



## From Molecules to Ecosystems Notes

From Molecules to Ecosystems (University of Sydney)



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# From Molecules to Ecosystems Notes!

## Week 1 Lectures

### 2. The Chemistry of Life - 7/08/2025

#### Properties of Life

- Order
- Energy processing
- Sensitivity or response to stimuli
- Reproduction
- Growth + development
- Regulation/homeostasis
- Adaptation
- Evolution

**Compound = 2 atoms together, Molecules = 2 same atoms together**

- All **compounds** are **molecules**
- Not all **molecules** are **compounds**

Molecules can be:

- Hydrophobic
- Hydrophilic
- Amphipathic (hydrophobic long chain, polar head e.g. **soap**)

#### Water

- Hydrogen bonds make water polar
- **Cohesion** = high surface tension = capillary action in plants when evaporation from leaves
- **Temperature moderation** = water has high specific heat as a medium
- Water is **less dense as a solid than a liquid**
- **Versatile solvent** due to **polarity**

#### Monosaccharides

- Linear + cyclic form
- **Cyclic** forms most common in nature, **energetically favourable**
- Carbonyl group depends ring forms in carbs

#### Disaccharides

- **Two monosaccharides** joint via **covalent bonds**
- **Glycosidic bond** (dehydration synthesis via loss h<sub>2</sub>O)
- Breaks down into monosaccharides

#### Polysaccharides

## For Storage

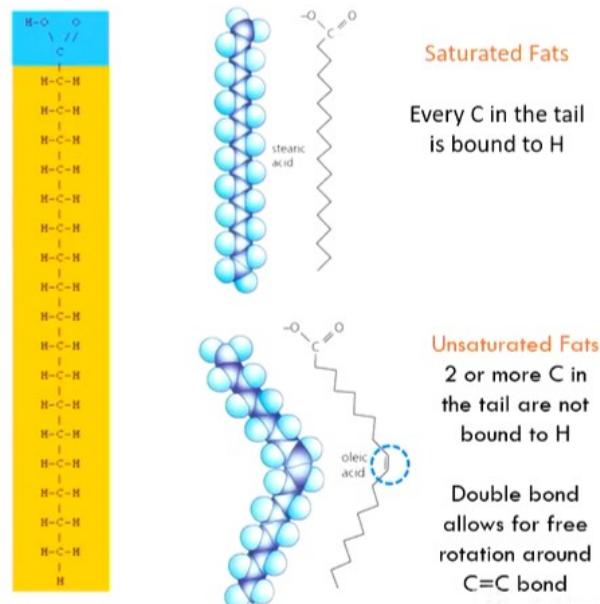
- Hydrolysed as needed to provide monosaccharides for cells
- Starch** in plants, made up of:
  - Amylose (unbranched)
  - Amylopectin (branched)
- Glycogen** in animals
  - Similar to starch but more extensively branched

## For Structure

- Building material for structures that protect the cell or the organism
- Cellulose** in plants
- Chitin** as the exoskeleton of arthropods
- Peptidoglycans** are complex polymers found in bacterial cell walls
  - Important targets for antibiotics

## Lipids: Structure

- Lipids are principally composed of:
  - C, H and O
- Diverse set of molecules including:
  - Fats, oils, waxes, steroids/sterols
- Large **energy release** when broken down
- Simple fatty acids are non-polar molecules made up of:
  - A **carboxylic acid group** ( $\text{COOH}$ )
  - A long **hydrocarbon tail** ( $R$ )



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- Important for membrane structure, forms a bilayer (hydrophilic + hydrophobic insides)

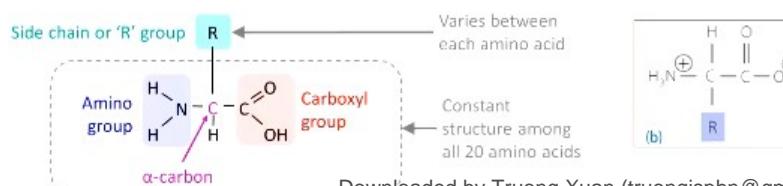
## Structure of Nucleic Acids

- Nucleotides = phosphate group, sugar, nucleobase
- DNA and RNA (RNA has a OH but DNA has only a H on bottom right pentagon)

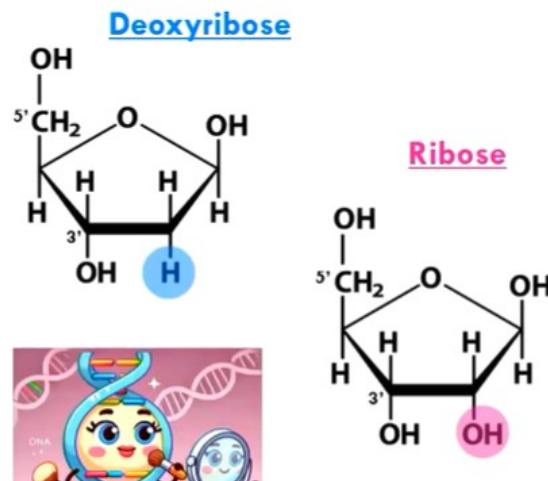
## Amino Acids

### $\alpha$ -Amino Acids

- Building blocks of proteins
- Technically any amino acid with an amino group ( $-\text{NH}_2$ ) and a carboxylic acid group ( $-\text{COOH}$ )
- The **20 commonly occurring amino acids** found in proteins and coded by our genes have the same basic alpha ( $\alpha$ ) structure
- In aqueous solution (pH 7) the amino and acid groups are **ionised** ( $-\text{NH}_3^+$  and  $-\text{COO}^-$ )
  - This is the normal state for amino acids in nature

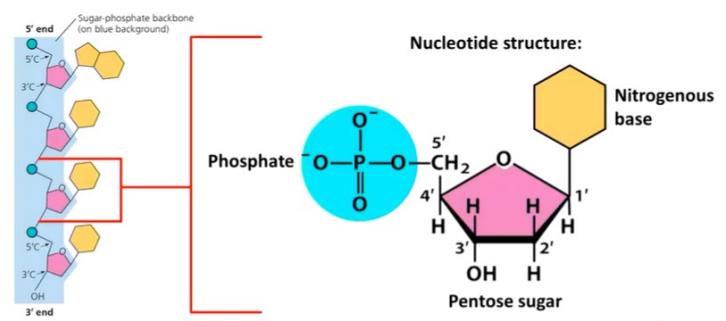


- The 20 common encoded amino acids have different sizes and chemical properties
  - Important for structure and function of proteins
- They each have:
  - A name
  - A 3-letter abbreviation
  - A 1-letter abbreviation
- How they make up proteins will be covered in later lectures



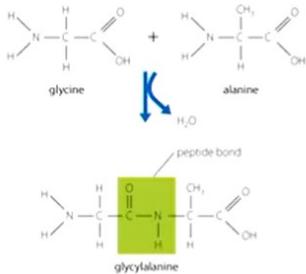
### 3. Biopolymers: DNA, RNA and Proteins - 8/08/2025

- 5 Carbons in the pentose sugar  
> 5th not in ring since it is oxygen,  
**binds to phosphate group through carbon**
- Glycosidic bond** (carbon binds through nitrogen (determines ATCG))
- Amino acid = amino group, carboxyl group, R group (side chain)



### Amino Acids Form Peptides

- Amino acids link via **peptide bonds**, formed by **dehydration synthesis reactions**
  - Two or more amino acids form a peptide
- Very energetically unfavourable
  - Doesn't happen spontaneously
  - Will cover this more during translation lectures



- R group determines what type of amino acid (all will have N-C-C repeat chain)

### DNA and RNA directional

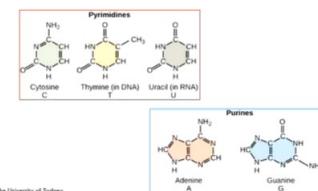
- Start at 5' end**
- Finish at 3' end**
- Nucleic acids synthesised in one direction only

### Amino acids (polypeptides) are directional

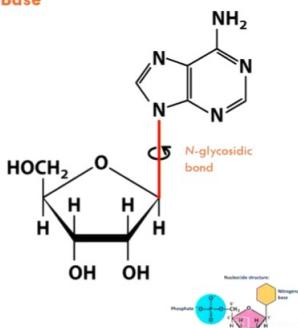
- Start at N (amino)

### Nucleic Acids: Attaching the Sugar to the Base

- In nucleotides the pentose ring is attached to the nucleobase via a **N-glycosidic bond**
  - Relatively free rotation around this bond
- The bases form the point of differentiation in polynucleotide chains (**C,T/U; A,G**)

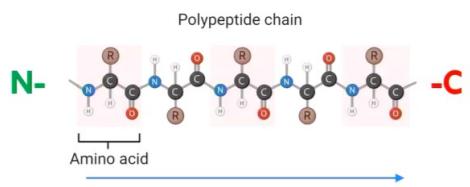


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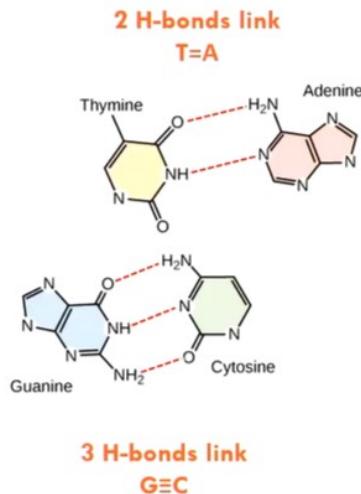
- Lots of varied properties
  - Size/shape
  - Charge
  - Polarity
  - Hydrogen-bonding potential
  - Hydrophobicity
  - Aromatic
  - Redox sensitive
  - Flexibility
- Provide shape/structure and function to the protein

- End at C (carboxyl)
- Only synthesised in one direction



### Base Pairing Between Nucleobases

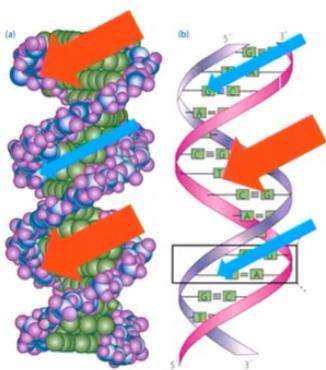
- There should be a 1:1 stoichiometric ratio of purine and pyrimidine bases
- The secondary structure of polynucleotides depends upon **hydrogen bonding** between bases = base pair
- 'Watson-Crick' base pairs predominate in double-stranded DNA
  - Purine pairs with pyrimidine
  - A pairs with T (or U in RNA)
  - G pairs with C
- 'Complementary' base pairing



- More bonds = stronger (**triple > double**)
- Therefore if stronger then we can tell has more bonds
- Can test via melting to break apart

- D-DNA common in cells (**asymmetrical strands in opposite directions**)

### DNA Double Helix

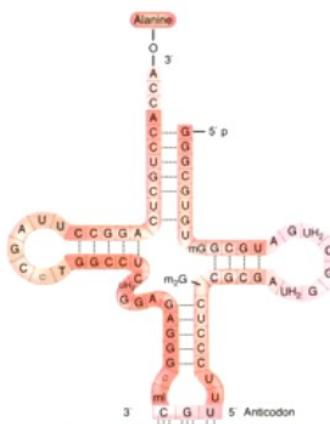


- A DNA double helix can take a number of forms
  - B-DNA is most common in cells
  - **Asymmetric strands run in opposite directions**
- Flat bases stack on top of each other in middle of the structure
- Negative phosphates repel each other
- **Major** and **minor** grooves

- mRNA (intermediary of gene expression, use gene info to specify amino acid sequence)

### DNA vs. RNA Structure

- RNA doesn't form B-type helical structures
  - RNA exists as **single strands**
- Extra -OH group prevents B-DNA-type helices
  - Also makes RNA **susceptible to degradation or breakdown**
- However, **different types of RNA structures** can exist
  - mRNA, tRNA, rRNA etc
- Complementary base pairing can occur:
  - Between regions of two RNA molecules
  - Between two stretches of nucleotides in the same RNA molecule

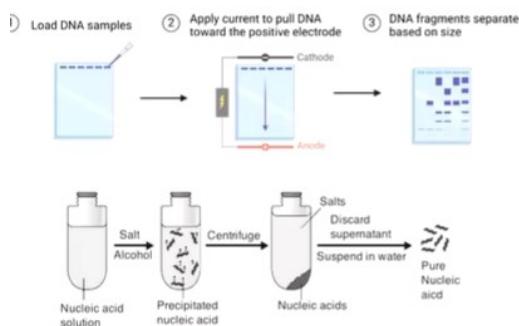


- Cytosine ( $H_2O$ ) can become Uracil ( $NH_3$ )

## DNA and RNA stability

- Dna will get rid of uracil when it deaminates  
> lasts a few years
- RNA has both cytosine + uracil so cannot detect + change as much (less stable)  
>Lasts a few hours
- DNA is negative, electrophoresis is positive, so it drags depending on size

## Exploiting the Sugar Phosphate Backbone for Experimentation



- Negative charge (phosphates)
- Hydrophilic (sugars and phosphates)
- Applications:
  - Electrophoresis
  - Ethanol precipitation



**Electrophoresis:** Nucleic acids migrate in an electric field because they are charged. The distance they migrate depends on size

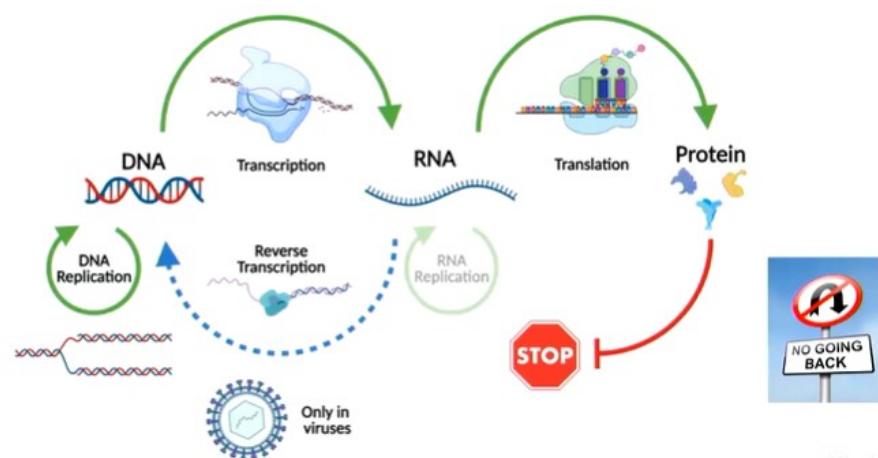
**Ethanol Precipitation:** Nucleic acids become insoluble when mixed with salt (to neutralise charge) and ethanol (you will do this in practical 2!)

- The more cytosine and guanine in a strand of DNA, the stronger (more hydrogen bonds)

## Week 2 Lectures

### 4. The Central Dogma of Molecular Biology - 11/08/25

## The Central Dogma of Molecular Biology



complete genetic

INFORMATION = ALL OF YOUR DNA

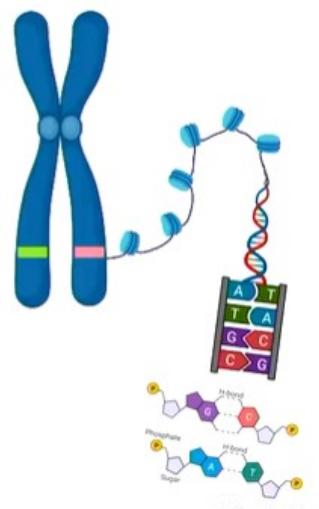
- All nucleated cells will have a full copy of the organisms genome
- *But not all cells have a nucleus!*
- Each cell uses a subset of expressed genes (RNA and protein) to achieve its structure and function(s)
  - **Transcriptome** and **proteome**
  - These can differ in response to different stimuli/environments/times

## Key components

- Genome (entire DNA)
- Transcriptome (entire RNA)
- Proteome (entire protein)

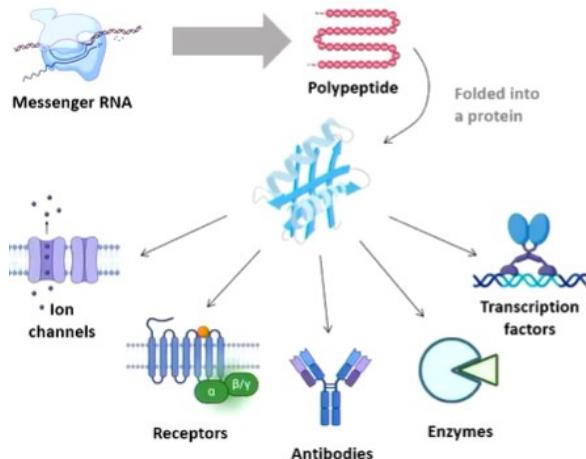
## The Genome: The DNA Blueprint for Every Part of an Organism

- **Chromosomes** are the repositories of genetic information
  - Some of this genetic information is organised into genes
- **Genes** are organised **segments** of **DNA**
  - Encode the primary sequence of DNA to synthesise a final biological product
- **DNA** is comprised of **nucleic acids**
  - Consist of nitrogenous base, pentose sugar and a phosphate group
- Genomes will vary in makeup, count and structure:
  - Between organism groups (e.g. eukaryotes vs prokaryotes)
  - Between species (e.g. plants vs humans)
  - Within species (e.g. sex chromosomes)
  - Between cells in a single organism (e.g. red blood cells do not have a nucleus = no genome)



- Proteome

## The Proteome: All Proteins Expressed in Any Given Cell



- Similar to the transcriptome – the **proteome is always changing** based on cellular needs
  - Two different cell types will have different proteomes
  - Two of the same cell types may have the same proteome
- A cell's proteome will differ from its transcriptome and genome
- Based on the cell's needs:
  - Different proteins may be expressed at different times
  - The cell may increase or decrease synthesis of specific proteins

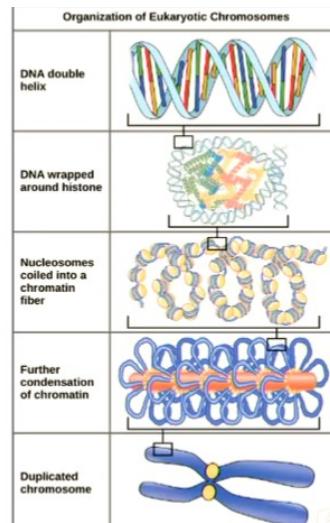
always changing, cell function, homeostasis, stimuli response

- Testing for RBC (proteome)
- Muscle cells and WBC have same genome
- Two liver cells exact same person have same transcriptome
- Intergenic DNA (non-coding), most of the DNA

## Eukaryotes have BIG linear genomes

### Eukaryotes Have BIG Linear Genomes

- Tend to be **big** (~10 Mb-150 Gb)
- Eukaryotic genomes are **linear**
  - Condensed into chromatin fibres
  - Wrapped around **histone proteins**
- The Japanese canopy plant *Paris japonica* contains 149 billion base pairs (bp)
  - 8 copies of 40 chromosomes
- Humans have ~6 billion bp
  - 22 pairs of chromosomes (plus the sex chromosomes)



- Smaller genome = faster

replication speed (Simple)

## Universal Genetic Code

- Singlet - 4 bases (A,G,C,U)
- Doublet - 16 possible pairs
- Tripelt - 64 possible sets of three
- order important, not all unique redundancy
- AUG encodes start codon (Met)
- Only second is correct down \

Singlet Code: 4	Doublet Code: 16	Triplet Code: 64		
5' U 3'	5' UU 3'	5' UCU 3'	5' UAU 3'	5' UGU 3'
5' C 3'	5' UC 3'	5' UCC 3'	5' UAC 3'	5' UGC 3'
5' A 3'	5' UA 3'	5' UCA 3'	5' UAA 3'	5' UGA 3'
5' G 3'	5' UG 3'	5' UCG 3'	5' UAG 3'	5' UGG 3'
	5' CU 3'	5' CCU 3'	5' CAU 3'	5' CGU 3'
	5' CC 3'	5' CCC 3'	5' CAC 3'	5' CGC 3'
	5' CA 3'	5' CUA 3'	5' CAA 3'	5' CGA 3'
	5' CG 3'	5' CUG 3'	5' CAG 3'	5' CGG 3'
	5' AU 3'	5' ACU 3'	5' AAU 3'	5' AGU 3'
	5' AC 3'	5' ACC 3'	5' AAC 3'	5' AGC 3'
	5' AA 3'	5' ACA 3'	5' AAA 3'	5' AGA 3'
	5' AG 3'	5' AUG 3'	5' AAG 3'	5' AGG 3'
	5' GU 3'	5' GCU 3'	5' GAU 3'	5' GGU 3'
	5' GC 3'	5' GCC 3'	5' GAC 3'	5' GGC 3'
	5' GA 3'	5' GCA 3'	5' GAA 3'	5' GGA 3'
	5' GG 3'	5' GCG 3'	5' GAG 3'	5' GGG 3'

## Finding the Correct Frame/Open Reading Frames

Now let's look at an mRNA sequence – we break it up the same way but use the genetic code to translate the codons to amino acids

mRNA 5'  CUGAAGCAUGCUAUUCUCCCCUAACGCGG 3'

Reading frame 1    CUG | AAG | CAU | GCU | AUU | UCU | CCC | CUA | ACG | CGG  
**Leu-Lys-His-Ala-Ile-Ser-Pro-Leu-Thr-Arg**

Reading frame 2    C | UGA | AGC | AUG | CUA | UUU | CUC | CCC | UAA | CGC | GG  
**-Stop-Ser-Met-Leu-Phe-Leu-Pro-Stop-Arg-**

Reading frame 3    CU | GAA | GCA | UGC | UAU | UUC | UCC | CCU | AAC | GCG | G  
**Glu-Ala-Cys-Tyr-Phe-Ser-Pro-Asn-Ala-**

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## 5. Copying DNA and RNA - 14/08/25

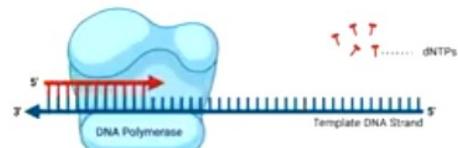
### Why does DNA Replicate?

- Cells will pass on genetic material via cell division, must **duplicate**
- Parent can't just give away half their DNA
- Semi conservative - split in half (maternal) and copied (parental)

## DNA Replication: A Simplified Overview

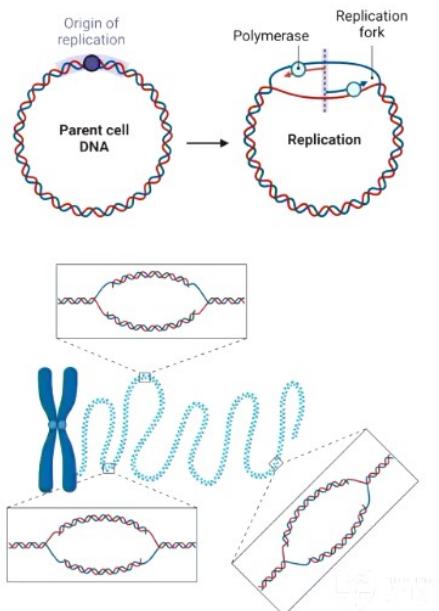
- Makes a complementary copy of DNA from a DNA template
- Requires a template strand for base-pairing
- Uses a DNA polymerase (enzyme)
- Needs a primer (short piece of DNA/RNA) to start synthesizing (not shown)
- Always creates the new strand 5' to 3'
- Uses nucleotide triphosphates (dNTPs) as substrate
- Adds the nucleotide monophosphate to the 3'(OH) end of the growing chain
  - Pyrophosphate (2 phosphates) released and broken down, which...
  - Drives the reaction forming a high energy phosphodiester bond

Creates a newly synthesised strand in a 5' to 3' direction



## Initiating DNA Replication

- Both strands must be replicated at the same time
- And needs to occur in opposite directions
  - Complementary strands are anti-parallel
- The parent DNA should remain relatively intact throughout replication
- Occurs simultaneously at the origin of replication
- Opens up the DNA and creates two replication forks
- Replication occurs in a 5' → 3' direction on both strands



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## Bi-Directional (DNA replication)

### The Origin (ORI) of Replication

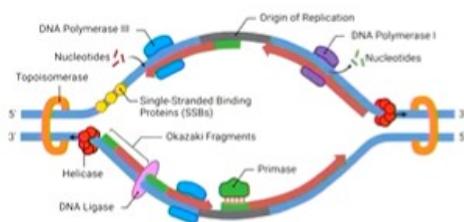
- Prokaryotic (**bacterial**) genomes are smaller but **circular** (no “ends”)
    - Generally, only **1 origin of replication**
  - Eukaryotic genomes are **linear**, but **LARGE**
    - Would be inefficient to only start at the end of a chromosome every time
    - **Multiple origins of replication**
    - Humans have between 40-80 thousand
  - Generally will be areas that are rich in A/T bases
    - Why??? (think about which base-pair is stronger)
- **DNA Helicase** - “Unzips” the DNA by separating base-pairs
  - **Topoisomerase** - Under-winds DNA and prevents local supercoiling
  - **Single-Stranded Binding (SSB) Proteins** - Stabilises separated DNA strands
  - **Primase** – Makes an RNA primer that identifies the start point for DNA synthesis
  - **DNA Polymerase III** - Synthesises new DNA strands
  - **DNA Polymerase I** - Fills in the gaps
  - **DNA ligase** - Bind the fragments together
- **Helicase** breaks apart hydrogen bonds ( 2 single stranded DNA)
- **Topoisomerase** enzyme (unwind **tension** of helical DNA + stick back together)
- **Primase** adds RNA primer sequence at start to initiate Replication
- DNA strands **anti-parallel (opposite directions)**, must be synthesised simultaneously



## Leading vs Lagging Strands

### Leading

- **DNA primase** makes an RNA primer to begin, then:
- **DNA polymerase III** makes a DNA copy of the strand in the  $5' \rightarrow 3'$  direction
- Continuous copying



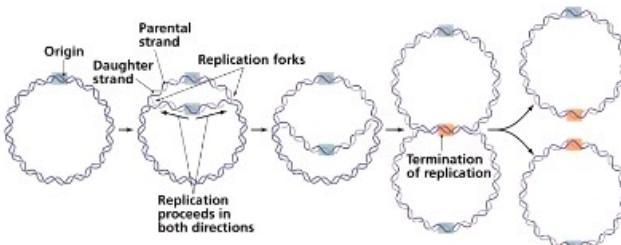
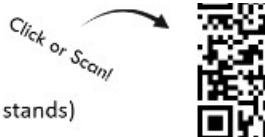
### Lagging

- **DNA primase** makes multiple RNA primers
- **DNA polymerase III** synthesises in  $5' \rightarrow 3'$  direction until it runs into the next primer making Okazaki fragments
- **DNA polymerase I** replaces the RNA primer with DNA
- **DNA ligase** joins fragments together

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## Termination of Replication

- Joining up the new strands (4 strands become 2 new daughter stands)
- Roughly opposite the origin in bacterial genomes
- Eukaryotes need to strip off **nucleosomes** before replication and reform nucleosomes immediately afterwards
- There are a few regulatory mechanisms in place, but for now just think of the strands meeting and joining up.



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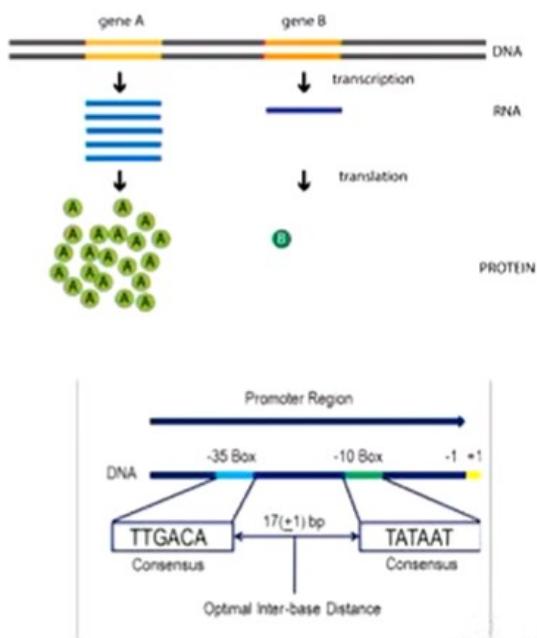
## Transcription Initiation

- 35 to -10 : **Promoter region** (RNA polymerase bind to transcribe gene)
- G/C region can stop transcription
- Rho protein can bind to ribosome free RNA to stop transcription

## Gene Expression Regulation

Genes can be expressed at different frequencies (including at different times/conditions) by:

- **Promoter region strength:**
  - DNA sequence affects how strongly RNA polymerase binds
- **Repressors**
  - Proteins that block polymerase binding or movement.
- **Accelerators/Activators**
  - proteins that enhance polymerase binding or activity
- **Small molecule modulators**
  - Metabolites that switch repressors/activators on or off



- Bacteria does not need RNA primer

## 6. Making Proteins - 15/08/25

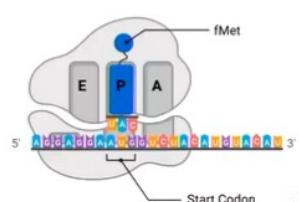
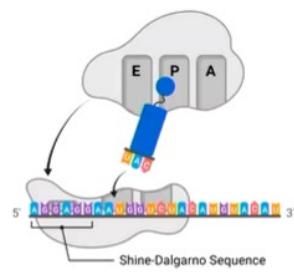
### Components for Translating mRNA into Polypeptides



- **Ribosomes** made up of two subunits
  - Contain rRNA, enzymes and ribo-proteins
- Three main sites in the ribosome
- **E site**
  - Aminoacyl site
  - Where new tRNAs will bind
- **P site**
  - Peptidyl site
  - Where peptide elongation will occur
  - Will align with the mRNA start codon during initiation
- **E site**
  - Exit site
  - Where the tRNA will exit the ribosome

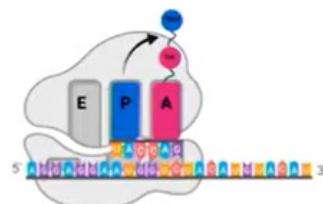
### Step 1: Initiation

- To get started the ribosome needs to recognise where to start
  - **Ribosome binding site** which is commonly the Shine-Dalgarno (SD) sequence in bacteria
- Small and large ribosome subunits assemble at the SD sequence
  - This is assisted by initiation factors (not shown here – don't need to know them)
- Start anticodon tRNA in prokaryotes is a formylated methionine-tRNA (**fMet**)
  - Formyl group is removed later
  - They still have Met-tRNA for other AUG codons downstream of the start codon

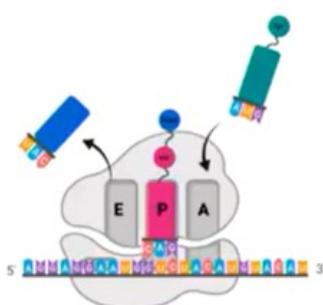


## Step 2: Elongation

- A new charged tRNA slots into the A site
  - Guided by anticodon/codon matching
- Activated amino acids are positioned next to each other
- Peptidyl transferase in the ribosome catalyses **peptide bond formation** using energy stored in the charged-tRNA bond
  - Forms a peptide (i.e. fMet-Val)
- This shifts the ribosome forward 3 bases
  - The now uncharged tRNA moves to the E site and exits the ribosome



- Just

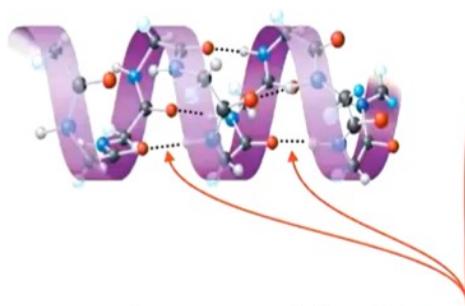


## translation

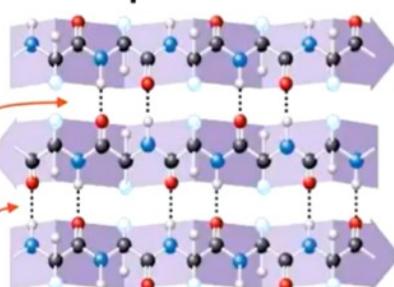
Cannot go back after protein synthesis occurs (cannot get exact DNA sequence from protein)

### The Two Major Protein Secondary Structures

#### $\alpha$ -helices



#### $\beta$ -sheets



- Alpha helix is not the same as DNA helix

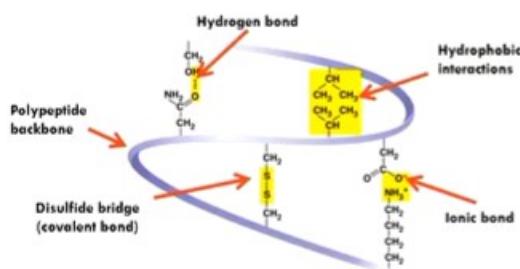
Polypeptide backbone winds tightly around longitudinal axis (hydrogen bonding)

**Both** are stabilised by **hydrogen bonds** between non-adjacent amino acids

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## Protein Tertiary Structure

- Tertiary structure refers to the overall spatial arrangement of atoms in a protein
- Stabilised by numerous **weak interactions** between amino acid side chains (R groups):
  - Primary = covalent bonding between amino acids
  - Secondary = hydrogen bonding between carbonyl oxygens and amide hydrogens
  - Tertiary** = interactions between R groups of amino acids
- Interacting amino acids are not always necessarily next to each other in the primary sequence



Side R  
groups  
of

different amino acid chains react together

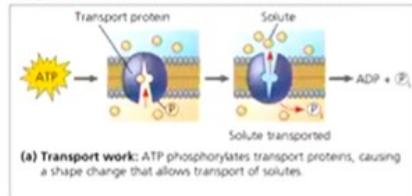
- Proteins usually cannot be renatured (after denatured)

## 7. Enzymes and Thermodynamics - 18/08/25

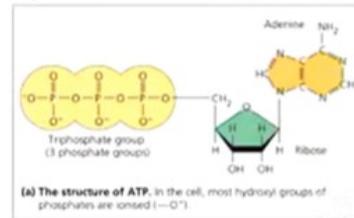
### Energy and the Cell

- Energy is the **capacity to do work** or cause change
- Why do cells need energy?
  - Biosynthesis:** building complex molecules
  - Movement:** cellular transport, muscle contraction etc.
  - Active transport:** moving molecules against concentration gradients
  - Thermoregulation:** maintaining internal temperature
  - Signal transduction:** within and between cells.
- Primary energy source is ATP
  - Generated through cellular respiration

▼ Figure 8.11 How ATP drives transport and mechanical work.



▼ Figure 8.9 The structure of adenosine triphosphate (ATP).



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### Types of Energy

**Kinetic:** Movement, active energy

> Thermal energy

**Potential energy:** storage

> Chemical energy that can be broken down to release energy

First Law: Energy cannot be created/destroyed

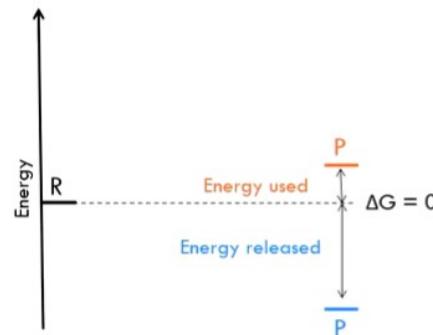
**Second Law:** Entropy of the universe is always increasing (continual loss of energy in universe)

**At equilibrium:** When forward and reverse reactions occur at the same rate (bad for cells because no net change in products)

## Thermodynamics and Equilibrium

- Gibbs Free Energy ( $G$ ) is the energy available to do work in a system
- The change in Gibbs Free Energy ( $\Delta G$ ) is the chemical potential of a reaction
  - $\Delta G = 0$  at (static) equilibrium and the rate of the forward and reverse reaction are equal
- Reactants ( $R$ )  $\rightleftharpoons$  Product ( $P$ )
  - $\Delta G = G_{\text{products}} - G_{\text{reactants}}$
- Reactions as above will either be:
  - Favourable and spontaneous where  $\Delta G < 0$  ( $-\Delta G$  reactions release energy / are exergonic)
  - Unfavourable and non-spontaneous where  $\Delta G > 0$  ( $+\Delta G$  reactions need energy input / are endergonic)

Reminder:  $\Delta = \text{"change in"}$



## Exergonic Reactions are Spontaneous

- Delta  $G$  is negative, total of delta  $G$  reactants higher than products

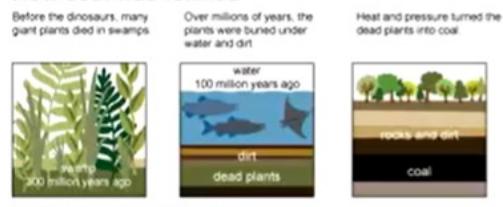
## Endergonic Reactions Require energy

- Cellular reactions never reach static equilibrium

## Thermodynamics vs. Kinetics: What's the Difference?

- Thermodynamics:** Determines if a reaction is energetically **favorable** ( $\Delta G$ ).
- Kinetics:** Determines how **fast** the reaction reaches equilibrium (activation energy,  $E_a$ )
  - A reaction can be thermodynamically favorable but kinetically slow
- For example: The remains of carbon-based life exposed to pressure and heat over millions of years spontaneous formed fossil fuels

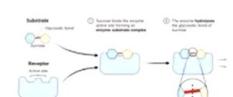
### How coal was formed



\*\*you don't need to know how coal forms, this is just an easy way to describe the difference between thermodynamics and kinetics

- Takes a long time for reactions to surpass activation energy (if lower then better/faster)
- Enzymes **biological catalysts** that speed up chemical reactions by **decreasing activation energy**

- Remember this:
  - Reactants ( $R$ )  $\rightleftharpoons$  Product ( $P$ )
- We will now think of our reactants ( $R$ ) as:
  - Enzymes ( $E$ ), and
  - Substrates ( $S$ )
- Enzymes stabilise transition states



Enzyme      Substrate

Enzyme-Substrate complex

Enzyme-Transition state complex

- > have specific activation sites
- > Does not: get destroyed/used up, change equilibrium

**Lock and Key** - specific

**Induced Fit**- substrate induces shape change to help for optimal binding

**Selection Model** - enzymes exist in multiple different forms

- Enzyme pathways can be interrupted due to mutations
- Enzymes partly regulated by **compartmentalism**

**Energy Coupling** - exergonic process to drive an endergonic reactions (use the energy produced to help when another process uses energy)

Enzymes can only function at specific temperatures

## 8. Photosynthesis 1- 22/08/2025

**Metabolism: redox**

OIL RIG - Oxidation is loss, reduction is gain



**Metabolism: Electron Carriers**

NAD<sup>+</sup> can accept electrons from organic



**Anabolism: Creating things (use energy)**

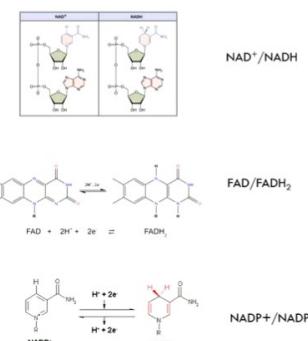
**Catabolism: Destroy things (release energy)**

**Autotroph:** make own energy

**Heterotroph:** rely on others (eating)

**Photosynthesis:**

**Metabolism: Electron carriers**



**1<sup>st</sup> stage**  
"Light reactions"

**Goal:**  
Trap sunlight and convert to chemical energy & reducing power for later use

**2<sup>nd</sup> stage**

"Calvin cycle" or "light-independent"

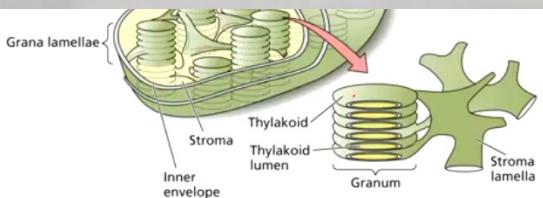
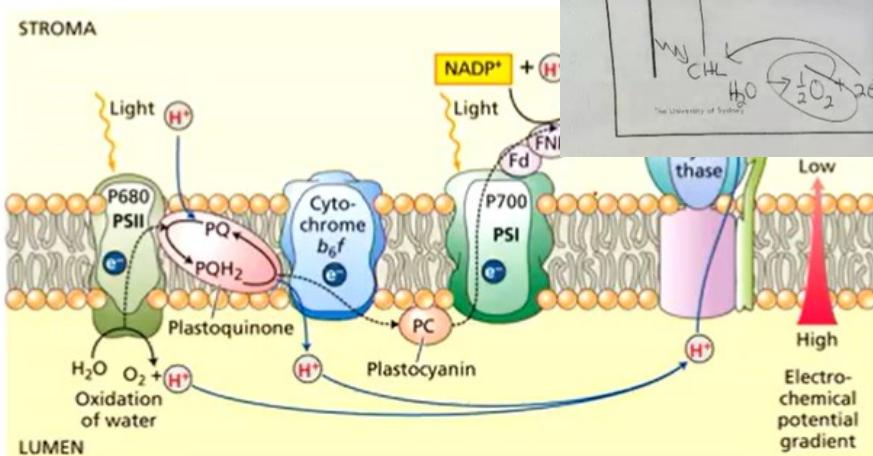
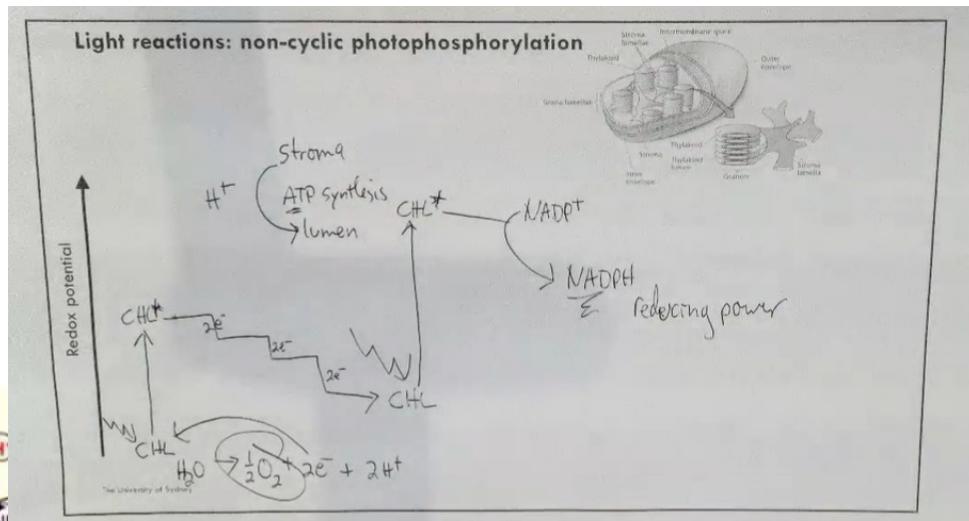
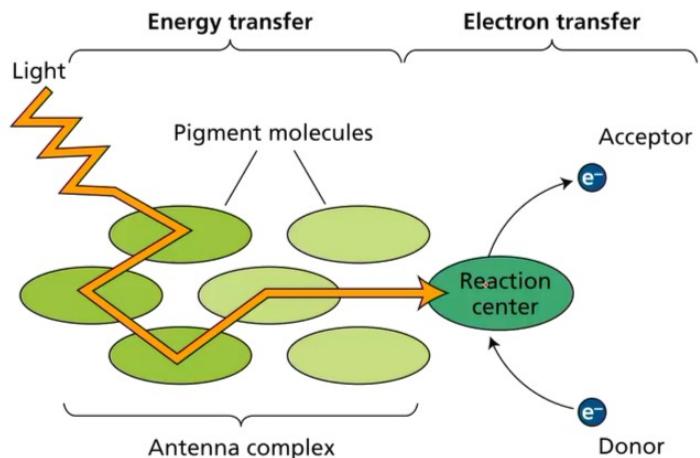
**Goal:**  
Convert CO<sub>2</sub> into sugars using chemical energy & reducing power produced in 1<sup>st</sup> stage

## Stage 1: Light Reactions (Linear)

- Chlorophyll absorbs light energy
- 300-400 chlorophyll creates **antenna complex** (captures energy → reaction centre where light reactions occur)

## Light reactions: Non-cyclic Calvin (Cycle)

- Electron transport chain from CHC+ to CHC
- Stroma to lumen is ATP synthesis
- NADP+ becomes NADPH (reducing power)
- Used to split water to create oxygen (reducing power) and energy.



- Electrons cannot go back across phospholipid bilayer (flow back via ATP synthase to create ATP)

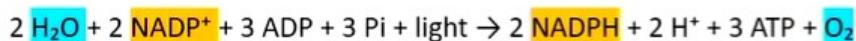
## Week 4 Lectures

### 9. Photosynthesis CO<sub>2</sub> Fixation- 25/08/2025

#### Photosynthesis: Redox

### 1<sup>st</sup> stage

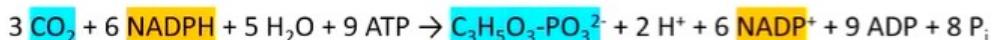
Non-cyclic photophosphorylation, AKA "Light reactions"



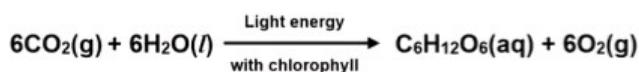
**RuBisCO -**  
2 substrates  
Most  
abundant  
protein on  
earth

### 2<sup>nd</sup> stage

Calvin cycle, AKA "light-independent"

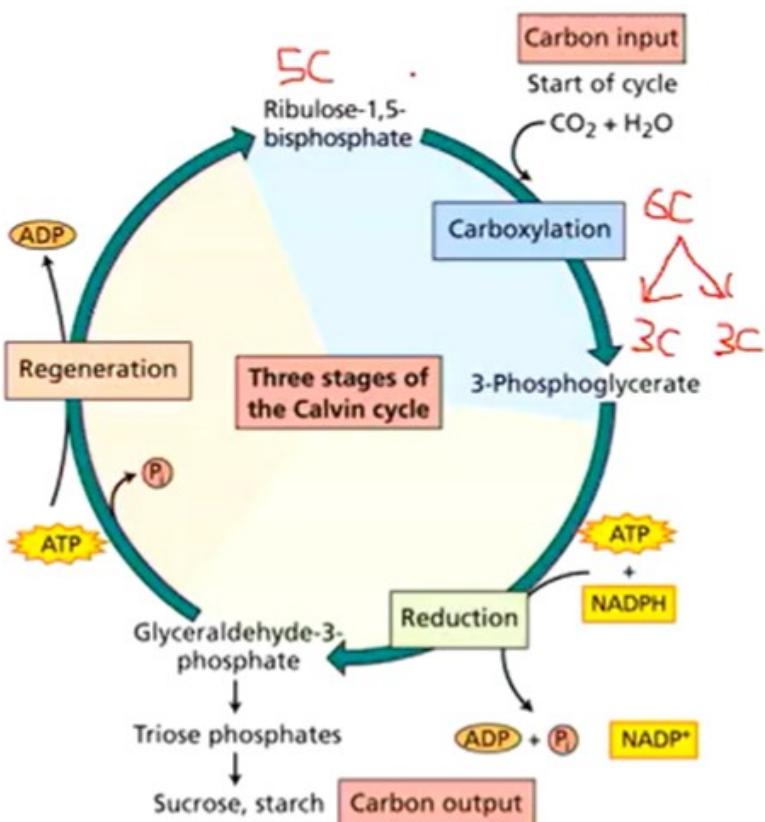


Combining the two stages and balancing...

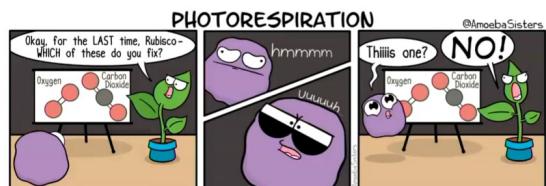


### The Calvin C3 Cycle in 3 stages

- Start with **5 carbons** → carbon input makes **6 carbons** → split into **3 carbons** each → electrons added with NADPH (which becomes NADP) **reduction** → **results in sugars** that can be used/detached with the 3 carbons
- \*\* not all carbon is used since it needs to regenerate (cycle)
- RuBisCO adds CO<sub>2</sub> to the 5 carbons that it starts with

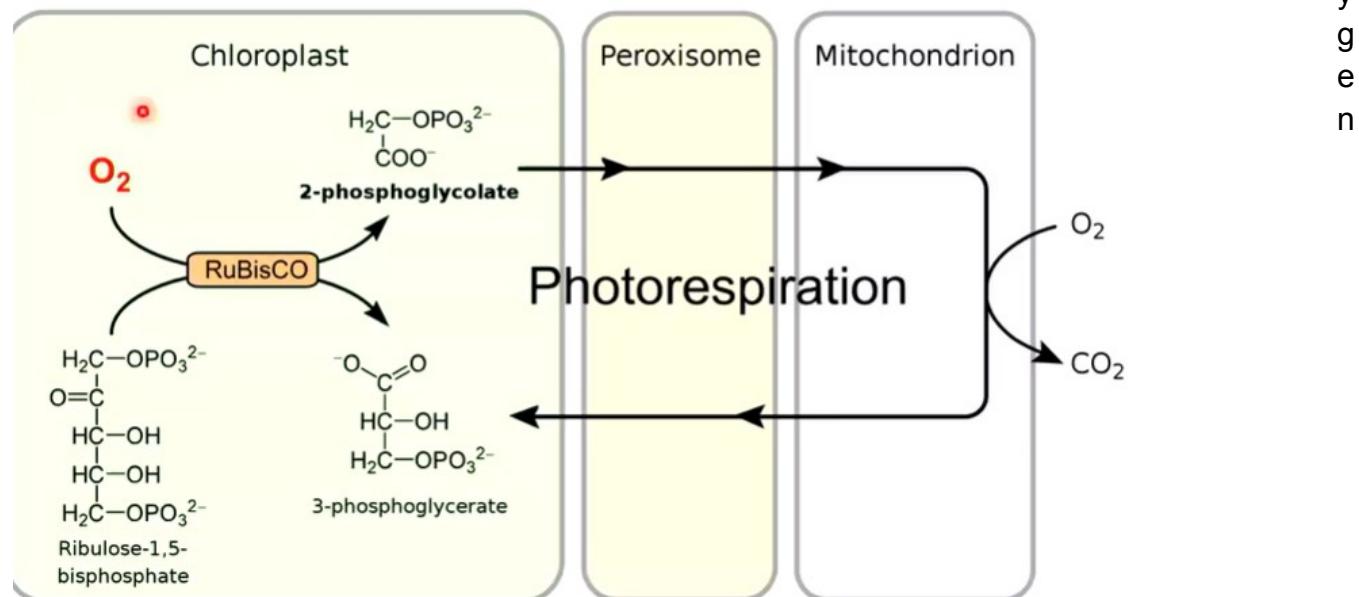


**Photorespiration** - when RuBisCo uses oxygen as a substrate instead of CO<sub>2</sub>



## Photorespiration

**(AKA C2 cycle or oxidative photosynthetic carbon cycle)**



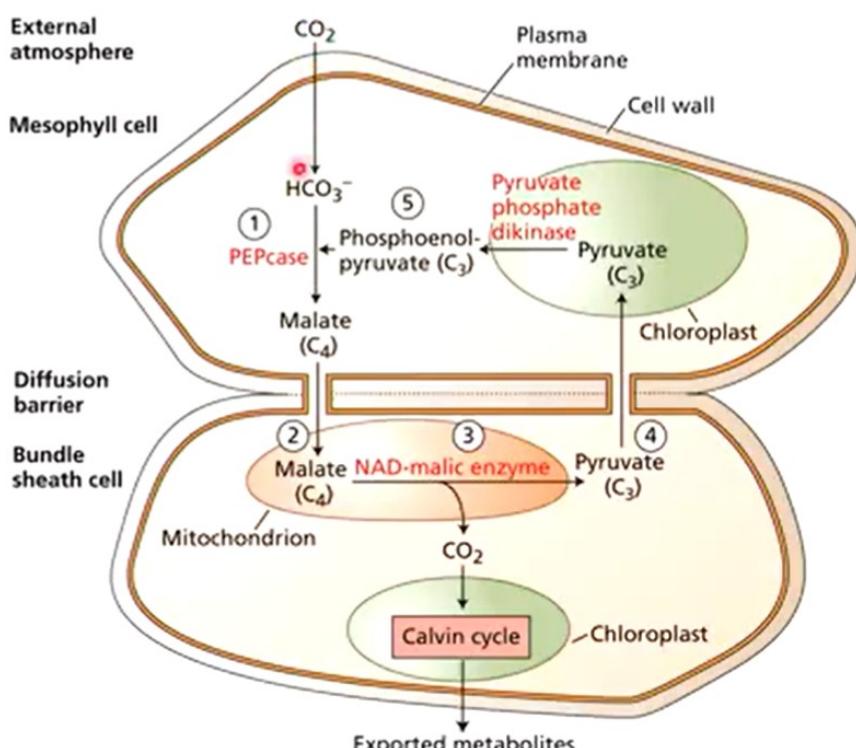
makes it toxic, thus needs to be detoxified (Net loss of  $\text{CO}_2$  bad for plant)

- $\text{CO}_2$  concentration dropping in earth's atmosphere creating C4 isotopes (photorespiration response)

### C4 Photosynthesis - solve photorespiration

- Series of metabolic + structural adjustments. **Concentrates  $\text{CO}_2$  around rubisco to help photosynthesis**

- Mesophyll turns  $\text{CO}_2$  into C4 Malate  
→ one  $\text{CO}_2$  knocked off to go into **calvin cycle** → turns into pyruvate and goes abc to cycle to recharge



## CAM Photosynthesis

- Open stomata at night, lose less water, CO<sub>2</sub> goes in and is stored
- In the light stomata closed, Rubisco saturated with the stored CO<sub>2</sub> to solve photorespiration

## 10 Respiration- 28/08/2025

### Aerobic Respiration



1. Glycolysis happens **outside** mitochondria
2. Krebs cycle happens inside mitochondria matrix
3. Electron transport chain uses inner membrane folds SA:V

### Glycolysis

Turns glucose (6 carbon), split into two 3 carbons (pyruvate), also spits out ATP + NADH

### Krebs Cycle

Pyruvate 3 carbon turns into 2 carbon **acetyl**, also spits out a bit of ATP

CoA picks up the acetyl since can't be used (Acetyl-CoA)

- When CO<sub>2</sub> lost, then NAD<sup>+</sup> takes the electron → NADH<sup>+</sup> by electron carriers
- **Thus: stripping electrons off in krebs cycle**
- **FADH<sup>+</sup> + NADH used for next step**

### Oxidative Phosphorylation

- Electrons from the krebs cycle used to be pumped out of matrix into intermembrane space.
- ATP pumped back in matrix via H<sup>+</sup> gradient electron transport chain
- Water is produced as oxygen enters H + O<sub>2</sub> → H<sub>2</sub>O
- Also creates ATP

### Mitochondria vs Chloroplast

Mitochondria	Same	Chloroplast
- Inner membranes	- Double membrane	- Stacks of thylakoid

for SA:V	bounded	things for SA:V
- NADH + FADH come from <b>glucose</b> to produce H+	- Compartmentation for proton gradient - High surface areas	- Energy comes from light - Splits <b>water</b> to pump H+

### Stopping ATP synthesis

- Channel on membrane allows H+ to go back thus cannot produce ATP
- O2 does not properly bind i think

**Alternative oxidase** - lotus can heat themselves up to retain constant temp. At low temps use a lot of oxygen to heat up

### Week 5 Lectures

#### 13 Metabolism- 1/09/2025

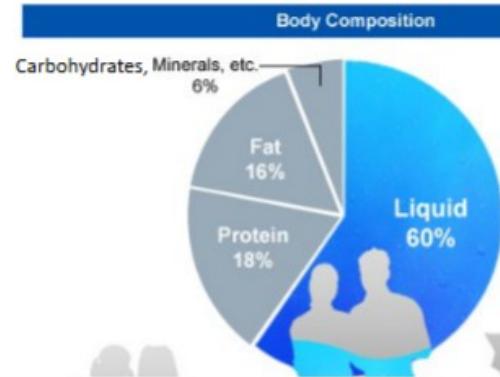
**Catabolic** - break down of molecules

**Vitamins** - co-enzymes sorta that help function

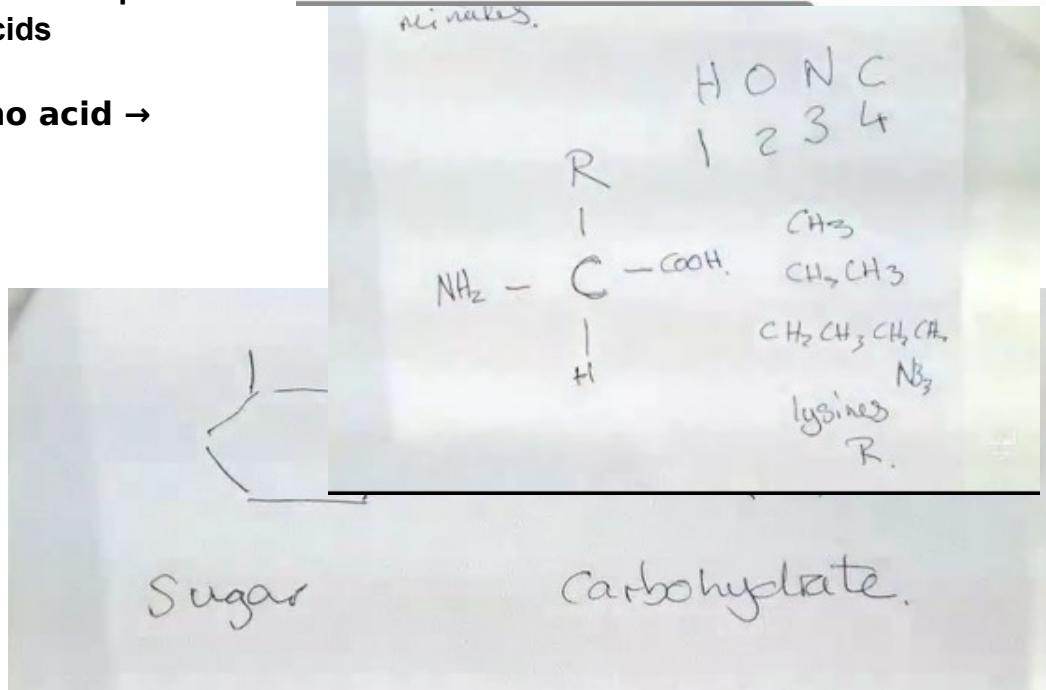
**Half-life** - how long it takes to break down to half concentration **for proteins**

We have **20 amino acids**

#### Structure of Amino acid →

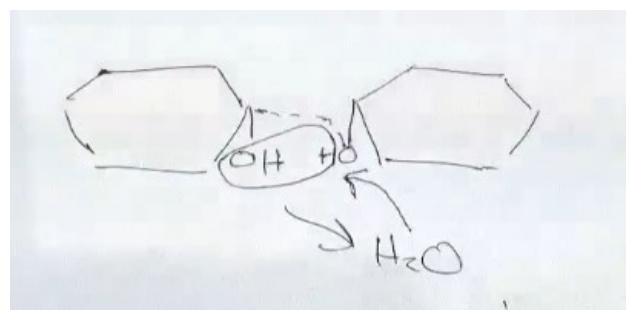


#### Sugar →



#### Dehydration

Carbohydrates have OH group, one from each detached and forms a water **catabolic reaction**.



Epithelium in intestines absorb **amino acids** not **proteins**

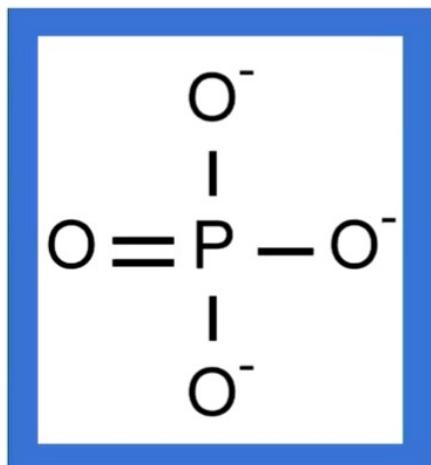
**Non- essential** - our body can make it ourself  
(e.g. can make the R group)

11 non essential and 9 essential amino acids

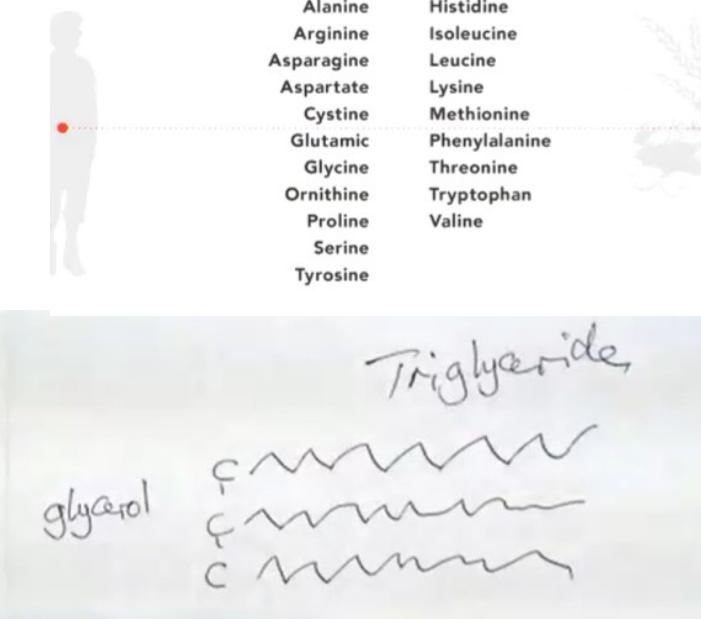
**Essential** - cannot make, so if we dont get the R group we diee

**Fat** - long hydrocarbon chain with R group?

Phosphate is a mineral micronutrient



Is phosphate hydrophilic or hydrophobic?

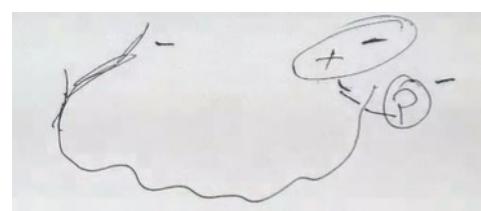
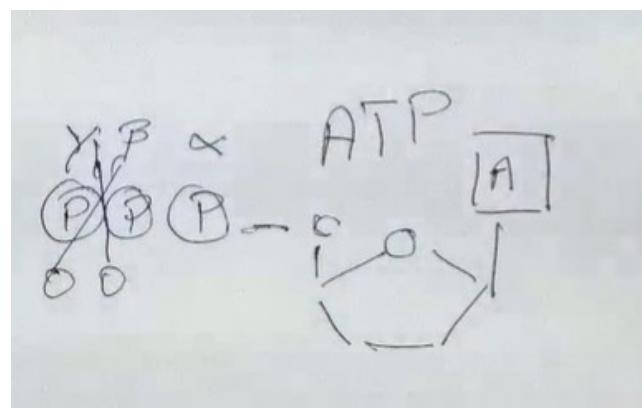


- The gamma phosphate in triphosphate is cut off to make diphosphate (recharged for ATP)
  - > Works via electromagnetic things e.g. the gamma phosphate is negative so when it leaves, the other 2 become neutral

**Fats, proteins and carbohydrates are invertible**

Carbohydrate → Pyruvate → Acetyl-COA

→ some become Ketone bodies via ketogenesis



→ Oxalic acetate (4 carbons) from mitochondria used in citric acid cycle, (4 carbons + 2 from Co<sub>2</sub> turn into 6 carbons citrate. **Essentially get out mitochondria**

-> goes out into cytosol

-> splits back into: Acetyl coa (2 carbons) and Oxaloacetate (4 carbons)

-> **2 carbons** from acetyl coa continuously joined with other hydrogens to make **fatty acids** (fatty acid synthesis)

## 14 Cell Diversity 3/09/2025

**Plasmids** - piece of DNA that can be exchanged.

> Used in prokaryotes like (reproduction)

- Peptides stack on top of each other to make layers (**Pepidoglycon cell wall**)

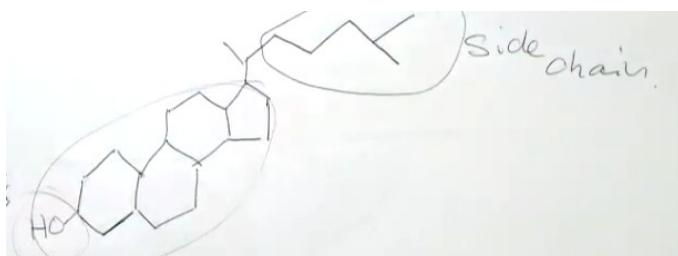
**Prokaryotes** - Single cell

**Bacteria** - Has peptidoglycan (sugar + amino acid lattice wall).

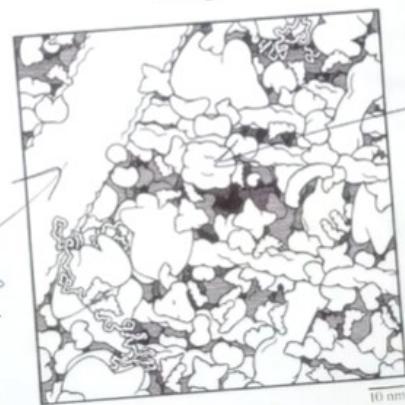
**Archaea** - does NOT have peptidoglycan as major part of cell wall, can live in extreme conditions (anoxic mud)

**All cells have a plasma membrane**

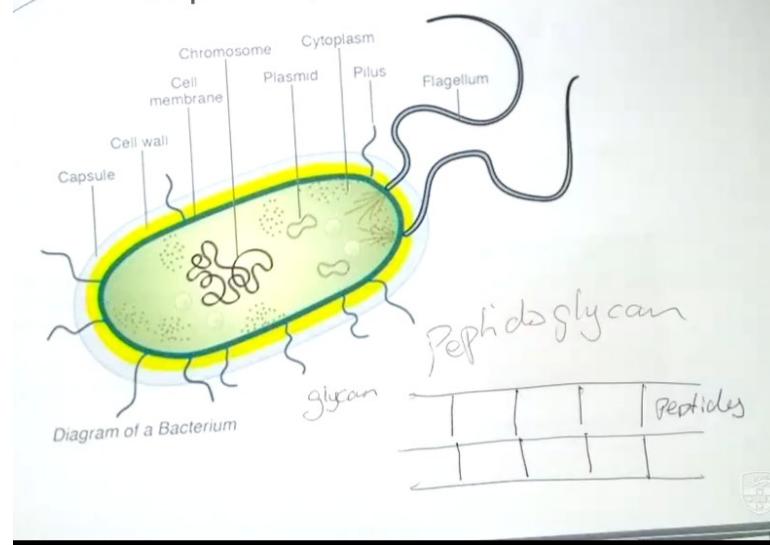
**Cholesterol Structure]**



A lot is missing from the often used diagram

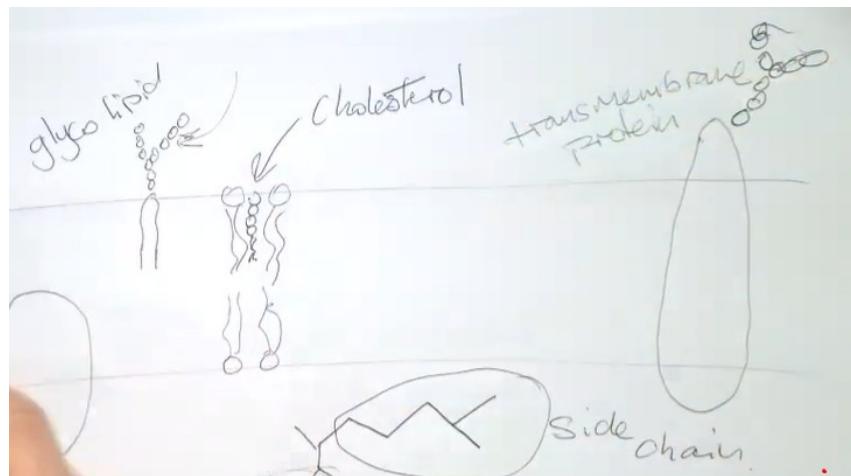


A prokaryotic cell



## Drawing structures in the cell membrane

- 4 circles + side chain = cholesterol
- The circles hanging off the glycolipid + protein is **polysaccharides**
- Hang on the **exterior** of the cell



## Why Oil + Water don't mix?

- Water repels oil
- Hydrogen is positive, oxygen is negative.

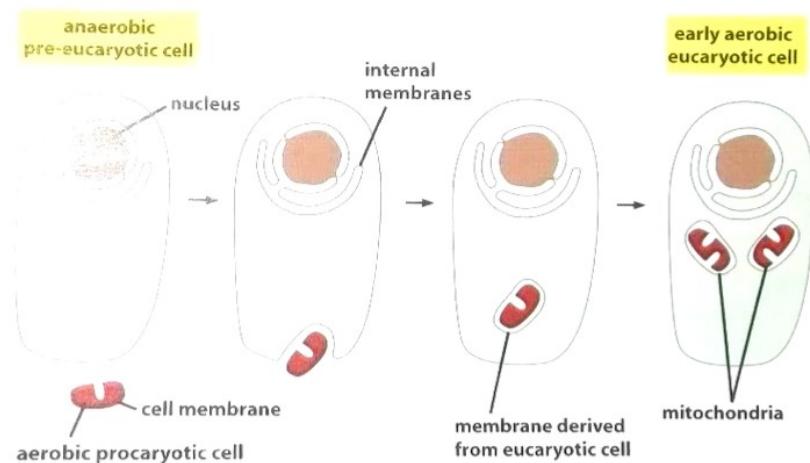
> Oxygen is more **electronegative**

thus, oil spends more time around oxygen than hydrogen

**Barriers** - organelles form barriers that allow for cells to **compartmentalise** for function + structure

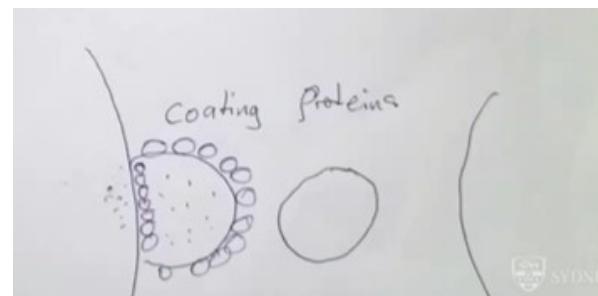
- Ancient eucaryotic cell had **no mitochondria** thus no respiration, energy, atp

## Evolution of the mitochondria



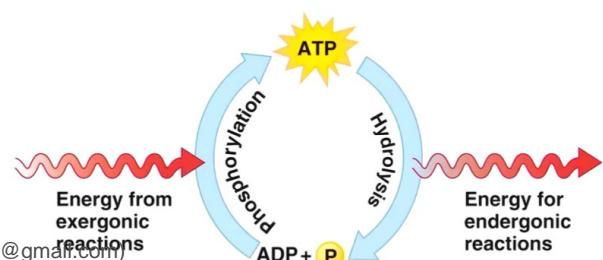
## 15 Compartmentalisation of cells 5/09/2025

Protein builds in the rough ER, builds up on the membrane inside the **vesicle** kept by the phospholipid bilayers → goes to other membrane



- **Capsule** = polysaccharide sugars outside the prokaryote

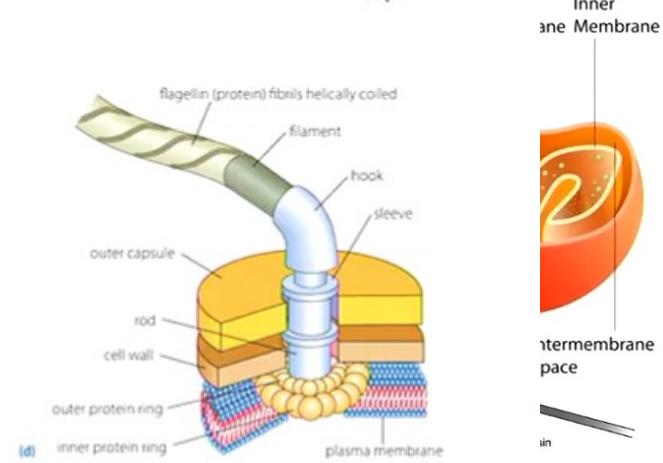
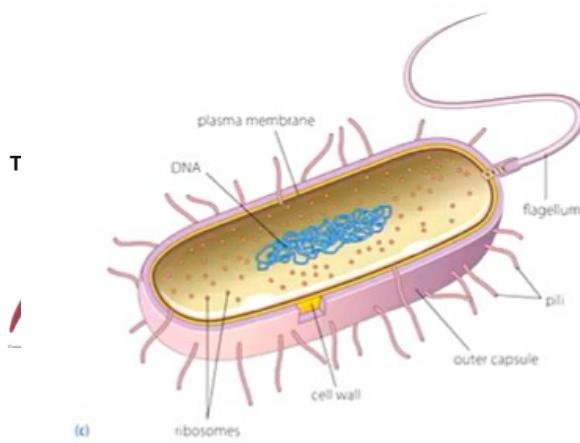
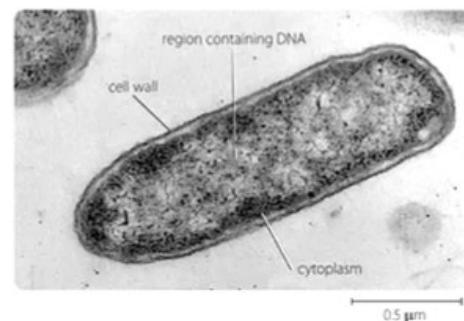
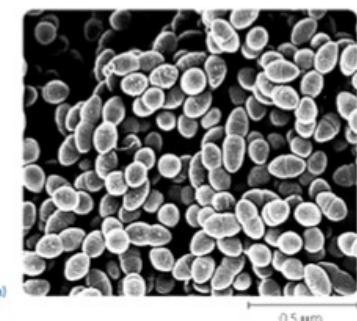
How does ATP power molecular machinery?



- ATP = via phosphate group linking and unlinking (has oxygen stuck on it)
- Endoergic reaction = transporting from membrane to membrane (using energy)

## Molecular machinery propels bacteria

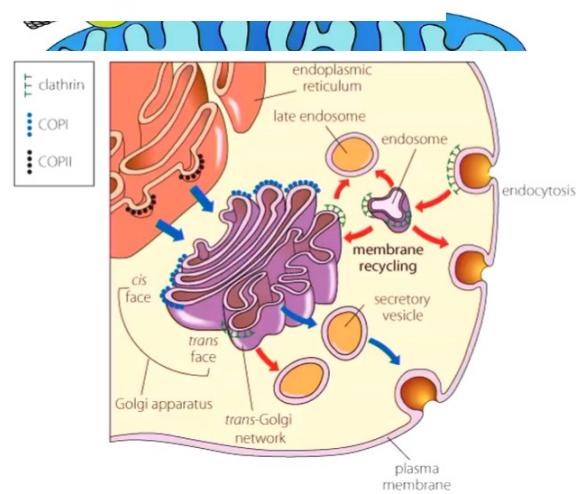
- C
- F
- M
- S
- M



## Mitochondria biological functions in mitochondria

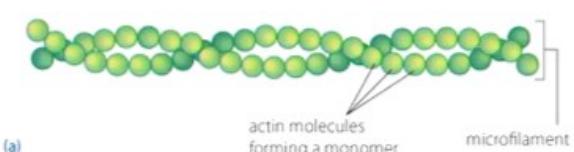
- ATP synthesis
- Steroidogenesis (production of steroid hormones)
- Apoptosis (cell death)

**Mitochondria attached to microtubules of cytoskeleton (allows for movement/provide energy)**



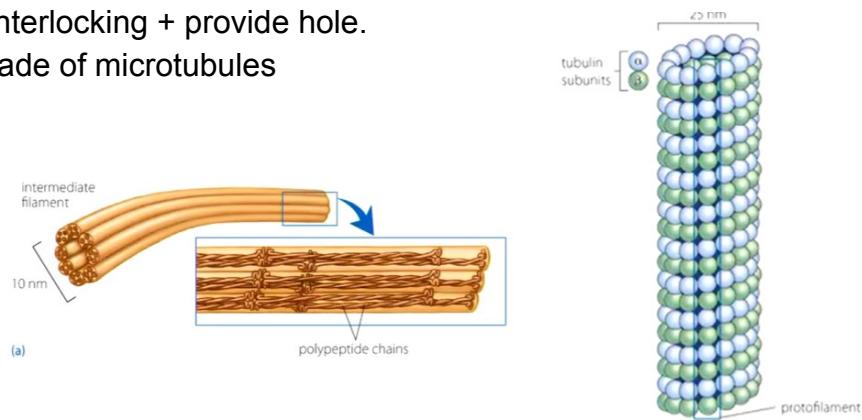
## Components of Cytoskeleton:

- Microfilaments (made of actin) *thickest*
- Microtubules (made of tubulin) *thinnest*
- Intermediate filaments (made of various proteins mostly keratin) *middle*
- **Allows for movement of protein vesicles to release in plasma membrane**
- Globular proteins → fibrous proteins in spiral shape (actin molecules)



- Alpha + beta cells in the microtubules
- Structured to become strong interlocking + provide hole.
- Spindles to carry things are made of microtubules

- Made of polypeptide chains
- Strong, allow for tension + pull, not as much as microtubule



### Movement across membranes

- Random movement across membranes
- **Osmosis:** water attracted to  $\text{Na}^+$  and  $\text{Cl}^-$  (some is also random)

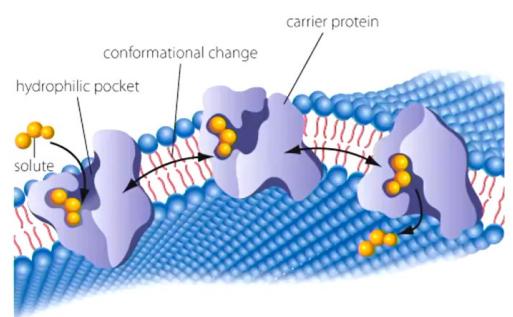
### Controlled channels

- E.g. voltage dependent channels in nerve cells (open changing potential)

### Powered transport

- Solute goes in  $\rightarrow$  phosphorylation (close up the top in turn making the bottom open)  $\rightarrow$  transport inside membrane)
- Powered by ATP
- Endocytosis + Exocytosis

### Powered transport



## Week 6 Lectures

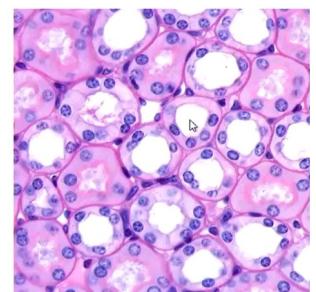
### 16 Cells, tissues and communication 8/09/2025

#### Types of Tissue:

- Epithelium
- Connective
- Nervous
- Muscle

#### Connective tissue

- Has: fibres, ground substances (salts, fluids), cells



#### Epithelium

- White hole (lumen)
- Basil laminar (borders that connect each other)

## Shapes:

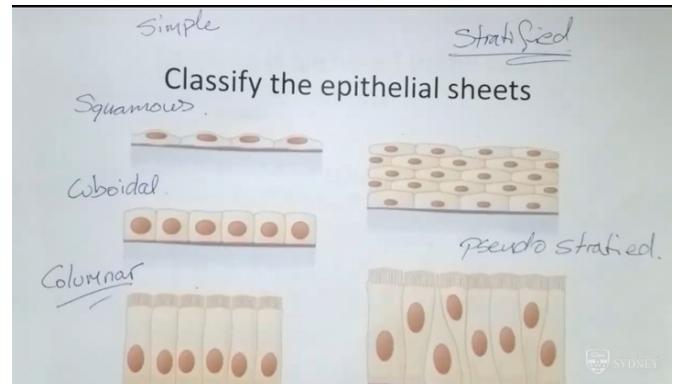
Single layers - **simple**

Multiple layers - **stratified**

**Basal**- bottom

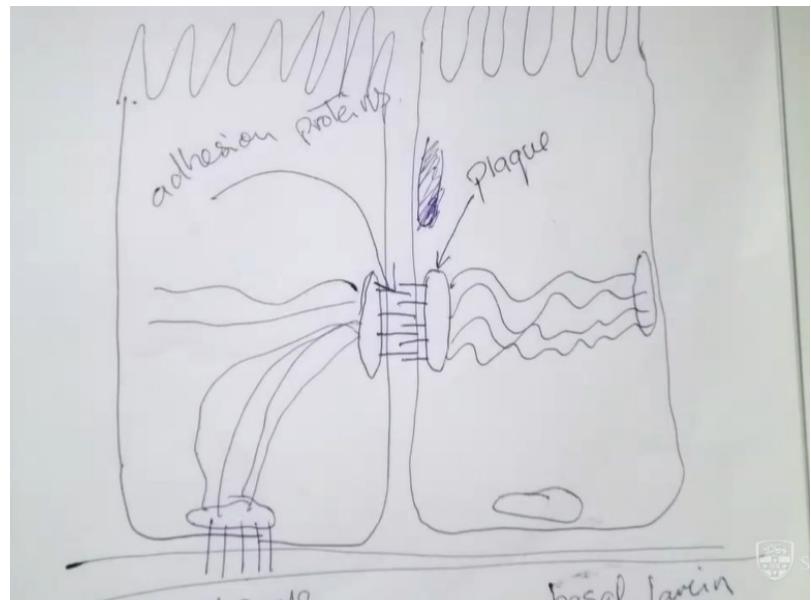
**Apex** - top

**Desmosome** - holds junctions together of a cell if there is a rip.



**Plaque** - adhesion of the tissue together embedded,-

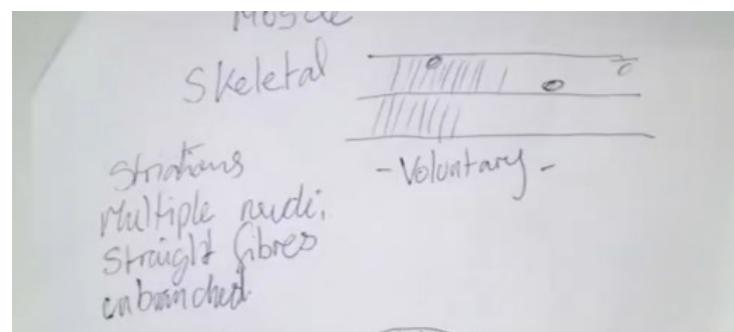
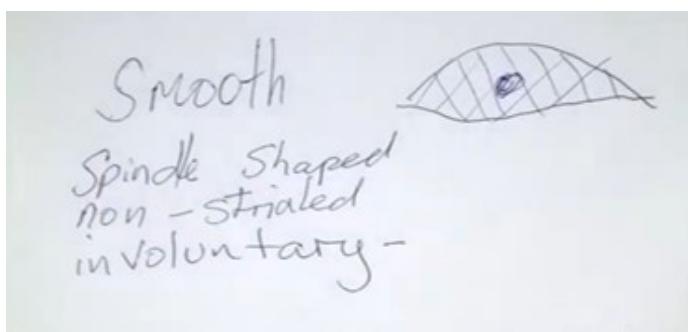
- Attached to other desmosomes via **intermediate filaments (cytoskeleton)**
- As it goes down into bloodstream
- Apical region**
- Basil lamina can hold back malignant (cancerous cells) for awhile. Over time, warts (benign) can turn cancerous



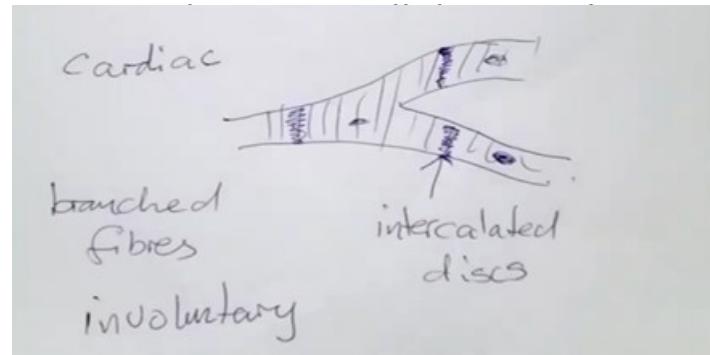
**Connective Tissue** - (non-living part called matrix)

**Muscle tissue** - stripes caused by actin + myosin

> Not in smooth muscle + cardiac since they are in cross pattern



- Different ways to trigger response in cells (receptors outside/inside)
- Steroid will always make protein
- Cell signals (can act on surface of the cell and its function, trigger enzyme) OR can act inside the DNA itself



**Neurotransmitter** - channel opens up, sodium comes **inside**

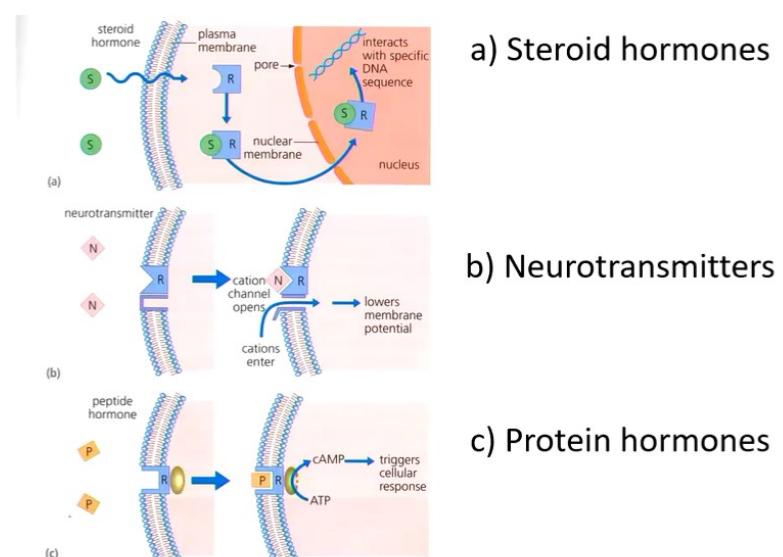
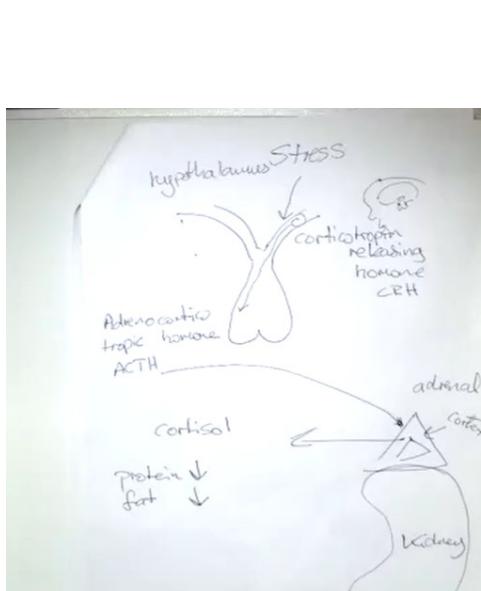
**Steroid hormones** - Enzymes bound with substrates inside **plasma membrane** → travels inside **nucleus** → interacts with **DNA**

**Protein Hormones** → ATP, has 3 phosphate tails, denison **cuts alpha and beta phosphate** (cAMP cyclic AMP) →

- Kinase phosphorylates protein (**allows for cell to be signalled**)

**Signals** e.g. stressed

Stress → Hypothalamus (release corticotrophin hormone) → release ACTH → reacts to the adrenal gland (above kidney) → release cortisol (decrease protein/fat to decrease stress)



## Week 7 Lectures

### 19 Microbiology and the 'One Health' Concept 15/09/2025

#### Viruses

- Smallest simplest entities, depend on **host cells** for replication + metabolism
- > Acellular, DNA or RNA in protein shell
- > Small size + genome but huge impact on ecosystems

#### Bacteria

- Unicellular structure  
> Prokaryotes?
- Smallest **cellular organism, complex**, self replicating (**binary fission, DNA doubles and split in membrane**)  
> Own metabolism
- Primary producers + decomposers

#### Fungi

- Large complex cells (eukaryotes)
  - > Membrane bound nucleus, complex organelles (mitochondria, golgi apparatus (not in bacteria))
- Unicellular and multicellular (molds + yeast)
- Microscopic + macroscopic stage (spores + fruiting bodies mushrooms)

## Protists

- Large complex cells (eukaryotes)
- 'Others' (huge diversity), complex morphology, evolution and lifestyles
- Photosynthetic (create own energy) OR predatory (protozoa), feed off others

## Algae

- Eukaryotic + prokaryotic
- Photosynthetic
- Complex structure

## "Cells"

- 1664 by Robert Hook
- Microscopic structures of blue mold at 30x, first to use the word 'cell'

## Bacteria + Protists

- 1684 by Antonie
- Developed powerful microscopes (300x), first evidence of above ^ + microbes everywhere, considered 'father of microbiology'

## Louis Pasteur

- Pasteurisation, disproved that **life cannot be formed from nonlife**
- Swan neck bottles allow oxygen but **No** microbes, disproved spontaneous generation

## Spontaneous Generation

- 1700s by John Needham, a "life force" in all matter causes spontaneous generation (using chopped hay boiled in water to sterilise + covered with mesh, then microbes inside (cloudy))
- Further proved by Lazzaro (covered both bottles first to prove anaerobic environment does not let things grow until one opens (oxygen = growth))

## Robert Koch

- Used potato slices as agar plate media (isolate colonies)

## Germ Theory Disease

- 1880s by Koch, microbes are the causative agent of disease (unknown at the time)
  - > Developed Koch's postulates, rivals Pasteur before

## Koch's Postulates

1. Must be found in all cases of disease (**find in host**)
2. Be isolated from disease host in pure culture (**remove and grow from host**)
3. Produce same disease in experimental infected host (**infect same disease in new person**)
4. Be re-isolated from the experimentally infected host (**isolate the same pathogen from new person**)

## Penicillin

- 1928 by Alexander Fleming
- Accidentally found mould growing that killed the bacteria (*Staphylococcus*), found that the 'mould juice' killed many bacteria.
- *Mass production of Penicillin helped in WWII*

## Normal flora

- Live on us, called **microbiota**, not really harmful help us
- Specific sites have different populations, specialised for different functions of organs
- Mostly bacteria
- Change on mood, lifestyle, food, etc

## Microbiota benefits

- Primes immune system, nutritional benefits (starch > glucose), competes with pathogens

## Drawbacks:

- Disease, wrong location, conditions change (cause acidic environment decay)

## Transient Microbe (temporary)

- contacts with surfaces, people, animals
- Can cause infection if not removed (hygiene/open wound)

## Pathogen

- Microbes that cause disease
- 2 types:
  - > Obligate: ALWAYS cause disease
  - > Opportunistic: cause disease under specific condition (e.g. large numbers, wrong location, host health, antibiotic resistance)

## One Health

- Consider animals, plants, environments when trying to manage human diseases

## Infectious disease today

- Emerging due to **new pathogens**, new problems with old pathogens

## Cholera Disease

- Vomiting from water source bacteria virus, John Snow map!!

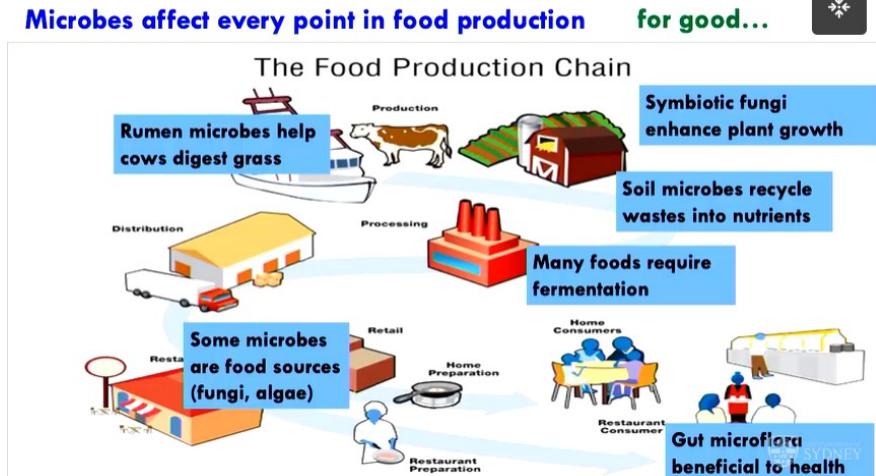
## 20 Microbes, food, and nutrition 17/09/2025

### Food supply is complex -

security, environment, weather, location

### Enhancing food production - in plants

- Microbes maintain soil health by:
  - > Fixing nitrogen (N<sub>2</sub>)  
→ NH<sub>3</sub> Ammonia
  - > Break down organic waste into inorganic nutrients (carbon, nitrogen, sulphur, phosphorus)
- Suppress animal + plant pathogens, breaking down toxins
- **Microbes promote plant growth via mutualism:**
  - > both parties benefit
  - > Mycorrhizal fungi (in most plants), enhance water + inorganic water uptake (fungi uses enzyme to transport unusable nutrients to usable, sugars after plant can use them is used by the fungi)
  - > Rhizobium bacteria (in legume roots), fix nitrogen, receive sugars in return



### In animals:

- Microbes enable animals to digest **cellulose**:
- Cellulose (sugar polymer) abundant in plants + carbon rich, difficult to digest
- **Rumen** microbes break down cellulose → sugar → organic acids → CO<sub>2</sub> → CH<sub>4</sub> (methane) but greenhouse gas.
- Organic acids + microbial cells digested by animals as nutrients

### Plant pathogens

- Fungi + viruses main problems
- TMV (tobacco mosaic virus →
- Cavendish bananas are **clones**, no seeds identical thus all susceptible

- Why is TMV a successful pathogen?
1. extremely stable
  2. spreads easily without needing vectors
  3. infects many plant species, and
  4. efficiently replicates without rapidly killing the host.

## Animal pathogens

- Viruses, bacteria, fungi or protists e.g. "foot and mouth" virus

## Zoonosis: human infection arising from animals

- E.g. rabies, human pathogen may be normal flora for animals (e.g. salmonella bacteria)
- Covid had a potential zoonotic origin, (bats to animals (pangolin) to humans)

## Fermentation:

- Brewers yeast (eukaryote fungi that can create budding to make copies)

## Microbial food spoilage:

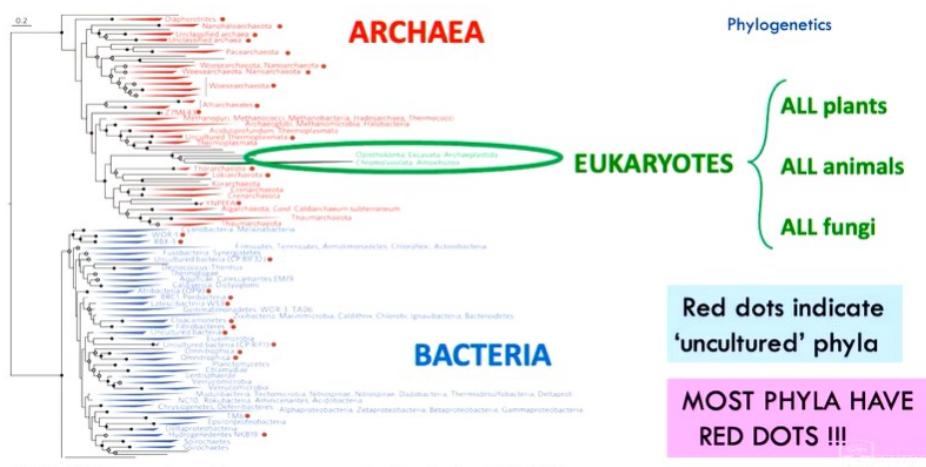
- Refrigeration, preservatives + fermentation can save.

## Food poisoning = infection/intoxication

- Food-borne infectionL microbes grow in gut (salmonella bypasses stomach acid and grows)
- Food-borne intoxication: microbes make toxins in food (bacteria dies in stomach acid but fragments (cell wall toxic and is absorbed in the body)

## 21 Microbes and the Ecosystem

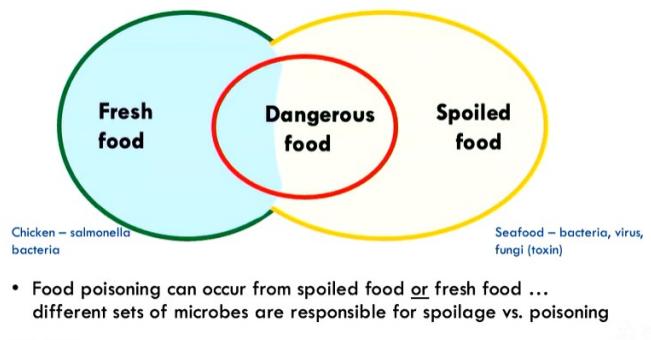
### "The wonders and realities of the universe"



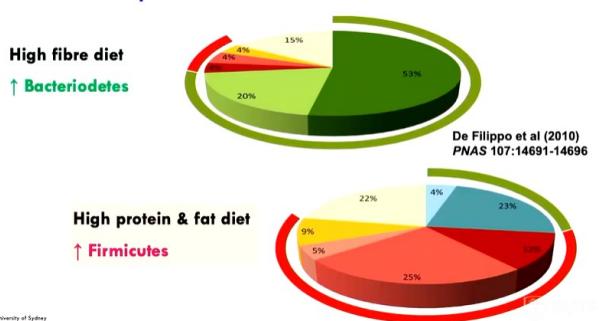
light as energy

*Chemoautotrophs* = use chemicals as energy

### Food spoilage vs. food 'poisoning'



### Gut microbiome depends on diet



19/09/2025

Most body reactions done by microbes

**Autotrophs in the carbon cycle - Algae**

- Self feeder, use CO<sub>2</sub> as source

*Photoautotrophs* = use

**Methanogens** - Consume CO<sub>2</sub> + H<sub>2</sub> to produce methane (CH<sub>4</sub>)

These are chemoautotrophs as the CO<sub>2</sub> is their carbon source and H<sub>2</sub> is their energy source

- Impacts on climate change: Uses CO<sub>2</sub> so decrease CO<sub>2</sub> (good) but produces CH<sub>4</sub> (BAD)
- Anaerobic, breathe in CO<sub>2</sub> + breathe out CH<sub>4</sub>

### Heterotrophs in the Carbon cycle - Methanotrophs

**\*\* NOTE** troph = eat. Metanotrophs = eat methane

Consume CH<sub>4</sub> to produce CO<sub>2</sub>.

- Use CH<sub>4</sub> as carbon source + energy

### Decomposers

- Feed off other organisms (e.g. fungi), recycle to make CO<sub>2</sub> which is BAD

### Predators

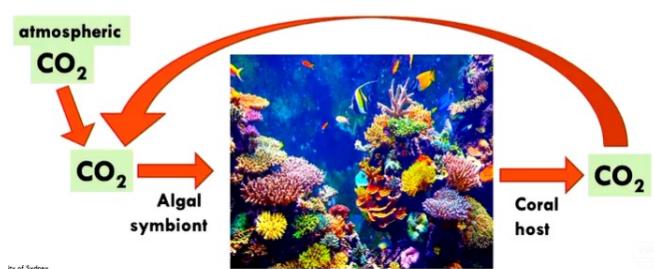
- Protists are predators of other microbes (e.g. amoebae)
- Not all protists are predators, some are detritivores (e.g. scavengers), others are photosynthetic

### Pollutant Degraders

- Methanotrophs = bacteria that use hydrocarbons as carbon + energy source
- Hydrocarbon-degrading bacteria (include methanotrophs), useful for bioremediation (cleanup of pollution by microbes)
- **Similar to decomposers** but are highly specialised

### Auto/Heterotroph interactions - Coral symbiosis (mutualism)

- Corals are primitive animals, depend on **symbiotic** microscopic algae to supply them with food
  - > **Algae**: photoautotrophs, convert CO<sub>2</sub> + light → sugars
  - > **Coral**: Heterotrophs, convert sugars → CO<sub>2</sub>

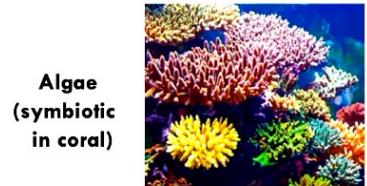
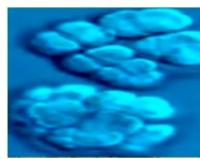


### Lichen symbiosis

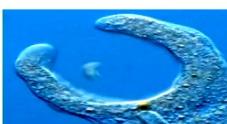
- **Lichens** = primary producers in terrestrial habitats (dry)
  - Photosynthetic but **NOT PLANTS**

- Symbiosis between heterotrophic fungus + autotrophic algae

### Summary of microbial autotrophs in this lecture



### Summary of microbial heterotrophs in this lecture



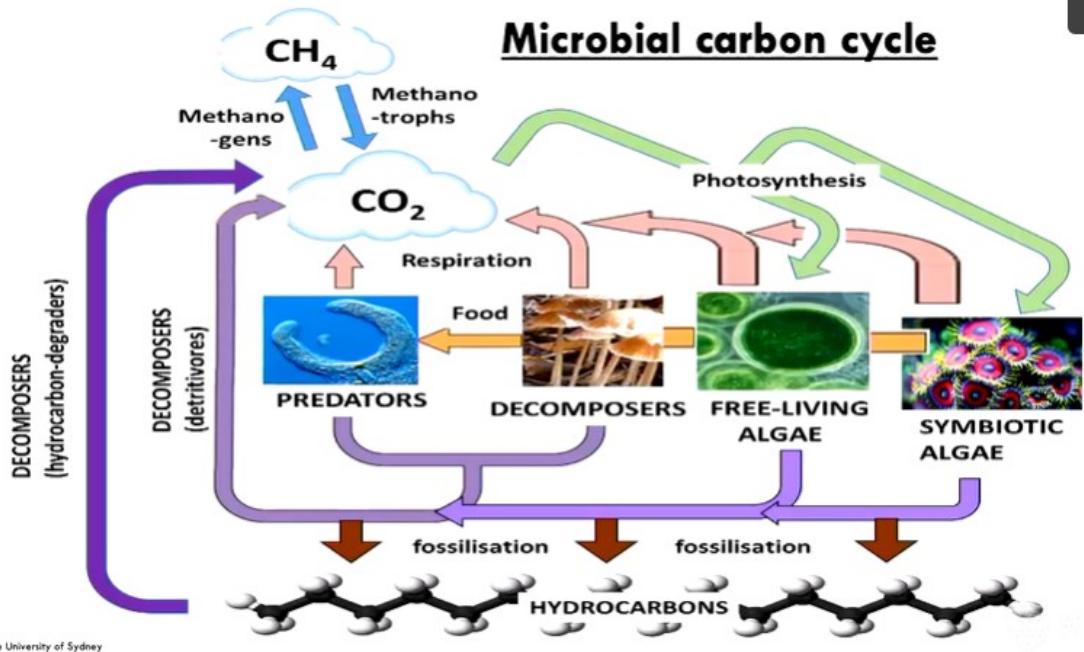
Predators: protozoa

Hydrocarbon-degraders

Lichen (host fungus)

The University of Sydney

### Microbial carbon cycle

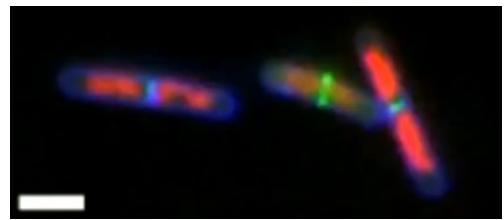


The University of Sydney

### Week 8 Lectures

#### 22 Cell Factories and Biotechnology 22/09/2025

Z-ring in bacteria (membrane split in blue)



Biotechnology used in

- Food, medicine, drink, agriculture, fuel, cleaning

#### Traditional biotechnology - Fermentation

- Leaving wine out/ food in cold (freezing fish),

#### Cellular biotechnology - whole cells

# Molecular biotechnology - cell mechanisms

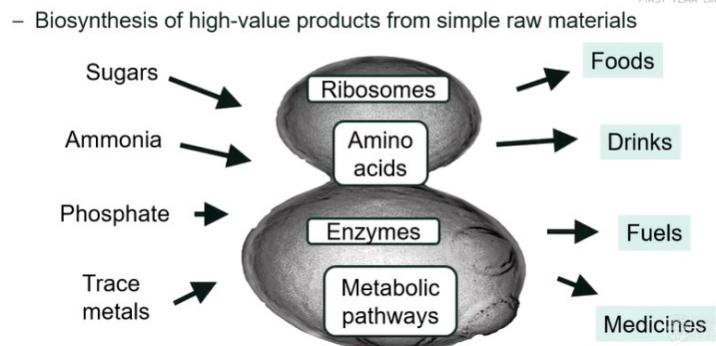
## Microbes for Biotechnology

- Virus
  - > Vectors: carry genes
  - > Source of enzymes (T4 ligase) to join the DNA
- Archaea
  - > Diverse living conditions
  - > Source of enzymes (Thermostable polymerases for copying DNA sequences PCR)
- Bacteria
  - > Hosts for cloning DNA (fast + not lot of resource)
  - > Expressing proteins
- Algae
  - > Green biotechnology (CO<sub>2</sub> + light into ethanol + H<sub>2</sub> gas)
  - > Low maintenance, biofuels, carbon negative (takes C from external env and converts it into ethanol GOOD)
- Fungi
  - > Yeasts (excellent for cloning + similar to bacteria)

## Host cells

- Bacteria is fast growing, very easy to extract + add plasmid DNA  
**prokaryotic not safe**
- Yeast (bread + beer), body more acceptable to yeast (food grade safe), can express **eukaryotic** genes

## Host Cells



## Vectors

- Deliver DNA (generally foreign)
- Plasmids (circular DNA in microbes can replicate independently of chromosomes)
  - > Naturally found + can help with antibiotic resistance

## Key features of Plasmid

- Selectable gene marker, replication function, cloning site (for manipulation)

## Molecular cloning

- Making copies of biological entity
- Follows 3 steps: 1. Recombinant DNA preparation. 2. Transformation + screening, 3. Copying + expressing

## 1. Recombinant DNA preparation

- Foreign DNA + plasmid vector
- Identify gene of interest (e.g. Green fluorescent gene from jellyfish)
  - > digest DNA with enzymes + cut it using enzymes

## 2. Transforming + Screening

- Transformation (host cell picks up recombinant DNA)
- Screening (selectable gene marker to see which one of the millions have taken up the plasmid)

## 3. Copying and Expressing

- Copies of organism/ DNA (express molecules or proteins)
- Cloning site to induce growth
- PCR to replicate DNA
- **Express foreign protein** (e.g. vaccines/ enzymes)
- **Purification** (if want to extract the gene that was replicated)

### Result: GMO

- GFP is protein
- Risks: antibiotic resistance of gene transfer into pathogens, legal constraints

### Vaccines

- Recombinant product
- *Herd immunity*: if most of the population has taken vaccine, those who haven't are still safe
- Adaptive immune response that recognises antigens
- Consist of:
  - > Live, dead, antigens,mRNA codes for antigens

### Other 2 this week practices (check again in study week)

### Week 9 Lectures

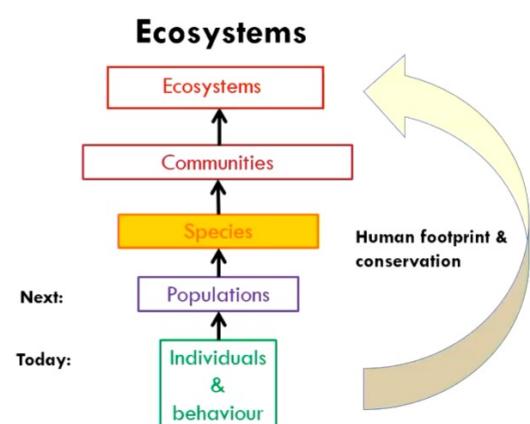
#### 23 Individuals, behaviour and environment

10/10/2025

**Ecology** - study between living organisms (including humans), and the physical environment.

### Behaviour

- Classically about animals
- Coping mechanism = (morphology + physiology + behaviour)



- Behaviour = part of how organisms respond to biotic + abiotic environment
- E.g. skull morphology, guts + flora (wolves have sharper teeth than koalas)
- In behaviours: foraging strategies, social behaviours, communication

### **Behaviour in relation to abiotic environment:**

- Lizards digging underground to reduce heat exposure in desert

### **How behaviour affects fitness?**

- Fitness = individuals relative contribution to next generation's gene pool
- E.g. butterflies, does food quality impact fitness. Resulted in how many eggs laid
- Shown that high quality had more eggs but no significant difference for adults vs larvae stage
- If male does not attract female, then fitness = 0

### **Behaviour is:**

- Ecologically significant because of
  - > Is a link between individuals + their environment
  - > Affects demographics (population level outcomes)
  - > Affects interactions among species (community-level outcomes)
- Evolutionarily significant because:
  - > Has some genetic basis (nurture vs nature)
  - > Affects fitness
  - > Can be selected (benefits > cost)

### **Behaviour: 3 key aspects**

1. Obtain food
2. Avoid becoming food
3. Reproduce

#### **1. Behaviour: obtain food**

##### *Optimal foraging theory*

- Modelled which food items to eat in non-depleting environment
- Predicts foragers should **maximise net rate of food (=energy) intake**
- Foraging strategies linked with predator avoidance strategies for prey

#### **2. Avoid becoming food**

##### *Feed in safe places*

- Run away, group, hide
- Act costly (dangerous/toxic organisms), be costly (have spines, poison frogs), feed in safe places (vegetation cover)

#### **3. Reproduce**

- Male-male competition, female choice
- Results in non-random mating + offspring, important related concept: sexual selection
- E.g. peacocks, high cost for tail + maintenance, risk of predation however, could be good for attracting females

#### *Parental care*

- Benefits: survival + growth of offspring = fitness
- Costs: missed opportunities (to reproduce again)

## Do only animals behave?

No, all things have behaviour (including plants)

- E.g. growing around light stimulus/ roots growing to more nutrient dense areas

**Behaviour:** Can occur in abiotic/biotic environments, does not require a brain, involves a stimulus + response

e.g. foraging behaviour?			
Forager	Brushtail possum ( <i>Trichosurus vulpecula</i> )	Thick-tailed bushbaby ( <i>Otolemur crassicaudatus</i> )	Slime mold ( <i>Physarum polycephalum</i> )
Food quality	Variable (leaves, fruits)	Variable (fruits, invert)	Variable (bacteria, yeasts, fungi)
Environment	Variably risky (predators)	Variably risky (predators)	Variably risky (dry, light)
They move?	Yes	Yes	Yes
Have a brain?	Yes	Yes	No



## Week 10 Lectures

### 24 Groups and Populations 13/10/2025

**Groups** - multiple organisms of same/diff species occupying common space

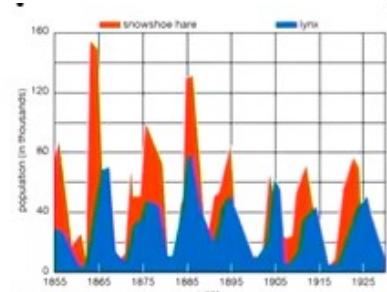
- Ephemeral/consistent
- Social (positive grouping), indirect (sharing common resource), or accidental (random chance)

**Populations** - Number of organisms of **same species** in defined geographical area

- Include: **number of individuals/population size**, area they occupy, age structure, sex ratio
- Play a central role in understanding factors that shape + drive diversity of life
- **Composition + structure are influenced by life history, mobility + habitat**

**Populations are essential for:**

- Ecology: distribution + abundance of individuals + density
- Evolution: population of organisms evolve, gene flow
- Conservation + management: invasive species, defining threat status of taxa, translocation + restoration



## Importance of population biology

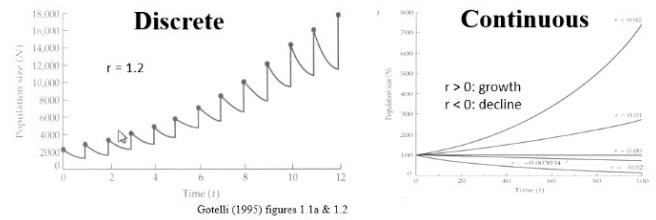
- Understand temporal dynamics of populations
  - > e.g. snow hare + foxes. Fox population increase following snowshare decrease
- Understand spatial distribution of populations

## Population growth

- Can be negative/positive growth

## Exponential growth

- Exponential = geometric, population grows faster as it gets bigger
- Dynamics overtime depend on life history of organism
  - > discrete - reproduction occurs periodically
  - > Continuous - reproduction occurs year-round
- R = instantaneous growth rate

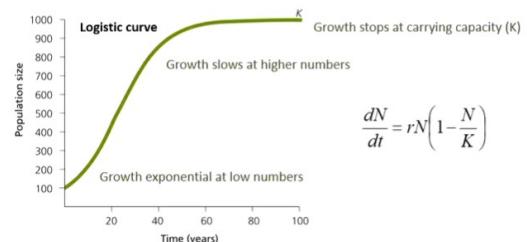


## Resource limited growth

- Population growth is often resource limited (food, space, water, nesting sites)
- Numbers cannot increase without bound
- E.g. lecture theatre has limited seats, if more and more keep coming it reaches a peak

## Resource limited growth

- Population growth is often resource limited (e.g. food, space, water, nesting sites...)
- Numbers cannot increase without bound



## Demographic rates

Variables that drive changes in population size:

- Birth + death
- Emigration, immigration, growth, age, sex ratio

## Birth and death rates

- Fundamental to population growth
- Balance between additions (births) + losses (deaths)
- Inherent to all types of population growth models

## Population growth in ‘closed’ system

- **Population growth rate** = changes in num of individuals over time
- In “closed”, no changes

## Estimating births

- Common methods: histology of reproductive organs, capture + counting of fertilised gametes, **counting of newly born individuals**

### **Estimating death rates (mortality), more challenging**

- Common methods: follow individuals (for sessile organisms), probability based

### **Population growth in ‘open’ systems**

- Moving to other systems (e.g. students moving/leaving lecture theatres)

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

### **Estimating demographic rates - migrants**

- Movement (tagging recapture, GPS)
- Population genetics, changing ratio of genetics in an area

### **Estimating population size**

- Mark release recapture MRR)
- Uses **proportion** of recaptures to estimate whole population size
- Assumptions often hard to satisfy: closed populations

### **Estimating growth + age**

- Trees - tree rings
- Perennial plants - rings in the tap root
- Mammals - teeth (e.g. grey-headed flying fox) (teeth rings when cut)
- Fish - otoliths (ear bones with rings similar to trees)

### **Understanding age + size structured population dynamics**

- Age + size affects probability of giving birth + survival
- Treating all members of population as identical = unrepresentative of natural structure

### **Spatially structured populations**

Metapopulations: local population where individuals move, but won't die unless metapopulation dies (extinction)

## **Lecture summary**

- Populations are groups of organisms of the same species in a defined area
- Biotic and abiotic factors can influence the processes of population change: birth, death, immigration and emigration
- Populations can be “closed” if they primarily change only by birth and death processes or “open” if immigration and emigration are also important in affecting changes in numbers
- Populations may grow exponentially at first but as resources become limiting, growth slows until they may reach the carrying capacity. Such growth is typically described by a logistic curve
- The age / stage structure of a population affects population growth
- Population viability analysis is a tool that can be used to determine the long-term vulnerability of a species to extinction under a variety of scenarios

## **25 Do Species Matter? 15/10/2025**

### **What are species?**

“Groups of actually or potentially interbreeding natural populations, which are reproductively isolated from other such groups”

- E.g. groups of organisms that can breed together (if they can't, not same species)

### **Biological species concept**

- Many species “hybridise”, some can produce viable offspring
- Concept is hard to apply for asexual organisms + organism fossils

### **Other species concepts**

- Phylogenetic species concept (differ in genetic/DNA)
- Ecological species concept (differ in ecology)

### **Do species matter? - YES**

- Strong historical precedents, are central to biodiversity conservation (**species, genetic, community + landscape**) are most commonly accepted types of biodiversity

### **Case study: the dingo**

- Differs in morphology, ecology, behaviour + genetics than dogs
- Can interbreed with domestic dogs + grey wolves
- Management defines dingos as **separate species**

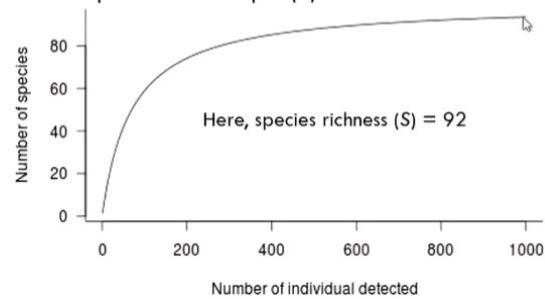
### **How do we count the number of species? Consider:**

- Area sampled, which kinds of organisms will be counted, methods (count, traps, camera), time of day, season, weather

### **Species diversity indexes**

- Berger-Parker index:
  - **Environment A:**  $1 - 91 / 100 D = 0.09$
  - **Environment C:**  $1 - 10 / 100 D = 0.9$
- **Alpha diversity** - species diversity at each site (e.g. site A has 10, site B has 5, site C has 10 of species richness)
- **Beta diversity** - how many species are in one environment compared to another (e.g. presence of how many diff species in A and B)

- **Gamma diversity** - How many types of species in the environment (12 types of lollies)
  - Species richness = number of species in a sample ( $S$ ):
- Increases sharply as we begin to count species, starts to decrease in growth as we get the same ones
- Lots of species of organisms still to be described/discovered



## Lecture 25 summary

- Despite some difficulties in defining species, the biological species concept is widely understood and used
- Species matter! And so do the taxonomists who discover and describe species
- Counting species requires us to define the area, the time and methods that we will use to achieve reliable counts
- As a general rule, the harder you look, the more species you will find
- Species richness and species diversity provide useful means of comparing species complements over time, space and between areas
- Most species in local, regional and continental areas, and on Earth, are bacteria – think of the gut microbiome

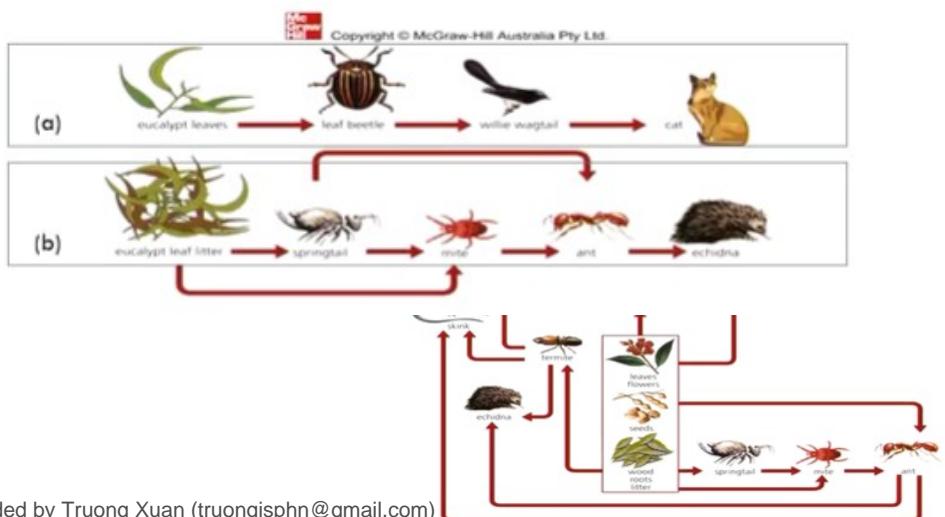
## 26 Trophic Ecology 17/10/2025

### How do Organisms get energy/nutrients?

1. **Autotrophs** - make own food
2. **Heterotrophs** - consumers, gets from other animals

### Food chains

- Describe energy flow between organisms among trophic levels
- First = autotroph
- All ones after = heterotrophs
- Primary consumer  
→ secondary consumer → tertiary consumer

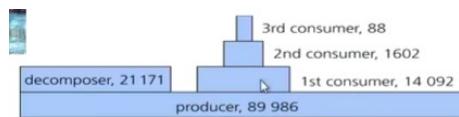


## Food Webs

- Describe more complex interactions

## Food chains are usually short:

- Less energy going since the consumers must use energy (waste)



## Why are food chains short?

- Hypothesis 1: the energy hypothesis
- Experiment shows that high numbers of producers can improve the no. of trophic links/species
- Hypothesis 2: the dynamic stability hypothesis
  - > More STABLE producers make longer food chain

## Ecological interactions

- **Symbiosis:** interactions between organisms that live together in close proximity, usually long period of time with at least one organism benefiting
  - > e.g. mutualism (2 organisms benefit), commensalism (1 organism benefits)

## Mutualism (+, +)

- Obligate mutualism (NEED); partners can only survive together
- Facultative mutualism (WANT); partners gain benefits from associating, but can survive on their own

## Competition (-, -)

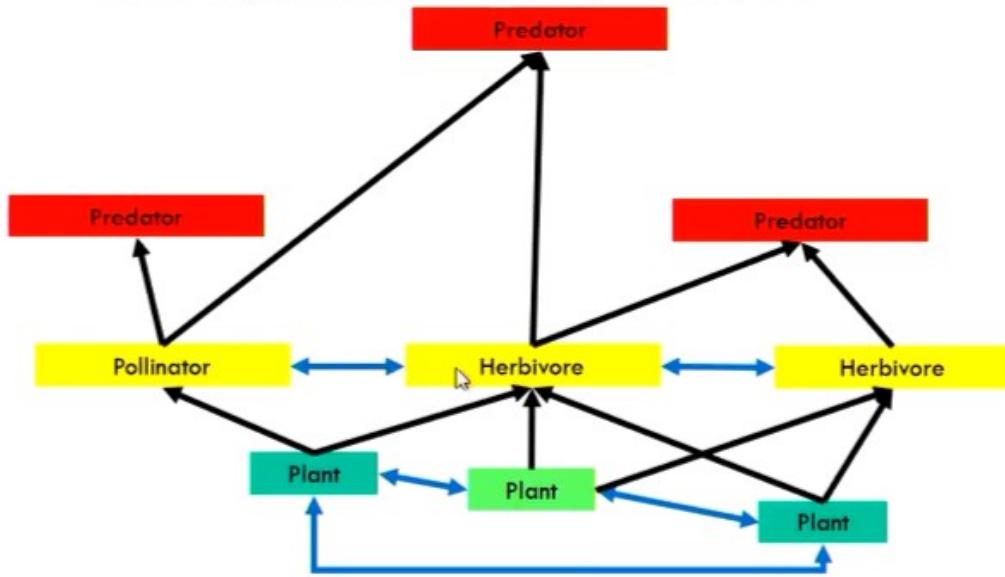
- Both using energy to get resources so negative

## Herbivory (+, -)

- Plants are not great food for animals because of low nutritional value, but:
- Herbivory can impact populations, ecosystems, biggest interaction on planet

## Herbivory & community ecology

Effects on populations → community level responses



## Week 11 Lectures

### 27. Assemblages and ecosystems 20/10/25

**Communities:** Two or (usually) more species that occur together in space and time

> interact with each other as an ecological unit

> Sometimes taken to be vegetation, should include all biota that occur together

**Assemblages:** Less well defined. Group of species that live together with no assumptions made about how/whether they interact

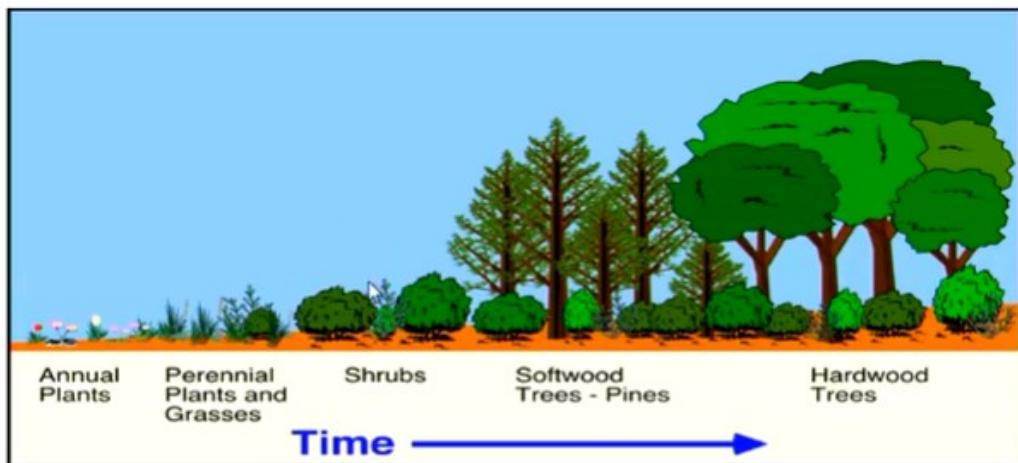
> e.g. I put ants and beetles in same area but idk if they will actually interact

### Communities over time

- Stable communities maintain consistent species richness + composition
- Change in species comp is norm
- Change driven by local colonisations/extinctions
- Predictable patterns of change occur in response to **disturbances** (eg. disasters)
- Classic models are underpinned by **succession of species**
- New communities are being assembled by human activity

### Succession - general

- Early ideas related to forest: trees fall down create gap for light
- Light unsuitable for certain species (shade-tolerant), creates high quality env for other species



#### **Succession of plant species on abandoned fields in North Carolina:**

- **Pioneer species** consist of a variety of annual plants
- Followed by perennials and grasses, shrubs, softwood trees and shrubs, and finally hardwood trees and shrubs
- Succession takes about 120 years to go from pioneer stage to the **climax community**
- The concept of the climax community has been questioned recently: what happens when the old trees die?

\*Original work by Billings (1938) Ecological Monographs 8: 437-499

10

#### **Pioneer species**

- Grow in sun
- Fix nitrogen
- Good dispersal
- Small seeds
- Rapid growth
- Short generation time
- Poor competitors

#### **Climax species**

- Shade tolerant
- slow growth
- long- lived
- good competitors

#### **Types of succession**

##### **Primary succession**

- Bare area without soil (sand-dune, bare rock)

##### **Secondary succession**

- Habitat modified by other species (e.g. forest gaps, abandoned agriculture field)

#### **Models of succession**

- **Facilitation** (earlier arriving species make env more favourable for later species). E.g. small species fix nitrogen in soil, other species move in
- **Inhibition** (early species inhibit later species) e.g. plants grow bunch of leaves that block sunlight for other plants
- Tolerance** (neither positive/negative environments between early + past species)

## Intermediate Disturbance

- When intermediate amount of disturbance, then has the highest amount of disturbance
- If low, then not much species interact, if too high then too much and species die

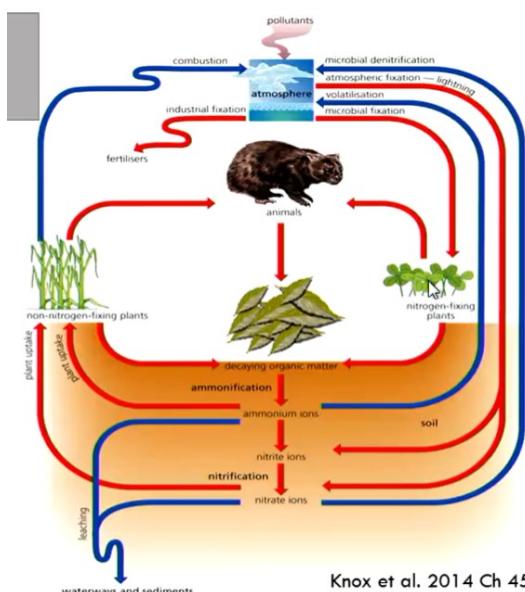
## Resilience and succession

- Resilience - how long before community returns to 'equilibrium' after disturbance
- The larger the disturbance takes, the longer it takes to recover (e.g. nuclear disaster = longer)

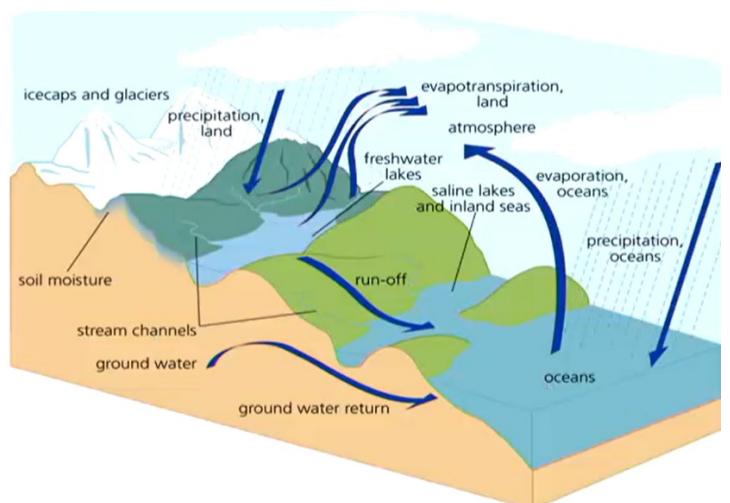
## Biogeochemical cycles

- Energy flows through biosphere, materials recycled
- **Global cycle** → can go into atmosphere
- **Local ecosystem cycles** → do not go into atmosphere (calcium, phosphorus)

## Water cycle: global cycle



Knox et al. 2014 Ch 45

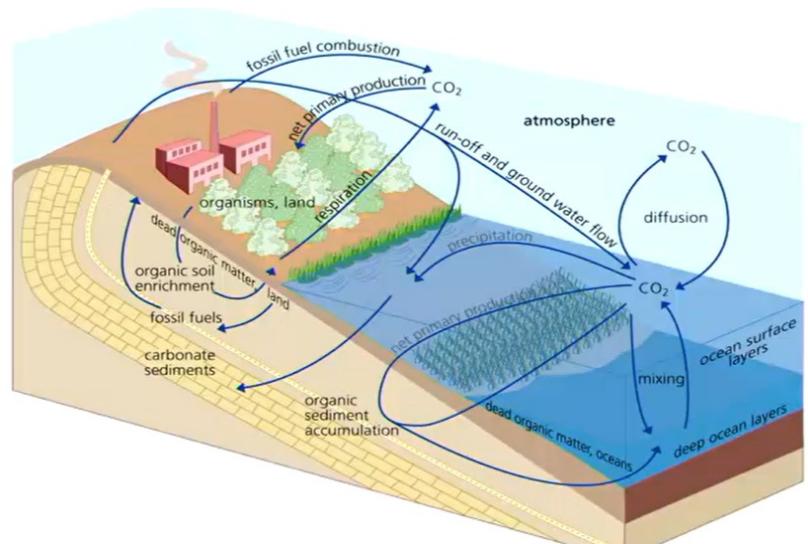


## Nitrogen cycle: global cycle

- Can come from lightning or nitrogen fixing plants

## Carbon cycle: global cycle

- Comes from fossil fuels
- CO<sub>2</sub> used in photosynthesis, used in respiration
- Burning fossil fuels returns CO<sub>2</sub>



## Sea otters, carbon

- Sea otters can help increase carbon. Plants can respire more, helps carbon storage
- If no sea otters, atmospheric carbon stays the same

## Phosphorus cycle: local cycle

- Essential in ATP, must be recycled efficiently
- Small phosphorus in the soil, adapted to low phosphorus

## 28. The Human Footprint 22/10/2 5

### Toxic Inputs

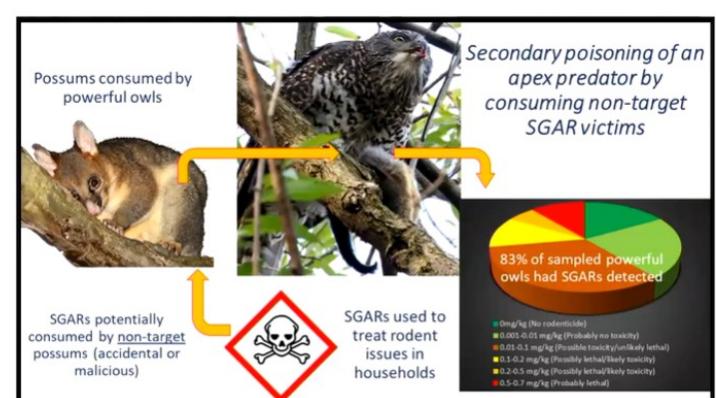
- Pesticides, pharmaceuticals, manufacturing, industrial accidents, chemical spills, plastics

**Contaminants (cause)**: Presence of substance where it should not be or concentrations above background

**Pollutant (effect)**: Contamination that results in/ can result in adverse biological effects to resident communities

### Bioaccumulation (more than loss)

- Occurs when organism absorbs toxic substance at greater rate than substance is lost (accumulation)
- Occurs in body tissues
- In higher predators at top of food chain/web



### Biomagnification (increase conc)

- Occurs when there is increase in concentration of substance in tissue at higher trophic levels
- In body tissues
- Particularly in higher predators at top of food chain

## Inuit people bioaccumulation

- Breast milk has high PCB concentration, consuming fish (narwhal, beluga whale) that has PCB. Already big animals = accumulation, passed down to children

## Habitat loss and fragmentation

- **Habitat loss is one of the major contributors to biodiversity loss**
- Fragment size + isolation primary drivers of loss
- Edge effects are prevalent (e.g. edges of park have weeds)

## Two classic effects of fragmentation

1. Biomass collapse
2. Ecological meltdown

## Biomass collapse in Amazonian fragments

- Experimentally fragmented landscape created between 1980-1986
- Patches of 1,10,100 ha isolated by clearing pasture
- Rate of biomass loss greater near forest edges (small patches)

## Ecological meltdown in predator-free fragments

- Habitat fragmentation, loss of large animals
- E.g. construction of dam made a large lake (making islands).
- Small insects, vertebrates survive since no predators can live here

## Trophic cascades

- If no predators, more herbivores → less plants, no plants → everything dies  
(ecological meltdowns)

## Types of changes expected and now observed

### Animals and Plants

- Range shifts (latitudinal or altitudinal)
- Abundance changes
- Change in growing season length
- Earlier flowering, emergence of insects, migration and egg-laying in birds
- Morphology shifts (e.g. body & egg sizes)

### Hydrology and glaciers

- Glacier shrinkage
- Permafrost thawing
- Later freeze & earlier break up of river and lake ice



## Week 12 Lectures

## 29. Conservation 27/10/25

### Australia's recent mammal extinctions

- Lost 34 species in last 200 years
- Non-flying mammals in “critical weight range”

### Aims of Conservation Biology

1. Describe problems and understand processes
2. Predict impacts of threats
3. Develop solutions: undo “human footprint”
4. Ultimately: stop more species/communities/ ecological processes going extinct

### Patterns and processes

- *Jared*: Alien species, over-hunting, habitat loss, co-extinction
- *Edward O*: Habitat destruction, invasive species, pollution, over-harvesting
- **Human over-population** is key difference, underpins everything else

### A. Alien species

- Australia has 56 introduced species of vertebrates
- Biodiversity + economic cost estimated at 800 million

### Our new Megafauna

- New invaders bought new megafauna
- Cattle, sheep, goats, pigs, buffalo are now all feral
- Many are major pests

### New Smaller invasive species

- Cats, rats, mice, rabbits, foxes, honeybees, wasps

### Invasion - getting there

- Deliberate introductions (comfort/familiarity)
  - > Ornamentals, agriculture, domestics
- Human traffic
  - > Trade routes, poor quarantine
- Native invaders

### “Tens rule”

- 1 in 10 of species brought in will become ‘naturalised’ into the land
- 1 in 10 become invasive

### Predicting who might invaded

- High reproduction, enable great ecological dispersal

## Impacts

- Red fox as a case study in Australia
- Competes with carnivorous marsupials, preys on everything, linked to 12 extinctions

## B. Overhunting -

### As food/resources

- Fisheries, overseas bushmeat, wild meat

### As potential competitors:

- 500,000 bounties

## C. Habitat loss and the extinction debt

- Not linear of land loss vs species loss
- Extinction debt = future ecological cost of current habitat destruction (e.g. more area destroyed have greater effect continuously)

## D. Co-extinction

- Critical ecosystem functions lost when species are lost (e.g. losing pollinators → no plants)
- E.g. Passenger pigeons, hunted to extinction (lice living on them probably extinct)

### Solutions: Experiments

- Key to **identifying processes** driving extinction + allowing management + future predictions
- E.g. predation experiments (removal/supplementation)
- **Alien predators have twice the impact of native ones**

### Solutions: Modelling

- Models of population dynamics useful to predict impacts + identify management options
- Population Viability Analysis

## Restoration - resetting the clock

Ecological restoration - process of repairing damage caused by humans to diversity/dynamics of indigenous ecosystems

Diverse goals: restoring ecosystems to some pre-impact or reference state.

### 1. Structural attributes

Returning with less floral diversity



### 2. Seed Dispersal By Ants

Function returned quickly, not linked to assemblage composition but identity of key functional groups



### 3. Insect Pollination

Replacement of native pollinators, similar services in different way



### 4. Beetle assemblages

"Field of dreams" supported



**Re-vegetation work?:** In helping increase the number of species: No