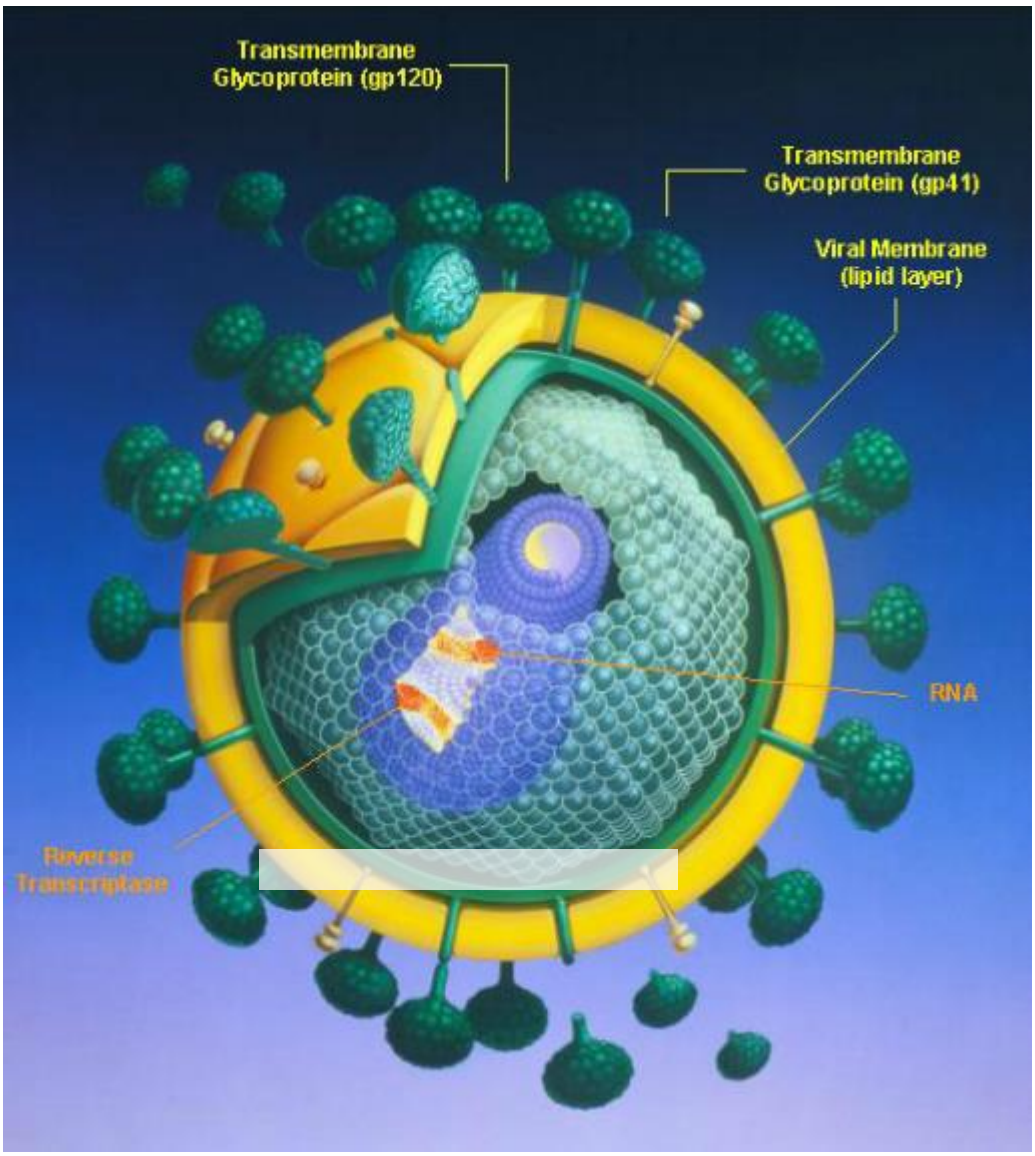
Topic 11: Animal physiology (16 hours)

11.1 Antibody production and vaccination: Immunity is based on recognition of self and destruction of foreign material.

Understandings:

∑ - Every organism has unique molecules on the surface of its cells.

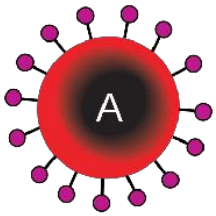
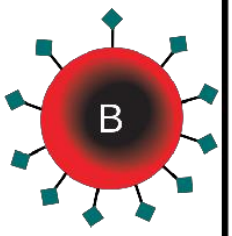
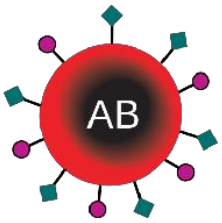
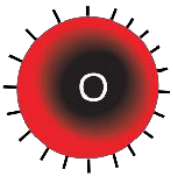
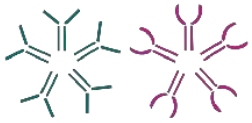
- All organisms have unique molecules or markers on the outer surface of the plasma membrane of their cells
- These highly variable molecules are generally glycoproteins and they identify a cell as being "self" or "non-self"
- These markers are called major histocompatibility complexes (MHC)
- These MHC proteins are genetically determined and are unique to that individual



Cell surface glycoproteins on the HIV virus

above(http://www.apsubiology.org/anatomy/2020/2020_Exam_Reviews/Exam_2/CH21_Diseases_of_the_Immune_System.htm)

β - Application: Antigens on the surface of red blood cells stimulate antibody production in a person with a different blood group.

	Group A	Group B	Group AB	Group O
Red blood cell type				
Antibodies in Plasma	 Anti-B	 Anti-A	None	 Anti-A and Anti-B
Antigens in Red Blood Cell	A antigen	B antigen	 A and B antigens	None

http://www.sciencetopia.net/sites/default/files/Antigen-antibody-relationship.png

- Blood groups such as A, B, AB and O are identified by cell surface antigens
- Rhesus (Rh) is another antigen that can be present on the surface of the blood cells, being either Rh positive (has antigen) or Rh negative (doesn't have antigen)
- A blood transfusion given to an individual with the wrong blood type can stimulate an immune response called **agglutination** (clumping or clotting of the blood cells)
- This is followed by the destruction of the RBC (**hemolysis**)
- For example, someone with blood type A (antigen A on the surface) contains anti-B antibodies in their plasma. If they get a transfusion with blood type B, their immune system will attack and destroy the foreign blood cells with the B-antigen on the surface
- People with blood type O just have the basic antigen sequence that all blood cells have and are therefore not attacked by A or B antibodies; therefore, blood type O is known as the universal donor (O negative has no Rhesus factor)

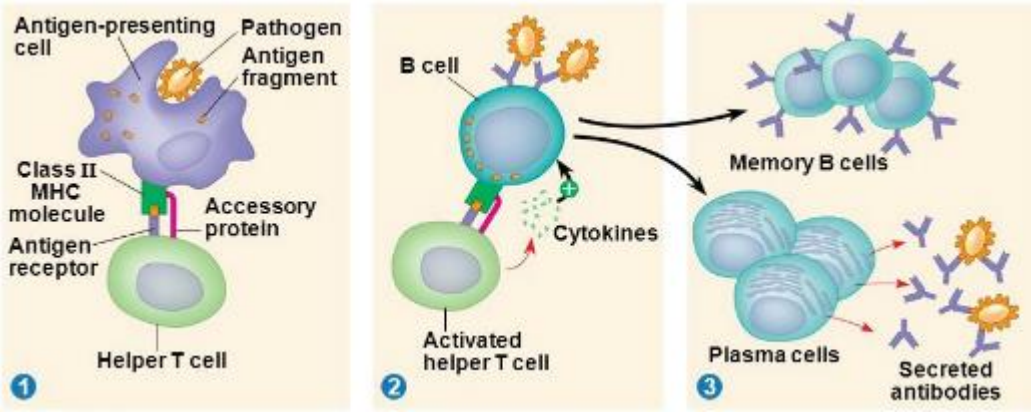
∑ - Pathogens can be species-specific although others can cross species barriers.

- Invading organisms such as a virus or bacterium that enters the body and causes a disease are known as pathogens

- Pathogens are generally **species specific,** for example, humans are the only known organisms susceptible to pathogens such as polio, syphilis, measles and gonorrhea but are resistant to many pathogens that infect other organisms
- However, there are pathogens that can cross this species barrier and infect a range of hosts, such as the Rabies virus, bird flu and the Bubonic plague
- Diseases from other animals that can infect or be transmitted to humans is called**Zoonosis**
- The passing of diseases from different species is a growing global health concern
- Video on Zoonosis: https://www.youtube.com/watch?v=PSQPikvU6pc

∑ - ***B lymphocytes*** **are activated by** ***T lymphocytes*** **in mammals.**

- When a pathogen enters the blood, the specific antigen on the surface of the membrane is identified.
- Specific phagocytes known as macrophages recognize a pathogen as a foreign entity because of the antigens on the surface.
- The macrophage engulfs and partially destroys the pathogen.
- The macrophage takes the antigens from the destroyed pathogen and displays them on the surface of the cell bound to a membrane protein called a MHC protein (called antigen presentation).
- Specific T-lymphocytes receptors recognize and bind to the antigen presented by the macrophage, thus activating the T-lymphocyte.
- The activated T-cell binds to a B-lymphocyte specific to the antigen; activating the B-cell through the binding and the release of a signaling protein

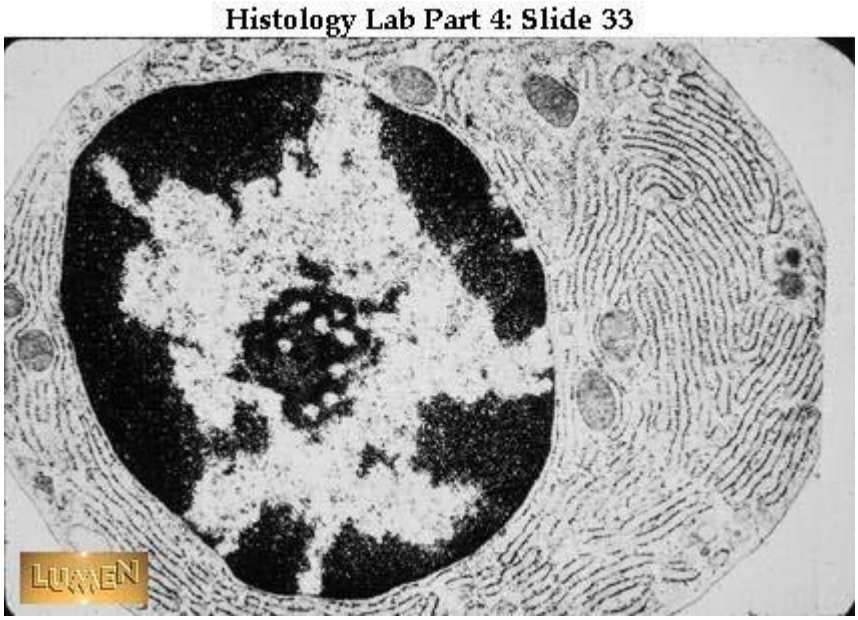


∑ - **Activated B cells multiply to form clones of** ***plasma cells*** **and** ***memory cells*****.**

- The active B-cells begin to clone themselves producing cloned plasma B cells thatproduce antibodies and memory cells. Memory cells remain in the blood in case a second infection occurs to provide long term protection and a quick response to the new infection.
- The plasma cells created produce and release mass amounts of antibodies into the bloodstream.
- These antibodies surround and bind to the antigens on the foreign pathogens.
- Through a variety of different methods the pathogens are destroyed by the antibodies and other white blood cells.

∑ **- Plasma cells secrete *antibodies*.**

- As stated above, plasma cells are specialized B lymphocytes (called B cells as they develop in the bone marrow) that secrete a large amount of antibodies during a selective immune response
- Since they are a cell that produces and secretes a large number of antibodies (proteins), they contain an **extensive amount of rER, ribosomes and mitochondria (for energy)**



http://www.meddean.luc.edu/lumen/Meded/Histo/HistoImages/hl2A-33.jpg

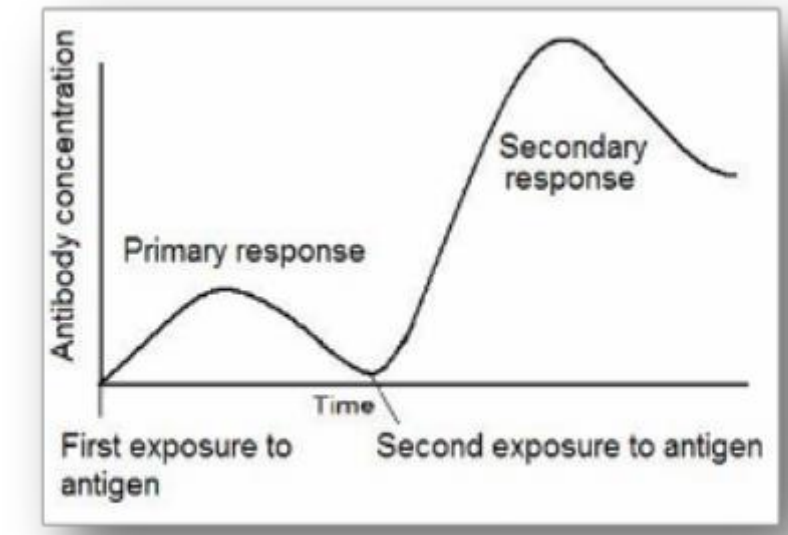
∑ **- Antibodies aid the destruction of pathogens.**

- **Antibodies aid in the destruction of pathogens in a variety of ways**

1. **Agglutination** – antibodies cause the sticking together of pathogens by attaching to the antigens on the surface. These clumped masses of pathogens are then easily ingested and destroyed by phagocytes
2. **Opsonization** – antibodies make pathogens recognizable by binding to them and linking them to phagocytes
3. **Toxin Neutralization** – Antibodies bind to toxins produced by pathogens in the blood plasma preventing them from affecting susceptible cells.
4. **Complement Activation** – After a pathogen is identified by antibodies, complement proteins in the blood plasma form a membrane attack complex that destroys the cell membrane in the pathogen causing the cell to lyse
5. **Bacteria and Virus Neutralization** – Antibodies can bind to the surface of viruses, preventing them from entering host cells

∑ **- Immunity depends upon the persistence of memory cells.**

- Long term specific immunity depends upon the presence of memory cells created during a previous infection from the same pathogen
- Memory cells are long-lived cells that make an effective response to a **reinfection of the body by the same antigen (on the pathogen)**



∑ **- Vaccines contain antigens that trigger immunity but do not cause the disease.**

- Vaccines are introduced to the body usually through an injection but can be administered through orally or through a nasal spray
- Vaccines contain a live attenuated (weakened) or killed version of the pathogen, itstoxins or one of its surface antigens.
- Vaccines stimulate a primary immune response
- If the body encounters the actually pathogen, it will be destroyed right away by theantibodies during a secondary immune response
- Vaccines has made great contributions towards public health through the prevention of many deadly or dangerous **diseases such as tuberculosis, measles and smallpox**

Herd Immunity - http://www.cbc.ca/news/health/measles-vaccinations-of-toddlers-at-89-below-herd-immunity-level-1.3161617

*****Do Data Based questions on page 473****

β - Application: **Smallpox** was the **first** infectious **disease** of humans to have been**eradicated by vaccination**. Human vaccines are often produced using the immune responses of other animals.

Good video on smallpox https://www.youtube.com/watch?v=yqUFy-t4MlQ

Eradication of smallpox in South-East Asia https://www.youtube.com/watch?v=Y6gkStkVSd8

- In 1959 a global initiative was undertaken by the WHO in order to eradicate smallpox
- The effort had mixed results until a well-funded Smallpox Eradication Unit was formed in 1967
- The last known case of smallpox was recorded in Somalia in 1977
- It was successful because of the following reasons

1. **Patients were easily identified by obvious clinical features**
2. **Transmission was through direct contact only**
3. **There were no animal vectors or reservoirs where the disease could remain and reemerge**
4. **Contacts of the patients identified were quickly identified and vaccinated**
5. **Immunity was long term so reinfection was unlikely**
6. **The infection period was short-lived (3 to 4 weeks)**
7. **The virus was stable and didn't mutate**
8. **There was international cooperation organized by the WHO**

Nature of science: Consider ethical implications of research—Jenner tested his vaccine for smallpox on a child.

- Edward Jenner was a scientist who infected a small child with cowpox
- After the boy recovered he then affected the child with the more virulent and possibly fatal smallpox, as he believed the child would be immune because of the original cowpox infection
- He did this on a young child well below the age of consent

Jenner's Story http://www.sciencechannel.com/tv-shows/greatest-discoveries/videos/100-greatest-discoveries-the-beginning-of-vaccination/

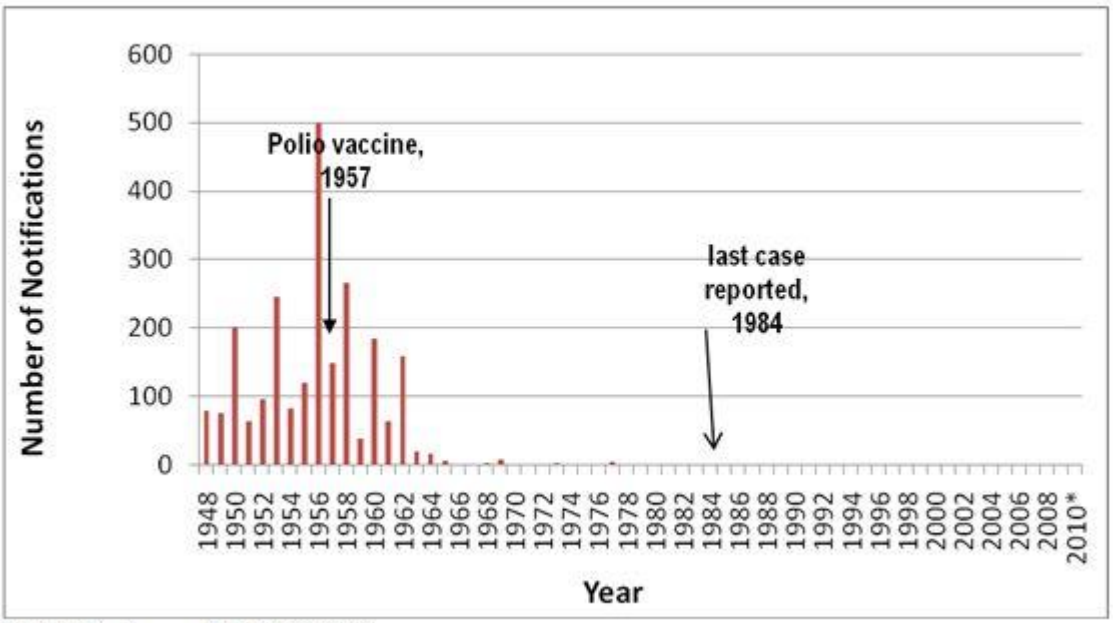
Ethics in medicine: http://study.com/academy/lesson/ethical-issues-in-medicine-psychology.html

β - Skill: Use databases to **analyse epidemiological data** related to **vaccination**programmes

Epidemiological Studies on Vaccinations

Vaccines and Autism http://www.ageofautism.com/2011/05/vaccines-and-autism-what-do-epidemiological-studies-really-tell-us.html

Figure 1. Polio notifications, Ireland 1948-2010 (as of 14/10/2010)

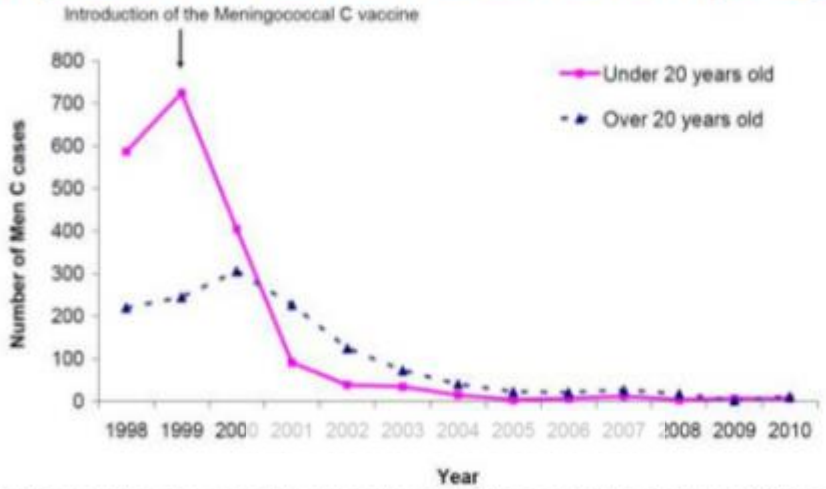


*2010 data as of 15/10/2010

Public Health England

oxford vaccine group

Impact of MenC vaccination programme



Number of laboratory confirmed serogroup C cases in England and Wales, 1998-2010

Source: Public Health England, Infectious Disease Epidemiological Data
http://www.hpa.org.uk/webw/HPAweb&HPAwebStandard/HPAweb_C/1234859709051?p=1201094595391

18

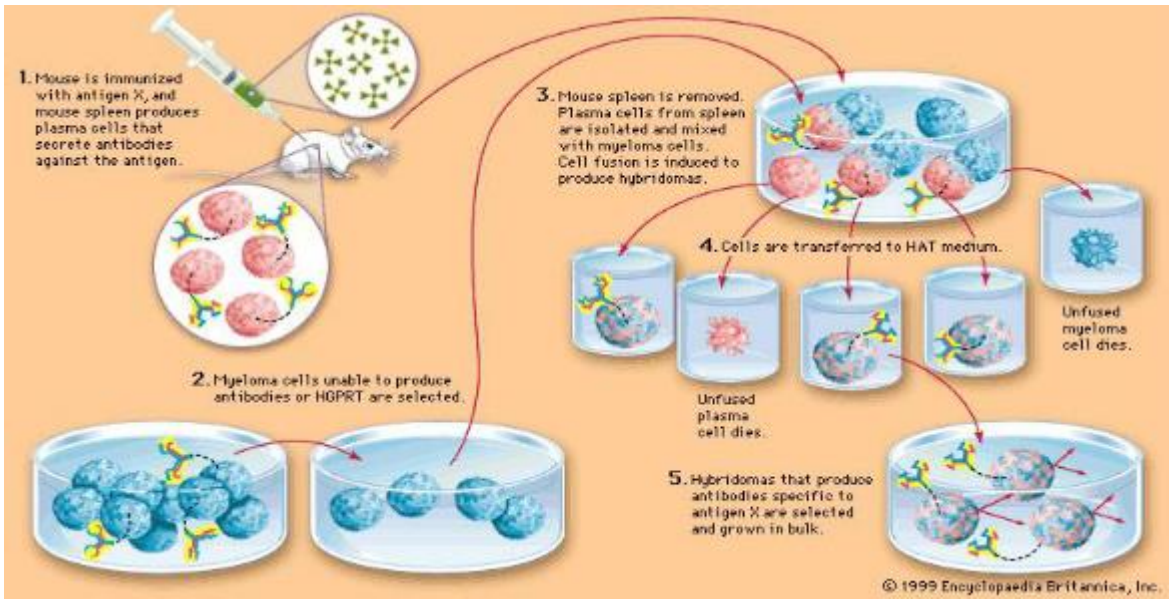
∑ - White cells release *histamine* in response to allergens.

- Mast cells found in connective tissue and Basophils circulating in the blood **secrete histamine** in response to antigens from an infection or response to an allergen
- Histamines cause the blood vessels of the infected area to dilate and increase flow of fluid containing immune components to the infected area
- Some of these immune components leave the blood vessels resulting in non-specific and specific immune response

∑ - Histamines cause allergic symptoms.

- A number of symptoms from allergic reactions are caused by histamines
- Cells throughout the body have histamine receptors
- The release of histamine causes many of the symptoms from an allergic response such as inflammation, sneezing, itching and mucous secretion
- Histamines play a role in the formation of rashes and swelling known as anaphylaxis
- Anti-histamine drugs, counteract these affects by blocking histamine receptors

∑ - Fusion of a *tumour* cell with an *antibody-producing plasma cell* creates a *hybridoma*cell.



http://media-2.web.britannica.com/eb-media/39/21139-004-1BC93D10.jpg

∑ - Monoclonal antibodies are produced by hybridoma cells.

- Monoclonal antibodies are identical antibodies produced by clones of a single parent immune cell that are specific to one type of antigen.
- A laboratory animal such as a mouse is injected with a specific antigen thatcorresponds with the needed antibodies.
- After the animal goes through a primary immune response, a plasma B-cell cell that produces the required antibody is removed from the spleen.
- Myeloma (cancer) cells are cultured in a petri dish.

- These dividing myeloma cells are mixed together with the plasma B-cells and aretreated to promote a fusion between the two cells, forming a cell called a hybridoma.
- The successful hybridomas have characteristics of both cells; produce antibodies and divide rapidly for a long time.
- These hybridoma cells are cultured and allowed to divide, producing many clone cellsthat are able to produce large amounts of antibodies.
- Monoclonal antibodies can be extracted and used for many different applications.

Video on Monoclonal Antibodies https://www.youtube.com/watch?v=kcxQyIfca4I

β - Application: Monoclonal antibodies to **HCG** are used in **pregnancy test kits**.

Use in diagnosis of pregnancy

- Human chorionic gonadotrophin (HCG) is produced by an embryo in early pregnancy.
- Monoclonal antibodies can be produced by injecting a lab animal with HCG, as it recognizes this as antigen.
- *HCG Antibodies* are combined with color-changing enzymes.
- When the mixture is introduced into a blood sample of a woman that is pregnant, theantibodies will bind to the HCG in the blood, causing a change in color.
- If the woman is not pregnant, no HCG will be present in her blood, and therefore there will be no color change.

Use in treatment of rabies

- Monoclonal antibodies are produced using the method described in 11.1.5.
- The antibodies are injected directly into the person after a possible rabies infection.
- The antibodies will control and fight the infection, giving time for the body to produce its own antibodies.
- If not treated with antibodies after a rabies infection, death can result.

Other examples are treatment of cancer cells and detection of HIV

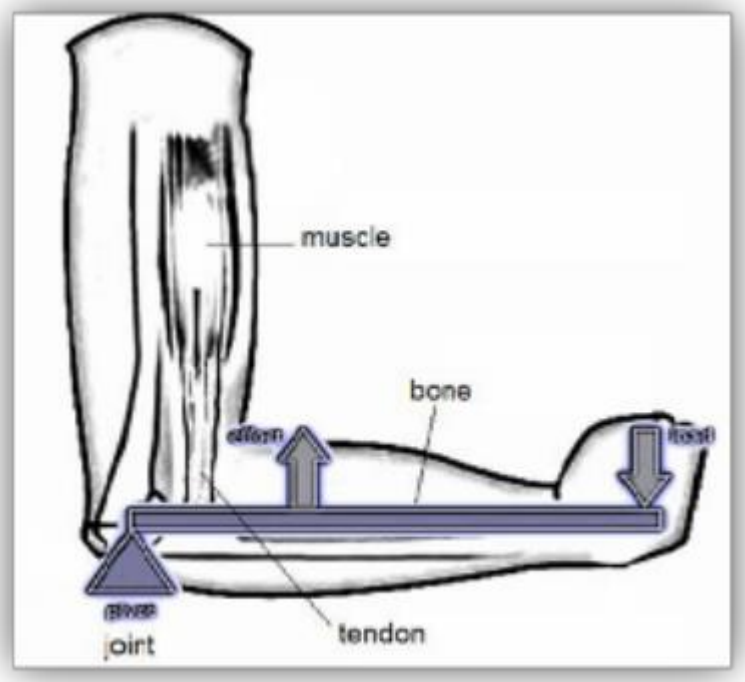
11.2 Movement: The roles of the musculoskeletal system are movement, support and protection.

Understandings:

∑ - *Bones* and *exoskeletons* provide *anchorage* for muscles and act as *levers*.

- Bones act as levers so the body can move and provide structural support (skeleton).
- Ligaments are strong bands that connect bone to bone strengthening the joint during movement.
- Tendons have dense connective tissue that connects muscles to bones, allowing movement of the bone when a muscle contracts.

- Muscles provide the force for movement by contracting (shortens the muscle fibers)



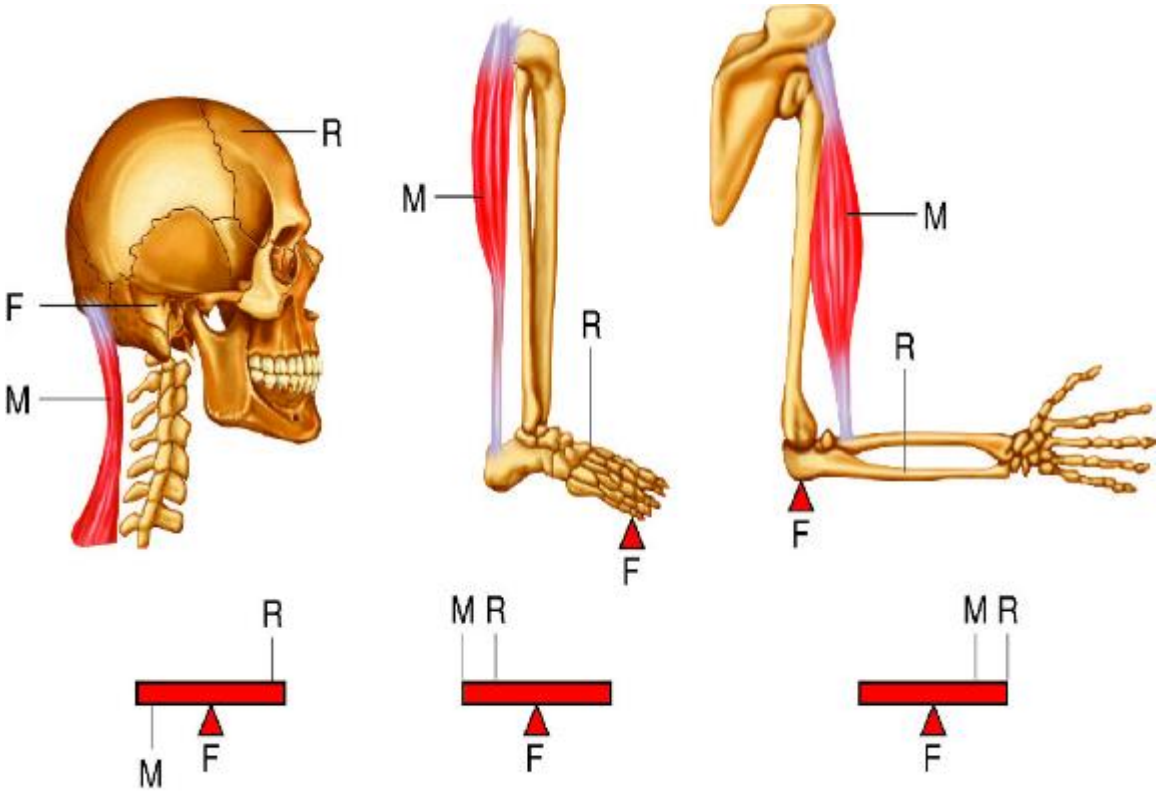
- The joint acts as a **pivot point or a fulcrum**
- The **force applied** (when the muscle contracts) is called the **effort**
- The force or load needed to overcome for movement to take place is called the **resistance**
- Levers are classified by first, second, and third class, depending upon the positions among the fulcrum, the effort, and the resistance.

- **First-class levers** have the fulcrum in the middle, like a seesaw. An example of a first class lever is when a human nods their head (top of the spinal column is the fulcrum, the effort force is provided by the muscles in the back of the neck, and the resistance is weight of the head).

- **Second-class levers** have a resistance in the middle, like a load in a wheel-barrow. The body acts as second class lever when engaged in pushup or calf raise. During a calf raise ball of foot is fulcrum, the body's mass is the resistance and the effort is applied by calf muscle.

- **Third-class levers** have the effort from the muscle in the middle of the lever. The majority of the human body's musculoskeletal levers are third class.

These levers are built for speed and range of motion. Muscle attachments are usually close to the fulcrum. In the example of the arm, the effort force is provided by the contraction of the biceps, the fulcrum is the elbow joint and the resistance would be provided by whatever weight is being lifted.



https://courses.candelalearning.com/olianp/wp-content/uploads/sites/167/2014/11/Muscle_22b.jpg

- Exoskeletons in insects and crustaceans can facilitate the movement by providing an anchorage for muscles; similarly to how bones provide anchorage for animals with internal skeletons

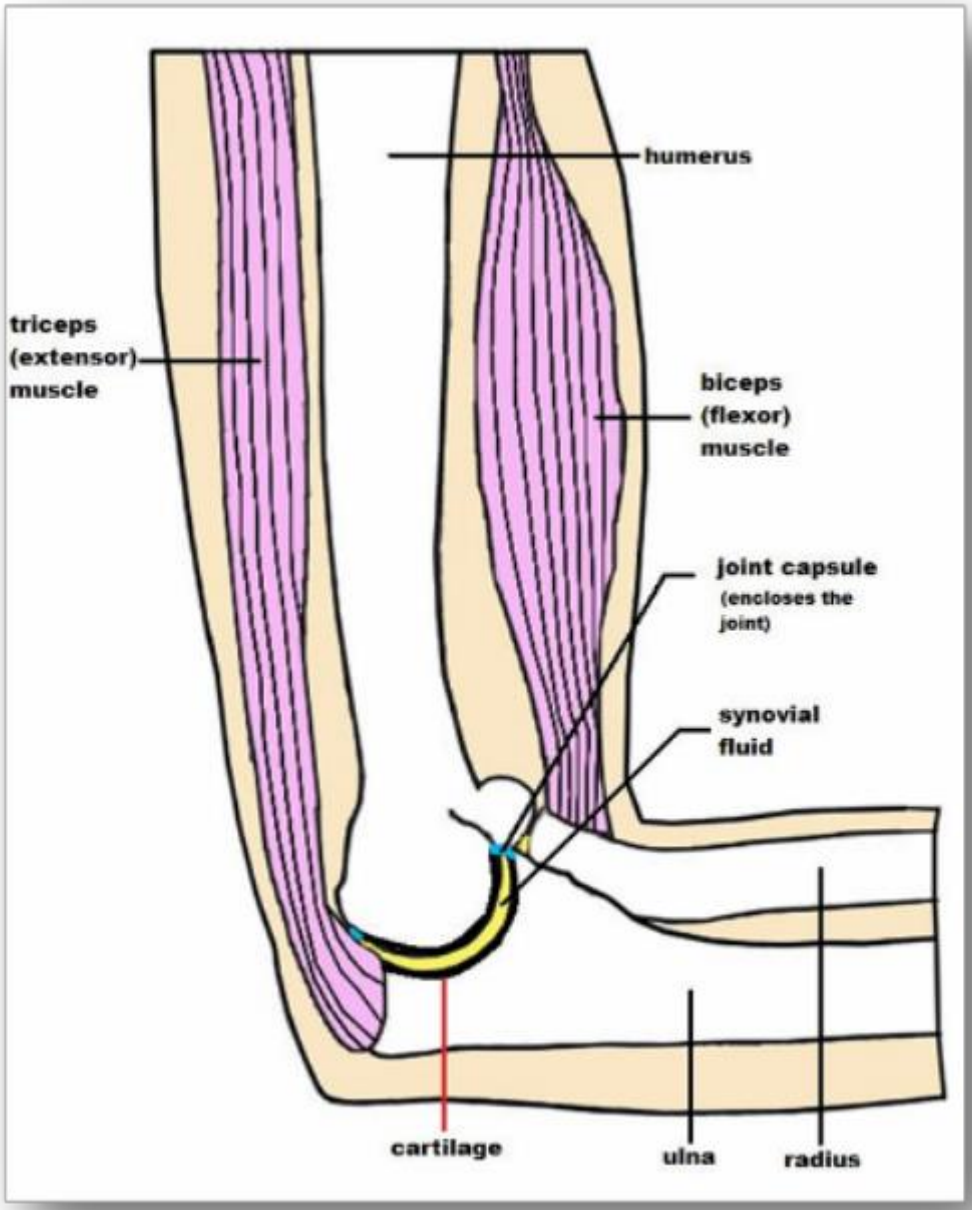
∑ - ***Synovial joints*** **allow certain movements but not others.**

- The type of joint determines the amount of movement that is possible
- For **ball and socket joints**, such as the hip or the shoulder, movement through all three planes are possible. At the hip joint, the head of the femur is the ball the fits into the socket of the pelvis. The movements possible at the joint are flexion, extension, rotation, abduction and adduction.
- For **hinge joints**, such as the knee, **flexions (bending) and extensions (straightening)** are the possible movements (movement in one plane); however, slight side to side movements are possible
-

• Hip Joint	• Similarities	• Knee joint

(differences)		(differences)
• Ball and socket joint	• Synovial joints separated by a fluid-filled cavity	• Hinge joint
• Free movement in all three planes	• Fluid is called synovial fluid that lubricates the joint.	• Allows movement in one plane (although there can be slight side to side movement)
• Greater range of motion than the knee joint (flexion, extension, adduction, abduction and rotation). Muscles involved are the quads, hamstrings, gluteus maximus and many other smaller muscles	• Ends of bones covered in cartilage, a smooth connective tissue which absorbs shocks more easily.	• Motions are flexion (contraction of hamstring muscle) and extension (contraction of quadriceps muscles)

β -Skill: Annotation of a **diagram** of the human **elbow**: include *cartilage*, *synovial fluid*, *joint capsule*, *named bones* and *named antagonistic muscles*.



Structure	Function
• cartilage - stiff yet flexible connective tissue found in many areas in the bodies such as the joints between bones, nose and ear	• cartilage reduces friction in the joint, provides high tensile strength and support, and absorbs compression
• synovial fluid – thick, viscous fluid found in the cavity of the synovial joints	• synovial fluid reduces friction by providing lubrication between the cartilage and other tissues in joints during movement • supplies oxygen and nutrients to and removes carbon dioxide and

	wastes from the cartilage cells
• joint capsule – two-layered sac surrounding the joint made from fibrous tissue	• The joint capsule seals the joint space and provides stability to the joint by limiting movements
• radius – smaller forearm bonethat extends from the lateral side of the elbow to the thumb part of the wrist	• Lever attached to the biceps. When the biceps contract, the radius provides a solid structure for lifting
• ulna – longer forearm bone on the medial side	• Lever connected to the triceps. When the triceps contract, the ulna provides support as a lever as the arm straightens out
• biceps – muscle connected to the radius	• contracts and causes flexion (arm bending)
• triceps – muscle attached ulna	• contracts and causes extension (arm straightening)

*****Data Based questions on page 477*****

∑ **- Movement of the body requires muscles to work in *antagonistic pairs***.

- Skeletal muscles occur in antagonistic pairs; therefore, when one muscle contracts, the other relaxes
- These antagonistic pairs produce opposite movements at the joint
- Examples are 1) biceps and triceps 2) quadriceps and hamstring

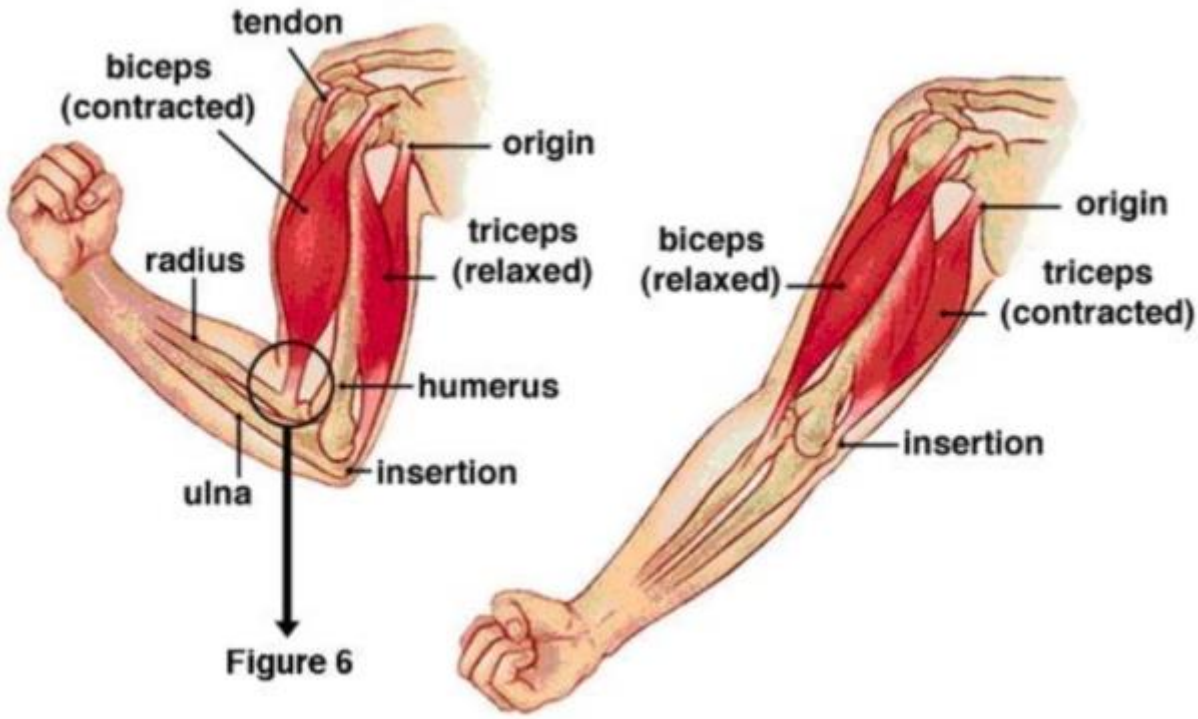
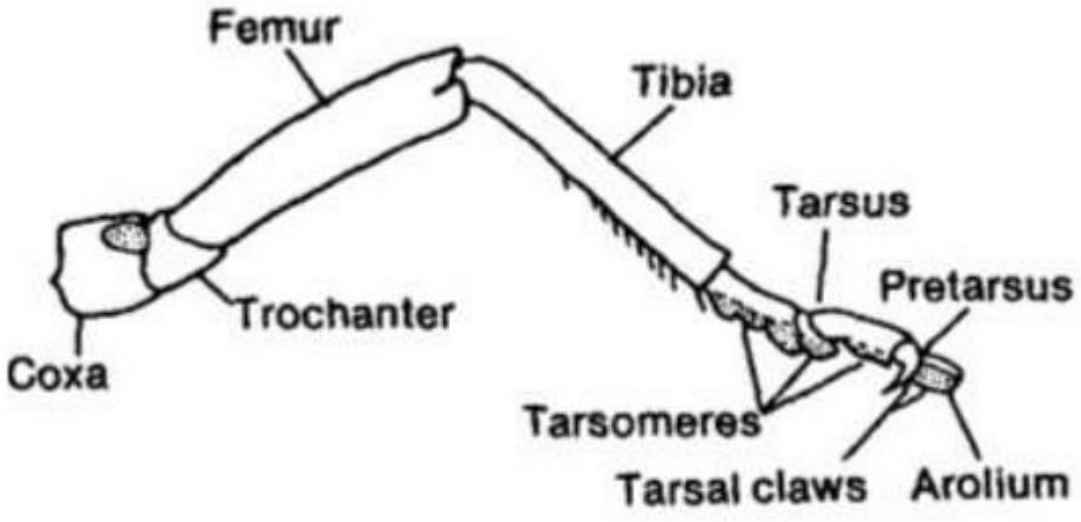


Figure 6

β - Application: Antagonistic pairs of muscles in an insect leg.

Grasshoppers

Ambulatory or walking leg



- The hind limbs of grasshoppers are specialized for jumping
- It has a jointed appendage with three parts
- Below the **joint is the tibia**, and at the base of the tibia is a**nother joint called the tarsus**
- Above the **joint is the femur**
- When the grasshopper jumps, **the flexor muscles contract**, and t**he femur and tibia are brought closer together (flexing)(extensor muscles are relaxed)**
- As the grasshopper jumps the **extensor muscles contract, extending the tibia, creating a powerful jump force**

Grasshopper jumping https://www.youtube.com/watch?v=cevL1RWcmqQ&list=PL0LFUbJiCoV67pVzNYsDnRE3roiMeCX3c&index=5

Interesting video http://www.smithsonianmag.com/science-nature/this-insect-has-the-only-mechanical-gears-ever-found-in-nature-6480908/?no-ist

∑ - Skeletal muscle fibres are *multinucleate* and contain *specializedendoplasmic reticulum*.

- Skeletal muscles are composed of bundles of muscle fibers and have a striped appearance because of areas of thick and thin filaments (myosin and actin)
- Muscle cells have many nuclei and are long because the embryonic muscle cells fuse together.
- Muscle fibers are composed of many parallel elongated fibers called myofibrils.
- A modified endoplasmic reticulum, called the sarcoplasmic reticulum (fluid-filled membranous sacs), extends throughout the muscle fibre, wrapping around each myofibril, sending a signal to the all parts of the muscle fibre to contract at the same time

∑ - Muscle fibres contain many *myofibrils*.

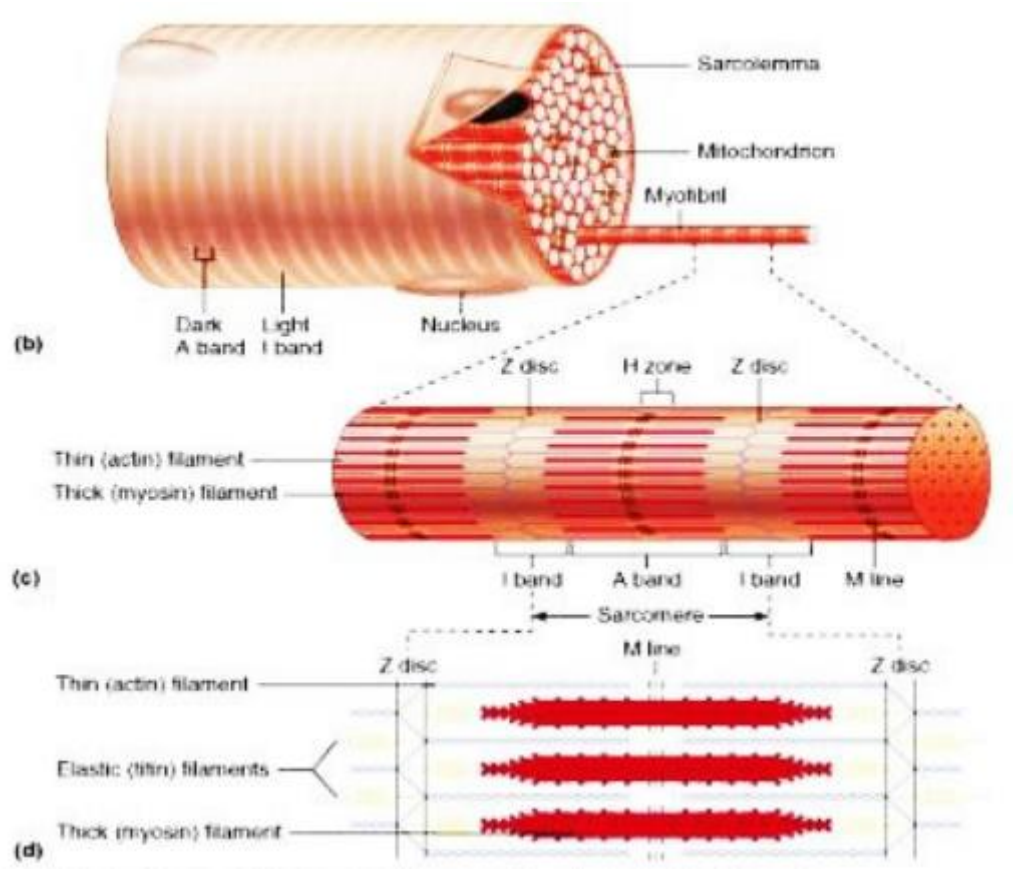
∑ **- Each myofibril is made up of contractile sarcomeres**.

Myofibrils – rod-shaped parallel bodies consisting of actin and myosin filaments

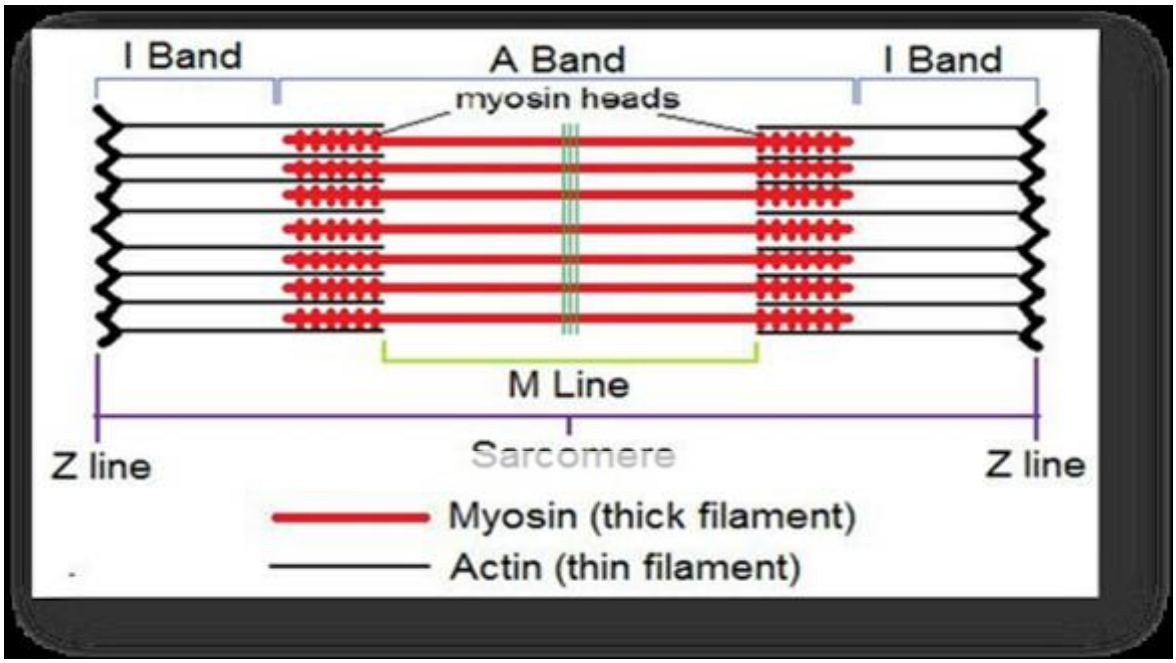
- *Sarcolemma* – plasma membrane of the muscle cell.
- *Mitochondria* – large numbers; found dispersed around individual myofibrils.

Sarcomere

- Lies between two Z lines which are dense protein discs.
- Contains the **thick filament (myosin) and thin filament (actin).**
- Myosin contains a head which binds to the **binding site on the actin**; interaction between **myosin and actin (cross-bridge) is responsible for muscle contraction.**
- Myosin is seen as **dark bands while actin is seen as light bands.**
- **A bands** contain a full length **of myosin and some of the actin filaments**.
- **I bands** contain only **actin filaments**.



<u>β - Skill</u>: **Drawing** labelled **diagrams** of the structure of a **sarcomere**: include *Z lines*, *actin filaments*, *myosin filaments with heads*, and the *resultant light and dark bands*.



*****Do data-based questions on page 481*****

∑ - The contraction of the skeletal muscle is achieved by the sliding of *actin*and *myosin* filaments. Use animations to visualize contraction.

- During a **muscle contraction**, **myosin filaments pull actin filaments**towards the centre of the sarcomere
- This shortens the sarcomere and the overall length of the muscle fibre
- When this occurs, the myosin heads bind to sites on the actin filaments, creating cross-bridges, pulling (sliding) the actin filaments along the myosin filaments with energy from ATP
- This is called sliding filament theory and is explained further below

Good videos on cross-bridge formation and muscle contraction:

https://www.youtube.com/watch?v=7wM5_aUn2qs

https://www.youtube.com/watch?v=Ct8AbZn_A8A

∑ - Calcium ions and the proteins tropomyosin and troponin control muscle contractions.

The first part in green is a lead up to the calcium binding to the troponin in the control of muscle contractions enhancing your understanding of what is occurring; however, it is probably not necessary to answer the understanding above*

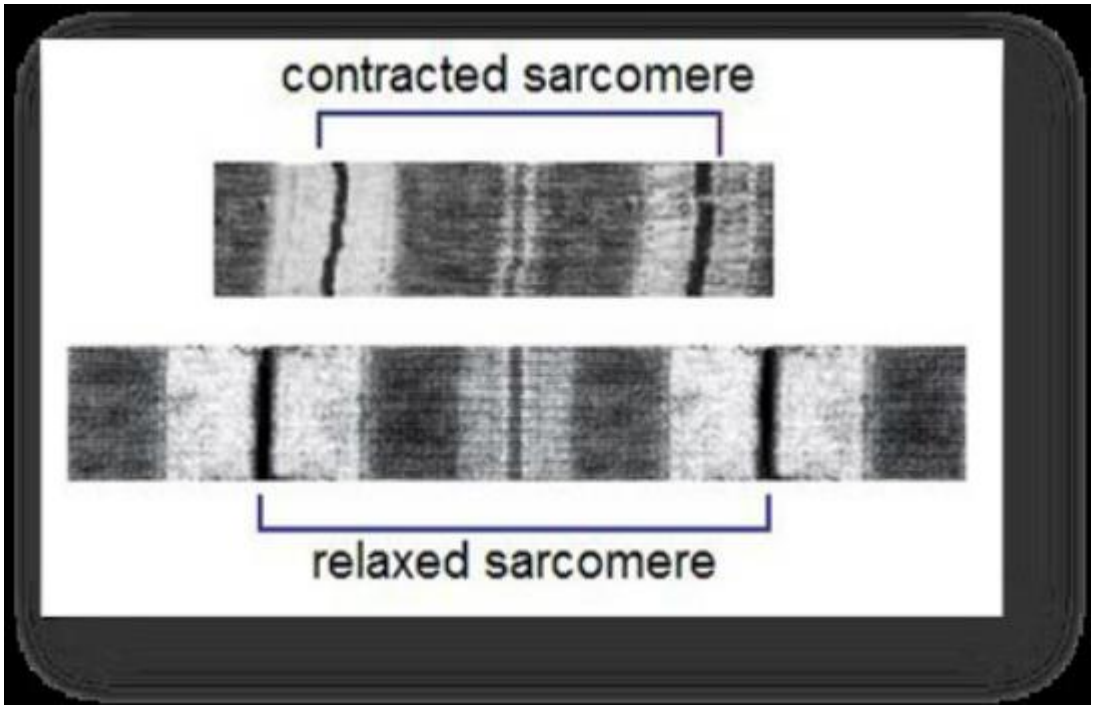
- An action potential propagated along a motor neuron arrives at the neuromuscular junction.
- This causes the release of the neurotransmitter acetylcholine into the synapsebetween the terminal axon of the motor neuron and the sarcolemma of the skeletal muscle.
- The acetylcholine binds to receptors on the sarcolemma, causing voltage-gated channels to open and Na^+ ions to flow into the muscle cells.
- This creates an action potential in the striated muscle.
- The action potential is further propagated along the sarcolemma of the skeletal muscle.
- The action potential moves into the interior of the muscle cell through folds called *t tubules*.
- The depolarization of the *t tubules* causes voltage-gated Ca^+ channels on the sarcoplasmic reticulum to open, causing an influx of Ca^+ ions into the sarcoplasm.
- Ca^+ ions bind to troponin which causes tropomyosin to move exposing the myosin binding sites (troponin and tropomyosin are regulatory proteinsblocking the myosin binding sites).

∑ - ATP hydrolysis and cross bridge formation are necessary for the filaments to slide

- ATP attaches to the myosin heads breaking the cross-bridges between the myosin heads and actin binding sites
- The ATP undergoes a hydrolysis reaction forming ADP + P_i.
- This causes a positional change in the myosin head (cocked back).
- The myosin heads bind to actin filaments forming cross-bridges at a site one position further from the centre of the sarcomere
- When the ADP + P_i are released the myosin heads change conformational position, sliding the actin filaments towards the center of the Sarcomere.
- This is called the "power stroke".
- After the power stroke ATP again binds to the myosin head, causing it to detach from the actin filament ready for another cycle.

β - Skill: Analysis of electron micrographs to find the state of contraction of muscle fibres. Measurement of the length of sarcomeres will require calibration of the eyepiece scale of the microscope.

Muscle Fiber (contracted and relaxed)



- Notice in the fully contracted sarcomere the actin filaments slide along the myosin causing the light bands to shorten, even though the dark bands stay the same length.
- The Z lines get closer together as the sarcomere contracts.
- The muscle also can be in various states of partial contraction.

β - Skill: Use of **grip strength data loggers** to assess muscle fatigue

Nature of science: Developments in scientific research follow improvements in apparatus—fluorescent calcium ions have been used to study the cyclic interactions in muscle contraction.

Read through article and make notes

Crash Course on Muscles: https://www.youtube.com/watch?v=jqy0i1KXUO4

11.4 Sexual reproduction: Sexual reproduction involves the development and fusion of haploid gametes.

Nature of science: Assessing risks and benefits associated with scientific research—the risks to human male fertility were not adequately assessed before steroids related to progesterone and estrogen were released into the environment as a result of the use of the female contraceptive pill.

Understandings:

∑ - *Spermatogenesis* and *oogenesis* both involve *mitosis*, *cell growth*, *two divisions of meiosis* and *differentiation*.

- Spermatogenesis is basically the production of sperm (male gametes) through meiosis.
- Spermatogenesis starts when **2n cells in the germinal epithelium (spermatogonia) divide by mitosis to form more 2n cells** that begin to move towards the middle of the **seminiferous tubules.**
- These cells grow and replicate their DNA to prepare for meiosis. These are now called **primary spermatocytes**.
- Oogenesis is basically the production of female eggs (female gametes) through meiosis.
- **Germ cells (2n)** in the fetal ovary divide by **mitosis to produce many 2n germ cells** called **oogonia.**
- Oogonia will grow in the cortex until they are large enough and ready to go through meiosis; they are called **primary oocytes**.
- The primary oocytes begin to go through the first division of meiosis, which is arrested (stopped) in prophase I when follicle cells surround the dividing oocyte.

- This is called the **primary follicle** (about 400,000 in a female when she is born).

- These follicles remain in the first stage of meiosis until the girl reaches puberty and begins her menstrual cycle.

- These **primary spermatocytes** undergo their first meiotic division resulting in two haploid (n) cells called **secondary spermatocytes**.

- Cells in between the developing spermatocytes called **interstitial cells (Leydig cells) produce testosterone in the presence of LH** (luteinizing hormone) to aid in the development of the sperm

- Secondary spermatocytes undergo a second meiotic division resulting infour spermatids (n).

- **Sertoli cells nourish** the spermatids as they **mature and differentiate into spermatozoa**.

- Sertoli cells are activated by **FSH**

- **Spermatozoa are released** into the **lumen of the seminiferous tubules**where they are transported to the **epididymis**. The sperm attain full motility in the epididymis.

- Every month a **primary follicle finishes meiosis I to form two haploid (n) cells** (one haploid cell is much larger than the other cell). This development is stimulate by FSH.

- The large cell is a **secondary oocyte** and the small cell is called the polar body.

- The secondary oocyte develops inside what is known as the **mature follicle**

- As the large secondary oocyte begins to go through the second meiotic division, it is **released from the ovary**. It will not complete the second meiotic division unless the oocyte is fertilized.

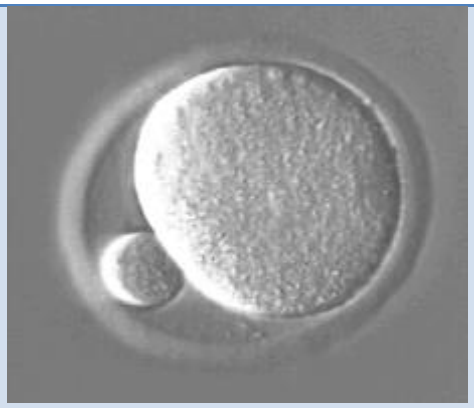
- When meiosis II is complete you have an ovum and another polar body.

Similarities between Spermatogenesis and Oogenesis (use the above information to fill in the table below)

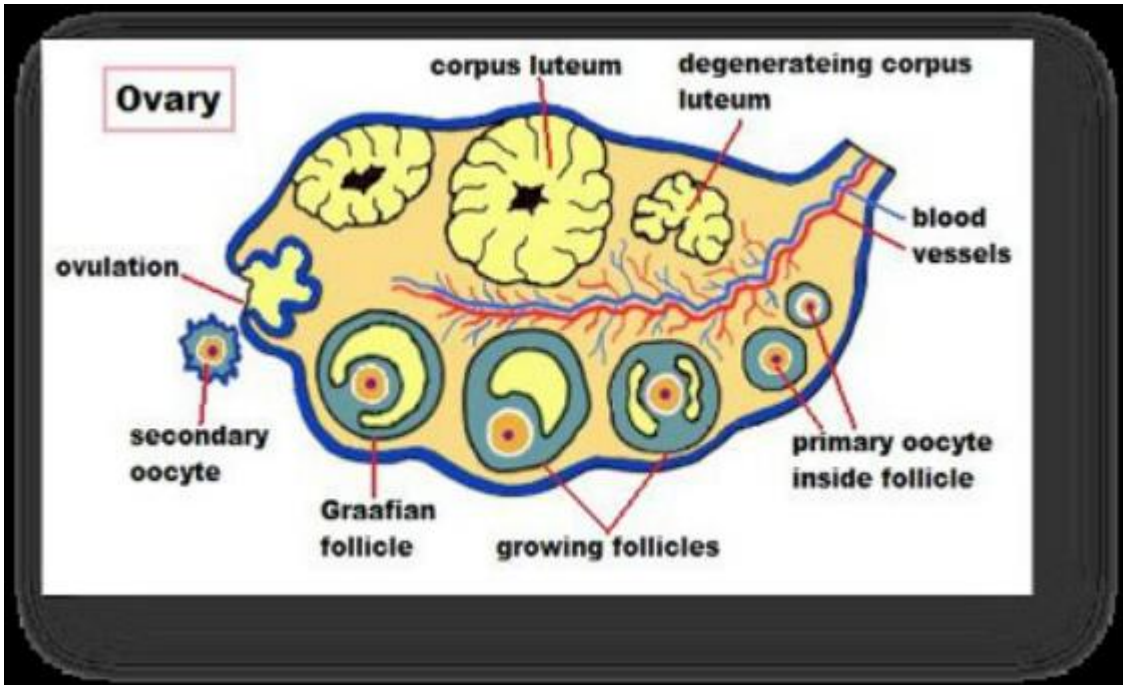
Spermatogenesis	Oogenesis

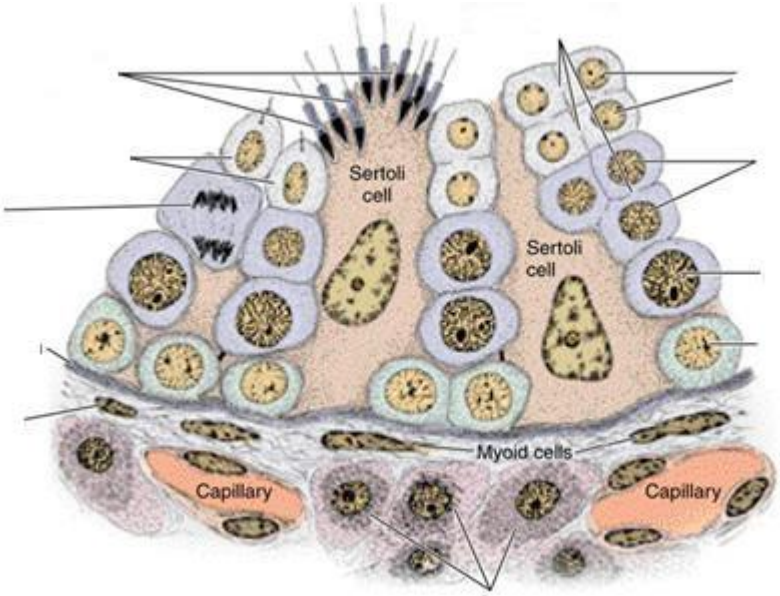
∑ - Processes in spermatogenesis and oogenesis result in different numbers of gametes with different amounts of cytoplasm. (Differences in the outcome of spermatogenesis and oogenesis

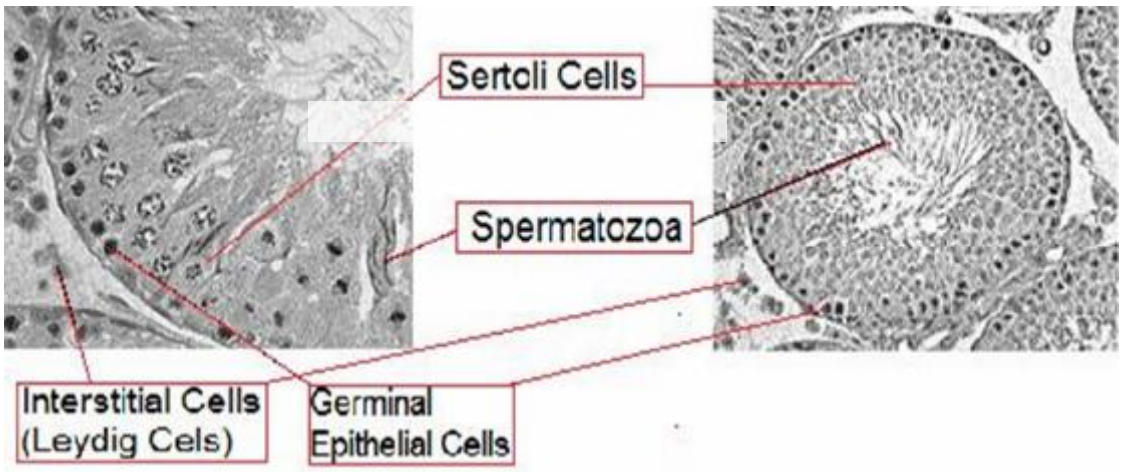
Spermatogenesis	Oogenesis

• Occurs in males (testis)	• Occurs in females (ovaries)
• Four male gametes (spermatids) are produced through meiosis for every germ cell.	• One female gamete (ovum) and 3 polar body cells for every germ cell are produced through meiosis.
• Each sperm cell is small and contains little cytoplasm	• The large egg cell contains large amounts of cytoplasm and the 3 polar bodies produced degenerate
• Millions of sperm produced every day from puberty until a man dies.	• One secondary oocyte is ovulated every month during the menstrual cycle until a woman reaches menopause.
	
• Spermatozoa are released during ejaculation.	• Secondary oocytes are released during ovulation.
•	•

Skill: **Annotation** of **diagrams** of **seminiferous tubule** and **ovary** to show the**stages** of **gametogenesis**.

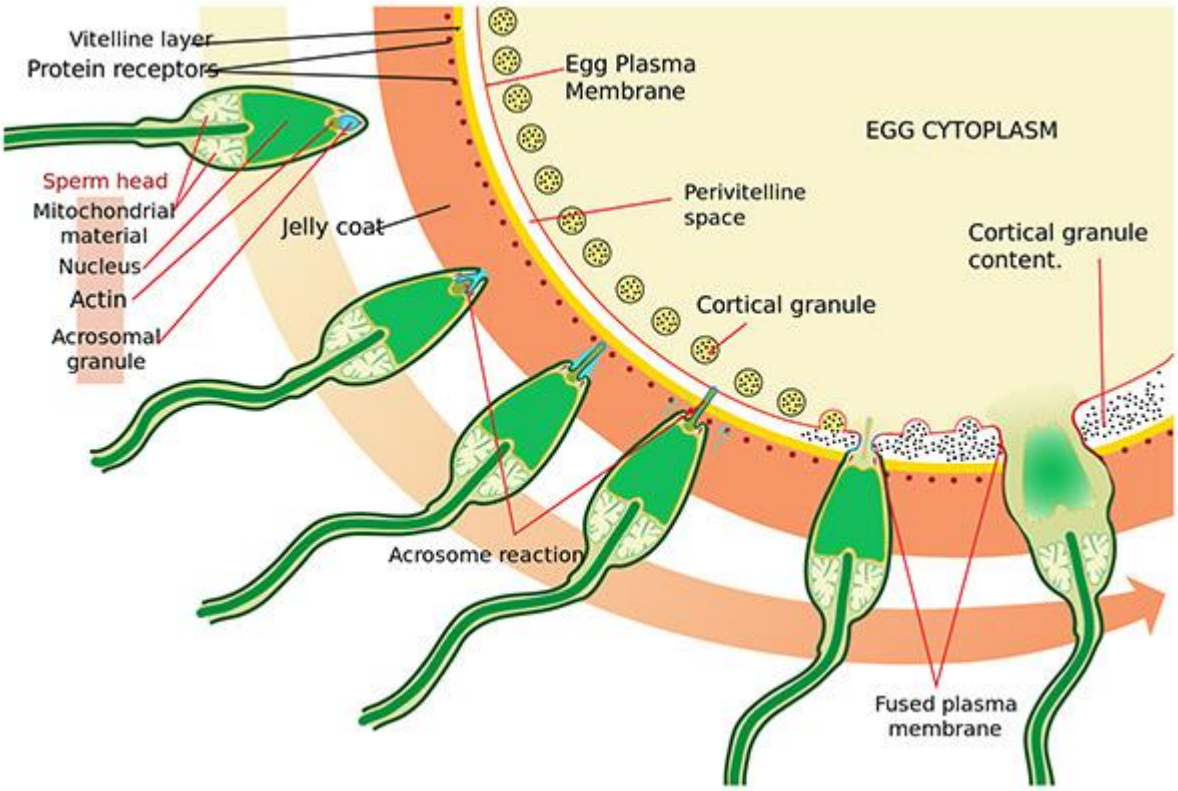

Ovary
corpus luteum
degenerateing corpus luteum
blood vessels
ovulation
secondary oocyte
primary oocyte inside follicle
Graafian follicle
growing follicles


Sertoli cell
Sertoli cell
Myoid cells
Capillary
Capillary


Sertoli Cells
Spermatozoa
Interstitial Cells (Leydig Cels)
Germinal Epithelial Cells

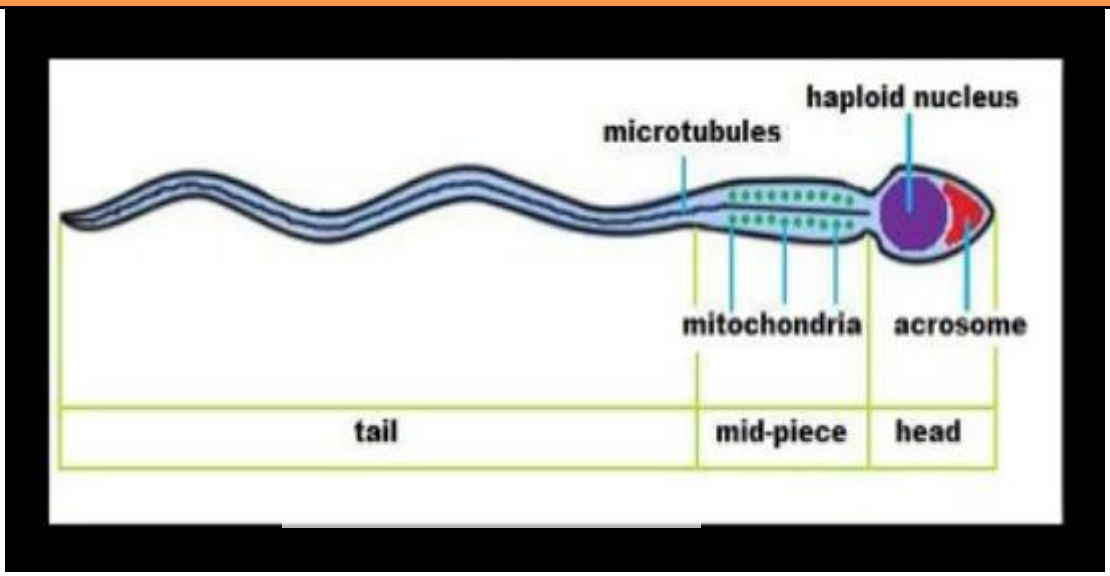
∑ - Fertilization involves the *acrosome reaction*, fu*sion of the plasma membrane of the egg* and *sperm* and the *cortical reaction*.

- Fertilization is the combining of the male and female gametes to produce a zygote.
- Sperm are ejaculated into the vagina of a female and are stimulated to swim by calcium ions in the vaginal fluids.
- The sperm follow chemical signals produced by the egg, until they reach the fallopian tubes, which is where the majority of fertilizations take place.
- When the sperm reaches the egg, a reaction called the ***acrosome reaction***takes place that allows the sperm to break through the layer of glycoproteins.
- The acrosome in head of the sperm **releases hydrolytic enzymes** onto the **glycoprotein layer** surrounding the egg **called the zona pellucida.**
- This digests the layer allowing the sperm to force their way through the zona pellucida through vigorous tail beating.
- The first sperm that makes it through comes into contact and fuses with the egg's membrane (The membrane at the tip of the sperm has special proteins that can bind to the now exposed membrane of the egg),releasing the sperm's nucleus into the egg cell.
- When the membranes fuse together, **cortical granules** near the surface of the egg membrane are **released by exocytosis**.
- The **chemicals in the granules combine with the glycoproteins** in the zona pellucida.This causes the glycoproteins in the zona pellucida to cross-link with each other, **creating a hard layer impermeable to the other sperm**.
- This prevents fertilization of an egg by more than one sperm.

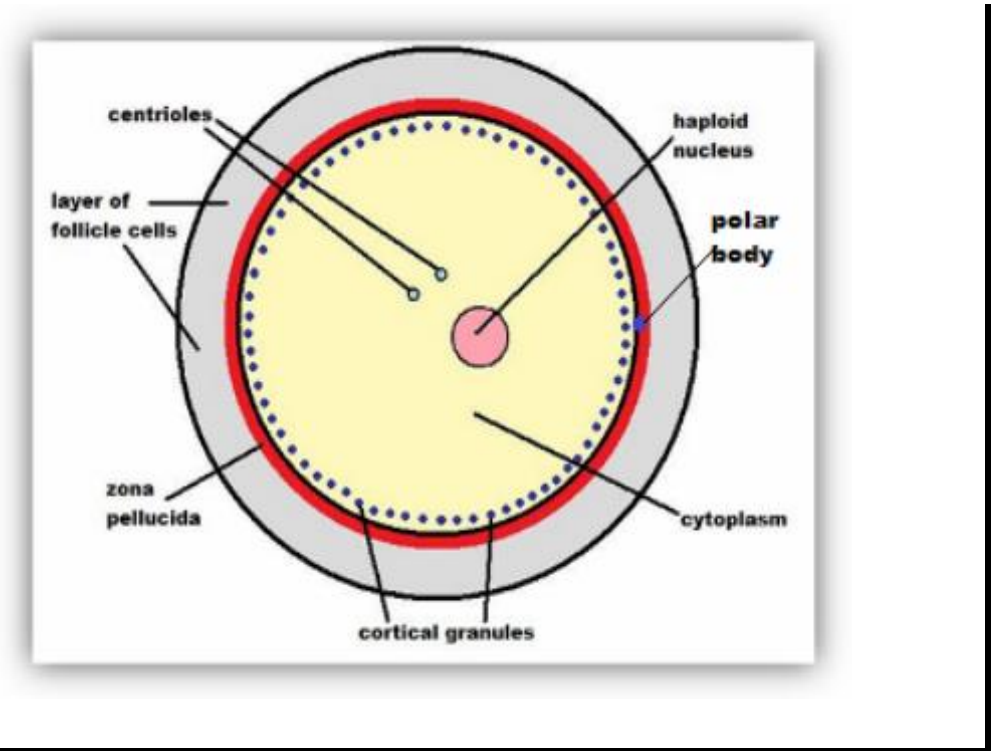


Skill: **Annotation** of **diagrams** of **mature sperm** and **egg** to indicate**functions**.

Sperm Diagram



Egg Diagram



∑ **- Fertilization in animals can be internal or external.**

- Without water to prevent drying out of the egg and sperm, terrestrial animals rely on internal fertilization
- This insures the close proximity of the sperm and egg in order to insure fertilization takes place
- Most aquatic organisms generally rely on external fertilization, which involves releasing the sperm and egg at a close proximity, into the water outside the female's body
- External fertilization increases the increases the risk of successfully creating offspring
- Several risks include predation and changes to the external environment (pH, pollution and temperature etc.)

External Fertilization Internal Fertilization

∑ **- Fertilization involves mechanisms that prevent polyspermy.**

- The membranes of the sperm have receptors that detect chemicals that the egg releases in order to move in that direction

- Once the sperm reaches the egg, the events explained above involving fertilization, the acrosome reaction and then the cortical reaction prevent multiple sperm from entering the egg (polyspermy)

∑ **- Implantation of the blastocyst in the endometrium is essential for the continuation of pregnancy.**

- After the male and the female gametes combine to form a **zygote**, thezygote divides by mitosis to form a **two-cell embryo**.

- They two cells grow and replicate their DNA, and undergo another cell division through mitosis to form a four-cell embryo.

- As the embryo is developing, it is moving along the fallopian tube towards the uterus.

- The four-cell embryo continues to divide by cell division until it reaches**16 to 32 cells**; called the morula.

- After continued cell divisions a blastocyst consisting of **100 to 128 cells**is formed and is ready for **implantation into the endometrium**.

- The blastocyst consists of an **inner cell mass** that will develop into the body of the embryo, a group of cells surrounding the embryo called thetrophoblast that will develop into the placenta, and a fluid-filled cavity called the blastocoel.

- The outer layer of cells will develop finger-like projections that will allow the embryo to penetrate the uterine wall during **implantation**.

  Video: - https://www.youtube.com/watch?v=3u251OXfsRU

∑ - HCG stimulates the ovary to secrete progesterone during early pregnancy

- When a human embryo is implanted into the endometrium or the uterine lining, it starts to produce the hormone, human chorionic gonadotrophin (HCG).

- HCG promotes the maintenance of the corpus luteum and prevents its disintegration.

- This allows for the continued production of progesterone which is critical for pregnancy.

- Progesterone enriches the uterus with a thick lining of blood vessels and capillaries so that it can sustain the growing fetus.

- HCG might repel the immune cells of the mother thus protecting the fetus during early development.

∑ - The placenta facilitates the exchange of materials between the mother and fetus.

- The placenta develops from the trophoblast layer of the blastocyst.

- When developed three blood vessels contained within umbilical cord connect the placenta to the growing fetus.

- Two umbilical arteries carry deoxygenated blood and waste away from the fetus to the placenta.

- As maternal blood enters the placenta it leaves the arteries and enters theinter-villous space, where it pools and surrounds the placental villi.

- The placental villi are finger-like fetal tissues that have **a large surface area for the exchange of materials** such as gases, nutrients and wastes.

- Fetal blood that circulates in capillaries within the villi and microvilli isvery close to the surface, allowing for **efficient exchange of materials**between the fetal and maternal blood.

- Materials such as oxygen, nutrients and vitamins diffuse into the fetal capillaries from the maternal blood in the inter-villous space, whilecarbon dioxide and wastes diffuse out of the fetal capillaries into the inter-villous space.

- One umbilical vein **carries oxygenated and nutrient rich blood back to the fetus** from the placenta.

- The cells that separate the fetal and maternal blood form a semi-permeable **placental barrier**

Materials are exchanged between the maternal and the fetal blood in the placenta.

Note: maternal and fetal blood is never mixed together.

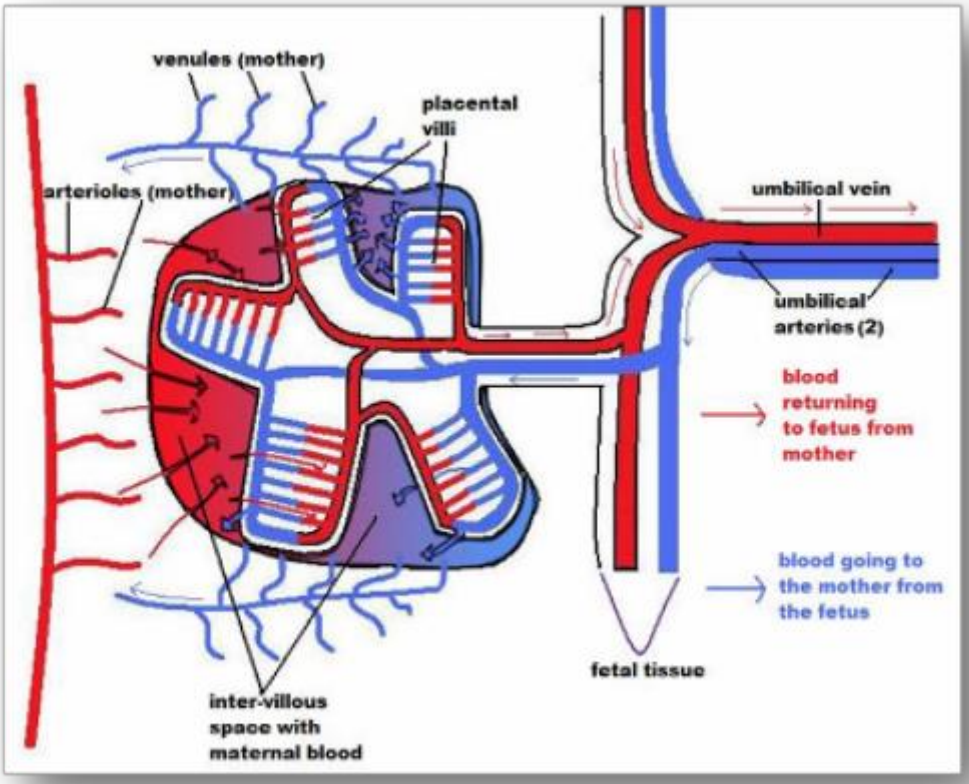
Materials passed from fetus to mother	**Materials passed from mother to fetus**
• **Carbon dioxide**	• **Oxygen**
• **Water**	• **Nutrients (i.e. glucose and amino acids)**
• **Urea**	• **Water**
• **Hormones (i.e. HCG)**	• **Vitamins and minerals**
	• **Hormones**

Good animations –

Fetal Circulation - https://www.youtube.com/watch?v=r0947ywQwos

Placenta - https://www.youtube.com/watch?v=bped-RVWsLk

Diagram of Placenta



∑ - Estrogen and progesterone are secreted by the placenta once it has formed.

- The placenta also starts to produce progesterone and estrogen after about 9 weeks taking over from the corpus luteum. The placenta produces enough of these steroids to maintain the pregnancy and the corpus luteum is no longer needed.

- These hormones are necessary to maintain the rich blood supply needed by the placenta.

*****Do data based questions on page 507 and 508*****

∑ **- Birth is mediated by positive feedback involving estrogen and oxytocin.**

- When the pregnancy is at term, the **fetus secretes hormones** that **signal the placenta** to **stop producing progesterone** (progesterone inhibits the secretion of oxytocin by the pituitary gland).

- **Oxytocin secreted** by the **anterior pituitary gland** stimulates the muscle fibers in the uterus to begin to contract.

- As the muscles in uterus contract, **mechanoreceptors in the uterinewall** signal the pituitary to **produce more oxytocin.**

- **More oxytocin increases the frequency** and intensity of the contractions, thus stimulating the production of even more oxytocin.

- This is an example of **positive feedback**.

- Contractions of the muscles of the uterus will cause the amniotic sac to break, releasing the amniotic fluid (This is when the "water breaks" in childbirth).

- Relaxation of the muscles in the cervix causes it to dilate, eventually allowing the increasing contractions to push the baby out through the vagina and the cervix.

- The placenta is expelled "afterbirth" about 15 min after the baby is born.

*****Do the data analysis questions on page 508 and 509*****

β -Application: The average **38-week pregnancy** in humans can be positioned on a graph showing the **correlation** between **animal size** and the **development of the young** at birth for other mammals.

- There is a correlation with animal size (mass) and the development of their young (viewed as length of gestation period)

- In many cases, the longer the gestation period, the greater the mass size and development at birth

- Species of mammals that give birth to smaller, immature and somewhat helpless offspring are called altricial species

- Species of mammals that give birth to more mature offspring that are generally larger, have their eyes open at birth and are immediately mobile. These offspring are precocial.

  Do the data analysis on page 510

β -Application: Disputes over the **responsibility** for **frozen human embryos**.

- http://www.creatingfamilies.com/intended-parents/?Id=169

- http://www.cnn.com/2014/03/24/living/frozen-embryos-elle-relate/