11. Immunity

1. Describe the role of lysosomes in animal cells in defence against pathogens.
   - formation of phagolysosomes / described: fusion of lysosome with phagosome / phagocytic vesicle or vacuole
   - breakdown / digestion of pathogen / bacteria / microorganisms
   - By two named enzymes: e.g. lysozyme, protease, lipase, carbohydrase, nuclease
   - Any two named substrates that are hydrolysed: e.g. polysaccharides, peptidoglycans, proteins, lipids, glycogen, nucleic acids
   - To form harmless / useful / soluble products

2. State what is meant by a non-self antigen.
   - foreign protein / glycoprotein that stimulates an immune response / production of antibodies / activation of lymphocytes

3.

Fig. 3.3 is a diagram of a protein in the cell surface membrane of a macrophage from a mouse.

Macrophages use these proteins in antigen presentation. Non-self antigens bind to the proteins and are involved in the activation of specific T-lymphocytes during the immune response.

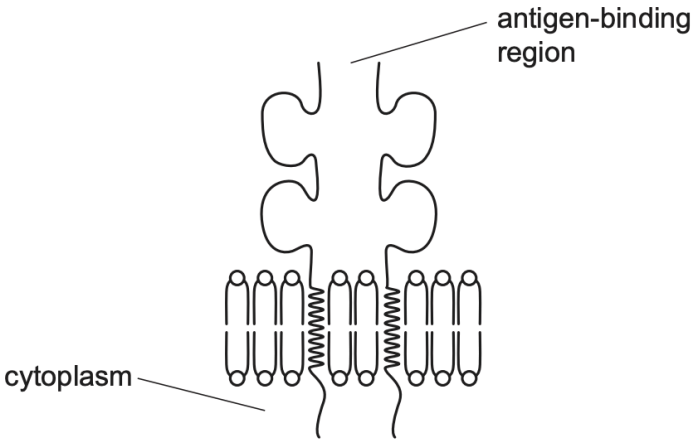


Fig. 3.3

Some pathogens enter human cells. Macrophages partially digest these pathogens and present antigens to T-lymphocytes during immune responses. With reference to Fig. 3.3, explain how T-lymphocytes respond to infection by a specific type of pathogen.

- specific T-lymphocytes have receptors complementary to the antigen
- specific T-lymphocytes bind to antigen on surface of antigen-presenting cell / macrophage
- T-lymphocytes divide many times by mitosis / undergo clonal expansion
- T-helper cells secrete cytokines / interleukins / interferon

- effect of cytokine: activation of B-lymphocytes / increased phagocytosis by macrophages
- T-killer cells bind / attach to infected cells and destroy them
- action of T-killer cells: ref to perforin / granzyme / hydrogen peroxide / toxins
- production of memory cells (in context of T-lymphocytes / T-helper cells / T-killer cells)

4. Outline the features of non-self antigens.
   - stimulates an immune response
   - usually protein / glycoprotein / polysaccharides
   - recognised by / activates / stimulates named immune system cell: e.g. phagocyte / macrophage / neutrophil / (B- / T-) lymphocyte
   - cause production of (specific) antibodies / bind to (specific) antibodies // complementary shape to antigen binding site on antibody // complementary to receptors on lymphocytes
   - example of location of non-self antigen:
     surface of pathogen / infected cell / tumour cell / non-body cell / foreign cell
     bacterial cell wall / flagella
     viral capsid / protein coat / envelope
   - AVP: high molecular weight

5.

(b) Four different types of cells of the immune system are shown in Table 3.1.

Complete Table 3.1:

- use a tick (✓) if the description applies to the named cell of the immune system
- use a cross (✗) if the description does **not** apply.

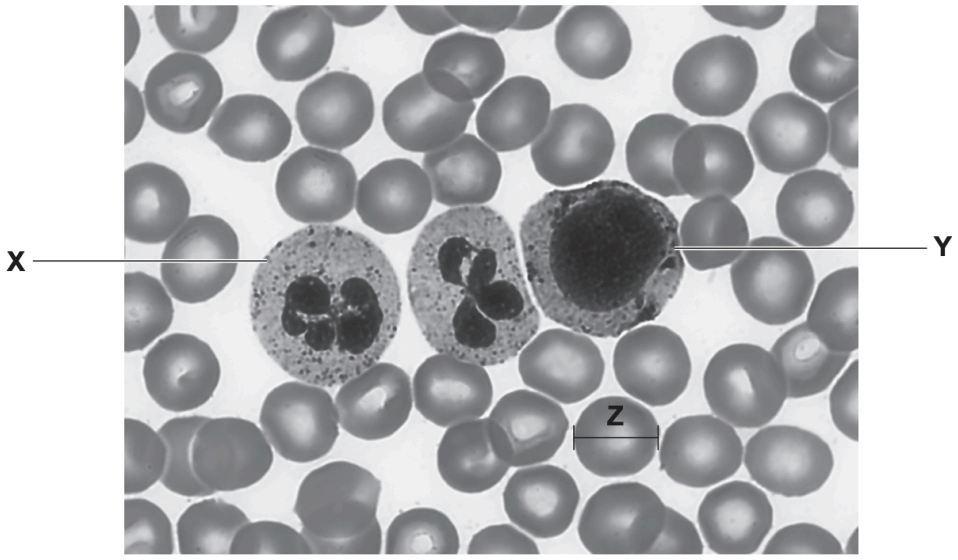
Table 3.1

description of cell	cell of the immune system			
	B-lymphocyte	**plasma cell**	**T-helper cell**	**T-killer cell**
able to go through a number of cell cycles (clonal expansion)				
main role is to secrete cytokine during an immune response				
present during a **primary** immune response to a virus				

description of cell	cell of the immune system			
	B-lymphocyte	plasma cell	T-helper cell	T-killer cell
able to go through a number of cell cycles (clonal expansion)	✓	x	✓	✓
main role is to secrete cytokine during an immune response	x	x	✓	x
present during a **primary** immune response to a virus	✓ ;	✓ ;	✓ ;	✓ ;

6.

(a) Fig. 3.1 is a photomicrograph showing different types of blood cell.



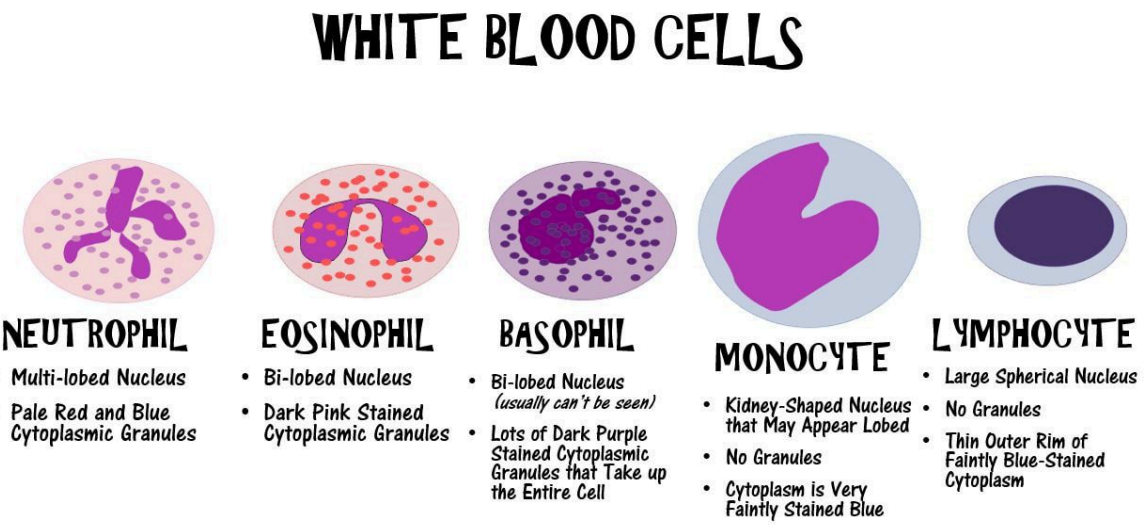
Identify cell X and cell Y

- X: neutrophil
- Y: monocyte (allow lymphocyte)

7. The presence of gliadin (a protein in gluten) causes the immune system of a person with coeliac disease to respond by producing anti-gliadin antibodies. Describe the sequence of events that results in the immune system producing antigliadin antibodies.
   - presence of non-self / foreign antigen // gliadin acts as antigen // ref. to antigen presentation by macrophages
   - recognition / activation of B-lymphocytes / T-lymphocytes; clonal selection
   - clonal expansion of B-lymphocytes and T-lymphocytes

- T-helper cells secrete / release cytokine
- cytokine stimulates B-lymphocyte response
- B-lymphocytes differentiate to form plasma cells
- plasma cells produce / secrete (anti-gliadin) antibodies

NOTE:



NOTE:

- Monocyte: A large cell that has a bean-shaped (kidney-shaped) nucleus. It can develop into a macrophage.
- Lymphocyte: A cell that has a large spherical nucleus and little cytoplasm. It responds to non-self antigens.
- Neutrophil: A cell that has a lobed nucleus. It is phagocytic.

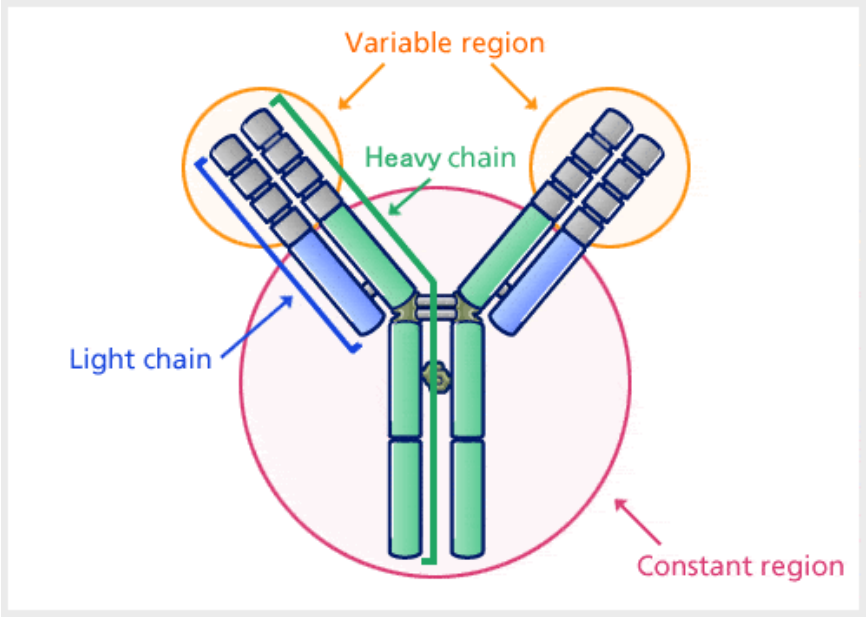
8. Explain how the ability of the immune system to resist the damaging effects of a pathogen is affected by destruction of T-helper cells.
   - fewer cytokines released
   - fewer plasma cells, so fewer antibodies produced
   - fewer macrophages stimulated / less production of 'angry' macrophages / less antigen presentation by macrophages
   - fewer T-killer cells stimulated to divide / less T-killer cells / less infected cells killed by T-killer cells
   - fewer memory cells produced by the primary response

9. Outline how anti-CCR5 monoclonal antibodies can be synthesised in the laboratory using the hybridoma method.
   - small mammal (eg. rat) is injected with CCR5 (antigen)
   - immune response occurs over several weeks
   - plasma cells / B-lymphocytes / B-cells extracted from spleen

- plasma cells / B-lymphocytes / B-cells fused with myeloma / tumour / cancer cells to form hybridomas
- screening / selection for hybridomas producing desired monoclonal antibodies
- AVP: hybridoma cells separated into wells to produce clones
- ref. to large scale production

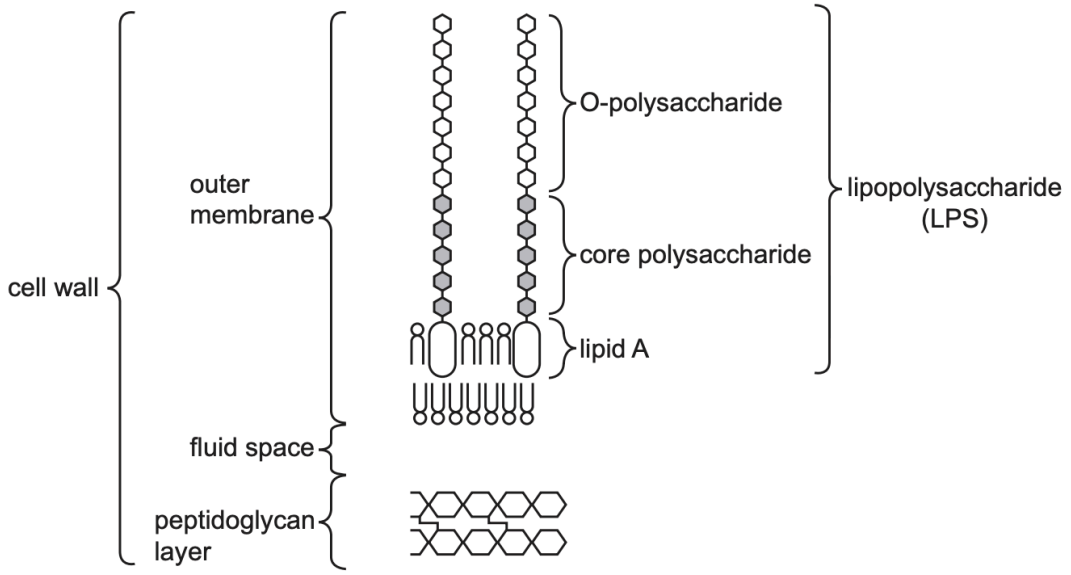
10. Vaccines stimulate an immune response with the production of antibodies. Explain how antibodies will reduce the spread of the malarial pathogen through the bloodstream.
    - antibodies bind to antigens / epitopes – form antibody-antigen complex
    - antibodies complementary in shape to antigens on surface of malarial pathogen
    - prevent pathogen / infective stage entering red blood cells / liver cells
    - help / facilitate / mark pathogen for destruction by phagocytes / stimulates phagocytosis
    - AVP: phagocytes have receptors for constant region of antibodies
    - AVP: ref. to agglutination / described

NOTE:
- Phagocytes have receptors that are complementary in shape to the constant region of antibodies
- Antigens are complementary to the variable region of antibodies



11.

Monoclonal antibodies (mAbs) can be designed to act against components of the cell wall of *V. cholerae*. The cell wall has an outer membrane with lipopolysaccharide (LPS) molecules, shown in Fig. 4.3.



• mAb 2D6 acts against the O-polysaccharide

• mAb ZAC-3 acts against the core polysaccharide and lipid A components.

Explain why the mAb ZAC-3 (a monoclonal antibody) produced against the core polysaccharide and lipid A components will not act against the O-polysaccharide of the LPS molecules.

- mAbs specific / different antigen binding sites / binding sites for antigen OR each mAb binds to a specific / particular antigen
- each mAb has specific / different tertiary structure / variable region / primary structure / sequence of amino acids
- binding site and antigen have complementary shapes OR ZAC-3 complementary shape to core polysaccharide and lipid A OR 2D6 complementary shape to O-polysaccharide

12. Choleragen is produced after V. cholerae has penetrated (passed through) the mucus lining and attached to intestinal epithelial cells.

Monoclonal antibodies (mAbs) can be designed to act against components of the cell wall of *V. cholerae*. The cell wall has an outer membrane with lipopolysaccharide (LPS) molecules, shown in Fig. 4.3.

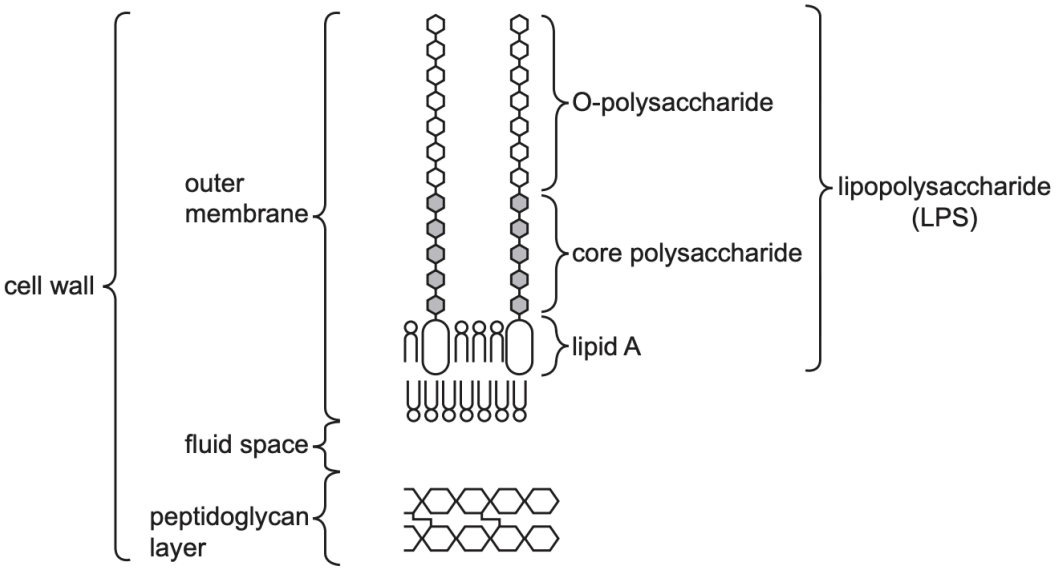


Fig. 4.3

The core polysaccharide and the lipid A components of the LPS molecules are the same in *V. cholerae* O1 and *V. cholerae* O139. However they have different O-polysaccharides.

There are also different types of *V. cholerae* O1 and these have different O-polysaccharides.

• mAb 2D6 acts against the O-polysaccharide
• mAb ZAC-3 acts against the core polysaccharide and lipid A components.

The results of the tests showed that both mAbs were effective in causing agglutination (clumping) of bacteria and in preventing their motility. This suggests they may be useful for preventing cholera and for treating the disease. Discuss whether mAb 2D6 and mAb ZAC-3 may be useful for preventing cholera and for treating the disease.

- agglutination / motility prevented, so bacteria less able to penetrate mucus / attach to intestinal epithelial cells / colonise intestine
- less / no choleragen / toxin released
- bacteria passed out in faeces not able to cause disease in others
- phagocytosis more effective: e.g. macrophages stimulated to carry out phagocytosis
- to prevent disease, needs to be given at early stages / before colonising intestine
- passive immunity / passive vaccine for immediate protection/ treatment
- acts beside immune system / immune system cells so increased effect
- quicker recovery if a person has cholera

- useful when, there is antibiotic resistance / antibiotics cannot be given
- mAb ZAC-3 may be more effective for cholera caused by wider range of V. cholerae OR mAb ZAC-3 may be useful if exact form of V. cholerae not known OR mAb 2D6, needs to be targeted against specific V. cholerae forms / may not be effective against other V. cholerae forms

13. Explain how the structure of an antigen-binding site makes it specific to a particular antigen.
    - antigen-binding site / variable region has a shape that is complementary to antigen
    - antigen-binding site / variable region has specific sequence of amino acids / primary structure
    - different amino acids have different R-groups / side chains so give different tertiary structures / shapes (for binding to antigens) ;

14. State the function of the hinge region of the antibody
    - allows flexibility for binding (to antigens)

15. Suggest an advantage of antibodies binding to receptors on macrophages.
    - easier for macrophage to engulf antibodies that have bound antigens / antibody-antigen complexes
    - facilitates destruction of pathogens ‘marked’ by antibodies

16. Outline the sequence of events that leads to the formation of a phagocytic vacuole after detection of bacterial cells by a macrophage.
    - chemotaxis / chemotactic response occurs: bacterial cells antigens bind to receptors on macrophage cell surface
    - endocytosis occurs: macrophage cell surface membrane surrounds bacterial cells OR pseudopodia surrounds / forms round bacterial cell OR macrophage/ phagocyte envelops / engulfs bacterial cells
    - membrane fusion occurs: phagocytic vacuole pinches off

17. Suggest and explain the advantages of using vaccine for prevention and control of TB. The vaccine uses live, weakened bacteria and can be freeze-dried
    - cells are replicating because live vaccine
    - high / increased levels of non-self / foreign antigen because live vaccine
    - so strong / effective / good primary immune response: T-/B-memory cells are formed
    - provides artificial active immunity
    - so boosters not needed to build sufficient immunity
    - vaccine does not cause disease / TB because weakened / attenuated
    - easy to transport / store / deliver because freeze-dried

18. Compare lysozyme and penicillin to show the similarities and differences between these two antibacterial agents.

    Similarities:

    - Both penicillin and lysozymes cause cell lysis / bursting
    - By weakening / destroying cell wall

    Differences:

Lysozyme	**Penicillin**
protein/ enzyme/ catalyst	antibiotic / enzyme inhibitor
hydrolyses glycosidic bonds/ peptidoglycan molecules	inhibits transpeptidases (transpeptidases are enzymes that cause crosslinking of peptidoglycan in bacterial cell walls)
	prevents formation of peptide linkages
effective at all stages	only effective when cell is growing / synthesising cell walls
globular	contains (beta-lactam / 4-member) ring

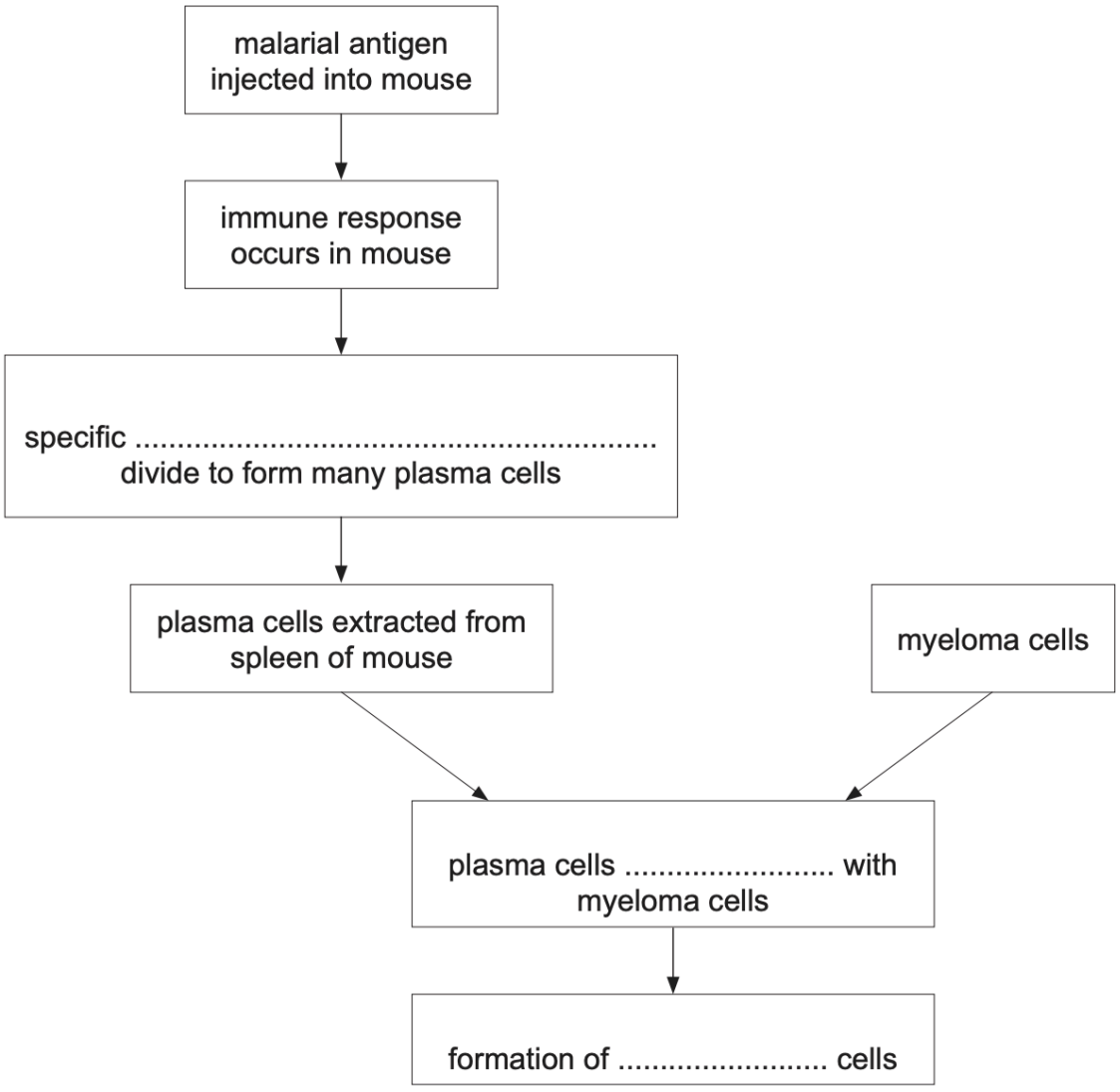
19. Explain how memory T-lymphocytes provide protection from TB in a person who has been given a vaccination.
    - provides long-term immunity
    - pathogen enters the body causing secondary immune response
    - because of presence of increased numbers of specific T-lymphocytes
    - memory T-lymphocytes recognise / bind to / are activated by the foreign antigen
    - T- helper cells secrete cytokine
    - example of consequence of increased cytokine release: increased phagocytosis / angry macrophages, increased B-lymphocyte response, enhanced T-killer cell response

20. tumour cells take up the weakened pathogens in the vaccine and act as antigen-presenting cells.Suggest how antigen presentation by tumour cells stimulates an immune response that leads to the destruction of the tumour cells.
    - some T-lymphocytes have receptors with a complementary shape to the antigen on the tumour cell
    - antigens on the surface of the tumour cell bind to receptor – clonal selection
    - T-lymphocytes divide by mitosis – clonal expansion

- T-killer cells are produced that destroy the tumour cell
- method used by T-killer cell to destroy tumour cell: e.g. perforin, hydrogen peroxide, granzymes (toxins)
- phagocytosis of cancer cells

1. The influenza virus can mutate frequently to produce different strains of the virus. A new vaccine is often necessary to stimulate the production of new antibodies to these new strains. Explain why different antibodies need to be produced to give immunity to these new strains.
   - as influenza virus mutates, antigen (proteins) altered / altered capsid proteins
   - antibodies are specific to antigens ;
   - ref. to complementary shape (between variable regions of antibody and antigen) ;
   - ref. to variable regions / Fab, at the ends

2. Complete: (stages in production of monoclonal antibodies)



- B–lymphocytes / B–cells
- Fuse
- Hybridoma

3. The diseases myasthenia gravis (MG) and HIV/AIDS both involve disorders of the immune system.
   The cause of MG involves a response by B-lymphocytes. Explain why MG is called a disorder of the immune system.
   - (MG is an) autoimmune, disease / disorder / condition
   - (disease in which) failure to distinguish between self and non-self antigens
   - immune response occurs against / antibody produced against, self antigens
   - idea that defective lymphocytes not destroyed (during development) ;

4. Studies have indicated that T-lymphocytes are involved in stimulating the B-lymphocyte response that causes MG. Research has been carried out on a vaccine that will provide a person with active immunity against these T-lymphocytes and B-lymphocytes. Suggest and explain how this vaccine will provide a person with active immunity against the T-lymphocytes and B-lymphocytes responsible for causing MG.
   - vaccine contains antigens: antigens of defective T-lymphocytes and B-lymphocytes
   - stimulates an immune response ;
   - Detail:
     - macrophages and antigen presentation
     - ref. to specific lymphocytes involved
     - clonal selection of lymphocytes
     - recognition by / activation of lymphocytes
     - clonal expansion of lymphocytes
     - production of plasma cells in context of B-lymphocytes
     - production of memory cells
     - T-helper cells produce cytokine
   - antibody produced against (defective) T-lymphocytes / B-lymphocytes in context of primary or secondary response
   - memory cells, remain / give long-lasting effect
   - memory cells allow secondary immune response to (defective) lymphocytes

5.

Smallpox is the only infectious disease of humans that has been globally eradicated. This eradication was due mainly to a successful global vaccination programme. Most people who were given the vaccine gained immunity to the disease.

A student correctly listed four reasons for the success of the global vaccination programme for smallpox. These reasons are listed in Fig. 2.1.

- The virus did not mutate.
- A live virus, closely related to the smallpox virus, was used in the vaccine.
- The vaccine was freeze-dried and so was thermostable (heat stable).
- The vaccine was easy to administer (give), so little training was required.

Did not mutate

- same vaccine could be used (everywhere / for many years) ; no need to manufacture different vaccines
- (so) a person was protected for a long time ; same virus so vaccinated person did not become ill on repeated exposure; no, risk of vaccine becoming ineffective
- no research / trials / development required for new vaccine(s) ;

Live and closely related

- (closely related so) same antigens / (gives the desired) immune response / antibodies produced / memory cells produced / memory cells remain ;
- live virus replicates, so gives a stronger immune response than inactive virus ;
- no need for boosters ;
- not smallpox virus, so fewer health and safety issues ; more people willing to have vaccine ;

Thermostable vaccine

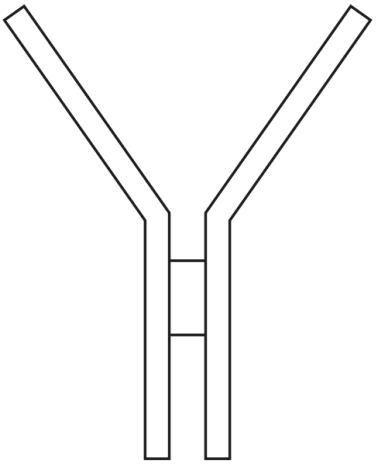
- longer shelf-life / doesn't degrade easily / no refrigeration needed ;
- could be easily stored / transported
- no wastage

Easy to administer

- using non-medical staff, increased number of people can be vaccinated / percentage cover / herd immunity ; makes vaccine) more accessible to people in developing countries.

6.

Fig. 2.2 shows the structure of an antibody molecule found in the blood plasma of a shark.



State how the quaternary structure of a human antibody molecule differs from the quaternary structure of the shark antibody molecule shown in Fig. 2.2.

- Human antibody molecule consists of 4 polypeptide chains – 2 light chains and 2 heavy chains

7. Human antibodies are used in the treatment of some forms of cancer. However, the antibodies injected into the bloodstream can only reach a small percentage of the cancer cells that form the cancerous tumour.
   Shark antibodies are smaller than human antibodies. Scientists are researching the possibility of injecting shark antibodies into the bloodstream to treat cancerous tumours in humans.
   Suggest how using the smaller shark antibodies may be more effective in reaching a greater percentage of cancer cells than human antibodies and lead to greater success at treating cancer.
   - easier to pass through gaps in capillary wall / endothelium ;
   - (so) more enter tissue fluid (surrounding tumour cells) ;
   - idea of more cancer cells destroyed quickly ;
   - (smaller so) may not trigger an immune response ;
   - AVP ;
     - e.g. easier to, diffuse / move, through tumour to reach, more / all, cells
     - binds more tightly to antigens on (cancer) cell surface(s)
     - suggestion that makes macrophage response stronger
     - smaller overall size even when drugs attached

8. Explain how injection of antibodies into the bloodstream can protect a person from disease after infection by a pathogen.
   - gives (artificial) passive immunity ;
   - fast acting / quick response / time not needed for immune response ;

- antibody binds to (non-self / foreign) antigen (on surface of a pathogen) ;
- antibodies bind to toxins, neutralising them / antibodies act as antitoxins ;
- ref phagocytosis ;
- AVP:
    - e.g. opsonisation
    - bind to flagella and immobilise pathogen
    - antibodies cause, agglutination / clumping of pathogen

9. The glycoproteins haemagglutinin and neuraminidase are found in the influenza virus and in the virosomes used in a vaccine against the influenza virus. Haemagglutinin binds to a receptor in the cell surface membrane of phagocytes. Suggest why haemagglutinin is present in virosomes used in the vaccine for influenza.
    - acts as a non-self / foreign, antigen ;
    - triggers / stimulates, primary immune response or provides (artificial) active immunity ;
    - (leads to) formation of antigen presenting cell ; endocytosis / phagocytosis, to present antigen (by, macrophage neutrophil)
    - Activates B lymphocytes / T lymphocytes ; clonal selection
    - formation of memory cells ;

10. Different strains of the influenza virus have formed as a result of mutations. Each strain of the virus contains the enzyme neuraminidase. Neuraminidase helps the virus to leave host cells after the virus has replicated. In each strain of the influenza virus, the primary structure of the active site of the neuraminidase enzyme remains unchanged. Suggest why the primary structure of the active site of neuraminidase remains unchanged in each strain of the influenza virus.
    - no change in, shape / tertiary structure / conformation, of active site ;
    - (same) substrate able to bind to active site ;
    - consequence ; e.g. so viruses can leave host cell to infect other cells ;
    - the mutation is not occurring in the, gene / section of gene coding for amino acids in active site for neuraminidase ;
    - the gene for neuraminidase is essential for survival ;

11. After a person has been infected with HCMV (virus), the virus remains in a dormant state in the body for life. If the virus becomes active again (reactivates), the virus will only cause serious illness if the person has a weak immune system at that time. Explain why the response to reactivation of HCMV is more likely to cause serious illness in a person who has a weak immune system.
    - time delay in immune response (compared to normal) ;
        - e.g. takes a longer time for, immune system to respond
        - slower (secondary) immune response

    - immune response similar to primary response
- more time / easier for HMCV to infect cells / replicate / spread (so cause damage) ;
- few(er) immune system cells (in circulation)
    - e.g. fewer macrophages / neutrophils
    - fewer (B- and T-) memory cells
    - fewer, (B/T,-) lymphocytes / T-helper cells / T-killer (or cytotoxic) cells
    - fewer / no, plasma cells
- consequence of fewer immune system cells – 2 marks:
    - less chance of encounter with / recognition of / activation by (non-self / foreign) antigen / HMCV / virus / pathogen / infected cell
    - (fewer memory cells) ref. reduced clonal expansion / AW (so fewer lymphocytes / plasma cells)
    - (fewer plasma cells) lower concentration of antibodies
    - (fewer T-helper cells) less cytokine released
    - (fewer T-killer cells) fewer infected cells killed
    - (fewer phagocytes) less phagocytosis for antigen presentation

12. To help prevent the development and spread of drug resistance in Plasmodium, WHO recommends using a treatment known as ACT. ACT involves 2 different types of drug:
    • a fast-acting drug which causes rapid decrease in number of P. falciparum
    • one or more longer-acting drugs that eliminate any remaining pathogens.
    Suggest why using ACT with the two different types of drug is more effective in preventing the development of drug resistance in Plasmodium than a treatment using only one type of drug.

- drugs have different, targets / mechanisms of action // drugs, act on different, structures / processes / stages of life cycle ;
- unlikely / less likely, for mutations against all drugs to occur ;
- unlikely for resistance to occur against all the drugs ;
- if there is resistance to one, the other drug(s) will, kill / AW, all pathogens ;
- (so) prevents, gene / allele, from being passed on ;
- AVP: low numbers left, so less probability of mutations arising; if all pathogens are killed, no replication / no mutations, for resistance to develop.

In some areas, partial artemisinin resistance has developed. This means ACT takes a longer time for the pathogen to be eliminated from the body. Explain why there is an increased risk of transmission of the pathogen to other people if a person is receiving ACT and the pathogen has partial artemisinin resistance.

- increased time when person has Plasmodium in blood / circulation ; person acts as a reservoir for Plasmodium

- (so) quantity / concentration / number, of Plasmodium, remains high / increases ; allows Plasmodium, to reproduce / replicate
- increased, time / risk / chance / AW, of, being exposed to, vectors / mosquitoes / Anopheles (for blood meal) ;
- more infected Anopheles / mosquitoes available to feed on uninfected people