Building a microbe
2. Eukarya

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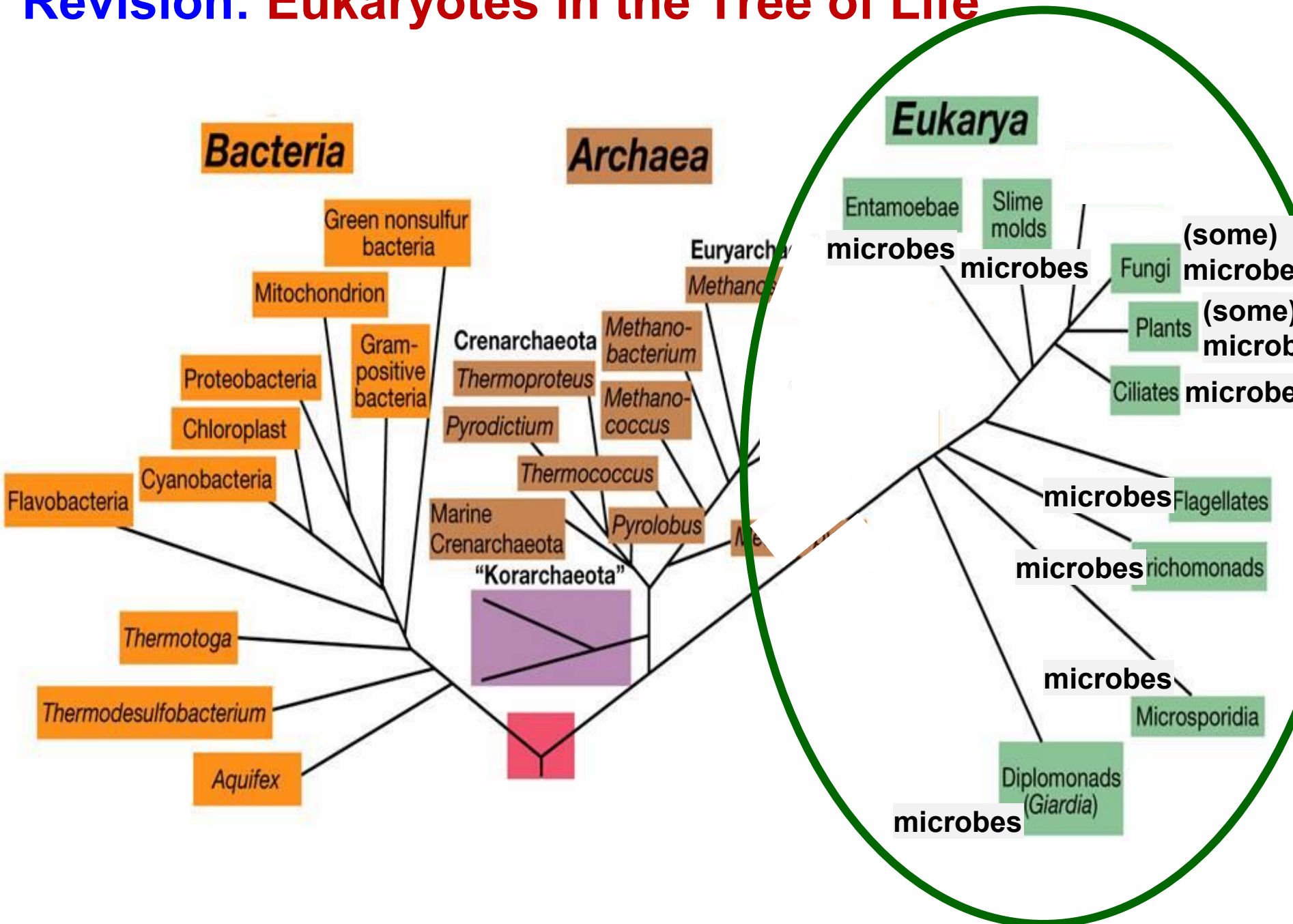
Learning objectives

'Prescott's Microbiology'
10th ed, 2017, chapter 5.

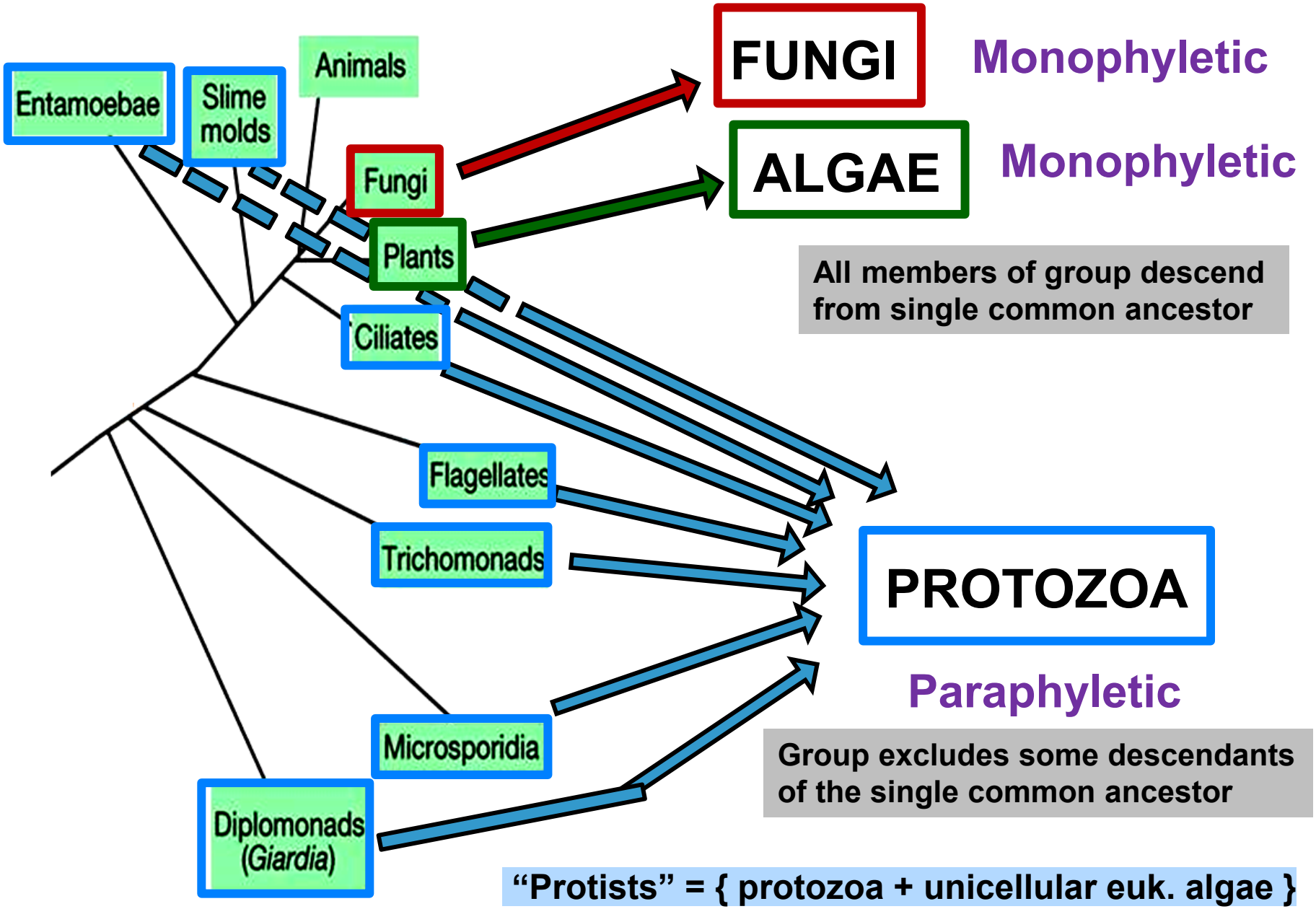
Students should be able to :

- Describe structural, functional, and taxonomic differences between the three types of microbial eukaryotes (algae, fungi, protozoa)
- Explain the significance of microbial eukaryotes to medicine, agriculture and biotechnology
- Explain the components, structure, functions, significance of:
  - cytoskeleton
  - secretory pathways
  - endocytic pathways
  - nucleus
  - mitochondria
  - cilia & flagella

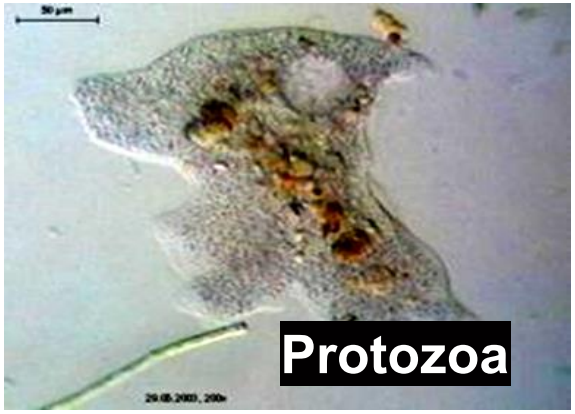
Revision: Eukaryotes in the Tree of Life

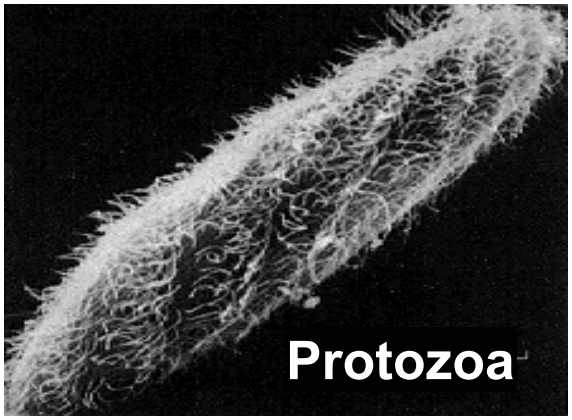


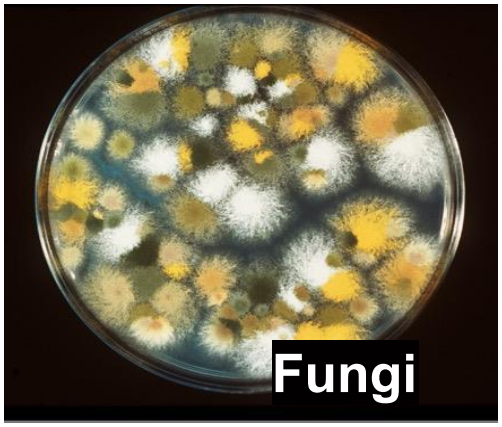
Microbial Eukaryotes: taxonomy of major groups

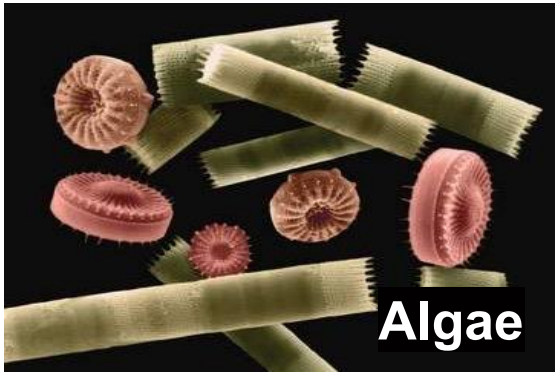


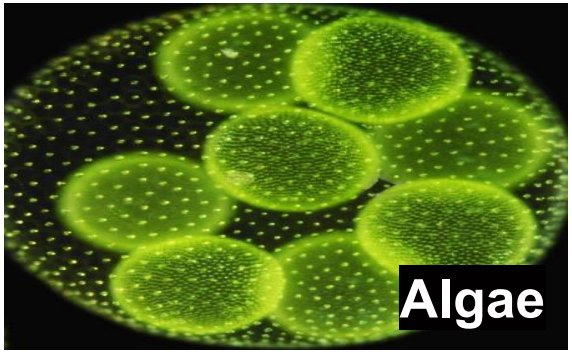
Microbial eukaryotes: morphologically diverse





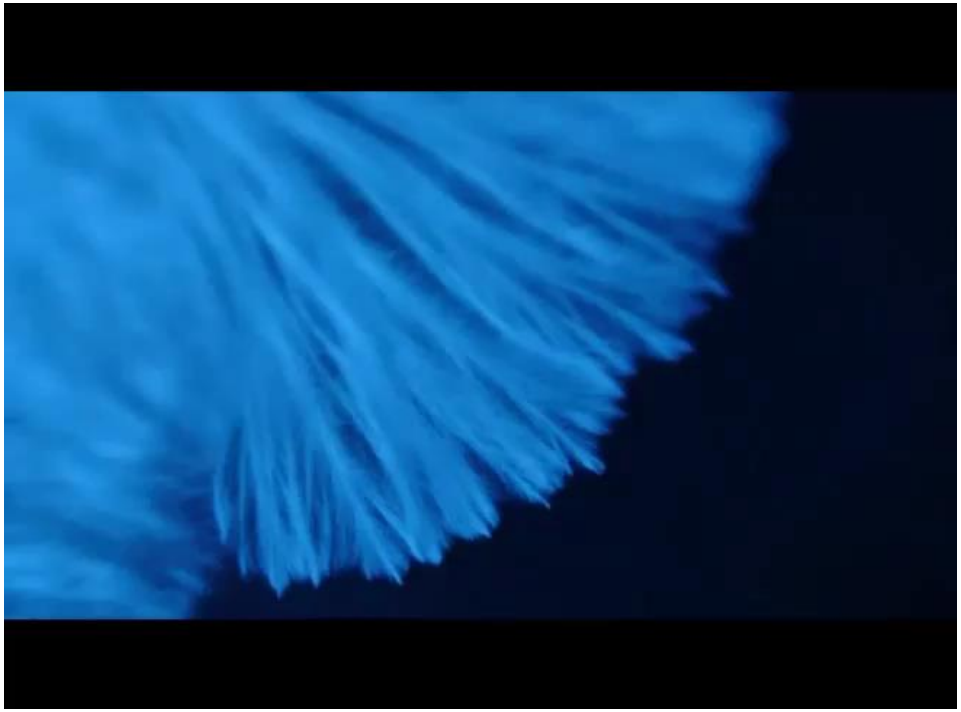






Distinguishing features of microbial eukaryotes

	Metabolism	Motility ★	Digestion
Algae	Photoautotrophs	Variable	n/a
Fungi	Heterotrophs	Non-motile	Extracellular
Protozoa	Heterotrophs	Motile	Intracellular



★ What do we mean by "MOTILITY" ? The fungi in this video are clearly moving from one place to another…

Microbial eukaryotes: significance – good guys

FUNGI

- **Food:** both mushrooms and yeasts
- **Fermentation:** alcohol, bread, soy sauce
- **Biotechnology:** yeasts for protein expression
- **Agriculture:** plant symbiosis, nutrient cycling
- **Medicine:** antibiotics, anti-cancer drugs etc …

Agaricus: food

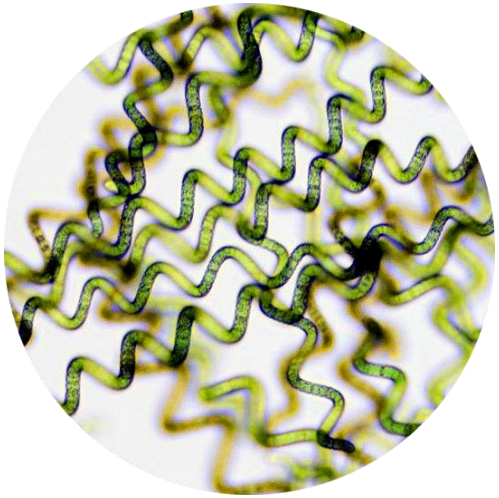
Penicillium: antibiotics

Hericium: nerve growth

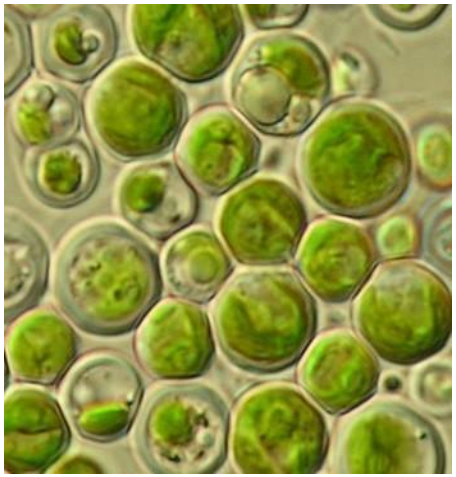
Microbial eukaryotes: significance – good guys

(MICRO) ALGAE

- **Food:** ***Spirulina, Chlorella***
- **Medicine:** **antioxidants, antivirals, anti-cancer drugs**
- **Biofuel:** **oils, biodiesel, hydrogen**
- **Biotechnology:** **gene-engineered biofuels**



***Spirulina*: food**



***Chlorella*: antioxidants**

***Dunaliella*: biodiesel**

Microbial eukaryotes: significance – bad guys

FUNGI

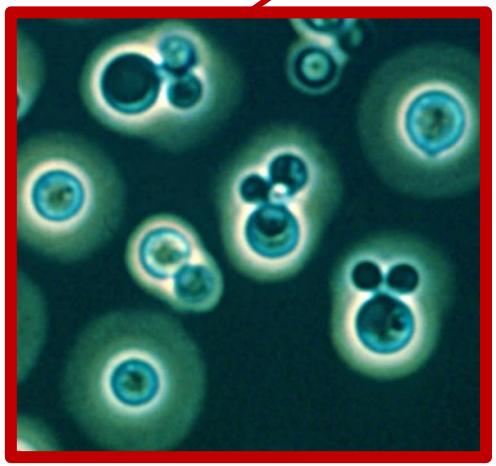
- Infectious diseases
- Toxins in food
- Food spoilage

PROTOZOA

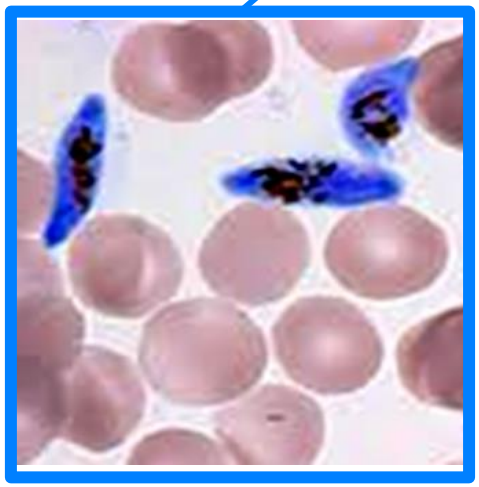
- Infectious diseases

ALGAE

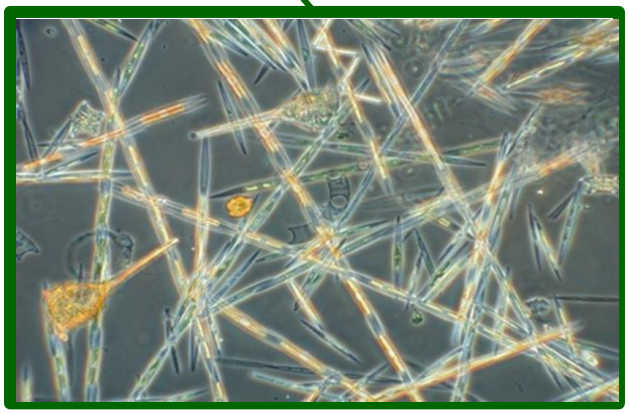
- Toxic algal blooms



Cryptococcus: infection

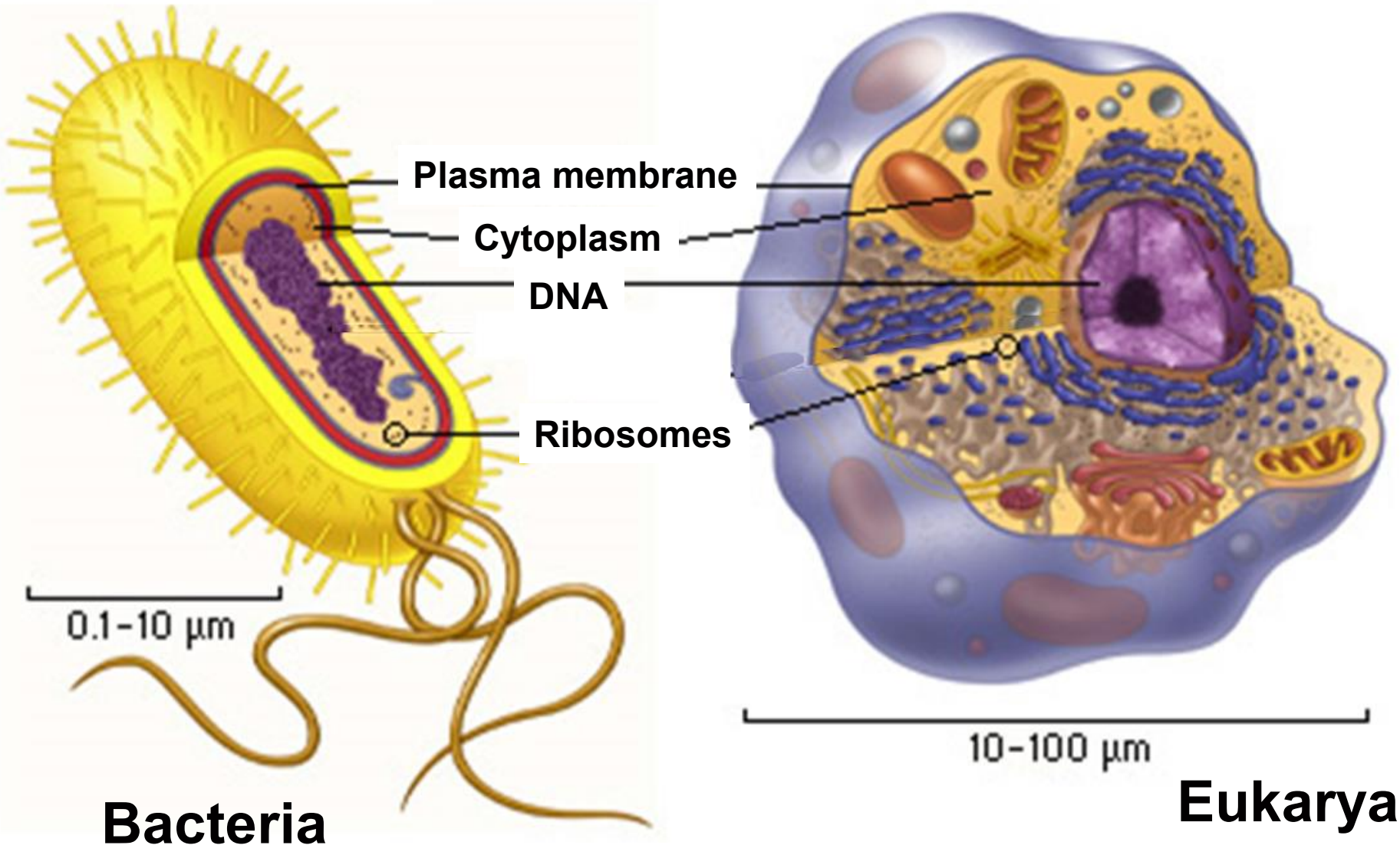


Plasmodium: malaria



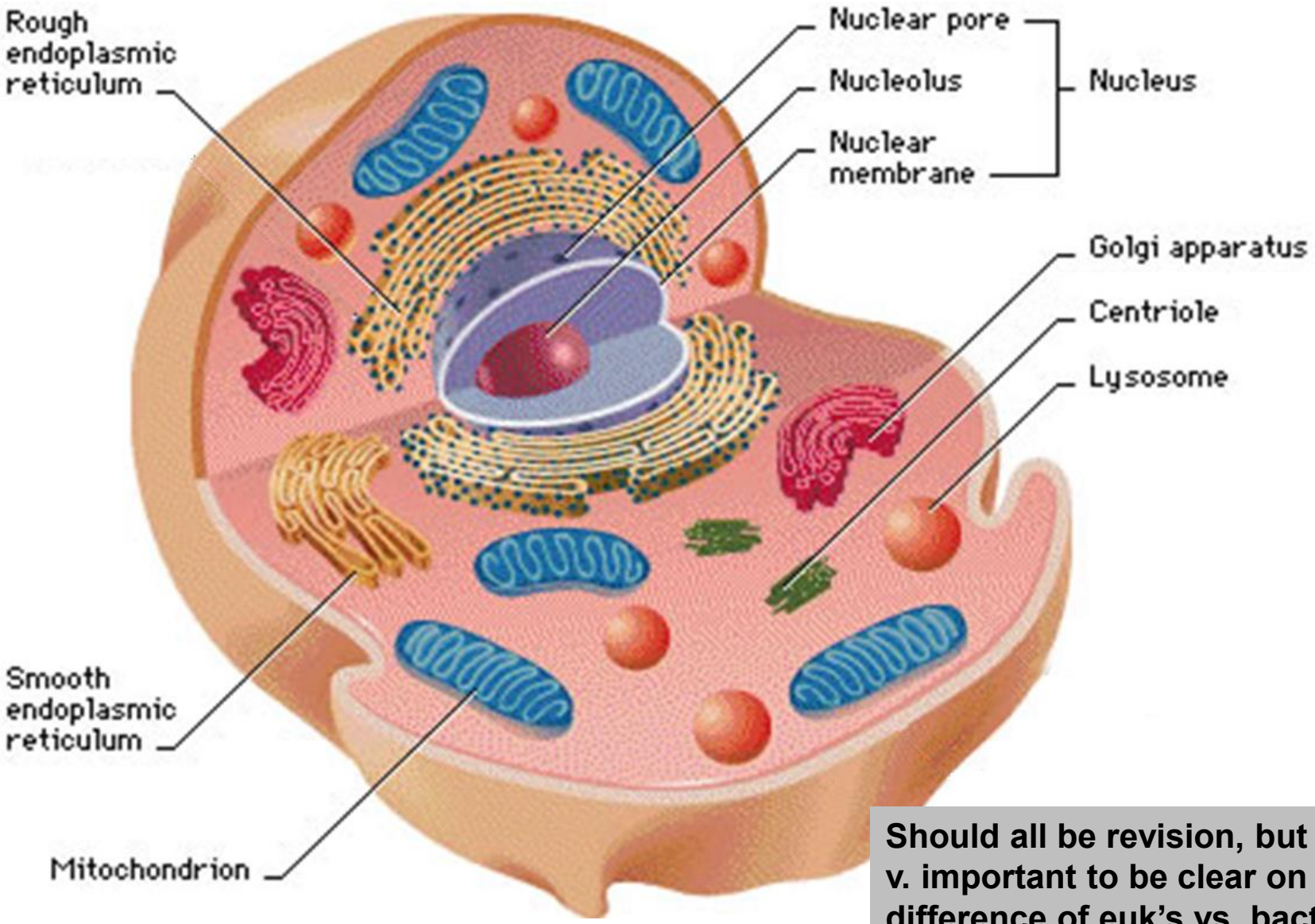
Pseudo-nitzschia: toxins

Structures shared by Bacteria and Eukarya



Note scale bars ! Drawings not to scale !

Structures unique to Eukarya



Should all be revision, but v. important to be clear on difference of euk's vs. bacteria

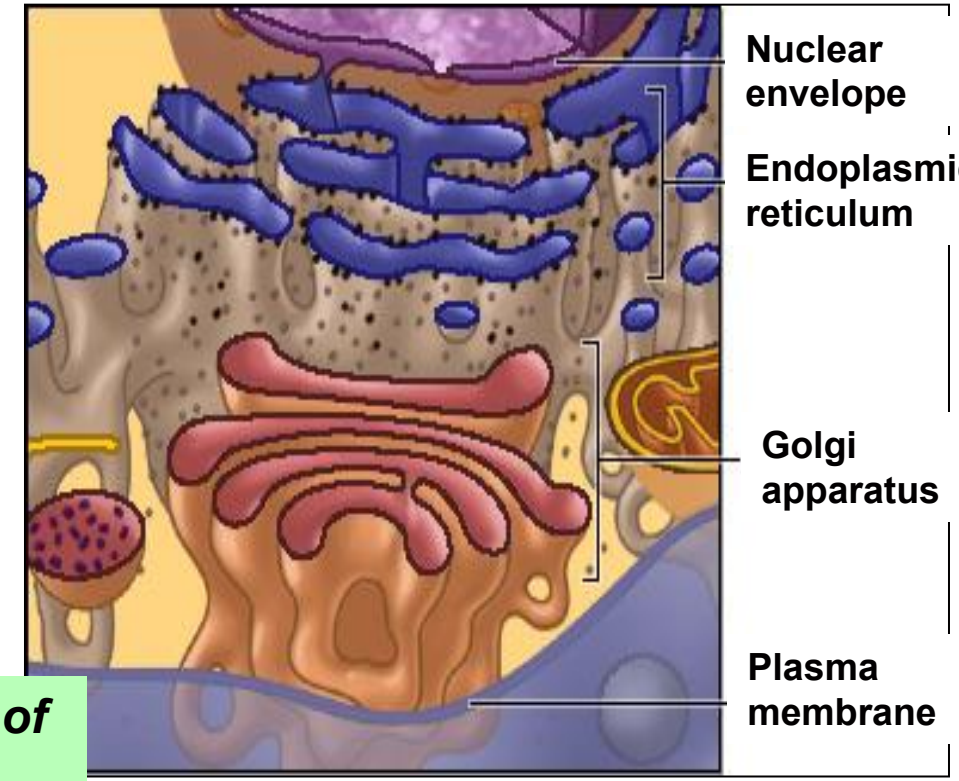
Eukaryotic internal membranes

Eukaryotes use internal membranes to separate cell compartments – this is rare in bacteria

- Provides places for different biochemical functions

- Gives greater surface area for respiratory and photosynthetic activity

- Allows transport of molecules between different cell locations



We will return to the function of these structures later

Eukaryotic cell envelope = cell membrane + cell wall

- **Membranes: contain phospholipids + sterols e.g. cholesterol, ergosterol. No outer membrane or LPS.**

- **Eukaryote cell wall: has NO peptidoglycan!**
  - **Fungi: wall of chitin**
  - **Algae: wall of cellulose**
  - **Protozoa: variable wall (none, cellulose, silica)**

The uniquely beautiful structure of diatoms is due to silica well walls

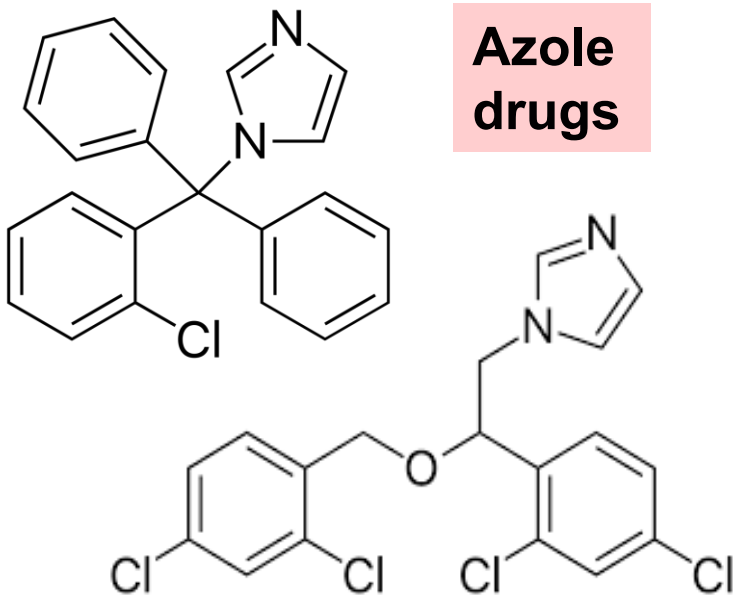
Eukaryotic cell envelope: significance – bad guys

- Pathogenic microbial eukaryotes are not affected by antibiotics that target peptidoglycan e.g. penicillin

- Need to target eukarya-specific features, e.g. sterol biosynthesis with azoles

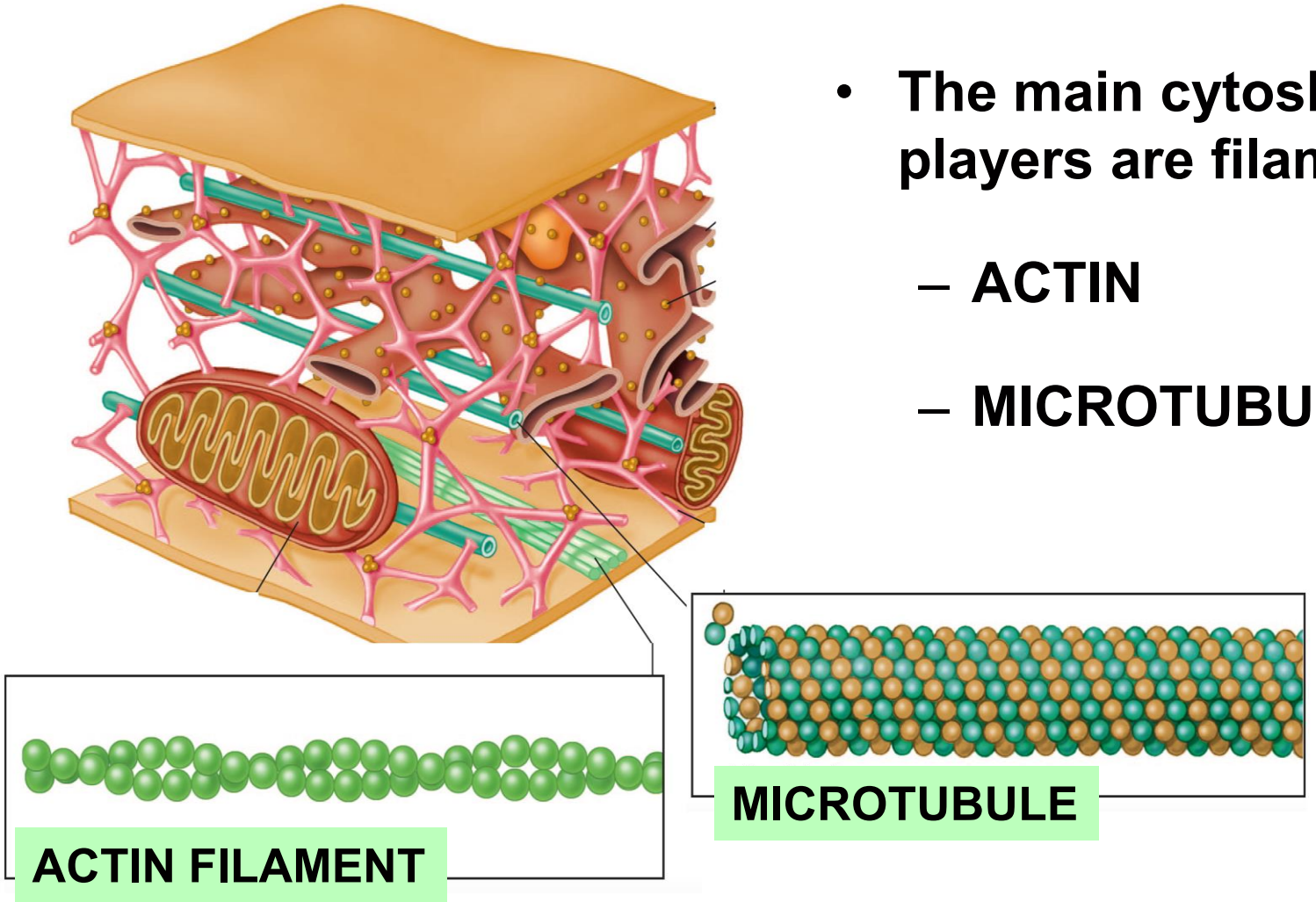
- Azoles are one of the few effective antifungal agents

Azole drugs



Eukaryotic cytoskeleton

- The cytoskeleton is involved in transport, motility and ensuring structural integrity of eukaryotic cells



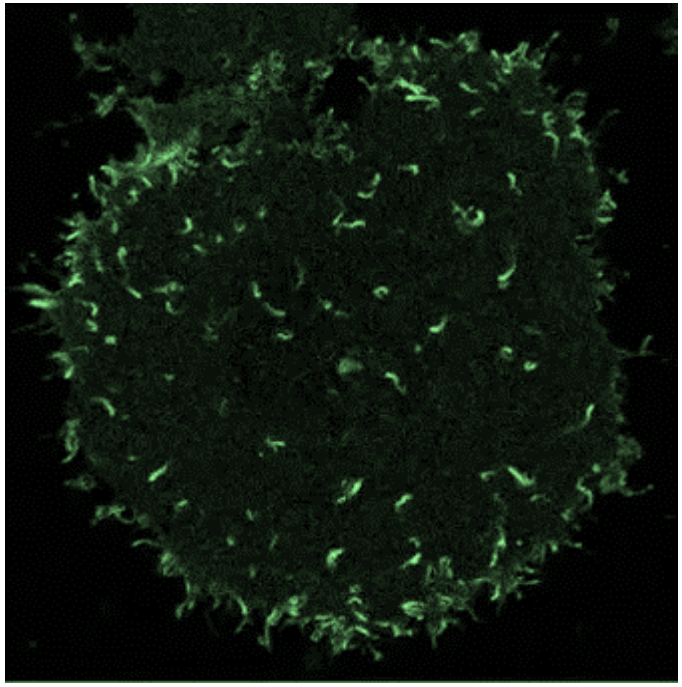
- The main cytoskeleton players are filaments:
  - ACTIN
  - MICROTUBULES

Eukaryotic cytoskeleton: functions + significance

- **Actin filaments:** amoeboid movement, endocytosis, cytokinesis, intracellular movement of small particles

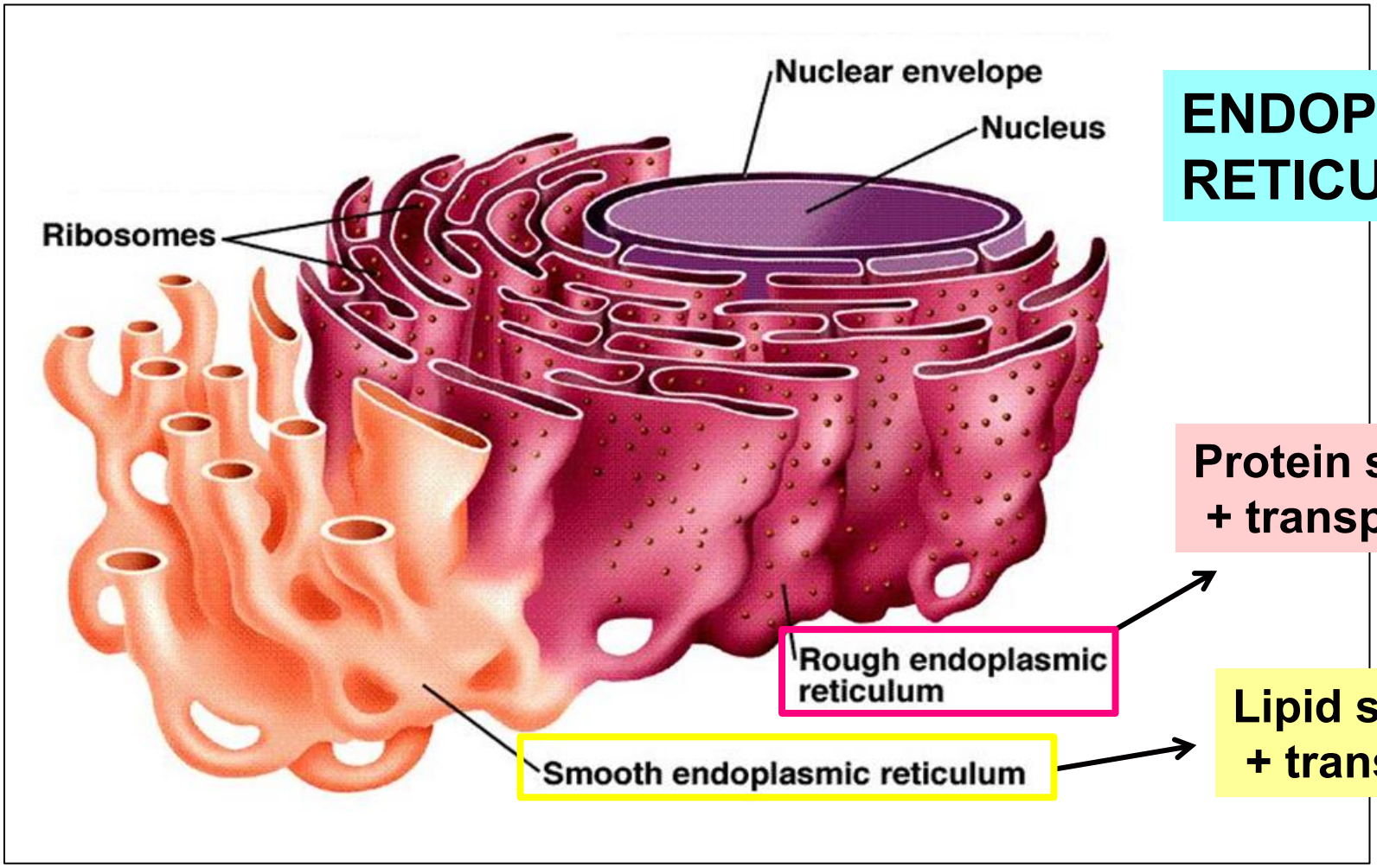
- **Microtubules:** spindle apparatus (mitosis / meiosis), cilia and flagella, intracellular movement of organelles

Some viruses hijack actin to move inside and between host cells e.g *Vaccinia*



Eukaryotic secretory pathways

- **Secretory pathway transports materials out of cell.**
  Nucleus → endoplasmic reticulum → Golgi apparatus



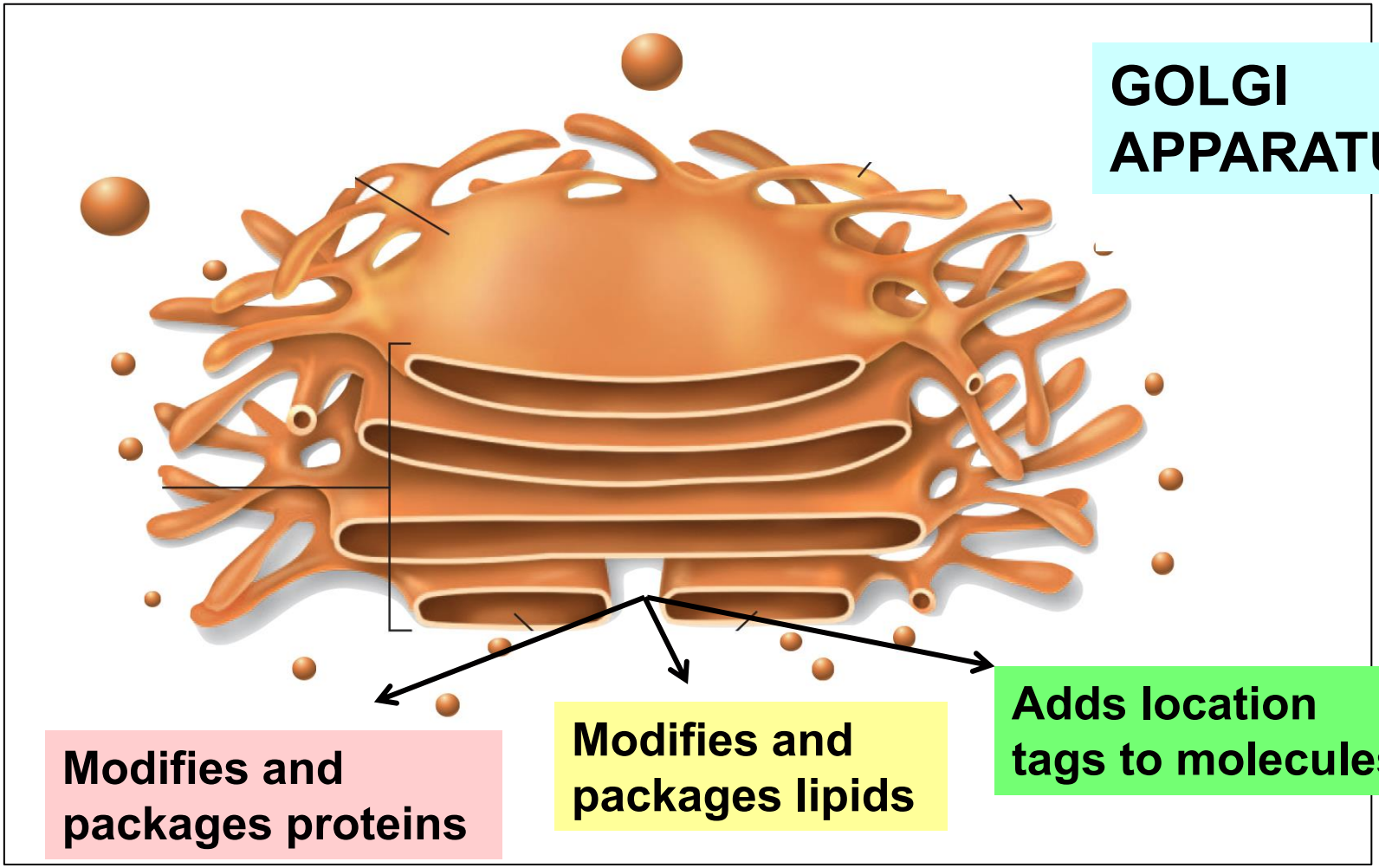
ENDOPLASMIC RETICULUM

Protein synthesis + transport

Lipid synthesis + transport

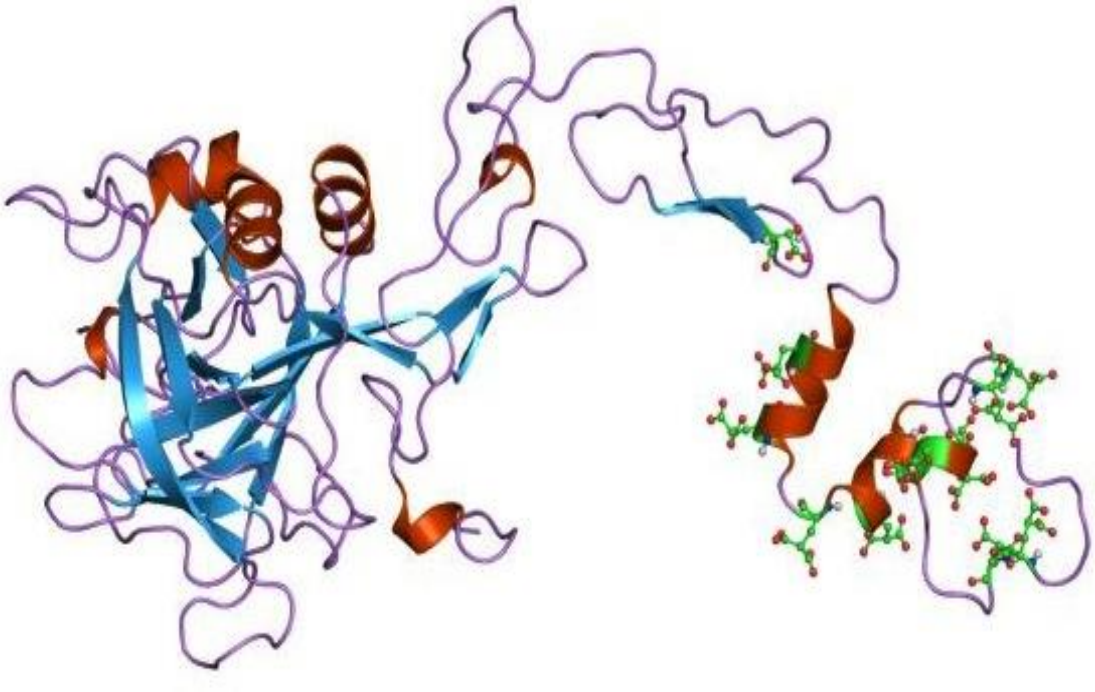
Eukaryotic secretory pathways

- Secretory pathway transports materials out of cell.
  Nucleus → endoplasmic reticulum → Golgi apparatus



Eukaryotic secretory pathways: significance

- Many human proteins contain post-translational modifications (e.g. glycosylation) done in ER or Golgi
- These proteins are non-functional if made in recombinant bacterial systems (lack ER and Golgi)
- e.g. coagulation factor IX protein (for haemophilia): manufactured in mammalian cell culture



Eukaryotic endocytic pathways

- Endocytic pathway: import of materials into cell

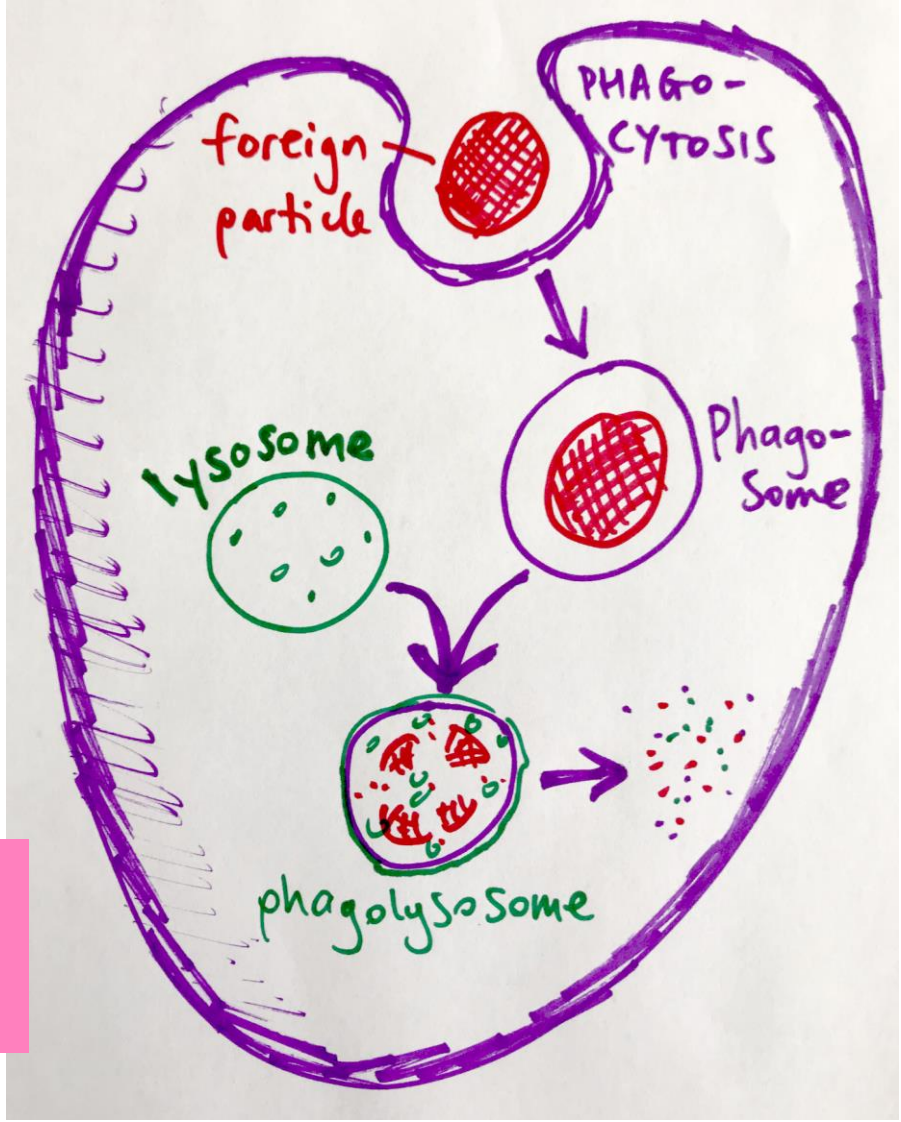
- Phagocytosis of foreign object (food, pathogen, etc)

  → phagosomes

  → merge with lysosomes

  → phagolysosome

  → digestion



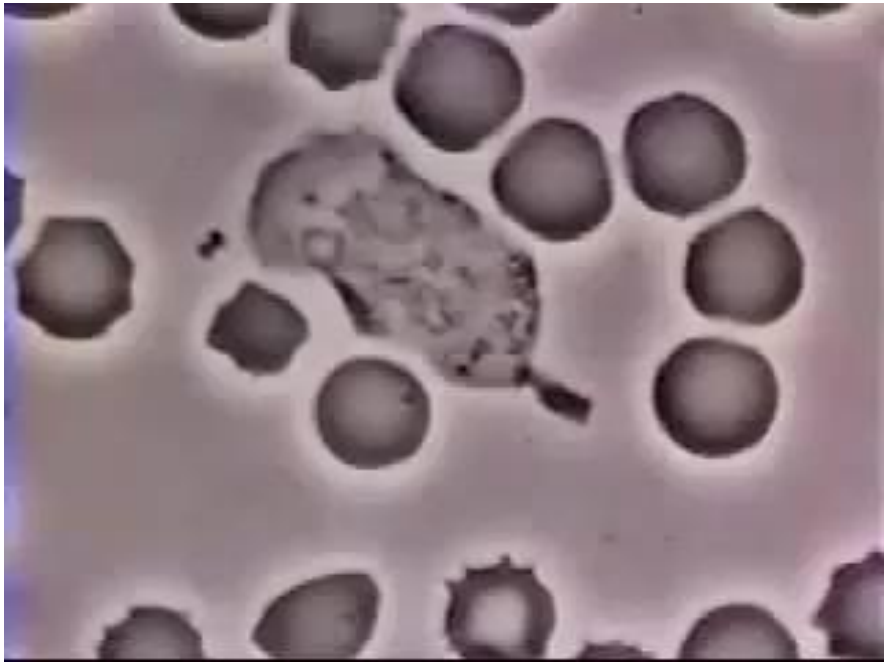
Lysosomes are the cell's recyclers. Enzymes + acid break down macromolecules

Eukaryotic endocytic pathways: significance

- Our macrophages use the endocytic pathway to destroy bacteria and other pathogens

BUT

- Some pathogens can exploit the endocytic pathway to invade cells … the system is not perfect !



Macrophage hunting *Streptococcus* in blood

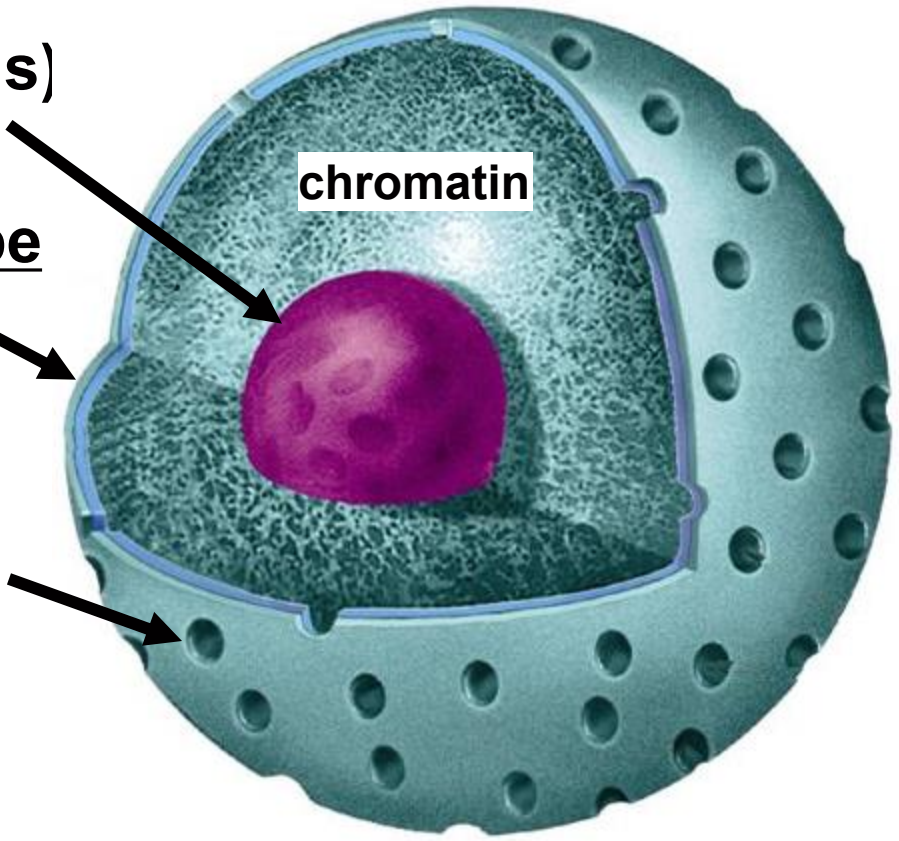
The eukaryotic nucleus: the information archive

- The nucleus of eukaryotes: structurally and functionally more complex than the bacterial nucleoid

- Has internal substructure (nucleolus: rRNA synthesis)

- Bound by nuclear envelope (a membrane)

- Nuclear envelope allows traffic (via nuclear pores)



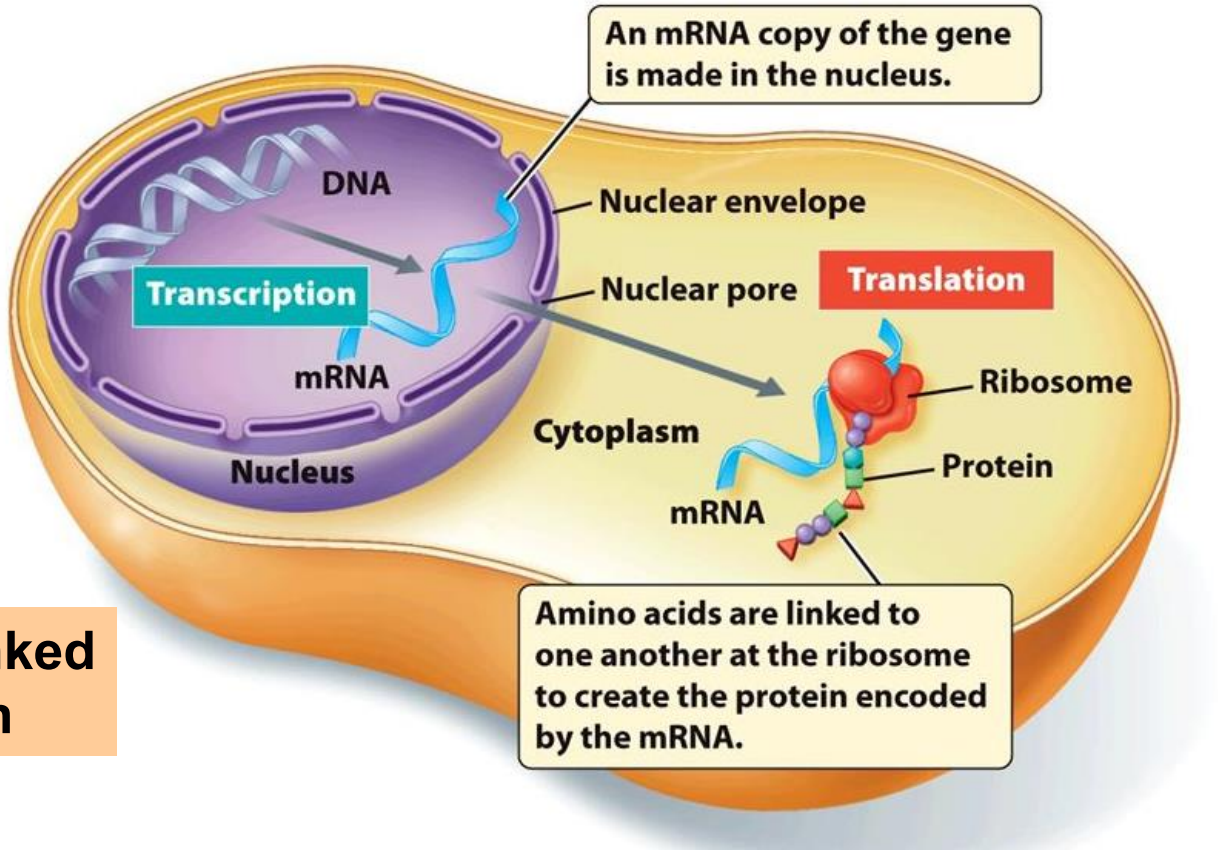
The eukaryotic nucleus: the information archive

- Significance of nuclear membrane: separates transcription (nucleus) from translation (cytoplasm)
- mRNA is transported via pores to get to ribosomes

What else moves out thru nuclear pores?

What moves in thru nuclear pores?

Contrast to Bacteria: linked transcription/translation



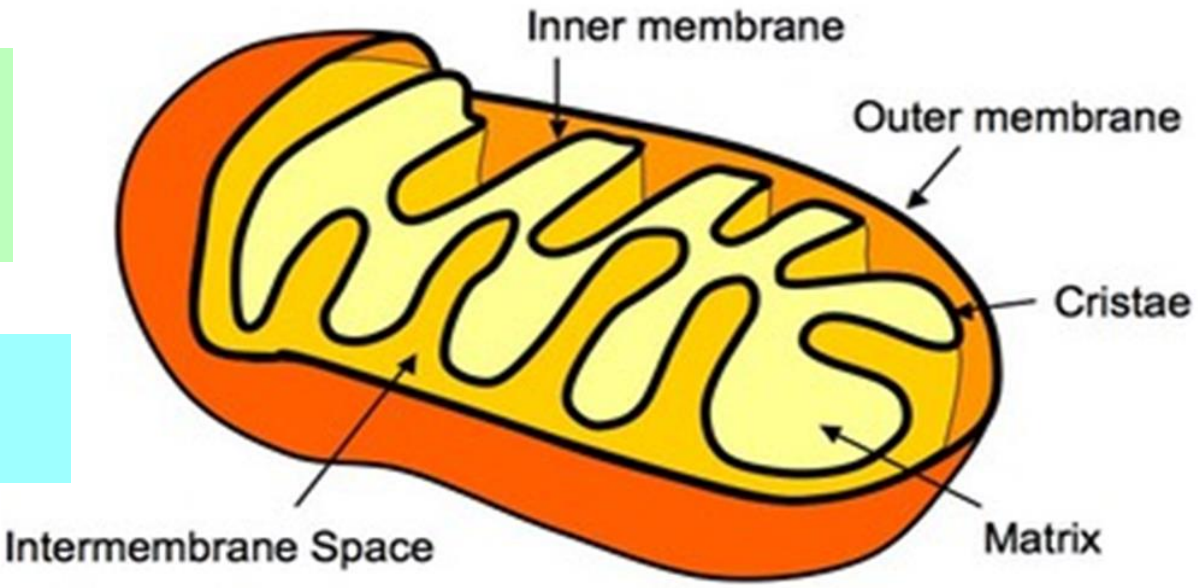
Helpful animation: https://dnalc.cshl.edu/resources/3d/central-dogma.html

Mitochondria : energy !!! … and a cell within a cell

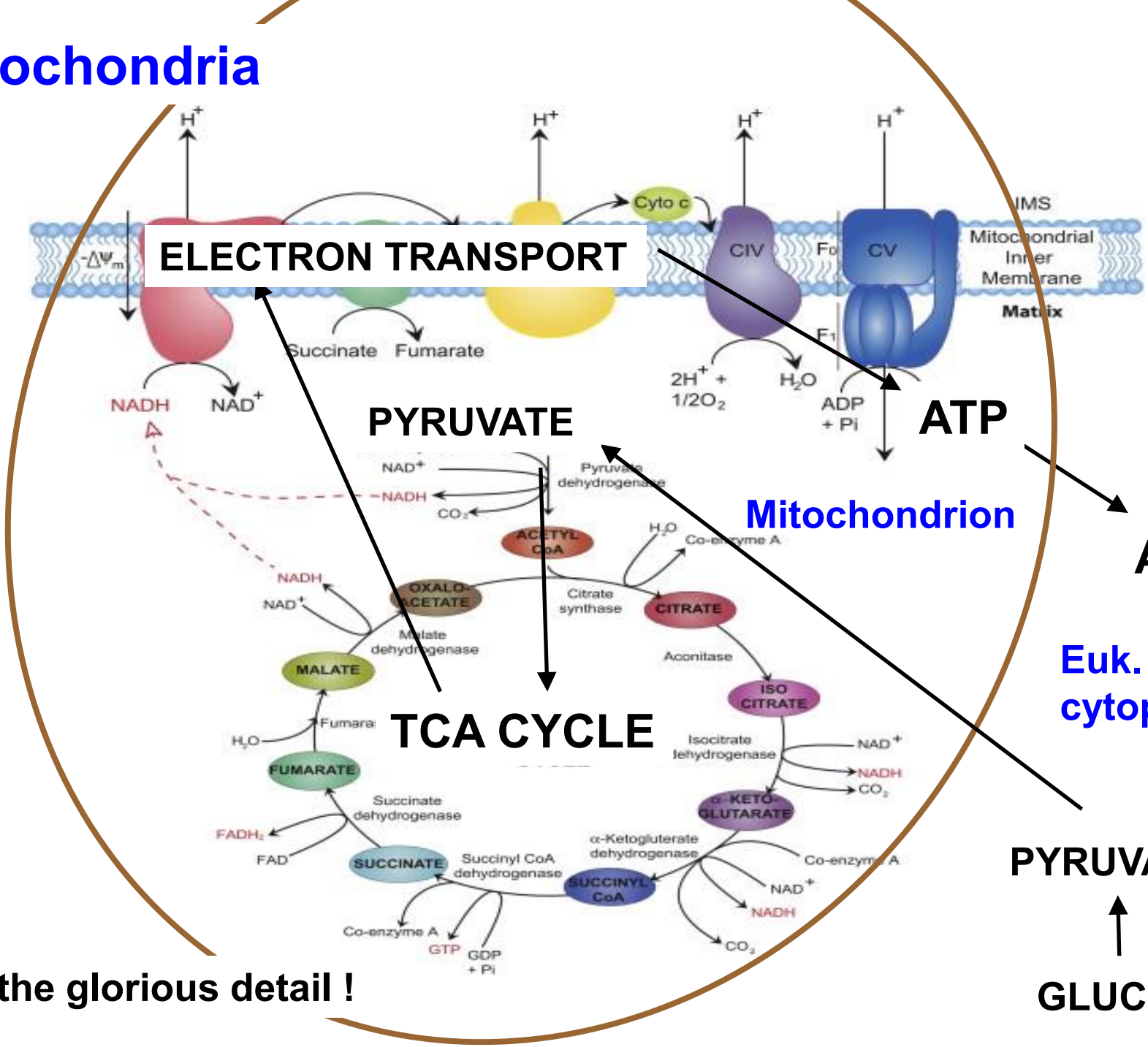
- **Structure similar to Gram-negative bacteria (inner and outer membrane)… why? … endosymbiosis !**
- **Retain their own DNA genome and own ribosomes, and share protein synthesis with host cell**
- **Primary function: aerobic energy generation via TCA cycle, and electron transport chain**

Why is mitochondrial inner membrane so complex ?

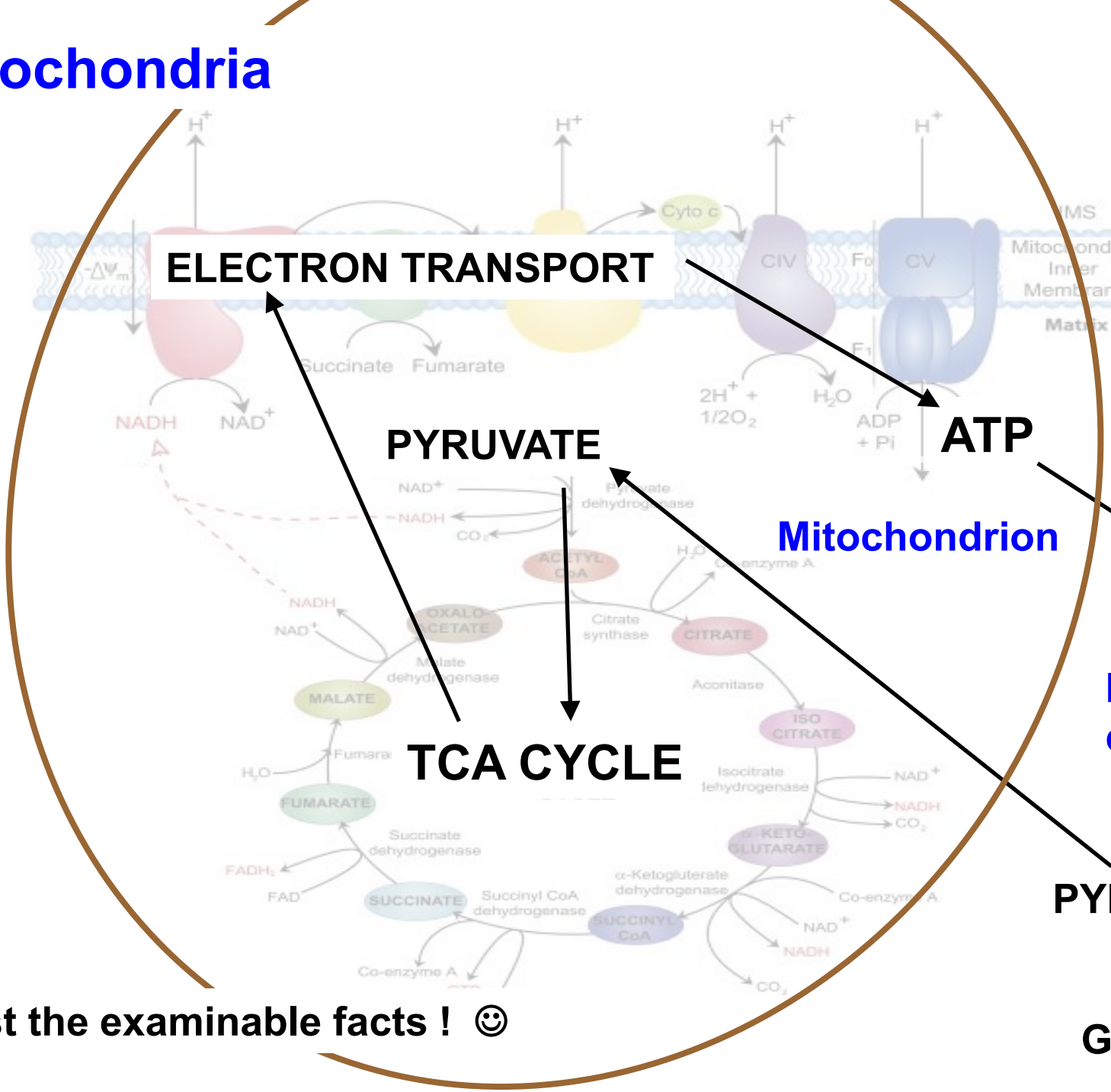
What about anaerobic eukaryotes?



Mitochondria



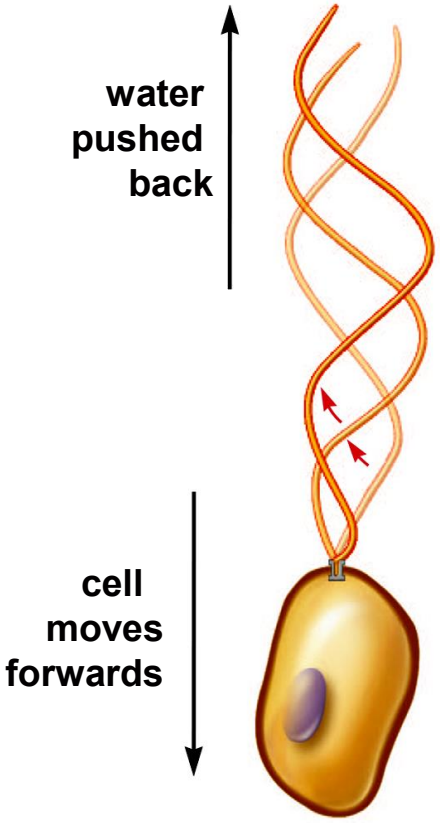
Mitochondria



Cilia and flagella: swimming motility

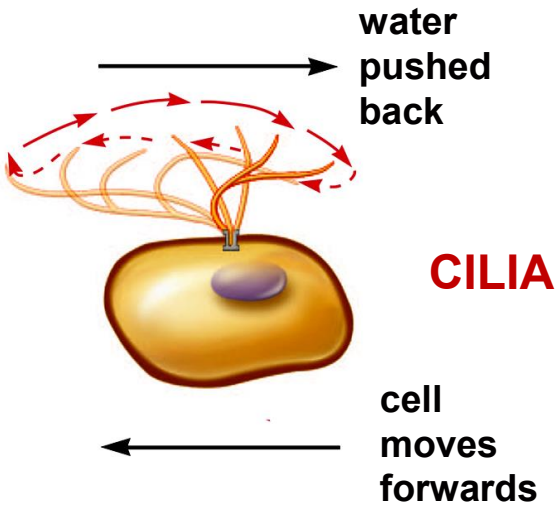
- **Both these structures made of microtubules, thus an extension of the cytoskeleton into the exterior**

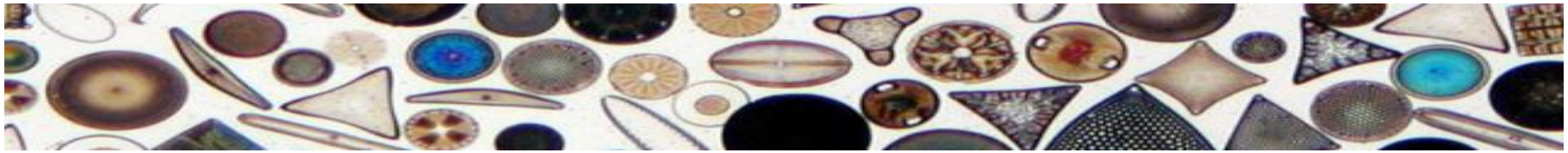
FLAGELLA



- **Cilia:** numerous, small (5-20 μm long), 'rowing'motion

- **Flagella:** few, large (100-200 μm long), 'propeller' motion



Summary: Euk. structures / functions / significance

- **Internal membranes:** critical to cell organisation
- **Cell envelope :** wall of chitin / cellulose / silica; sterols-azoles
- **Cytoskeleton:** actin, microtubules, intra-cell transport
- **Secretory pathway:** Golgi + ER, post-translation mods
- **Endocytic pathway:** phago- & lyso- somes, roles in infection
- **Nucleus:** membrane (with pores), nucleolus, transcription only
- **Mitochondria:** aerobic energy, pyruvate→ATP, endosymbionts
- **Cilia & Flagella:** extracellular microtubules, swimming