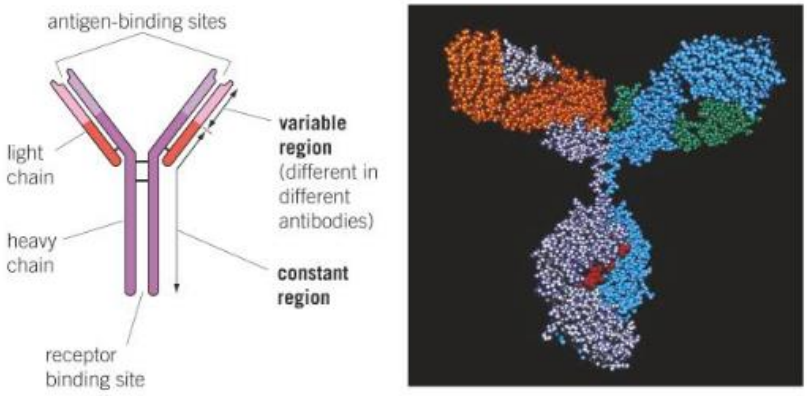
How the antibody leads to the destruction of the antigen

It is important to understand that antibodies do not destroy antigens directly but rather prepare the antigen for destruction. Different antibodies lead to the destruction of an antigen in a range of ways. Take the example of when the antigen is a bacterial cell – antibodies assist in its destruction in two ways:

- They cause agglutination of the bacterial cells (Figure 2). In this way clumps of bacterial cells are formed, making it easier for the phagocytes to locate them as they are less spread-out within the body.
- They then serve as markers that stimulate phagocytes to engulf the bacterial cells to which they are attached.

Study tip

Agglutination is possible because each antibody has two antigen binding sites.



◀ **Figure 1** *Structure of an antibody (left); molecular model of an antibody (right). This Y-shaped protein is produced by B lymphocytes as part of the immune response*

Questions

1. Explain in as much detail as you can why an antibody is described as a quaternary protein.

2. Precisely what type of molecule is an antigen, and where in the cell would it be found.

3. When we are infected by a virus our lymphocytes produce antibodies specific to the antigens on the pathogen. In this context explain the meaning of the term 'specific'.

4. Explain what a memory cell is.

2. Planning an Essay

As part of your final A-level exam you will need to write an essay (you will have a choice of 2). You are now going to plan an essay and then write it. This essay will be marked by your teacher when you start the course. The title of the essay is.

The importance of protein in biology.

Start by identifying 6 areas of biology where protein is important. Complete a summary of what you know in the table below.

1. Enzymes
2.
3.
4.
5.
6.

Guide to writing an essay in Biology.

The essay is worth 25 marks.

It should take you around 45 minutes to complete (not including planning or research).

It should be between 400 and 600 words. Five marks will be deducted if it is outside this range.

You should choose the 4 areas that you can write about most confidently. You will only gain marks for 4 areas. If you write on more than 4 areas the best 4 will be marked.

You must address the theme of the question; in this case it is the importance of the protein. At the end of each area you write about explain why this is important in biology.

Do not write an introduction or summary paragraph. Although in many subjects it might be important, in a Biology essay you will almost never gain marks, and it may take you over your word count.

Any inaccurate or irrelevant material will be negatively marked (that means it can reduce your mark).

Complete your essay below.

3. Help and Mark Scheme

1. Describe how a phagocyte helps to fight disease.
    - Engulfs pathogen
    - Releases enzymes
    - Digests

2. Describe how a lymphocyte helps to fight disease.
    - Produces antibodies
    - Specific to antigens on pathogen
    - Destroys pathogen
    - Produces antitoxins
    - Specific to toxin
    - Neutralises toxin

3. What is an antigen?
    - (Glyco)protein
    - Found on cell surface of pathogen (and all other cells)
    - Recognised by pathogen

4. What is an antibody?
    - Protein
    - Produced by lymphocyte
    - Specific to antigen

5. Covid-19 is a virus. It is currently uncertain if humans will develop lasting immunity to Covid-19 after infection.

(iv) Explain why it was initially assumed that if someone had Covid-19 they would not get it again.
    - Exposure to virus would result in memory cells
    - Which produce antibodies
    - Quickly/in greater numbers
    - After second exposure

(v) Explain why it might be the case that someone who had previously had Covid-19 might not have lasting immunity.
    - Virus might mutate
    - Resulting in different antigens
    - Now not recognised by memory cells
    - Number of memory cells might reduce over time

(vi) Explain how a vaccination for Covid 19 might be developed.
    - Antigen(s) on virus identified
    - Antigens injected into patient
    - Reference to trialling/safety issues

Questions

1. Explain in as much detail as you can why an antibody is described as a quaternary protein.

- More than one polypeptide chain
- 2 light and 2 heavy chains

2. Precisely what type of molecule is an antigen, and where in the cell would it be found.

- Glycoprotein
- Projects from cell membrane

3. When we are infected by a virus our lymphocytes produce antibodies specific to the antigens on the pathogen. In this context explain the meaning of the term 'specific'.

- The tertiary/quaternary structure is complimentary
- Idea of 3D shape matching

4. Explain what a memory cell is.

- Lymphocyte
- Produced in large numbers after initial exposure to pathogen/antigens
- Remains in blood
- Able to produce specific antibodies in large numbers/quickly