Topic 1: Cell Structure and Evolution

Completed	☑
Module Code	BIO1CO
School	La Trobe University
Week	Week 1

▼ Cells and Cell Evolution

- Cells are compartments enclosed by a **membrane** that keeps the **internal matrix (the cytoplasm) separate from the outside environment**
- They may look **simple** (as in **bacterial** cells) or incredibly **complicated** (as in **unicellular** organisms)
- **Complex processes** go on in all cells and the **conditions** under which they proceed must be **precisely regulated**

Bacterial Cells

- The **earliest cells** resembled **bacterial** cells
- Modern bacterial cells have **no internal compartments, organelles or a nucleus**
- The **circular DNA lies freely** in the **cytoplasm** along with **ribosomes**
- These cells are enclosed by a **cell wall** and are classified as '**prokaryotic**' (meaning 'before nucleus')
- Their size is approximately **1 μm**

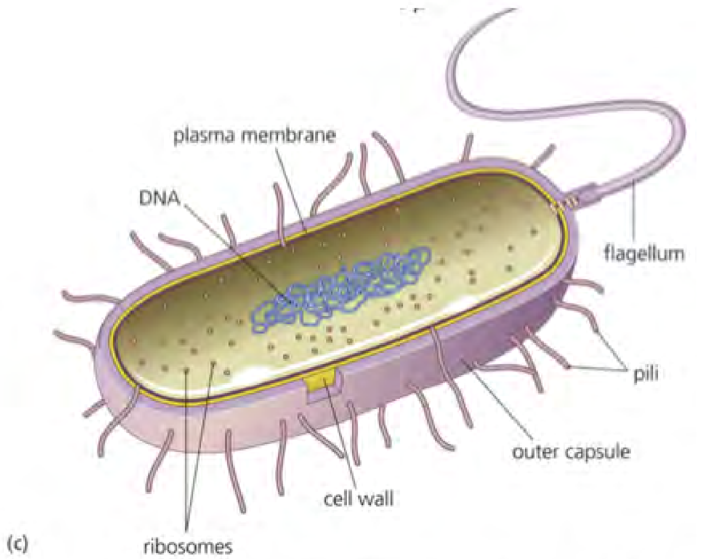
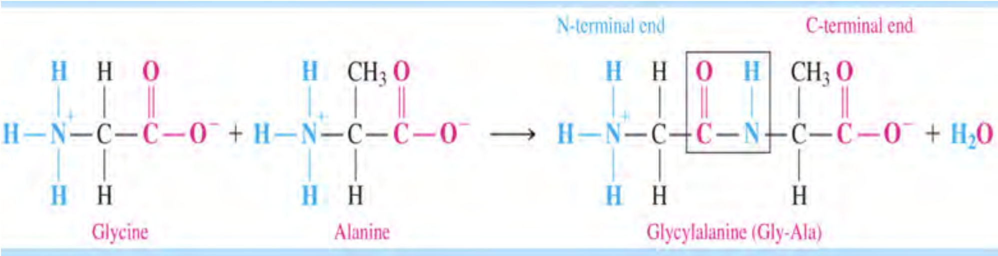
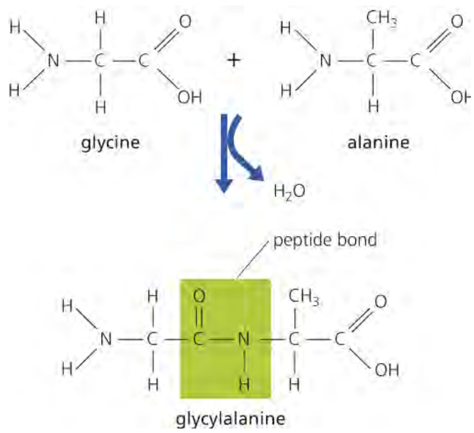


Figure 4.1c. A generalised bacterial cell (Ladiges

Peptide Bond

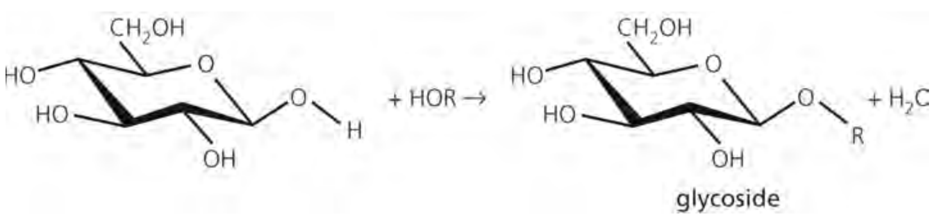
- An **amide** bond
- Forms between the **carbonyl** group of one amino acid and the **amino** group of the next amino acid
- Contains an **N terminal** on the **left**
- Contains a **C terminal** on the **right**
- Peptides are always written from the **N-terminus to the C-terminus**





Peptide and Polypeptide Formation

- **Repeated** linkages of **hundreds** or even **thousands** of amino acids result in a unique **polypeptide chain** with **particular properties** due to the **nature** (hydrophilic versus hydrophobic) and **polarity (charge) of each contributing amino acid**
  - **Polypeptide — polymer of amino acids**
  - **Protein** — polypeptides that have **folded properly** and combined with any additional components needed for proper functioning, is **functional**
- **Carbohydrate** chains are made similarly by **glycosidic bonds** between reactants
  - **Condensation** reaction — **water is removed**



- After being **reduced**, it is called **FADH2**
- The vitamin, riboflavin (or B2) is used to derive this compound
- Riboflavin provides the ring structures that will directly participate in the transfer of **two hydrogen atoms** (each with 1 electron)
- Similar to NAD, FAD works in association with a **"dehydrogenase" enzyme**
- The reaction removes **2 hydrogen atoms**; each a proton with 1 electron
- Both hydrogen atoms **bond with FAD**
- This reaction **does not release an H+ into solution** like the reduction of NAD does.
- Flavin adenine dinucleotide in the oxidized form **(FAD) accepts 2 hydrogen atoms** (each with 1 electron) and becomes **FADH2**

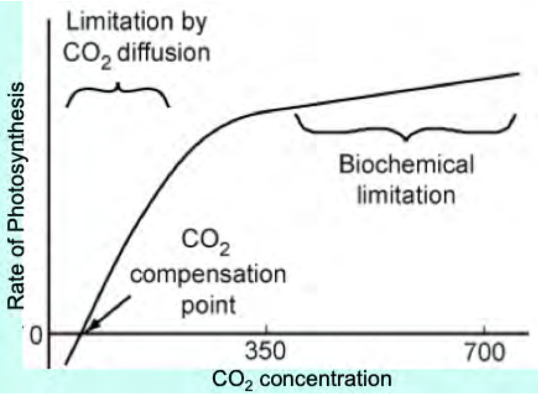
▼ **Cellular Respiration**

1. **Glycolysis**

- Takes place in the **cytoplasm**
- The glucose molecules are derived from **enzymatic break-down of starch (plants)** or **glycogen (animals)**
- Glycolysis **does not require oxygen**
- Not a very efficient process but is a **quick** way to derive energy via carbohydrate-based fuel molecules

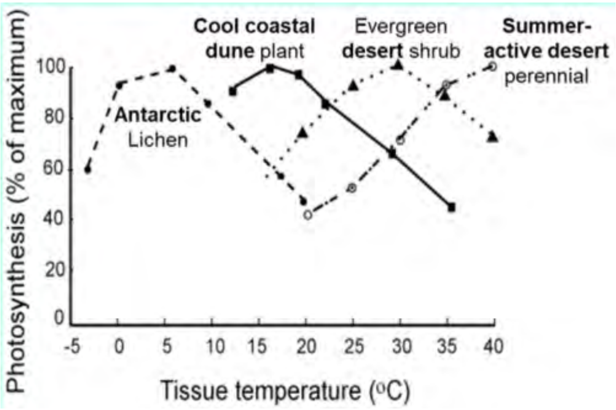
1. First half of glycolysis is **energy-requiring steps (endergonic)** from glucose to **glyceraldehyde-3 phosphate**
2. Second half of glycolysis is **energy-releasing steps (exergonic)** from glyceraldehyde-3 phosphate to **pyruvate**

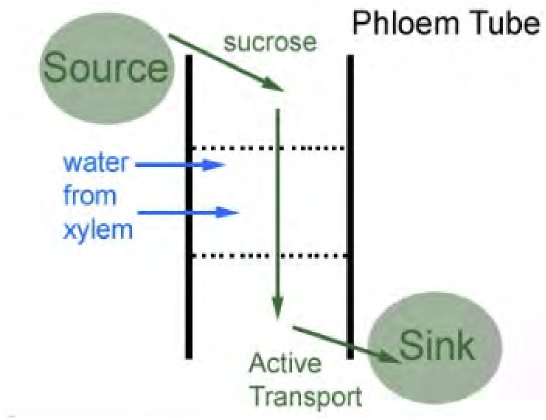
- The net outcome from **1 glucose molecule**:
    - **2 ATP** (high energy molecules, but not many)
    - **2 NADH (carrier of electron)**
    - **2 Pyruvate** (molecules that enter **respiration**)
- **Fats** are also **hydrolysed** by enzymes and the resulting fatty acids are utilised in the process of **b-oxidation**.
    - This breakdown occurs **inside the mitochondria**
    - The net outcomes of **beta-oxidation** are:
        - Acetyl CoA
        - Acyl CoA (2 C-shorter)
        - NADH (carrier of electron)
        - FADH2 (carrier of electron)



Temperature

- **Each type of plant** has a **temperature range** where photosynthesis is **optimal**





Mass-Flow (or Pressure Flow) Theory

- The theory of mass flow explains how sugars move from one part of the plant to another
- **Incoming water from adjacent xylem vessels** provides the necessary **turgor pressure** for the mass movement

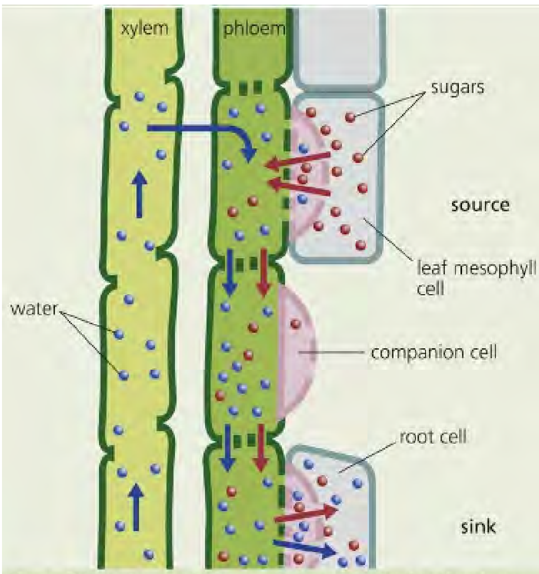
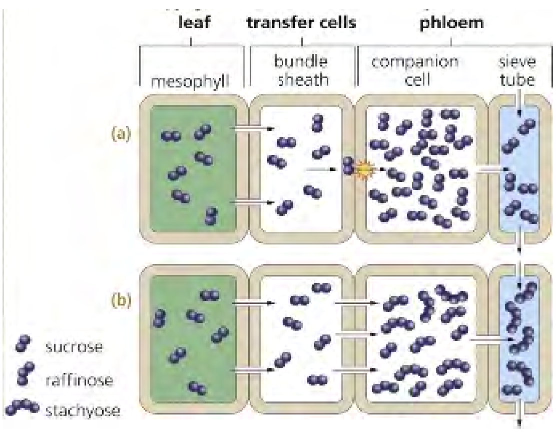
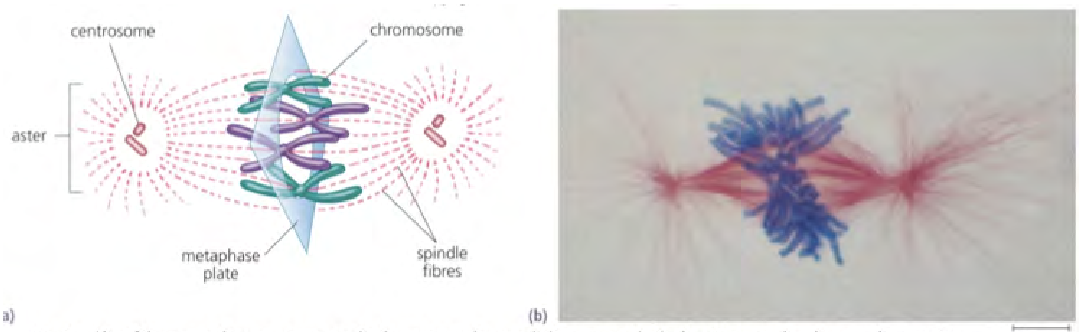


Figure 18.26. Transport of sugars from source leaf to the sieve tubes. ATP is required at one step (both images from Ladiges et al. 2014)

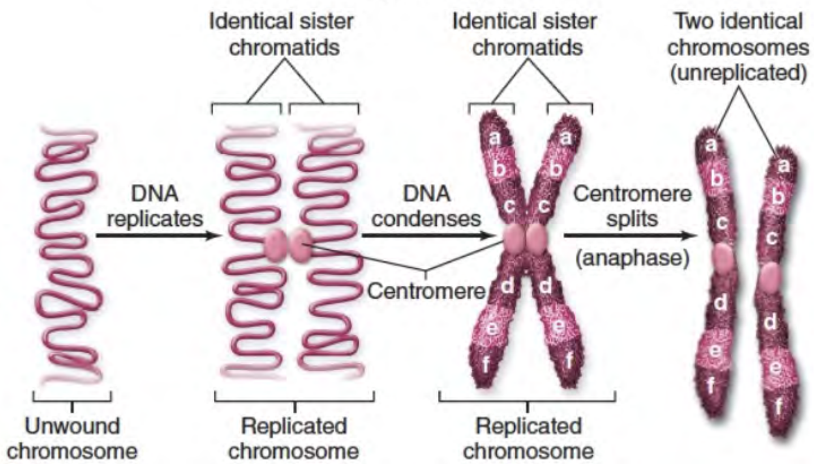




Spindle fibres elongate and shorten by adding and deleting tubulin sub-units

- Once separated during anaphase, each ex-sister chromatid is now called a **chromosome in its own right**
- Once the **new chromosomes reach the two ends** of the cell, they **de-condense** and a **new nuclear membrane forms** around them during **telophase**
- **Cytokinesis** follows, and this differs in plant cells that have a cell wall (with laying down of a new cell membrane and new cell wall) and animal cells that are surrounded by a flexible membrane, which **pinches in** with the help of **contractile fibres**
- This process is called '**cleavage**'

This figure summarizes the changes that occur to one chromosome during a cell cycle.

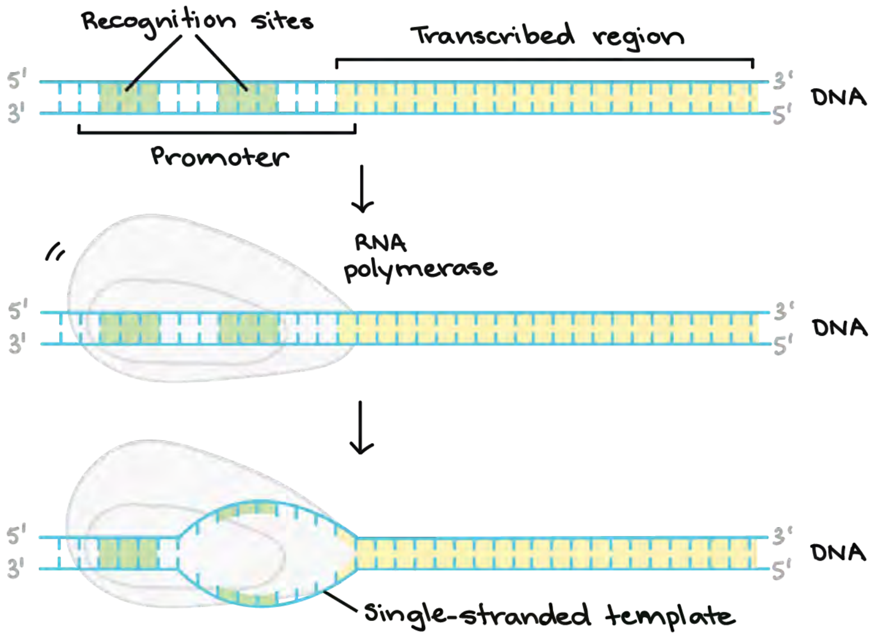


Animal vs Plant Cytokinesis

- **Plant cells do not possess centrosomes**, thus making their 'spindle' more barrel-shaped

- In most cases of transcription, **only one side of the double helix is transcribed** to produce a **single stranded mRNA**
- **RNA polymerase does not need a primer** to begin transcription of the sequence
- Instead, it **begins the process of transcription** at a specific nucleic acid sequence called the **promoter**, and it **ends replication at a specific termination sequence**
- The **whole DNA does not get transcribed**, only a **certain portion** that encodes for a **specific protein**
- Various different types of RNA are generated this way, but **only mRNAs are translated into a polypeptide sequence** during **translation**

1. **Initiation**
    - **RNA polymerase** binds to a sequence of DNA called the **promoter**, found near the **beginning of a gene**
    - Each gene (or group of co-transcribed genes, in bacteria) has its own promoter
    - Once bound, **RNA polymerase separates the DNA strands**, creating a **transcription bubble** and providing the **single-stranded template** needed for transcription



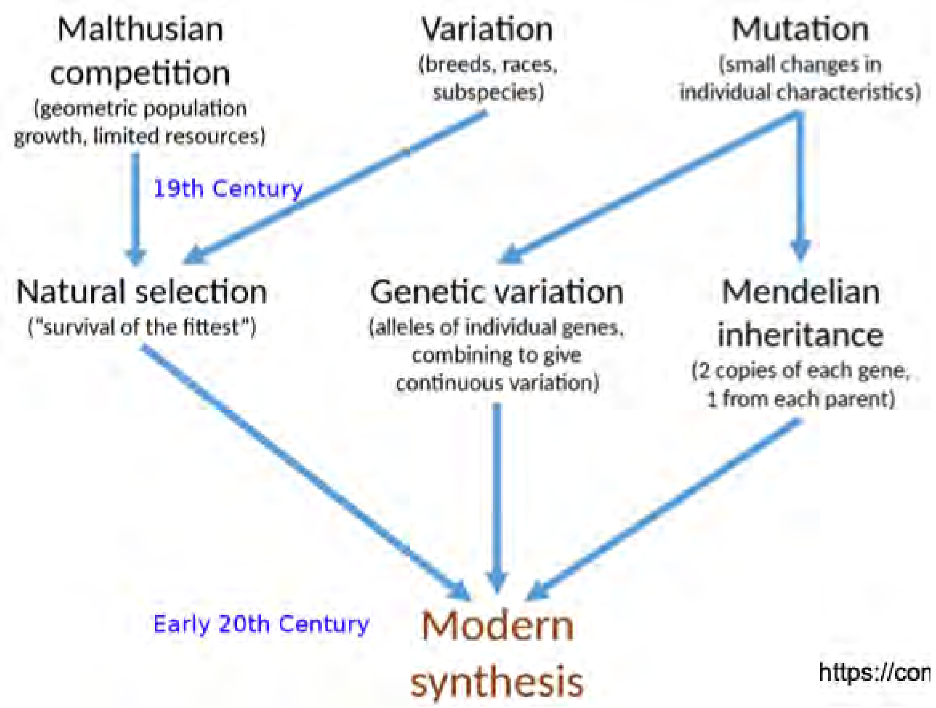
2. **Elongation**
    - One strand of DNA, the **template strand (3' to 5')**, acts as a **template for RNA polymerase**
    - Only 1 strand is being used as the **template**, the other strand is used to **stabilise** the DNA
    - As it "reads" this template one base at a time, the **polymerase builds an RNA molecule** out of **complementary nucleotides**, making a chain that grows from **5' to 3'**

Process of Natural Selection (ICE AGE)

- **Inherited Variation** — There is **genetic variation** within a population which can be **inherited**
- **Competition** — There is a **struggle for survival** (species tend to **produce more offspring than the environment can support**)
- **Environmental pressures** — lead to **differential reproduction** within a population
- **Adaptations** — Individuals with **beneficial traits** will be **more likely to survive** and pass these traits on to their offspring
- **Genotype frequency changes across generations**
- **Evolution occurs over time**

Modern Synthesis Theory of Evolution

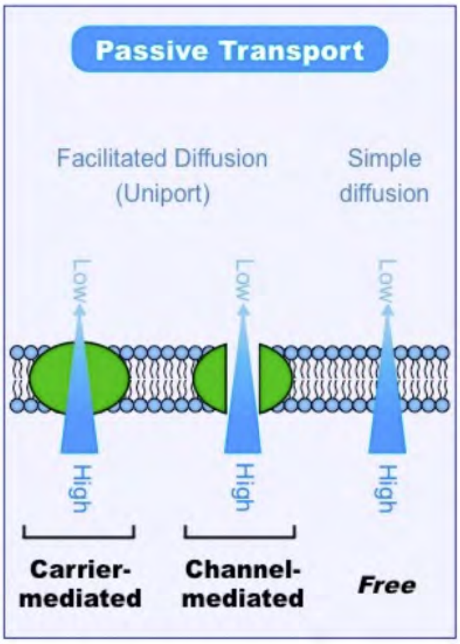
- Brought together **macroevolution** (palaeontology) and **microevolution** (Mendel's peas)
- Started to take **genomics** into account – had **identified DNA as the heritable 'thing'** but still did not know how it worked



Natural Selection

- Living things **produce more offspring than the finite resources available** to them can support
- Thus living things face a **constant struggle for existence**
- The individuals in a population **vary in their phenotypes**

  - Be a **gas**
  - Be **lipid soluble**
- **Passive transport — does not need energy (ATP)** to cross the membrane
  - Always moves **high to low** on a **concentration gradient**
- **Simple diffusion —** movement of **small** molecules
- **Facilitated diffusion —** movement of **large/charged** molecules by **membrane proteins**
- **Osmosis** — redistribution of **water** molecules



- **Active transport —** requires **energy (ATP)** to move molecules **against the gradient** across a membrane
  - Always moves **low to high** on a **concentration gradient**
    - **Primary/direct** transport — uses **ATP directly**
    - **Secondary/indirect** transport — **couples the molecule with another** moving **along** the electrochemical gradient

performs work, existing in a complex regime which combines stability and adaptability in the phase transition between order and chaos, as a plant, animal, fungus, or microbe"

- 2020, Tetz and Tetz offered the definition of life as **"an organised matter that provides genetic information metabolism"**

Artificial Life

- Build or synthesis a living life form **from not-alive parts**
- Many large scientific consortiums working towards this
- Predominant approach is consider three categories:
  - **Compartmentalisation** — the **separation of biomolecules in space**
  - **Metabolism** — the **biochemistry** that sustains **life, glucose or ATP** and appropriate **enzymes**
  - Informational control, the storage and management of **cellular instructions**, a **genome** and the **proteins** needed to **transcribe/translate**
  - **Combine**

Minimal Life

- **Endosymbiotic bacteria and viruses** can have **very small genomes**
  - Mycoplasma genitalium, 580kb, 482 protein-coding genes
  - Bacteriophage MS2, 3569 nucleotides, 4 proteins
- **These require a host organism**
- **Independent prokaryotes** have **larger genomes** with the **smallest coding** for around 1300 proteins
- Venter headed a consortium who successfully synthesised a 473 gene independent life form
- Of these, the essential functionality of 149 remained unknown
- Later work led by Strychalski identified 7 other genes that made the synthetic cells behave more like natural bacteria
- It is thought a **true minimal cell** will be a **good analogue for LUCA**

Abiogenesis: the start of life from not-life

- The general consensus is that there is no discernible moment of life 'sparking' into existence
- **Not-alive** things gradually **increased in complexity**, through some early form of evolution, until there was some sort of alive thing, probably a very simple prokaryote
- The in-between time fulfilled the same demands of any artificial/minimal life:
  - Compartmentalisation, or the separation of biomolecules in space
  - Metabolism, the biochemistry that sustains life, glucose or ATP