State 1 difference in cellular structures between immature B cell and a plasma cell.

- More extensive rER/ GA
- More ribosomes

Explain why plasma cells are rich in endoplasmic reticulum and mitochondria. (3)

- Plasma cells function by secreting large amount of antibodies which bind to foreign antigens
- Large number of mitochondria are needed to synthesize ATP to provide large amount of energy which is used in
- Endoplasmic reticulum to synthesize antibody proteins for secretion

Define the term antibody. (2)

- Antibody is a protein complex that is secreted from plasma cells.
- Antibody has a specific antigen binding site that binds to a specific epitope on an antigen

Define the term antigen. (1)

- Antigen is a substance that elicits immune response; usually by binding to the receptors found on the surface of immune cells such as on B cells and T cells.

State 1 reason why blood plasma usually contains a variety of antibodies. (1)

- Blood plasma contains a variety of antigens and each antigen may contain a variety of epitopes.
- Acquired immunity responds to these antigens by the production of a variety of specific antibodies.

Explain the term single specificity with respect to antibodies. (1)

- An antibody can bind to only one epitope.

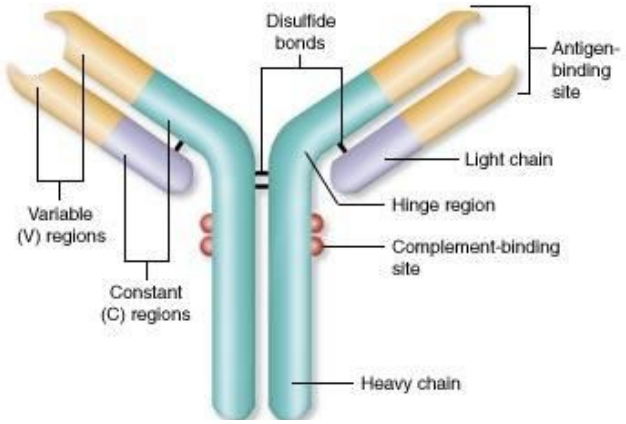
Explain how different antibodies recognise different antigens. (1) (IJC 2015)

- Antigen binding site with specific 3D configuration
- Complementary in shape to specific antigen

Explain fully how the structure of antibody proteins gives them single specificity. (3)

- The variable region of an antibody forms an antigen binding site.
- Different antigen binding sites has different conformations due to somatic recombinations and somatic hypermutations of the V segment of the VDJC genes during lymphocyte development
- Therefore, each antibody has an antigen binding site that is complementary in shape to the conformation of only one epitope.

Draw and label the basic structural features of an antibody. [3]



How do the basic structural features allow the antibody to function? [4]

- The bivalent (2 antigen recognition sites on 1 antibody) structure assists in making antigen-antibody complexes.
- The disulfide bridges keep the 4 peptide chains in proper, robust structure
- The light and heavy chain combinations allow for greater combinatorial diversity
- The variable regions allow for very high antigen specificity
- The constant regions determine isotype (e.g. IgG) and effector functions e.g. agglutination

Distinguish self and non-self. (2)

- Self refers to antigen(s) within a person's body;
- all the antigens that the immune system does not recognise as foreign
- Non-self refers to antigen(s) that are not in a person's body;
- Recognises as foreign

State the importance of the antigens on the RBC. (1)

- For cell recognition i.e. for the immune system to be able to differentiate between cells that belong to itself and cells that are foreign/ self and non-self

Suggest how a viral infection may cause the immune system to turn against its own body cells. [2]

- Viral RNA/DNA codes for the synthesis of glycoproteins that are then embedded into the host cell surface membrane prior to the virus budding
- The viral glycoproteins are recognised as foreign antigens

Predict 1 component of the virus which likely be of importance in producing a vaccine against the virus. Give a reason for your answer. (2)

- Surface glycoproteins;
- Surface glycoproteins are projected towards the external environment which makes it easy for antigen receptors/ antibodies to recognise and bind

Ref. to fig. 6.1, explain why injecting human proteins into a chicken causes an immune response. (2)

- Human proteins are recognised as foreign/ antigens
- Stimulates macrophages to engulf it
- Stimulates B cells to differentiate to form plasma cells and antibodies against it

Suggest why investigators describe the reaction of the chicken antibodies with human proteins as 100% (tube A).

- Tube A acts as a positive control with the highest % of antibodies reacting
- Taken as 100% immunological reaction for comparison with the rest of the samples

Describe and explain the conclusions which could be made about the evolutionary relationships between the mammals shown in fig. 6.1. (4) (IJC 2015)

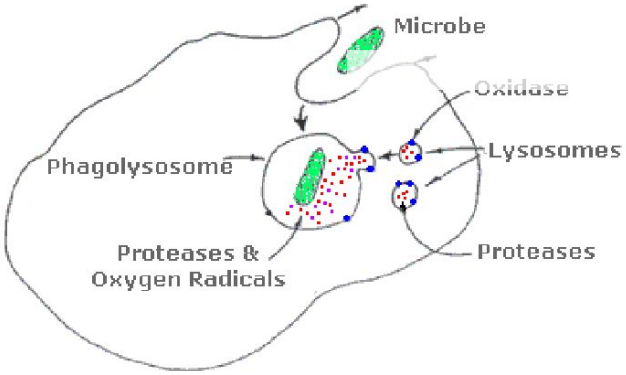
- Chimpanzees are the most closely related to humans
- Followed by Baboons
- Dogs are not closely related to humans

(explanation)

- Chimpanzee and human antigens are the most similar in terms of amino acid sequence
- Gives the strongest immunological response to chicken antibodies suggest that humans and chimpanzees share the most recent common ancestor
- DNA sequence coding for antigen is similar with high degree of homology

Describe by means of annotated diagrams, how a phagocyte destroys bacteria after they have been engulfed. (4)

- The phagosome which enclosed the bacteria within it fuses with lysosomes
- This result in a phagolysosome which contains various factors which will kill the bacteria
- The bacteria in the phagolysosome will be killed by the proteases found within it
- The bacteria in the phagolysosome will be killed by the acidification within the phagolysosome due to the H+ transport into it by H+ transporter found within the membrane of phagolysosome
- Waste materials are released outside of the cells via exocytosis.



Describe how particles such as bacteria are taken up by phagocytes. (2)

- endocytosis/phagocytosis
- Receptors on cell surface/bacteria marked by antibodies
- Pseudopodia surrounding/engulfing the bacteria + formation of vacuole/phagosome

Phagocytes contain many lysosomes. State the function of lysosomes in phagocytes. (1)

- Hydrolytic enzymes such as proteases found in lysosome digests bacteria

Explain how the action of phagocytosis such as neutrophils is assisted by the humoral immune response. (3)

- During opsonization, antibodies bind to antigens on bacteria
- Which renders the bacteria easily recognisable by neutrophils as the neutrophils have receptors for these antibodies
- Binding of antibodies to foreign particles causes agglutination which also increases rate of phagocytosis

Suggest how antibodies can aid in fighting infection. (2)

- Binding antigen, blocking it from attaching to host cell
- Cause agglutination of virus to allow phagocytes to engulf pathogen more easily
- OR cause opsonization of pathogens to attract phagocytes to the pathogen

Describe the roles of
(i) T cytotoxic cells in the cell mediated immune response. (2)

- CD8+ T cells bind to antigen displayed by the antigen presenting cells which are infected by the pathogens to differentiate into cytotoxic T cells
- Cytotoxic T cells then secrete perforin that forms pores in the membrane of the infected cell.
- Granzyme enzymes break down proteins and granulysin enzymes that induce apoptosis in the infected cell

(ii) T helper cells in the humoral immune response. (3)

- The T cell receptors of CD4+ T cells bind to the antigen displayed on the antigen presenting cells. The CD4+ glycoproteins bind to MHC II.
- Both cells stimulated to produce cytokines which activate $CD4^+$ T cells to become T helper cells.
- The T cell receptor of T helper cells bind to antigen displayed by B cells, secretes cytokines and activate B cells to differentiate and proliferate into plasma cells which secretes antibodies

Describe briefly the differences in the way the B and T lymphocytes act during the immune response. (3)

B cells	T cells
Able to engulf the foreign antigens by receptor mediated endocytosis and display it on the CSM by MHC II	Not able to carry out endocytosis of antigen, but it binds to the antigen presented to activate itself, then activating the B cell and CD8+ T cell
Differentiate into plasma cells	Differentiate into T helper cells and T cytotoxic cells
Plasma cells secrete antibodies which bind to pathogen and triggers neutralisation, opsonization, activation of complement system and recruitment of natural killer cells	T helper cells activates T cytotoxic cells and B cells; T cytotoxic cells secrete perforin that forms pores in the CSM, and enzymes that break down proteins and induce apoptosis in the infected cell

State 4 ways which a B cell differs from T cells. (4)

B cells	T cells
Antigen receptors have 2 light chains and 2 heavy chains	Antigen receptors have 1 alpha and 1 beta chain
Stem cells develop into B cells in the bone marrow	Stem cells migrate to the thymus to develop into T cells
differentiate into plasma cells upon activation	Differentiate into T helper cells/ T cytotoxic cells
Are antigen presenting cells and contain class II MHC	Are not antigen presenting cells but contain CD4 or CD8 which binds to class II and class I MHC respectively

Explain the production of antibodies against a pathogen. (6)

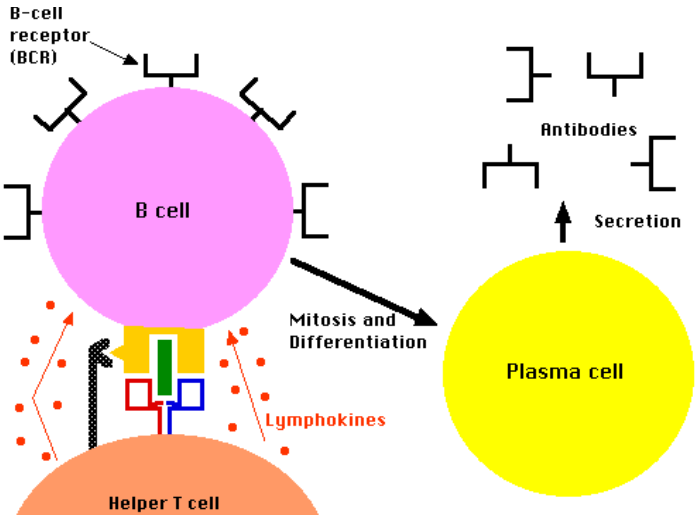
- Antigen engulfed by macrophage by endocytosis, and antigen presented by macrophage on MHC II on CSM
- CD4+ T cells binds to macrophage and becomes activated (during T cell maturation)
- Activated helper T cell binds to naive B cell and activates naive B cell
- B cells start to differentiate and proliferate to plasma cells and memory B cells
- Plasma cells begin to produce antibodies via VDJ and VJ genetic recombination (during B cells maturation), class switching and somatic hypermutation (only upon antigen binding) to increase the antibodies' affinity to the specific antigen and
- Antibodies are secreted by exocytosis to bind to antigen on pathogen
- Memory B cells give long-term immunity/ allow rapid antibody production upon secondary exposure to antigen

Describe how vaccination can control disease. [8]

- Vaccination stimulates immune response by introducing viral or bacterial antigen into the host
- Antigen engulfed by macrophage (by endocytosis) and antigen presented by macrophage on MHC II on CSM
- CD4+ T cells binds to macrophage and becomes activated
- Activated T helper cells binds to naive B cells to activate them
- B cells start to differentiate and proliferate to plasma cells and memory B cells
- Activated T helper cells also activate CD8+ T cells which differentiate and proliferate into cytotoxic T cells and memory T cells
- Upon encounter with pathogen, antibodies binds to pathogen quickly and effectively.
- Memory T cells are also able to bind to antigens expressed on infected cells effectively; preventing pathogen from multiplying and causing disease in host.

Describe how B lymphocytes (B cells) would respond in the body of a person after vaccination against whooping cough. (4)

- B cells will engulf the foreign antigens by receptor-mediated endocytosis and display it on the cell membrane by class II MHC
- CD4+ T cells binds to the antigen displayed and develops into T helper cells
- T helper cells secrete cytokine which activates B cells to differentiate and proliferate into plasma and memory cells
- The antigen receptors of B memory cells in the body produced after vaccination will have higher affinity for the antigen from the bacteria
- When the antigen is encountered in the future, the memory cells bind more readily and proliferate and differentiate faster into plasma cells.



Describe briefly the changes that occur to lymphocytes as they mature in thymus. (3)

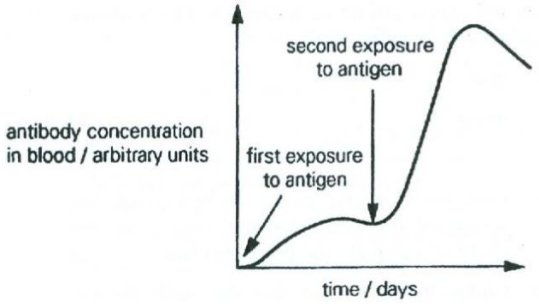
- Somatic recombination of the VJC segments of the genes occurs to produce T cells with antigen receptors of different specificity.
- Clonal selection/ test for self-reactivity occurs
- T cells with antigen receptors complementary to the epitopes of body's own molecules are removed by apoptosis

Explain why people are often ill for several weeks after they catch a disease, even though they can make antibodies against the disease. (3)

- The primary response to an antigen is slow.
- B cells which are activated upon antigen binding divides by mitosis in clonal selection and clonal expansion. It can take several weeks to produce enough antibody molecules to fight the infection effectively.
- During this time, we usually show the symptoms of the disease concerned

Explain how memory cells is responsible for long-term immunity to tetanus. (3)

- Memory cell remains in circulation/ lymph system/ body
- Is specific to an antigen on tetanus bacteria
- Responds quickly to another infection by same strain of pathogen as there are a large number
- During secondary immune response;
- Differentiate into plasma cells to give large number of antibody molecules in short space of time



Describe and explain the differences between the first and second responses to the antigen shown in Fig. 3. [4]

Describe:

- The time taken/speed for antibody concentration to reach a peak after first exposure to antigen is longer/slower than the time to reach a peak after second exposure to antigen.
- The antibody concentration at the peak of response after first exposure to antigen is lower than the concentration after second exposure to antigen.

Explain:

- During the first exposure of the antigen, there are no memory cells specific to the epitope on the antigen. Time is needed for a few circulating T cells specific to the epitope to bind and activate the proliferation and differentiation of T cells and B cells to antibody secreting plasma cells.
- During the second exposure of the antigen, memory cells which are produced from previous exposure are able to recognise and bind the antigen within a short time. Memory cells are able to proliferate and differentiate quickly to effector T cells and plasma cells.

Explain the pattern of maternal and infant antibody shown in figure 1. (4)

- Natural passive immunity during first 9 months after conception- maternal IgG increases during pregnancy as it crosses the placenta.
- It decreases after birth as it is removed from circulation
- During first 9 months after conception- the fetus does not produce its own antibodies, because it does not have any mature B and T cells and develops in a sterile environment.
- After birth, natural active immunity- the infant produces its own antibodies shortly after birth as it begins to encounter infections;
- After birth, artificial active immunity- infant is vaccinated. Body mounts an immune response to increase concentration of antibodies further.

Explain the advantage of natural passive immunity for newborn infants. (1)

- Infant is temporarily protected against diseases which are endemic and which the mother has caught/ been vaccinated against
- Safe as opposed to vaccination where attenuated virus are injected.

Explain, with examples, what is meant by passive immunity. [4]

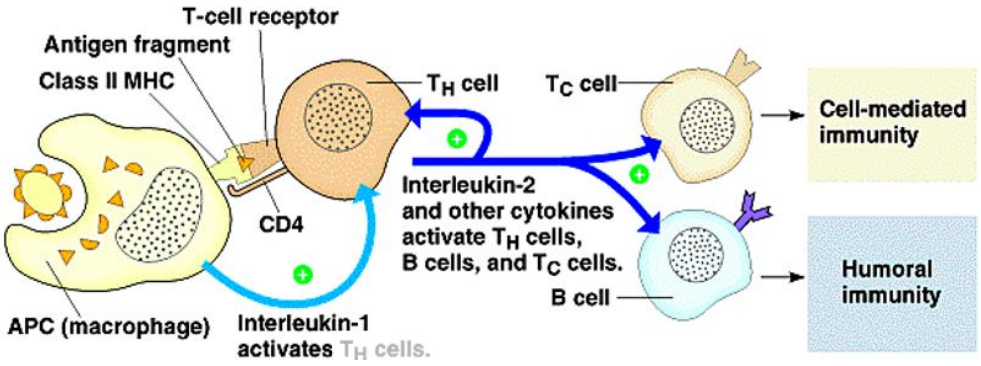
- Passive immunity refers to the immunity produced when an individual receives antibodies from another individual.
- Individual is immune to the antigens without having been exposed to the antigen.

Any 2 examples:

- foetus are immuned when mother's antibodies are transferred from mother's bloodstream through the placenta to the foetus bloodstream
- new born babies obtain immunity from the transfer of antibodies from mother's breast milk to the infant's digestive tract where they are absorbed
- injection of antivenin into person bitten by snake to neutralise venom quickly

Explain two differences between artificial active immunisation (vaccination) and artificial passive immunisation. (2)

	Artificial active	**Artificial passive**
antigen/ antibody injected	Antigens are introduced into the body by injection or by mouth, and stimulate an immune response by B and T cells	Antibodies are injected into the body to give immediate protection against a pathogen or toxin
long/ short term immunity	This provides long-term immunity but is not immediate, as the immune response takes several weeks to become effective	Antibodies are soon removed from circulation, and no immune response has occurred, so this is a temporary form of immunity



Describe how the innate and adaptive immunity interact to prevent infection by a range of microorganisms.

The innate response is the first line of host defence, with the adaptive response becoming prominent after several days.

Upon infection, innate immune system is initiated. Complement proteins are activated to form membrane attack complex on pathogen to cause cell lysis/ chemotaxis/ opsonization of pathogen;

Phagocytes such as macrophages engulfs and phagocytise pathogen;

Macrophages also acts as antigen presenting cells and presents foreign antigens on MHCII receptors;

Macrophages travel via bloodstream to lymphoid tissues where lymphocytes of adaptive immune systems are found;

Macrophages presents antigens to T cells and activates CD4 to T helper cells and CD8 to cytotoxic T cells;

Cytotoxic T cells can go on to kill infected host cells;

T helper cells may also go on to activate macrophages, which are then more efficient in degrading pathogens that it has engulfed;

B cells with complementary B cell receptors binds to antigen and undergoes clonal selection and clonal expansion via mitosis;

B cells are activated by T helper cells to produce high affinity antibodies against antigen;

Antibodies opsonize pathogen and facilitates phagocytosis by phagocytes of innate immune system;

Antibodies can also activate complement proteins of innate system to kill pathogens;

Antibodies may also cross link antigens to form insoluble antigen-antibody complexes to enable easier phagocytosis by phagocytes of innate system;

Innate immunity is nonspecific and recognises all pathogens;

While adaptive immunity is specific to an antigen and develops memory cells against the same antigen, allowing for a faster and more effective response during the second exposure;

Explain the relationship of the molecular structure of antibodies to their functions, using IgG as an example.

Structure of IgG	Function of IgG
2 γ heavy chains & 2 light chains (either k/ λ) held together by disulfide bonds	Neutralises toxins and inactivates venoms by blocking their active sites via F_{ab} region
2 identical antigen-binding sites (F_{ab}) formed by both light and heavy chains seq. of amino acids in these regions make the specific 3D shape which binds to only 1 type of antigen	Immobilises motile bacteria by binding to the bacteria's flagella and cilia at F_{ab} region. Induces agglutination + prevents their ability to spread and invade tissues F_{ab} binds to antigens on the virus coat. This prevents viral attachment and thus infection.
Antigen-binding sites form the variable regions, which differs on each type of antibody molecule produced due to diff. in amino acid seq. (due to somatic hypermutation)	Allows them to recognise a wide diversity of antigen. High-affinity antibodies.
Globular glycoproteins with quaternary structure	Soluble, able to pass through placenta, enabling the mother to transfer her immunity to the foetus
The 'hinge' region gives the flexibility for the antibody molecule to bind around the antigen	F_{ab} region able to cross-link antigens, forming insoluble antigen-antibody complexes which are easily phagocytized and destroyed by phagocytes.
The F_c region cannot bind antigen but is responsible for the functions of the antibody molecule after antigen has been bound to the F_{ab} region of IgG.	Many phagocytes bear F_c receptors for the F_c regions of antibodies and adhere to the antibody-coated bacteria, leading to phagocytosis of the bacteria. IgG's F_c region binds with specific F_c receptors on natural killer (NK) cells. NK cells destroy the target by releasing toxic substances contained in its cytoplasm granules (NOT phagocytosis) Binding of IgG to complement proteins via F_c region activates the complement proteins that causes opsonization, phagocytosis and lysis of infectious agents F_c regions able to bind to F_c protection receptors on placental cells

Phagocytosis

Complement Cascade

Po,Pin,Toa,Boom
G10-1

Lobed Nucleus
A Nuetrophil has 2-5 lobed Nucleus.
Joined together by hair-like filaments.

StoredAntibiotic Proteins

Primary Granuel
It is lysosomal. Consist of acid hydrolases, myeloperoxidase, and muramidase (lysozmes)

Secondary Granuel
More specific to neutrophils.
Contains lactoferrin and lysozyme.

Mitochondria

Glycogen

Golgi Apparatus

Phagosome
It fuses with lysosomes to form phagolysosomes where the microbe will be destroyed.

Ribosome
It is freely in the cytoplasm because nuetrophil doesn't have any rough endoplasmic reticulum.

Neutrophil

● white blood cell

Neutrophils are immunecell. Neutrophil can change its shape from circular shape to another shape, in order to engulf bacteria and viruses by swallowing them.

Immune Cells

Leukocytes (White Blood Cells)

Granulocytes

-- **Neutrophils**
-- **Eosinophils**
-- **Basophils**
-- **Mast Cells**

Key Functions:
Release granules with digestive enzymes
Fight bacterial infections
Support inflammatory response with histamine & heparin

Lymphocytes

-- **B Cells**
--- Plasma
--- Memory
--- Regulatory
-- **T Cells**
--- Helper T (Th)
--- Cytotoxic T (Tc)
--- Memory T (Tm)
--- Suppressor T (Treg)
--- Natural Killer T (NKT)
--- Gamma-Delta T (γδ T)

Key Functions:
Secrete antibodies
Specific immune response
Recognize antigens
Help activate B cells
Remember past infections

Monocytes

-- **Macrophages**
--- M1 (Inflammation)
--- M2 (Tissue repair)
-- **Dendritic Cells (DC)**
--- Myeloid (mDC)
--- Plasmacytoid (pDC)

Key Functions:
Engulf bacteria
Present antigens

Other

-- **Natural Killer Cells**
-- **Phagocytes**
--- Macrophages
--- Neutrophils
--- Eosinophils
--- Monocytes
-- **Antigen-Presenting Cells (APCs)**
--- Macrophages
--- Dendritic Cells
--- Certain B Cells

Key Functions:
Engulf bacteria
Kill viral, stressed, tumor cells

1 After an antigen-presenting cell engulfs and degrades a pathogen, it displays an antigen fragment complexed with a class II MHC molecule. A helper T cell that recognizes the complex is activated with the aid of cytokines secreted from the antigen-presenting cell.

2 When a B cell with receptors for the same epitope internalizes the antigen, it displays an antigen fragment on the cell surface in a complex with a class II MHC molecule. An activated helper T cell bearing receptors specific for the displayed fragment binds to the B cell. This interaction, with the aid of cytokines from the T cell, activates the B cell.

3 The activated B cell proliferates and differentiates into memory B cells and antibody-secreting plasma cells. The secreted antibodies are specific for the same antigen that initiated the response.

▲ **Figure 43.18 Activation of a B cell in the humoral immune response.** Most protein antigens require activated helper T cells to trigger a humoral response. A macrophage (shown here) or a dendritic cell can activate a helper T cell, which in turn can activate a B cell to give rise to antibody-secreting plasma cells.

Useful Links:

https://online.science.psu.edu/micrb106_wd/node/6151

http://slideplayer.com/slide/10564113/ **<< voice recording and slides**

http://biology4alevel.blogspot.sg/search/label/Immunity **<< good for understanding!**