DP Biology – A2.2 (HL extension)

Cell origins and specialization

- What do all cells share, and how do they differ?
- How do we use microscopes to study cell structure?

HL statements A2.2.12–14. Textbook pp. 82–87.



Image: Paramecium bursaria with green algae living inside it. Picturepest, CC BY 2.0.

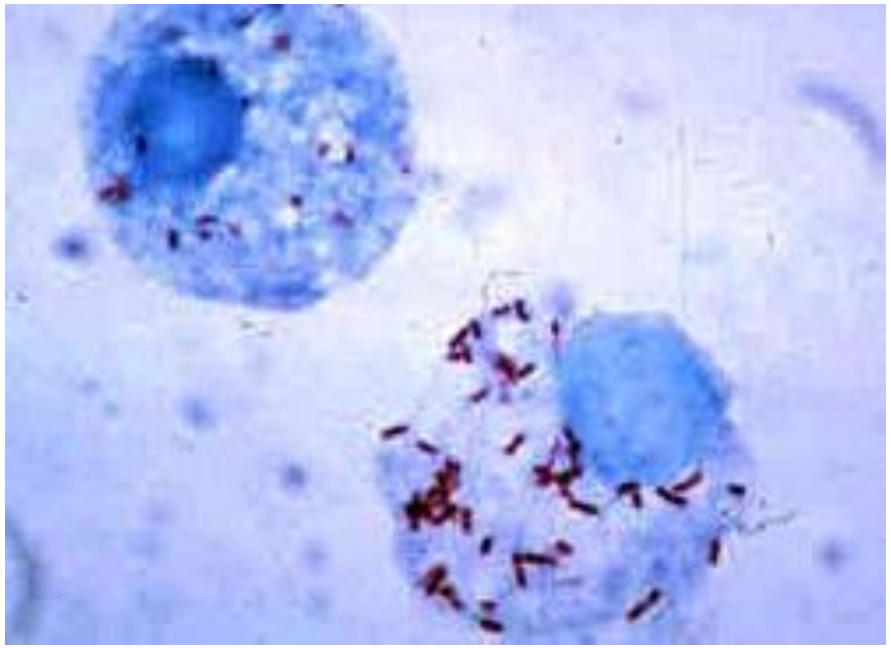
Objectives for each class

Class	Statements	By the end of the class, you can...
1	A2.2.12	Explain the endosymbiotic origin of mitochondria and chloroplasts, and evaluate the evidence for it
2	A2.2.13–14	Explain differentiation as a result of gene expression, and outline the evolution of multicellularity

Where did eukaryotic cells come from?

A2.2.12

Evidence	Approximate age
Oldest fossil prokaryotes	About 3500 million years
Oldest fossil eukaryotes	About 1600 to 1800 million years
Oldest multicellular eukaryotes	About 1000 to 1600 million years



Rickettsia (red-stained rods) inside host cells. CDC, public domain.

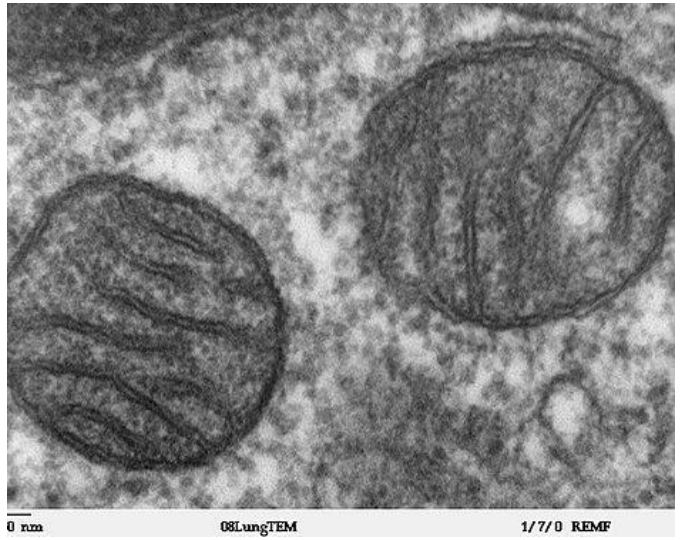
Key idea

All eukaryotes seem to share one unicellular ancestor that already had a nucleus and reproduced sexually. Mitochondria were then gained by endosymbiosis: a prokaryote was engulfed but not digested, and lived on inside its host. Mitochondrial DNA is closest to that of alphaproteobacteria, the group that includes Rickettsia.

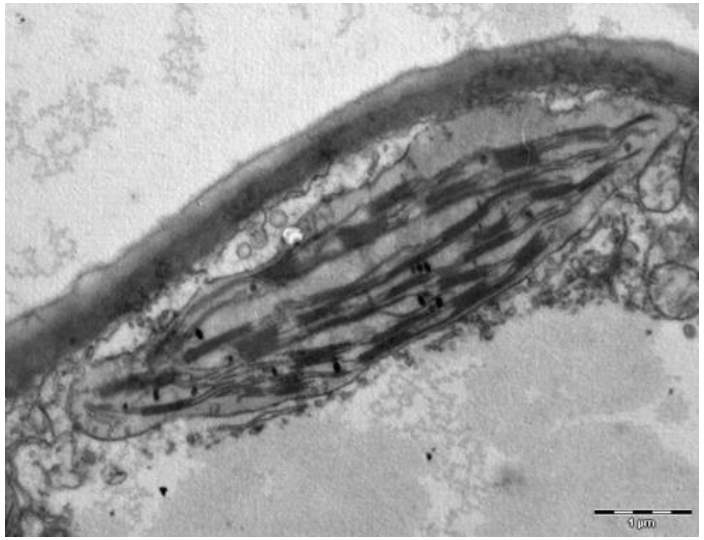
Endosymbiosis step by step

A2.2.12

A large host cell with a nucleus takes in an aerobic bacterium by endocytosis → The bacterium is not digested; it respires aerobically and supplies ATP → The host gives protection and food; both benefit (mutualism) → Over generations it becomes a mitochondrion and loses many genes → Later, in the ancestor of algae and plants, a cyanobacterium becomes a chloroplast



Mitochondria (TEM). Louisa Howard, public domain.



Chloroplast (TEM). and3k and caper437, CC BY-SA 3.0.

Common mistake

The engulfing cell is called the host. Mitochondria came first, so every eukaryote has them (or once had them); only some lineages later gained chloroplasts.

Evidence for endosymbiosis

A2.2.12

Observation	Why it supports the theory
70S ribosomes	Same size as in bacteria; eukaryotic cytoplasm has 80S
Naked, circular DNA	Like a bacterial chromosome, with no histones
Replicate by binary fission	New mitochondria and chloroplasts form only from existing ones
Double membrane	The outer membrane matches the host vacuole from endocytosis
Size	Similar in size to bacteria
DNA sequences	Chloroplast genes match cyanobacteria; mitochondrial genes match alphaproteobacteria

Making predictions from the theory

A2.2.12



Paramecium bursaria. Picturepest, CC BY 2.0.

1. **Predict** which mitochondrial membrane should have bacterial features, and which eukaryotic features.
2. **Predict** whether antibiotics that block bacterial ribosomes might affect mitochondria.
3. **Explain** why human mitochondrial DNA has only 37 genes, while a free-living bacterium has thousands.
4. **Discuss** how Paramecium bursaria, which keeps living algae inside it, supports the theory.

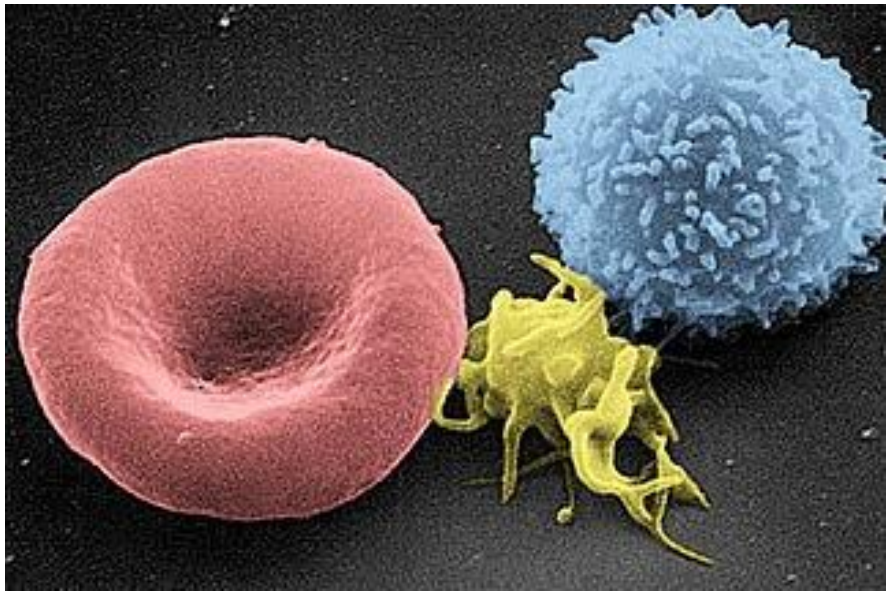
Nature of science

A strong theory explains many observations and makes predictions that can be tested. Endosymbiosis made predictions about organelle DNA that were later confirmed by sequencing.

Differentiation: same genes, different expression

A2.2.13

- Every cell in an organism has the same **genome**, because all come from one zygote by mitosis
- During **differentiation**, some genes are switched on and others off
- Signals from the environment and the cell's position trigger these changes
- Each cell type has a different **proteome**: the set of proteins it makes



Blood cells (SEM). NCI, public domain.

Specialized cells divide the work (division of labour), but each depends on the others.

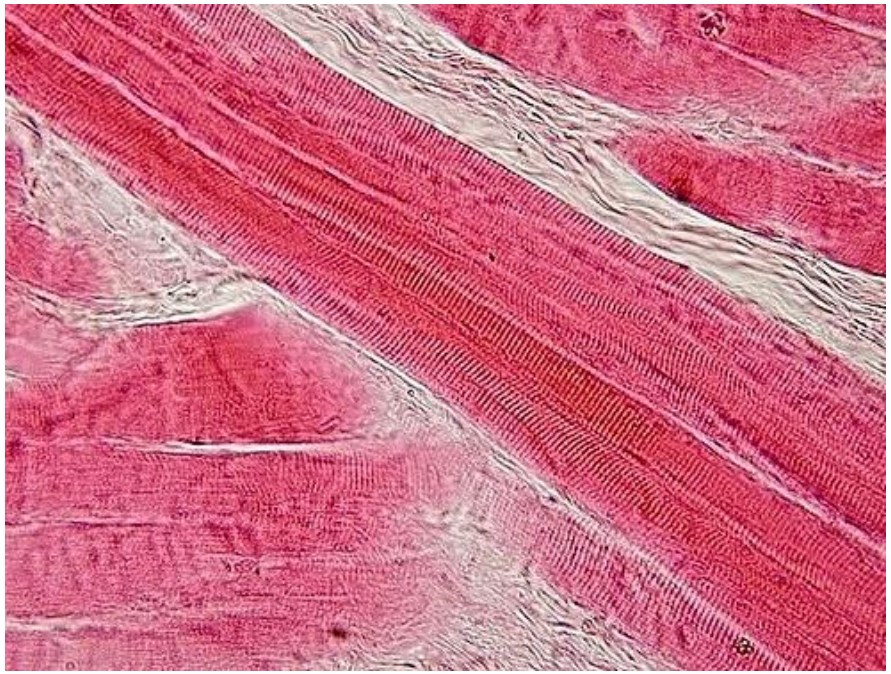
Example

A developing red blood cell expresses the haemoglobin genes strongly. A muscle cell does not, but makes actin and myosin instead.

From cells to tissues and organs

A2.2.13

Level	Meaning and example
Specialized cell	One cell type, such as a muscle fibre
Tissue	Similar cells working together, such as smooth muscle
Organ	Several tissues with one main role, such as the small intestine
Organ system	Organs working together, such as the digestive system



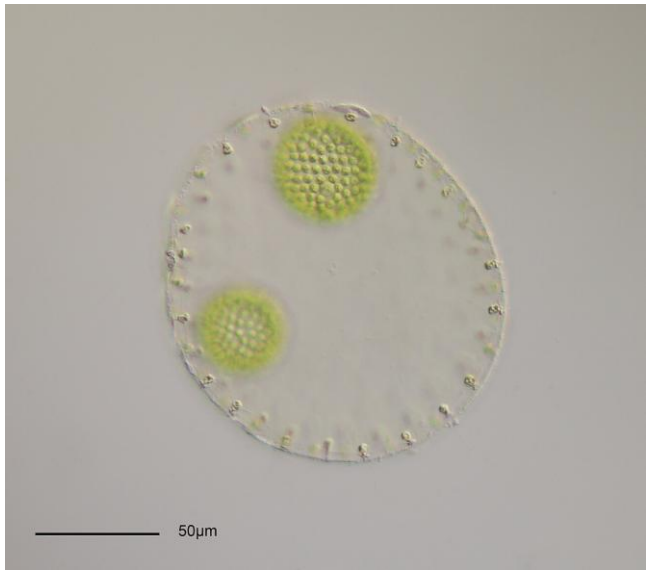
Skeletal muscle (light micrograph). Wikimedia Commons, CC BY-SA 3.0.

Cost of specialization

A nerve cell cannot get its own oxygen: it relies on red blood cells and the heart.

Multicellularity evolved many times

A2.2.14



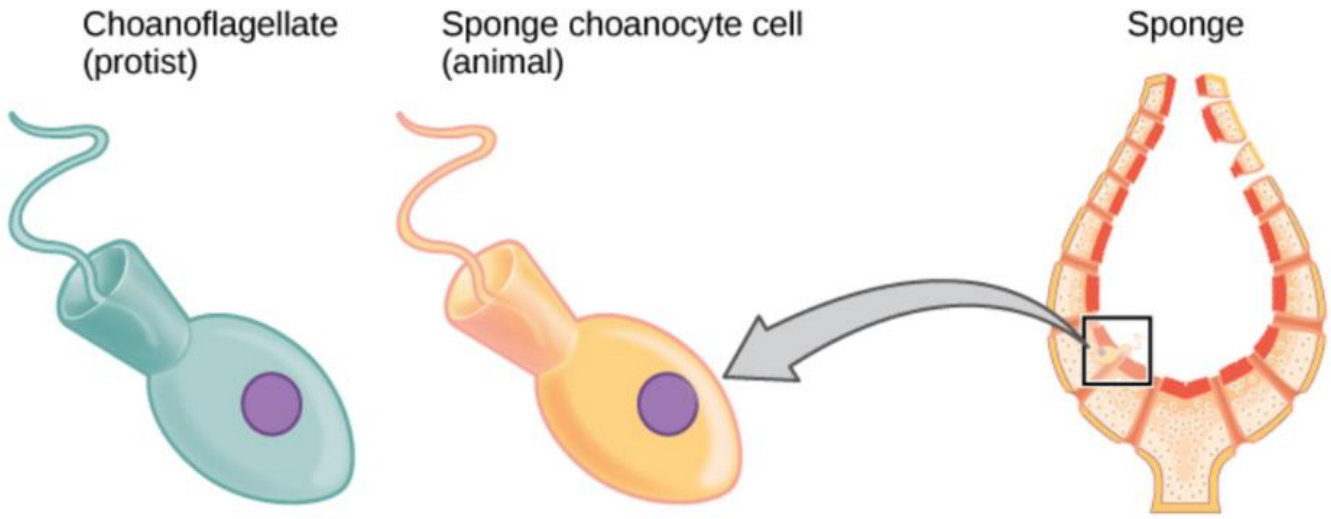
Volvox colonies with daughter colonies inside.
Picturepest, CC BY 2.0.

- All animals and plants, many fungi and many algae are multicellular
- These groups are far apart on the tree of life, so multicellularity arose **independently** many times
- Volvox: a hollow ball of up to thousands of flagellated cells, with a few cells kept for reproduction

Advantages	Requirements
Larger body size, so fewer predators and new niches	Cells must stick together (adhesion)
Specialized cells, so each task is done efficiently	Cells must signal to each other, and differentiate

The closest living relatives of animals

A2.2.14



A choanoflagellate and a sponge collar cell. Clark, Choi and Douglas, CC BY 4.0.

Evidence

Choanoflagellates are single cells with a collar and one flagellum, like the collar cells of sponges. Some form colonies. Gene sequences place them as the sister group of animals.

Discuss

Unicellular organisms still make up much of the biomass on Earth. Suggest why single cells have not been replaced by multicellular organisms.

Check that you can explain

1. The sequence of endosymbiosis for mitochondria, then chloroplasts
2. Five pieces of evidence for endosymbiosis
3. How the theory made predictions that were later tested
4. Why all cells have the same genome but different proteomes
5. How signals and position trigger differentiation
6. Why multicellularity is thought to have evolved many times
7. Two advantages of multicellularity

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. State two features of mitochondria that suggest they were once bacteria.
2. Explain how cells with identical genomes become different.
3. Give one reason multicellularity is thought to have evolved more than once.

Image credits

Paramecium bursaria – 400x (13263096305).jpg – Picturepest – CC BY 2.0

Rickettsia rickettsii.jpg – CDC – Public domain

Mitochondria, mammalian lung – TEM.jpg – Louisa Howard – Public domain

Chloroplast in leaf of Anemone sp TEM 12000x.png – and3k and caper437 – CC BY-SA 3.0

Red White Blood cells.jpg – Electron Microscopy Facility at The National Cancer Institut – Public domain

Skeletal muscle – longitudinal section.jpg – Author not stated – CC BY-SA 3.0

Volvox aureus – 160x – Crosssection – daughter colonies (14811155248).jpg – Picturepest – CC BY 2.0

Choanoflagellate and choanocyte.png – Clark MA, Choi J and Douglas M – CC BY 4.0

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