"Symbiogenesis"

Professor Peter O'DONOGHUE

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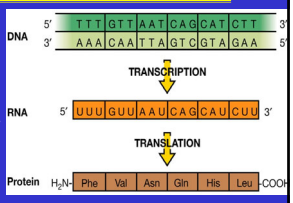
Origin of Species

Evolution through:
- mutation
- recombination
- lateral gene transfer

('selfish' gene)



Phenotype
- survival of fittest
- natural selection

Darwinism "Evolution based on competition"

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Living Together

Inter-species relationships

Comparative cell biology identified:
- progressively complex organisms
- differential possession of organelles

Suggestive of:
- common ancestry
- symbiotic associations

SET posits "Evolution aided by collaboration"

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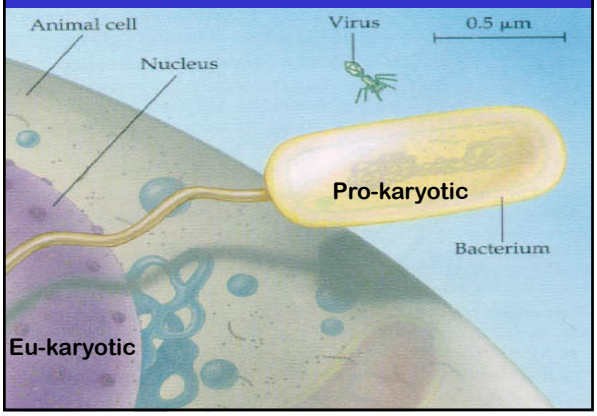
KARYOTIC DOMAINS



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COMPARISON

PROKARYOTE
- anucleate cells
- single circular chromosome
- limited number of genes
- little error checking
- poor regulation of water/salt (mechanically strong cells to withstand osmotic forces)
- most with anaerobic metabolism (use fermentative pathways)

EUKARYOTE
- nucleate cells
- many chromosomes
- complex gene organization
- error checking in genome
- good regulation of salt/water flux (active transport systems in cell membranes)
- most with aerobic metabolism (use mitochondria)

Major differences in cell biology
(endomembranes, flagella, organelles)

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PROKARYOTES

Archaea
(extremophiles)
methanogens
requiring H

Eubacteria
(true bacteria)
anaerobes
producing H

LUCA [4 BYA]
(last universal common ancestor)

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SYMBIOGENESIS

Eukaryotes [2 BYA]

Archaea (extremophiles) methanogens requiring H

Eubacteria (true bacteria) anaerobes producing H

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EUKARYOTES

Protists 1.8 BYA

Plants 1.0 BYA

Fungi 0.7 BYA

Animals 0.5 BYA

Eukaryotes [2 BYA]

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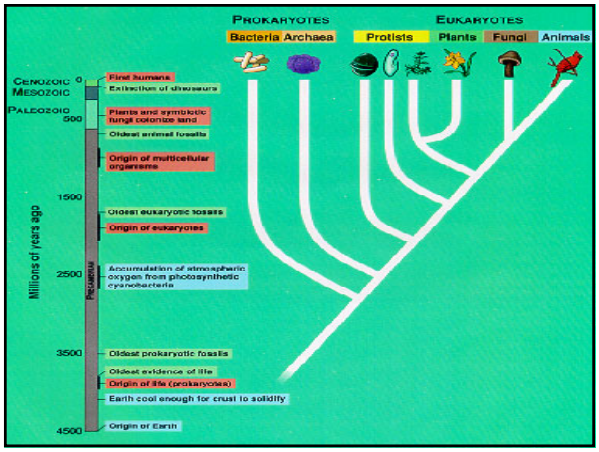

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Serial Endosymbiosis Theory (eukaryotes = chimeras)

ur-karyote

endomembranes (nuc env, ER, Golgi)

phagotrophic? syntropic?

flagella (2+9)

direct filiation? exogenous? (spirochaetes)

mitochondria

α-proteobacteria

chloroplasts

cyanobacteria

other plastids

miscellaneous?

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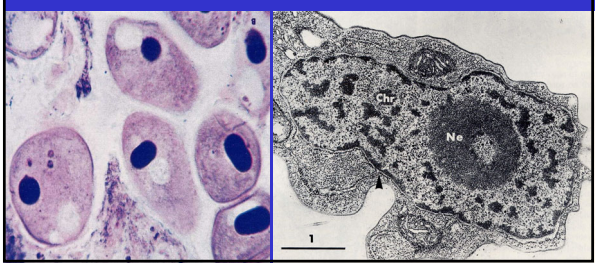
Endomembranes – nuclear envelope

- DNA, genes, chromosomes/chromatin
- nuclear envelope (incl. transcription) (excl. translation)



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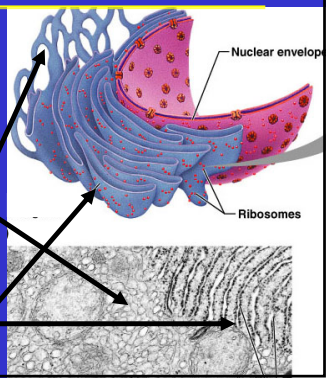
Endomembranes – endoplasmic reticulum

- smooth ER elaborate membrane system
- rough ER with ribosomes (sites of protein synthesis)



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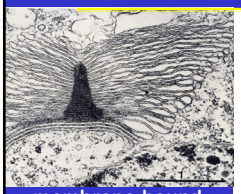
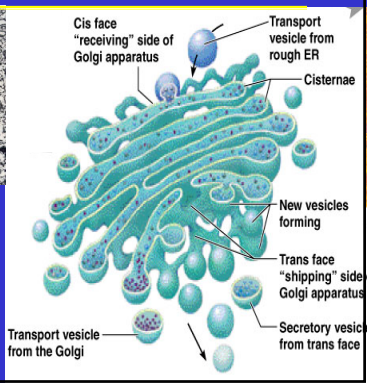
Endomembranes – dictyosomes (Golgi bodies)





- membrane-bound compartments (transport system)
- selective processing, sorting and secretion of proteins

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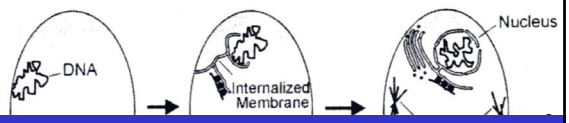
ENDOMEMBRANES

phagotrophic (autogenesis)

- DNA associated with cell membrane
- membrane invaginates, encapsulates DNA
- ER involved with protein synthesis
- Golgi bodies involved with protein trafficking



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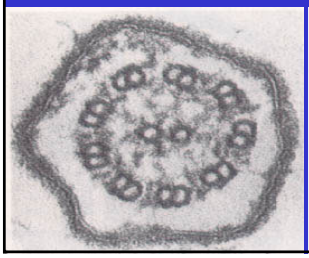
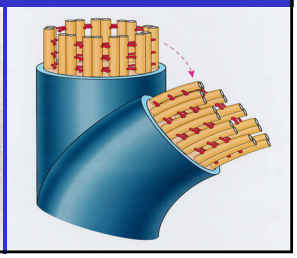
FLAGELLA (UNDULIPODIA)

- membrane-bound extensions of cell
- 2+9 microtubular core
- dynein walking (not rotary)





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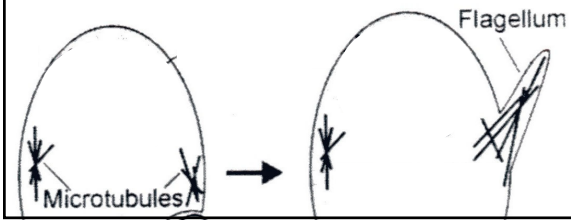
FLAGELLA

autogenesis (endo..)	symbiogenesis (exo..)
- direct filiation of micro-tubules, membrane pockets	- spirochaetes
- mitotic spindle	- attach to membrane
	- rotary flagella?



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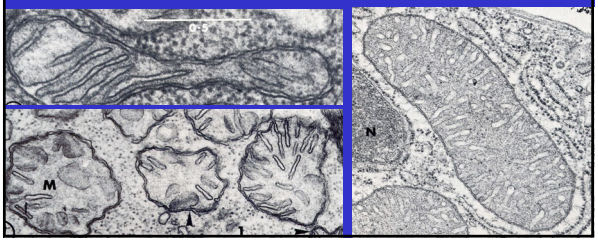
MITOCHONDRIA

- proteobacterial origins
- membrane-bound organelles with cristae
- oxidization of pyruvate produced by glycolysis
- citric acid cycle with chain of electron carriers



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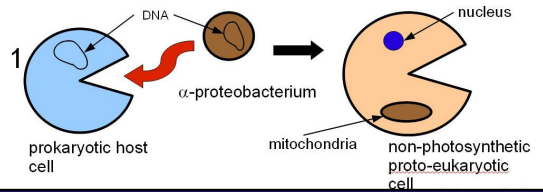
MITOCHONDRIA

Symbiogenesis

- attachment of alpha proteobacterium
- endocytic uptake into cytoplasm
- mutualistic symbiosis



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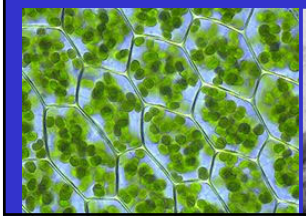
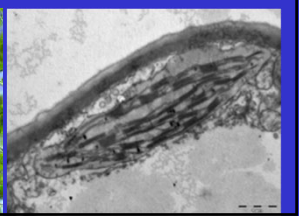
CHLOROPLASTS

- cyanobacterial origins
- membrane-bound organelles with chlorphyll
- absorb solar energy for photosynthesis
- produce glucose from water and carbon dioxide





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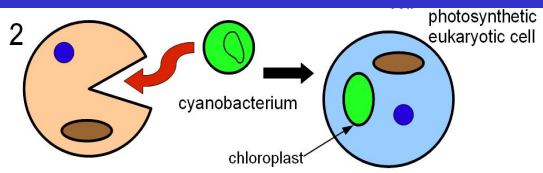
CHLOROPLASTS

Symbiogenesis

- endocytic uptake of cyanobacterium
- biochemical modification in cytoplasm
- mutualistic symbiosis



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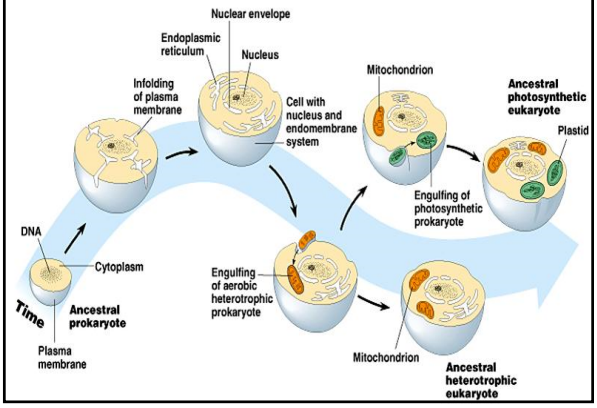
Serial endosymbiosis



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Order of acquisition

SET = serial endosymbiosis theory (Margulis)

- endomembranes
- mitochondria
- chloroplasts

HH = Hydrogen hypothesis (Muller)

- mitochondria
- endomembranes
- chloroplasts

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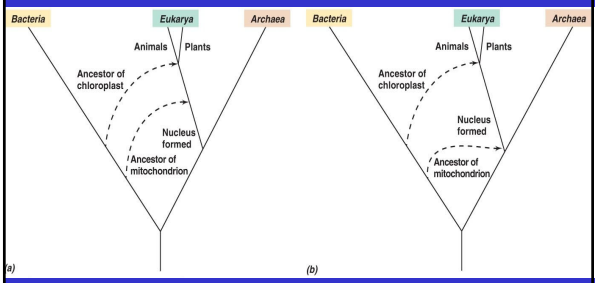
Competing theories



phagotrophic
some eukaryotes evolved without mitochondria

syntrophic
all eukaryotes evolved with mitochondria

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Evidence for syntropic

mitochondrial DNA
(evidence that all eukaryotes had mitochondria)
(those without still retain genetic elements)

- CoRR (co-location for redox regulation)
  (why most plastids retain DNA)
- Numt (nuclear mitochondrial DNA)
  (transfer of DNA from plastid to nucleus)

primary/secondary/tertiary acquisition/loss

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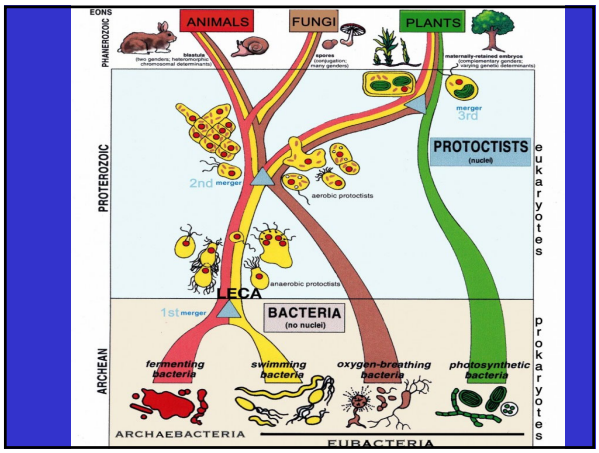
EONS
PHANEROZOIC
PROTEROZOIC
ARCHEAN
ANIMALS
FUNGI
PLANTS
PROTOCTISTS
(nuclei)
2nd merger
aerobic protoctists
anaerobic protoctists
LECA
1st merger
BACTERIA
(no nuclei)
fermenting bacteria
swimming bacteria
oxygen-breathing bacteria
photosynthetic bacteria
ARCHAEBACTERIA
EUBACTERIA
eukaryotes
prokaryotes

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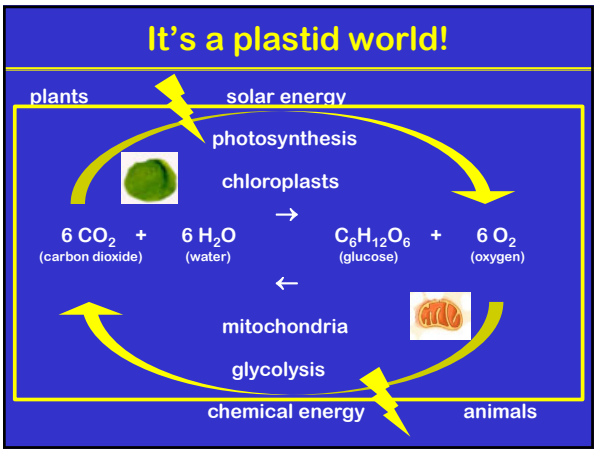
It's a plastid world!
plants
solar energy
photosynthesis
chloroplasts
6 CO2 + 6 H2O
(carbon dioxide) (water)
C6H12O6 + 6 O2
(glucose) (oxygen)
mitochondria
glycolysis
chemical energy
animals

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