



BIOL1007

From Molecules to Ecosystems (University of Sydney)



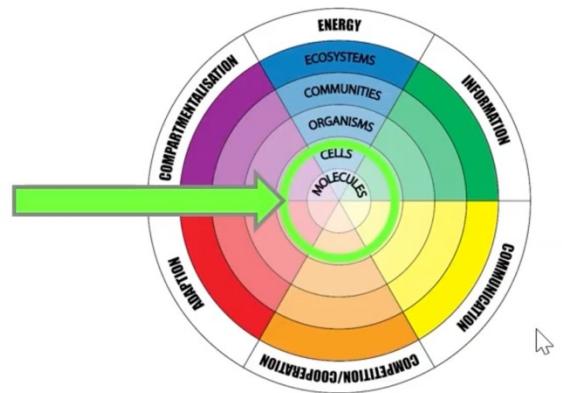
Scan to open on Studocu

BIOL1007: From molecules to ecosystems

WEEK 1

LEC 2: Life

- Genetic material is shared between generations.
- Genetic material encodes the molecules of life.
- All species share common genes and cellular functionalities.

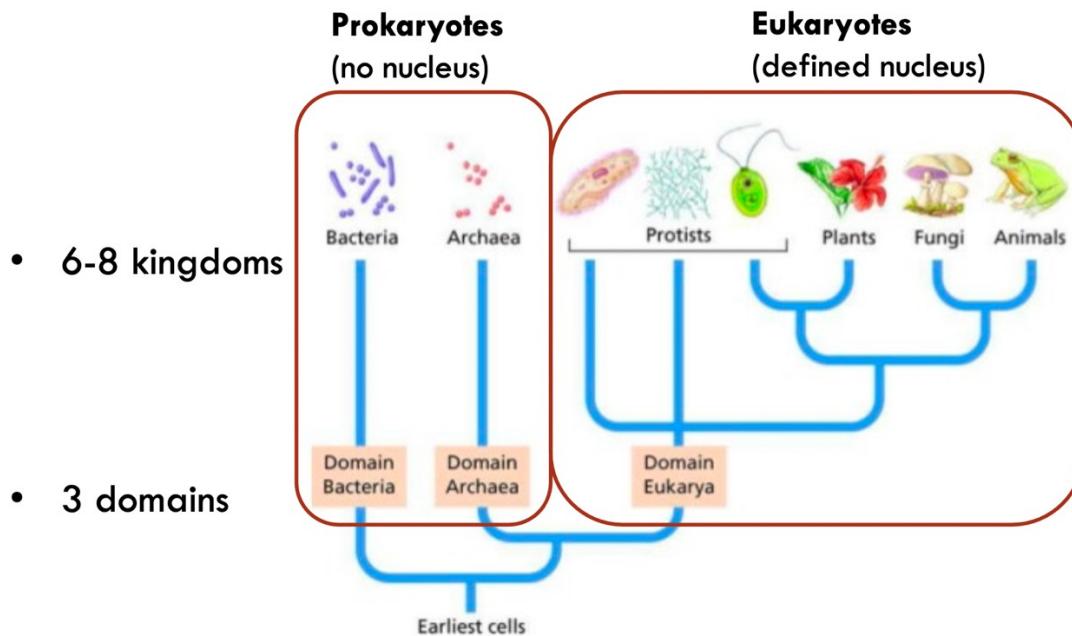


Living things:

- Order
 - o Life is cell based, complex and organised.
- Energy processing
 - o Organisms capture energy from the sun and convert it into chemical energy in food (plants) or use chemical energy from food (animals).
- Response to stimuli.
- Reproduction
 - o Sexual reproduction.
 - o Asexual reproduction e.g., budding, spores.
- Growth and development
 - o We develop and adapt all throughout life.
- Regulation/homeostasis
 - o Homeostasis = returning to a steady internal state. We can cope with change because our regulatory processes bring the cell/organism back to that state. (Body heat, blood sugar levels).
 - Stimulus
 - Receptor (sensor)
 - Control centre
 - Effector
 - Effect
 - Balance is restored.
- Adaption
 - o Physical
 - o Behavioural
 - o Physiological
- Evolution

- Change in heritable characteristics over populations.

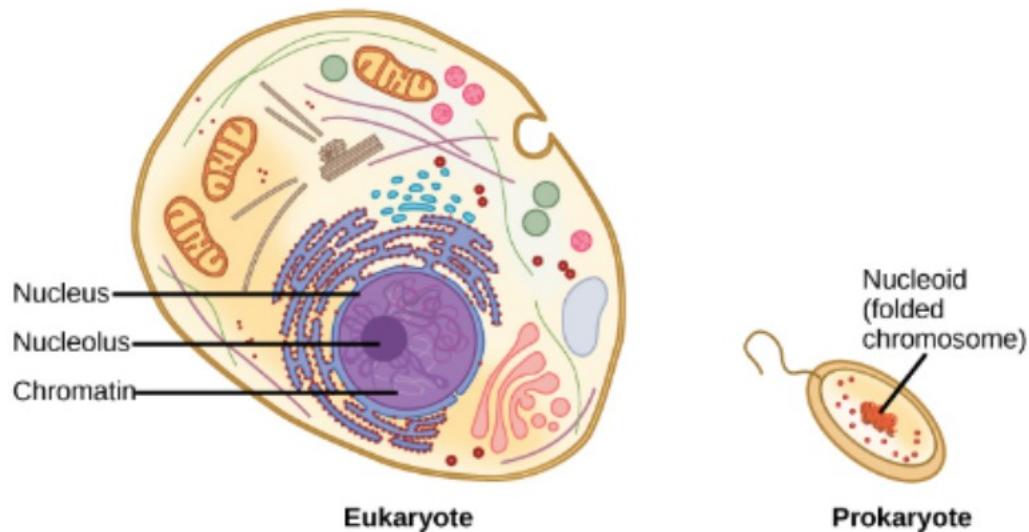
Classifying living things



3 domains – bacteria, archaea, Eukarya

Prokaryotes and eukaryotes

- Eukaryotes have a defined nucleus and membrane bound organelles.
- In Prokaryotes the chromosome lies in the cytoplasm in an area called the nucleoid.



Life is Carbon-based

- Carbon can bond with itself and other elements to make 3D shapes.
- All major biopolymers (e.g., a protein, cellulose or DNA) have a carbon backbone.
- Has a 'sweet spot' of stability, pretty stable but not too stable, if it was too stable things couldn't change.

Essential elements for life

- **Common**

- Carbon – C/C
- Hydrogen – H/H
- Nitrogen – N
- Oxygen – O

- **Smaller amounts**

- Phosphorous – P
- Sulfur - S

- **Trace elements**

The table shows the atomic number (1-104), atomic mass, and element symbols for each element. The highlighted elements are: H (1.008), He (4.003), O (16.00), N (14.01), C (12.01), and Mg (24.31).

(6 most common elements listed)

Hydrophobicity and polarity

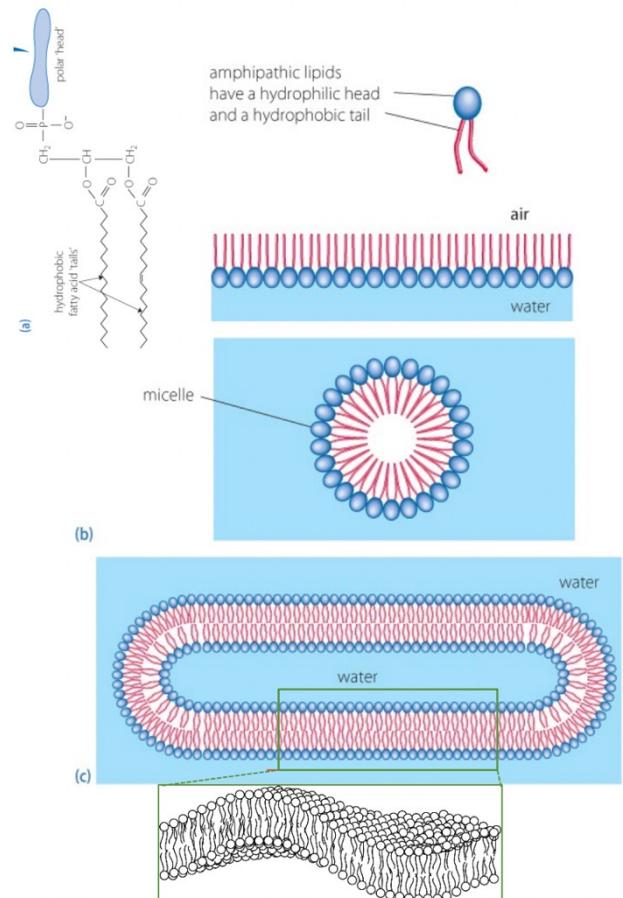
- Carbon is neutral (uncharged, non-polar, hydrophobic – doesn't like to be inside water)
- Oxygen, nitrogen, phosphorus tend to make compounds, polar, like charge and are hydrophilic (water loving).
- Hydrogen is heavily influenced by what it is near.
- Some molecules have a mixture.

The chemistry of life: MOLECULES

Main molecule types

- Water
 - Polar compound with extensive hydrogen bonding.
 - Ability to make networks and supports living systems.
 - Water stabilises temperature.
 - Good evaporative cooling
 - Freezing water releases energy, melting water absorbs it.
 - Ice floats, layer of ice can insulate water underneath it.
 - Water tension/capillary action (can flow through small tubes eg. in plants)
 - Solvent of polar molecules (water molecules can solvate ions (- and +) like salt)

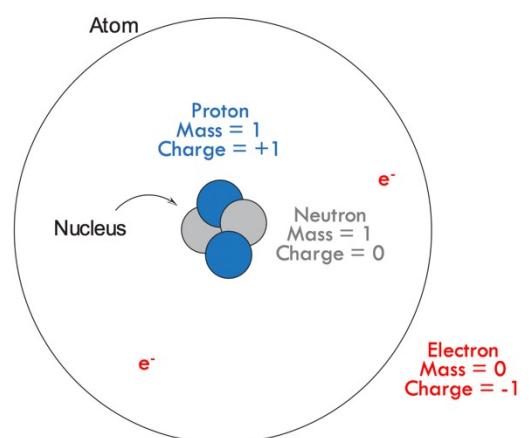
- Poor solvent of hydrophobic molecules
- Carbohydrates (sugar)
 - Aka saccharides
 - Monosaccharides – such as glucose, galactose, fructose
 - Composed of Carbon, Hydrogen, Oxygen
 - Very polar
 - Monosaccharides usually form rings
 - Glucose (6 atom ring)
 - Ribose (5 atom ring)
 - Disaccharides (2 monosaccharides joined together)
 - Lots of different connections
 - Sugar polymers are long chains of monosaccharides that can create
 - Starch – storage
 - Chitin (exoskeleton of insects) – protection
 - Cellulose – structure
- Lipids (fats)
 - A diverse set of molecules including:
 - Fats
 - Oils
 - Waxes
 - Steroids
 - Poorly soluble in water
 - Very hydrophobic
 - High proportions of C/H
 - Function of lipids:
 - energy stores
 - important signalling molecules (steroids)
 - protection and waterproofing (waxes)
 - structure/barriers (waxes/phospholipids)
 - **Phospholipids:** form cell membrane
- Mostly hydrophobic, but with a polar end.
- The polar parts interact with the aqueous environment, hydrophobic parts cluster together.
- Lipid bilayers separate different aqueous layers (inside and outside of cell).



- Amino acids
 - o Building blocks of proteins.
 - o 20 commonly occurring amino acids found in proteins and coded by our genes follow the same basic alpha structure.
 - o In aqueous solution, amino and acid groups are charged – normal state of amino acids in nature.
 - o 20 common encoded amino acids have different sizes and chemical properties that are important for the shape and function of the protein.
 - o Each have a name, 3 letter abbreviation, 1 letter abbreviation.
- Nucleotides
 - o A phosphate group (negatively charged)
 - o A sugar (ribose or deoxyribose)
 - o A nucleobase (A,T,C,G)

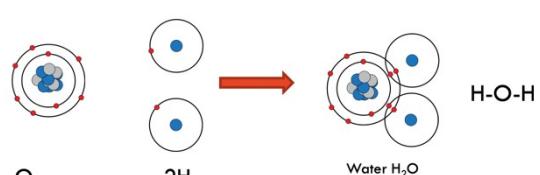
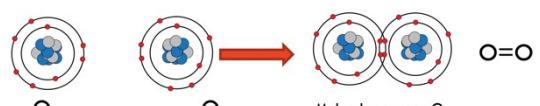
ATOMS, PROTONS, NEUTRONS, ELECTRONS

- **Atoms:** basic units of matter and defining structure of elements
 - o Centrally locate nucleus made of **protons** and usually **neutrons**.
 - o And **electrons** at various distances out of the nucleus (very mobile).
 - o Different no. of neutrons = isotopes, which can be useful but don't affect the chemistry.



FORMING COVALENT BONDS

- Atoms are stable with certain numbers of electrons and often share electrons with other atoms to reach ideal number.
- Sharing electrons keeps atoms close to one another and forms a **covalent bond**.
- Covalent bonds are relatively stable, not affected by normal changes in environment.
- **Chemical reactions usually involve breaking & making covalent bonds.**
- (Shown as solid lines in models)

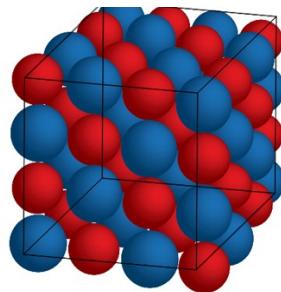
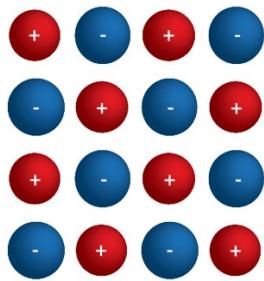


ATOMS VS IONS

- Some atoms lose or gain electrons to reach stable arrangements.
- When an atom **loses one or more electrons** it becomes a **positively charged ion**.
- When an atom **gains one or more electrons** it becomes a **negatively charged ion**.
 - o Meanwhile the protons and neutrons stay in the nucleus!

ELECTROSTATIC INTERACTIONS

- 2 ions of **opposite charge** will **attract one another** to form electrostatic interactions (salt bridges when whole charges are involved).
- 2 ions at the **same charge** will **repel one another**.
- Crystalline salts are arrays of alternate positive and negative ions (table salt)
- Tend to be soluble in water (hydrophilic)
- Electrostatic interactions vary in strength depending on the environment.



VAN DER WAALS INTERACTIONS

- When atoms get closer than a certain distance, the positive nuclei will repel each other.

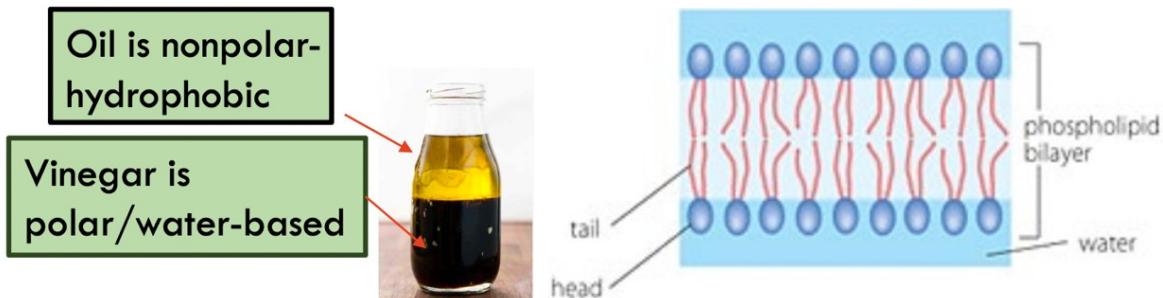
DIPOLES, POLARITY, POLAR INTERACTIONS

- **Polar interactions:** atoms that share electrons unequally.
- This can set up permanent **dipoles** which have a partially positive and negative end.
 - o Molecules with dipoles are **polar** and tend to be soluble in water.
 - o A molecule with some oxygen/nitrogen is probably polar.
- **HYDROGEN BONDS** (a type of polar interaction)
 - o Where a hydrogen sits between either an oxygen or nitrogen.
 - o Water has lots of hydrogen bonding.
 - o Individual hydrogen bonds in the network can swap around.
- **INDUCED DIPOLES**
 - o Influence of other atoms/nuclei/dipoles can induce temporary dipoles which can attract and repel each other.
 - o Interactions tend to be weak in isolation but strong in combination.

- **Dipoles** - pair of equal and oppositely charged or magnetized poles separated by a distance.

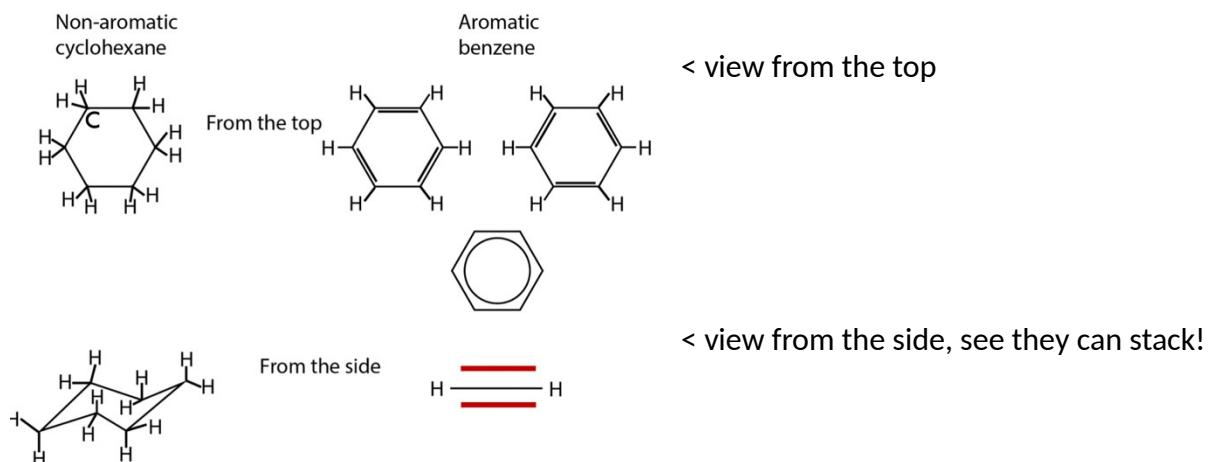
HYDROPHOBIC EFFECT

- Non-polar (hydrophobic) molecules don't like being around water.
- In aqueous environments they cluster together to exclude water.
 - Referred to as the hydrophobic effect.



AROMATICS

- Ring structures that have alternating double and single bonds.
- The **electrons** become equally distributed around the ring.
- Like to **pack against each other** / make interactions with positive charges
- Can stack upon each other since ring is flat.
 - Usually absorb light in the UV range.



CONCENTRATIONS

- **Concentration** = density of molecules
- Referring to solutions

IONISATION AND pH

- Water spontaneously splits into very small amounts of ions.
- pH refers to concentration of hydrogen ions/proteins.
- acids decrease the pH

- bases/alkaline increases pH
- buffers resist changes in pH (eg. proteins, phosphates, bicarbonates).

Summary of Molecule Types

Term	Definition	Property
Atom	Smallest part of a chemical element	Defined by number of protons, balanced by number of electrons
Molecules	Smallest set of covalently bonded atoms in a substance	Need a chemical reaction to break bonds
Ions	Atoms have completely lost or gained an electron = charged	Like to be around polar molecules and balanced by opposite charge.
Polar or hydrophilic molecules	Molecules with partial charges (usually have O, N and P)	Like being around water and other polar molecules
Non-polar or hydrophobic molecules	Uncharged, neutral (mostly C and H)	Don't like being around water and polar molecules
Aromatic molecules	Cyclic (ring-shaped) flat molecules with conjugated (alternating single and) double bonds	Mostly hydrophobic, like to pack together, can interact with + charges

Summary of Bonds

Term	Definition	Property
Covalent bond	Bonds within molecules	Strong
Ionic bond	Electrostatic attraction between oppositely charged ions/repulsion between like charges	Can be strong or weak depending on environment, affected by salts
Van der Waals interactions	Attraction between closely spaced, partially charged atoms (permanent or temporary)	
Polar interactions	i) Electrostatic interactions between permanent dipoles	Weak-Moderate
	ii) Interactions between induced dipoles	Individually weak, but lots together can be strong
Hydrogen Bonds	Attraction between partially charged atoms involving hydrogen and 2 x (oxygen or nitrogen)	Moderate
Hydrophobic interactions	Tendency of hydrophobic molecules to stick together and avoid water	Can be strong or weak depending on environment

Biopolymers: basic structure of DNA, RNA and proteins

DNA – deoxyribonucleic acid

RNA – ribonucleic acid

Proteins

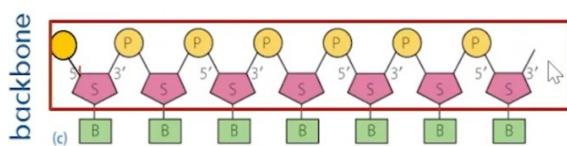
- Can be very long polymers.
- Sequence within a polymer is important for **function** and differs for each type of protein of DNA/RNA.

Biopolymers: information-containing biopolymers have a defined beginning and end.

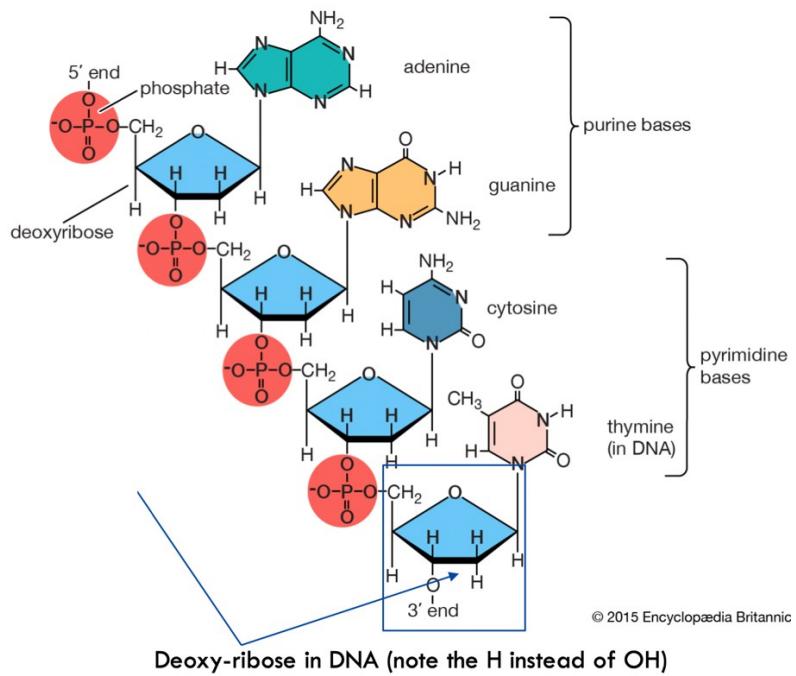
- Synthesised in one direction, only increasing the backbone.
- We write the from the same direction (left to right).
 - o Nucleic acids: 5' to 3' prime
 - o Proteins: N-terminus to the C-terminus

Residues: when we start putting monomers together, we end up losing some of the entity. Leaving a 'residue' incorporated into the growing chain.

Nucleic acid polymers – DNA/RNA



- Nucleotide building blocks = phosphate/ sugar backbone and nucleobase (A,T,G,C)
- **Negative charges** on phosphates
- **Hydrophilic** (sugars and phosphates)
- 5' and 3' ends



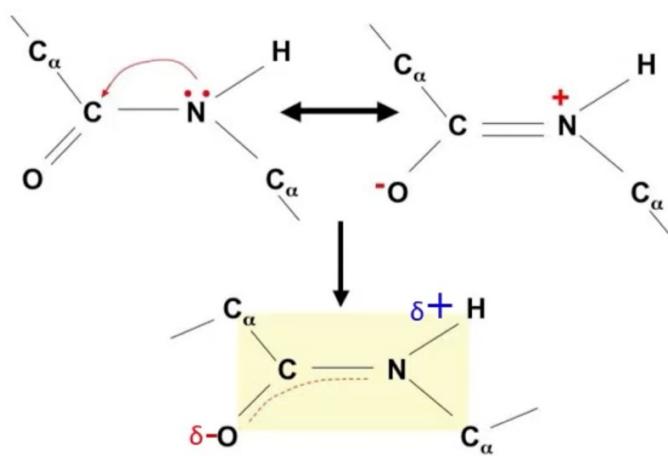
Thymine is in DNA but is swapped for Uracil in RNA.

Proteins

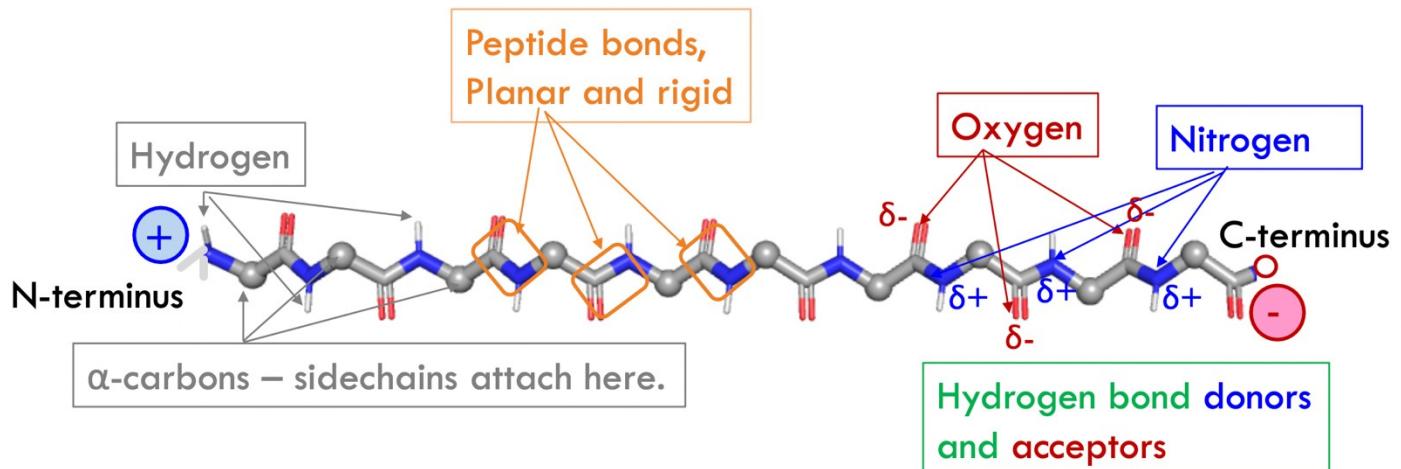
- Amino acid building blocks
- Common peptide backbone
- Sidechains (R) of the different amino acids differ.
- Peptides – short
- Proteins – long (over 50 amino acids in the chain)

Peptide Bond Formation

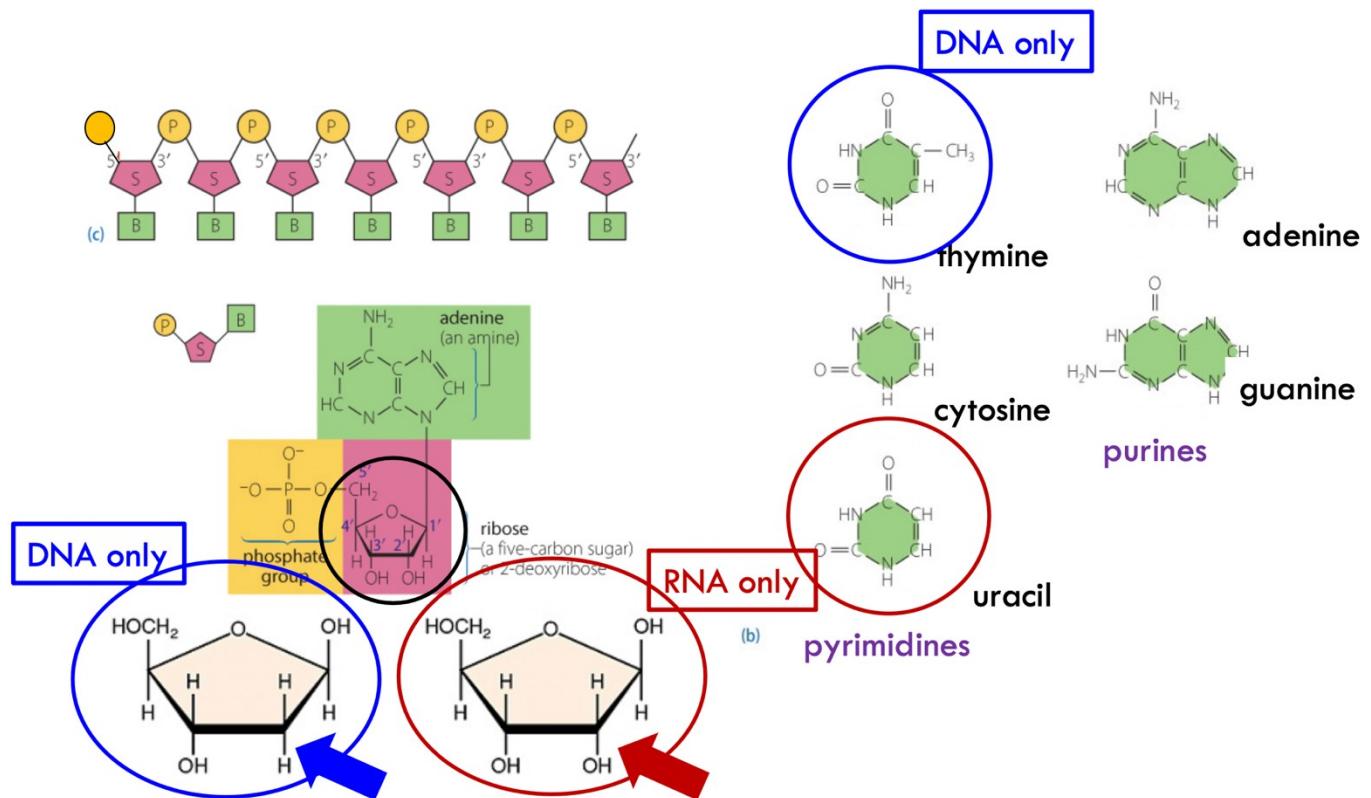
- 2 amino acids combine by a condensation mechanism to form a dipeptide.
- Partial double bond makes the peptide bond flat and rigid.
- Partial charges encourage hydrogen bonding (important for protein structure & function).



Polypeptide backbone:



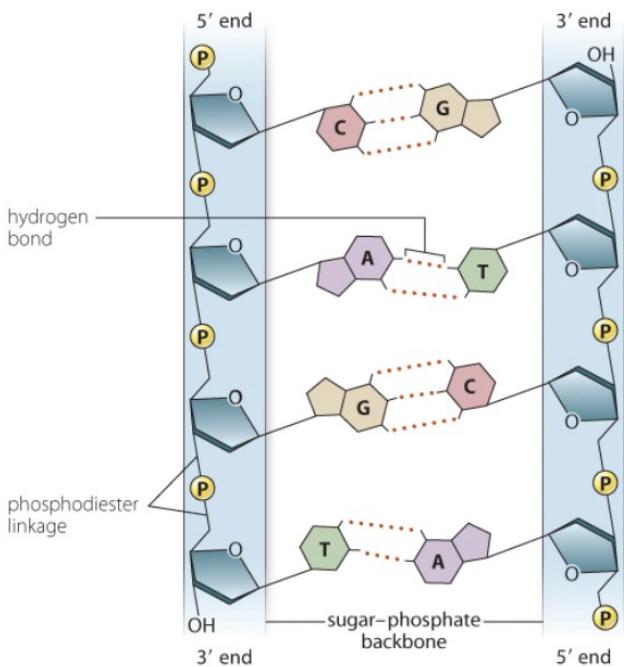
DNA VS RNA



DNA

- The source of genetic information.
- $A + G$ (purines) = $C + T$ (pyrimidines) = 50%

- DNA is a double helix structure.

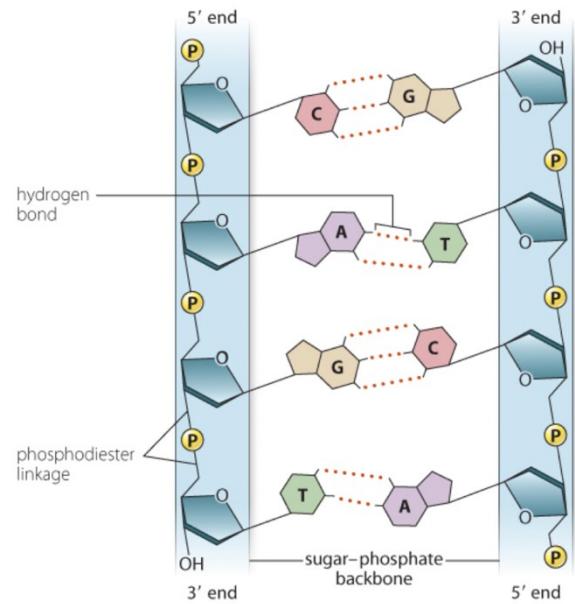
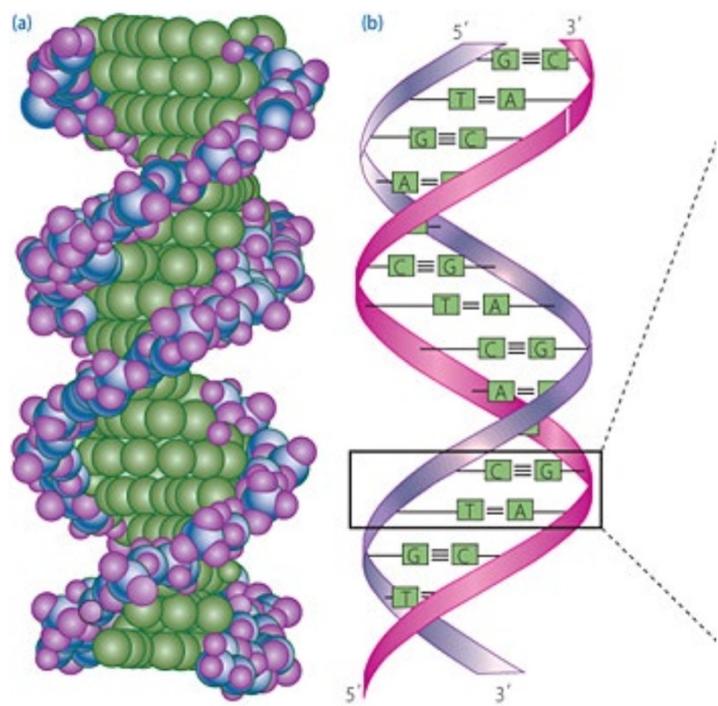


Base pairing

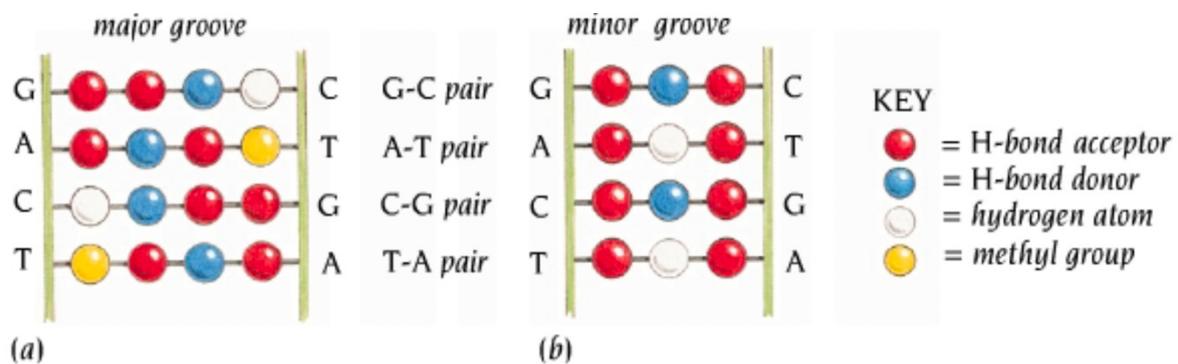
2 strands held together by hydrogen bonds between complementary bases

C and G complement (3 hydrogen bonds, stronger binding)

A and T/U complement (2 hydrogen bonds, so a bit weaker)



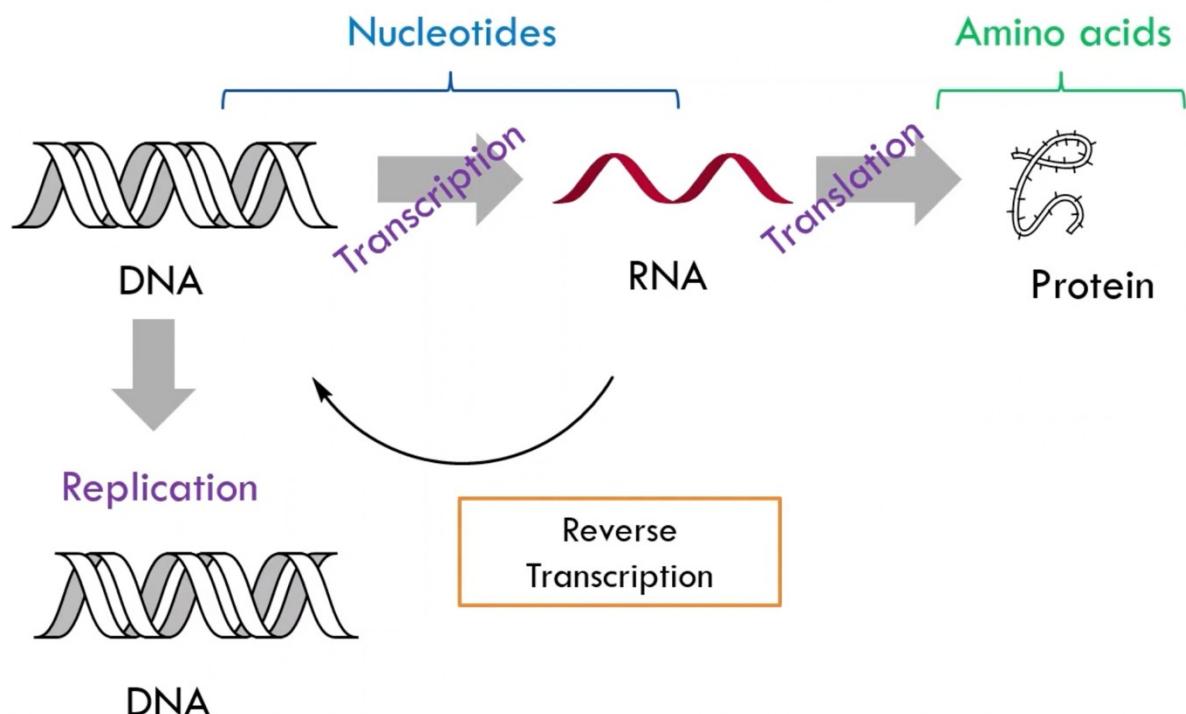
- Strands run in opposite directions,
- Flat bases stack on top of each other in the middle of the structure,
- Negative phosphates repel each other,
- Major and minor grooves



RNA

- Doesn't form B-type structure (doesn't pack as tightly due to different sugar)
- Base pairs C, G and A, U
- Bases are generally stable except under conditions such as, the deamination of cytosine to uracil. (happens approx. 100x a day)
 - o In DNA, uracil is recognised as wrong and is repaired.
 - o But in RNA, uracil is there all the time so is not corrected.

WEEK 2: Central Dogma of Molecular Biology



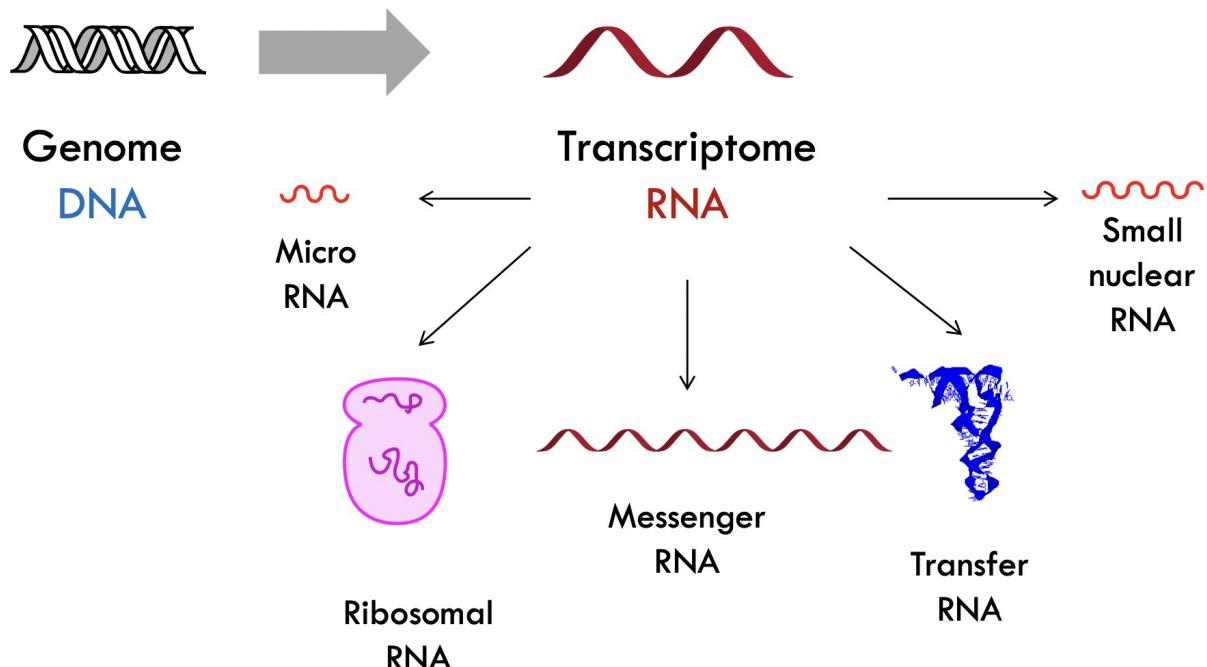
The genome (DNA)

- DNA stores genetic info
- Double stranded – provides template for repair, base pairing.
- Stable, not prone to degradation.
- Same DNA in all cells.
 - o Each cell uses a subset of expressed genes (RNA & Protein) to achieve structure and function.
- Bacterial genomes: most **prokaryotes** (bacteria, archaea) have circular chromosomes that tend to be small (12k to 15m bases).
- **Prokaryotes have small genomes.**
- **Eukaryotes have big genomes.**
- **Eukaryotes** have linear chromosomes, condensed into chromatin wrapped around histones.

Human genome

- Eukaryotic
- Linear
- 6 billion bp
- 22 pairs of chromosomes
- Encode for around 20,000 proteins.

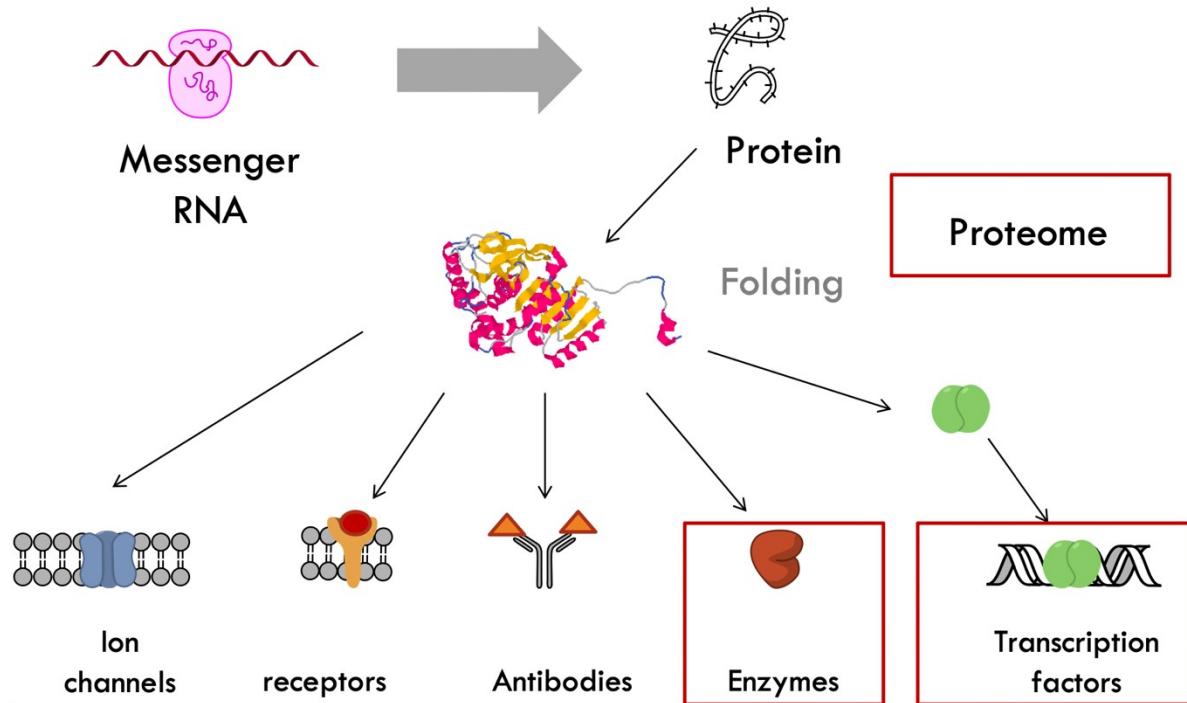
The transcriptome (RNA)



- mRNA is the message **encodes for making proteins.**
 - o Often multiple copies made,
 - o Cytosine deamination to uracil matters less in DNA,
- MicroRNA and snRNA have regulatory roles.

- Ribosomal RNA and transfer RNA are important for protein synthesis/translation.

The proteome (Protein)

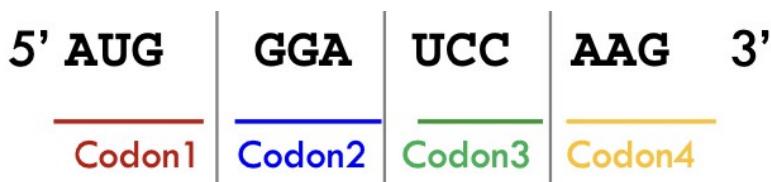


Proteins

- **Amino acid sequence determines the structure of proteins.**
- Proteins make up approx. 50% of the cell by dry weight.
- Proteins give **cells shape, form receptors, enzymes, hormones, growth factors, toxins, transporters and antibodies.**

Possible codes

- Genetic code is based on a triplet code – 64 possible sets of 3.
- o Referred to as codons.
- **Combination of 3 bases which codes for amino acids is called a codon.**
- Codon sequence is quoted following the 5' to 3' from the mRNA.



- Non-overlapping triple code.
 - o Some amino acids are STOP codons.
 - o Some amino acids have multiple codon combinations.
 - o **AUG** codes for Methionine which is the **START codon**.

- Genetic code is used by ALL lifeforms, its universal.

Finding the correct reading frame.

- LOOK FOR START CODON!
- Read through in 3s and find the STOP codon.

Mutations of DNA/RNA:

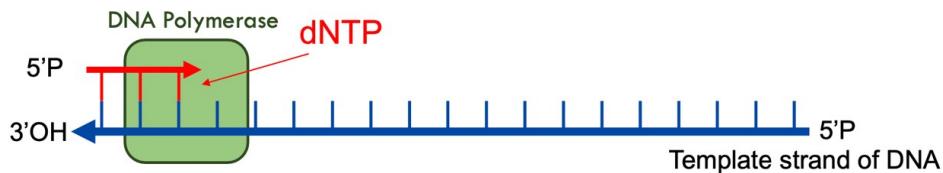
Mutation	Description
Point	Mistake in the DNA code, one of the DNA base pairs is changed (can also refer to a small number of bases being modified added or lost in the nucleotide sequence)
Silent	A mutation of the protein coding region that has no effect on the protein sequence
Nonsense	Single change in DNA code produces stop codon, prematurely terminates protein synthesis
Insertion	Addition of one (or more) nucleotide base pairs into the DNA sequence
Deletion	A piece of DNA is removed from the sequence
Missense	A single amino acid has been changed
Frameshift	Insertion or deletion mutation results in a change to a gene's reading frame
Duplication	Incorrect copying leads to repeated sequences

Copying DNA and RNA

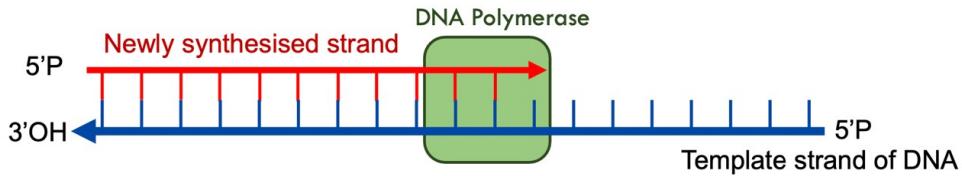
DNA REPLICATION

- Making **complimentary** copy of DNA from a DNA template,
- Requires a **template** for base pairing,
- Always copy the new strand **5' to 3'**,
- Using nucleotide **triphosphates as substrate**,
- Add the **nucleotide monophosphate** to the 3'OH end of the growing chain,
- Form a high energy phosphodiester bond,
- **Release pyrophosphate (PPi)**,
- Uses a **DNA polymerase** (enzyme),
- Need a **primer** (short piece of DNA/RNA) to start.

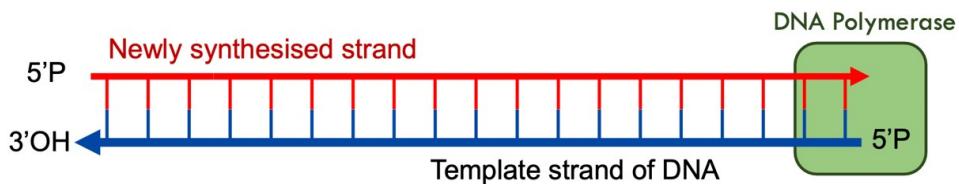
1.



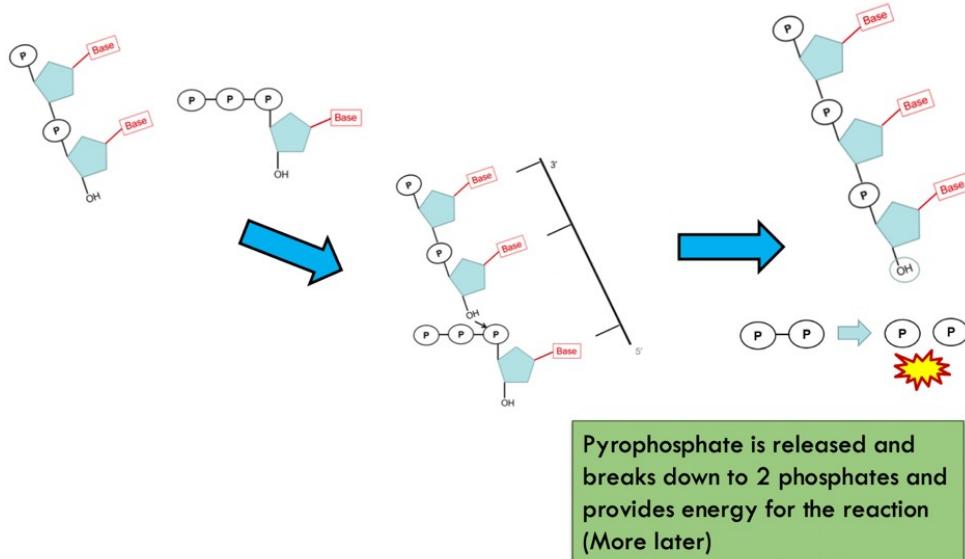
2.



3.



Adding nucleotides:



DNA Polymerases can:

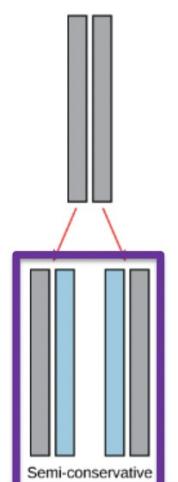
- Make a DNA copy from the DNA template.
- Need a primer to start.
- Use the deoxynucleotide triphosphates as substrate.
- Can 'proofread' the last nucleotide added, so it can chew back on the 3 prime end and correct a mismatch.

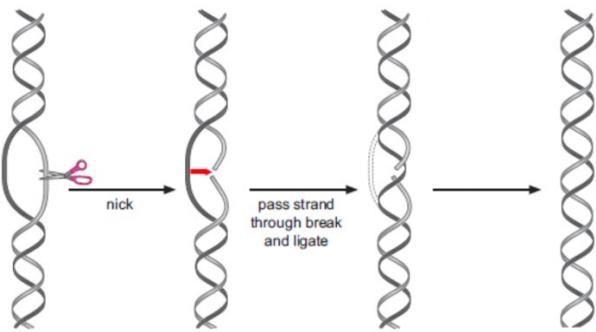
Bacterial DNA Replication

- Genomes are BIG and made up of long strands of double stranded DNA,
- Strands are complementary of each other, BOTH strands need to be copied,
- **Semi-conservative** replication model.

Helical DNA needs to be unwound pulling long helical strands apart causes supercoiling.

- Topoisomerase enzymes cut strands, allow to unwind and stick back together.
- In cells, only unwinds small sections of DNA at a time.





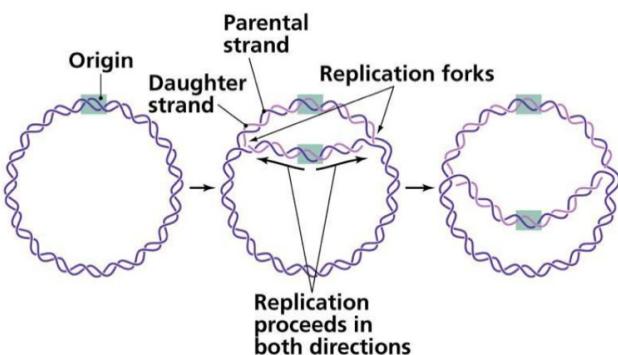
In biopolymer synthesis we follow 3 steps:

1. Initiation (start)

An 'origin' site (ORI) is AT-rich – and is easier to pull long strands apart because it's less stable. And DNA binding proteins open up the site. DNA helicase unwinds part of the DNA. And DNA topoisomerase stops supercoiling. Forms replication forks and single-stranded binding proteins coat the single-stranded DNA (ssDNA) to keep fork separated.

Both strands of DNA being copied at the same time. In BOTH directions.

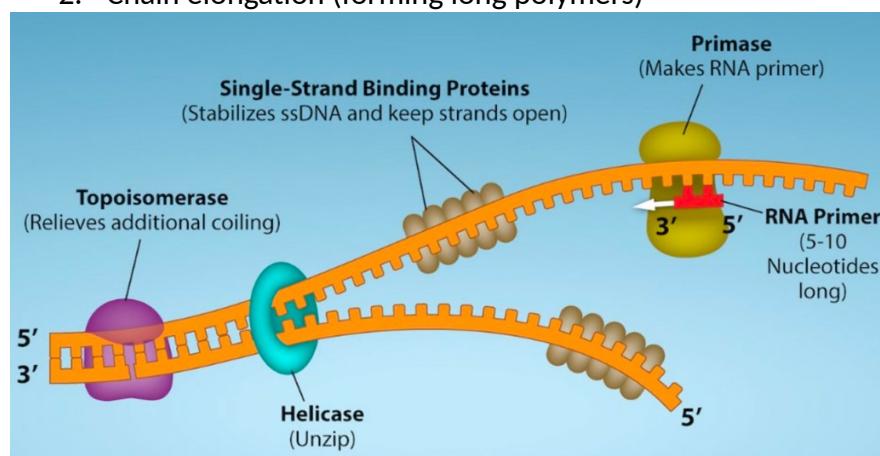
- 2 replication forks, 2 strands being copied at each fork = 4 strands being copied.
- Will eventually join to become circular – 2 newly copied chromosomal strands.



DNA strands run in opposite directions.

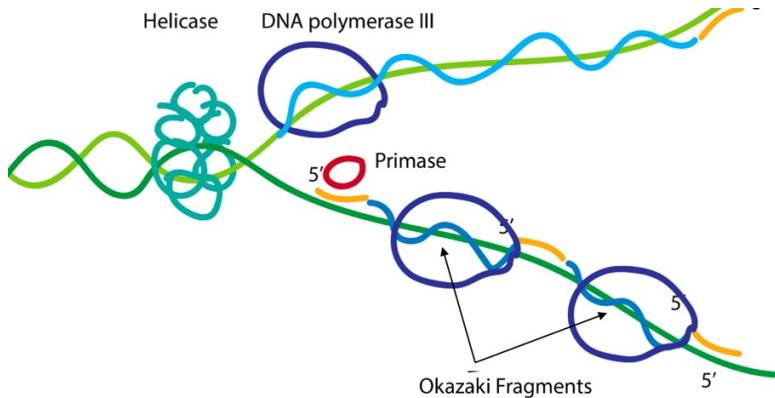
- Can only synthesise in a 5' to 3' direction.

2. Chain elongation (forming long polymers)



Lagging strand replication

- The primase lays down multiple primers, as the helicase unwinds the DNA.
- Then DNA polymerase makes lots of small fragments, not yet joined together.
- Then a different DNA polymerase removes the RNA primers and fills them with DNA.
- DNA ligase then joins the fragments to make the lagging strand.



SUMMARY:

Leading

- Primase makes an RNA primer to begin, then:
- DNA polymerase III makes a DNA copy of the strand in the 5'→3' direction
- Continuous copying

Lagging

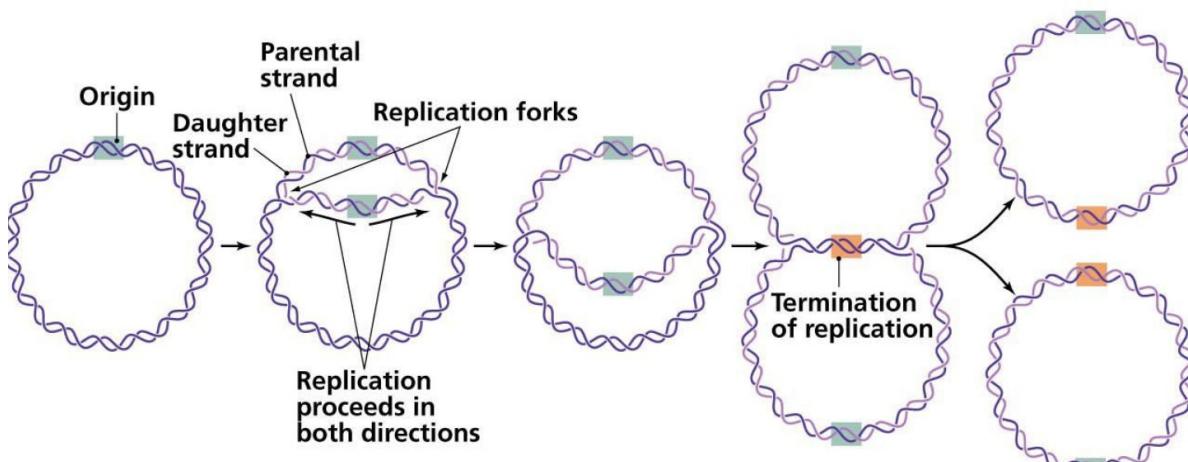
- Primase makes multiple RNA primers
- DNA polymerase III synthesises in 5'→3' direction until it runs into the next primer making Okazaki fragments
- DNA polymerase I replaces the RNA primer with DNA
- DNA ligase joins the pieces of DNA

made in small pieces
that get joined together

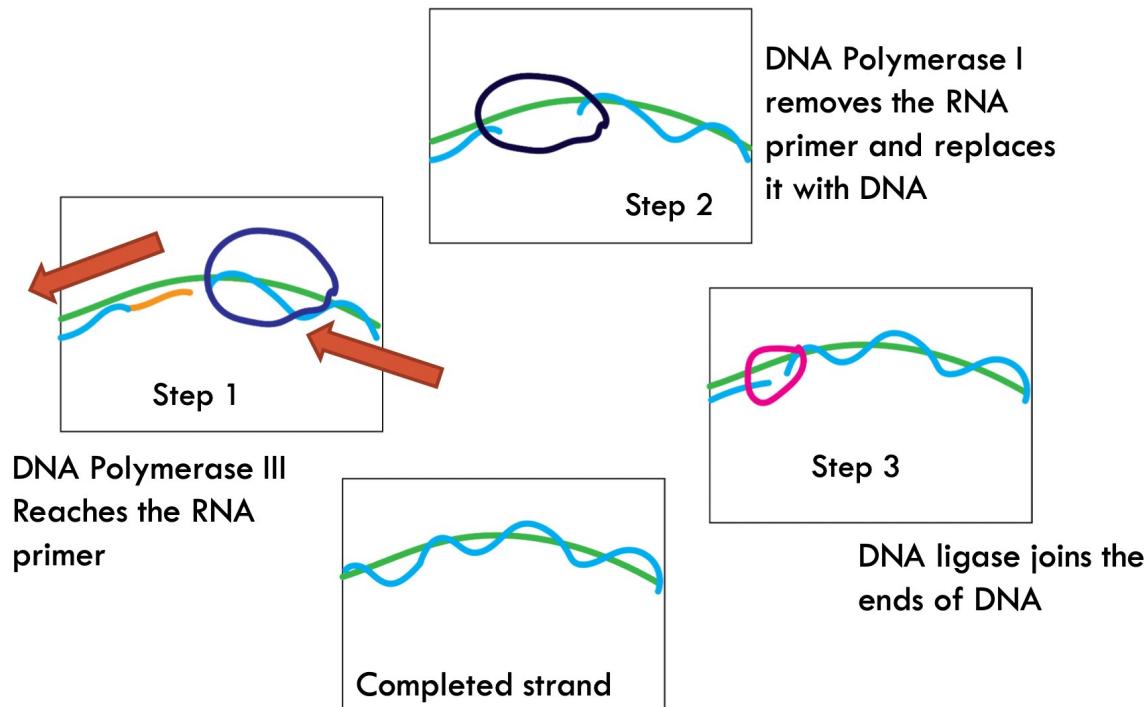
When the two replication forks come together

3. Termination (stop)

- Joining up the 2 strands (4 strands becomes 2 new daughter strands)
- Roughly opposite the origin



Joining the ends of circular chromosomal DNA



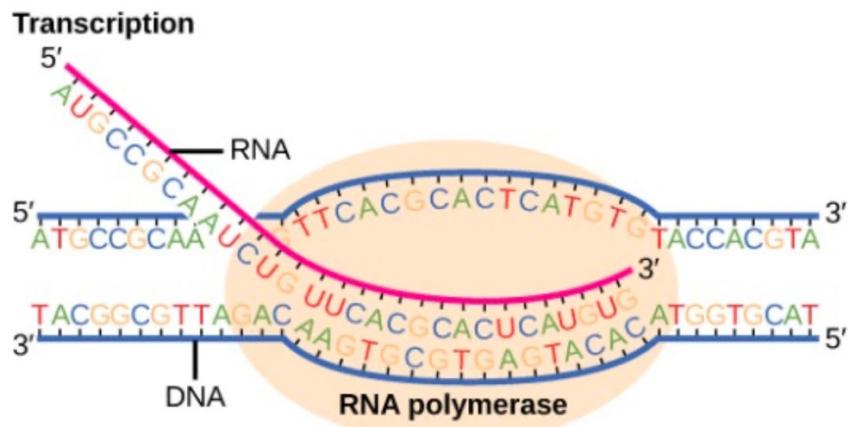
TRANSCRIPTION

- Make an RNA copy from a DNA template,
- DON'T NEED A PRIMER TO START
- Uses ribonucleotide triphosphates as substrate,
- Limited proofreading, no 5' to 3' exonuclease activity (makes more mistakes)
- Only small sections of the genome need to be transcribed.

Initiation and termination

- RNA polymerase binds to a region of DNA called a **promotor** – sits just upstream (past the 5' end) and transcribes downstream from that region.
- Transcription stops at the terminator.

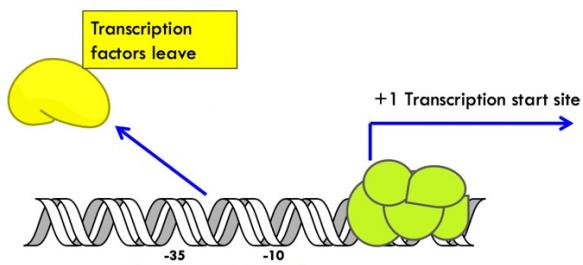
Only ONE strand of DNA is transcribed for each gene, but the strand being copied can vary – depending on the sequence.



Initiation:

1. transcription factor

- Known as the sigma factor in bacteria = proteins capable of recognising a specific base sequence,
- The RNA polymerase is a multisubunit enzyme, that binds with the sigma factor.
- The part it binds to (-10 region) has the sequence TATA which is easy to melt DNA.
- Promotor region, where RNA polymerase binds to transcribe the gene.
- Transcription factors leave, and RNA polymerase binds to the DNA where it starts producing.



Elongation

- A fast process of joining complementary strands (A,U G,C)

Termination

- Uses a signal encoded in the transcribed RNA to stop – a G/C rich sequence often followed by a A/T rich sequence.
- G/C region forms a hairpin structure – causing transcription to pause and RNA be released.
- Or, Rho protein binds and uses helicase to dissociate the DNA/RNA complex.

Repressors: blocks the binding of the sigma factors.

Accelerators/activators: helps weaker promoters.

Making Proteins

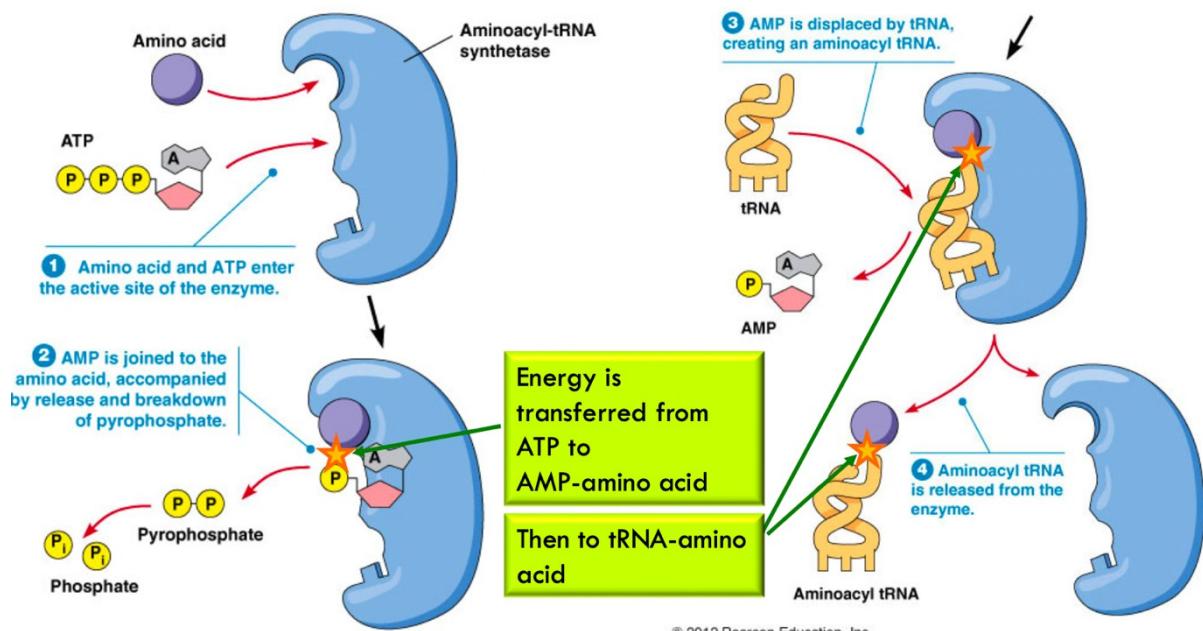
mRNA (messenger) – contains template for protein synthesis.

tRNA (transfer) – matches each amino acid to the template.

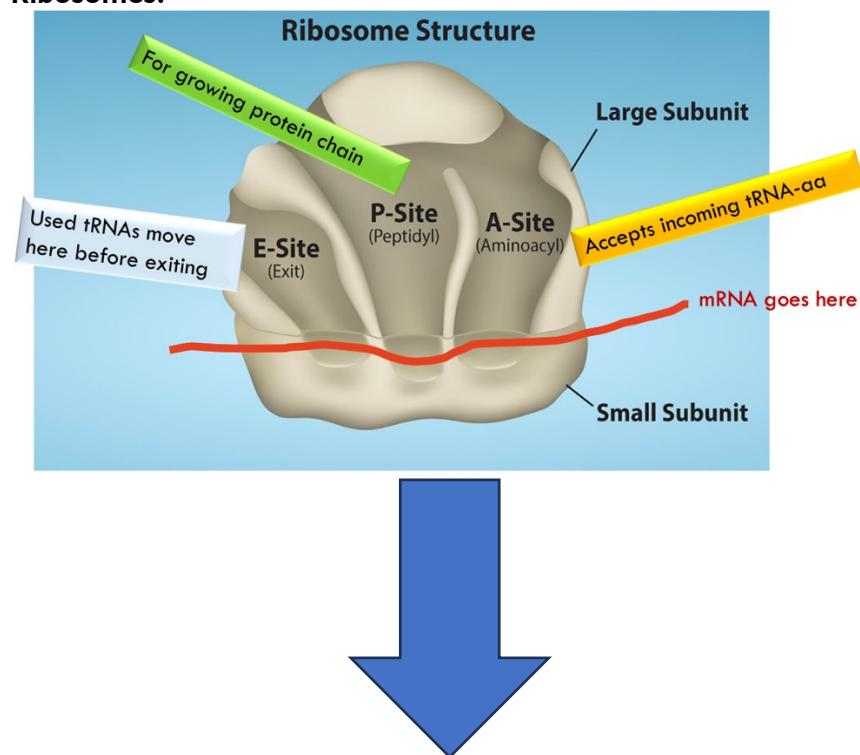
rRNA (ribosomal) – combines with proteins to form peptide bonds,

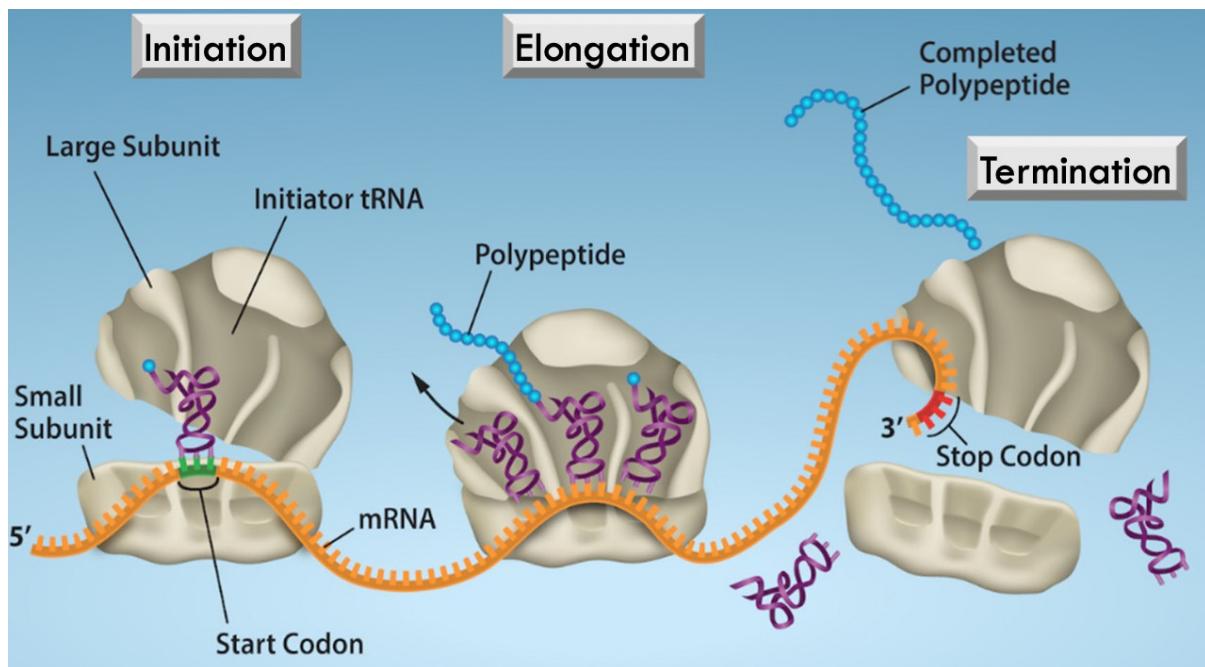
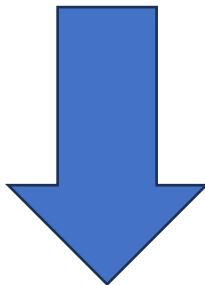
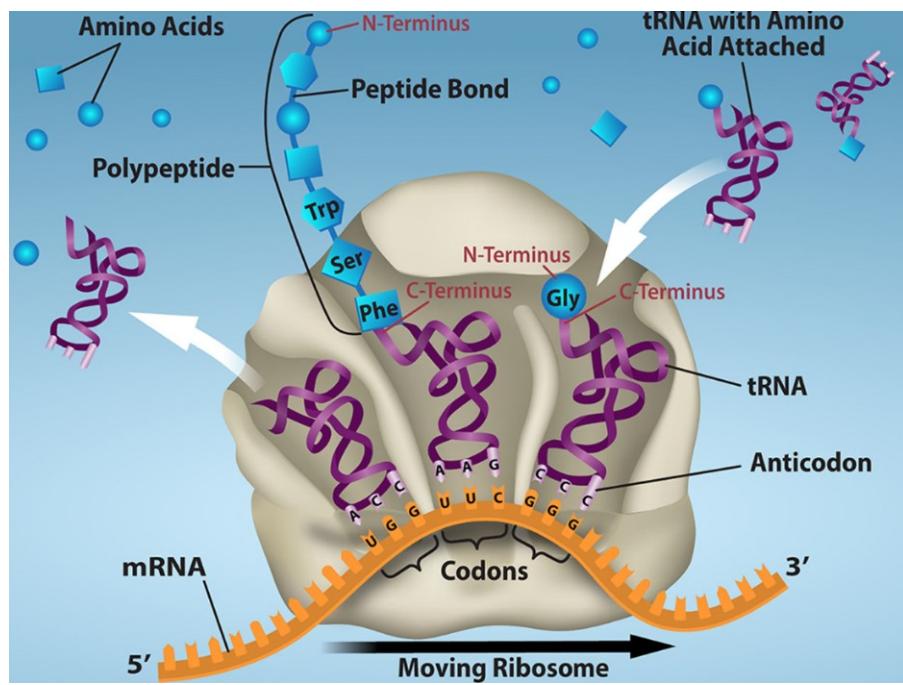
ANTICODONS ARE COMPLEMENTARY TO CODONS.

- Different tRNA for each amino acid combination.
- Aa-tRNA-synthetases (are proteins/enzymes) and **attach the correct amino acid to its' matched tRNA.**



Ribosomes:





Initiation: a bit of extra sequence in the mRNA helps to identify the start codon. Small subunit of the ribosome binds mRNA, then large subunit of ribosome binds.

Elongation: tRNA recognises codons and connects the correct amino acids to the mRNA sequence.

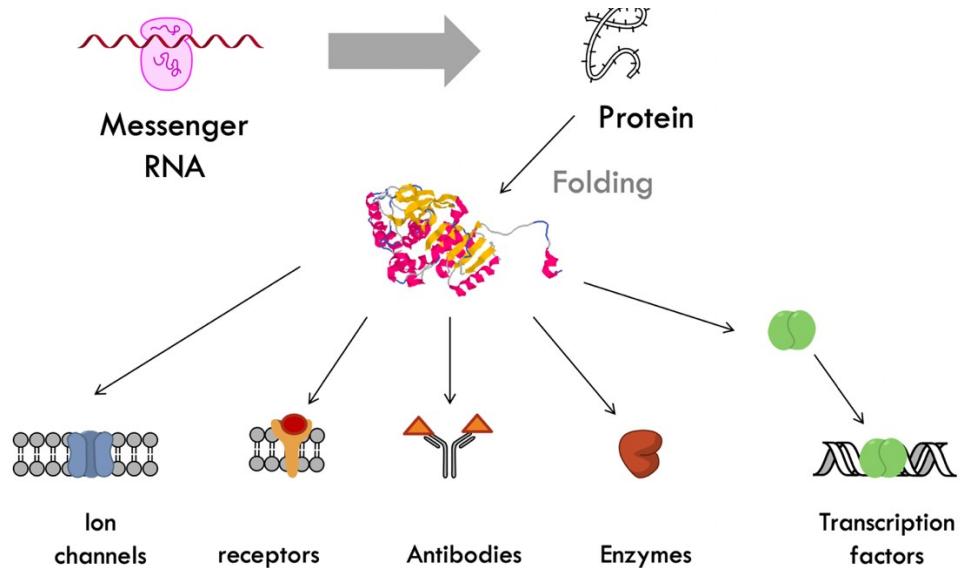
When the tRNA is used it moves away from the ribosome.

Amino acids join by polypeptide chains to create a protein.

Termination: when stop codon is reached, no more tRNA comes to bind. The release factor binds. The Peptidyl transferase adds water instead of amino acid and thus releases the polypeptide.

- Machinery disassembles and can then be reused.

PROTEIN STRUCTURE



1. PRIMARY

- Amino acid sequence

2. SECONDARY

- Local structures, e.g., Alpha helix and Beta sheet.
- Backbone-backbone hydrogen bonding interactions.
- Sidechain interactions help hold the structure together and form tertiary structure.

3. TERTIARY

- Overall 3D arrangement of a polypeptide chain,
- Held together by lots of different interactions/bonds,
 - o Hydrogen bonds,
 - o Ionic/electrostatic and polar interactions,
 - o Hydrophobic interactions/hydrophobic effect,
 - Driving force for protein folding is hydrophobic effect.
- pH solvents, temperature important to maintain structure.

4. QUATERNARY

- Organisation of subunits, (coming together of more polypeptide chains to create a protein, not all proteins do this)

WEEK 3: Enzymes and Thermodynamics, Photosynthesis

Equilibrium and Thermodynamics

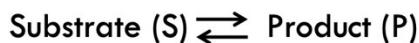
Energy – capacity to do work.

- **Potential energy** (stored in chemical bonds/interactions)
- Kinetic energy – energy expressed as movement (heat/radiant energy)
- **Bioenergetics** the transfer of potential to kinetic energy and back in living systems.
- **Entropy** is a measure of disorder – from an ordered state, to being scattered around.

Laws of thermodynamics

- 1st law – energy can neither be created nor destroyed.
 - But it can be transformed.
- 2nd law – the entropy (disorder) of the universe is increasing.
 - Chemical and physical processes favour randomness.
- BUT if you apply energy to this state you can get it back to an ordered state.

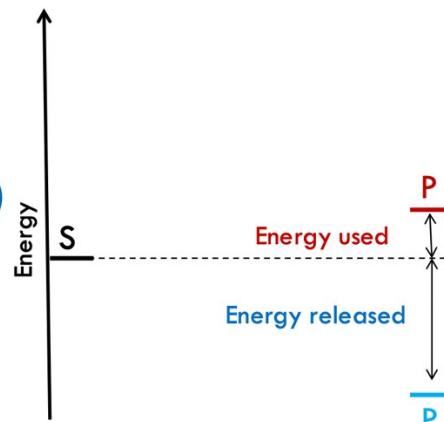
Reactions



will either be:

- **Favourable (give out energy/exergonic)**
- **Or unfavourable (need energy input/endergonic)**

Will the reaction take place?

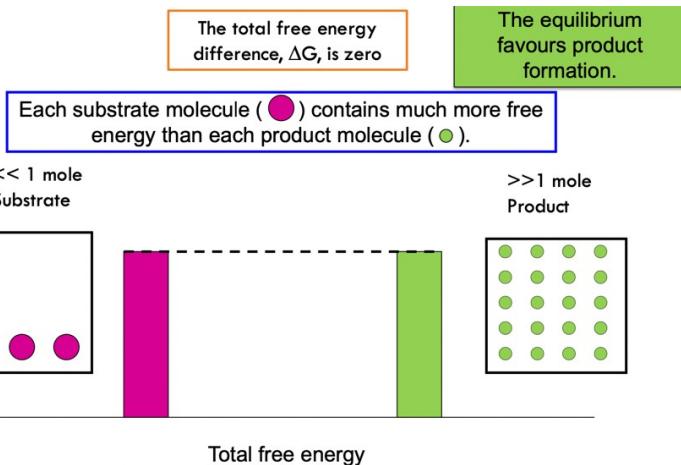


At equilibrium – overall keep the same balance (same concentrations of molecular species), but at a molecular level some molecules will swap.

- Forward and reverse reactions happening at the same rate.

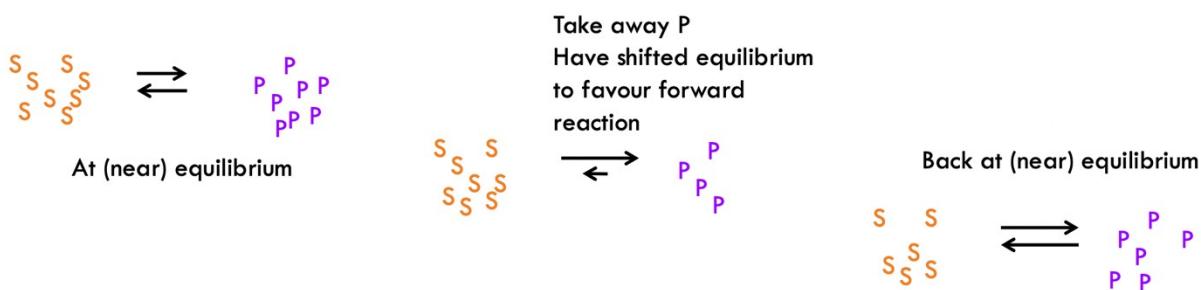
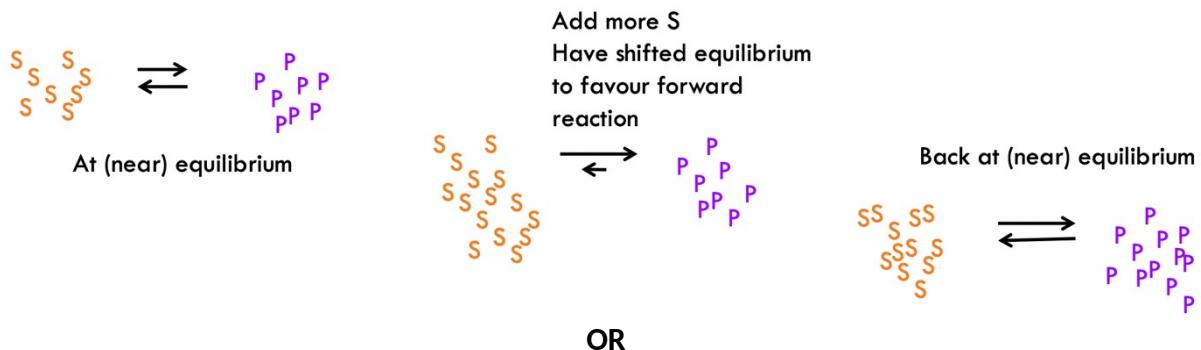
Under STANDARD conditions

- Starting with the same concentration of substrate and product and measuring the energy differences between them.



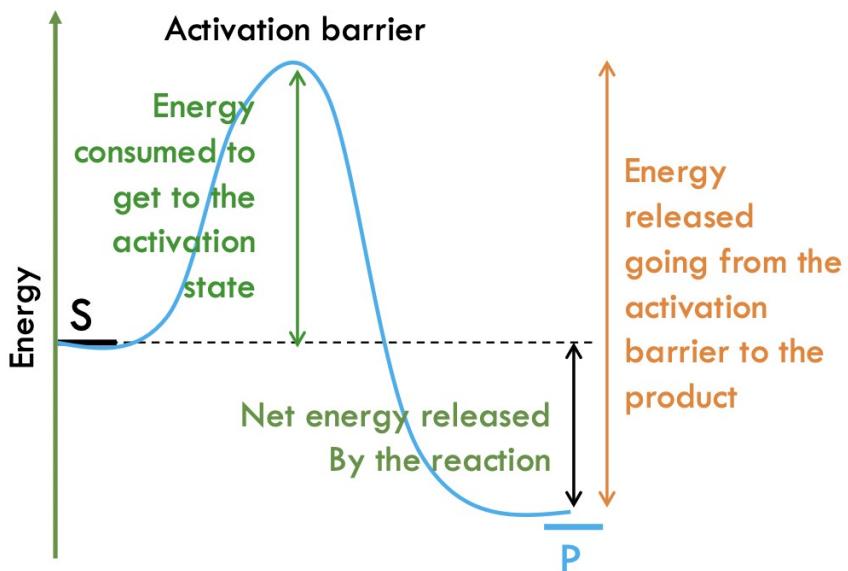
In cells:

- Living cells reactions never quite reach equilibrium,
 - o As new substrates are added and products are used up.
- Increasing equilibrium can “push” equilibria towards the other side; decreasing concentrations by using them up to “pull” the equilibrium towards the low concentration side.
- Other reactions would be topping up S, and use up P.



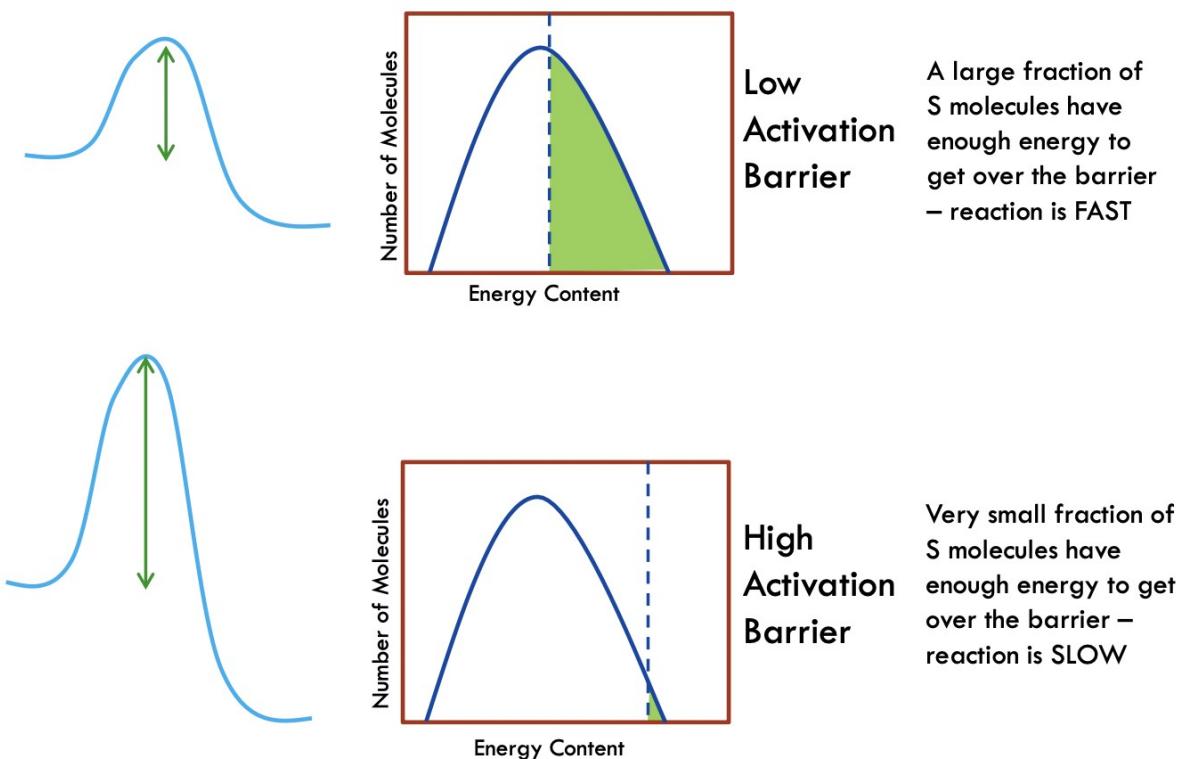
KINETICS

- Still making the substrate and product but focusing on how quickly something will happen.
- To have a chemical reaction – need to break bonds in order to make some bonds.



How fast will reaction happen?

- Need to get over energy barrier.
- Only S molecules that have enough energy to get over the barrier will be converted to P molecules.



GLOSSARY

- **Activation energy/barrier** – The energy required to initiate a reaction.
- **Chemical energy** – energy stored in bonds.
- **Energy** – capacity to do work.
- **Endergonic** reaction – requires an input of energy.

- **Entropy** – measure of disorder.
- **Equilibrium** – rates of forward and reverse reactions are the same; concentrations of substrates and products don't change; overall energies are balanced.
- **Ergonic reaction** – gives out energy.
- **Kinetics** – how quickly an event happens; rates.
- **Kinetic energy** – energy associated with movement.
- **Potential energy** – see chemical energy.
- **Product** – result of a reaction.
- **Thermodynamics** – measures and transitions of intrinsic energy.
- **Transition state** – high energy state that has to be bypassed to form products.
- **Substrate** – starting compound of a reaction.

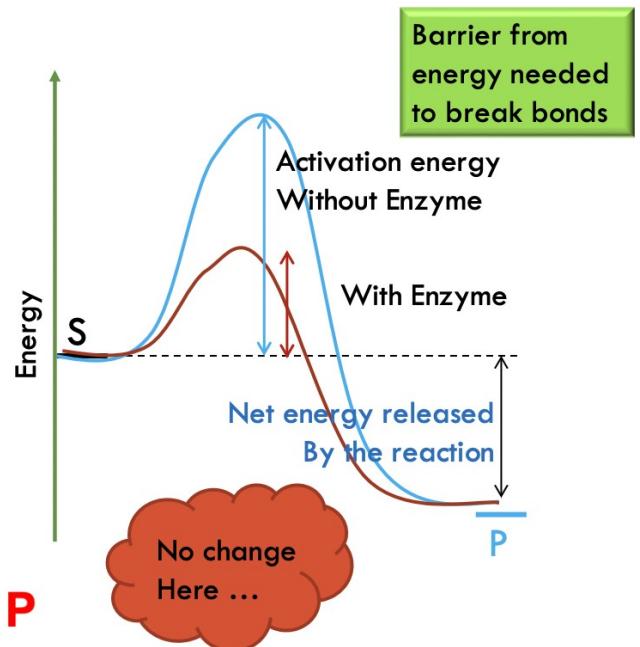
ENZYMES

Thermodynamics – starting and finishing states (will reaction take place?)

Kinetics – how fast will reaction happen (need to get over an energy barrier)

Enzymes are biological catalysts!

- Speed up the reaction time,
- And lower the energy barrier.
- Not changing the balance but just the speed.
- They "stabilise" the transition state.



Enzyme	Substrate	Enzyme-Substrate complex	Enzyme-Transition state complex	Enzyme	Product
					PRODUCT

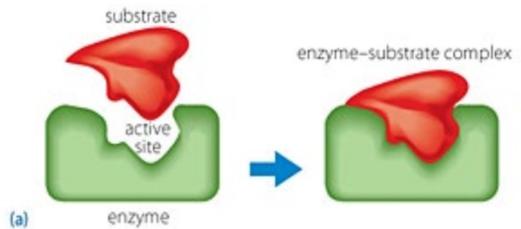
...to energy or equilibrium

Enzyme binding:

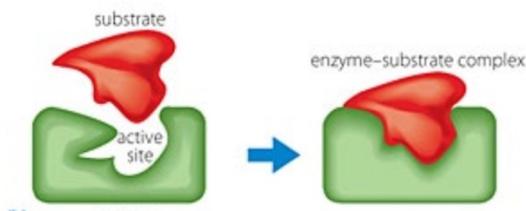
- Enzymes are specific for their substrates.
- Relatively big, highly functionalised binding pockets,
- "Lock and key" analogy – substrate molecule fits directly into the active site.

Then turned to the:

- **Induced-fit model** – the substrate induces a shape change for optimal substrate binding and activity.

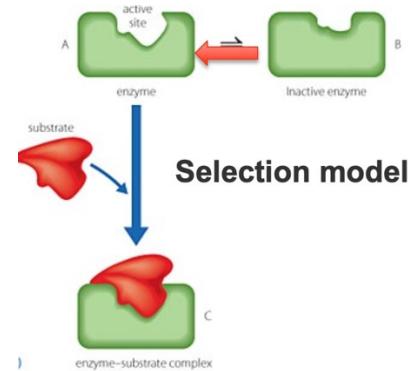


Lock and key model



Induced-fit model

Selection model - the enzyme exists in multiple forms of equilibrium, only one of (A) binds substrate.



Features of enzymes:

- Enzymes usually end in 'ase'.
- Are mostly proteins,
- Highly varied in function, size, ability to be regulated,

Enzyme regulation:

- Have evolved to work in specific temperatures and pH,
- Many require additional chemical component (cofactor) for optimal activity,
- Can be inhibited.
- Collected into pathways, for metabolism, synthesis of cellular materials, communication (signalling) etc.
- **Mutations** reduce activity/ change specificity/ increase activity/ alter regulation and cause disease.

Driving unfavourable interactions by coupling reactions:

- Unfavourable interactions need energy input,
- So, coupling/linking reactions effectively combines the energy/effects the equilibria of both reactions.

Metabolism and energy currency

- ALL organisms require constant input of energy,
- Cellular processes like building and breaking down complex molecules require chemical reactions,
- Chemical reactions occurring inside cells, using and releasing energy = **cell's metabolism**,

Metabolic pathways

Anabolic: Small molecules assemble into large ones. *Energy is required.*



Catabolic: Large molecules break down into small ones. *Energy is released.*

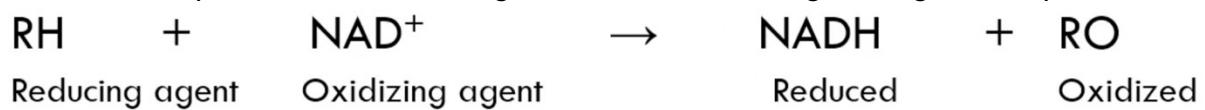


Reduction and oxidation reactions (redox)

- LEO GER = loss of electrons oxidation; gain of electrons reduction
- OIL RIG = oxidation involves loss, reduction involves gain of electrons.

Metabolism: Electron carriers

NAD⁺ can accept electrons from an organic molecule according to the general equation:



- Can carry electrons from one molecule to another.

Energy in cells

- ATP = adenosine triphosphate
- ADP = adenosine diphosphate

Phosphate bonds are **high energy** bonds.

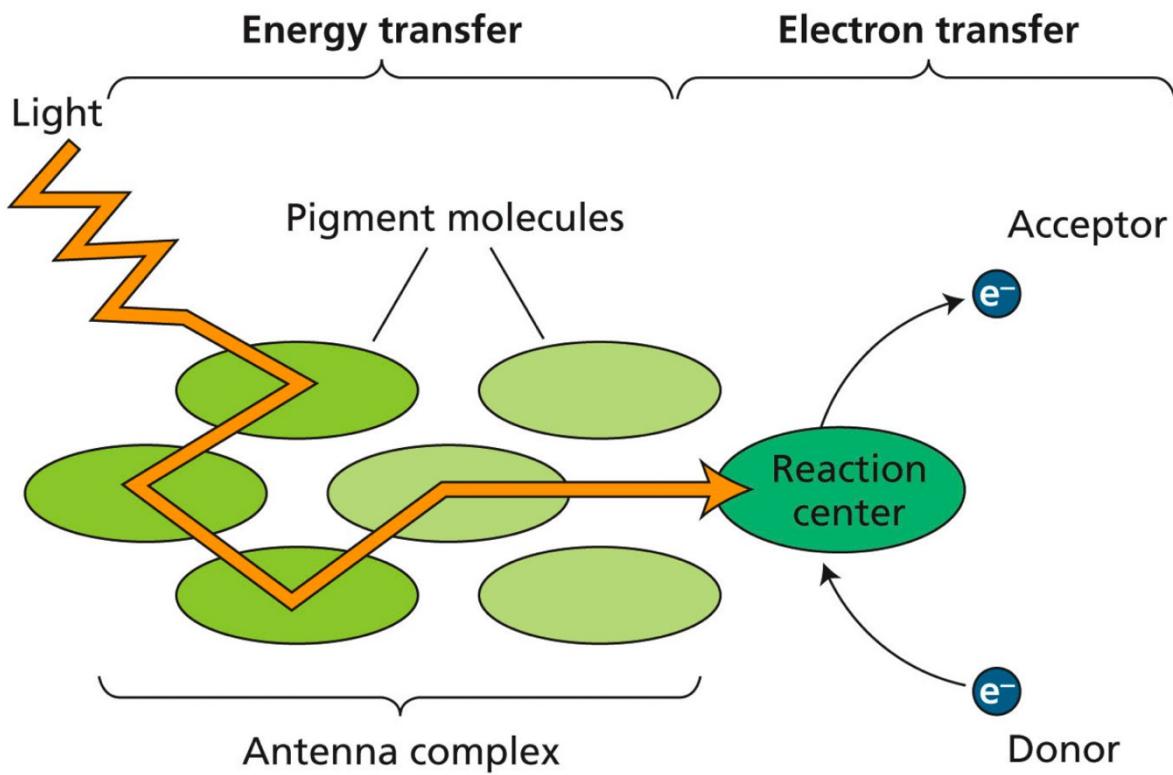
- Cellular energy carrier!
- Energy is stored as ATP and is used when needed.

There are 2 main ways organism can require energy

- **Heterotrophy** (eat food and use cellular resp to release energy in the food)
 - o Heterotrophs: eat food > cellular respiration > energy
- **Autotrophy** (create their own food from inorganic compounds)
 - o Autotrophs: photosynthesis > sugars > cellular respiration > energy

PHOTOSYNTHESIS

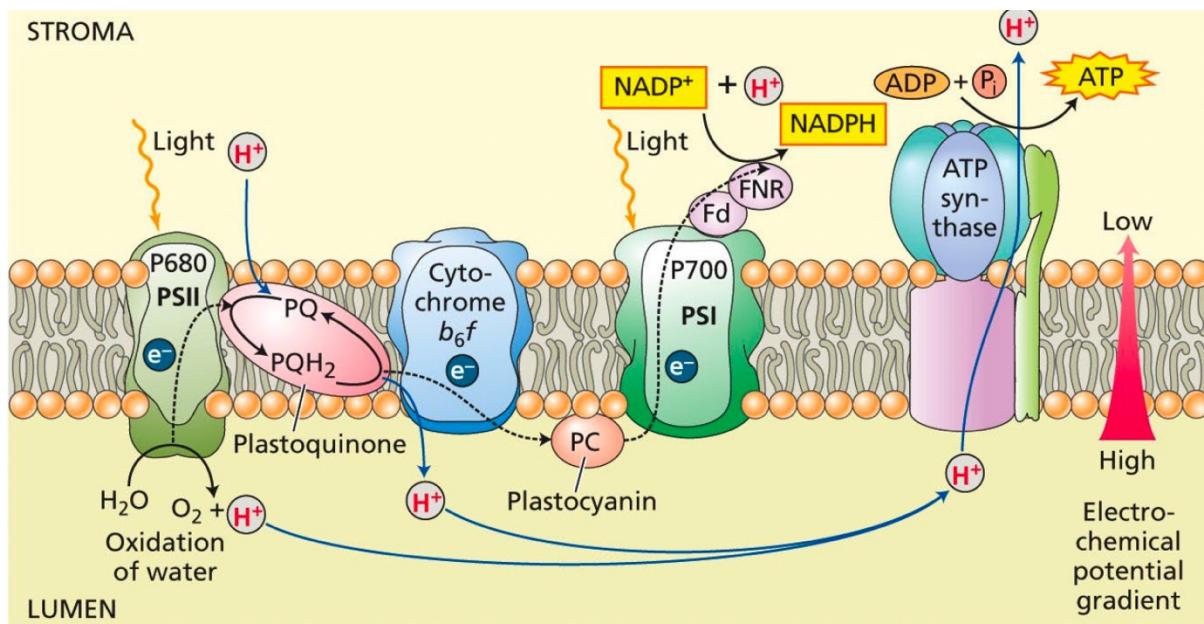
- Chlorophylls capture light energy, in chloroplasts.
- Chlorophylls work in an 'antennae complex'. Which works to transfer light energy into the reaction centre. (shown below)



- A resonance energy transfer: when hit by light one of the electrons is raised to a higher level and its energy is passed to the neighbouring chlorophyll. And this keeps happening into the reaction centre. Like a 'Mexican wave'.

Photosynthesis – uses sunlight to make proton gradient, then proton gradient leads to production of ATP and NADPH and converts CO_2 into glucose.

- Evolutionary advantage to heterotrophs, as they aren't dependant on other resources.



- Energy from the movement of protons from the ATP synthase which leads to the production of ATP.
- Cyanobacteria produced free oxygen via photosynthesis.
- Led to the 'great oxidation event' 2 to 2.5 billion years ago.
- Changed earth's evolutionary trajectory.

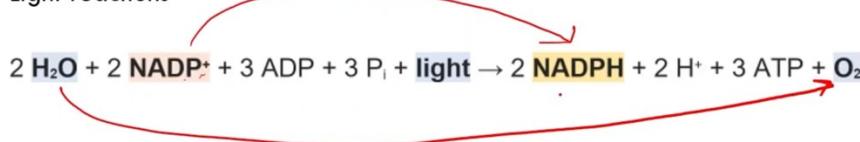
WEEK 4: PHOTOSYNTHESIS

- Looking at how plants convert CO₂ into carbohydrates.

REDOX

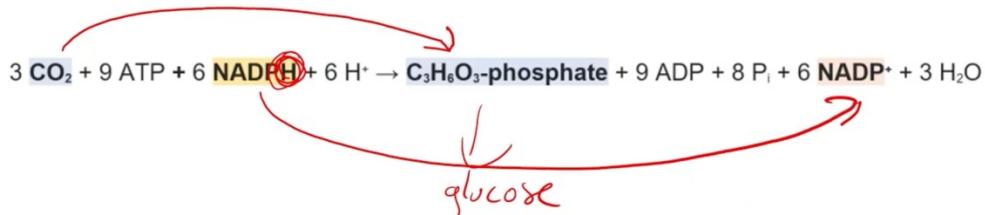
1st stage

"Light reactions"

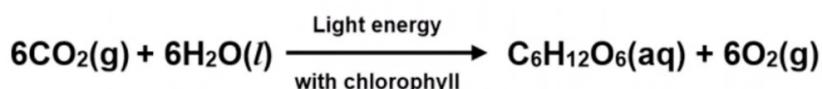


2nd stage

"Calvin cycle" or "light-independent"



When these 2 reactions are put together we get the equation for photosynthesis.



- Photosynthesis occurs in **chloroplasts**.
- Chlorophylls are pigments that absorb light (absorb red and blue light, reflect green light hence many plants are green).

2 steps of photosynthesis:

1st stage: '**light reactions**'

- Trap sunlight and convert to chemical energy (ATP, NADPH) for later use.

2nd stage: '**Calvin-cycle**' or '**light-independent**'

- Capture CO₂ from the air and convert into sugars using chemical energy produced in stage 1st stage.
- Occur in the stroma

Rubisco – takes in CO₂ and converts it into sugars. In the chloroplast stroma.

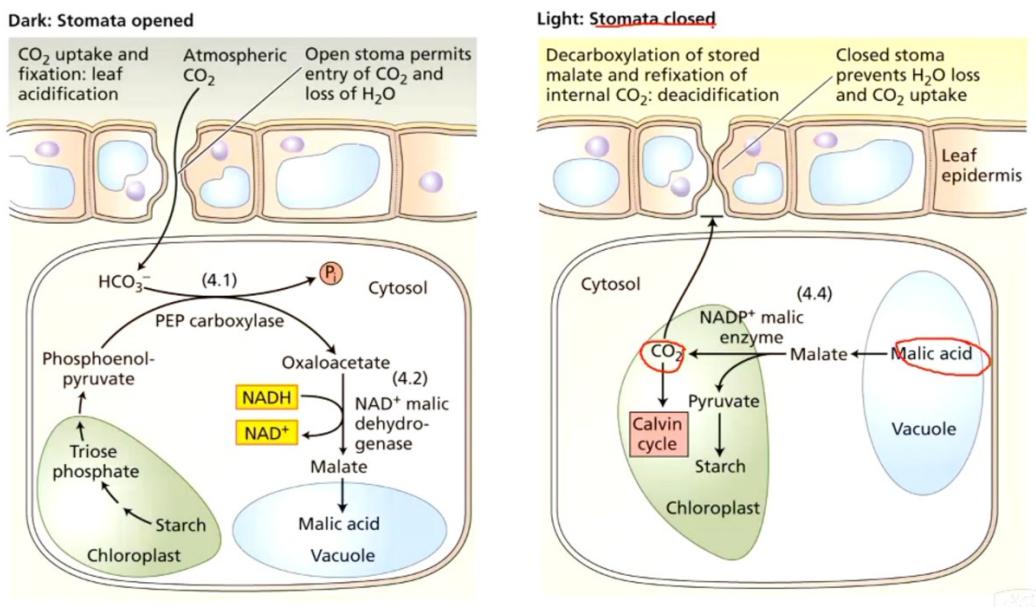
Rubisco = ribulose bis-phosphate carboxylase/oxygenase

Photorespiration

- When CO₂ is being produced in the light.

When dark: stomata opened, for entry of CO₂ and loss of H₂O

When light: stomata closed, to prevent H₂O loss and CO₂ uptake



In photosynthesis: the C from CO₂ is reduced (electrons added) to become glucose.

In respiration: the C from glucose is oxidised (loses electrons) to become CO₂.

Cellular respiration

- Occurs in the mitochondria.
- The Krebs cycle - removes electrons from pyruvate into electron carriers,
- Electron transport chain (ETC): electrons are transferred from NADH to protein complexes and electron carriers. Travel through ATP synthase and make ATP.

WEEK 5: METABOLISM AND CELL DIVERSITY

- 60% of an animal's body is made up of water,

2 types of metabolic reactions

- Anabolic - building up (small molecules are assembled into large ones)
- Catabolic - breaking down (large molecules are broken into smaller ones)

Glycogen - a carbohydrate

Is mainly stored in the liver and skeletal muscle so it can quickly feed the body.

Glucagon causes the catabolism.

When you eat food, your blood stream absorbs **amino acids**. And are transferred to the cells to build proteins.

ALL ESSENTIAL amino acid components of protein are made by plants.

Fats - Stored in adipose tissue.

CELL DIVERSITY

Cell evolution: over 3.5 billion years, some cells have evolved complex structures and functions.

- Endocrine cells that can respond to homeostatic signals and release hormones,
- Voluntary muscle,
- Fibroblasts that can repair wounds,

Different modifications have given organisms amazing abilities.

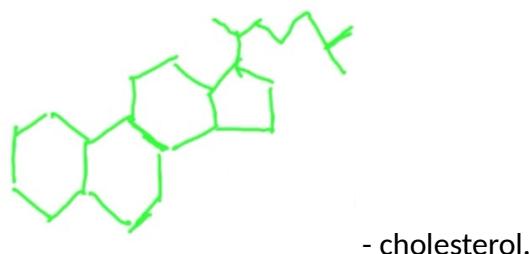
Prokaryotic vs eukaryotic:

- Eukaryotic: have membrane bound organelles and a nucleus, linear DNA.
 - o Plants, animals, Protista, fungi, some bacteria
- Prokaryotic: single celled, circular DNA in plasmids, flagellum allows cell to move when it encounters an obstacle.
 - o Bacteria and archaea

Plasma membrane:

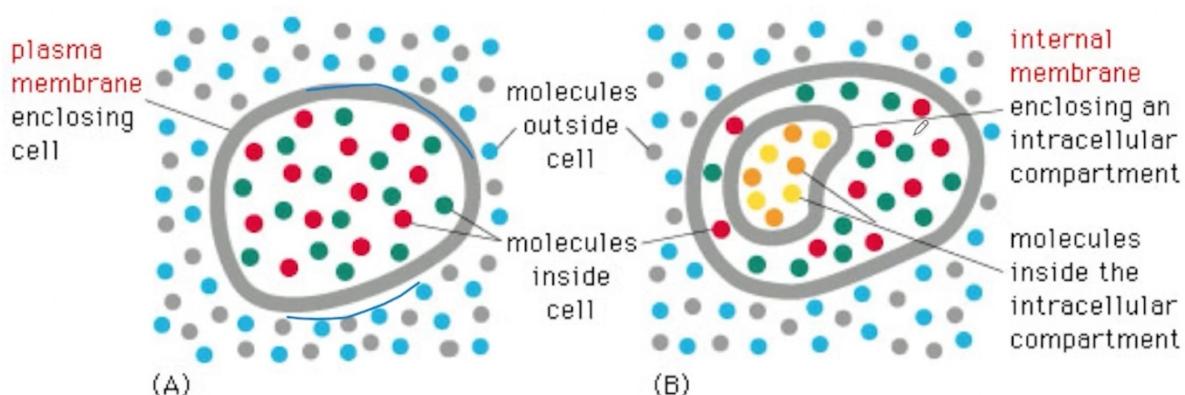
Membranes are made out of **phospholipids**. With a hydrophilic head and hydrophobic tail.

- Become a Phospholipid bilayer,
- Animal plasma membranes are stabilised with cholesterol. Cholesterol has hydrophobic and hydrophilic elements.



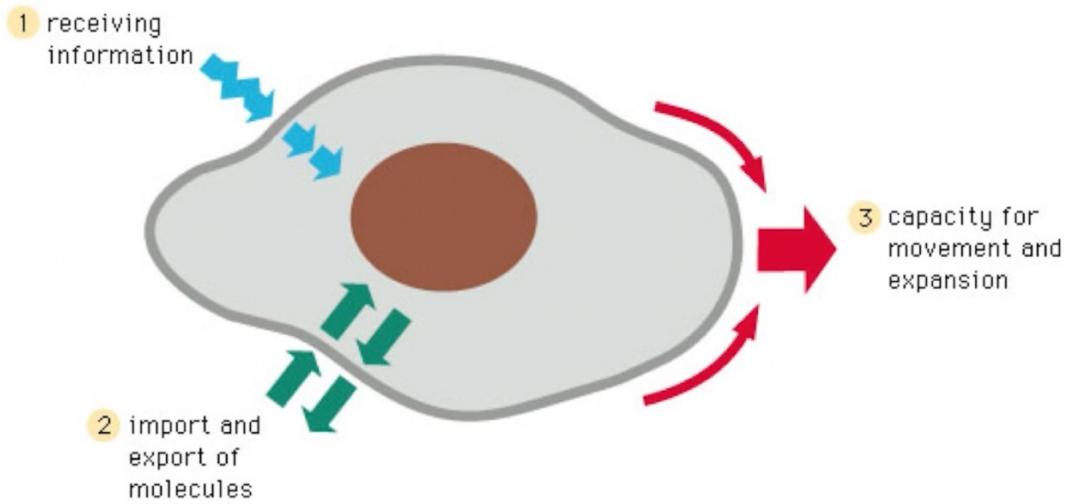
Barriers

- Allow for specialised functions.



Enables

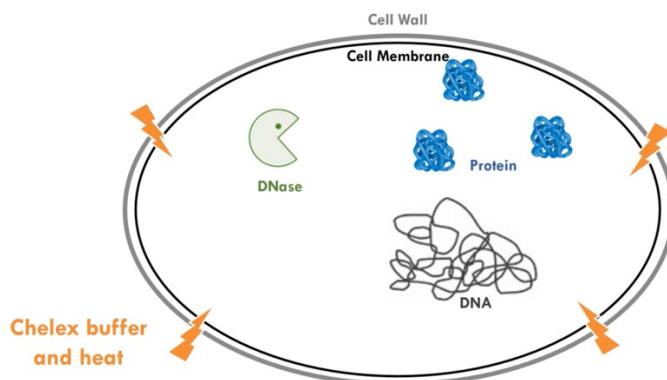
- **Border police** – Import and exporting molecules into environment,
- **Cell signals** – Receiving information, and recognise chemical info in the environment,
- **Shape, size, environment** – Capacity to move and expand.



The nucleus encircles the DNA inside,
 The endoplasmic reticulum (ER) is connected to the nucleus. The nucleus has pores that allow proteins such as transcription factors which regulate genes to go in and out of the nucleus. And the nuclear membrane is continuous with the ER membrane.

DNA EXTRACTION PROCESS

Introduction to Activity 2.1: DNA Isolation from *E.coli*



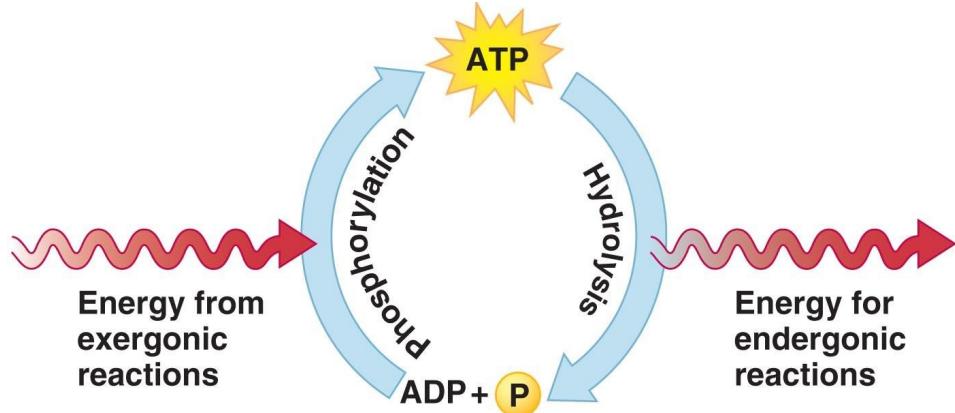
1. Proteinase K clumps together and removes the proteins
2. Isopropanol sorts the DNA
3. Ethanol removes the chelex buffer and heat, and isopropanol and proteinase K

4. EDTA removes DNase
 > DNA is isolated.

WEEK 6: COMPARTMENTALISATION OF CELLS, & CELLS, TISSUES AND COMMUNICATION

Function of plasma membrane:

How does ATP power molecular material?



Ender - from within

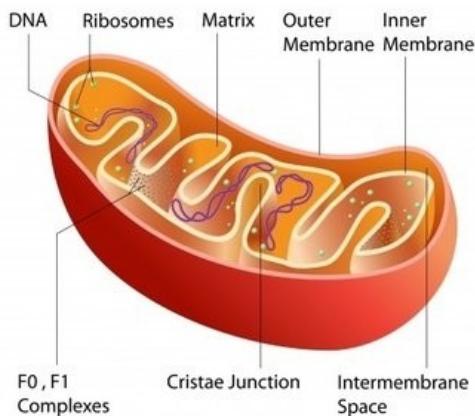
Exer - from outside

Vesicles are bubbles of membrane that carry protein cargo.

Exocytosis - taking proteins out of the cell.

Endocytosis - proteins bind to the surface of membranes and is drawn into the cell.

Mitochondria are descendants to prokaryotic cells that had their own DNA. Lots of that DNA is still present in mitochondria.



Functions of **mitochondria**:

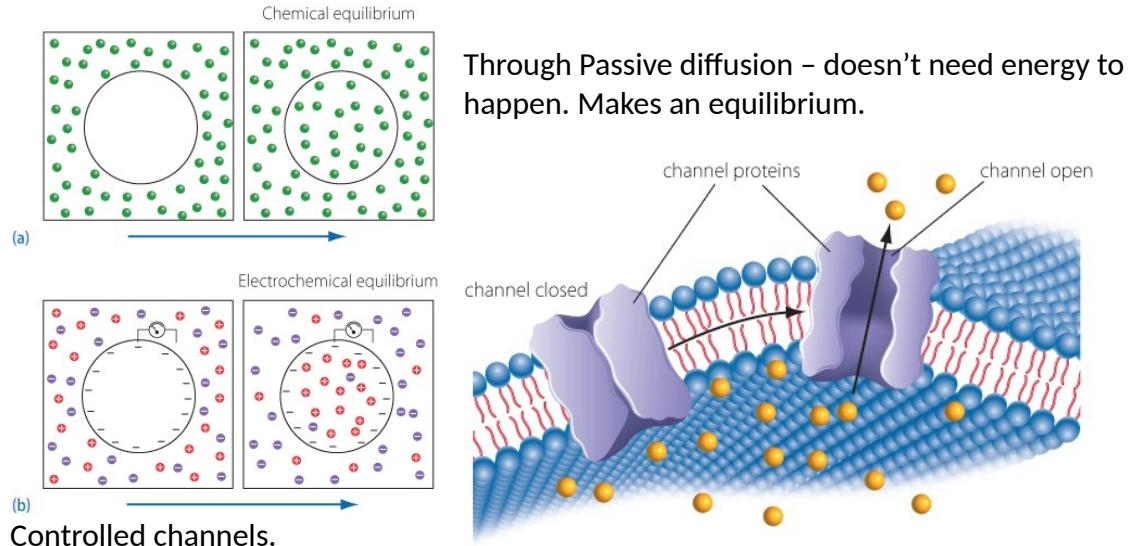
- **Production of ATP** (ATP synthesis)
- **Steroid synthesis**
- **Apoptosis** (signal to the cell to destroy itself)

Mitochondria are often attached to microtubules of the cytoskeleton.

- Components of cytoskeleton:
 - o Microfilaments – made of actin (muscle)
 - o Microtubules – made of tubulin (act as train tracks for mitochondria)
 - o Intermediate filaments – made of various proteins, often keratin. Helps reduce pushing against cell. Reinforces.

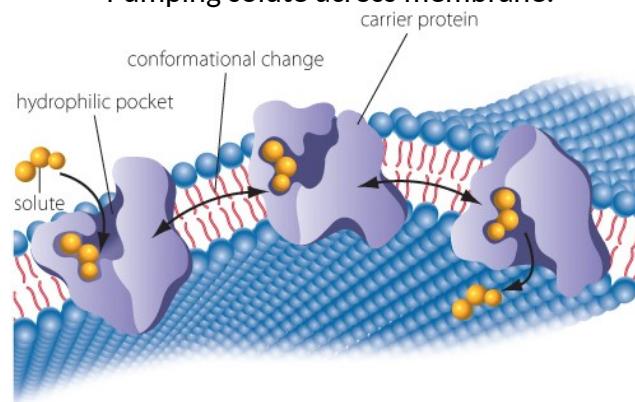
Passive and active processes: (DIFFUSION AND OSMOSIS)

MOVEMENT ACROSS MEMBRANES

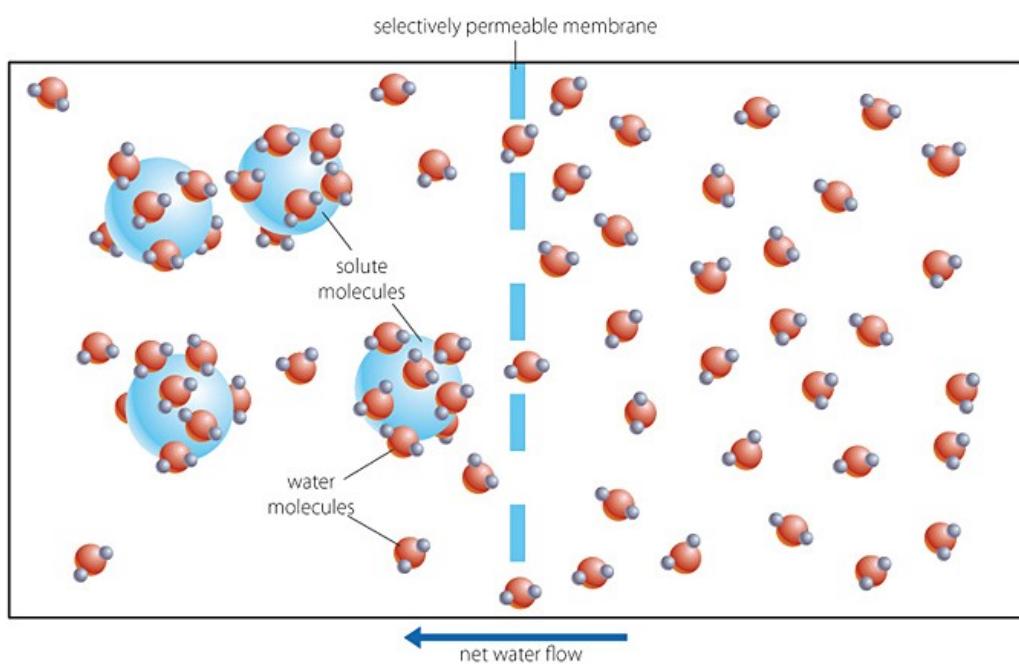


Powered transport.

- Uses ATP energy to power transport against the flow.
- Pumping solute across membrane.

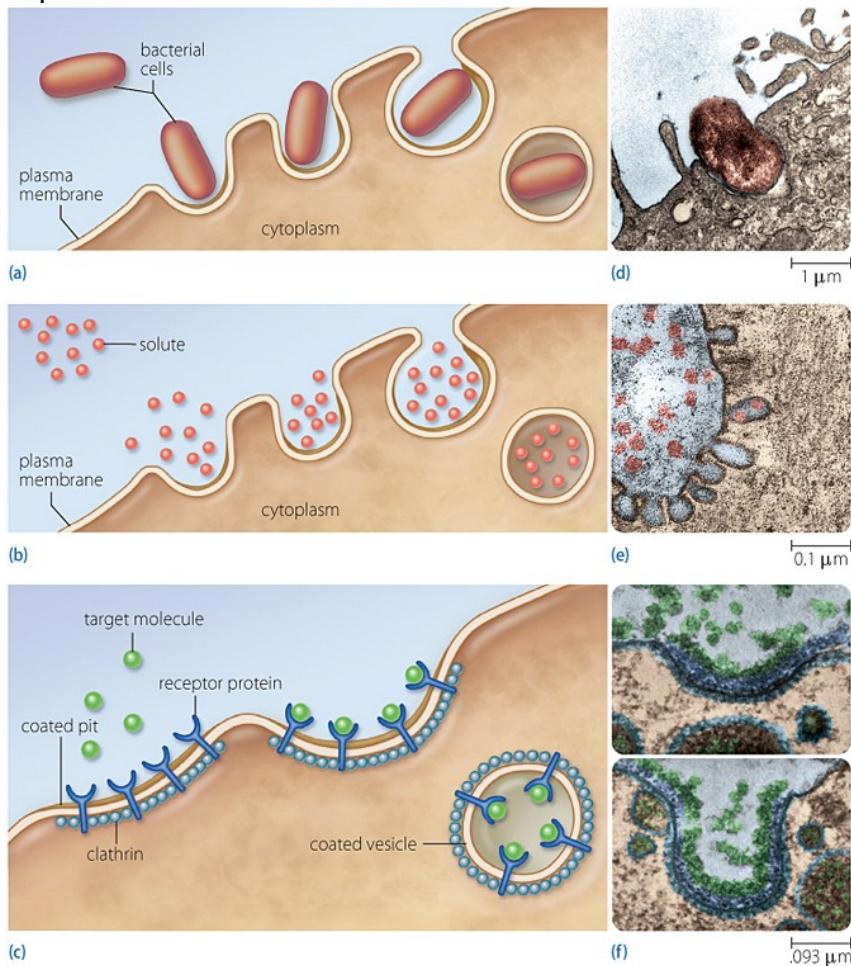


OSMOSIS



- Where salt goes, water follows.

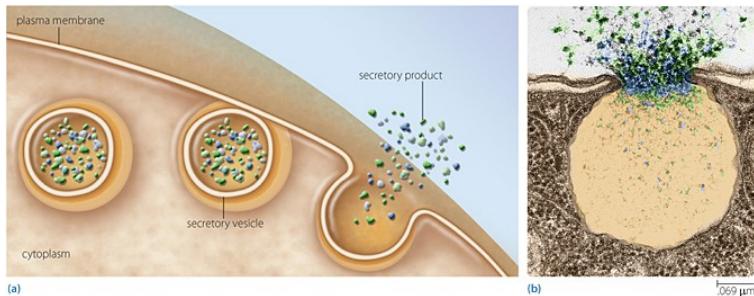
Imports into the cell.



- a) **Phagocytosis:** One cell engulfs another organism. Then the bacteria is wrapped in a vesicle.
- b) **Pinocytosis:** Forms a vesicle where some of the watery liquid goes in the vesicle and closes at the top to form a vesicle of the water and organism inside the membrane. "Cell drinking".
- c) **Endocytosis:** Where the cell uses receptors to take up one type of molecule. Receptors are specifically designed to connect to the particular protein/molecule.

Exports from the cell

- a) **Exocytosis:** eg. a hormone to release. The vesicle runs down the microtubule tracks to the surface of the cell or plasma membrane. Then diffuses and releases its product outside the cell.



Cells, tissues, and communication

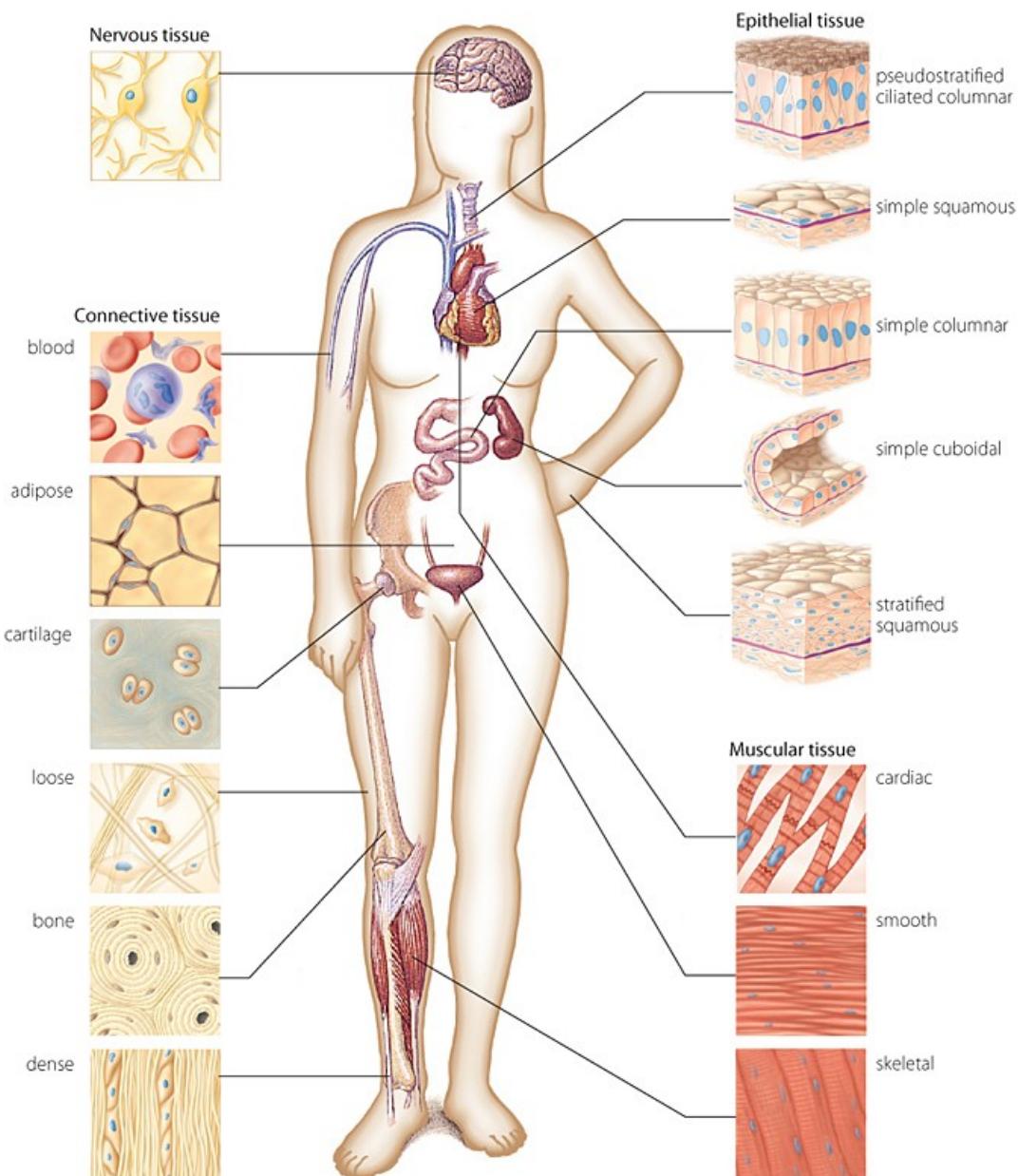
Objectives

- Explore the ways that cells aggregate with each other to form tissues,
- Compare and contrast the four types of animal tissue.
- Explain how cells communicate and regulate cell growth in a healthy state (e.g. differentiation of stem cells)
- What can go wrong to result in a pathophysiological state (e.g. cancer).

Most multicellular animals are made of just 4 major tissue types.

- Epithelium
- Connective
- Nervous
- Muscle

Tissue

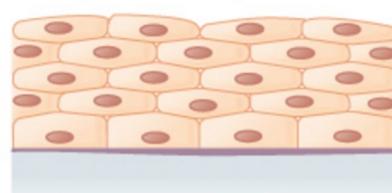
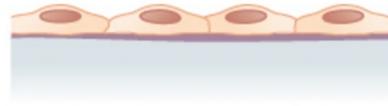


- Epithelium

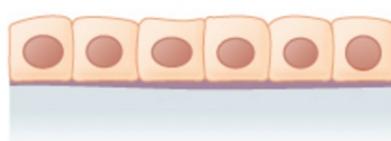
Lining tubes.

- 1 layer of epithelium cells are called – **simple layers**.
- Multiple layers are called – **stratified epithelium**.
- When the nuclei is at different levels, but just one layer is called – **pseudostratified**.

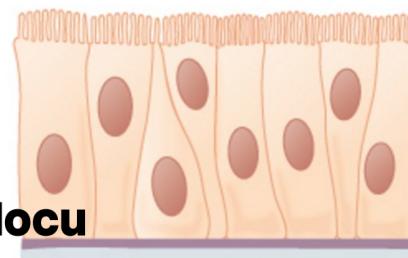
'squashed' are called squamous.



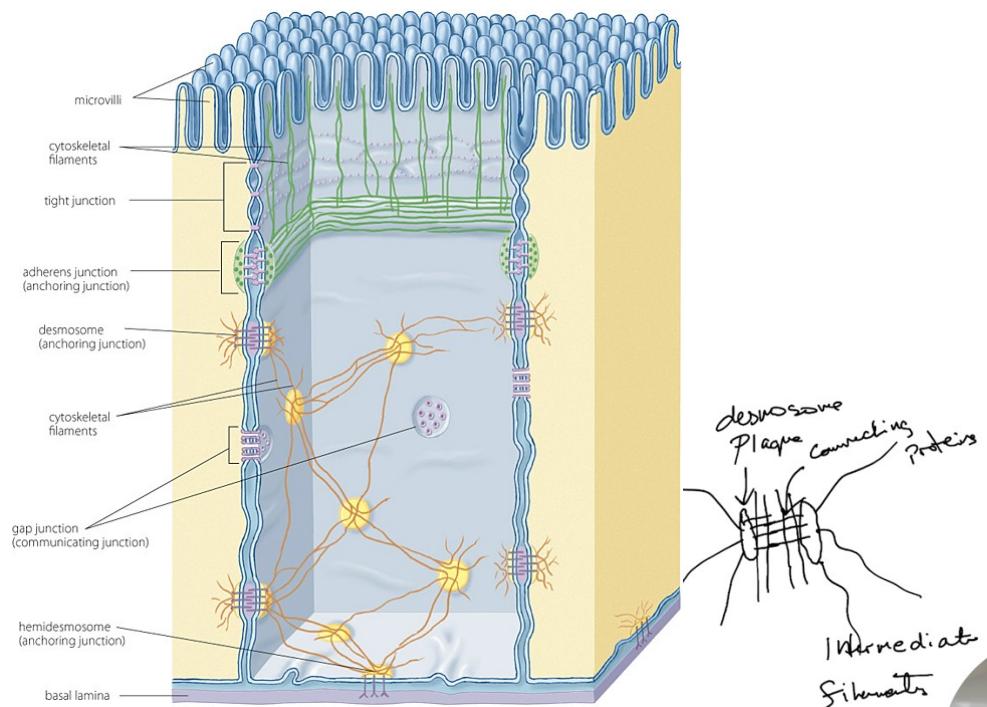
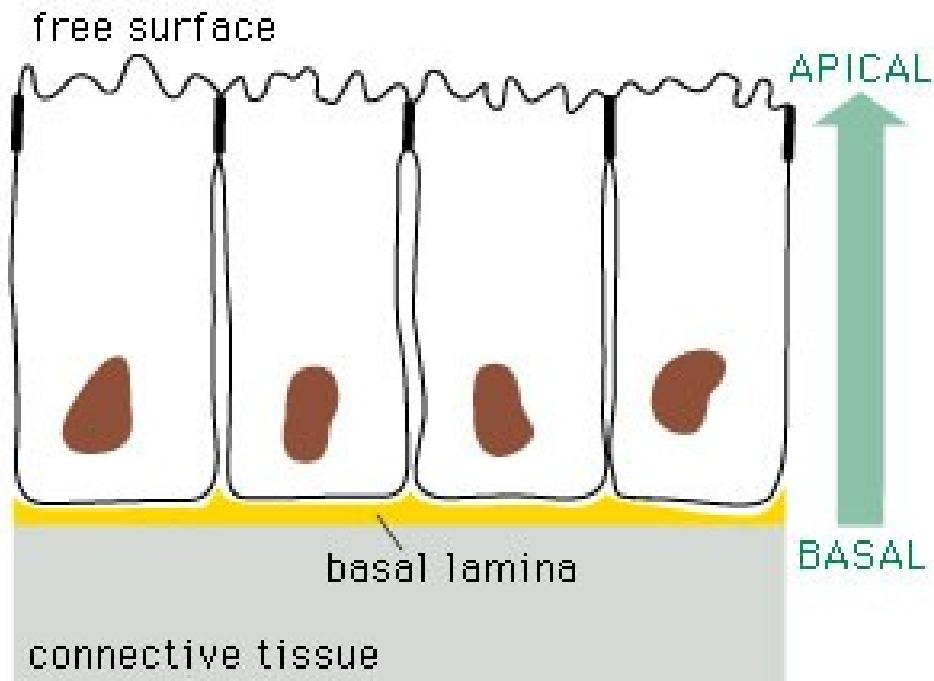
'Cubed' are called cuboidal



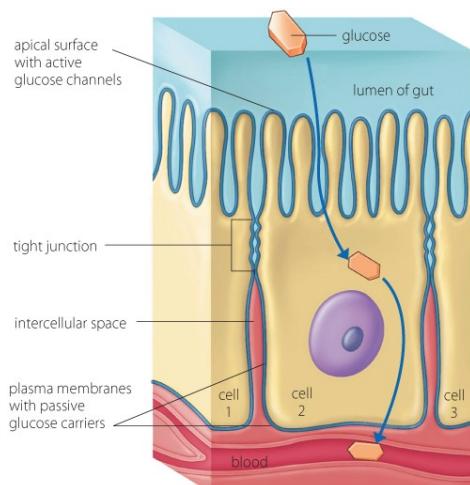
'long' are called columnar



Epithelial cells always sit on connective tissue. And are anchored to the basal lamina.



Some have microvilli, extended portions. Allows transport of molecules through molecular transporters in the plasma membrane in the epithelial cell.



Transported by passive diffusion.

Basal lamina can contain cancerous epithelial cells. Can hold them in a spot – primary tumour. But if left for too long, they will develop enzymes on their external portion which can cut through the basal lamina and travel through the blood stream – metastasis.

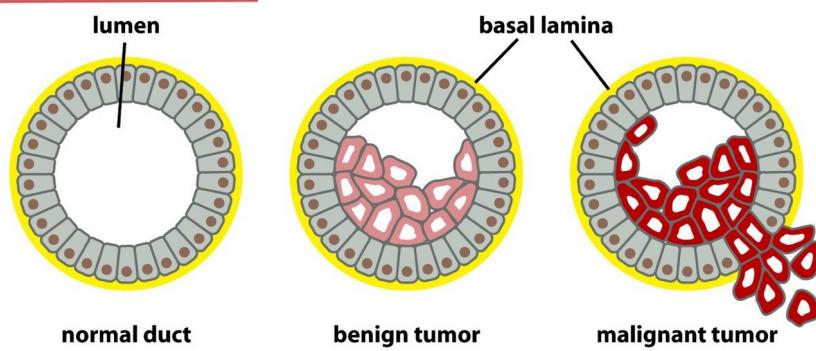
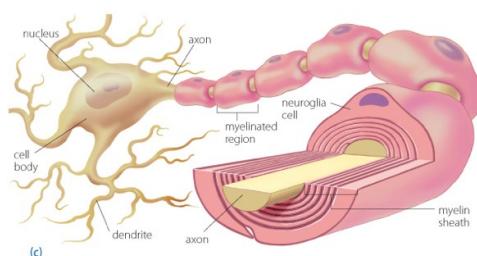
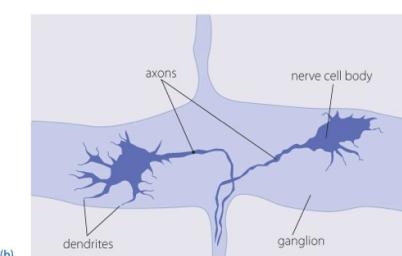
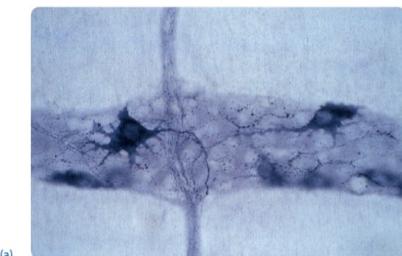


Figure 20-3 Molecular Biology of the Cell 5/e (© Garland Science 2008)

- Nervous Tissue

Allows multicellular animal with coordinated movement and behaviour.

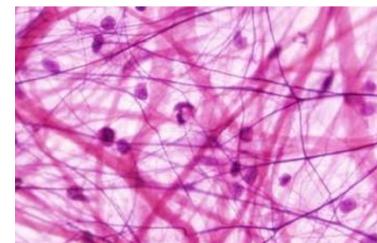


- Connective Tissue

Connects tissues together, reinforces organs, has a lot of strength and can make organs resistant to a lot of stress.

Components:

1. Fibres,
2. Cells,
3. Ground substance, } Extracellular matrix



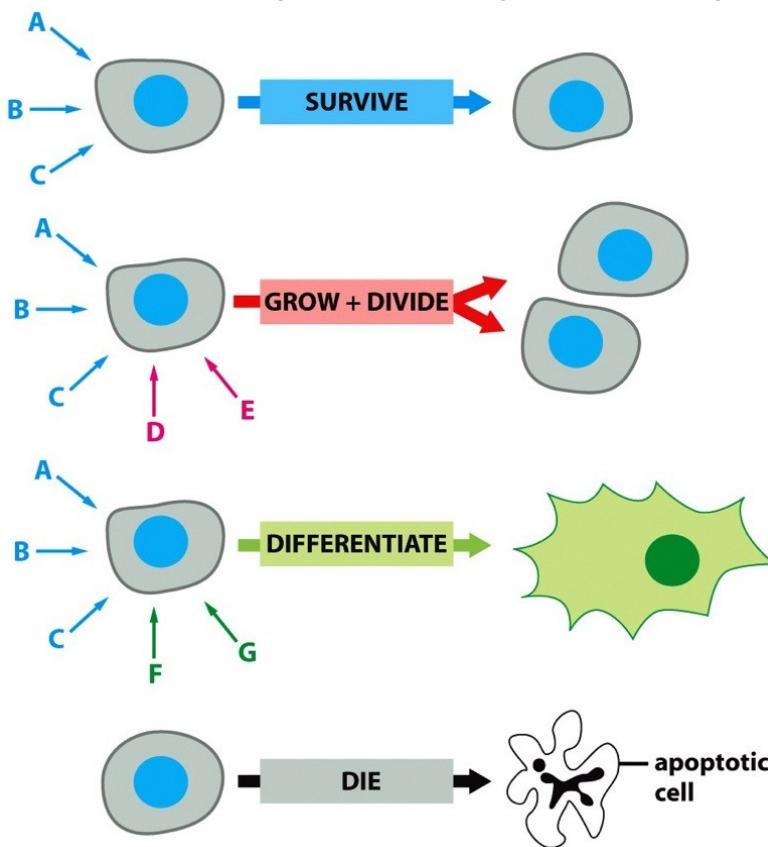
- Muscle Tissue

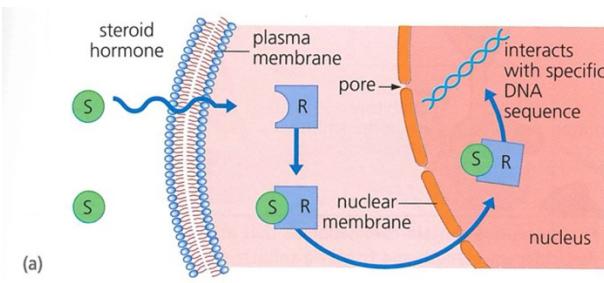
3 different types of muscle

- **Skeletal muscle:** made from round stem cells that all join together and form long, elongated skeletal muscles. Straight and unbranched. Have stripes/striations. Voluntary.
- **Cardiac muscle:** striated but with branching fibres. Involuntary. Cells are usually joined together by an intercalated disc.
- **Smooth muscle:** spindle shape, filaments running in a criss-cross direction. No striations. Involuntary. Present and lines every hollow organ (except heart).

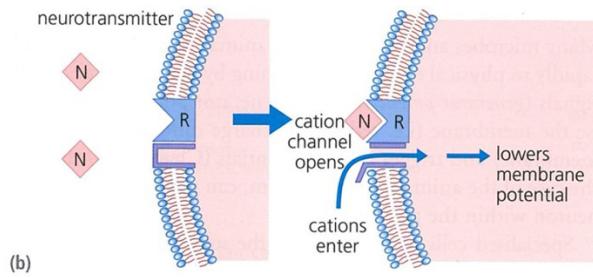
A cell can respond to signals – homeostasis.

Use hormones that signal cells to change their physiology in response to stress.

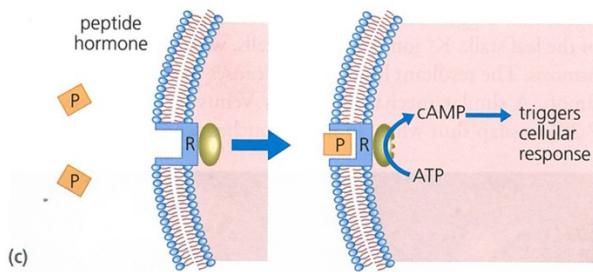




a) Steroid hormones



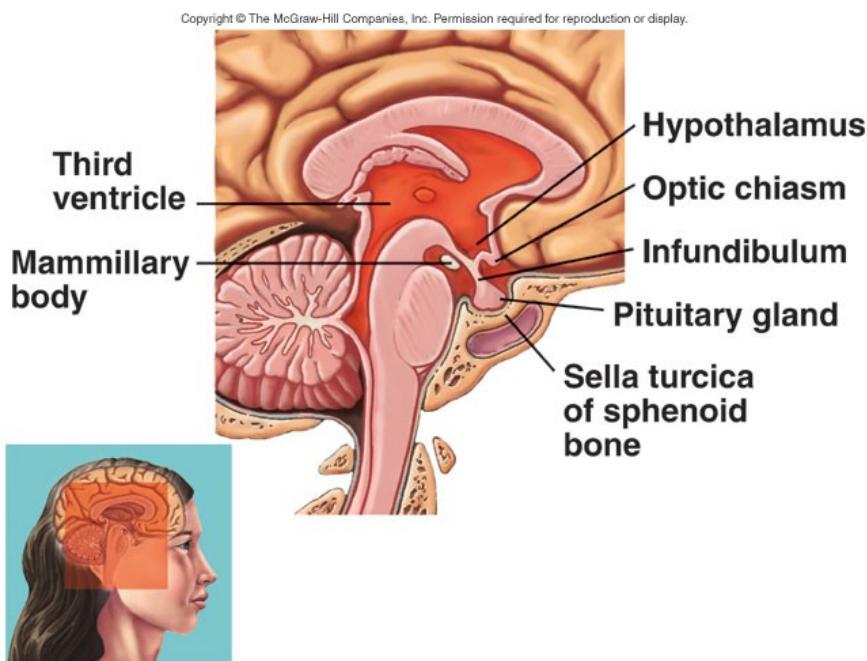
b) Neurotransmitters



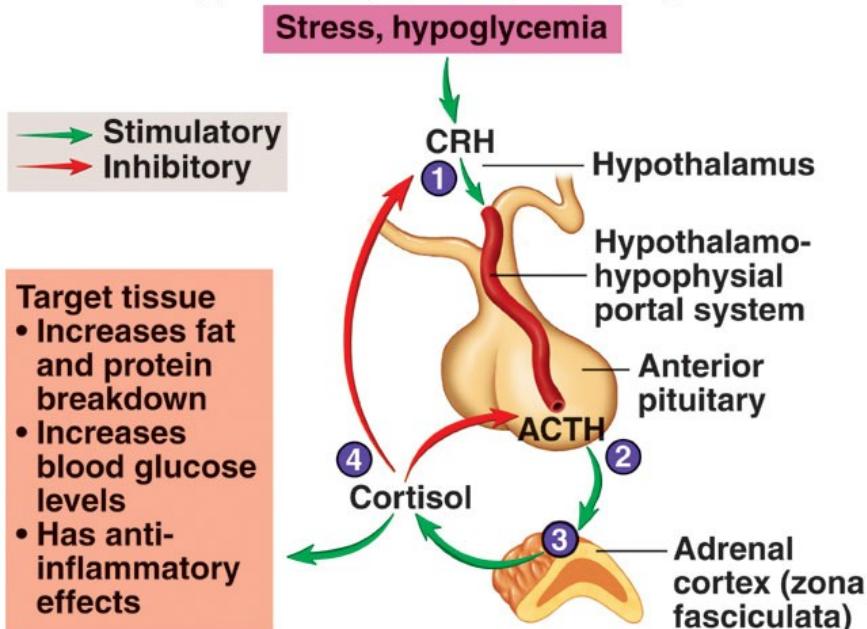
c) Protein hormones

- Steroid, come straight through plasma membrane, into nucleus and combine with DNA to produce protein as endpoint of steroid hormone stimulation.
- Interact with receptor on outside of cell. Receptor changes shape, interacts with relay proteins that relay the signal to parts of cell that can change cell physiology to trigger a cellular response to the signal.
- Neurotransmitters bind to channels, rushing into cell thereby triggering the voltage dependent channels that transmit that signal right along the distance of the Axon to the Axon boutons at the end or terminal parts of the Axon.

Stress response is a central endocrine response that allows the body to react to a bigger demand for nutrition and fuel to fill metabolic processes.



Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



MODULE 3

WEEK 7: Microbiology and the 'One Health Concept'

Microbes, Food and Nutrition

Planetary Health - Microbes & Ecosystems

Microbiology and the 'One Health Concept'

1. Viruses – smallest, simplest biological entities. Depend on host cell for replication & metabolism.
2. Bacteria – unicellular structure, smallest free-living independent organisms. Have own metabolism & replication.

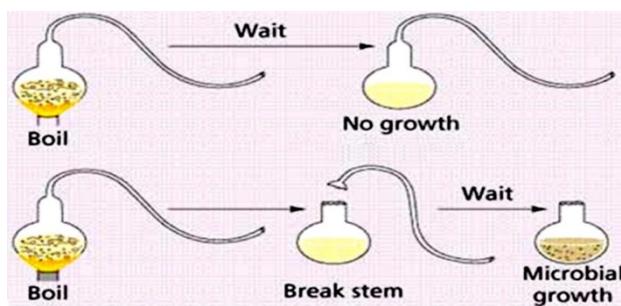
3. Fungi – large complex cells (eukaryotic); nucleus, mitochondria. Internal organisation. Can be unicellular, can have both macroscopic and microscopic parts.
4. Protists – large complex cells (eukaryotes); nucleus, mitochondria. **Protozoa:** protists that are animal-like (predatory). Diverse in morphology, lifestyle, evolutionary history.
5. Algae (plant-like protists) – large complex cells (eukaryotic); nucleus, mitochondria. **Photosynthetic.**

Robert Hooke – 1664. **Idea of “cells”**, Invented first microscope. First to use the word “cell”.

Van Leeuwenhoek – 1684. Developed powerful microscopes (300x mag). First evidence of bacteria and protists. Considered “father in microbiology”.

Louis Pasteur – disproved the theory of spontaneous generation (idea that non-living objects can give rise to living organisms).

- **Vaccination,**
- **Fermentation** (eg. beer and wine),
- **Pasteurisation** (heating liquids to kill pathogens without destroying quality or flavour).



Swan neck flask experiment. Allows entry of air but not microbes.

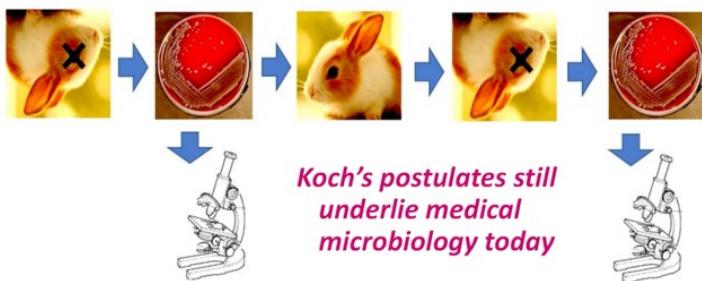
Robert Koch – pioneered staining methods for microscopy, use of solid growth medium (agar). Identified cholera, tuberculosis, anthrax.

- Germ theory – microbes are agents for disease.
- Prove cause of a disease (Kochs' postulates).
- Built on Pasteur's work and both disproved the theory of spontaneous generation.
- Found MICROBES CAUSE DISEASE > GERM THEORY

Koch's postulates:

An organism that causes a disease must :

- Be found in all cases of the disease
- Be isolated from the diseased host in pure culture
- Produce same disease in experimentally-infected host
- Be re-isolated from the experimentally-infected host



Koch's postulates still underlie medical microbiology today

Alexander Fleming – penicillin.

- Found mould growing on a petri dish that killed the bacteria around it.
- An accidental discovery.
 - o Penicillin

Howard Florey and Ernst Chain purified penicillin and developed mass production methods.

- **Penicillin became the first really effective antibiotic.**
- Estimated that penicillin saved 100,000 lives in WW2, and saved 200million lives since then.

Normal flora: microorganisms that live on us and in our bodies.

- Body has approx. 30 trillion human cells and 40 trillion microbial cells!
- Acquired at birth, from diet and from the environment.
- Everyone's normal flora is different.

What does it do?

- Trains our immune system to recognise friends/foes.
- Provides nutritional benefits, breaks down large molecules.
- Competes with pathogens for space.

Negative effects

- Can cause disease if moved to wrong location,
- Can cause disease in normal habitat (tooth decay),

Pathogens: a disease-causing microorganism.

- 'Obligate pathogens' are always harmful e.g. viral infection usually destroys the host cell.
- 'Opportunistic pathogens' cause disease in specific conditions:
 - o Numbers - abnormally high cell density can cause disease,
 - o Location - get into the wrong place,
 - o Host health - immune system compromised,
 - o Virulence factors - when pathogens gain antibiotic resistance.

'One health': healthy people, healthy animals, healthy environment.

Why?

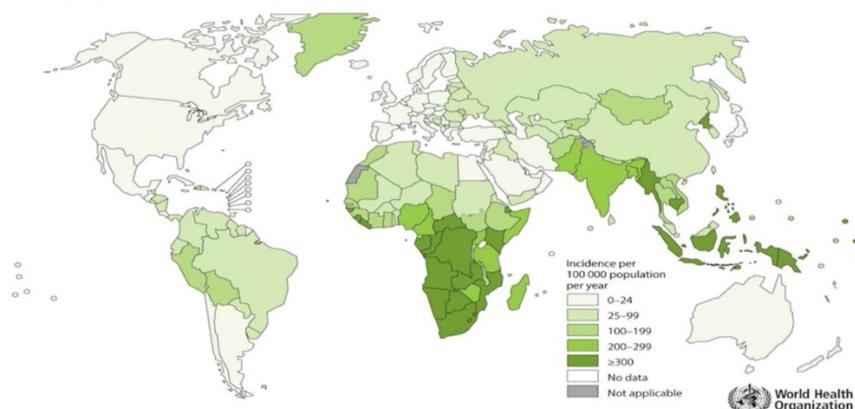
- Many human diseases originate in the environment or in animals,
- Use of antimicrobials in agriculture impacts on human pathogens,
- Emergence and spread of disease influenced by urbanisation, globalisation, climate change, pollution etc.

Example:

Tuberculosis (TB): old disease, new problems

- Caused by bacterium **Mycobacterium tuberculosis**
- Spread person2person by airborne droplets (coughing)
- Infects lungs → cough, chest pain, weight loss, death.
- Can be latent (no symptoms for many years)
- Non-specific symptoms
- One third of world's population infected.

Estimated TB incidence rates, 2016



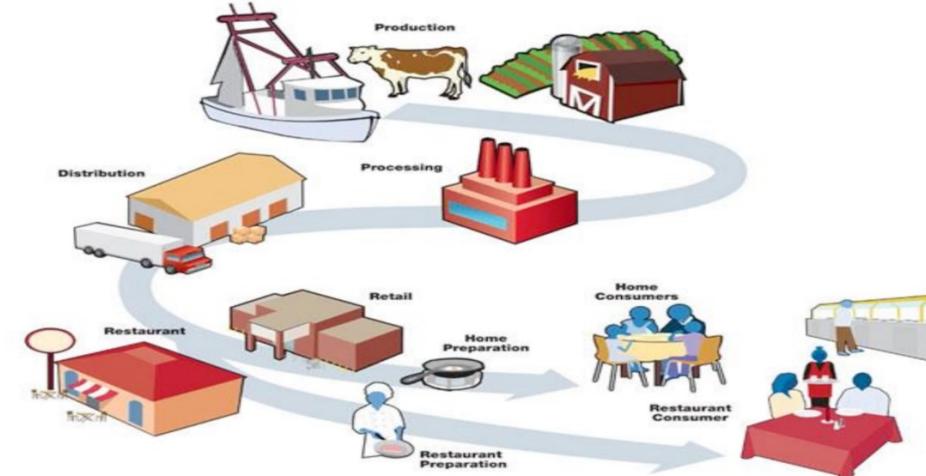
- New strains of TB are **antibiotic resistant**.
- Multidrug resistant – BAD
- Extensively drug resistant – VERY BAD

A vaccine available, not very effective.

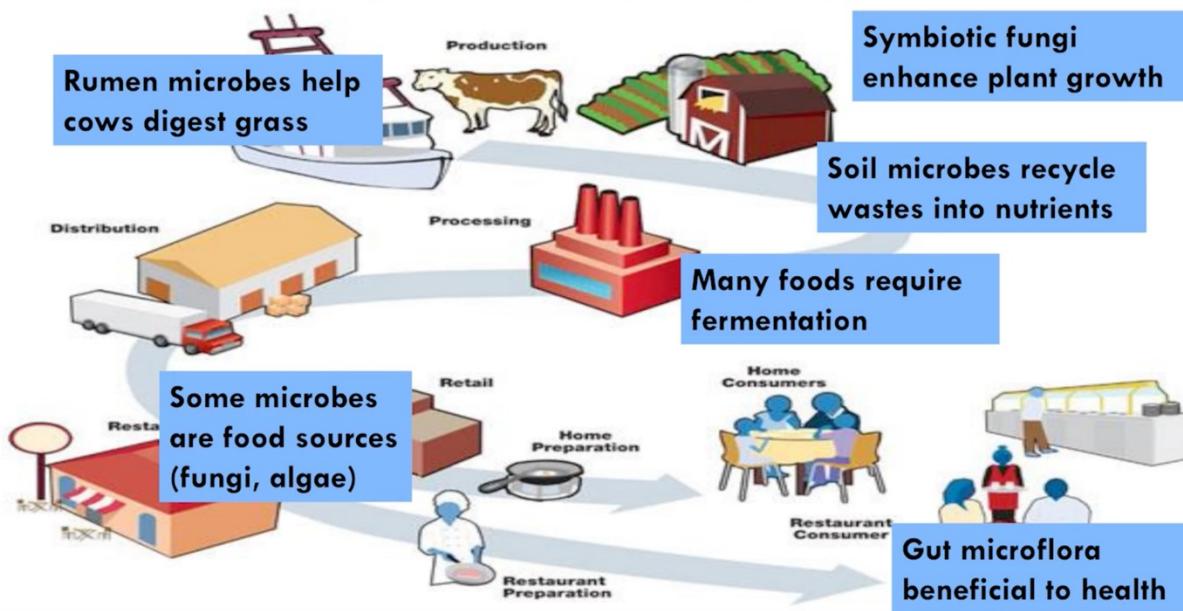
Microbes, food and nutrition

Microbes affect every point in food production – can be **good and bad**.

The Food Production Chain



The Food Production Chain

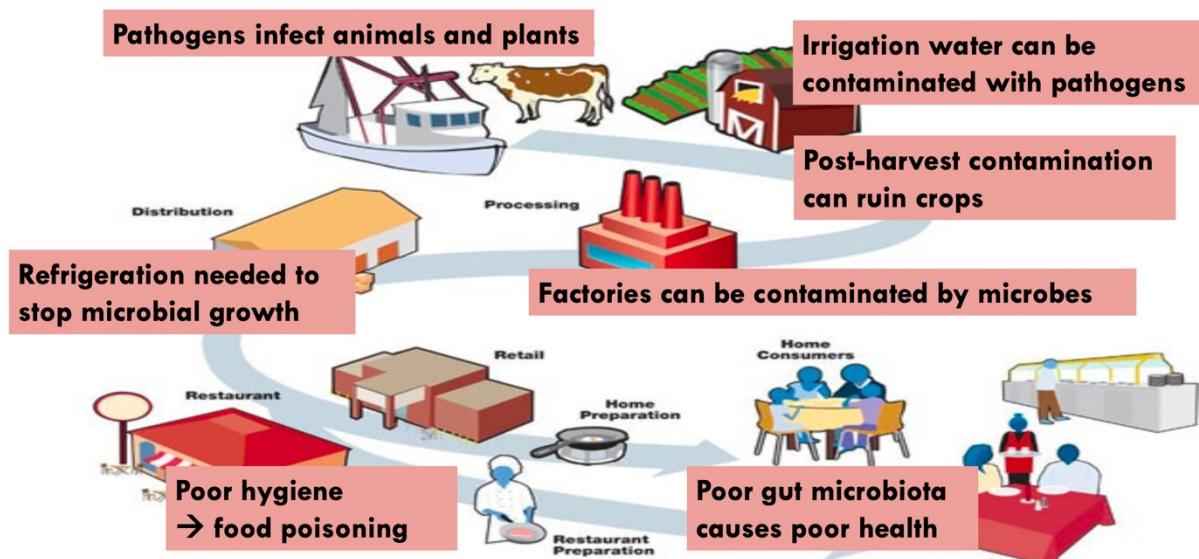


The good.

Vs

The bad.

The Food Production Chain



Microbes in SOIL

Microbes maintain soil health by:

- | |
|---|
| - Fixing nitrogen to allow growth and soil to thrive. |
| - Decomposition: break down organic waste products into inorganic nutrients. |
| - Suppressing plant and animal pathogens. Through diverse, healthy competition. |
| - Break down toxic substances like pesticides. Microbes break these down. |

Microbes in ANIMALS

Microbes enable animals to digest cellulose:

- Cellulose: a sugar polymer, abundant in plants, carbon-rich, but hard to digest. So are dependent on gut microbes to break the cellulose into sugars,
- Rumen microbes break down cellulose → sugars → organic acids CO₂, CH₄ (carbon dioxide and methane).

Microbes in PLANTS

Microbes promote plant growth via mutualism:

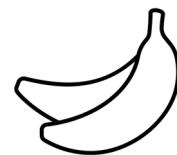
Mutualism: ecological interaction where BOTH partners benefit.

- Mycorrhizal fungi (in most plants) enhance water + inorganic nutrients → receive sugars from the plant.
 - Rhizobium bacteria (in legume roots) fix nitrogen, receive sugars in return.
-
- Just like humans and animals, plants are subject to diseases caused by microbial pathogens.
 - Fungi and viruses = main problems.
 - Crop pathogens cause global losses of 30% of total yield.

Example:

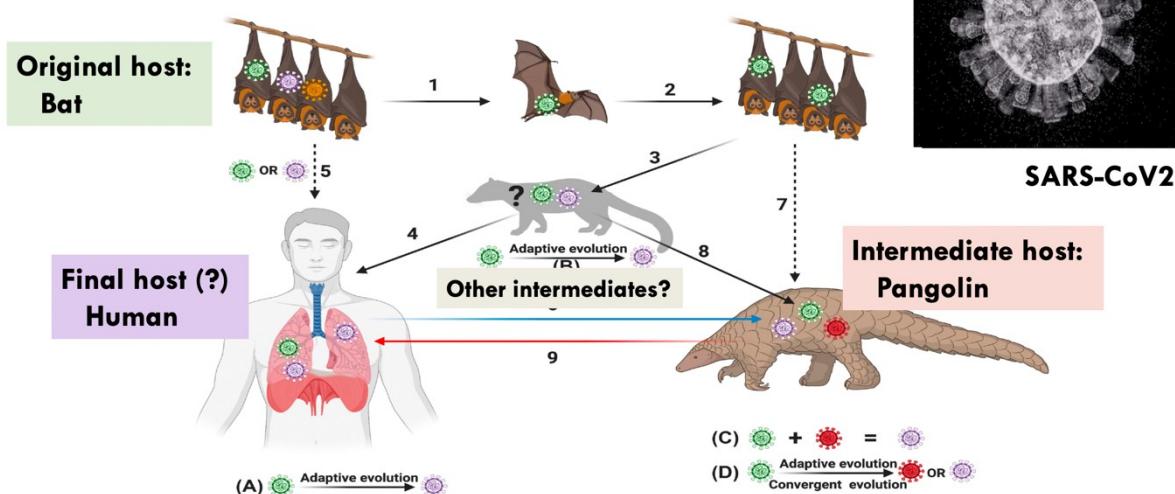
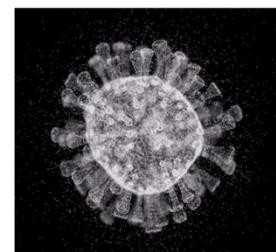
Sigatoka fungi threatens bananas globally.

- Modern Cavendish bananas are all grown from cuttings, not seeds,
→ genetically identical → all equally susceptible
- Need to apply fungicides, but they are rapidly evolving resistance.



Zoonosis: human infection arising from animals

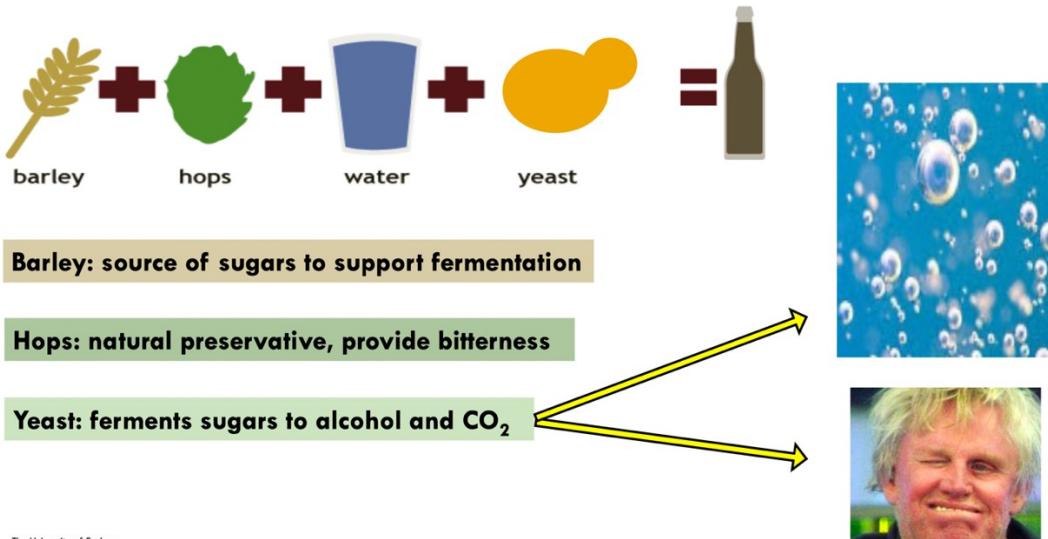
- The covid pandemic most likely had a zoonotic origin



Enhancing food processes – FERMENTATION

- “Fermentation”- has multiple meanings:
- Microbial transformation of foods by fungi or bacteria
- Anaerobic metabolism of sugars → alcohols, acids, CO₂

Examples: beer, wine, bread, kimchi, yogurt, cheese, pickles.



Microbial food spoilage

- Due to growth of fungi or bacteria and/or enzymes that these microbes make and secrete.
- Approx. 20% of food is LOST to MICROBIAL SPOILAGE.

Prevention: refrigeration (prevents microbial growth), preservatives (inhibits microbial growth, eg. salt/sugars), fermentation (once fermented is hard to spoil).

Food poisoning = infection or intoxication

- **Food-borne infection:** microbes grow in gut.
- **Food-borne intoxication:** microbes make toxins in food.

Food poisoning *risk factors*:

- Food origin – from an organism or soil?
- Storage and prevention – stored refrigerated, raw/cooked?
- Human factors – hygiene!

One health concept in FOOD PRODUCTION

- SOIL
- PLANTS
- ANIMALS
- PEOPLE
- FACTORY
- KITCHEN

The human gut microbiome

- **Gut microbes** are most important element of our normal flora. Primarily BACTERIA
- Approx. 40 trillion bacteria in gut microbiome; now considered a separate body 'organ'.

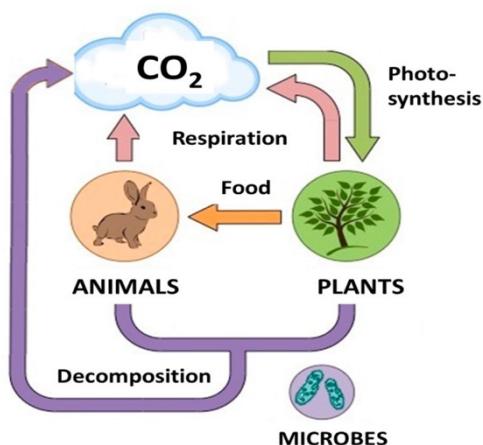
How does it influence us?

- Healthy microbiome important for:
 - Proper food digestion
 - Resistance to pathogens
 - Immune functioning
 - Mental health
- "Bad" microbiome linked to:
 - Allergies
 - Type 2 diabetes
 - Cancer
 - Obesity

Planetary health – Microbes and Ecosystems

Majority of ALL biodiversity is microbes.

- Most microbes cannot be isolated or cultured.



BIOGEOCHEMISTRY: biological processes that impact chemistry at a global scale,

Most of these reactions are done by microbes.

← simplified carbon cycle

The FOUR laws of Ecology

1. Everything is connected,
2. Everything must go somewhere,
3. Nature knows best,
4. There is no such thing as free lunch.

Autotrophs in the Carbon Cycle: 'self-feeder' – uses CO₂ as carbon source.

Algae

- May use light as energy source (photoautotrophs) or may use chemical energy sources (chemoautotrophs)
- Convert inorganic C into organic C, act as 'SINKS' for CO₂ → limit climate change.
 - Algae perform 50% of global photosynthesis.

Methanogens

- Methanogens: consume CO₂ and H₂ → produce methane.
- Chemotrophs – CO₂ is C source H₂ is energy source.
- Impact on climate change: act as sinks for CO₂ (good) but act as sources for CH₄ (very bad!)
- An example of Archaea
- Are anaerobic = KILLED by OXYGEN
- 'breathe' CO₂ and exhale CH₄

Heterotrophs in the Carbon Cycle: methanotrophs

- **Methanotrophs:** Consume methane, produce CO₂
 - Are heterotrophs where methane is used as both carbon source and energy source.
 - Impact on climate change: act as sinks for CH₄ (very good), but are sources for CO₂ (not so good).
 - A bacteria.
 - Useful for removing methane.
 - Also attack toxic pollutants e.g. trichloroethene
- broad substrate range.

Decomposers

- **Heterotroph:** "other-feeder" – needs to eat other organisms, or other organic carbon sources; supply energy.
- Heterotrophs are SOURCES of CO₂ → bad for climate change.
- **Decomposers:** key group, recycle dead cells back to CO₂

Predators

- **Protists** (protozoa type) are often predators of other microbes; predators include, ciliates, flagellates & amoebae.

Pollutant degraders

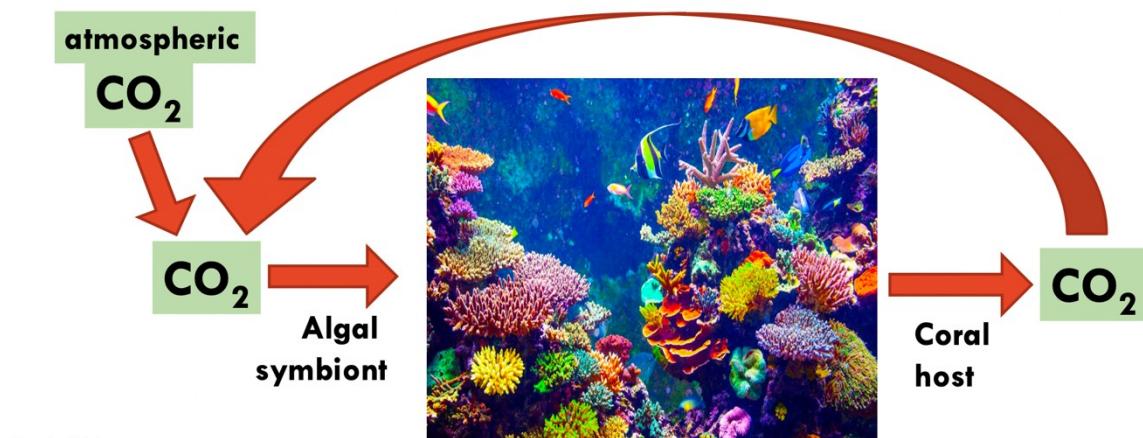
- Methanotrophs are an example of bacteria growing on hydrocarbons as their Carbon and energy source.
- Hydrocarbon-degrading bacteria – very useful for "bioremediation" (useful in cleaning up oil spills by breaking down hydrocarbons.)
- **Bioremediation:** the clean-up of pollution by microbes.
- Similar to decomposers BUT contain special enzymes which can attack hydrocarbons.
- Specialise in eating hydrocarbons – ancient fossilised organic carbons.

Auto/heterotroph interactions – Coral symbiosis

- Corals: primitive animals which depend on symbiotic microscopic algae to supply them with food.
- **Algae:** photoautotrophs, convert CO₂ + light → sugars
- **Coral:** heterotrophs, converts sugars → CO₂

The CNIDARIANS (anemones, corals, jellyfish) are an ancient group of animals >580 million years old.

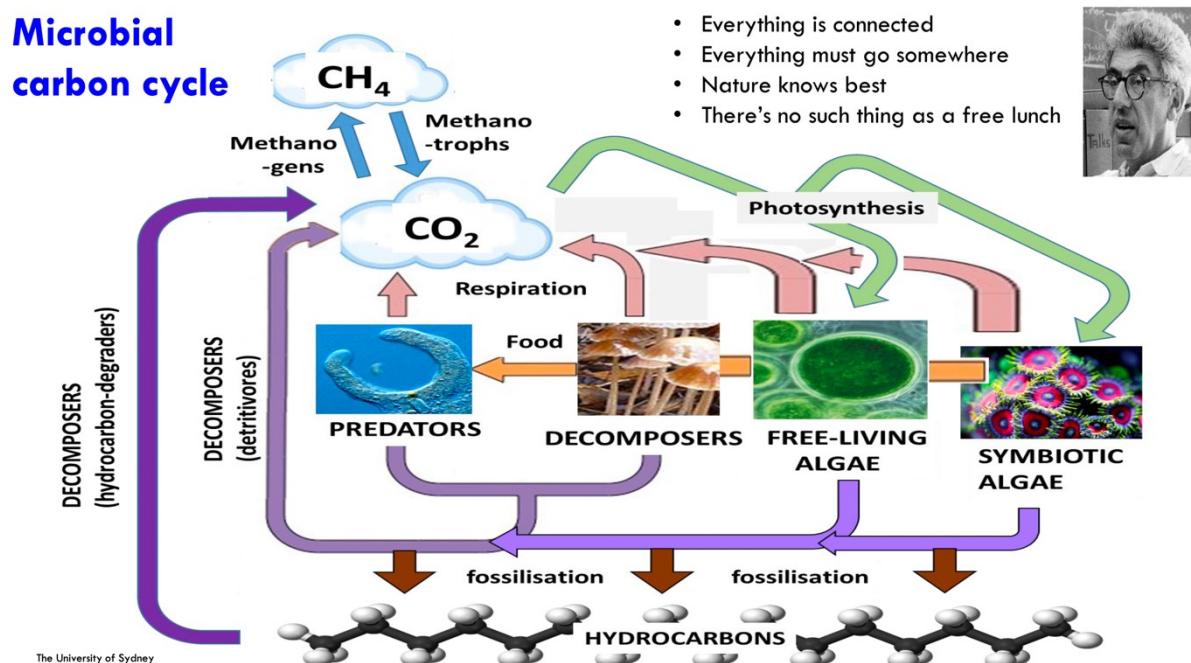
The coral symbiosis is like a miniature ecosystem...
Carbon cycles between organic and inorganic forms,
biomass is produced, and both partners 'win'.



Auto/heterotroph interactions – Lichen symbiosis

LICHENS are primary producers in some terrestrial habitats (dry environments)

- Photosynthetic but NOT plants
- A symbiosis between 2 microbes: heterotrophic fungus and an autotrophic algae.



WEEK 8: Cell factories and Biotechnology

"biotechnology" has been done by humans for >9,000 years.

Eg. fermentation to preserve foods, or make alcohol.

Fermentation: traditional biotechnology, earliest firm evidence was alcoholic fermentation from around 7000 BC.

Cellular vs molecular biotechnology

- Fermentation could be defined as "cellular biotechnology".
- Modern methods are "molecular biotechnology" (needing high-level biology skills, and understanding of DNA, RNA, proteins etc).

Molecular biotechnology

- Diverse microbes (viruses, archaea, bacteria, algae, fungi, protists) are useful.

MICROBES				
Viruses	<ul style="list-style-type: none">- <u>Vectors</u> to carry genes into new hosts.- Resource for enzymes eg. <u>T4 ligase</u> (used to join 2 DNA strands)			
Archaea	<ul style="list-style-type: none">- Many archaea live in extreme environments, their enzymes are very <u>thermostable</u>.- Source of <u>thermostable polymerase enzymes</u> for copying DNA sequences. (Important for PCR)- Can replicate DNA at high temp.			
Bacteria	<ul style="list-style-type: none">- Excellent hosts for <u>cloning</u> DNA and <u>expressing</u> proteins.			
Algae	<ul style="list-style-type: none">- Conversion of CO₂ + light into biofuels (ethanol, hydrogen).- Removes CO₂ from the atmosphere to convert into fuel (GOOD).			
Fungi	<table border="1"><tr><td>Yeast</td><td><ul style="list-style-type: none">- Excellent <u>cloning</u> and <u>expression</u> hosts.</td><td>Moulds<ul style="list-style-type: none">- Antibiotic synthesis.</td></tr></table>	Yeast	<ul style="list-style-type: none">- Excellent <u>cloning</u> and <u>expression</u> hosts.	Moulds <ul style="list-style-type: none">- Antibiotic synthesis.
Yeast	<ul style="list-style-type: none">- Excellent <u>cloning</u> and <u>expression</u> hosts.	Moulds <ul style="list-style-type: none">- Antibiotic synthesis.		

Host cells for biotechnology – the 'workhorses'

BACTERIA

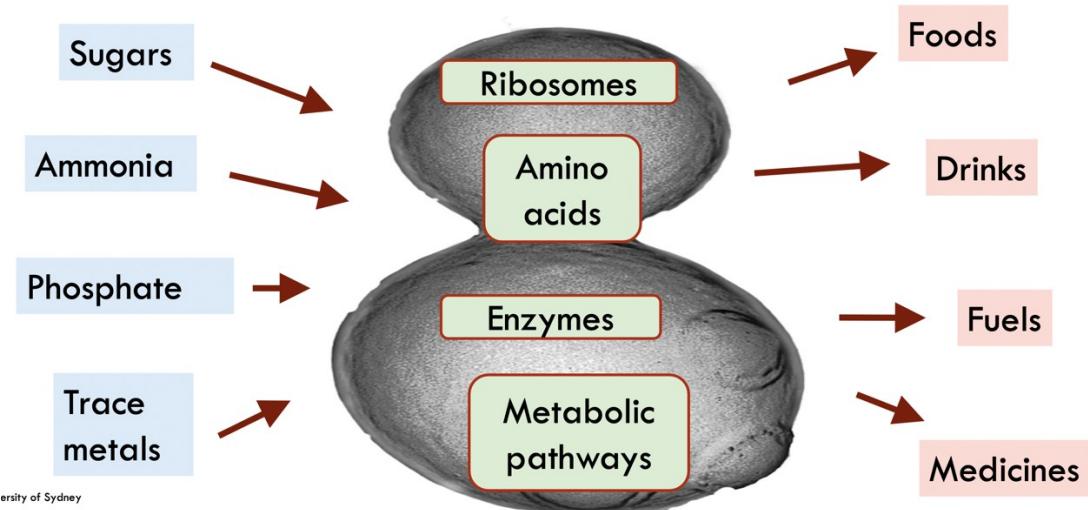
- Fastest growth,
- Very easy to extract or add plasmid DNA,
- Horizontal gene transfer (HGT) refers to the movement of DNA between different species of organisms. (SWAP GENES between them in plasmids)

YEAST

- Better for expressing eukaryote genes,
- Generally recognised as safe (GRAS) (food grade organism).

What do these host cells do?

- Host cells contain machinery for biosynthesis of high-value products from simple raw materials.



What do we need to provide these cells with?

- Instructions = DNA
- Host cell factory needs instructions or a blueprint to tell it what products to make.

How to DELIVER THESE INSTRUCTIONS?

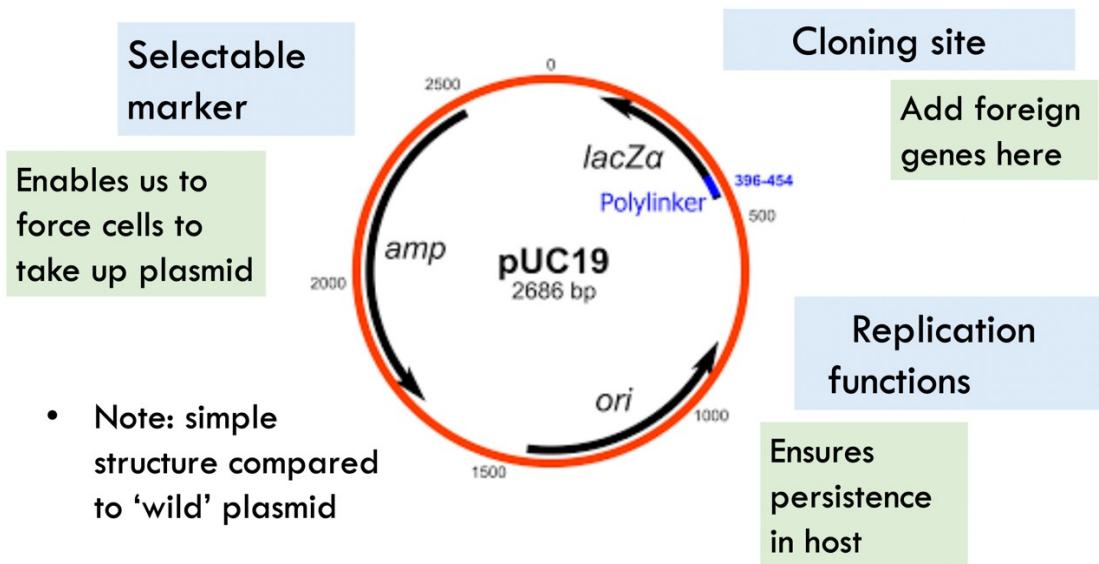
PLASMIDS: circular DNA elements found in microbes; replicate independently of the chromosomes.

- The most commonly used **vector** for delivery of foreign DNA into a target host cell.
- (viruses can also be used as vectors)

Where do plasmids come from??

- 'wild' plasmids found in nature > **allow microbes to swap useful genes**.
- Horizontal gene transfer (like being able to transfer DNA with a handshake).
- Eg. antibiotic resistant genes. Where transfer of plasmids to gain antibiotic resistant genes. Instant transfer.

Key features of plasmids used for biotech



Cloning: to make many copies of a biological entity.

EITHER: creating identical organisms,

OR: making lots of copies of a piece of DNA by adding it to a plasmid, then replacing the plasmid.

TOOLS NEEDED FOR DNA CLONING: ENZYMES

Copying DNA



Thermostable polymerase

Cutting DNA



Restriction enzyme

Joining DNA

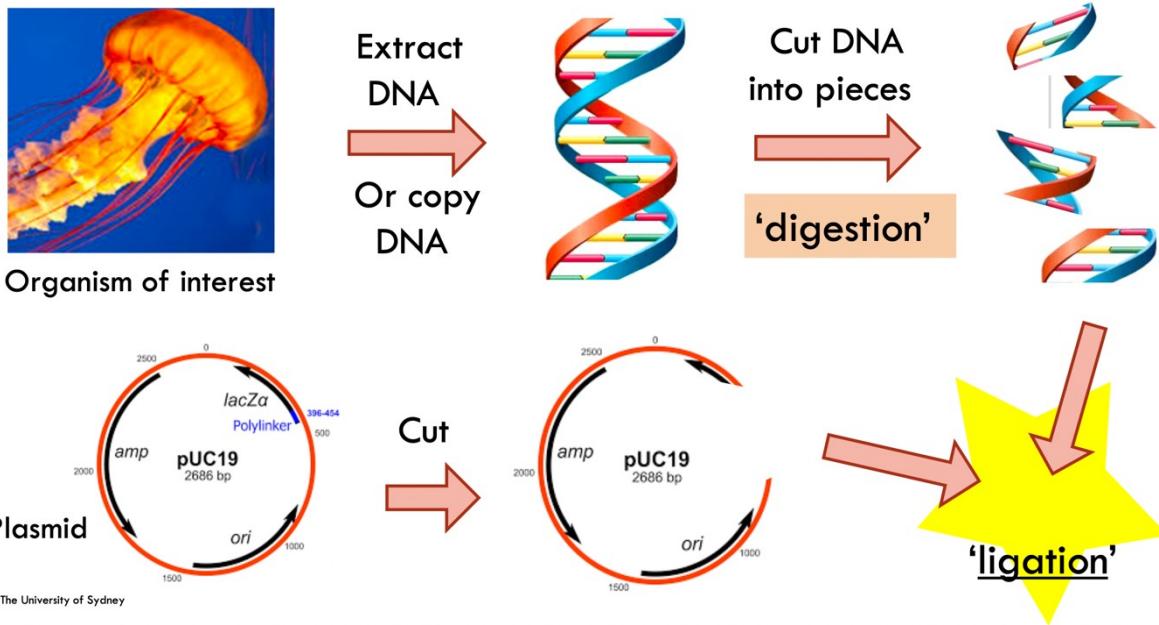


T4 ligase

DNA CLONING

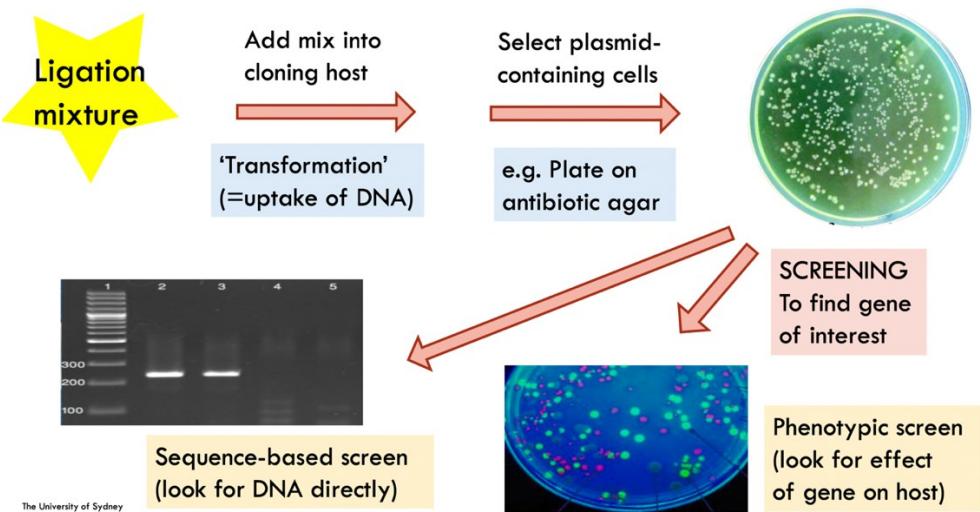
Part 1: Digestion and ligation

- Take the protein (for example) out of organism of interest.
- Extract total DNA or copy/amplify a part of the DNA,
- Cut the DNA into pieces,
- Then, take plasmid vector and cut it with the same enzyme that leaves same sticky overhangs, and ligate together to create recombinant DNA.



Part 2: Transformation and screening

- Transformation – uptake of DNA into a cell. Through electric or heat shock, or by conjugation (where a plasmid naturally transfers itself into a cell).
- Take ligation mixture into host cell, then plate those cells out onto agar which will enable/force them to take up that plasmid.
- Screen based on phenotype and genotype; screen fluorescence for phenotype and PCR for genotype – amplify a piece of DNA very specifically lets us find the clone amongst the other colonies).



Part 3: final product... a GMO

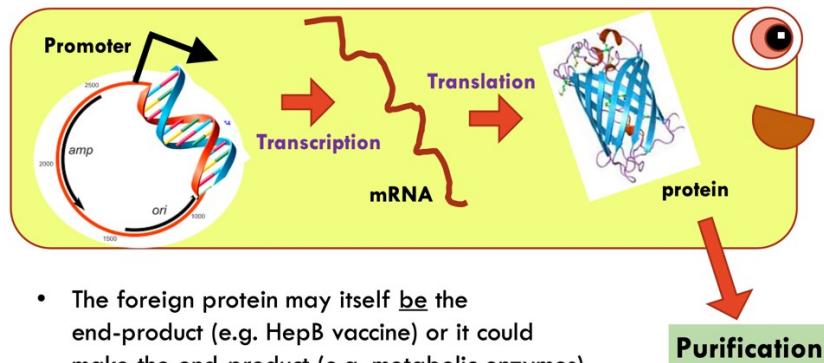
- Recombinant microbe carrying gene of interest.
- GMO = genetically modified organism.

Risks of GMO's

- What foreign gene have we added to the organism? How does that change behaviour of that organism?
- Antibiotic resistance gene transfer into pathogens?
- Legal constraints, public perceptions?

Part 4: expression of genes

- Requires transcription/translation and gene to be driven by a promoter (DNA element that recruits RNA polymerase and allows transcription to take place).
- Then can extract protein, purify it and use it for what we need/want.
- The foreign protein may be the end-product or it could make the end-product.



EXAMPLE: Vaccines

- A primary defence against infectious disease; save approx. 3million lives/year.
- Protect against: smallpox, polio, rabies, diphtheria, pertussis, tetanus, hepatitis, measles, mumps, rubella, influenza, pneumonia, rotavirus, meningitis, etc.
- Some diseases have NO cure... only prevention.
- Vaccines lead to '**heard immunity**'

How do the work?

- By 'training' the immune system to recognise antigens associated with an invader.
- Present antigen to the body without involving live, dangerous microbe that normally has the antigen.

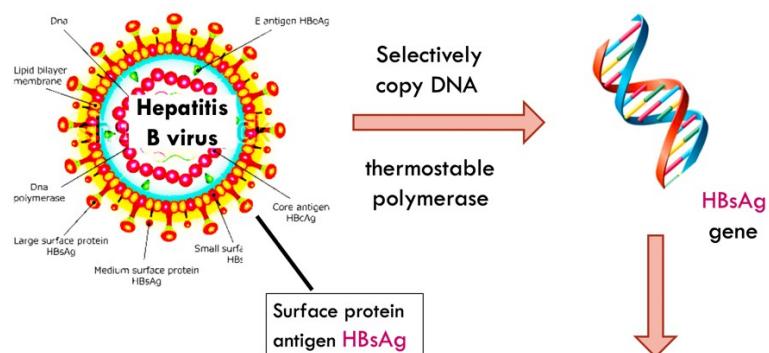
May consist of

1. Live attenuated microbes (give live organism as vaccine, but a strain that no longer causes disease, still stimulates immune response).
2. Killed microbes (killed cells can still be antigenic and stimulate the immune system).
3. **Antigens (proteins) produced in GMO host** (stimulate body by presenting antigen to it which is a protein from original infectious organism – very safe).
4. mRNA coding for antigens.

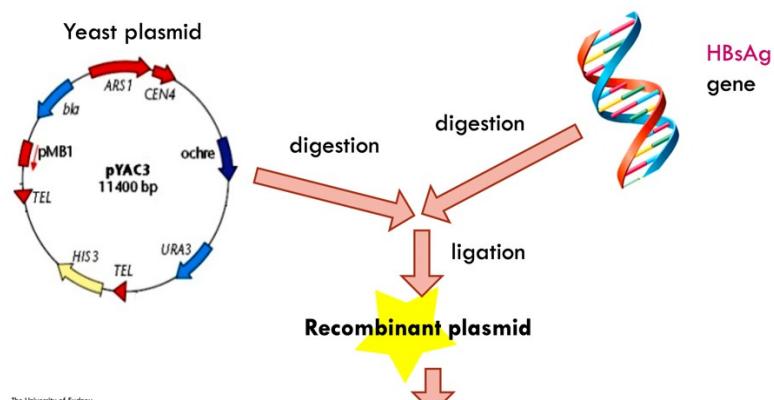
Antigens (proteins) produced in GMO host

Example:

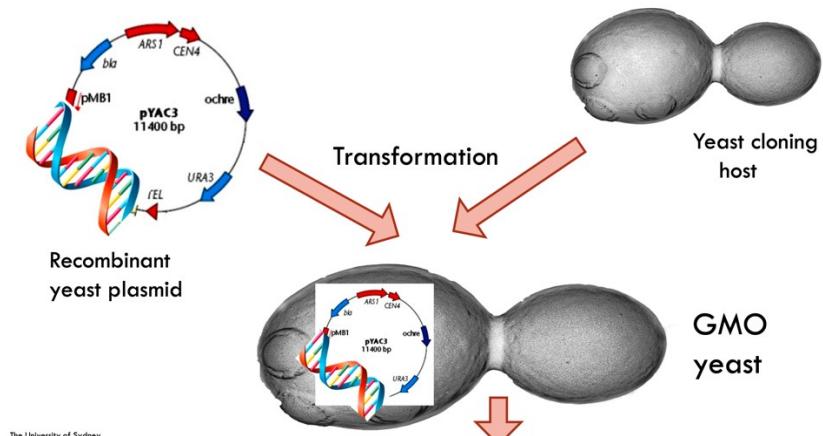
Hepatitis B vaccine 1. Isolate gene coding for antigen



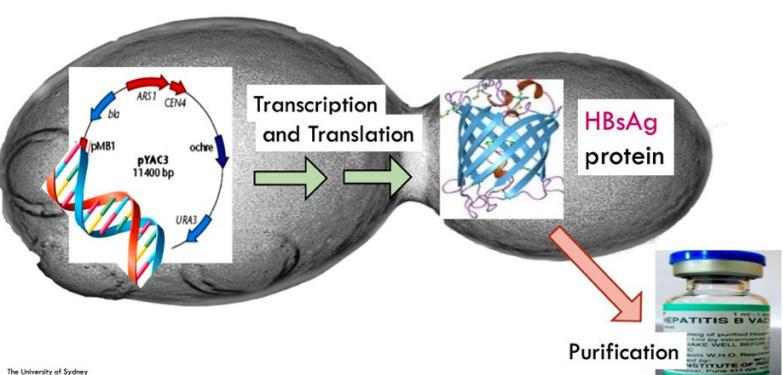
Hepatitis B vaccine 2. Cloning antigen gene



Hepatitis B vaccine 3. Transformation into yeast



Hepatitis B vaccine 4. Gene Expression, Protein purification



Week 9: Healthy planet = Healthy people

NATURE – provides WATER to drink, AIR to breathe, INTACT ECOSYSTEMS > absorb about half of the global CO₂ emissions.

Protecting/restoring 50% of Earth's lands and seas > essential to preserve biodiversity and solve climate crisis.

FOOD – in Aus, land used for agriculture is 46% of our continent! Used for livestock grazing.

Ecosystems are INTERCONNECTED communities of the species and dynamics between them.

- Loss of species = consequences to food chains/ ecosystems.

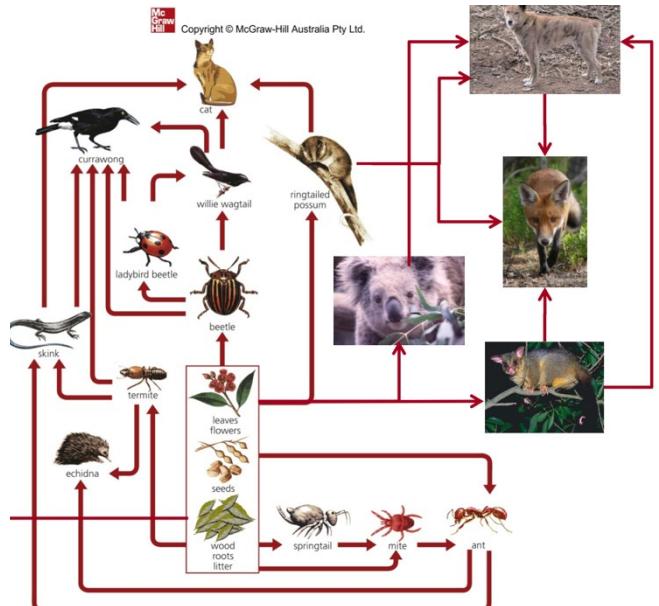
Ecosystems: living organisms intertwined with the physical environment they inhabit.

Ecosystems are the BASIS FOR LIFE: provide **habitat, promote food chain webs, control ecological cycles/processes**.

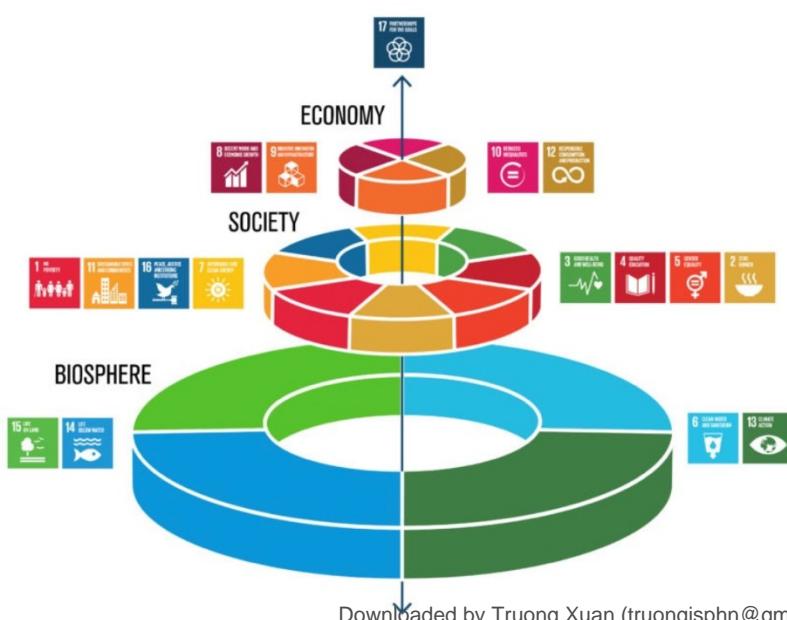
Aus ecosystems in poor conditions, getting worse (2021). We rely on these systems for all our food, crops, livestock.

Australia's biodiversity is rich and unique. We have only named and classified approx. 30% of our species.

We rely on the biosphere for all aspects of life, economy etc.

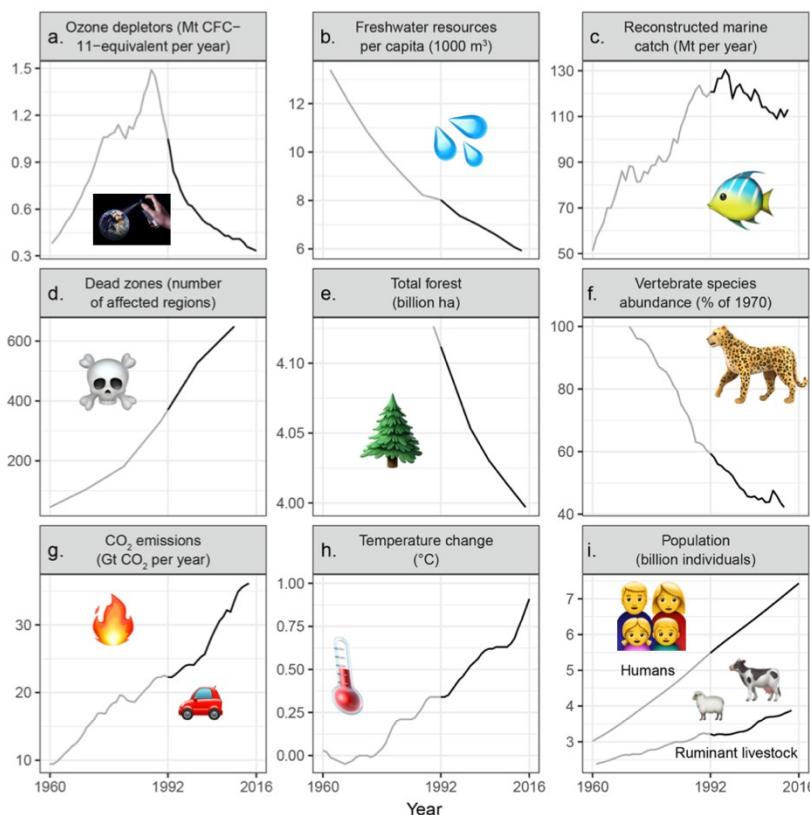
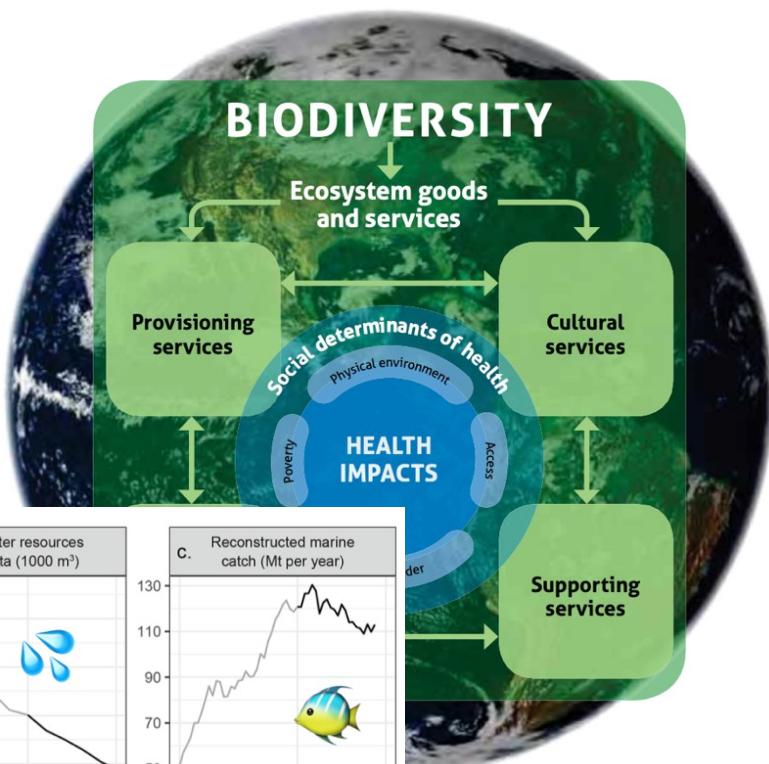


Ecologists





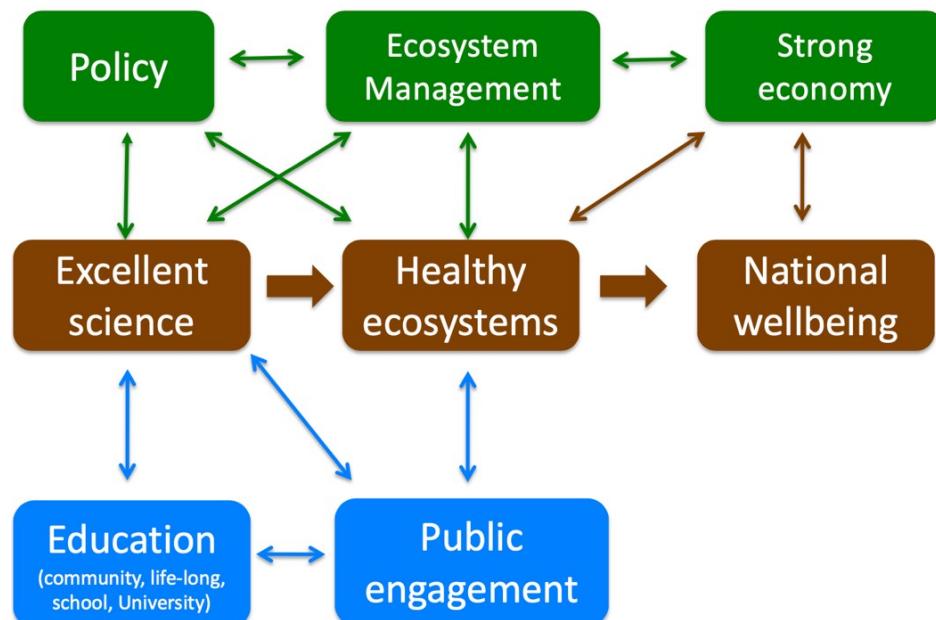
- Physical and mental wellbeing enhanced with access to nature.
- Fresh water to drink,
- Impacts on foodchains of water poisoning and lack of biodiversity.



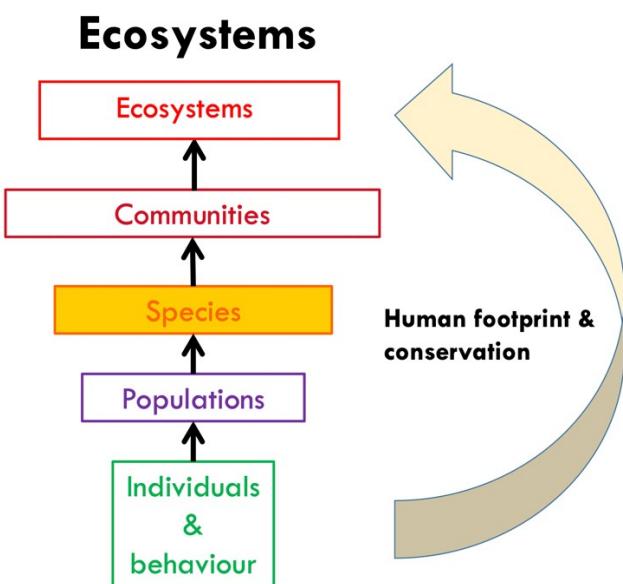
2017 state of the world.
World population is still increasing,
Increasing ice mass loss,
water goes into the seas,
rising sea levels, displacing homes, animals and plants.

Value of long-term studies: document changes, identify drivers of change, provide evidence for knowledge needed to better inform natural resource management.

Framework for influence:



W9 Pt. 2 Individuals, behaviour and environment



Behaviour – classically about animals,

- Coping mechanisms = (1) morphology (2) physiology (3) behaviour

→ **BEHAVIOUR** = part of how organisms respond to the biotic and abiotic environment.

E.g. foraging strategies, communication, social behaviour.

Behaviour is fundamental. It affects fitness.

e.g. Gelada Baboon: foraging behaviour linked to

1. Morphology (teeth, guts)
2. Physiology (capacity to digest plant cell wall in grass)
3. Social behaviour (group size, conflict between feeding, safety, mates).

Fitness – an individual's relative contribution to the next gen's gene pool.

Food affects fitness. Study shown that butterflies with high quality diet had higher reproductive rates.

- **Behaviour affects fitness.**

Behaviour is:

Ecologically significant

- Link between individuals and environment
- Affects demographics (population levels)
- Affects interactions among species

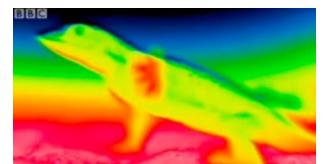
Evolutionarily significant

- Has some genetic basis (nature vs. nurture)
- Affects **fitness**
- Can be selected

Know this through – observations, and manipulative experiments.

Behaviour in relation to:

Abiotic environment – eg. lizard cooling feet by alternatively moving on hot Namib desert sand.



Obtain food: ambush vs active

Foraging strategies linked with morphology and physiology.

Ambush predators: camouflage

Active predators: agile, fast

Optimal foraging theory

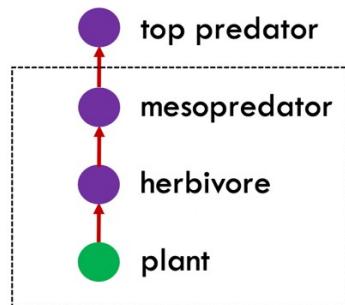
- Which food items to eat in a non-depleting environment,
- Foragers should maximise net rate of food intake.

Marginal value theorem

- When to leave a patch in a depleting environment,
- Foragers should leave patches when harvest is below average.

Optimal foraging theory = efficiency of energy gain

- Most foragers are also prey:



So, foraging strategies linked to predator avoidance, food/fear.

Avoid becoming food:

- ➔ Strategies to lower predation risk

 1. Run away
 2. Group
 3. Hide
 4. Act costly (act dangerous, mimic unpalatable, toxic organisms)
 5. Be costly (toxic compounds, have spines)
 6. Feed in safe places/times (vegetation cover, new moon)

Grouping together? Competition for food, spotted more easily, social aggression.

Benefits > costs

Reproduce:

- Courtship and mating behaviour: non-random
 - Male/male competition, female choice,
 - Sexual selection eg. peacock tail in male peacocks

Sexual selection:

1. Intrasexual selection ➔ **competition** (often male/male) ➔ sexual dimorphism (eg. gorillas, kangaroos: hefty vs slight, male deer's have antlers)
 2. Intersexual selection ➔ **mate choice** (often by female) ➔ sexual dimorphism (eg. flashy vs plain)
- Parental care **costs/benefits**: variety or types/amounts
 - Benefits: survival & growth of offspring = fitness
 - Costs: missed opportunity to reproduce again

Not only animals behave.

- Leaves and stems: grow towards light, respond to their environment by MOVING,
- Roots: grow along chemical gradients towards nutrients,
- Slime molds: move across environments.

WEEK 10: Groups and populations

Groups: multiple organisms of same or different species.

- Occupy a common space – **general** term,

- Can be ephemeral or consistent,
- Social (positive grouping), indirect (share common resources), accidental (chance).

POPULATIONS: 'number of organisms of the same species in defined geological area.

- No. of individuals / population size,
- Area they occupy,
- Age structure,
- Sex ratio.

➤ Composition + structure influenced by *life history, mobility & habitat*.

Land and water

Sessile (fixed in one place) and motile (capable of motion)

- Monarch butterflies: very mobile from north to southern hemisphere.
- Coral fish: live around the same coral outcrops for their whole lives.
- Aspen trees: don't move once in the ground, only their seeds are mobile.

Populations essential for:

Ecology:

- Distribution + abundance of individuals,
- Density

Evolution:

- Populations of organisms evolve > not individuals,
- Gene flow

Conservation / management:

- Invasive species,
- Defining threat,
- Translocations + restoration.

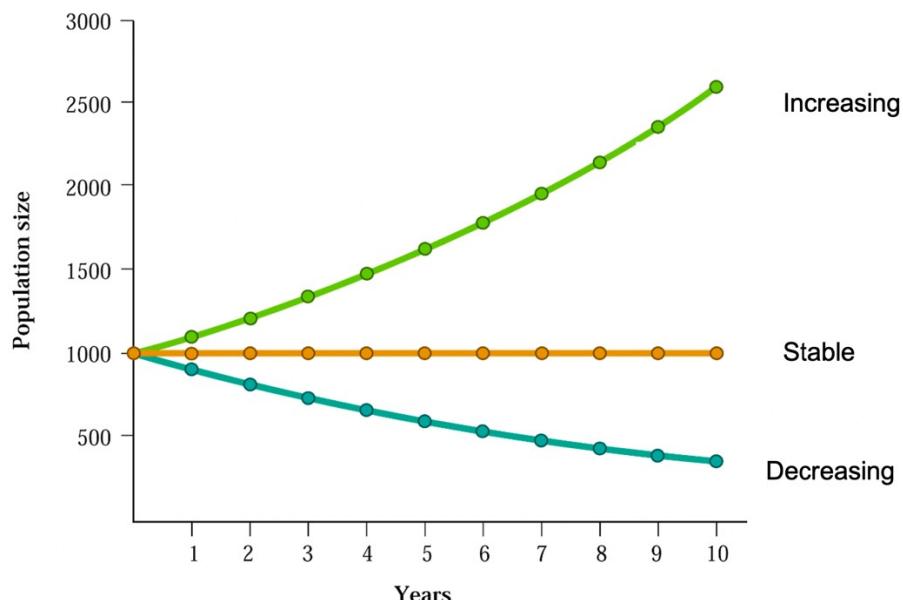
Importance:

- Temporal dynamics.
- Spatial distribution.
- Natural selection occurs within populations!!

POPULATION GROWTH

- Populations change in numbers over time,
- Change can be positive or negative,
- World (human) population growth is **exponential**.

Population growth rates



Demographic rates:

Birth and death = variables that change population sizes.

Emigration = no. leaving population

Immigration = no. entering population

Growth (individual)

Age at maturity

Sex ratio

Birth and death rates → fundamental to pop growth.

- Balance between birth/death determines growth rates,
- If pop is “closed” system (no emigration or immigration e.g. isolated areas, islands, mountain tops)

$$\circ \quad N_{t+1} = N_t + \text{Births} - \text{deaths}$$

N_t : no. of indivs in the pop at time

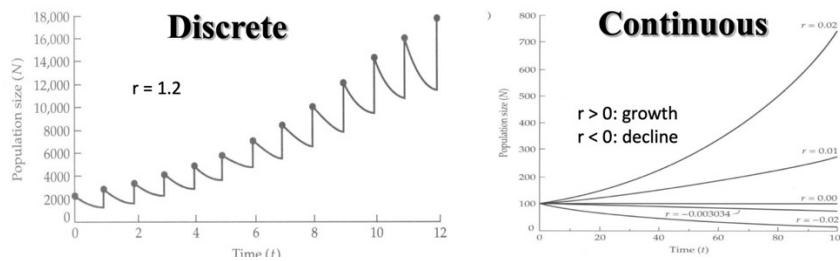
N_{t+1} : no. next year.

(Pop next year = pop this year + births - deaths)

Exponential growth

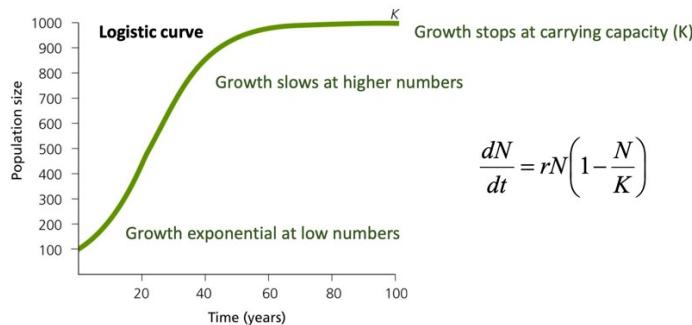
- Dynamics over time depend on life history of organism
 - Discrete – reproduction occurs periodically
 - Continuous – reproduction occurs year-round
 - r = instantaneous growth rate

$$\frac{dN}{dt} = rN$$



- Discrete: input of young, then lifespan
- Continuous: continuous breeding

...Resource limited growth – growth is resource limited (food, space, water, nesting sites)



In “OPEN” systems

o $N_{t+1} = N_t + \text{Births} - \text{deaths} + \text{immigrants} + \text{emigrants}$

Pop next year = pop this year + births - deaths + immigrants + emigrants

Estimating demographic rates – migrants

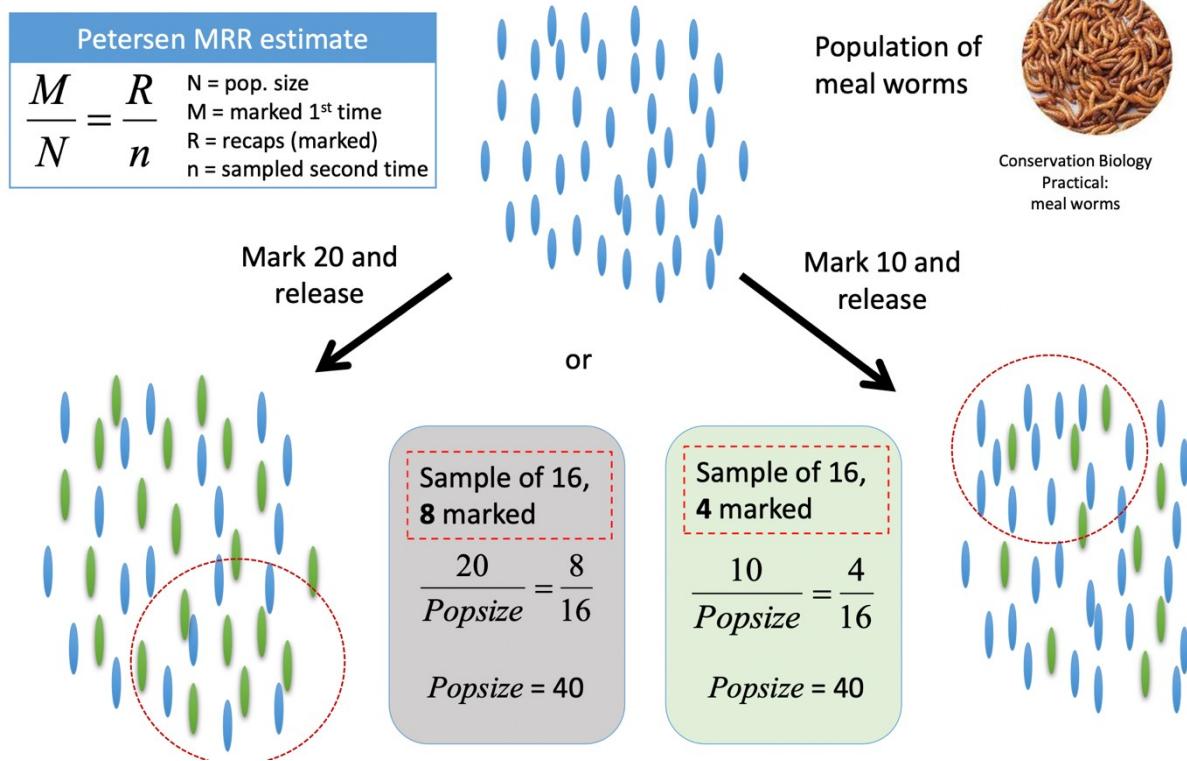
- Tagging and recapture (GPS, satellite)
- Counts
- Mark and recapture

Mark-release-recapture (MRR)

- The MRR method estimates the total population size from a sample proportion of a mobile species
- Uses the *proportion* of recaptures to estimate whole population size
- Assumptions often are hard to satisfy
 - closed* population (i.e. no immigration, no emigration)
 - all individuals equally likely to be marked
 - marked individuals do not lose their mark
- Technique has been used successfully on many animals, including whales, lizards, small mammals

$$\frac{\# \text{ marked}}{\text{Population size}} = \frac{\# \text{ recaptures that were marked}}{\# \text{ recaptures total}}$$

Mark-release-recapture



Spatially Structured Populations (metapopulations)

- Local populations, but individuals move,
- Demographic rates vary spatially,
- Large-scales dynamics dependent on local demographics and connectivity

Eg. Mayfly

- Larval stages in local pools
- Adults disperse between pools
- Mortality variable from pool to pool
- Some pools are sources (low mortality) while others are sinks (high mortality)

Growth and age

Trees – tree rings

Mammals – teeth

Fish – otoliths

Flying foxes - cementum rings in teeth to estimate age



Dendrochronology is the dating and study of annual rings in trees

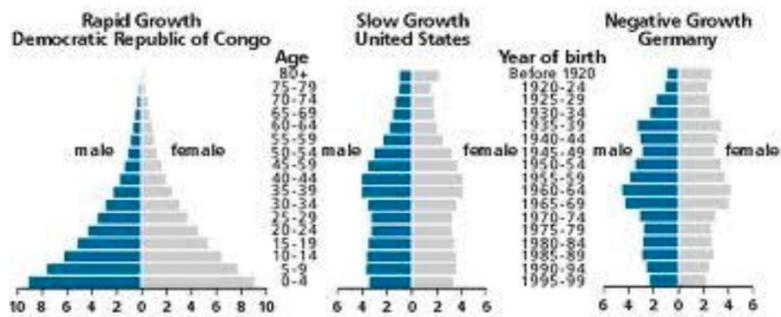
Age and size

Affects probability of giving birth and survival.

AUS POP: approx. 25million, median age – 37

- Current trend: aging population

Age structure pyramid:



PVA: Population viability analysis (measures population dynamics over time)

Extinction = Loss of all populations of a species

- Genetic stochasticity (small populations)
- Demographic stochasticity (random nature of births and deaths)
- Environmental stochasticity (variability)
- Catastrophes (cyclones, epidemics, fire)
- Human impacts (habitat loss, fragmentation, over-exploitation, hunting, pollution, introduction of new pest species, other environmental changes; e.g., climate change)

Eg. Dodo, Tasmanian Tiger, Western black rhinoceros.

DO SPECIES MATTER?

Species: groups of interbreeding natural populations, which are reproductively isolated from other such groups.

Biological species concept

- Many species hybridise; some produce viable offspring (dogs)
- Concept hard to apply for asexual organisms,
- Genetic species (differ in DNA)
- Ecological species (differ in their ecology)
- Phenetic species (defined by overall similarity)

Species provide convenient means of labelling organisms.

Species underpin local, state, national, international conservation efforts.

Counting species

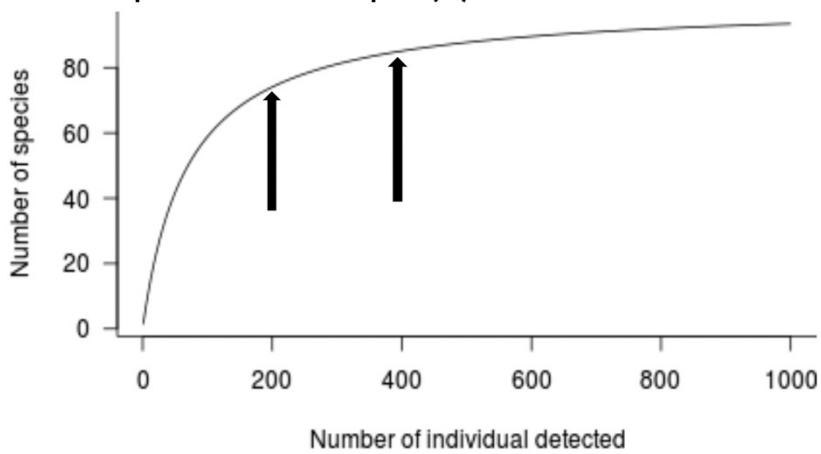
- Define area of interest,
- How much area can be sampled,
- What organisms will be counted,
- Methods: counts, traps, cameras, genetic methods (eDNA for aquatic species)
- Time of day/season/weather conditions.

Species richness and species diversity

- Species richness = number of species in a sample (S):

- But note that S can vary with sample size
- At a sample size of 200, $S = 71$
- At a sample size of 400, $S = 82$

- Large sample sizes are needed to detect all the rare species that are present



Species richness = simple count (or estimate) of the no. of species

Species diversity = measure of no. of species *and* no. of individuals of these species brought together into a single index. (low or high diversity, even or uneven diversity)

- An example – the Berger-Parker index (D): $1 - N_{\max} / N$, where N = number of individuals in the sample and N_{\max} is the number of the most abundant species

- Pond 1: $1 - 10 / 100 D = 0.9$
- Pond 2: $1 - 91 / 100 D = 0.09$

- Counts of species and diversity indexes are helpful BUT don't tell us about the relationships between samples.

- **Alpha (or α) diversity:** the number of species **within** a particular areas or habitats

Local diversity

- **Beta (β) diversity:** the difference in species **between** areas or habitats

Turnover diversity

- **Gamma (γ) diversity:** the number of species from all areas or habitats combined

Regional diversity

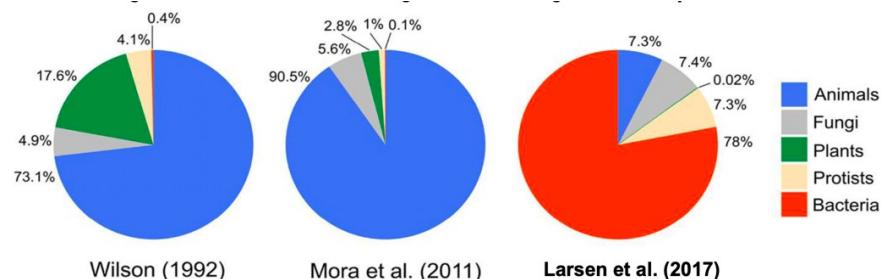
WORLD SPECIES

1.5 – 1.8 million species described and named.

But many more species remain to be discovered > mostly insects and invertebrates.

Until 2017, estimated 10-100 million species on Earth, most comprising of animals in tropical areas.

YET, with recognition of bacteria... this changed!



Larsen et al. (2017) estimated ~**2.238 billion species** on Earth, with 70-90% of these being bacteria.

Communities: Trophic Ecology

How organisms gain nutrients/energy:

1. Autotrophs

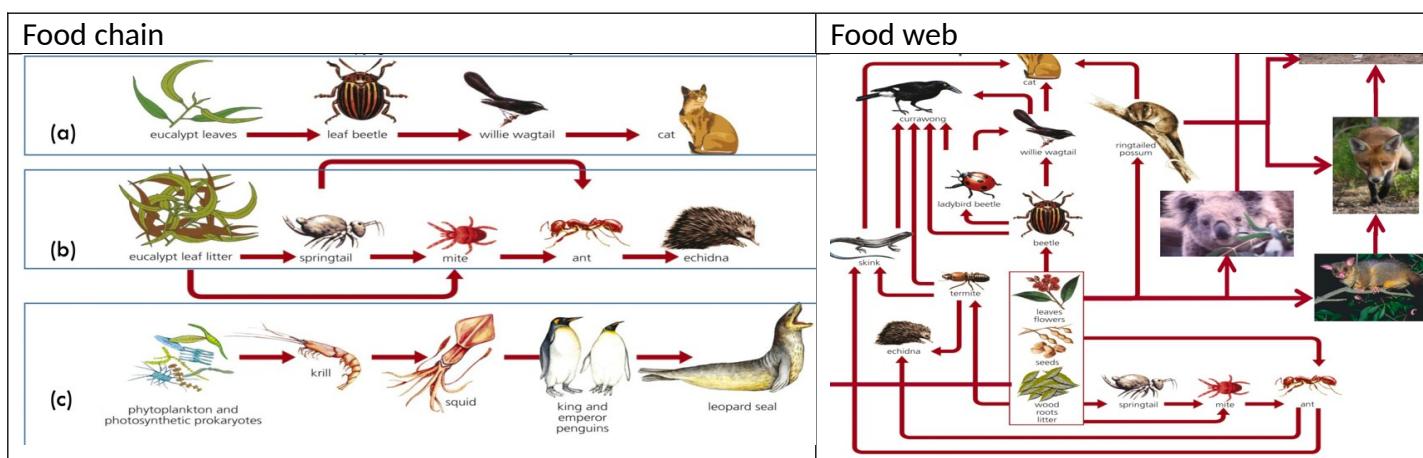
- Producers, make energy themselves from inorganic compounds (photosynthesis).
- Green plants, phytoplankton, algae

2. Heterotrophs

- Consumers, degraders, decomposers: get nutrients from others.
- Animals.

Food chains - describe energy flow between organisms among trophic levels.

Food webs - describe more complex interactions.



Trophic cascade: downward arrows. Top predators influence.

In most natural systems, food chains usually short.

- Longer food chains are less stable since fluctuations at low trophic levels magnify at high levels. Top predators more likely to go extinct.

Why food chains are SHORT: they lose energy needed to sustain them or the stability of the environment is not reliable enough to maintain food chains more than the 5-6 links.



Food webs - involve ecological interactions:

- **Competition** (-, -) for food, mates, space, water, light between plant species, and between animals competing for access to most nutritious plant resources/prey.
- **Predation** (+, -)
- **Parasitism** (+, -)
- **Mutualisms** (+, +) 2 organisms come together and both benefit.
 - o Obligate mutualism; symbiosis: partners can only survive together.
 - o Facultative mutualism: partners gain benefit but can survive on their own.
- **Commensalism** (+, 0) where one organism benefits and the other has not been affected.
- **Amensalism** (0, -) no impact on one, but negative impact on the other. Eg, stepping on ants.
- **Herbivory** (+, -) plants aren't great food for animals as they have low nutritional value (locked behind plant cell walls). Biggest interaction on the planet, affect ecosystem processes.

Herbivores

1. Tissue loss to herbivores: how much could plants have reproduced if not eaten?
2. Herbivores selectively eat high quality plant tissue
3. Plants have defences against herbivores (e.g. spiky thorns or tough, waxy epidermis – images) to reduce their tissue loss
4. The world is green because much plant tissue is not available to herbivores.

WEEK 11: Assemblages and Ecosystems, The human Footprint

Assemblages and Ecosystems