

IB BIOLOGY

Notes

From IB Biology HL Pearson

I. What causes infectious disease?

A. pathogen: an organism or virus that causes a disease

1. includes viruses, bacteria, fungi, parasitic worms etc.

II. The Body's Defences Against Infection

A. Non-specific Defences

- ## 1. Barriers to pathogen entry

- a. Skin and mucous membranes in the respiratory, digestive and urinary tracts are mechanical barriers

b . cilia in upper respiratory tract sweep mucus and particles up to the throat to be swallowed

c. Secretions from oil glands of the skin inhibit bacterial growth on skin

d. low pH of stomach inhibits bacterial growth/kills bacteria

- ## 2. Phagocytes and Natural Killer Cells

a. neutrophils are white blood cells that can leave the blood and phagocytize bacteria in connective tissue

b. eosinophils are phagocytic but are mainly used to attack large animal parasites

c. Natural killer cells kill virus-infected cells and tumour cells by cell-to-cell contact

- ### 3. Inflammatory Response

- a. occurs when tissue gets damaged
- b. inflamed area becomes red, painful, swollen and hot
- c. Damaged tissue releases histamine
 - i. along with mast cells (a type of white blood cell) causes vasodilation and increased permeability of nearby capillaries
 - a. results in redness and increase in temperature
 - ii. Swelling from escaped fluid and proteins occurs
 - iii. A protein called bradykinin stimulates nerve endings resulting in the sensation of pain
- d. neutrophils and monocytes move to the site of injury by squeezing through the capillary wall
 - i. neutrophils phagocytize bacteria
 - ii. Monocytes differentiate into macrophages that phagocytize bacteria
 - iii. Macrophages also stimulate the growth of white blood cells, especially neutrophils, by releasing a growth factor
- e. Inflammation can also result in fever
 - i. inhibits the growth of microorganisms and stimulates immune cells
- f. Pus forms from dead neutrophils, dead cells, dead bacteria and some living white blood cells

4. Protective Proteins

- a. complement proteins are plasma proteins that complement certain

immune responses.

- make
 - i. may amplify an inflammatory reaction, bind to antigens to them more recognizable, make holes in the walls and cell membranes of bacteria
- b. interferons are proteins produced by virus-infected cells
 - i. bind to the surface of uninfected cells which then produce substances that prevent viral replication

Here is an animation: http://glencoe.mcgraw-hill.com/sites/0035456775/student_view0/chapter33/antiviral_activity_of_interferon.html

B. Specific Defences (Antigen-Antibody Response)

- a. antigen: any chemical that can stimulate an immune system response,
 - often a protein on the surface of a cell membrane
- b. antibody: a protein produced by the human body that is specific to a particular antigen (as a lock is for a key or vice versa)
 - i. antibodies may make the antigen-carrying pathogen more recognizable to phagocytic cells, bind to viruses and prevent them from invading a host cell or cause agglutination/clumping of antigen-infected cells

Here is an animation:

http://glencoe.mcgraw-hill.com/sites/0035456775/student_view0/chapter33/the_immune_response.html

C. Antibody production

1. macrophages display antigen from engulfed pathogen

fits the 2. antigen is recognized by helper T-cells that have a receptor that particular antigen and is activated

a. activated helper T-cell produces interleukin-2

and B i. interleukin-2 causes proliferation of certain cytotoxic T cells cells

destroy a. cytotoxic T-cells bind to and produce chemicals that cells that present the particular antigen

Here is an animation: http://glencoe.mcgraw-hill.com/sites/0035456775/student_view0/chapter33/cytotoxic_t-cell_activity_against_target_cells.html

antigen b. activated helper T-cell binds to B cells that recognize the same

by a T i. there are many parts of the antigen that can be recognized cell, called epitopes

ii. therefore, many different B cells can be activated, each producing different antibodies against the same pathogen

different a. Therefore, against the same pathogen, a number of antibodies can be made

capable b. since many different B cells produce plasma cells, each of cloning itself, this is a polyclonal response

ii. B cells divide into many plasma cells

antigen a. plasma cell produces antibody that is specific to the

antibodies from the mother can be found in her breast milk

4. can be induced by giving vaccine with antibodies

IV. Vaccination

Here is an animation about constructing vaccines: http://glencoe.mcgraw-hill.com/sites/0035456775/student_view0/chapter33/constructing_vaccines.html

A. goal of vaccination is to produce an immune response without disease

1. vaccine may contain pathogen that has been treated so that it is less

virulent, i.e. Less able to cause disease

a. often referred to as the attenuated pathogen

2. vaccine can also contain inactivated toxins

3. goal is to initiate "challenge and response"

a. the immune system is challenged by a pathogen and responds by producing antibodies

i. since there are many B cells involved in producing the antibodies, this is a polyclonal response

B. vaccine introduced into the body most commonly by injection (the dreaded "shot")

C. Vaccination stimulates the primary immune response, hopefully leading to the development of the appropriate memory B cells

D. exposure to the pathogen should stimulate the secondary immune response

which is faster, stronger and more specific than the primary response

1. the pathogen should be inactivated or destroyed before the onset of

disease

Figure 1: Speed of primary versus secondary response.

<http://www.colorado.edu/intphys/Class/IPHY3430-200/image/24-11.jpg>

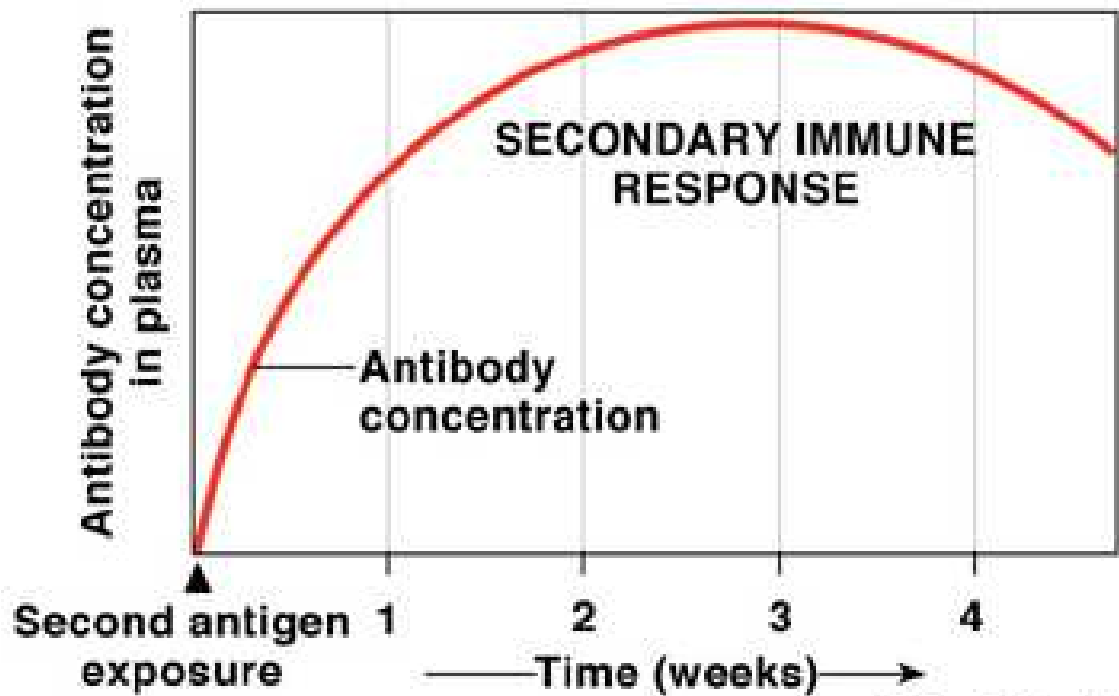
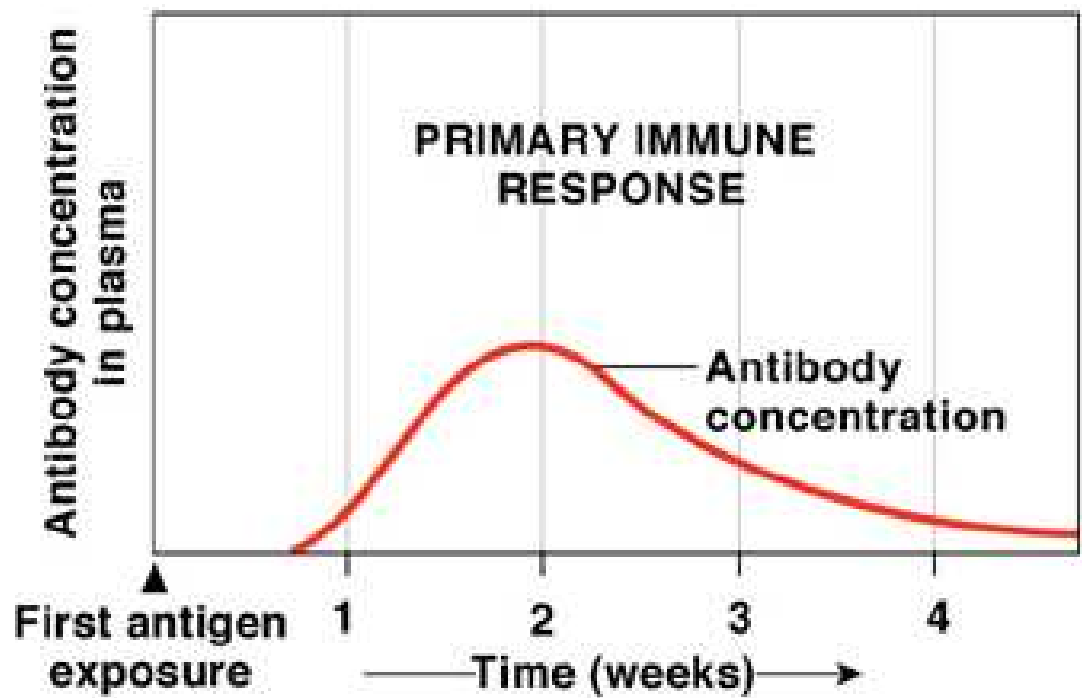


Fig. 24-11

E. Benefits of vaccination

1. total elimination of certain diseases
2. preventing epidemics/pandemics
3. decreased health care costs
4. preventing harmful side effects of disease

F. Possible dangers of vaccination

1. Side effects such as soreness near the injection site, low-grade fever
2. allergic reactions to some of the vaccine's ingredients
 - a. e.g. Some vaccines contain egg proteins, yeast proteins, antibiotics, (leftover from the production process), human serum albumin (help stabilize live virus), formaldehyde (eliminates the effects of bacterial toxins and makes viruses unable to replicate), aluminum salts (help the vaccine work better), or gelatin that may cause an allergic reaction
3. a preservative called thimerosal contains mercury and there have been concerns about its safety (in the US it "has been removed from or reduced to trace amounts in vaccines for children 6 years of age and younger with the exception of the inactivated influenza vaccine" (Iannelli, 2008))
4. possible overload of the immune system
5. IB lists possible links to autism but...

For a comprehensive list of side effects for many vaccines, try this website:

<http://www.cdc.gov/vaccines/vac-gen/side-effects.htm>

G. So...should you use vaccines?

1. Personal choice of informed individuals is the key

V. Antibiotics

A. antibiotic: a chemical that inhibits the growth of microorganisms, particularly bacteria

1. typically work by inhibiting some aspect of bacterial metabolism
 - a. inhibition of cell wall synthesis
 - i. most common method
 - ii. e.g. Penicillin, vancomycin, Bacitracin
 - b. inhibition of protein synthesis
 - i. second most common method
 - ii. e.g. Tetracyclines, streptomycin, erythromycin, chloramphenicol
 - c. Alteration of cell membranes
 - i. e.g. Bacitracin (topical)
 - d. inhibition of nucleic acid synthesis
 - i. e.g. Rifampin, bacitracin
 - e. Antimetabolite activity
 - i. e.g. Sulfonamides

*Note that the names of antibiotics is not required for IB but included for interest; I tried to find relatively common antibiotics

V. Monoclonal Antibody Production

Here is a video about monoclonal antibody production:

http://glencoe.mcgraw-hill.com/sites/0035456775/student_view0/chapter33/monoclonal_antibody_production.html

Here is another address for the same animation of monoclonal antibody production: http://highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::640::480::/sites/dl/free/0073532223/811363/Monoclonal_Antibody_Production.swf::Monoclonal%20Antibody%20Production

A. monoclonal antibodies: antibodies made by clones of the same B cell

1. since each B cell makes only a specific antibody, ensures that all the antibodies are the same

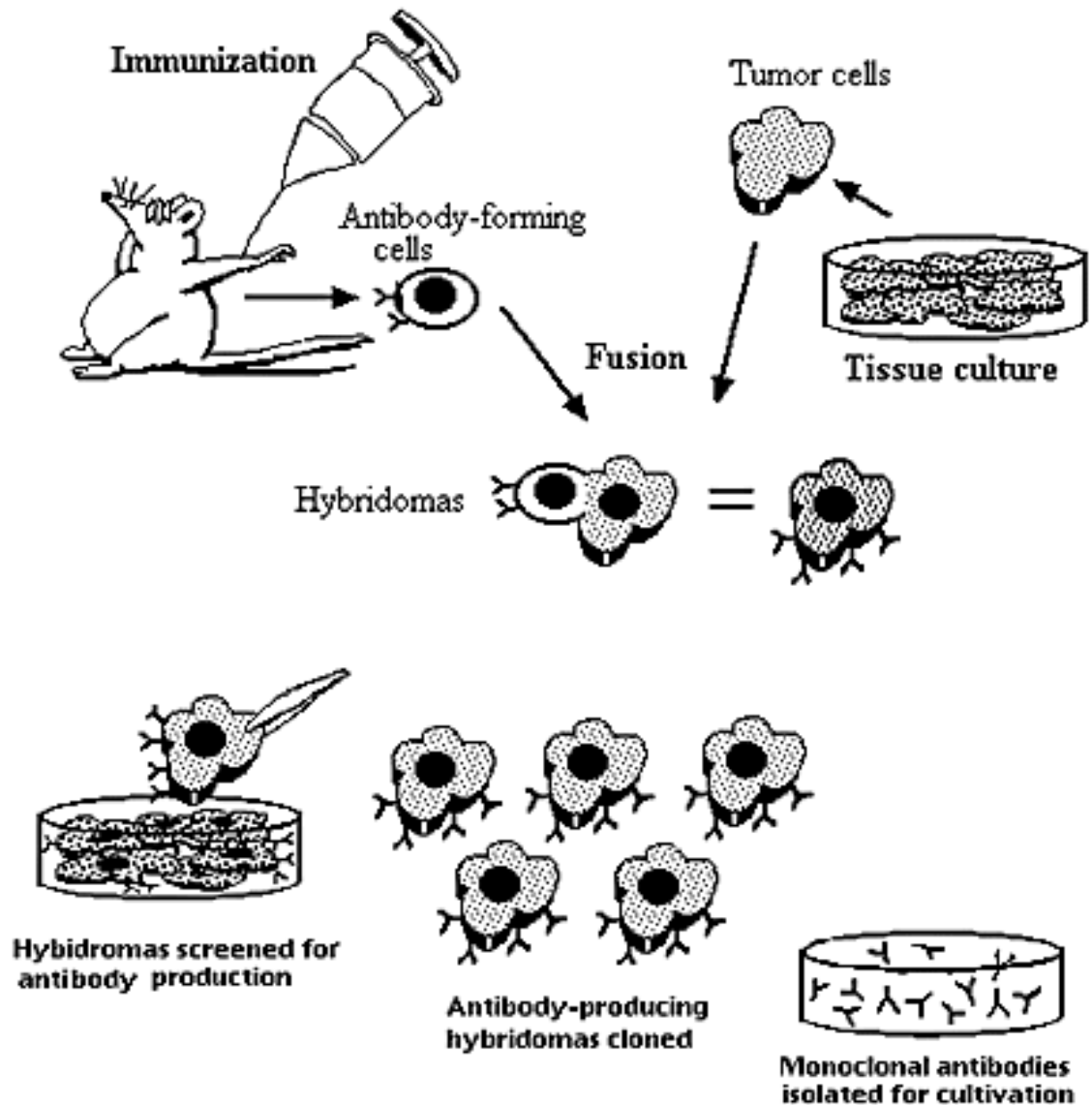
2. allows scientist to "harvest" a substantial amount of a single antibody

3. antibodies obtained from the blood are called polyclonal antibodies

B. Production of monoclonal antibodies

*Köhler and Milstein devised this technique for mice in 1975 and won a Nobel Prize

<http://www.accessexcellence.org/RC/VL/GG/monoclonal.php>



Monoclonal Antibody Production

Here is an animation of monoclonal antibody production:

http://highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::640::480::/sites/dl/free/0073532223/811363/Monoclonal_Antibody_Production.swf::Monoclonal%20Antibody%20Production

1. B lymphocytes, usually from mice are exposed to a particular antigen

- tumour
2. activated B lymphocytes are fused with myeloma cells/bone cells/cancerous B cells that divide indefinitely
 3. fused cells are called hybridomas because they are hybrids, one of the cells used was cancerous, thus the "-oma" part of the name

C. Uses of monoclonal antibodies

- to select
1. since they are highly specific, monoclonal antibodies can be used out/find a specific molecule among many others

- a. diagnose illnesses such as AIDS
- b. identification of blood types and tissue typing for transplant compatibility
- c. detect substances in the blood such as HCG (human chorionic gonadotrophin) , the hormone that women produce when pregnant

Here is an animation of the home test for pregnancy:

http://bcs.whfreeman.com/thelifewire9e/default.asp#542578__591564__

- d. identify infections
- e. Sort out different T cells
- f. Distinguish between cancerous and normal cells
 - i. thus can be used to carry radioactive isotopes or toxic drugs to kill tumours
- g. Treatments for various illnesses
 - i. emergency treatment of rabies
- h. purification of industrially produced interferon
- i. Detection of certain markers (cardiac isozyme) the are indicative of

heart attack

VII. HIV and AIDS

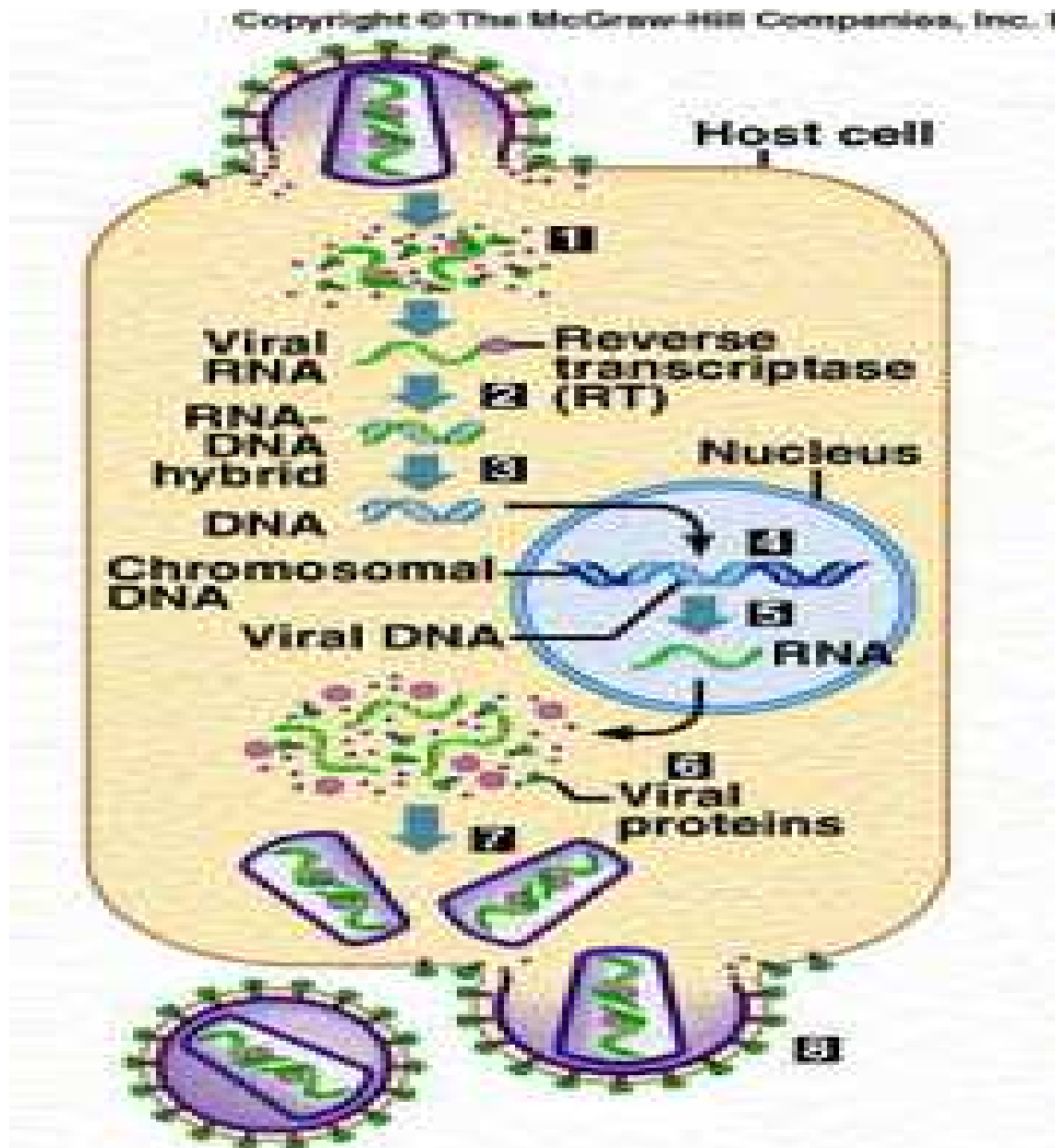
Here is an animation about HIV replication: http://highered.mcgraw-hill.com/sites/0072943696/student_view0/chapter14/animation__hiv_replication.html

Here is an animation about how the HIV infection cycle works: http://highered.mcgraw-hill.com/sites/0072943696/student_view0/chapter14/animation__how_the_hiv_infection_cycle_works.html

Here is an animation of treatment of HIV: http://highered.mcgraw-hill.com/olcweb/cgi/pluginpop.cgi?it=swf::640::480::/sites/dl/free/0073532223/811363/Treatment_of_HIV_Infection.swf::Treatment%20of%20HIV%20Infection

Figure 2: How HIV infects a cell.

<http://www.citruscollege.edu/lc/biology/Pages/Chapter39-Rabitoy.aspx>



A. What is HIV? What is AIDS?

1. AIDS: acquired immune deficiency syndrome
2. HIV: human immunodeficiency virus
 - a. causes AIDS
 - b. a retrovirus

- i. genetic material is RNA rather than DNA
 - c. Transmitted from human to human via blood semen, vaginal secretions and breast milk
 - i. must "come in contact with a mucous membrane or damaged tissue or be injected directly into the blood-stream (from a needle or syringe) for transmission to possibly occur" (<http://www.cdc.gov/hiv/resources/qa/transmission.htm>)
 - ii. HIV can also be transmitted via infected blood, infected blood products, organs from HIV infected individuals

3. Infection by HIV

- a. HIV infects host cell which is the helper T cell
 - i. recall: helper T cells activate B cells to become plasma cells and also stimulate cytotoxic T cells to destroy infected cells and foreign antigen carriers
- b. HIV attaches to the helper T cell and injects its RNA and an enzyme called reverse transcriptase into the cell
- c. Reverse transcriptase uses viral RNA as a template to make DNA
- d. viral DNA enters the host nucleus and attaches to the host DNA
 - i. host treats the viral DNA as its own and will transcribe and translate the viral genetic material
- e. Host cell will fill with viral parts which will assemble into viral particles

f. The infected cell will burst and die, releasing viral particles into the bloodstream to infect other helper T cells

g. This is essentially the same mechanism as other viruses use however, the important point is that the cells that are infected by this virus are cells that would normally aid in fighting an infection

4. Consequences of HIV infection

a. eventually number of helper T cells declines

b. infected person is less able to produce antibodies

c. Immune system functioning is suppressed and opportunistic infections such as pneumonia and Kaposi's sarcoma (a form of skin cancer) may set in

i. individuals with normal immune systems can usually fight off these infections

d. HIV positive: have antibodies against HIV in your blood which indicates that the virus is in your body

e. AIDS patients are HIV positive and have a T cell count below 200 or are HIV positive and have an opportunistic infection

f. many AIDS patients die within 2 years of the onset of symptoms but many individuals live for years with no apparent immune complications

VIII. BLOOD CLOTTING (same as from Circulatory System package)

A. Clotting: formation of a solid mass of platelets, red blood cells and fibrin (a protein)

1. also called coagulation
2. **Fibrinogen**: a protein found in blood that is the precursor of fibrin
3. **Prothrombin**: inactive form of thrombin found in blood
 - a. Vitamin K is necessary for production of prothrombin
4. **Serum**: blood plasma without fibrinogen

B. STEPS IN BLOOD CLOTTING

1. Blood vessel is damaged
2. platelets clump at the site and partially seal the leak
3. platelets and damaged tissue release prothrombin activating factor
4. prothrombin activating factor converts prothrombin to thrombin
 - a. requires calcium ions (Ca^{2+})
5. thrombin acts as an enzyme that removes 2 short amino acid chains from each end of a fibrinogen molecule, making them "sticky"
6. shortened fibrinogen molecules join end to end forming long threads of fibrin
7. fibrin threads tangle themselves around the platelets that are plugging the leak
8. red blood cells are trapped in the network of fibrin and give colour to the clot
9. when repair of blood vessel initiated, the enzyme plasmin destroys fibrin network

A cute video, some details are slightly different from the notes though:
<http://www.youtube.com/watch?v=9QVTHDM90io&feature=related>

C. Rewind: Thrombosis

1. thrombosis: formation of a clot in a blood vessel

- a. often the result of damage to the wall of a blood vessel as in atherosclerosis
- b. other causes are outlined below:

<http://www.nhs.uk/Conditions/Thrombosis/Pages/Causes.aspx>

References:

Allott and Mindorff. IB Diploma Program Biology Course Companion

Ian Jeff, 2003.

http://petrazzics.about.com/od/vaccinations/a/0608_vac_against_h1n1.htm

Mader, Sylvia. Inquiry Into Life Seventh edition and Tenth edition.

<http://www.life.umd.edu/classroom/bsci424/Chemotherapy/AntibioticMechanisms.htm>

<http://pathmicro.med.sc.edu/mayer/antibiot.htm>

<http://www.elmhurst.edu/~chm/vchembook/654antibiotic.html>

<http://www.molecular-plant-biotechnology.info/hybridoma-and-monoclonal-antibodies-mabs/uses-of-monoclonal-antibodies.htm>

<http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/M/Monoclonals.html>

<http://www.colorado.edu/intphys/Class/IPHY3430-200/014immune.htm>

<http://www.cdc.gov/hiv/resources/qa/transmission.htm>

This article gives detailed information on antibody structure and function including applications of monoclonal and polyclonal antibodies:

http://dels-old.nas.edu/ilar_n/ilarjournal/46_3/pdfs/v4603Lipman.pdf

This is an interesting site as it is written for the computer sciences and outlines how the study of the immune system is relevant to computer sciences in the introduction.

<http://www.cs.unm.edu/~immsec/html-imm/introduction.html>

Review and Practice:

1. ~~IB Diploma Program Biology Course Companion~~ by Allott and Mindorff: page 238 #1-7

2. A case study: Clinical Application from http://highered.mcgraw-hill.com/sites/0070272468/student_view0/chapter16/clinical_applications.html

Answer the six questions for homework.