# **Lecture 1 – Introductory Lecture**

What you should know (Learning outcomes):

- Why is "Evolution" considered the great unifying theory in Biology?
- How can the "Unity of Biological Processes" and "Cell Theory" be explained by Evolution?
- What were the objections to Darwin's theory of Evolution, and how has science resolved many of these questions?

- First Generalization of Biology = Evolution through Natural Selection by Charles Darwin

- What is the origin of life? What forces created life on Earth?

1. Extra-terrestrial origin, the infection of spores from another planet/star, or the theory of panspermia
2. Special creation, by supernatural or divine forces
3. Evolution?

- NASA – Curiosity/Mars Science Lab
- European Space Administration – Mars Express
- NASA – Looking at the Universe – Hubble
- European Space Administration – The Rosetta Mission – Investigating comets
- NASA – The Kepler Mission – The search for another Earth or Earth like planet
- NASA/ESA/ASI – Cassini-Huygens mission to Saturn and its moons
- Evolution is the great unifying theory in biology. What does it say?

1. That the Earth has a long history
2. All living organisms arose in the course of this history from earlier, more primitive forms
3. As a consequence of this theory, all organisms are related or share a common ancestor

- Evolution is a two-step process
  1. Variability
  2. Ordering that variability by Natural Selection ("Descent with modification")

- Second Generalization of Biology – Because all organisms share a common ancestor, there is a unity of biochemical processes, where all organisms share certain biochemical reactions

- Examples of the unity of biochemical reactions include:
  1. All organisms have genetic material, the DNA, that contains the instructions on how that organism will develop
  2. Organisms also have the machinery to carry out the instructions – the Proteins

- Third Generalization of Biology – All organisms consist of cells. A cell is a bag, a closed domain where the chemical reactions required for life are carried out

- The cell theory says that:

1. All living organisms are composed of cells
2. All cells come from pre-existing cells

3. The cell is the smallest organisational unit

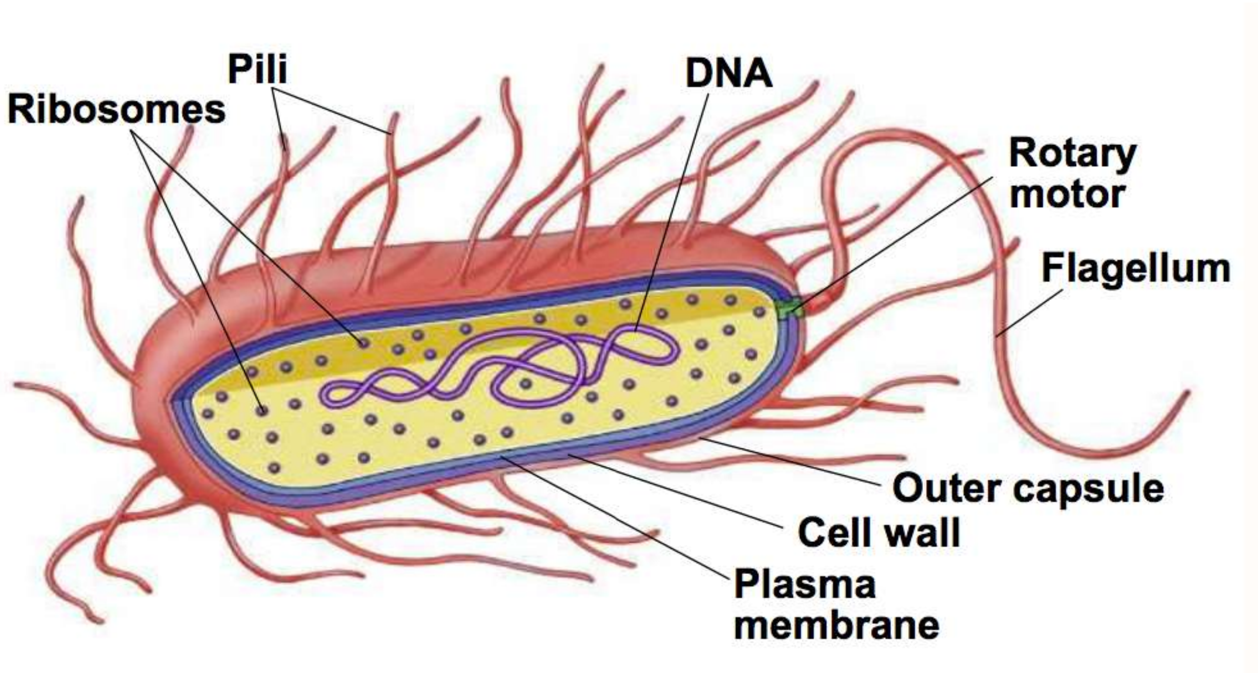
- Darwin's Dilemma: Where did the first cell(s) come from? How to explain the Cambrian explosion and the appearance of complex cells and organisms? How did eukaryotic cells evolve from prokaryotic cells?

## Lecture 2 – Structure and Function of Prokaryotic Cells

What you should know (Learning outcomes):

- What structural features characterize the prokaryotes and where are they found?
- Although structurally simple, why are prokaryotes considered highly evolved?
- What features of the Archaea place them in their own domain?
- Why are the Cyanobacteria so significant to the evolution of life on Earth?

- The first inhabitants of Earth were Prokaryotes
- Early in Earth's history, the atmosphere and oceans had zero oxygen, high Carbon Dioxide, ammonia, methane and intense radiation. Photosynthetic cyanobacteria (The first prokaryotes) changed all of that. The oxygen they released, over 2 billion years built up the Ozone layer, which allowed sea creatures to evolve on land. This was known as the Great Oxygenation Event. This also caused anaerobic organisms to die off to retreat to places with less oxygen.

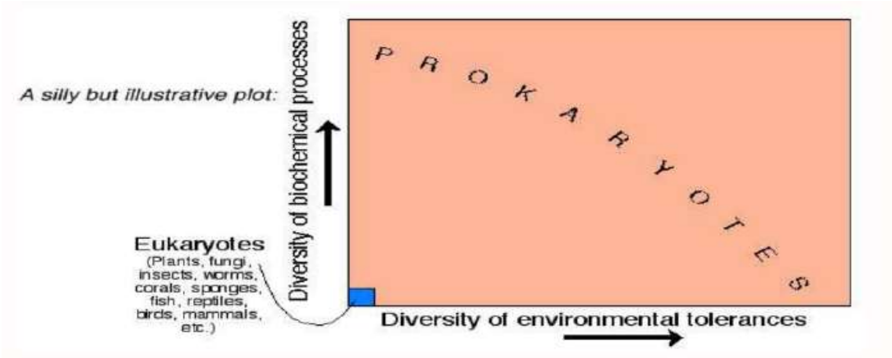



**Note: + Cytoplasm**

- Ribosomes – Site of protein synthesis, where mRNA is translated to protein
- Pilli – Cell to cell adhesion, allows for DNA transfer between prokaryotes
- Rotary motor and Flagellum – Generates movement and locomotion
- Cell wall – Semi rigid, gives shape and provides structure
- Outer capsule – Composed of polysaccharides for cell recognition
- Plasma membrane – Selectively permeable to control entrance and exit of substances in and out of the cell
- DNA – The nucleoid, which contains one double-stranded piece of DNA

- Prokaryotes are tiny cells typically ranging in size from less than 1 micron to or up to 10 um (microns)
- Resting spores of bacteria have been "woken up" after 250 million years inside ancient salt crystals
- Prokaryotes have 0.001 times as much DNA as a eukaryotic cell, and divide every 20 minutes. Eg. In 8 hours, you have 16,777,216 bacteria

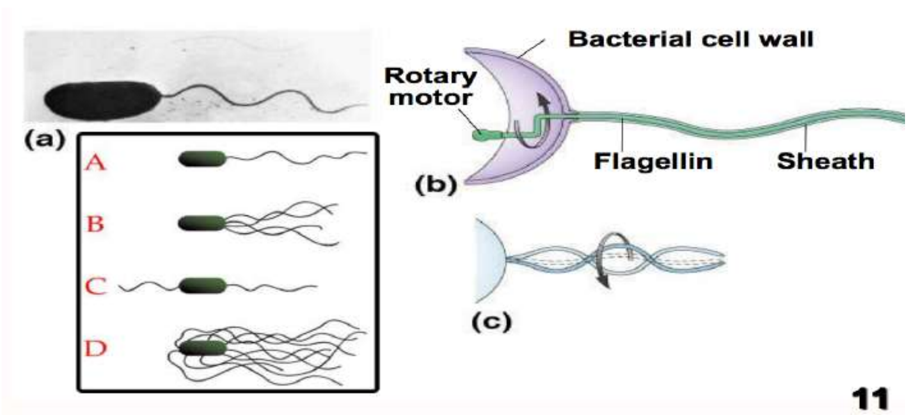
- Prokaryote v Eukaryote diversity - "Spontaneous mutations occur at high frequencies in prokaryotes, and explains their biochemical diversity"

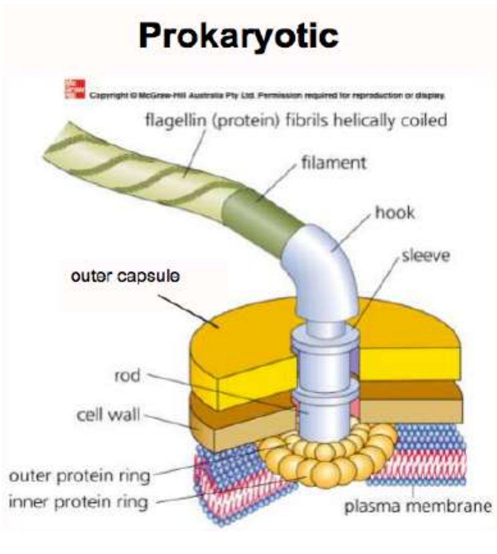


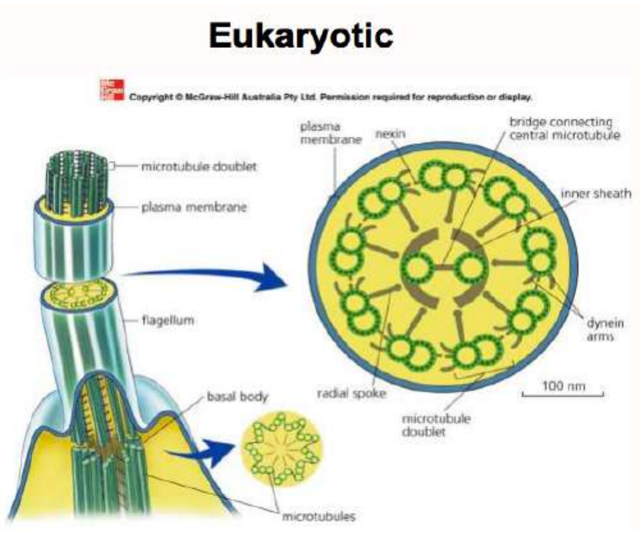

- Prokaryotes have extracellular flagellum, whilst Eukaryotes have a much more complex intracellular flagellum

- Prokaryotes divide by binary fission and cytokinesis, where the plasma membrane elongates after genomes replicate, resulting in two identical cell. Meanwhile, Eukaryotes undergo extensive compartmentalization (Mitosis) in cell division

- Two of the three domains of life are Prokaryotes: Bacteria (previously known as Eubacteria) and Archaea (previously known as Arcaheobacteria). The Archaea are more closely related to the third domain of Eukarya or Eukaryotes



How do Archaea differ from Bacteria?

- Morphologically (How they look, basic structure etc) they don't
- Over half of Archaean genes were new to science (Genetically different)
- Comparison of nucleic acid sequences allows us to construct phylogenetic trees
- Biochemically, Archaea are nearly as different from Bacteria as they are from Eukarya, making them a separate domain
- The two central biological processes in Archaea, genetic transcription and translation, are more similar to those of eukaryotes than bacteria
- Features of the Archaean lipids and their membranes are unusual and Archaea lack a peptidoglycan wall
- Most Archaeans were believed to be extremophiles (hot, cold, acidic, alkaline, highly saline, extreme pressure etc) but are now known to be found everywhere
- Archaeans have not been found to produce resting spores
- As of 2015, no clear examples of Archaean pathogens are known

Bacteria

- Ubiquitous (Everywhere) and metabolically diverse
- Cause of many diseases
- Decomposers and recyclers
- Agents in industrial and agricultural processes
- Nitrogen fixation
- Biotech applications
- Include the Cyanobacteria, a major primary producer

- Bacteria, unlike Eukaryotes, can tolerate extremes. Like Archaea, some Bacteria are extremophiles where they can live at extreme conditions of temperature, pH, osmolytes etc. For example, Pyrolobus grows at over 100 degrees Celsius up to 121 degrees Celsius

- Hyperthermophiles are a type of bacteria, that reduces sulphur to sulphide for energy (chemoautotroph). It doesn't use oxygen or light to fix Carbon dioxide into organic carbon

- Bacteria can be found even in saturated salt water, such as Salt Late in Kangaroo Island, South Australia

- Bacteria can cause disease such as Pharyngitis, dental caries, cellulitis and impetigo

- Bacteria are decomposers and recyclers: They are critical in removing dead organic matter, recycling carbon, nitrogen, sulphur, degrading toxic chemicals etc

- Bacteria are agents in industrial and agricultural processes: They are utilized by humans for recycling, for example in the Werribee sewage treatment plant, where bacteria do the work of cleaning up the wastes in water to a level safe enough that the water can be released into Port Phillip Bay

- Bacteria are used in foods: Fermented foods are produced via the action of microbes such as bacteria or fungi. Eg. Yoghurt, cheese, wine, beer, vinegar, sauerkraut, salami, tempeh, kimchi, soy sauce etc

- Some bacteria are involved in nitrogen fixation, where gaseous nitrogen is incorporated into organic molecules. Eg. Root nodules contain nitrogen-fixing bacteria

- Bacteria is also used in biotech applications, such as using GM (Genetically modified) bacteria to make pharmaceuticals. Eg. E.coli has been engineered t produce Human Insulin, Human Growth Hormone and Human Interferon
- Agrobacterium tumefaciens makes GM plants: 181 million hectares of genetically modified (GM) crops were sown in 28 different countries in 2014

- Bacteria also includes Cyanobacteria, which are major primary producers. It contains chlorophyll A, plus phycocyanin and phycoerythrin as accessory pigments

- Bacteria has also been incorporated in methods for reducing pollution (bioremediation) and even biofuels

## Lecture 3 – Eukaryotes I

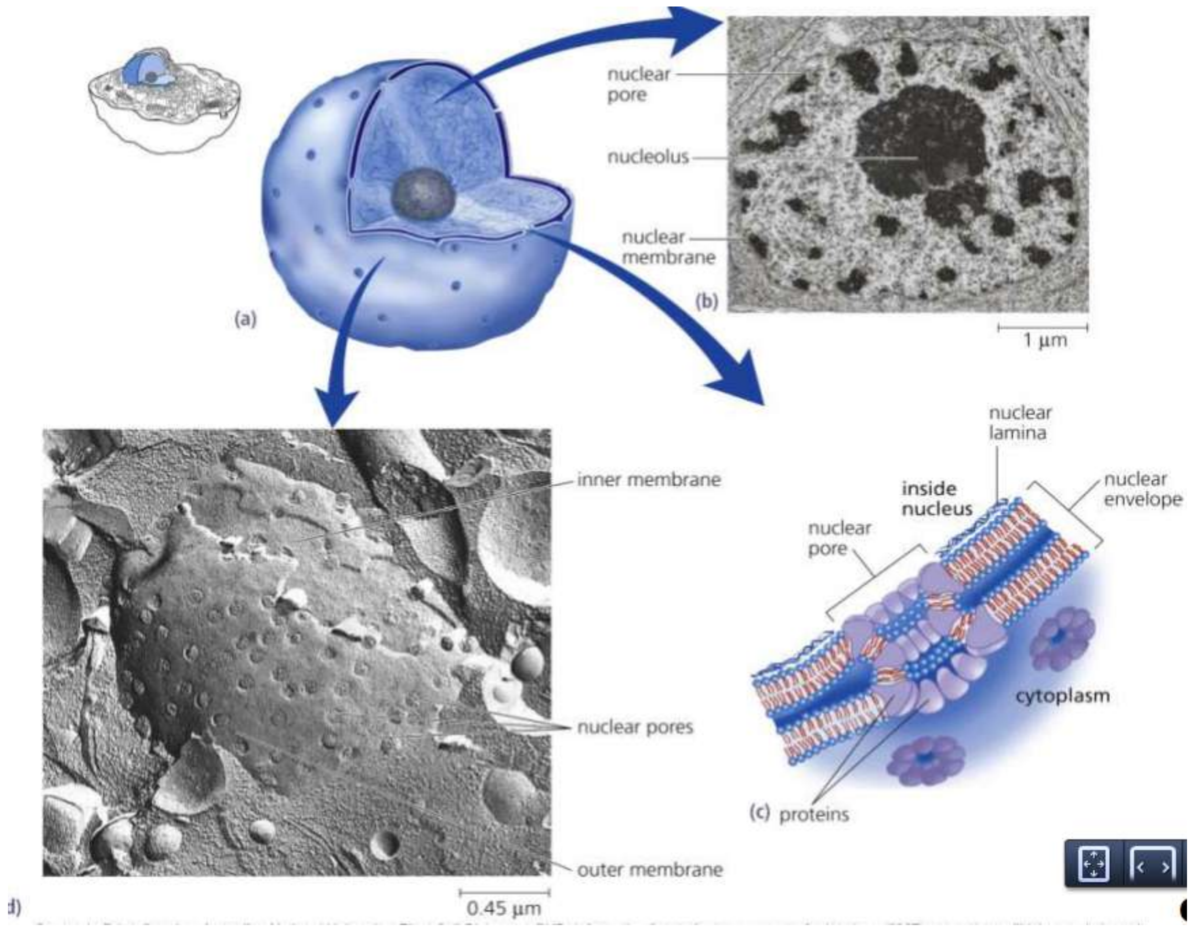
What you should know (Learning outcomes):

- How do prokaryotes differ from eukaryotes?
- Understand the basic structure of the nucleus, mitochondrion and chloroplasts
- What is the evidence that mitochondria and the chloroplasts evolved from the processes of primary endosymbiosis?
- How does secondary endosymbiosis explain the origin of protistan pirates?

- The three domains of life are Bacteria, Archaea and Eukarya
- Around 2.1 billion years ago, unicellular eukaryotic algae were first assumed to exist
- Biggest transition of cellular life was from Prokaryotes to Eukaryotes

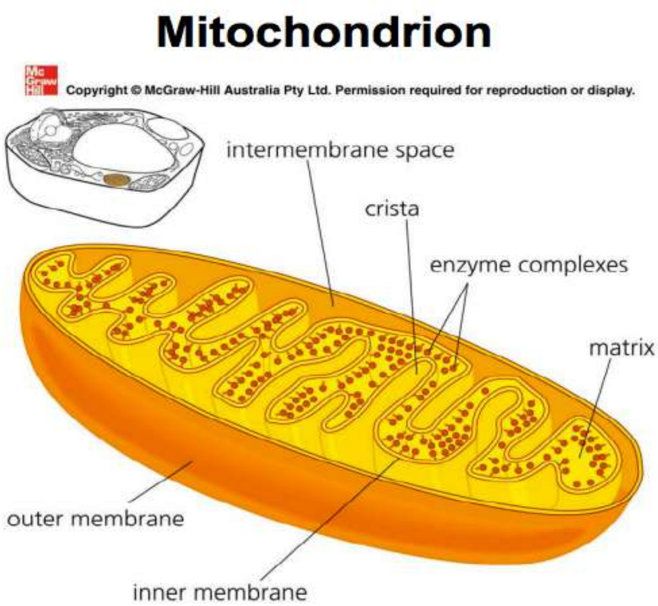
Features of the eukaryotic nucleus

- Surrounded by a double membrane or nuclear envelope
- Presence of nuclear (annular) pores (75 nm in diameter)
- Nucleolus = Subregion of nucleus containing ribosome genes
- DNA in long strands covered with histones = Chromosomes
- Different organisms have different number of chromosomes
- RNA transcribed from DNA leaves nucleus via pores and is translate in cytoplasm



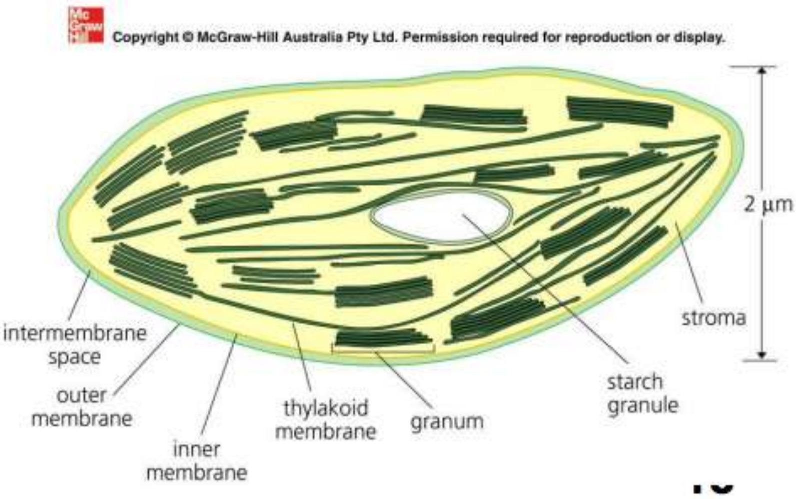

Mitochondria – Power plant of the cell

- Cells may contain several of these organelles or have a single, large mitochondrion
- They are surrounded by two membranes, an outer membrane and a highly convoluted inner membrane, whose inward projections are called cristae
- Mitochondria carry out the aerobic respiration of all eukaryotic cells



Chloroplasts – Energy catchers of plant cells

- Cells may contain one or many chloroplasts per cell
- They are surrounded by two membranes, an outer membrane plus an inner membrane that forms a complex internal network of lamellae or thylakoids
- The photosynthetic pigments are located within the thylakoids
- Chloroplasts are responsible for photosynthesis, or the conversion of light energy to chemical energy



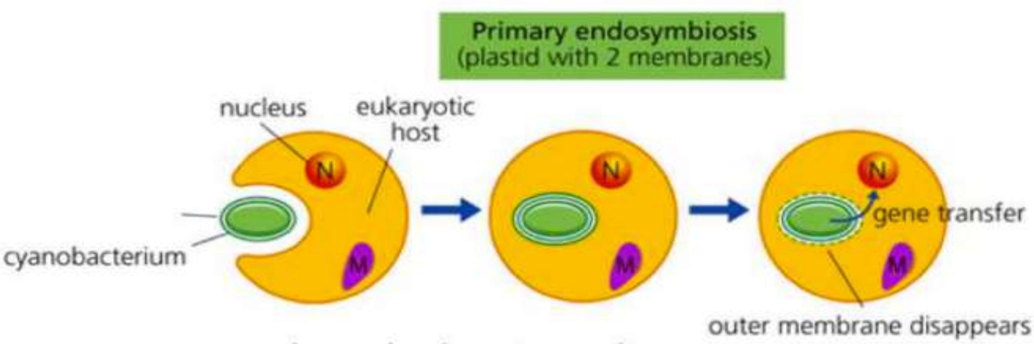

Accessory pigments

- Green algae – Chlorophyll B - Broadens range of wavelengths of light for plants to capture
- Brown algae – Chlorophyll C and Fucoxanthin
- Red algae – Phycoerythrin and Phycocyanin

Under the microscope: Mitochondria and Chloroplasts

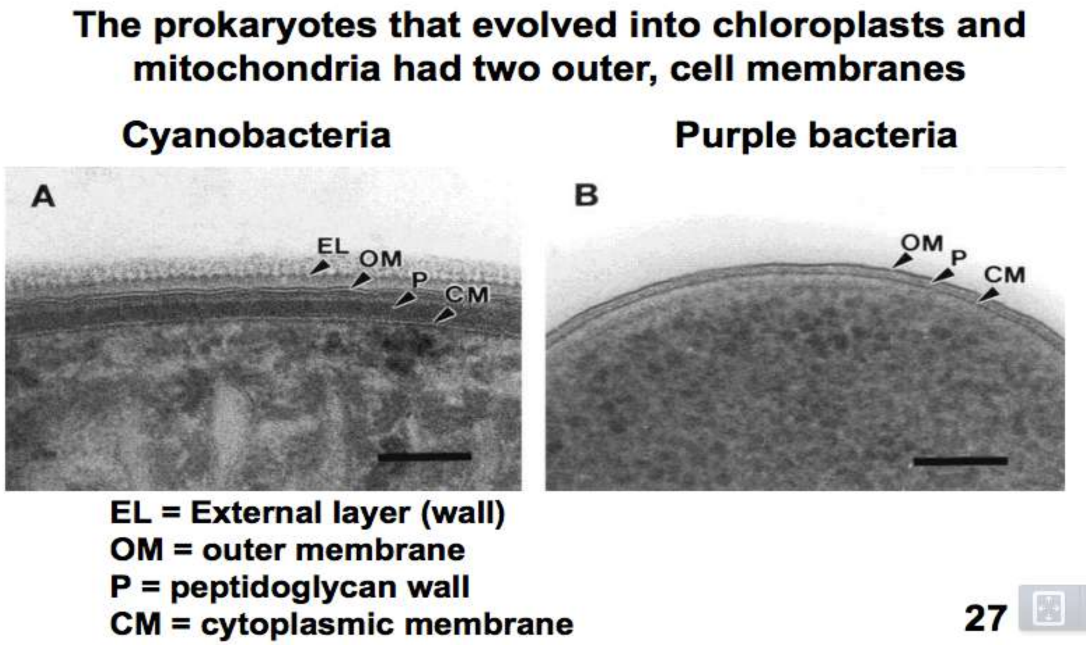
- Complex organelles believed to be derived from relict symbionts (Or relict endosymbionts)
- Mitochondria are believed to be derived from purple bacteria
- Chloroplasts are believed to be derived from symbiotic, photosynthetic bacteria called cyanobacteria

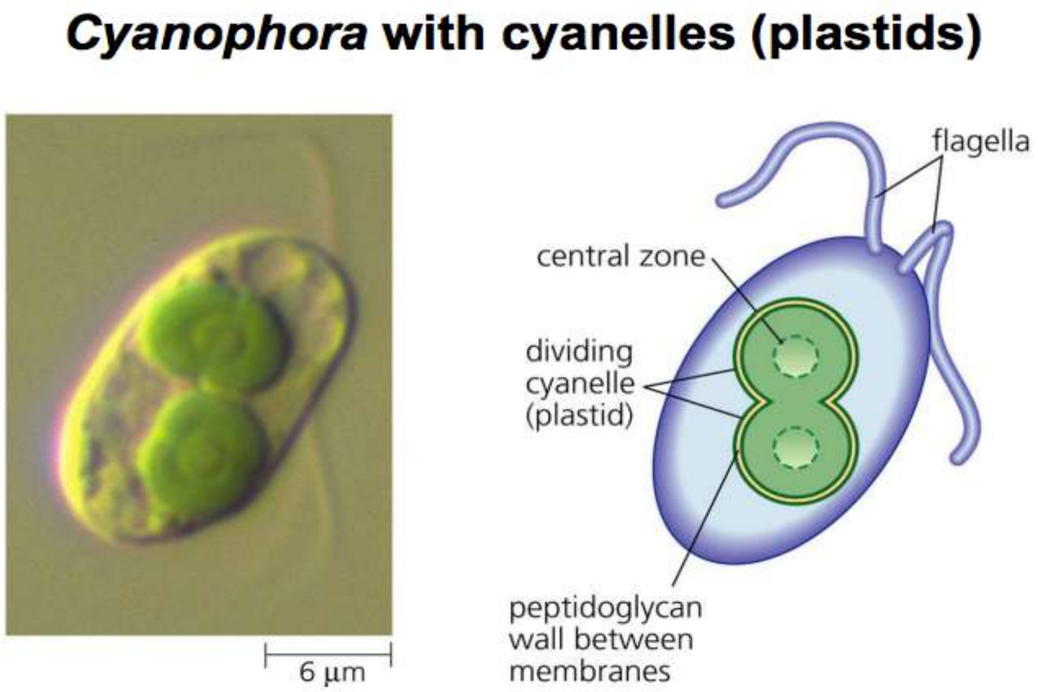
Endosymbiosis and the Origin of Chloroplasts



Evidence of the endosymbiotic origin of mitochondria and chloroplasts

- These organelles appear morphologically similar to bacteria
- They are surrounded by an outer membrane similar to a cell membrane while their inner membrane invaginates to form lamellae or cristae
- Mitochondria and chloroplasts are semi-autonomous, retaining their own genome (DNA, RNA)
- They also retain their own machinery for synthesizing proteins, including ribosomes
- Their metabolism is like existing prokaryotic organisms (Cyanobacteria for chloroplast and a purple bacteria for mitochondrion), as they both use Oxygen to generate ATP (Oxidative phosphorylation)
- Some chloroplasts still have the bacterial peptidoglycan wall between the inner and outer membranes (E.g Cyanophora)

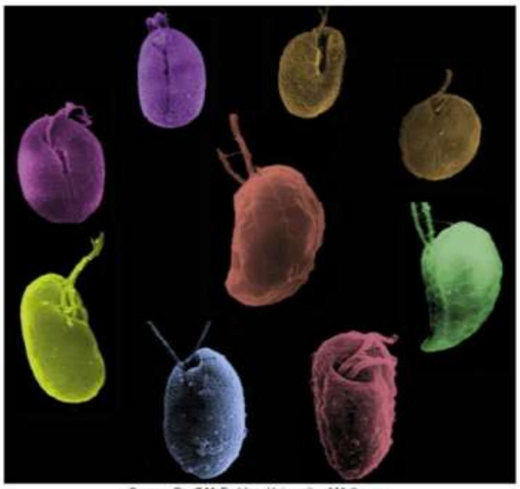


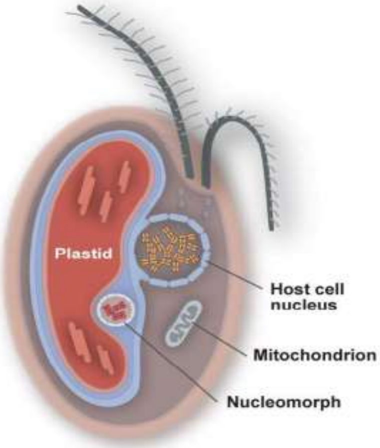
Secondary or Eukaryotic Endosymbiosis

- When a chloroplast is believed to be derived from a symbiotic eukaryotic cell rather than a prokaryote
- E.g When a eukaryote ingests the other eukaryote

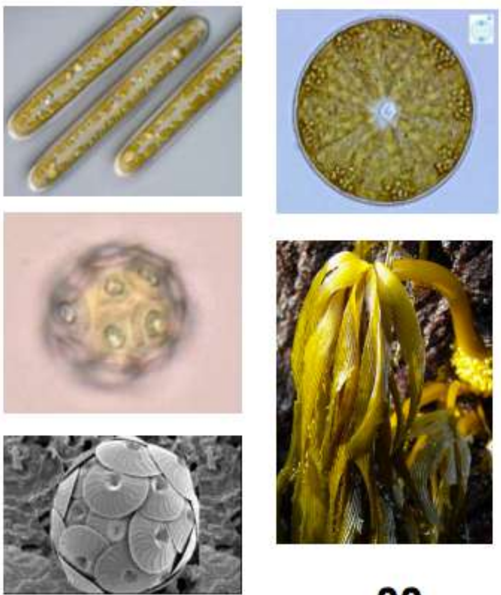
**Cryptomonads**



Source: Geoff McFadden, University of Melbourne




**"Protistan pirates"**



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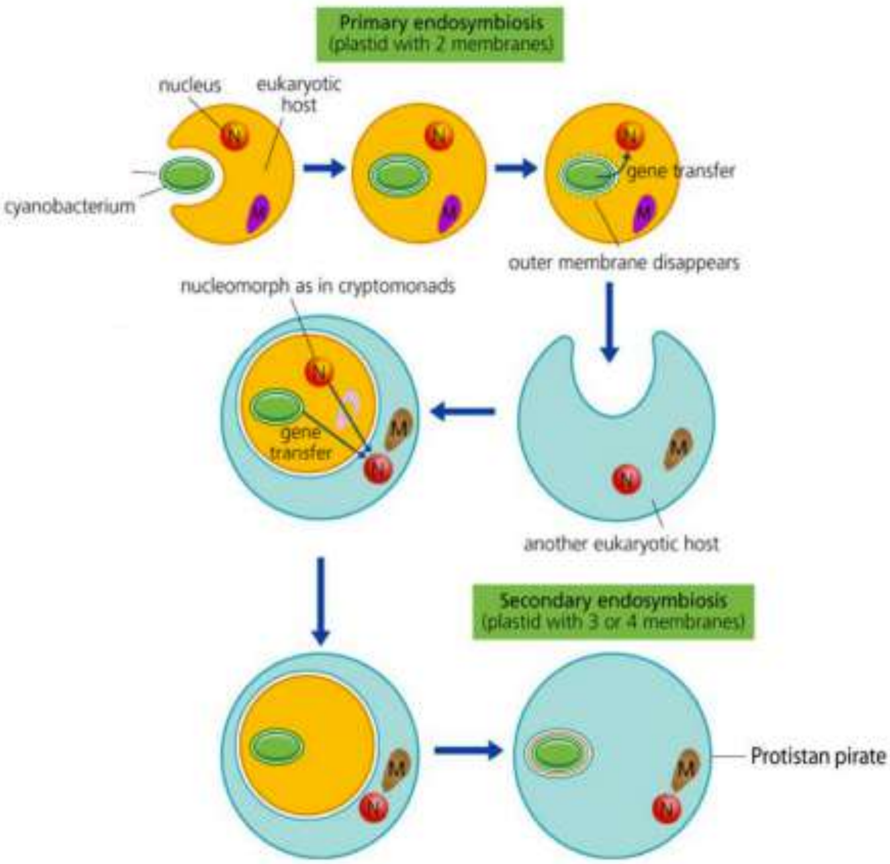

**Lecture 4 – Eukaryotes II: Endomembrane system & Cytoskeleton**

What you should know (Learning outcomes):

- What cellular components comprise the endomembrane system and how do they interact with one another?
- What are the functions of intracellular membranes?
- How are glycoproteins synthesized within cells and secreted to the cell surface?
- Understand the structure and function of the cytoskeleton
- What features of microtubules and actin filaments are similar, and how do they differ rom one another? Which associated "motor proteins" generate cell movements?
- Why are plant cell walls important?

## The Endomembrane System

A system of compartments that generally includes all of the membrane-bound components of the cell (including the nuclear envelope) except for the mitochondria and chloroplasts

### Major functions of intracellular membranes

- Provide a surface for biochemical reactions
- Establish a number of compartments to prevent mixing
- Provide for transport of materials within the cell, from the cell to its exterior, or from the cell to an adjacent cell

### Important things to remember about membranes

- Membranes always enclose a space – A cisterna or vesicle. Membranes are never open-ended, unless the cell is damaged
- Biological membranes never form T-junctions
- Membranes are the consistency of olive oil in water, not stiff barriers as indicated in diagrams

### Endoplasmic Reticulum (ER)

- The heart of the endomembrane system
- Consists of membrane Cisternae that ramify through the cytoplasm. The result is internal compartments and channels
- The ER is a dynamic structure, ever changing in structure and function
- If the ribosomes are attached to the ER, it is called Rough ER; If the ribosomes are absent, then it is referred to as Smooth ER
- The ER provides surfaces for the synthesis of proteins, lipids and carbohydrates