LECTURE 1: To see biology in an evolutionary context and review the three generalisations of biology. To understand how far back we have extended the fossil record since the days of Darwin.

FIRST GENERALISATION OF BIOLOGY – EVOLUTION THROUGH NATURAL SELECTION

- Charles Darwin.
- A great **unifying theory** in biology – with this theory we can account for diversity and similarities in plant and animal species.

EVOLUTION

- The Earth has a long history.
    - 4.5-4.6 billion years.
    - Life began about 4 billion years ago.
- All organisms arose in the course of this history from earlier, more primitive forms.
- As a consequence of this theory all organisms are related or **share a common ancestor**.

A 2 step process: 'descent with modification'

- Variability (via mutations).
- Ordering that variability by natural selection.

SECOND GENERALISATION OF BIOLOGY – UNITY OF BIOLOGICAL PROCESSES

- Because all organisms share a common ancestor, there is a unity of biological processes.
- All organisms have **DNA**.
- All organisms also have the machinery to carry out the instructions from the DNA – **proteins**.
- All organisms share certain **biochemical reactions**.

THIRD GENERALISATION OF BIOLOGY – ALL ORGANISMS CONSIST OF CELLS

- **Cell** = a bag, a closed domain where the chemical reactions required for life are carried out.
- Cells have probably succeeded because of the membrane separating the living protoplast and the harsh environment.

Cell Theory

- All living organisms are composed of cells.
- All cells come from pre-existing cells.
- The cell is the smallest organizational unit.

DARWIN'S DILEMMA

- Where did the first cells come from?
- How did eukaryotic cells evolve from prokaryotic cells?
- Cambrian explosion – the emergence of eukaryotes greatly accelerated the pace of evolutionary change.

Note: reproduction, changeable inheritance, metabolic activity and containment (i.e. being surrounded by a membrane) define life.

LECTURE 2: To understand the differences between prokaryotic and eukaryotic cells. To understand the structure, diversity and function of archaea and bacteria and how they differ. The importance of cyanobacteria.

PROKARYOTIC VS EUKARYOTIC CELLS

Prokaryotes were the first cellular lifeforms to emerge.

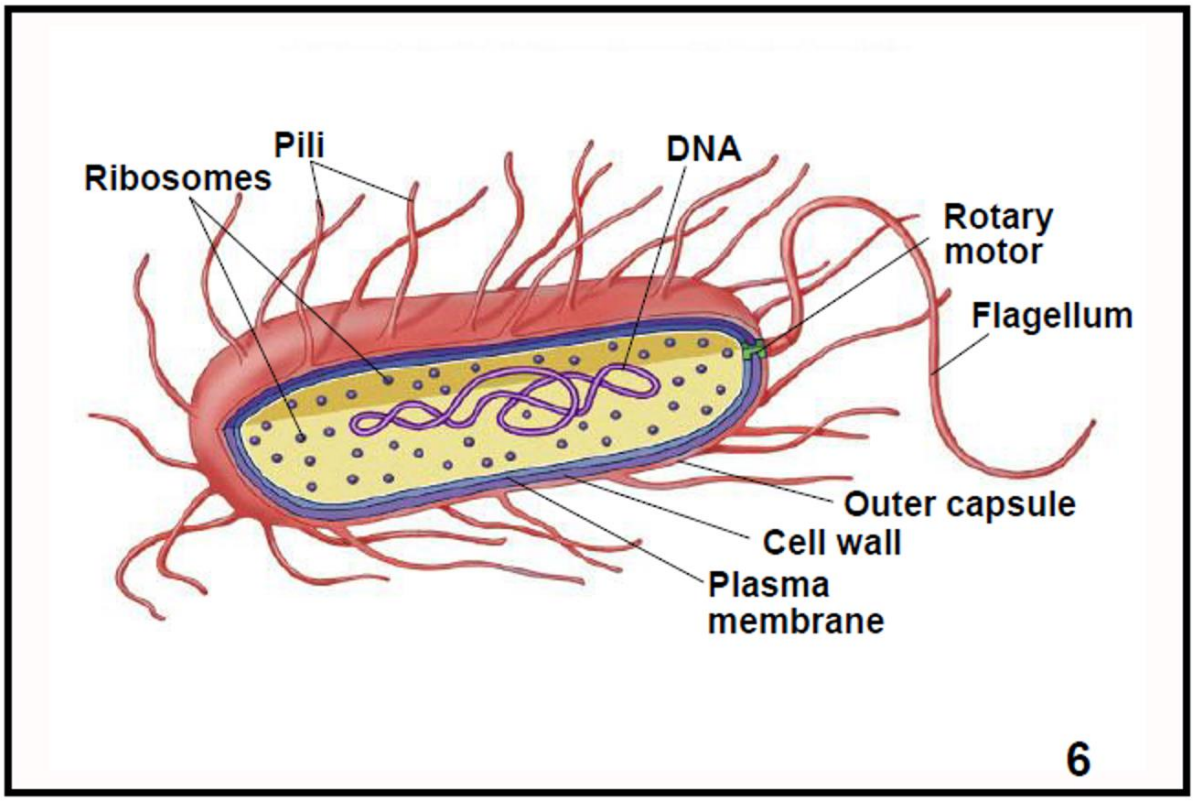
- Evolved in the oceans.
- Earliest bacteria (predecessors of cyanobacteria) were capable of **anoxygenic photosynthesis**. Evolving chlorophyll allowed prokaryotes to capture inorganic CO_2 and turn it into organic C, releasing O_2. THE GREAT OXYGENATION. Earth: inhospitable →hospitable.

Feature of Cells	**Prokaryote: Bacteria**	**Prokaryote: Archaea**	**Eukaryote**
Size	Microscopic 0.1-10μm	Microscopic (but can be macroscopic)	Microscopic 10-100 μm
Chromosome structure	Circular	Circular with histones	Linear with histones
Chromosome number	Single	Single	Multiple and variable
Cell division	Binary fission	Binary fission	Mitosis/meiosis
Internal compartmentalisation	Never	Never	Always, endomembrane system
Flagella	External, flagellin acts as a motor	External, flagellin acts as a motor	Internal, 9+2 arrangement of microtubules
Cytoskeleton	Rudimentary cytoskeleton in some	Rudimentary cytoskeleton in some	Microfilaments (actin and intermediate), microtubules
Cell wall	Peptidoglycan	No peptidoglycan	Sometimes cellulose, sometimes chitin, sometimes absent
Uni or multicellular	Unicellular	Unicellular	Sometimes multicellular
Autotrophism Chemosynthetic = can oxidise inorganic compounds and harvest energy	Sometimes chemosynthetic, sometimes photosynthetic	Sometimes chemosynthetic (think extremophiles)	Sometimes photosynthetic
Nitrogen fixing	Sometimes	Sometimes	Never

STRUCTURE OF PROKARYOTES

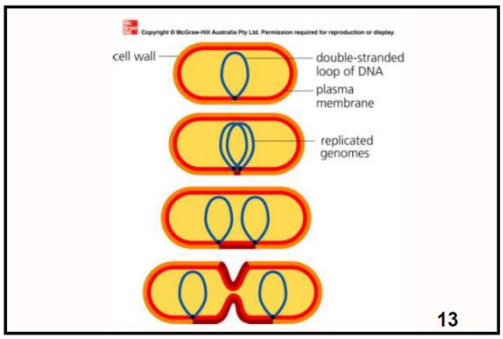
- All prokaryotes are surrounded by a semi-rigid **cell wall**.
- **Cell membrane** – phospholipid, semi-permeable.
- **Cytosol** – liquid interior.
- **Ribosomes** – translate protein.
- Together the ribosomes and cytosol are the **cytoplasm**.
- **DNA** – flows freely and is a single, circular strand.

- **Outer capsule** – composed of polysaccharides. Important for recognition of other cells and disease resistance.
- **Pili** – allow prokaryotes to lineup and transfer DNA back and forth between different cells.
- **Flagellum** – movement. Composed of a single protein called flagella. Extra-cellular.
- **Rotary motor** – turns the flagellum and propels the cell.



BINARY FISSION

- Much simpler process than mitosis/meiosis.
- Allows prokaryotes to divide every 20 mins.



ARCHAEA VS BACTERIA

- Morphologically similar – can't tell them apart under a microscope.
- However vastly different DNA.
- The two central biological processes in archaea, genetic transcription and translation, are more similar to those of eukaryotes than bacteria.
- Archaea lack a peptidoglycan wall (a distinct feature of bacteria).
- There are no known archaean pathogens.

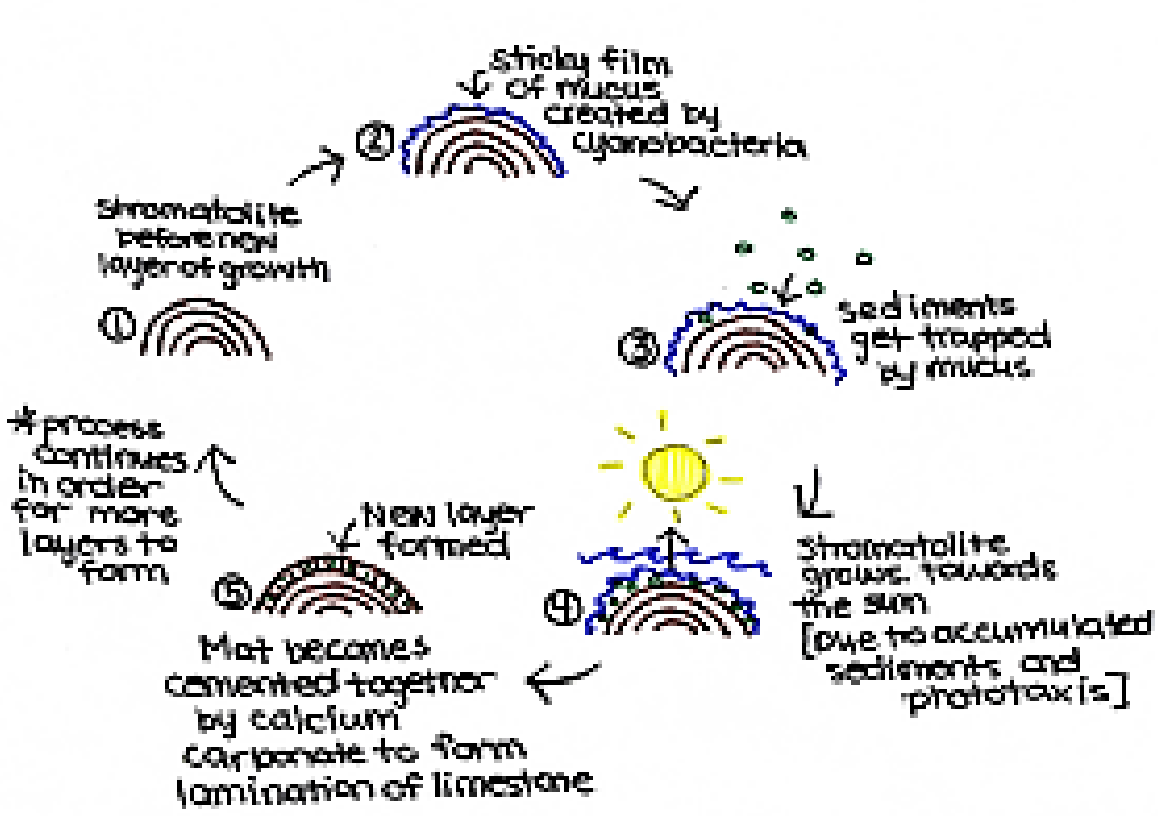
WHY STUDY PROKARYOTES?

- Cause many diseases.

- Decomposers and recyclers – critical in removing dead organic matter, recycling carbon, nitrogen, sulfur, degrading toxic chemicals etc.
- Agents in industrial and agricultural processes. E.g. bacteria fermenting food.
- Nitrogen fixation i.e. can bring nitrogen into organic material.
- GM bacteria produce pharmaceuticals – human insulin, human growth hormone etc.

CYANOBACTERIA

- Major primary producers.
- Contain chlorophyll A and generate molecular oxygen during photosynthesis (similar to plants and algae not other bacteria).
- Responsible for the earth's atmosphere becoming oxygen-rich.
- **Stromatolites** which formed from the activities of cyanobacteria are the oldest fossil evidence of life on earth.

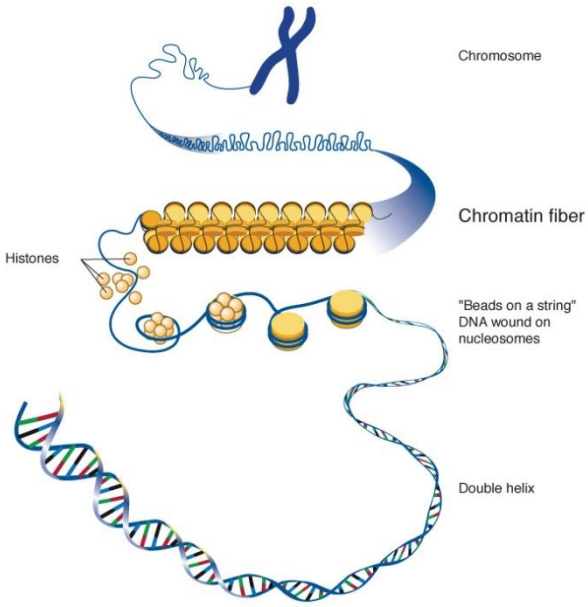


LECTURE 3: To understand the complex structure and differentiation of eukaryotic cells and the possible origin of mitochondria and chloroplasts through the processes of endosymbiosis.

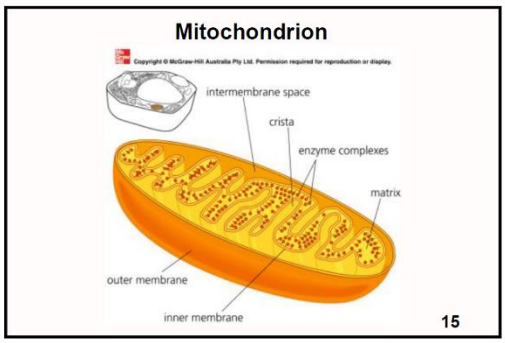
FEATURES OF THE EUKARYOTIC NUCLEUS

- **Double membrane** – nuclear envelope. Inner and outer which are joined at nuclear pores (annular pores).
    - Outer membrane is continuous with ER.
    - Nuclear pores regulate the passage of proteins and RNA into and out of the nucleus.

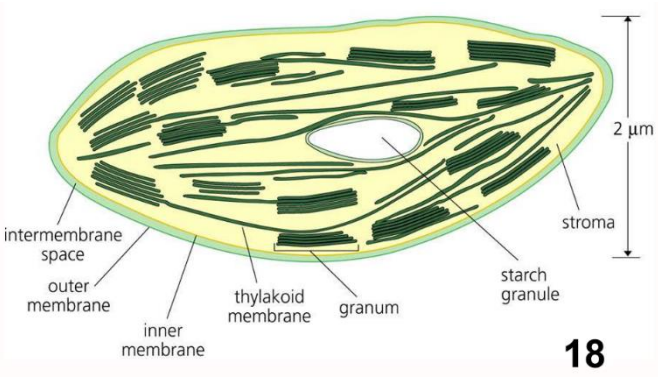
- **Nucleolus** – sub-region containing ribosome genes.
    - Nucleus can contain one or several.
    - Darkly staining regions.
    - Contain high concentrations of RNA, protein and DNA.
    - Site of synthesis of ribosomal RNA (rRNA) and assembly of ribosomal subunits for export to the cytoplasm for protein synthesis.



- **DNA**.
    - Long DNA molecules wind around clusters of **histone** molecules (simple proteins) to form **nucleosomes** (=1 histone group with DNA wrapped around).
    - This arrangement allows DNA to twist into a helix, forming a **chromatin** strand.
    - (DNA has a negative charge because of phosphate backbone and histones have a positive charge – allows association between them).
    - Eukaryotes have multiple chromosomes (vs prokaryotes which have a single, circular molecule).
- **Mitochondria** – powerhouse of the cell.
    - Cells may contain one or several.
    - AEROBIC RESPIRATION – generate ATP.
    - Double membrane.
        - Outer membrane – smooth, permeable.
        - Inner membrane – arranged into folds (cristae) to increase SA, highly impermeable.
    - Matrix space (inside inner membrane) contains mitochondrial ribosomes and copies of mitochondrial DNA. Enzyme complexes are responsible for ATP synthesis.



- **Chloroplasts** – energy catchers of plants.
    - Cells may contain one or many.
    - PHOTOSYNTHESIS – contain chlorophyll, a light-absorbing pigment.
    - Double membrane.
        - Outer.
        - Inner – forms flattened disc-like sacs, **thylakoids**, which lie on top of each other forming stacks, **grana**. Large SA of internal membranes increases ability to capture light (chlorophyll is assembled on thylakoid membranes).

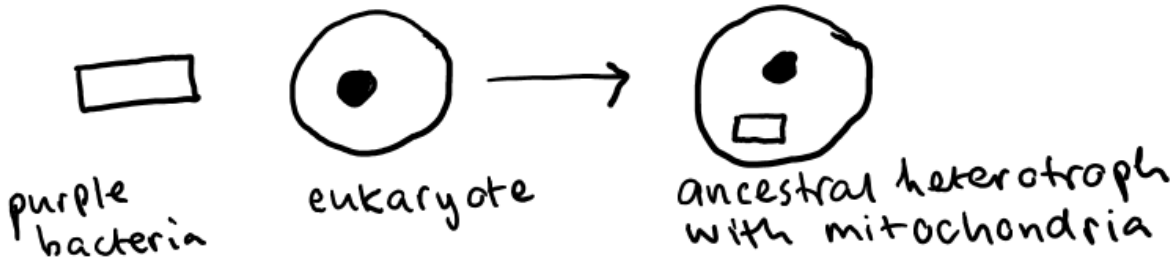


ORIGINS OF COMPLEX ORGANELLES

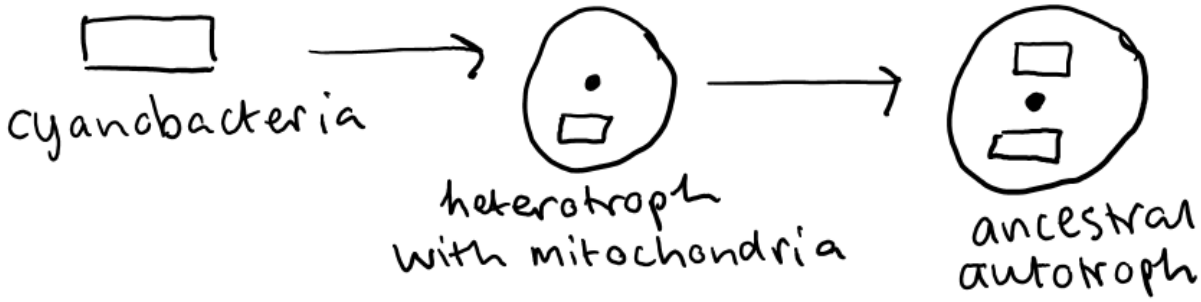
Mitochondria – believed to be derived from purple bacteria.
Chloroplasts – believed to be derived from cyanobacteria.

PRIMARY ENDOSYMBIOSIS

- **Endosymbiosis** = an organism living inside another (for the benefit of them both).
- **Mitochondrial evolution** is thought to have preceded the evolution of chloroplasts.
- A eukaryotic host engulfed a purple bacterium (prokaryote) in a food vacuole = **phagocytosis**.
- The purple bacteria didn't get digested (perhaps because of a mutation in the cell wall).
- The purple bacterium lost its autonomy and became an organelle.

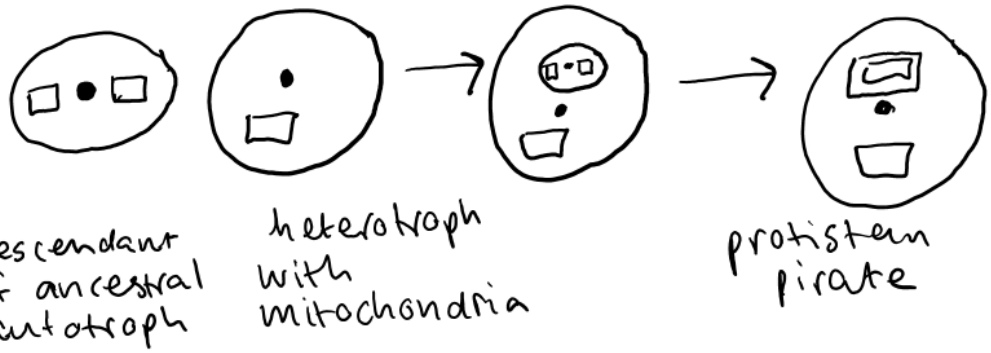


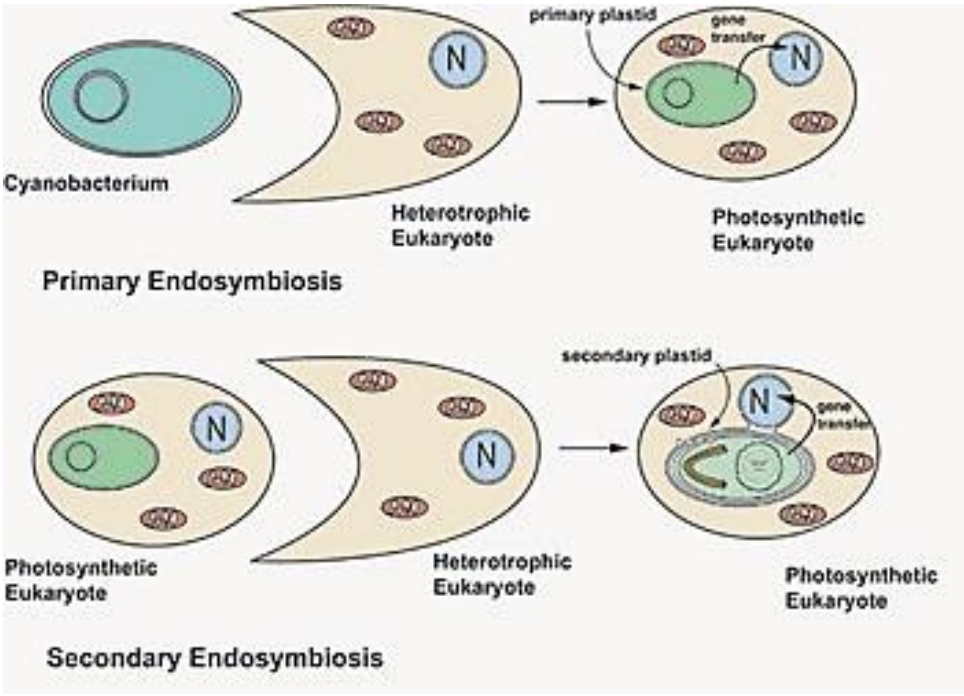
- **Evolution of the chloroplast** involved primary endosymbiosis.
- Chloroplast evolved from cyanobacteria.



SECONDARY ENDOSYMBIOSIS

- When eukaryotes 'stole' their chloroplast from another eukaryote rather than engulf a prokaryote.
- "Protistan pirates".
- The number of membranes around the chloroplast indicates whether primary or secondary endosymbiosis.
    - 2 membranes = primary.
    - 3 or 4 membranes = secondary.





EVIDENCE FOR THE ENDOSYMBIOTIC THEORY

Mitochondria and chloroplasts:

- Are morphologically similar to bacteria. I.e. they look like prokaryotes.
- Are surrounded by an outer membrane similar to a cell membrane.
- Are semi-autonomous. They retain their own genome (DNA, RNA).
- Also retain their own ribosomes.
- Similar metabolism to existing prokaryotes.
- Some chloroplasts still have the bacterial peptidoglycan wall between the inner and outer membranes.