SUMMARY OF BIOLOGY AS

陈 思

CHENSIMICHELLE@GMAIL.COM

目录

Cellular Structure

Microscope

Microscope is a device that gives magnified picture of substance we study, so as to provide us the details that we cannot observe by naked eyes.

$$\text{Magnification} = \frac{\text{Image size}}{\text{Actual size}}$$

With the combination of *eyepiece graticule* and *stage micrometer* we can calculate the actual size of species we observe.
Eyepiece graticule divides a length on eyepiece into 100 subunits.
Stage micrometer is the scale etched on slides whose smallest subdivision is 0.1 or 0.01 mm.

Resolution is the smallest distance that can be distinguished between two points.
The wave length of photons (400-700nm) is much larger than that of electrons (0.1nm-10nm). Wave diffracts when it passes through slits that have similar size of their wavelength. Thus, light microscope cannot observe objects smaller than 400nm clearly.

The comparison of light microscope and electron microscope

Microscope	Resolution	Specimen	Observed area	Objects observed
Light	$0.1\ \mu m - 100\ \mu m$	Dead and dehydrated	Either surface or the cross section	Eukaryotic cell Nucleus
Electron	$10\ nm - 100nm$	No special requirement	Surface	Organelles Detail of membrane

The advantage of using light microscope:

- It is much more convenient to use
- It can be used to observe living cell; thus, we can see the process that takes place inside of the cell

The disadvantage of using light microscope:

- It has lower resolution; thus, less detail can be observed. Because light diffracts over small subjects.
- It has lower magnification

Some organelles sometimes are unexpectedly absent from the slides, this may result from:

- Not included in the cross section
- Not stained correctly

The difference between scanning microscope and transmission microscope:

- Scanning microscope can only show the surface of the sample
- Transmission microscope can show the internal structure of the sample

Cell

Cell is the basic unit of life.

Comparison of prokaryotic cell and eukaryotic cell

Features	Prokaryotic cell	Eukaryotic cell
Organism	Bacteria	Fungi, animal, plant
Size	$1-5\ \mu m$	$40-100\ \mu m$
Nuclear envelope	Absent	Present
DNA	Circular and naked	Linear and bond with histone protein
Membrane bounded organelle	Absent	Nucleus, mitochondrion, chloroplast, rough ER, smooth ER, Golgi body, lysosome
Cell wall	Peptidoglycan	Cellulose in plant cell
Ribosome	70S	80S
Replication	Binary fission	Mitosis
Structures that can be only found in some prokaryotic cell: flagellum, plasmid, pili, capsule		

Endosymbiont theory holds that eukaryotic cells are developed from prokaryotic cells. Chloroplast and mitochondrion were originally independent prokaryotes. They were swollen by eukaryotic cell and live within them.

Organelle found only in plant

Organelle	Size	Description	Function	Light Microscope
Cell wall		Cellulose made by β-glucose	Withhold hydrostatic pressure Prevent cell busting	Visible
Chloroplast	$10\mu m$	Double membrane with grana presents	Photosynthesis, producing ATP	Visible
Vacuole	$50\mu m$	Tonoplast and sap	Storage of nutrient, pigments and waste products Maintain the shape of cell Maintain the turgor pressure	Visible
Plasmodesmata		Pore-like structure in cell wall	Connects cytoplasm of neighboring cells	no

Organelles found in animals

Structure	Size	Structural Property	Function	Light microscope
Nucleus	$10\ \mu m$	Double membrane with pores on its outer surface	Separate chromatin from the rest of the cell Synthesize rRNA and ribosome	Visible
Rough ER		Extends from outer membrane of nucleus with ribosomes on it	Provide support for ribosomes and transfer of polypeptide	Invisible
Smooth ER		Single membrane with no ribosome on it	Synthesis of lipid and steroid	Invisible
Golgi Body		Keep absorbing sacs from rough ER and budding off vesicles	Process polypeptide to form functional proteins (post-translational process) Fold polypeptide into right shape Contain proteins in a sac, preparing them for exocytosis Form lysosome	Invisible
Lysosome	$10\ nm$	Vesicle budding off from Golgi body, containing hydrolytic enzymes	Breaks down unneeded structures and alien organism Hydrolyze protein into amino acid or cell wall into monosaccharides	Invisible
Mitochondria	$1\ \mu m$	Double membrane with inner membrane folded inwardly to form cristae	Site for respiration which produce ATP molecules	Visible
Ribosome	$20\ nm$	Two subunits	Site for protein synthesis	Invisible
Centrosome	$500\ nm$	Two centrioles, made by microtubules, perpendicular to each other	Organize chromosome during mitosis Form spindle	Invisible
Microvilli		Finger liker structure at the edge of cell	Increase the surface area of cell	Visible

Centrosome is the structure that be found only in animals

Biological Molecules

Major type of biological molecules

Biological molecules	Elements involved	Components	Bond between components	Function
Carbohydrate	$C_x(H_2O)_y$	Glucose	Glycosidic bond	Fuel and energy storage
Lipid	C, H, O	Glycerol, fatty acid	Ester bond	Energy storage
Protein	C, H, O, N, S	Amino acid	Peptide bond	Structure Enzyme
Nucleic acid	C, H, O, N, S, P	Nucleotide	Phosphodiester	Genetic material

Condensation joins two molecules with a release of water molecule.

Hydrolysis splits one molecule into two parts by adding a water molecule.

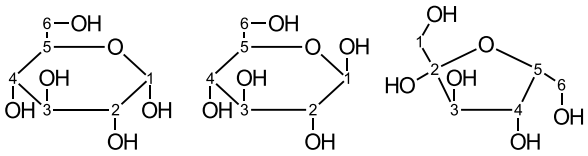
Carbohydrate

Carbohydrate	Molecules	Formula	Components	Function
Mono-saccharides	Triose	$C_3(H_2O)_3$		
	Pentose	$C_5(H_2O)_5$	Ribose Deoxyribose	Components of nucleotide
	hexoses	$C_6(H_2O)_6$	α-glucose β-glucose fructose	Fuel of respiration Monomer of polysaccharides
Disaccharides	Sucrose	$C_{12}(H_2O)_6$	α-glucose Fructose	
	Maltose		α-glucose	
Poly-saccharides	Amylose	$C_x(H_2O)_y$	α-glucose 1-4 glycosidic bond	Both amylose and amylopectin make up starch which acts as energy storage in plants
	Amylopectin	$C_x(H_2O)_y$	α-glucose 1-4 glycosidic bond 1-6 glycosidic bond	
	Glycogen		α-glucose 1-4 glycosidic bond 1-6 glycosidic bond	Glycogen is the energy storage in animals
	Cellulose		β-glucose 1-4 glycosidic bond	Cellulose is the major components of plant cell wall

All the carbohydrates hydrophilic. Because they contain large amount of hydroxyl group (-OH), that can form hydrogen bond with water.

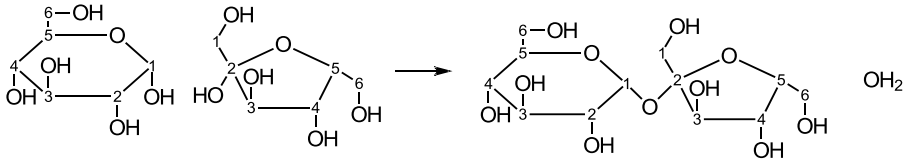
Monosaccharides and disaccharides are soluble in water.

Monosaccharides



α-glucose β-glucose fructose

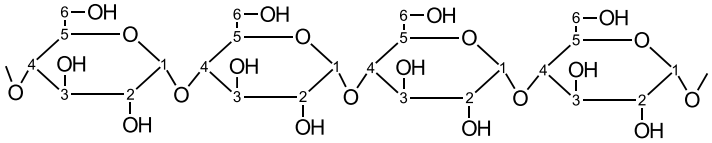
Disaccharides



α-glucose fructose sucrose

Monosaccharides condense to form disaccharides while disaccharides hydrolyze to form monosaccharides.

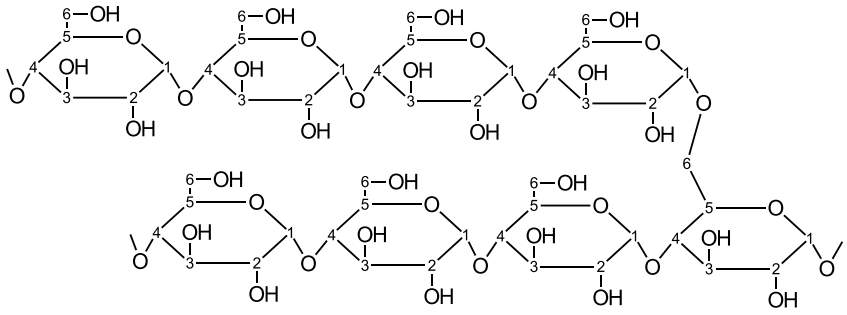
Amylose



The chain of amylose curve and coil into a helical structure. This produces a more packed polymer, taking less space.

Only α(1-4) glycosidic bond in amylose, no branch present.

Amylopectin or glycogen



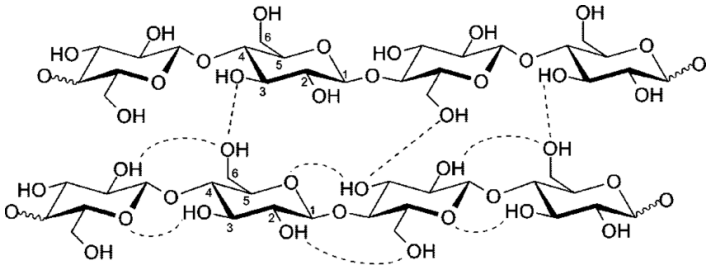
Both α(1-4) and α(1-6) glycosidic bond present in amylose. Both amylopectin and glycogen are branched and the branches are connected via α(1-6) glycosidic bond.

Glycogen is more branched than amylopectin.

Branches save more space.

Branches allow more ends in the molecules to be processed by enzyme; add glucose into the polymer via condensation or remove glucose from the polymer by hydrolysis

Cellulose



Cellulose is insoluble and ideal material for cell wall

- The two neighboring glucose residues are upside down relative to each other.
- The cellulose molecule is in straight chain. Only β(1-4) glycosidic bond presents.
- Cellulose molecules lie parallel to each other. Cellulose molecules are held by hydrogen bonding and together they form fibrils and fibres.
- This gives cell wall strength and prevent cell from bursting. Fibres are crisscross with gaps between them, allowing passage of water and other soluble substances

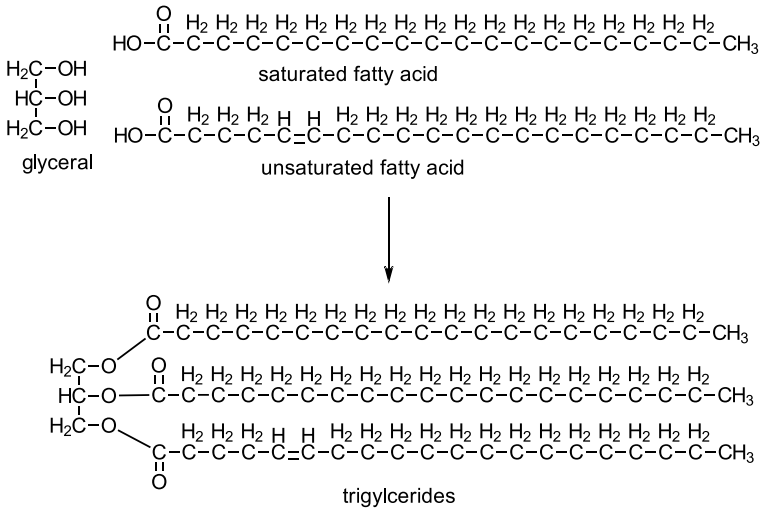
Water

Water has many special properties making it an ideal substance for life.

- It is polar thus polar substance can form hydrogen bond with it and dissolve in it.
- It has high specific heat capacity, thus very limited fluctuated in temperature.
- It has high latent heat of vaporization, large amount of heat can be taken away during vaporization
- Lower density in solid compared with water
- High surface tension, so small organisms such us insects can stay on its surface.

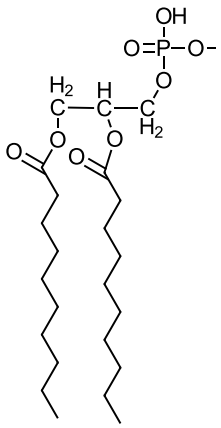
Lipid

Lipid	Components	Structure detail	Function
Triglycerides	Glycerol Fatty acid	If C=C presents in fatty acid, melting point of triglycerides is lowered	Energy store
Phospholipid	Glycerol Phospholipid Fatty acid	If C=C presents in fatty acid, membrane becomes more fluid	Major component of membrane
Steroid			Reproductive Hormone



glycerol and the carboxyl group of fatty acid is hydrophilic because they can form hydrogen bond with water.

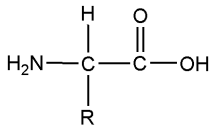
The alkyl group of fatty acid and triglycerides are hydrophobic, because they are non-polar thus cannot form hydrogen bond with water.



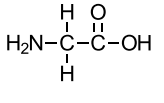
phospholipid is made by glycerol with two fatty acids and one phosphate group.
Phosphate forms hydrophilic head and fatty acid forms hydrophobic tail.
Fatty acid can be either saturated or unsaturated. The presence of "C=C" increases the fluidity of cell membrane.

Protein

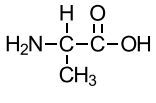
Amino acid is the monomer of protein.



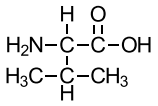
Each amino acid has a central carbon bond with an amino group, a carboxyl group, a hydrogen atom and a side chain. The side chain can be polar or non-polar, hydrophilic or hydrophobic.



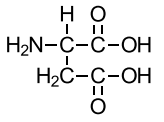
Glycine



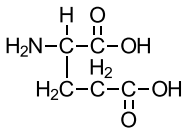
Alanine



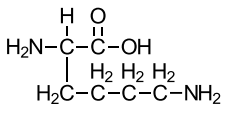
Valine



Asparic acid

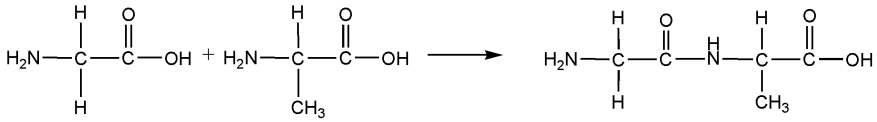


Glutamic acid



Lysine

Dipeptide is formed when two amino acids condense together.



Glycine Alanine Dipeptide Gly-Ala

Structure of protein

1. Primary structure is the sequence of amino acid.
2. Secondary structure, α helix and β sheet, is maintained by hydrogen bond between peptide bond.
3. Tertiary structure gives the 3D shape of the protein and is maintained by the interaction between side chains of amino acid residue. The interaction involves hydrogen bond, hydrophobic force, ionic bond and disulfide bridge. Tertiary structure is unstable. It can be easily damaged by high temperature, extreme pH value and etc.
4. Quaternary structure involves the arrangement of polypeptides.

The shape of protein is decided by the sequence of amino acids. Thus, when primary structure changes, the tertiary structure will be changed as well. The protein may fail to function.

Haemoglobin

- Haemoglobin is spherical and soluble. It is composed of four polypeptides (two α chains and two β chains).
- The surface of haemoglobin is composed of hydrophilic amino acid residue while the core of the globin is composed of hydrophobic ones.
- Each chain has a non-protein group, haem, at its centre.
- Each haem has an iron bonded while each iron atom can bond with an oxygen molecule.

Collagen

- Collagen is fibrous protein composed of three polypeptides.
- Each third amino acid in the polypeptide is glycine enabling it forms a compact triple helix.
- The triple helix winds together via hydrogen bond.
- Collagen molecules lie parallel to each other, linked by covalent bond. This enables collagen to afford great strength.

Chemical test

Substance	Reagent	Observation
Reducing sugar	Boil with Benedict reagent	Blue solution suggests no reducing sugar present in the solution Green solution suggests trace of reducing sugar present Orange solution suggests moderate amount of reducing sugar present Red solution suggests substantial amount of reducing sugar present
Non-reducing sugar	Boil with acid then boil with Benedict reagent	Color change in the above way suggest the presence of non-reducing sugar.
Lipid	Emulsion test	Dissolve first the sample in ethanol, then apply water to the alcoholic solution. If emulsion turns up, lipid present
Protein	Biuret	Purple compound formed with the presence of protein.

Enzyme

Mechanism of enzyme

Enzymes are biological catalysts which are usually made of protein. It speeds up reaction rate because it can lower the activation energy of the reaction by bringing reagents together at its active site.

Lock and key model

- The substrates usually have complementary shape with active site of enzymes.
- Substrate binds to active site to form enzyme substrate complex (ESC).
- This lowers activation energy of the reaction.
- ESC is maintained by intermolecular force which can be easily broken.
- Thus, when reaction is completed, products diffuse away from the enzyme.
- Enzyme can be reused

Induced fit model

- The shape of substrate is not exactly complementary to the shape of active site.
- The shape of active site changes slightly with the entrance of substrate. This makes the two shapes become completely complementary.
- Then substrate bind to enzyme to form enzyme substrate complex.
- This lowers activation energy of the reaction.
- Products leave the active when reaction is complete.
- Enzyme can be reused

Intracellular enzyme works in cells while **extracellular enzyme** works outside of enzyme.

Enzyme	Substrate	Products
Amylases	Starch	Maltose
Lipases	Lipids	Fatty acids and glycerol
Proteases	Proteins	Shorter peptides and amino acids
Trypsin	Proteins	Shorter peptides and amino acids

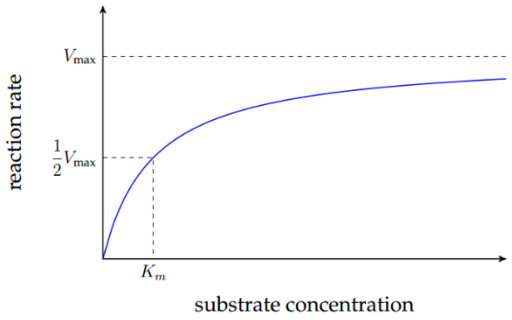
Rate of enzyme catalyzed reaction

Activity of enzyme depends on the fitness of enzyme and substrate. Thus, when the shape of active site changes, it becomes hard for substrate to bind and the rate of reaction decreases.

Concentration of enzyme

Rate of reaction increases as concentration of enzyme increases. As more ESC formed in unit time at higher enzyme concentration.

Concentration of substrate



At lower concentration of substrate

Reaction rate increases significantly as concentration of substrate increases. At lower concentration of substrate, most active sites are unoccupied. As concentration of substrate increases, more ESC formed in unit time. Reaction rate increases. Concentration of substrate is the limiting factor.

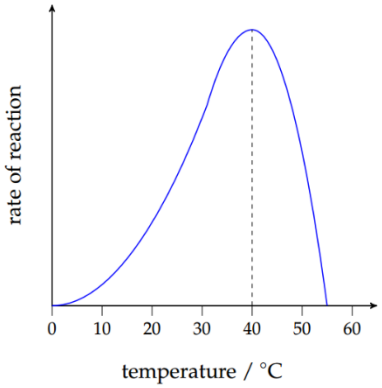
At higher concentration of substrate

The increase in reaction rate slows down, as most active site become occupied.
Reaction rate reach its maximum when substrate concentration reaches certain value. As all the active sites are occupied and enzyme become the limiting factor. Maximum amount of ESC is formed in unit time.

V_{max} and K_m

K_m is the substrate concentration that is required for half of the V_{max} is achieved. K_m is determined by the affinity of enzyme. For enzyme with higher affinity, lower K_m will be found. For the enzymes whose active site is more fitted with substrate, they usually have higher affinity and lower K_m.

Temperature



At lower temperature

Reaction rate increases as temperature increases. Kinetic energy of substrate increases as temperature increases, thus higher collision frequency at higher temperature. More ESC formed in unit time.

At higher temperature

Reaction rate decrease as temperature increases. Because the tertiary structure of enzyme is broken at higher temperature. The shape of active site changed and substrate can bind to the enzyme no more. Less ESC formed at higher temperature, though collision frequency is higher at higher temperature.

pH

Reaction rate decreases in extreme acidic or basic environment. Because the tertiary structure of enzyme is broken. The shape of active site changed and substrate can bind to the enzyme no more. Less ESC formed.

Immobilized Enzyme

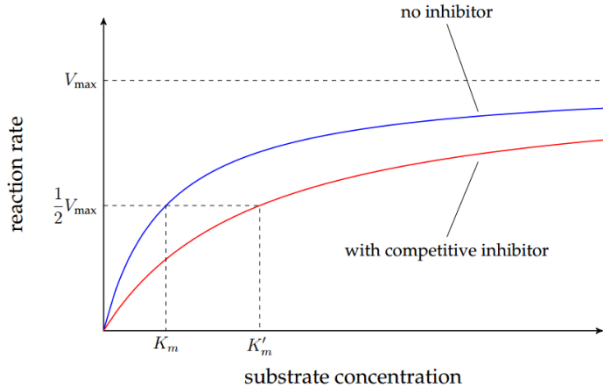
Immobilized enzyme is formed when enzyme is fixed on solid support. This stabilizes the structure of enzyme.

Advantage of Immobilized Enzyme

- Immobilized enzyme is able to tolerate wider range of pH and temperature compared with free enzyme.
- It can be used in higher temperature. Substrate has higher kinetic energy at higher temperature, thus higher reaction rate.
- Immobilized enzyme is easily to be recovered and separated with products.
- Products are not contaminated by enzyme and less downstream process is needed.

Inhibitor

Competitive Inhibitor



Competitive inhibitor has similar shape with substrate. It binds to active site, making it unavailable to substrate.

At lower substrate concentration

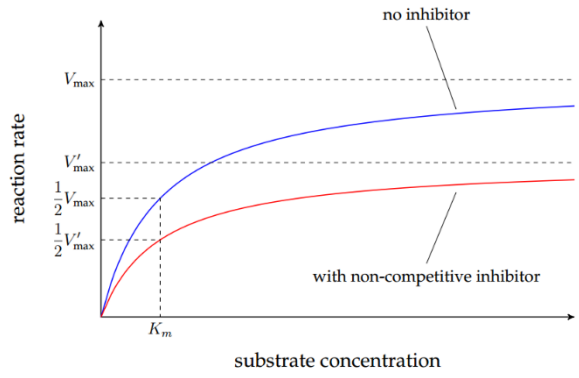
Due to the presence of competitive inhibitor, fewer ESC is formed in unit time and reaction rate decreases. Thus, the curve with the inhibitor is to the right of the curve without inhibitor.

At high substrate concentration

The effect of competitive inhibitor is reversed when the substrate concentration is high enough. The same will be achieved. Because the value of V_{max} is determined by the concentration of enzyme.

Competitive inhibitor decreases the affinity of enzyme, and K_m becomes larger.

Non-competitive Inhibitor



Non-competitive inhibitor binds to allosteric site (not active site) of enzyme. The shape of active site changed with the binding of non-competitive inhibitor. Substrates cannot bind to the enzyme.

Due to the presence of non-competitive inhibitor, fewer ESC is formed in unit time and reaction rate decreases. Thus, the curve with the inhibitor is to the right of the curve without inhibitor. With the presence of non-competitive inhibitor, V_{max} will never be reached. Because the concentration of effective enzyme decreases.

Non-competitive inhibitor does not change the affinity of enzyme. Thus, K_m stays the same.

Cell membrane and Transport

Cell membrane separate the extracellular environment from intracellular environment. It has a wide range of function, including:

- Barrier of cytoplasm and extracellular environment
- Selection of substances that enter a cell
- Cell signaling receptor
- Cell recognition (surface antigen)
- Cell to cell adhesion
- Site for enzyme reactants
- Anchoring the cytoskeleton

Cell membrane

Components	Function
Phospholipid	Hydrophilic heads form hydrogen bond with water to stabilize membrane. Hydrophobic tails impede the entrance of polar substance
Cholesterol	Stabilize membrane structure Improve the fluidity of membrane
Glycolipid Glycoprotein	Receptor for cell signaling molecule Antigen for cell recognition Stabilizing membrane structure (carbohydrate form hydrogen bond with water) Cell adhesion
Protein	Transport protein Anchor point for cytoskeleton Enzyme

Membrane is only 7nm wide. The detail of the structure can be only observed by electron microscope.

Mosaic Fluid Model

"Mosaic" refers to the fact that proteins are scattered among phospholipid bilayer.

"Fluid" means that both phospholipids and proteins are moving around

Signal transmission

Identify both signal molecule and target cell.

Signal molecule binds with the receptor on the membrane of target cell. They bind because they have complementary shape. Once they bind, internal reactions take place in cell.

Transport

Transport	Protein involved	Substance transported	Concentration gradient	ATP consumption
Simple Diffusion		Small non-polar molecules	Down	No
Facilitated Diffusion	Carrier protein Transport protein	Ions Polar molecules	Down	No
Osmosis	Aquaporin	Water	Down Water potential	No
Active Transport			Against	Yes
Bulk Movement	Receptor	Antibody, hormone, bacteria	Down or against	Yes

The hydrophobic part of phospholipid prevents the entrance of hydrophilic molecules but allow the entrance of hydrophobic molecules.

Transport and carrier protein

Transport proteins span across the membrane. Its hydrophilic hollow core is filled with water molecules. They are usually gated. It allows hydrophilic molecules moving through when the gate opened.

Carrier proteins bind with the substances it transports and shifts them to the other side of the membrane.

Osmosis and water potential

- Concentrated solution has more negative water potential compared with dilute solution. Water moves from the place of higher water potential to the place of lower water potential.
- When cells are put into the environment with lower water potential, it loses water and shrinks; plant cell would become plasmolyzed.
- When cells are put into the environment with higher water potential, it absorbs water. If too much water is absorbed, animal cells would burst out while plant cell would not. Plant cells are contained in cellulose cell wall which is able to sustain high hydrostatic pressure.

Endocytosis and exocytosis

- Exocytosis takes place when large amount of proteins, such as antibody and hormone, are secreted out of the cell. They were processed and contained in Glogi vesicles which then fuse with membrane and being released.
- During exocytosis, vesicles containing substance is first fused with cell membrane. Substances are then released. ATP is required
- Endocytosis takes place when bacterial are devoured by cells such as macrophage. Antigen on bacterial binds with the receptor on cell membrane. Cell membrane pinches in and engulfs bacterial. Membrane fuses to form a vesicle around bacterial. ATP is required.

Cell Cycle

Eukaryotic cell replicates by mitosis while prokaryotic cell by binary division. Cell replication is important in the following ways:

- Growth
- Replacement
- Repair damaged tissue
- Asexual reproduction
- Immune response

Cell cycle

Stage	G1 Phase	S Phase	G2 Phase	Mitosis	Cytokinesis
Events	Synthesize organelles for newly formed cells	DNA replicate	Centrosome replicates Check Error made in replication	Prophase Metaphase Anaphase Telophase	Cytoplasm is divided Organelles redistribute

Mitosis

Stage	Events
Early Prophase	Centrioles move to two poles of the cell Chromosome coils up
Late Prophase	Nuclear envelope and nucleolus disappear Spindle forms (represent the end of metaphase)
Metaphase	Chromosome lies up in the equator of the cell Centromere splits (represent the end of metaphase)
Anaphase	Each of the sister chromatids moves to two opposite poles of the cell Each chromatid is V shaped with its centromere facing towards centrosome
Telophase	Nuclear envelope and nucleolus reform Chromosome uncoils

Centrosome

Centrosome replicates in G2 phase and each of them move to opposite poles of the cell. Centrosome is involved in arranging microtubules to form spindle. One end of the microtubule binds centrosome while the other end bind with centromere of the chromosome.

- In metaphase microtubule arrange chromosomes in equator of the cell
- In anaphase microtubule contracts to pull each of the sister chromatid to the pole

Plants have no centrosome and the microtubules anchored at the cell wall.

Nuclear envelope

- In prophase nuclear envelope dissemble into small vesicles
- In telophase vesicles fused with each other to reform nuclear envelope

Cytokinesis in plant

Cellulose is synthesized and contained in vesicles, which are then transport to the equator. Cell plate forms across the equator of the cell and cytoplasm is divided into two. Cytoskeleton guides the distribution of the organelles to two newly formed cell.

Chromosome

Chromosome coils up into X shape at the end of prophase. Each chromosome has two identical chromatids (sister chromatids) joined by centromere. Each chromatid is composed of one DNA molecule wrapping around histone proteins.
The ends of the chromosome are sealed with telomere. Telomere is a section of repeated bases that code for no protein. It prevents loss of gene during DNA replication and allows continued mitosis.

Stem cell and Cancer cell

Stem Cell

- Stem cells are undifferentiated cells that can keeps on replication by mitosis. Stem cell has telomerase to replace the lost telomere, enabling them to divided indefinitely.
- Stem cells have the potential to differentiate into specialized cells for cell displacement.
- Some of the stem cells divide and remain as stem cell while other stem cells differentiate into specialized cells when needed.

Cancer Cell

- Cancer cells are undifferentiated cells that can keeps on replication by mitosis.
- Cancer cells have extremely short interphase. They are not differentiated and plays no function.
- They have different size compared with normal cell and their replication cannot be inhibited by space.
- It is resulted by gene mutation stimulated by carcinogen. When pro-oncogene mutates into oncogene, normal cells are converted into cancer cell.
- Cancer cells have no response to signal that control mitosis. Check points of cell cycle are lost.
- They hall no programed cell death. They have telomerase; thus, their telomere does not shorten.

Nucleic Acid and Protein Synthesis

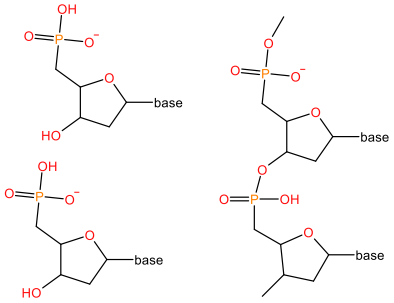
DNA (deoxyribonucleic acid) records genetic information while RNA (ribonucleic acid) transform the information.
Both nucleic acids are made by condensation of nucleotides and each nucleotide is made by three part:

- Phosphate
- Pentose deoxyribose and ribose
- Base Purine (double ring) adenine and guanine
  Pyrimidine (single ring) thymine, cytosine, uracil

Features	DNA	mRNA	tRNA
Monomer	DNA nucleotides	RNA nucleotides	RNA nucleotides
Sugar	Deoxyribose	Ribose	Ribose
Base	A, T, C, G	A, U, C, G	A, U, C, G
Strand	Double strands	Single strand	Single strand
Base pairing	Yes	No	Yes
Shape	Double helix	Straight chain	Clover-leaf
Function	Store genetic information	Involved in both transcription and translation	Translation

DNA and Semi-conservative Replication

DNA nucleotide is made by phosphorylated deoxyribose binds with one of the following bases: adenine, guanine, thymine and cytosine. DNA nucleotides joined with each other when the hydroxy group of deoxyribose condense with phosphate group of the other nucleotide to form phosphodiester bond.



- DNA molecule is composed of two strands in helical structure. Strands are connected by hydrogen bond between bases. Two strands are anti-parallel. One runs from 3' end to 5' end while the other run from 5' end to 3' end.
- Adenine forms two hydrogen bonds with thymine while guanine forms three hydrogen bond with cytosine. Thus, adenine always pairs with thymine while guanine always pairs with cytosine.

Semi-conservative Replication

- During replication, the original DNA molecule separates into two single strands. Hydrogen bonds between bases are broken.
- Two DNA polymerases bind with both strands, forming replication fork.
- These two single strands as template to direct the addition of nucleotides. Free nucleotides are first activated, complementary nucleotides are added by DNA polymerase.
- Nucleotides can only be added for 5' end to 3'end, while the two template strands are anti-parallel. Therefore, the reading of the template running from 5' end to 3' end need ligase to join Okazaki fragments together. This results in a slower synthesis. The stand that is synthesised more quickly is called leading strand while the other is called lagging strand.
- Nucleotides are added step by step along the whole DNA molecule.
- Two DNA molecules are then produced. Each of them has a strand from original DNA molecules and a newly synthesized strand.

Function of DNA polymerase

- DNA polymerase reads DNA template and holds nucleotides with complementary base in right place
- It adds nucleotides to polynucleotide by forming phosphodiester bond
- It checks and repairs mismatched base pairs

mRNA and Transcription

RNA nucleotide is made by made by phosphorylated ribose binds with one of the following bases: adenine, guanine, uracil and cytosine. Notes that uracil take the place of thymine to pair with adenine. mRNA (messenger RNA) is singe stranded and synthesized in nucleus during transcription.

Transcription

- **Gene** is a length of base sequence that codes for proteins.
- During transcription, DNA double strands where gene locates are separated. One of the strands is used as template.
- Free RNA nucleotides are first activated, complementary nucleotides are added by RNA polymerase, forming transcription bubble. Nucleotides are added step by step along the gene.
- When transcription ends, the newly synthesized RNA diffuses out from nucleus through nuclear pores.

Codon (triplet code)

Codon is the sequence of three bases in mRNA or DNA. Each codon corresponds to a specific amino acid. The genetic code is universal. Each triplet code relates to the same amino acid or stop codon in all the organisms.

tRNA and translation

tRNA synthesis

- tRNA (transfer RNA) is singe stranded and synthesized in nucleus.
- Gene codes for tRNA are separated by breaking the hydrogen bonds between bases. One strand is used as template and RNA polymerase collects free nucleotides to form tRNA.
- Bases of the same strand pair with each other to form clover-leaf shape.
- Each type of tRNA has a unique anticodon part and binds with a specific amino acid.

Ribosome

- Ribosome is a tiny organelle that is only 20 nm big. It is synthesized in nucleus.
- It composed by two subunits, big subunit and small subunits. It involves in translation of polypeptide.
- It provides binding site for mRNA and two tRNA molecules. Two amino acids are held close together and one peptide bond is formed between them. This allows assembly of amino acids into right sequence.

Translation

- During translation, mRNA bind with ribosome.
- tRNA carries an amino acid to ribosome and each type of tRNA carries a specific amino acid. Anticodon binds to codon on mRNA by hydrogen bond.
- The first codon is always AUG which spells for amino acid Met. Two tRNA holds two amino acids in place for peptide bond formation.
- Ribosome moves along mRNA, making another tRNA binds to mRNA. This makes sure that polypeptide is made with correct amino acid sequence.
- The previous tRNA detached from mRNA.
- When amino acids detached from tRNA, it can bind with amino acid again and be reused.
- Translation terminates when stop codon is encountered. The polypeptide is released.

Mutation

Mutation is a change in the original DNA sequence. This may produce a different amino acid sequence in the protein translated.

- Change in base sequence of nucleotide altered mRNA codon.
- Because each codon specifies for a particular amino acid.
- tRNA with different amino acid is brought to the polypeptide.
- This changes primary structure and secondary structure.
- The interaction between R groups changes and the shape of the protein changes.
- The shape of protein is related to its function. Thus, gene mutation may result in malfunction of the organism.

Sickle Cell Anaemia

Sickle cell anaemia is a disease arise from a single mutation in the DNA coding for polypeptide chain in haemoglobin. The DNA sequences for the Hb^A (normal) and Hb^S (sickle cell) alleles of the gene for the β-globin polypeptide differed by only one base. The triplet CTC in Hb^A is replaced by CAC in Hb^S, swapping the amino acid from glutamic acid to valine.

- For β-globin, mRNA codon is altered and different tRNA brings a different amino acid to ribosome.
- A hydrophilic amino acid is replaced by a hydrophobic amino acid.
- Primary structure is changed and shape of protein is altered.
- Haemoglobin becomes less soluble and tend to stick together. Haemoglobin is less able to bind oxygen.

Plant Transport

Plant is normally composed of three parts: roots, stem and leaves. Root is responsible for absorption of water and mineral ions; stem is responsible for transportation and support; leave is responsible for making assimilates by photosynthesis.

Vascular bundle is responsible for mass transportation.

- Mass transportation is needed because large organism has very small surface area to volume ratio.
- Diffusion rate is too slow to meet the requirement of substance exchange. Mass transportation is much faster.
- Vascular bundle is composed of phloem and xylem. Phloem is responsible for transportation of assimilates while xylem for water and mineral ion.

Vessel	Xylem Vessel Element	Sieve Tube Element
Function	Transport of water and mineral ion	Transport of assimilate
Shape	Elongated tube with no ends	Elongated tube with sieve plate
Cell wall	Cellulose and Lignin	Cellulose
Cytoplasm	Dead cell without cytoplasm	Thin cytoplasm with few organelle No nucleus only rough ER and vacuole
Direction	From root to leave	From source to sink
Driving force	Transpiration provides water potential gradient between roots to leave	Companion cell around sieve element maintain concentration gradient of assimilate
Movement	Adhesion helps water to move up while cohesion keeps water in a continuous water column.	Sucrose solution moves in xylem vessel down hydrostatic pressure
Lateral movement	Pits at xylem wall	Plasmodesmata between sieve element and companion cell

Water transport

Xylem

- Xylem vessel element has elongated cells to form tubes.
- No end or cytoplasm is present, so as to minimize the resistance to water flow.
- Pits at xylem wall to allow lateral transport of water.
- Cellulose lines xylem vessel; it forms adhesion with water molecules helping water to move up the stem.
- Lignified walls contain lignin
  - preventing water loss
  - preventing inward collapse
  - allowing elongation of stems.

Water transport from leaf to air

Transpiration is used to describe water loss in the form of water vapor from leaves.
It is an inevitable consequence of gas exchange in plants. Because photosynthesis needs fresh supply of carbon dioxide. Thus, stoma at the leaf surface has to open to allow carbon dioxide to diffuse in.

- Because outer space of leaves has lower water potential, water vapor at intercellular space diffuse out and this creates water potential gradient.
- The loss of water vapor decreases water potential of air space in spongy mesophyll. Thus, water evaporates from mesophyll cell.
- This brings down the water potential in mesophyll cell and water move from xylem vessel to mesophyll cell by lateral transport through pits in xylem vessel.
- Water keeps on moving up along xylem vessel to replace the water loss.

Water transport in Xylem

- Water molecules are attracted to each other by hydrogen bonding. This attraction is called cohesion.
- They are also attracted to the cellulose and lignin in the walls of the xylem vessels, and this attraction is called adhesion.
- Adhesion helps water to move up while cohesion keeps water in a continuous water column.

Water transport from soil to stem

From soil to root

- Water in soil has very little ions dissolved in it. Thus, it has higher water potential compared with the solution in cytoplasm of root hair.
- Water diffuses from soil into root hair through osmosis along water potential gradient.
- Root hair increases the surface area for water absorption.

From root epidermis to root endodermis

- Water moves from root epidermis to endodermis via both symplastic and apoplastic pathway.
- In symplastic pathway, water moves into cytoplasm by osmosis. It moves through cell membrane and tonoplast. It may also shift from cell to cell via plasmodesmata.
- In apoplastic pathway, it moves in intercellular space, between cytoplasm and cell wall.

From root endodermis to stem

- The intercellular space of endodermis is filled by Casparian strip. Casparian strip is composed by suberin which is impermeable to water.
- Thus, apoplastic pathway is blocked and only symplastic pathway is allowed.

- Mineral ions in solution are absorbed along with water by the root hairs. They are transported by apoplastic and symplastic pathways before moving in the mass flow of xylem sap up the xylem to the rest of the plant.
- Casparian strip forces ions to pass through living cells before they can enter the xylem. Facilitated diffusion and active transport allow cells to control what ions enter or leave cells.

Solutes such as mineral ions are pumped into xylem vessels in the root. This lowers the water potential of the solution in the xylem, thus drawing in water from the surrounding root cells. This is known as root pressure

Transpiration rate

Transpiration takes place through stoma as the water potential of environment is lower than water potential in leaves. Transpiration speeds up at:

- Higher temperature — water vapor diffuses faster at higher temperature
- Higher light intensity — larger stomata aperture as more CO_2 is needed
- Lower humidity — lager water potential difference

Xerophyte are plants in environments of extremely low humidity. They have the following adaption to avoid water loss

- Leave rolled
- No stoma at the outer surface
- Leaves form folded inner surface to trap water vaper
- Numerous hairs around stomata prevent water vapor from diffusing out
- Leaves are covered with waxy cuticle, so as to prevent water loss from leave surface and reflect heat load on leave surface

Translocation

Translocation is the mass flow of assimilates in plants via sieve elements in phloem. The direction of translocation is from source to sink.

- Sources are location where assimilates are produced such as leaves and storage organ
- Sinks are location where assimilates are consumed or transformed to other substance, such as root tips, buds, flowers, fruit and storage organ.

Sieve tube element

- Sieve tube elements are made from cell with thin cytoplasm with no nuclear and very few organelles.
- Sieve tube elements has much thinner cell wall and sieve plates with sieve pores.
- The sieve plates prevents phloem tube from collapse inward and the pores on it lower the resistance of transport.
- Each sieve tube element has at least one companion cell by its side.

Loading

Sucrose made by photosynthesis is first uploaded to companion cell.

- Protons are pumped out from companion cell to its cell wall, creating proton gradient
- Protons re-enter cell through cotransporter protein (facilitated transport)
- Sucrose enters companion cell together with protons against the concentration gradient of sucrose

Sucrose then moves from companion cell to sieve tube elements.

- Sucrose concentration in companion cell increases and it diffuses into sieve tube element through plasmodesma along its concentration gradient
- The water potential of sieve elements decreases with the entrance of sucrose
- Water moves into sieve element, creating hydrostatic pressure
- Pressure drives mass flow of water and solutes away along sieve tube elements

Unloading

When sink is arrived, assimilates such as sucrose will be unloaded from sieve element to companion cell and then to cells of sink. This removal of sucrose lowers the hydrostatic pressure at sink. Thus, assimilates can be continuously move from source to sink along hydrostatic pressure

Mammal Transport

Transportation system is needed because large organism has very small surface area to volume ratio. Diffusion rate is too slow to meet the requirement for substance exchange. Mass transportation is much faster than diffusion, thus circulation system is needed.

Double circulation refers to that blood contained in blood vessels circulated in both systemic and pulmonary system. For each complete circle around bond, it passes through heart twice.

Heart

Heart acts as a two chamber pumps. In each circulation, the deoxygenated blood enters right heart and being pumped through lungs, where it become oxygenated. The oxygenated blood leave lungs and enters left heart which pumps it through the peripheral organs

Each chamber is composed by an atrium and a ventricle. The atriums behave like a primer pump for the ventricle, helping to move blood into ventricle. The ventricle then supplies the main pumping force that propels the blood into pulmonary circulation (right ventricle) and systemic circulation (left ventricle)

Wall of left ventricle is thicker than right ventricle

- The left ventricle pumps blood to the body while right ventricle pumps blood to the lungs.
- Blood travels much longer distance in systemic circulation compared with pulmonary circulation.
- Thus far greater resistance needs to be overcome by the blood pumped from left ventricle.
- To ensure the blood pumped from heart is able to complete systemic circulation, the pressure in aorta is significantly higher than vena cava.
- To squeeze blood into aorta, the pressure developed in left ventricle must be higher than that in aorta. Greater force is required.

Cardiac Cycle

Stages	Atria Systole	Ventricular Systole	Ventricular Diastole
Atrium	Emptying	Filling	Filling
Atrioventricular Valve	Open	Closed	Open
Atria Pressure	Rise	Goes down	Goes down
Ventricle	Filling	Emptying	Filling
Semilunar Valve	Close	Open	Close
Ventricular Pressure	Low	Rise	Low
Direction of blood flow	From atrium to ventricle	From ventricle to aorta and pulmonary artery	From vena cava or pulmonary vein to atrium. From atrium to ventricle

Electrical conduction in heart

Structure	Location	Function
SAN Sinoatrial Node	Right wall of right atrium	Set electrical impulses
AVN Atrioventricular Node	Top of septum	Delay electrical impulses and sent it down septum
Purkyne Tissue	Wall of heart	Allow electrical impulse to be conducted to the bottom of ventricle

SAN → contraction of atria → AVN → Purkyne Tissue → bottom of ventricle → contraction of ventricle

- SAN acts as pacemaker, initiating heartbeat
- It releases electrical impulses which spread across atrial walls, giving rise to atrial systole
- Electrical impulse arrives at AVN.
- AVN delays the signal for fraction of second and passes the impulse to down septum along Purkyne fibres.
- Atria contracts before ventricles, allowing ventricles to be filled before emptied

Ventricular systole begins at the base of the ventricles, so most blood in ventricle is forced upwards into arteries. Both ventricles contract at the same time

Blood vessel

Blood Vessels	Function	Pressure	Lumen	Tunica Intima	Tunica Media	Tunica Externa
Artery	Carry blood away from heart	Very High	Small and regular	endothelium	large amount of elastic fiber, collagen and smooth muscle	Mostly collagen
Vein	Carry blood back to heart	Very Low	Large and irregular	endothelium	Some elastic fiber and smooth muscle	Mostly collagen
Capillary	Allow substance exchange between blood and cells	Lower	tiny 7μm wide	endothelium	none	none

Components and their function:

Smooth muscle: the contraction of smooth muscle alters volume of blood
maintaining blood pressure and making sure that blood flows forward
Thick tunica media: withstand high pressure
Elastic tissue: elastic fibre coil to increase the blood pressure; uncoil to smooth out blood flow when pressure increases

Arteries transport blood away from heart to the rest of body. To make sure the blood is able to complete the circulation and return to heart, the pressure in artery is very high. Artery has thick wall to withstand the blood pressure.
Capillaries take blood as close as possible to all cells, allowing rapid transfer of substances between cells and blood. Capillary wall is single layered and its lumen is only 7μm wide so as to allow rapid substance exchange
Veins take blood back to heart. There is little restriction need to overcome, the pressure in vein is very low. Thus, vein has much larger lumen and thinner wall compared with artery.

Blood and Tissue Fluid

Components	Blood	Tissue Fluid	Lymph	Function
Water	Yes	Yes	Yes	Solvent and Reactant
Glucose	Yes	Yes	Yes	Fuel for respiration
Urea	Yes	Yes	Yes	Metabolic waste
Protein	Yes	Small amount	Small amount	Enzyme Hormone
Red blood cell	Yes	No	No	Too large to squeeze through capillary wall
Neutrophil	Yes	Yes	Yes	Mainly patrol in blood but may leave blood when infection is found
Monocyte	Yes	Yes	Yes	Mainly found in blood and leave blood when mature into macrophage
Macrophage	Few	Yes	Few	Long lived and patrol in tissue
Lymphocyte	Yes	Yes	Yes	Stay at lymph nodes or patrol in blood and tissue fluid

Haemoglobin

Water soluble globin made of four polypeptides, two α chains and two β chains. Each chain binds with a non-protein group, haem and each haem have an iron (II) ion on in it. Each Fe^{2+} binds with an oxygen molecule by relatively weak interaction, thus, totally four oxygen molecules can be transported by one haemoglobin.

Notes that carbon monoxide is able to bind with iron (II) ion irreversibly to form carboxyhaemoglobin. Different from oxygen, carbon monoxide cannot be unloaded from carboxyhaemoglobin. Thus, when exposed to large amount of carbon monoxide, people may die from lack of oxygen.

$$O_2 + \text{haemoglobin} \leftrightharpoons \text{oxyhaemoglobin}$$
$$CO + \text{haemoglobin} \rightarrow \text{carboxyhaemoglobin}$$

Loading and Unloading of Oxygen

Oxygen saturation of haemoglobin increases as partial pressure of oxygen increase. When partial pressure of oxygen is extremely low, the oxygen saturation increases sharply as partial pressure of oxygen rises. This is because with the binding of first oxygen molecule, the shape of haemoglobin changes making it easier for other oxygen molecules to bind.

At respiring tissue, carbon dioxide diffuses from tissue fluid to red blood cell through capillary wall. Carbon dioxide reacts with water to form carbonic acid with the enzyme called carbonic anhydrase. Carbonic acid split into proton and hydrogencarbonate. This brings down the concentration of free carbon dioxide in red blood cell so carbon dioxide is able to continually travels from tissue fluid to red blood cell down concentration gradient.

$$CO_2 + H_2O \xrightarrow{\text{carbonic anhydrase}} H_2CO_3$$

$$H_2CO_3 \rightarrow H^+ + HCO_3^-$$

The proton then binds with haemoglobin to form haemoglobinic acid which encourage oxyhaemoglobin to release oxygen. Thus, at the higher partial pressure of carbon dioxide, the affinity of haemoglobin to oxygen would decreases. The oxygen saturation curve shit to the right with the presence of high partial pressure of carbon dioxide. This is **Bohr Effect**.

$$\text{oxyhaemoglobin} + H^+ \rightarrow \text{haemoglobinic acid} + O_2$$

Then oxygen then travels from red blood cell to tissue fluid down concentration gradient via simple diffusion.

Most of carbon dioxide travel in the form of hydrogencarbonate. Some carbon dioxide dissolve in blood while others binds with haemoglobin to form carbaminohaemoglobin. Deoxygenated blood is then pumped into lung via pulmonary artery. Gas exchange takes place in alveolus. Alveolus is made by single celled squamous epithelium. Then continual inhalation and exhalation make alveoli air composition is always of high oxygen and low carbon dioxide. In capillary passing through alveoli, gas exchange takes place.

Oxygen travels from alveolus to red blood cell down concentration gradient. They bind with haemoglobin and proton is released.

$$\text{haemoglobinic acid} + O_2 \rightarrow \text{oxyhaemoglobin} + H^+$$

The proton binds with hydrogencarbonate to form carbonic acid which decompose into carbon dioxide and water with the help of carbonic anhydrase.

$$H^+ + HCO_3^- \rightarrow H_2CO_3$$

$$H_2CO_3 \xrightarrow{\text{carbonic anhydrase}} CO_2 + H_2O$$

Carbon dioxide diffuse into alveolus down concentration gradient. The oxygenated blood returns to heart and being pumped into systematic circulation. While carbon dioxide is exhaled out of our body.

Gas Exchange System

Air goes into our body through nose and arrives in trachea. Trachea branch into bronchus while bronchus branch into bronchiole. Bronchiole connects with alveoli. Numerous capillary surrounds alveoli and that is the place gas exchange takes place.

Anatomic structure of gas exchange system

Air way	Diameter	Cartilage	Goblet cell	Smooth muscle	Epithelium	Gas exchange
Trachea	1.8 cm	C shaped Incomplete	Many	Yes	Ciliated	No
Bronchus	1.2 cm	Block Irregular	Some	Yes	Ciliated	No
Bronchioles	1.0 mm	No	Very few	Yes	Ciliated	No
Alveoli	250 μm	No	none	No	Squamous	Yes

Components	Site	Function
Cartilage	C shaped in trachea Block in bronchus	Keep air way open and reduces the resistance of air flow. Prevent air way from bursting while air flow is large
Smooth muscle	Trachea Bronchus	Support airway and adjust its diameter
Elastic fibre	Trachea Bronchus and bronchiole Alveoli	Allow size adjustment of trachea and bronchus. It surrounds alveoli. It coils to allow gas being expelled during exhalation; it stretches to prevent alveoli from bursting during inhalation
Goblet Cell	Ciliated epithelium	Secret mucus. Mucus is very sticky and able to trap dust, bacteria and viruses.
Mucus Gland	Beneath epithelium	Each mucus gland is made of several cells and able to secrete mucus as well.
Ciliated epithelium	Trachea wall and bronchus wall	Keep moving mucus upwards to larynx where it can be swallowed to stomach.
Squamous epithelium	Alveoli wall	Alveoli wall is made by single celled squamous epithelium. This shortens the distance that gas molecules need to travel when gas exchange takes place.

Beneath the ciliated epithelium of trachea is an area of loose tissue with blood vessels and mucous glands.

Beneath the ciliated epithelium of bronchus, there are elastic fibres.

Infectious disease

A disease refers abnormal condition that reduces the effectiveness of function of the organism.
Infectious Disease is the disease caused by pathogen and can be transmitted.
Non-Infectious Disease is the disease that is not caused by pathogen and not transmissible.

Disease	Name of Pathogen	Type of Organism	Symptom	Method of Transmission
Malaria	*Plasmodium falciparum*	Protoctist	Anaemia	*Anopheles* Mosquito Vector Pathogen enters mosquito when it drinks blood from an infected person. When the same mosquito drink blood from an uninfected person, pathogen goes into the uninfected.
TB	*Mycobacterium tuberculosis*	Bacterium	Cough	Airborne droplet; Undercooked meat; Unpasteurised milk When infected person cough, he produces aerosol droplet contaminated by pathogen. If the droplet is inhaled by an uninfected person, it will be transmitted.
Cholera	*Vibrio cholera*	Bacterium	Diarrhea	Faeces Oral Transmission; Flies Drinking water and food is contaminated with faeces of infected. When they are eaten by uninfected, the disease is transmitted.
AIDS	Human Immunodeficiency Virus (HIV)	Virus	Weak immunity	Body fluid; Sexual intercourse
Measles	*Morbillivirus*	Virus	Rash	Contact
Smallpox	*Variola* virus	Virus	Rash	Contact

Disease	Prevention and treatment	Problem
Malaria	Mosquito net Insecticide Drug like chloroquine	Symptomless at the early stage, thus hard to diagnose Variable antigen at different stage, thus no effective vaccine Drug resistance Insecticide resistance
TB	Vaccination Antibiotics	Dormant pathogen; symptomless at the early stage HIV+ is more susceptible to the disease Multiple drug resistant strains
Cholera	Better sewage treatment Oral rehydration therapy (solution of salt and glucose)	
AIDS	Drug that mimic the structure of thymine	Symptomless at the early stage No effective vaccine Drug resistance
Measles	Vaccination	Booster is needed Vaccine is not thermal stable
Smallpox	Eradicated by vaccination	Thermal stable vaccine Constant antigen No booster is needed No animal reservoir

Prevention of Infectious Disease

Preventing malaria

Mosquito Anopheles acts as vector for malaria spread.

- They live in hot and humid environment and breed near water sources.
- Malaria is pandemic in tropical or subtropical area with poor living condition
- Insecticide that kills mosquito can effectively restrict the spread of malaria. But some mosquitoes developed resistance against insecticide.
- Mosquito nets impregnated with insecticide are also able to prevent malaria.

Diagnose and Treat malaria

- Artemisinin is effective towards plasmodium. But more and more plasmodium has developed resistance against the drug.
- Symptom for the disease is not obvious at the early stage of infection, making it hard to diagnose the disease.

Vaccination

- Malaria is caused by four different species (*Plasmodium falciparum, P. vivax, P. ovale, P. malariae*) and each species has its specific antigens.
- Each type of pathogen has many antigens as it is eukaryotic.
- Pathogen has different stages of life within human with different antigens.
- Pathogen spends part of life cycle within host cells, concealing its antigens.
- For successful prevention, more than one type of vaccine is needed.

Social problems

- People cannot afford insecticide or mosquito nets
- People have little access to medical resources for diagnose or treatment
- People are poorly educated thus don't know how to protect themselves from the disease.

Preventing Cholera

Oral rehydration therapy is effective, thus no need to use antibiotics.

The disease may outburst after natural disaster. Because:

- There may be damage to sewers, mixing sewage with drinking water.
- Contaminated water cannot be treated before being drunken.
- Flies exposed to contaminated faeces also contribute to the transmission
- Limited accommodation facilitates the spread of disease.
- Not enough water containers make people need to share their drinking vessels.

To prevent the spread of cholera, we can:

- Sterilize drinking water and keep drinking water sources separated from sewage
- Provide sewage treatment plants
- Discourage use of human faeces for fertilizer
- Control the breeding of flies (vector)
- Isolate infected people
- Educate public about the disease and encourage hand washing
- Rapid diagnosis and rapid treatment
- Use rehydration therapy or antibiotics
- Provide vaccine against disease

Preventing Small pox

- Virus for smallpox has no mutation, thus, same vaccines can be used repeatedly. This saves expense for developing new vaccine.
- The vaccine is thermal stable can be used in tropic area.
- Infected people are easy to identify and it does not infect animal, thus, there is no reservoir for virus

Preventing Tuberculosis

Transmission

- Tuberculosis is spread by aerosol droplet
- Overcrowded living condition may facilitate its transmission
- People who are infected may not be treated and serve as reservoir of the disease
- Travel from area with high rates of TB may spread it to other places

HIV

- Infection with HIV may activate dormant TB pathogen
- Immunodeficiency makes people more susceptible to TB

Diagnosis is difficult

- TB remains dormant and the carriers are symptomless
- Those susceptible to the disease many have limited heath care for diagnosis

Treatment

- Treatment may not start early enough
- Treatment is long term and people may not finish the course of treatment
- People may have limited access to health care for treatment

Acquired resistance

- Bacteria may develop resistance to antibiotics
- Multi-drug resistance

Education

- Limited education about prevention for general population
- Limited education for health care professionals

Vaccination

- Vaccine may not always be effective in providing protection
- TB is intracellular parasite; antibody has no effect on the bacteria inside the cell; it is only effective when bacteria are in plasma
- Difficult to achieve herd immunity
- People may have misconception about vaccination
- Limited access to vaccination
- Poor immune response in people who are malnourished
- Poor thermostability of vaccine

Preventing HIV

- No effective vaccination is now available.
- People who are HIV positive have higher tendency to catch disease such as TB.
- Because their immune system is weakened by HIV virus which attacks T lymphocytes, thus, they are more susceptible opportunistic disease. TB is opportunistic disease.

Preventing Measles

- Vaccine for measles is not thermal stable and booster is needed, thus, not all the people on earth is vaccinated.
- Herd immunity is achieved only when more than 90% people are immuned from the disease.
- Vaccination may have little effect for some people.
- Disease maybe spread from people that are not vaccinated.

Antibiotics

Antibiotics are groups of chemicals that inhibit the growth of prokaryotic cell while has no effect on eukaryotic cell. Antibiotics may also kill gut bacterial and disturbs normal digestion.

Penicillin

- Penicillin weakens the cell wall of newly reproduced bacteria or growing bacterial.
- It prevents the formation of cross linkage of peptidoglycan.
- When bacterial is at the environment of low water potential, it bursts when turgor pressure develops inside the cell.

Antibiotics and virus

- Antibiotics is only used against bacteria and has little effect on virus.
- Virus has no cellular structure on which antibiotics acts
- Viruses are in host cells thus are not within the reach of antibiotics
- Antibiotics act on growing cell while virus does not grow
- Antibiotics do not act on protein coat on virus

Bacterial may develop resistance towards antibiotics.

- Antibiotics acts as strong selection pressure towards population of bacterial.
- Mutations take place in bacterial.
- Some mutation may enable some bacterial to synthesize enzyme that is not inhibited by antibiotics.
- Those bacterial survived while others died.
- The survived bacterial reproduce rapidly and its offspring are all unaffected by antibiotics.

Antibiotic resistance poses severe threats to public health.

- It increased the risk for further spread of bacterial.
- The chance of successful treatment decreased
- It takes longer to treat the disease, increasing hospital expense.
- Fewer antibiotics left are effective and it may develop further resistance.
- We have to develop new antibiotics which is expensive.

To prevent resistance, it is important to minimize the exposure of bacterial to antibiotics. Once antibiotics are used, making sure that all the bacterial are killed leaving no chance for evolution.

It is advised to:

- Prescribe antibiotics only when necessary
- Use effective antibiotics and follow the instructions.
- Keep on monitoring the effectiveness of antibiotics
- Control the use of antibiotics in animals for food
- Improve public awareness about antibiotic resistance
- Develop new drugs
- Report the patten of antibiotic resistance so as to break the transmission cycle.

Immunity

Immunity is the protection against disease provided by the body's internal defence or immune system.

	Neutrophil	Macrophage	B Lymphocyte	T Lymphocyte
Produced at	Bone marrow	Bone marrow	Bone marrow	Bone marrow
Mature at	Blood	Tissue	Bone marrow	Thymus
Found at	Mainly blood	Mainly tissue	Blood Lymph nodes Spleen	Blood Thymus
Function	Phagocytosis	Antigen presentation Phagocytosis	Form plasma cell that secretes antibody	T helper secretes cytokine to stimulate phagocytosis T killer secretes cytotoxic substance to kill pathogen
Involves in	Specific and non-specific immunity	Specific and non-specific immunity	Only specific immunity	Only specific immunity
Memory cell	No	No	Yes	Yes

Immunity term

Non-self antigen:

It is usually a protein found at cell surface membrane. It can be recognized by the immune system cells, such as macrophage and stimulate an immune response. It gives rise to the production of antibody that binds with it.

Self antigen refers to substances produced by the body that the immune system does not recognize as foreign and do not stimulate an immune response.

Phagocytosis

Phagocytosis takes place when pathogens are recognized by phagocyte

- Bacteria is engulfed by neutrophil or macrophage by phagocytosis.
- Lysosome fuse with the vacuole containing bacteria.
- Hydrolytic enzyme, such as protease, in lysosome hydrolyze the protein in bacteria.
- It breaks the peptide bond in protein molecule and break them into amino acids.
- Bacteria are thus killed.

Specific immunity

Clonal selection

- When the antigen enters the body for the first time the small numbers of B cells with receptors complementary to the antigen are stimulated.
- Macrophage is an APC (antigen presenting cell). It cuts antigen from pathogen and present the antigen on its surface.

Clonal expansion

- The small clone of cells divides repeatedly by mitosis so that huge numbers of identical B cells and T cells are produced over a few weeks.

Action

- B lymphocytes develop into plasma cell and secrete antibody
- Antibody binds to pathogen making it easier to be found by macrophage and being engulfed.
- T helper secrete cytokine to stimulate B lymphocyte and phagocytosis
- T killer secrete cytotoxic substance to kill pathogens

Memory cell

- Antibody concentration in plasma would decreases substantially after immune response.
- Most B lymphocytes and T lymphocytes will be disappeared as well.
- Some B lymphocytes and T lymphocytes will remain in body and act as memory cell for life time.
- Because there are more memory cells compared with the specific lymphocyte during primary immune response
- The chance for the pathogen to be encountered and recognized is much higher
- The secondary immune response will be faster and more effective compared with primary immune response.
- Higher concentration of antibody will be produced in shorter time

Antibody

Antibody is soluble globin. Each antibody has four polypeptides, two light chains and two heavy chains. They are bonded by disulfide bridge.

Variable region

- Each molecule has two identical antigen-binding sites (variable site) whose shape is complementary to the shape of antigen.
- The sequences of amino acids in these regions of antibody make the specific three-dimensional shape.
- Each type of antigen binds to variable site of specific antibody by interacting with the side chain of amino acid residue.
- The 'hinge' region gives the flexibility for the antibody molecule to bind around the antigen.

Invariable region

- The constant region of antibody binds to the receptor on neutrophils or macrophage, enabling phagocytosis to take place with higher efficiency.

Active and passive immunity

Immunity	Antigen	Immune response	Antibody	Memory cell	Protection
Active	Encountered	Yes	Produced by plasma cell	Produced	Permanent
Passive	Not encountered	No	injected	Not produced	Temporary

A **vaccine** is a preparation containing antigens which is used to stimulate an immune response artificially.

	Active	Passive
Artificial	Vaccine	Antibody injection
Natural	Infection	Breast milk

Vaccine against smallpox

- Variola virus was stable thus same vaccine can be used anywhere
- The vaccine was made from a harmless strain of a similar virus
- Vaccine is thermal stable

Vaccine against malaria

- Malaria is caused by four different species (*Plasmodium falciparum, P. vivax, P. ovale, P. malariae*) and each species has its specific antigens.
- Each type of pathogen has many antigens as it is eukaryotic.
- Pathogen has different stages of life within human with different antigens.
- Pathogen spends part of life cycle within host cells, concealing its antigens.
- For successful prevention, more than one type of vaccine is needed.

Vaccine against Tuberculosis

- Vaccine may not always be effective in providing protection
- TB is intracellular parasite; antibody has no effect on the bacteria inside the cell; it is only effective when bacteria are in plasma
- Poor immune response in people who are malnourished
- Poor thermostability of vaccine
- Difficult to achieve herd immunity
- People may have misconception about vaccination
- Limited access to vaccination

Monoclonal antibody

Monoclonal antibody is widely used in

Diagnosis of the disease

- Monoclonal antibody used all have the same specificity. They detect only one type of antigen. It provides fast diagnosis of the pathogen that causes disease.
- Monoclonal antibody can be marked with fluorescent label. They can detect location of tissue expressing the antigen.

Treatment of the disease

- Monoclonal antibody directly acts on target cells by binding to specific antigens on cell surface. Drug or enzyme can be attached to monoclonal antibody, so they can be activated at the site of action
- Monoclonal antibody can be used in passive immunity, stimulating immune system to kill infected cells
- Monoclonal antibody can be used to treat cancer because cancer has antigen that is different from normal cell

Production of monoclonal antibody

- Antigen is first introduced into mice. Plasma cell that developed from B-lymphocytes is then isolated from spleen.
- Those plasma cells were then fused with myeloma (cancer cells) using fusogen PGG or electrical current.
- The cell produced by this fusion of a plasma cell and a cancer cell is called a hybridoma
- Testing is applied to find out if hybridoma cells are able to produce right antibody
- Those hybridoma cells are prepared for large scale production