

# EVENTUALLY “DAWNS ON HETEROTROPH”

**HETEROTROPHIC  
HOST CELL**

**DNA W\ HISTONE PROTEINS**

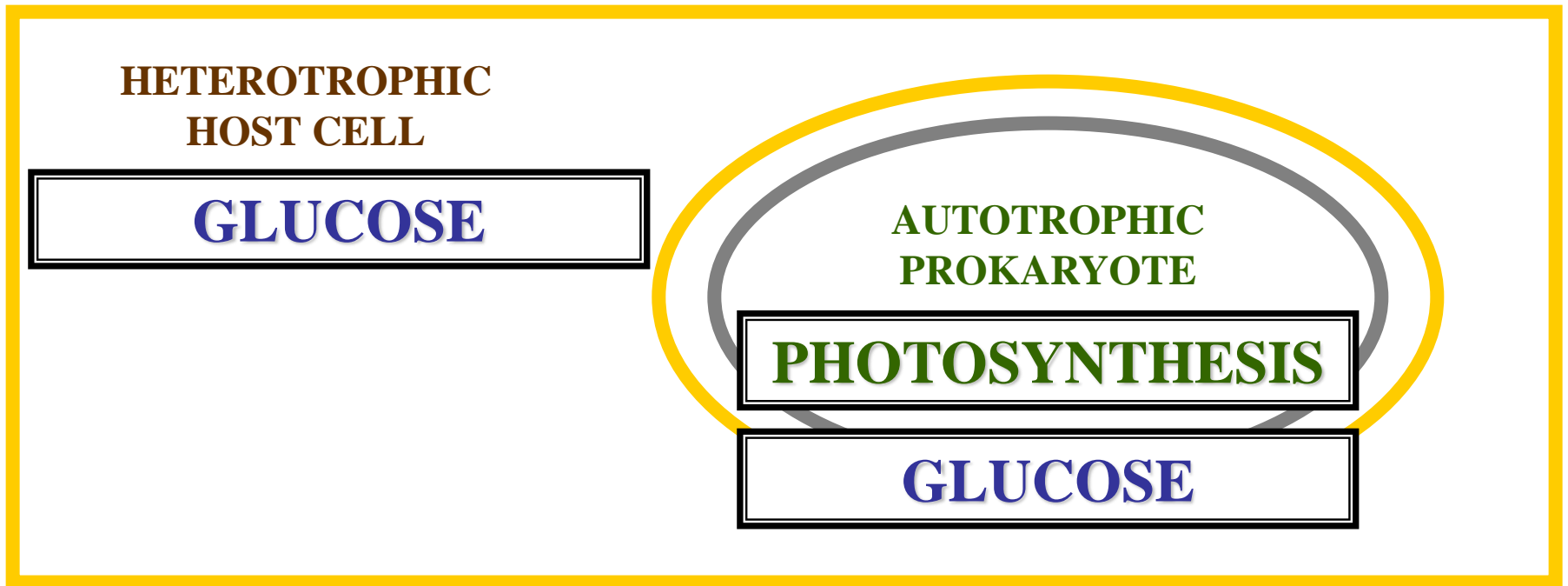
**LARGE RIBOSOMES**

**AUTOTROPHIC  
PROKARYOTE**

**PHOTOSYNTHESIS**

**GLUCOSE**

# EVENTUALLY “DAWNS ON HETEROTROPH”



# **AUTOTROPH LIVING WITHIN HETEROTROPH**

**HETEROTROPHIC  
HOST CELL**

**DNA W\ HISTONE PROTEINS**

**LARGE RIBOSOMES**

**AUTOTROPHIC  
PROKARYOTE**

**CHL A&B + CAROTENOIDS**

**GRANA PRESENT**

**2 SPECIES LIVING  
INTRICATE ASSOCIATION**

# SYMBIOSIS

**HETEROTROPHIC  
HOST CELL**

**DNA W\ HISTONE PROTEINS**

**LARGE RIBOSOMES**

**AUTOTROPHIC  
PROKARYOTE**

**CHL A&B + CAROTENOIDS**

**GRANA PRESENT**





# **SYMBIOSIS**

## **ENDOSYMBIOSIS**

**HETEROTROPHIC  
HOST CELL**

**DNA W\ HISTONE PROTEINS**

**LARGE RIBOSOMES**

**AUTOTROPHIC  
PROKARYOTE**

**CHL A&B + CAROTENOIDS**

**GRANA PRESENT**

# SYMBIOSIS

## ENDOSYMBIOSIS

**HETEROTROPHIC  
HOST CELL**

**DNA W\ HISTONE PROTEINS**

**LARGE RIBOSOMES**

**AUTOTROPHIC  
PROKARYOTE**

**CHL A&B + CAROTENOIDS**

**GRANA PRESENT**

**AUTOTROPH PROVIDES  
HETEROTROPH WITH?**

# SYMBIOSIS

## ENDOSYMBIOSIS

**HETEROTROPHIC  
HOST CELL**

**DNA W\ HISTONE PROTEINS**

**LARGE RIBOSOMES**

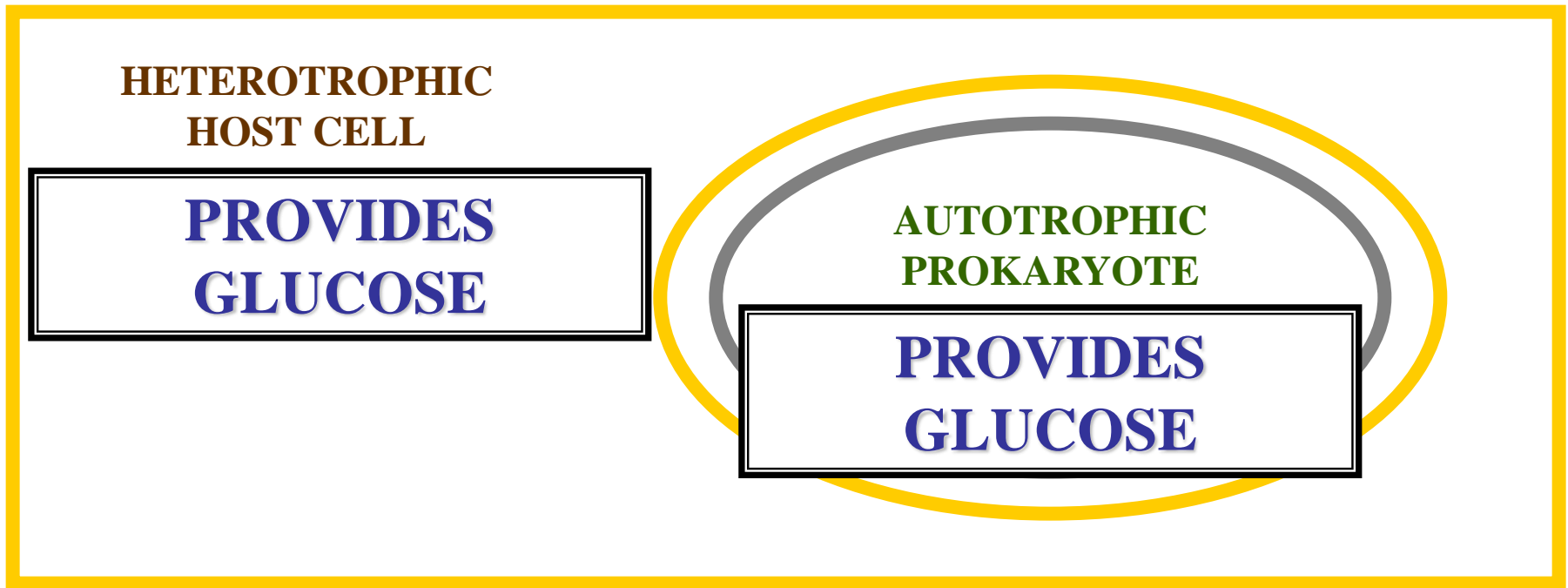
**AUTOTROPHIC  
PROKARYOTE**

**PHOTOSYNTHESIS**

**AUTOTROPH PROVIDES  
HETEROTROPH WITH?**

# SYMBIOSIS

## ENDOSYMBIOSIS



**AUTOTROPH PROVIDES  
GLUCOSE**

# SYMBIOSIS

## ENDOSYMBIOSIS

**HETEROTROPHIC  
HOST CELL**

**DNA W\ HISTONE PROTEINS**

**LARGE RIBOSOMES**

**AUTOTROPHIC  
PROKARYOTE**

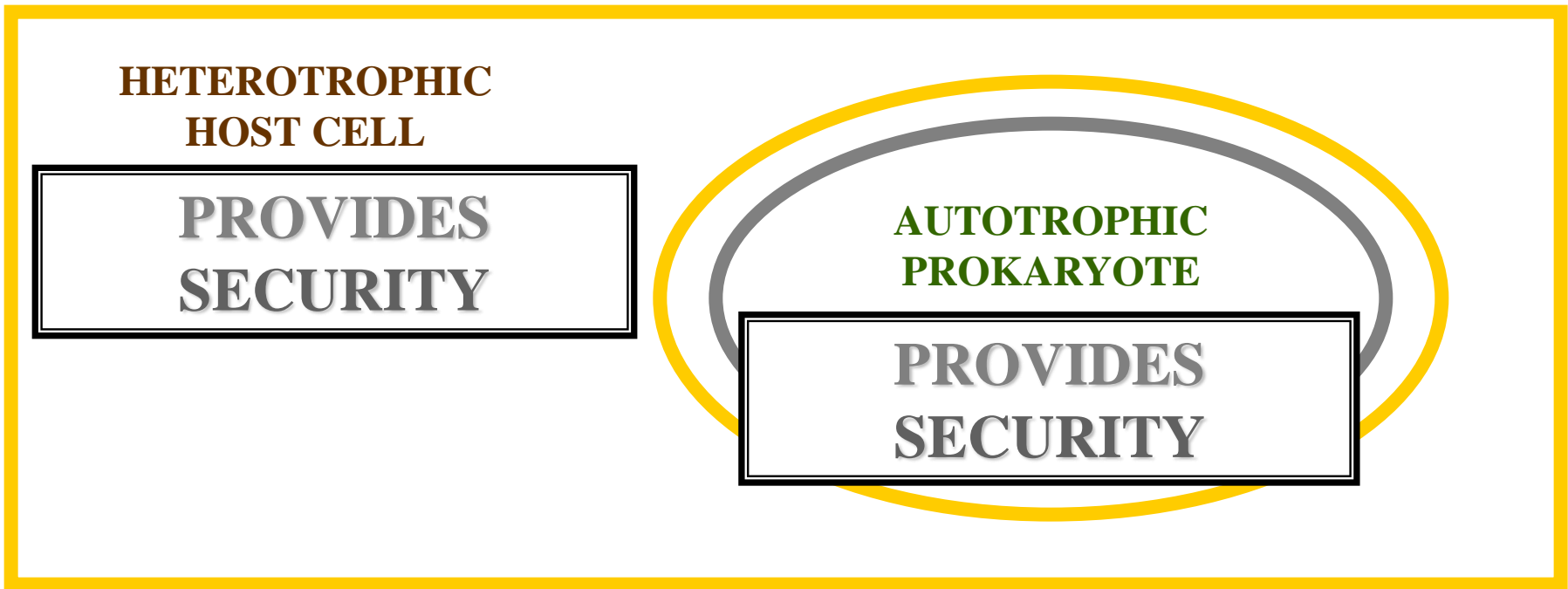
**CHL A&B + CAROTENOIDS**

**GRANA PRESENT**

**HETEROTROPH PROVIDES  
AUTOTROPH WITH?**

# SYMBIOSIS

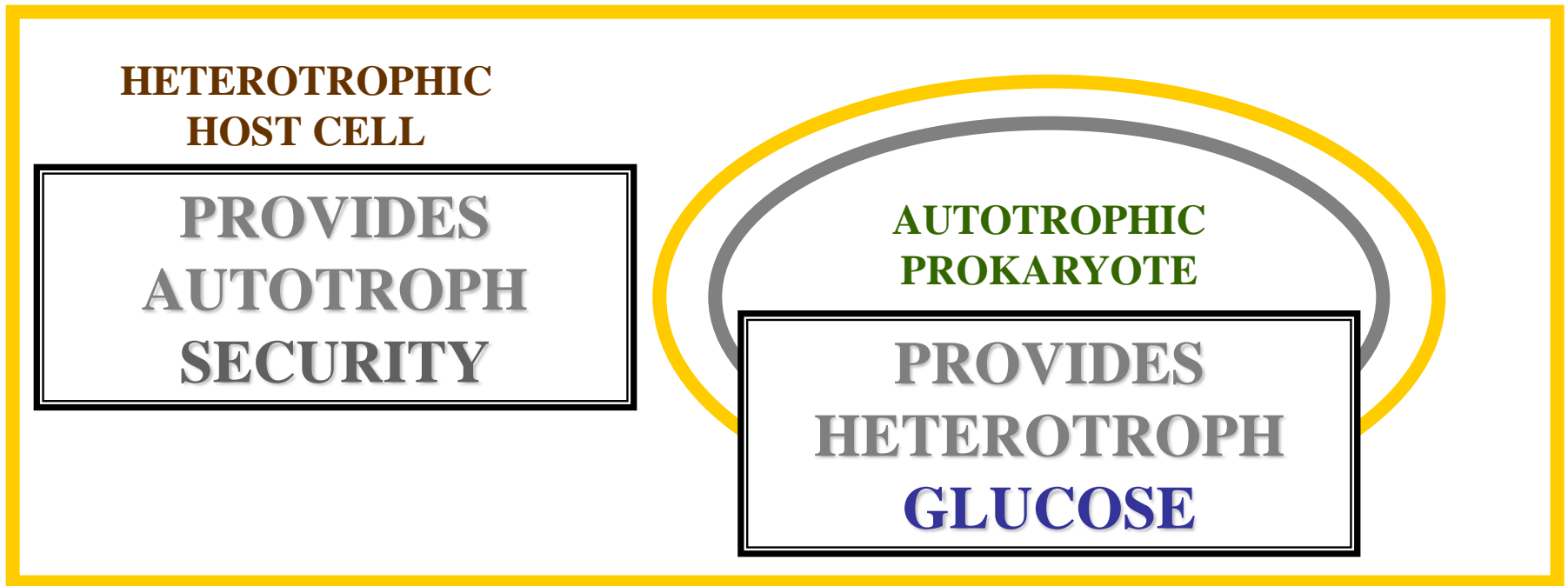
## ENDOSYMBIOSIS



**HETEROTROPH PROVIDES SECURITY**

# SYMBIOSIS

## ENDOSYMBIOSIS



**BOTH SYMBIONTS  
BENEFIT**

# SYMBIOSIS

## ENDOSYMBIOSIS

**HETEROTROPHIC  
HOST CELL**

**PROVIDES  
AUTOTROPH  
SECURITY**

**AUTOTROPHIC  
PROKARYOTE**

**PROVIDES  
HETEROTROPH  
GLUCOSE**

# MUTUALISTIC ENDOSYMBIOSIS



# MUTUALISTIC ENDOSYMBIOSIS

**HETEROTROPHIC  
HOST CELL**

**DNA W\ HISTONE PROTEINS**

**LARGE RIBOSOMES**

**AUTOTROPHIC  
PROKARYOTE**

**CHL A&B + CAROTENOIDS**

**GRANA PRESENT**

**GIVEN LONG TIME PERIOD**



# OBLIGATE DEPENDENT RELATIONSHIP EVOLVES



**SYMBIONTS CANNOT  
EXIST INDEPENENTLY**

# AUTOTROPHIC PROKARYOTE

**HETEROTROPHIC  
HOST CELL**

**DNA W\ HISTONE PROTEINS**

**LARGE RIBOSOMES**

**AUTOTROPHIC  
BECOMES ?**

**CHL A&B + CAROTENOIDS**

**GRANA PRESENT**

# AUTOTROPHIC ORGANELLE

**HETEROTROPHIC  
HOST CELL**

**DNA W\ HISTONE PROTEINS**

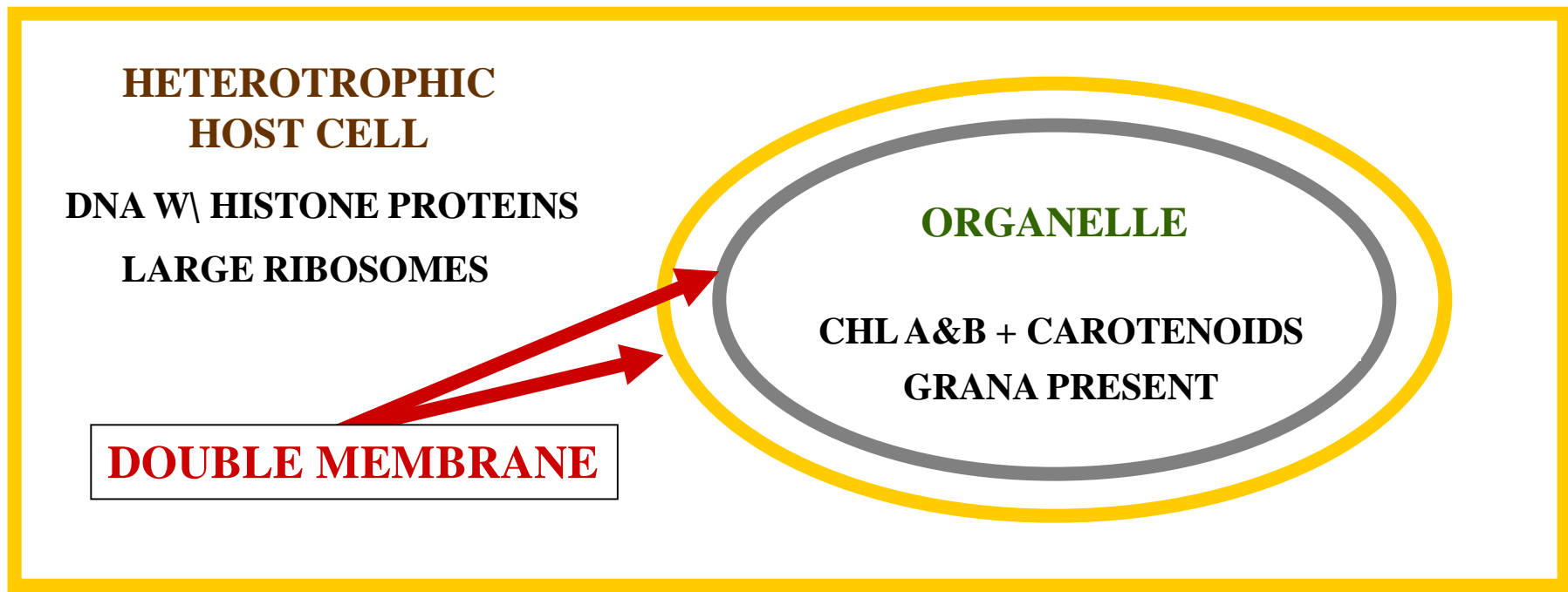
**LARGE RIBOSOMES**

**ORGANELLE**

**CHL A&B + CAROTENOIDS**

**GRANA PRESENT**

# AUTOTROPHIC ORGANELLE



# AUTOTROPHIC ORGANELLE

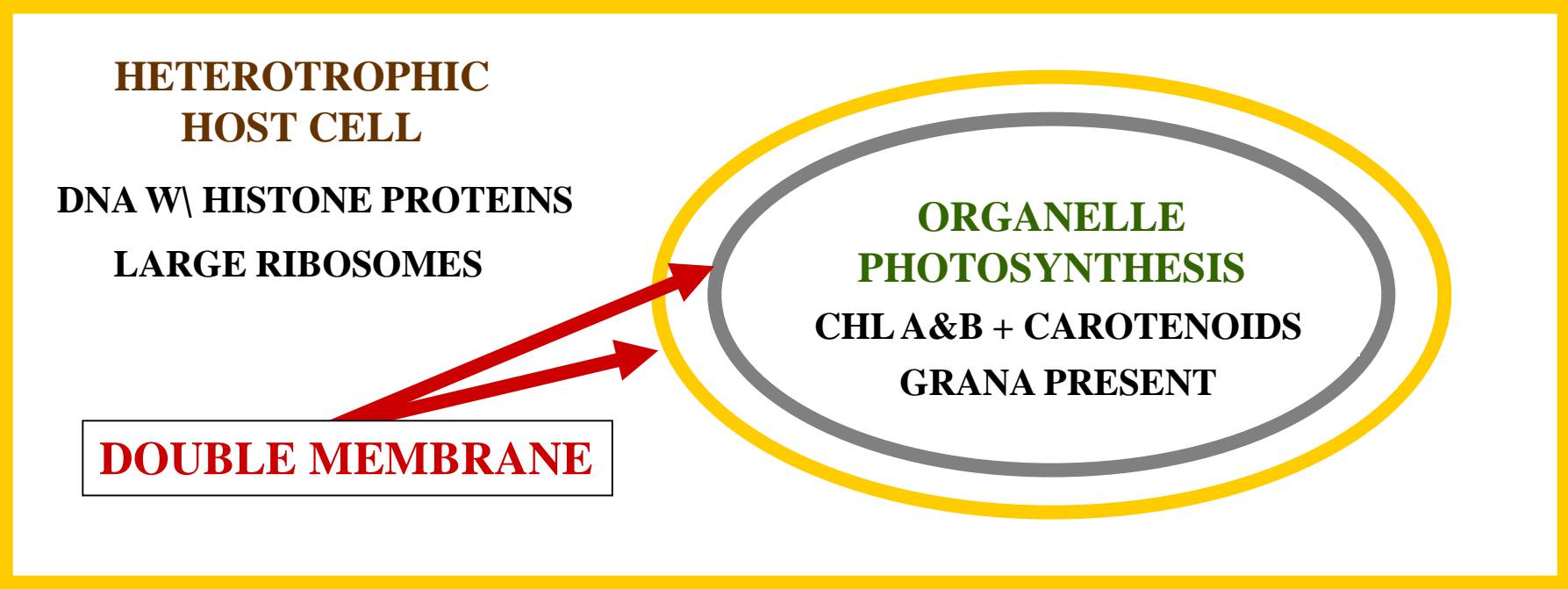
**HETEROTROPHIC  
HOST CELL**

**DNA W\ HISTONE PROTEINS**

**LARGE RIBOSOMES**

**DOUBLE MEMBRANE**

**ORGANELLE**  
**PHOTOSYNTHESIS**  
**CHL A&B + CAROTENOIDS**  
**GRANA PRESENT**



# AUTOTROPHIC ORGANELLE

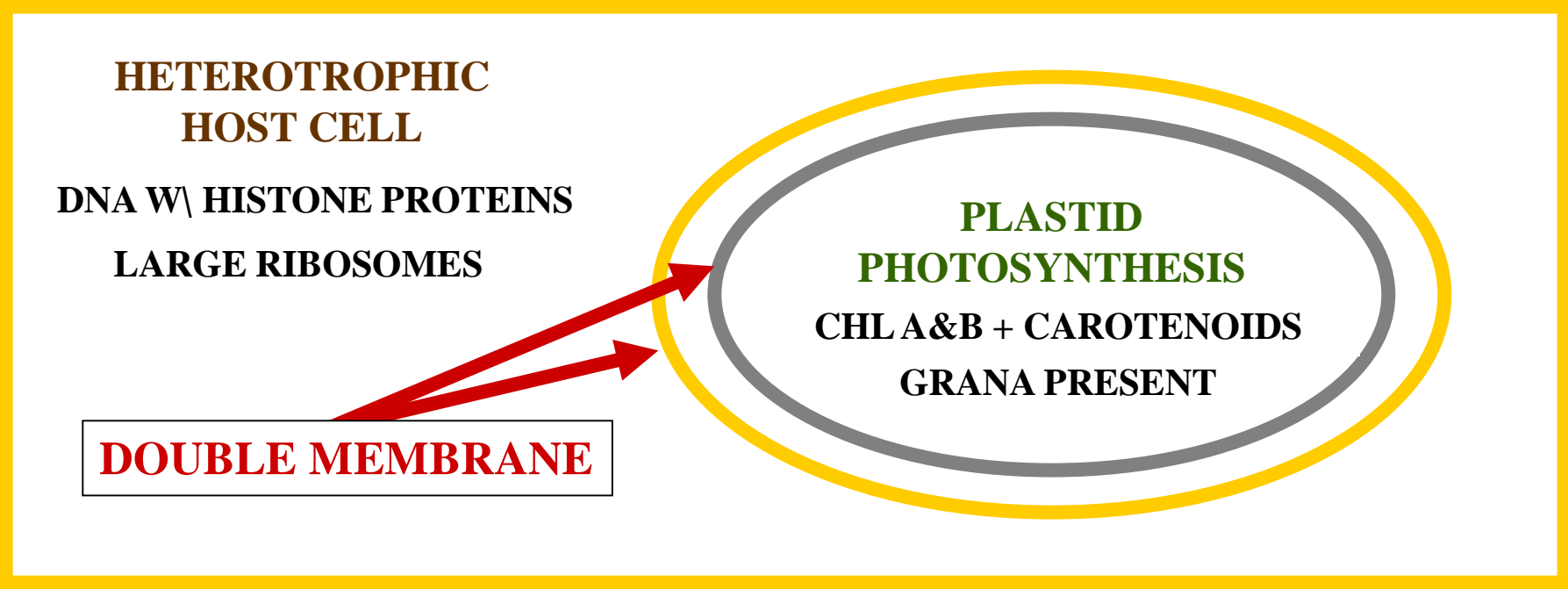
**HETEROTROPHIC  
HOST CELL**

**DNA W\ HISTONE PROTEINS**

**LARGE RIBOSOMES**

**DOUBLE MEMBRANE**

**PLASTID**  
**PHOTOSYNTHESIS**  
**CHL A&B + CAROTENOIDS**  
**GRANA PRESENT**



# AUTOTROPHIC ORGANELLE



**HETEROTROPHIC  
HOST CELL**

**DNA W\ HISTONE PROTEINS**

**LARGE RIBOSOMES**

**DOUBLE MEMBRANE**

**PLASTID  
CHLOROPLAST**

**CHL A&B + CAROTENOIDS**

**GRANA PRESENT**





# HETEROTROPHIC HOST CELL

**HETEROTROPHIC HOST CELL  
BECOMES ?**

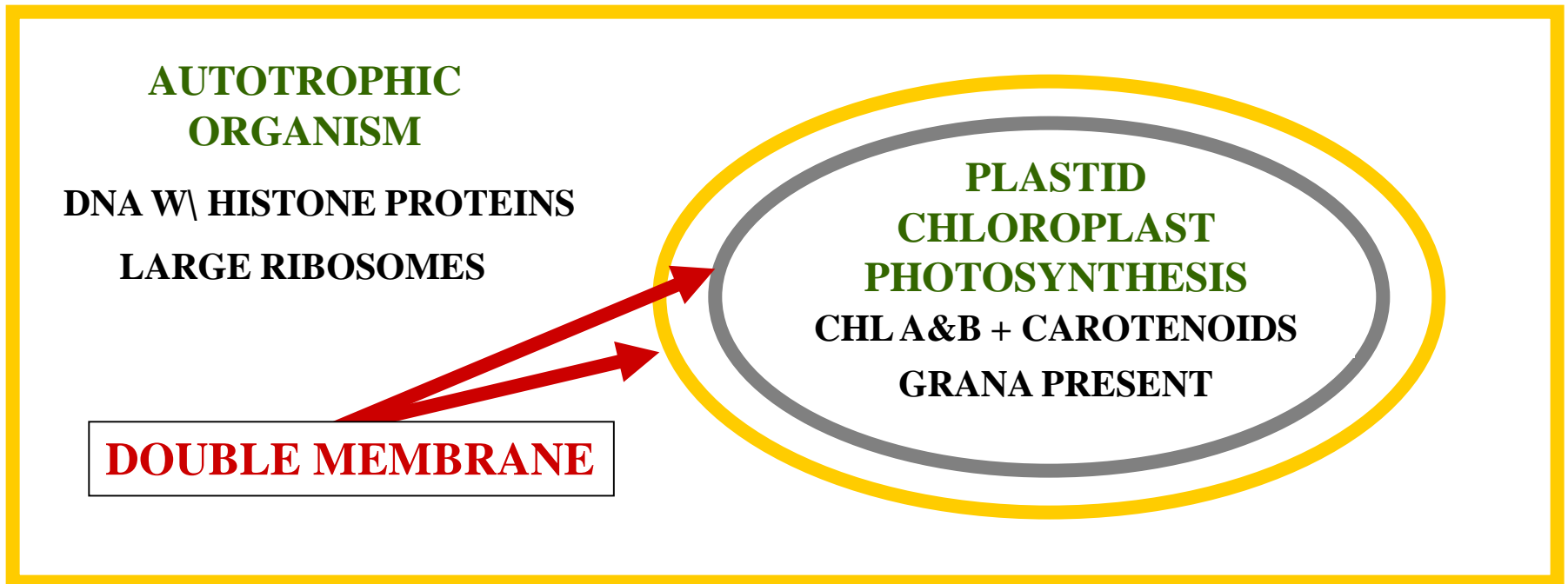
**DNA W\ HISTONE PROTEINS**

**LARGE RIBOSOMES**

**DOUBLE MEMBRANE**

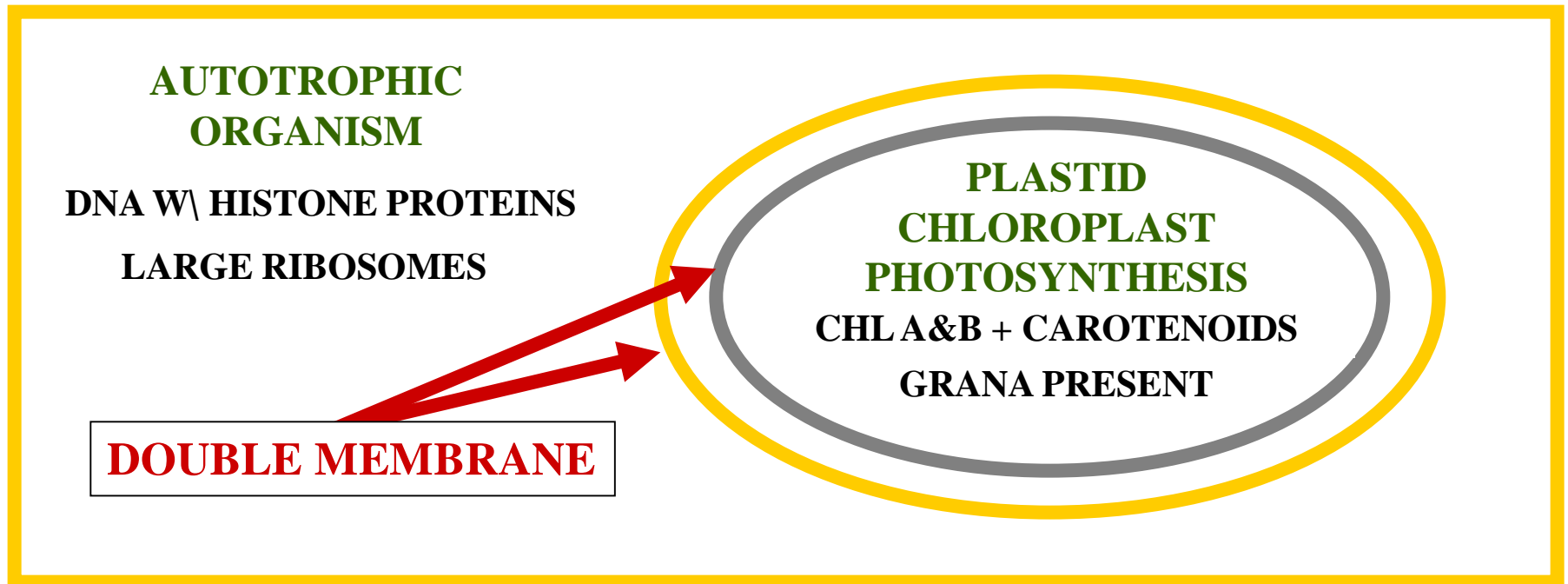
**PLASTID**  
**PHOTOSYNTHESIS**  
**CHL A&B + CAROTENOIDS**  
**GRANA PRESENT**

# AUTOTROPHIC ORGANISM



**CELL**

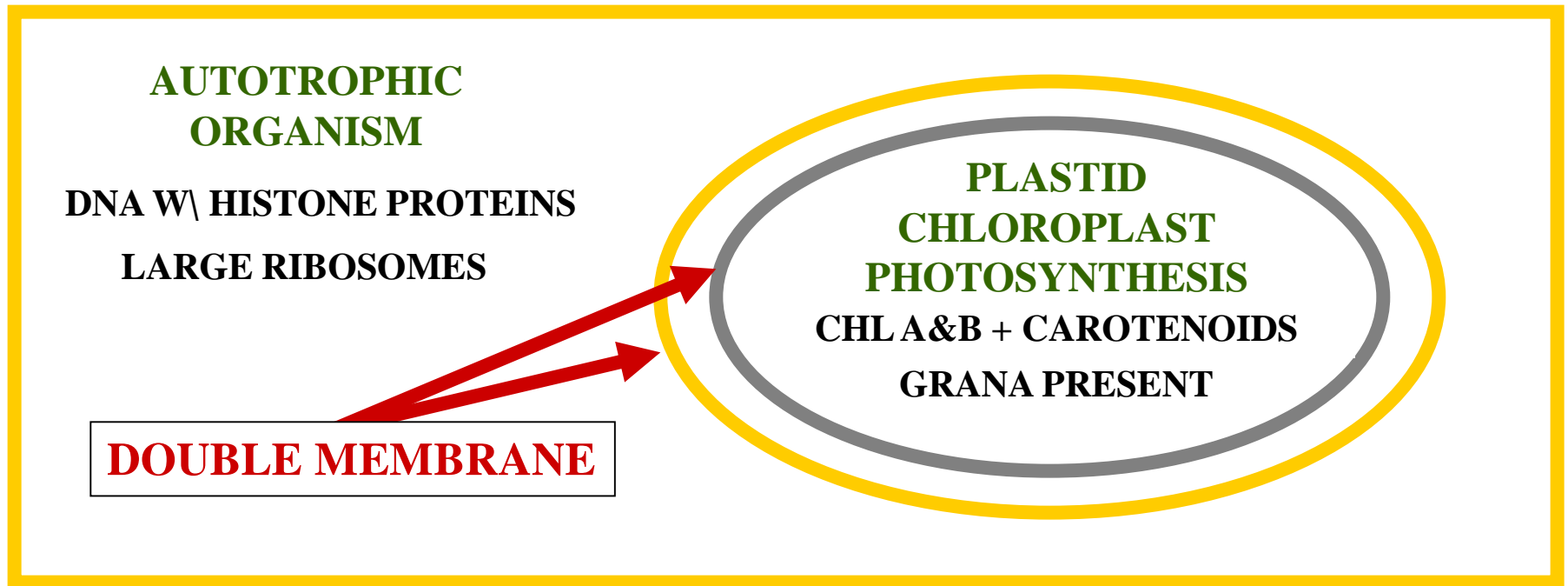
# AUTOTROPHIC ORGANISM



## PLANT CELL



# AUTOTROPHIC ORGANISM



## TRUE PLANT CELL



S



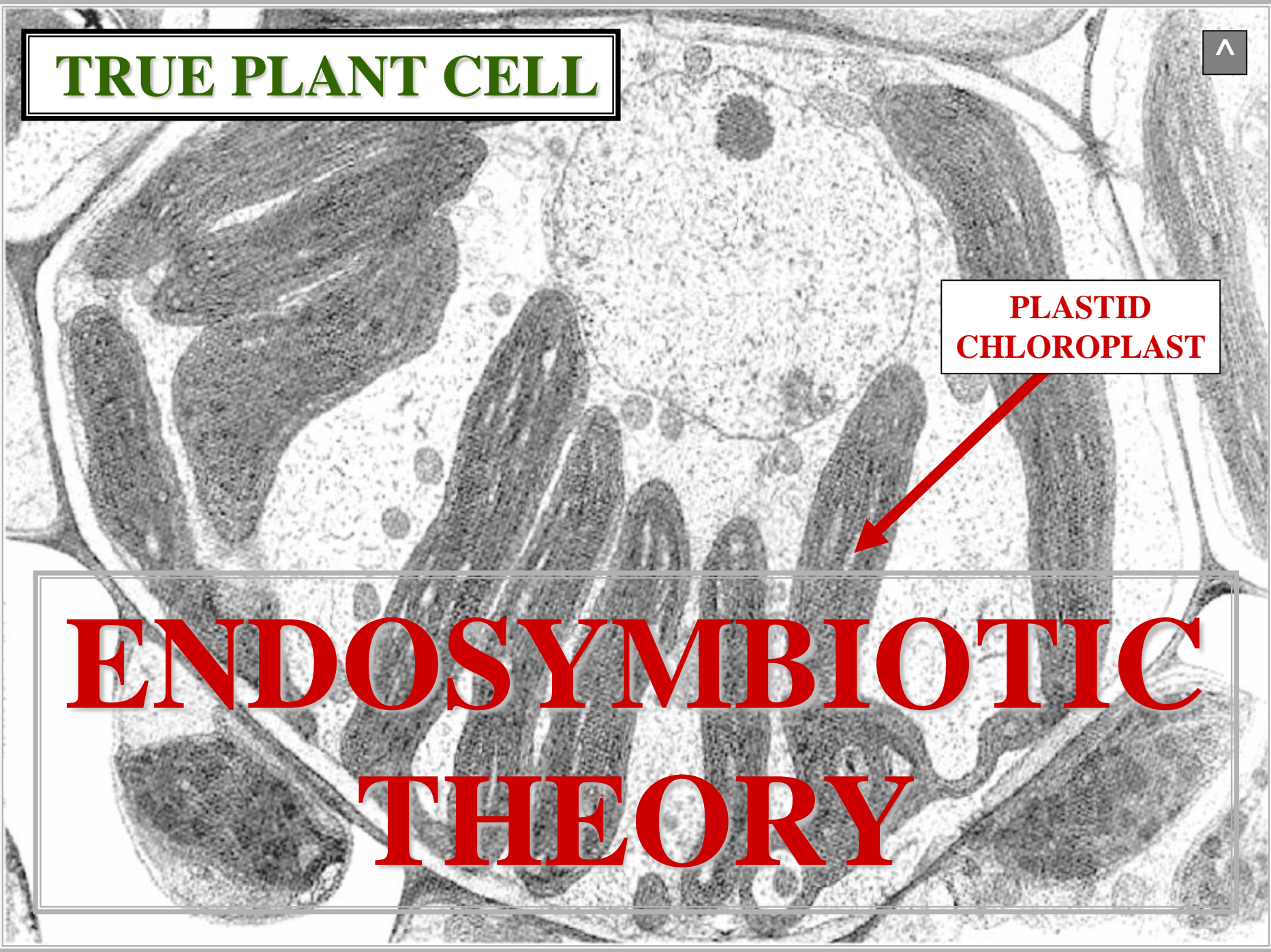
**GREEN ALGAE**



# TRUE PLANT CELL

PLASTID  
CHLOROPLAST

# ENDOSYMBIOTIC THEORY





# MITOCHONDRION EVOLUTION



**MITOCHONDRION**  
**EVOLUTION**  
**HYPOTHETICAL**  
**SCENARIO**



# TRUE PLANT CELL

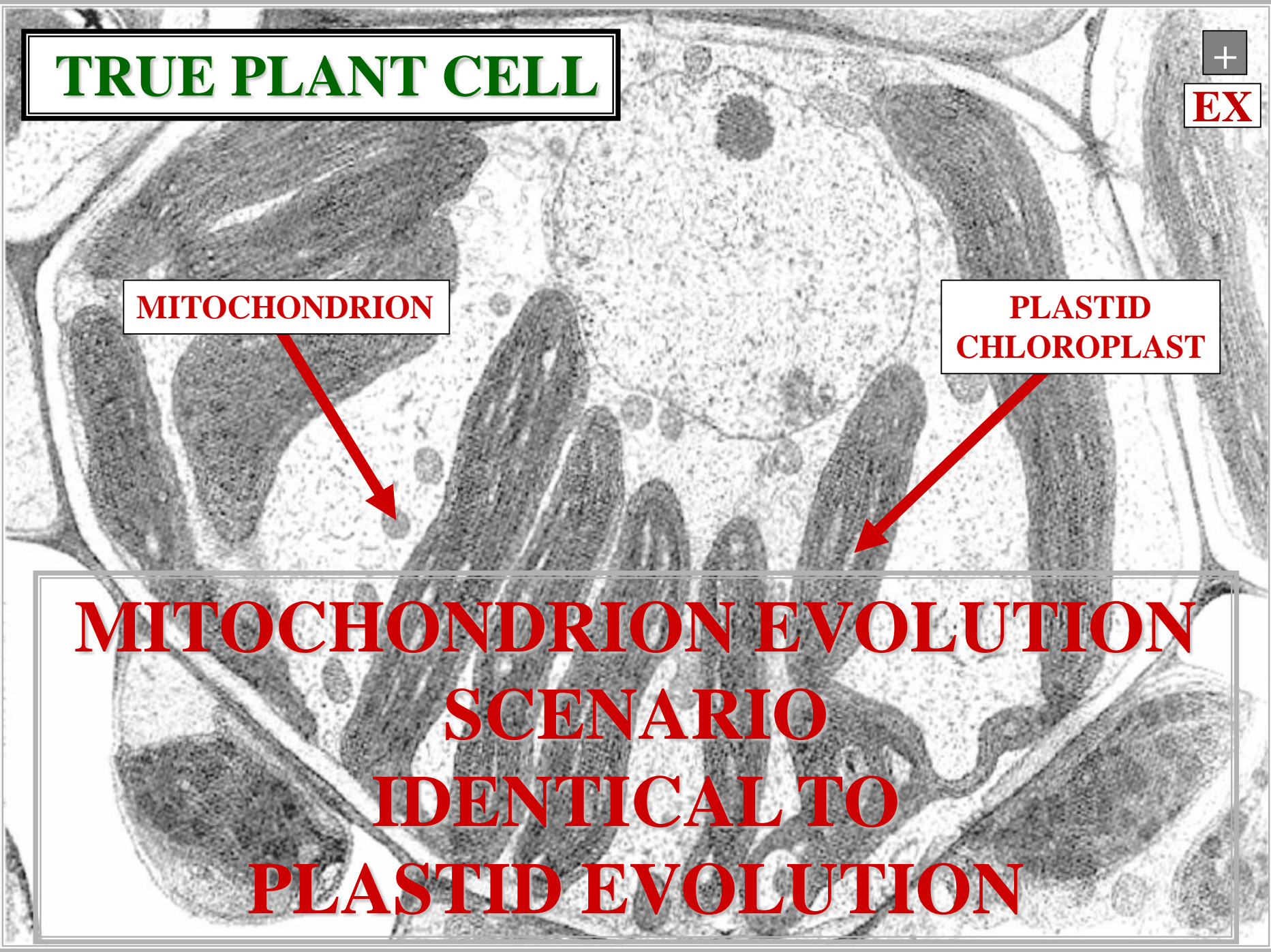
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EX

MITOCHONDRION

PLASTID  
CHLOROPLAST

MITOCHONDRION EVOLUTION  
SCENARIO  
IDENTICAL TO  
PLASTID EVOLUTION



**HOST CELL**  
**DNA W\ HISTONE PROTEINS**  
**LARGE RIBOSOMES**

**AEROBIC  
PROKARYOTE**  
**DNA W\OUT HISTONE PROTEINS**  
**SMALL RIBOSOMES**

**EXCEPTION: AEROBIC PROKARYOTE UNDERGOES ENDOSYMBIOSIS**

**HOST CELL**  
**DNA W\ HISTONE PROTEINS**  
**LARGE RIBOSOMES**

**AEROBIC**  
**PROKARYOTE**  
**AEROBIC RESPIRATION**  
**DNA W\OUT HISTONE PROTEINS**  
**SMALL RIBOSOMES**

**EXCEPTION: AEROBIC PROKARYOTE UNDERGOES ENDOSYMBIOSIS**

# MUTUALISTIC ENDOSYMBIOTIC RELATIONSHIP EVOLVES

HOST CELL

DNA W\ HISTONE PROTEINS

LARGE RIBOSOMES

AEROBIC

PROKARYOTE

AEROBIC RESPIRATION

DNA W\OUT HISTONE PROTEINS

SMALL RIBOSOMES

# MUTUALISTIC ENDOSYMBIOTIC RELATIONSHIP EVOLVES

# OBLIGATE DEPENDENT RELATIONSHIP EVOLVES

HOST CELL

DNA W\ HISTONE PROTEINS

LARGE RIBOSOMES

AEROBIC  
PROKARYOTE  
AEROBIC RESPIRATION  
DNA W\OUT HISTONE PROTEINS  
SMALL RIBOSOMES

## SYMBIONTS CANNOT EXIST INDEPENDENTLY



# MITOCHONDRION EVOLUTION

**HOST CELL**

**DNA W\ HISTONE PROTEINS**

**LARGE RIBOSOMES**

**ORGANELLE  
MITOCHONDRION**

**DNA W\OUT HISTONE PROTEINS**

**SMALL RIBOSOMES**

# MITOCHONDRION EVOLUTION



# TRUE PLANT CELL

An electron micrograph of a plant cell. The cell is roughly hexagonal in shape. In the center, there is a large, circular nucleus with a prominent nucleolus. Surrounding the nucleus are various organelles. On the left side, there is a large, bean-shaped structure with internal folds, identified as a mitochondrion. On the right side, there are several elongated, dark, rod-like structures with internal membranes, identified as plastids or chloroplasts. The cytoplasm is filled with various smaller organelles and a network of membranes.

**MITOCHONDRION**

**PLASTIDS  
CHLOROPLAST**

# ENDOSYMBIOTIC THEORY



# ENDOSYMBIOTIC THEORY SUPPORTING EVIDENCE





**PROPONENT: ENDOSYMBIOTIC THEORY**

**LYNN MARGULIS**

# ELECTRON MICROSCOPE



M





# TRUE PLANT CELL

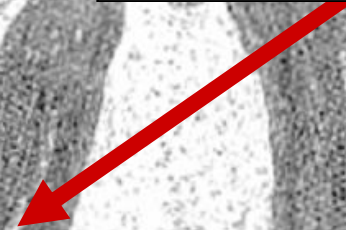
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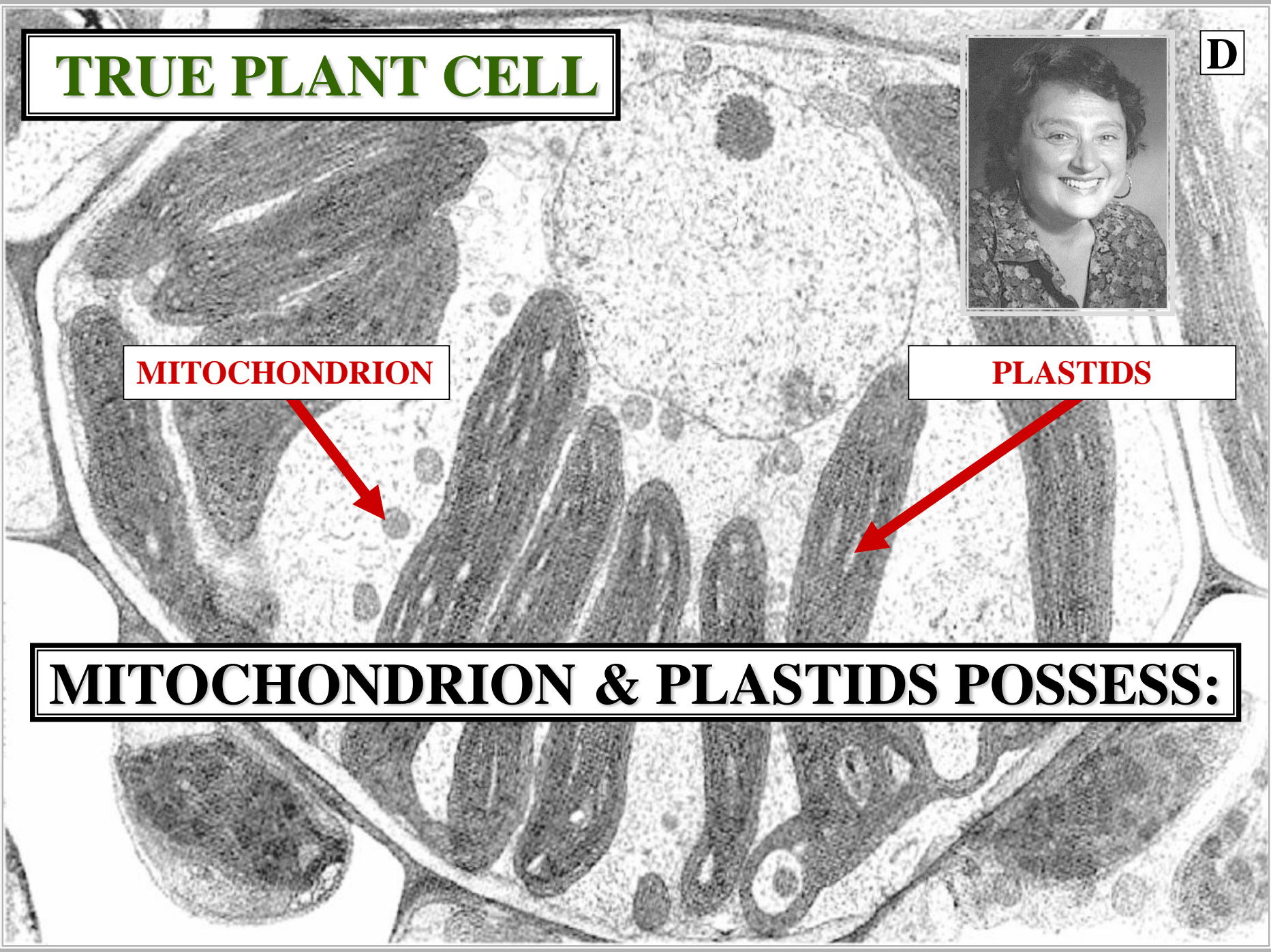
MITOCHONDRION



PLASTIDS



## MITOCHONDRION & PLASTIDS POSSESS:



# TRUE PLANT CELL

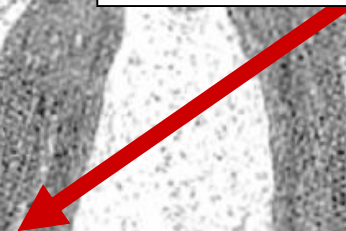
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MITOCHONDRION



PLASTIDS



MITOCHONDRION & PLASTIDS POSSESS:

DNA



# TRUE PLANT CELL

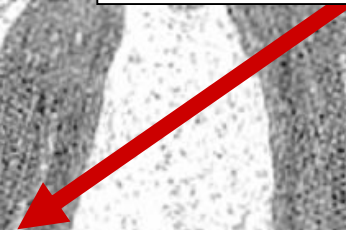
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MITOCHONDRION



PLASTIDS



MITOCHONDRION & PLASTIDS POSSESS:

DNA PROKARYOTE-LIKE

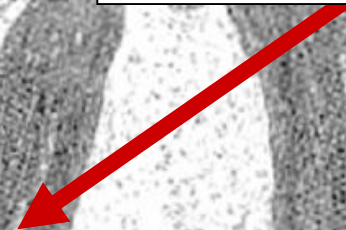
# TRUE PLANT CELL



**MITOCHONDRION**



**PLASTIDS**



**DNA PROKARYOTE-LIKE**

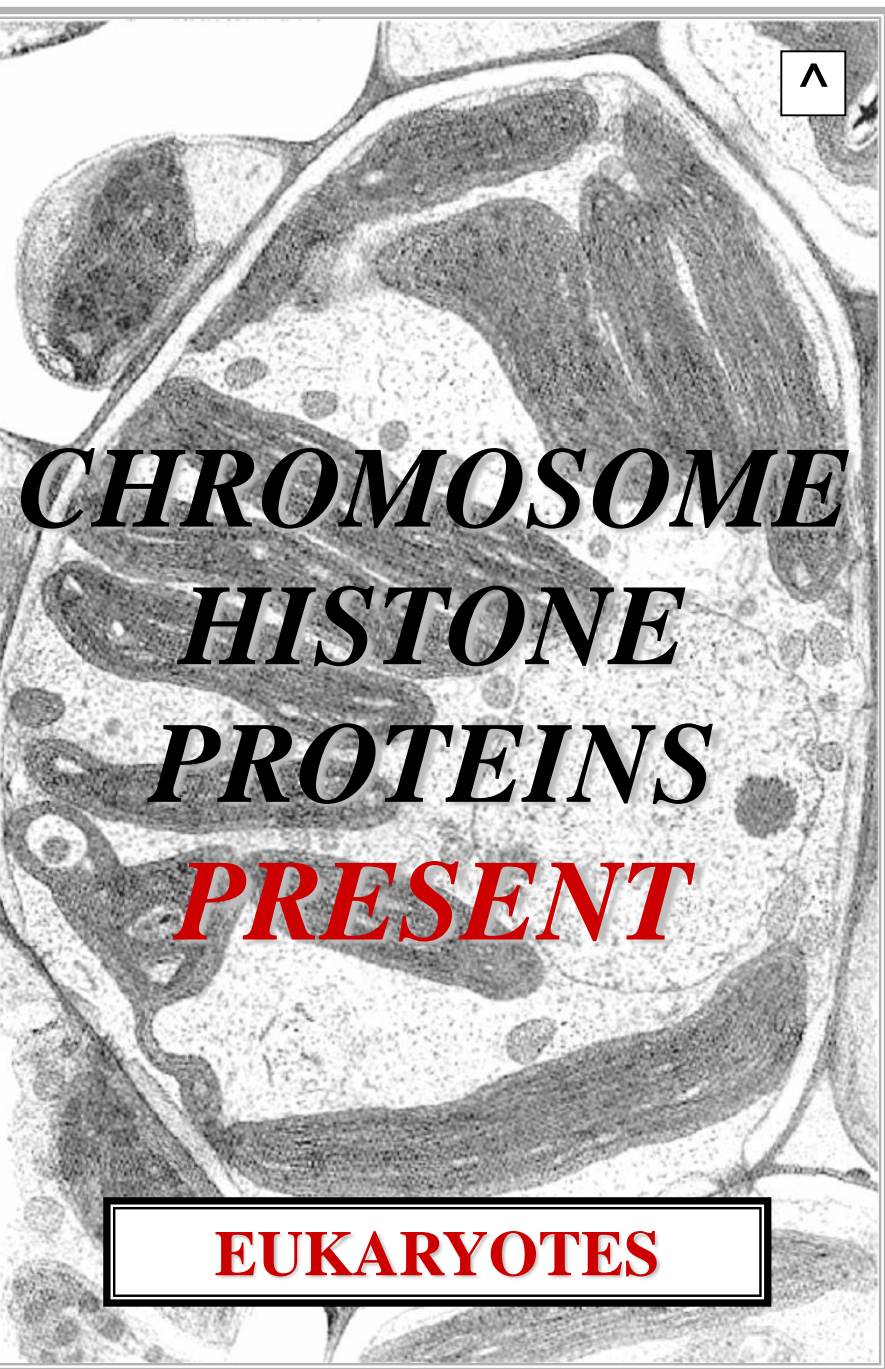
**HISTONE PROTEINS: ABSENT**





***CHROMOSOME***  
***HISTONE***  
***PROTEINS***  
***ABSENT***

**PROKARYOTES**



***CHROMOSOME***  
***HISTONE***  
***PROTEINS***  
***PRESENT***

**EUKARYOTES**



# TRUE PLANT CELL

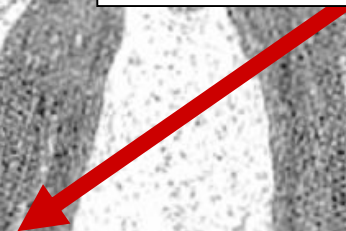
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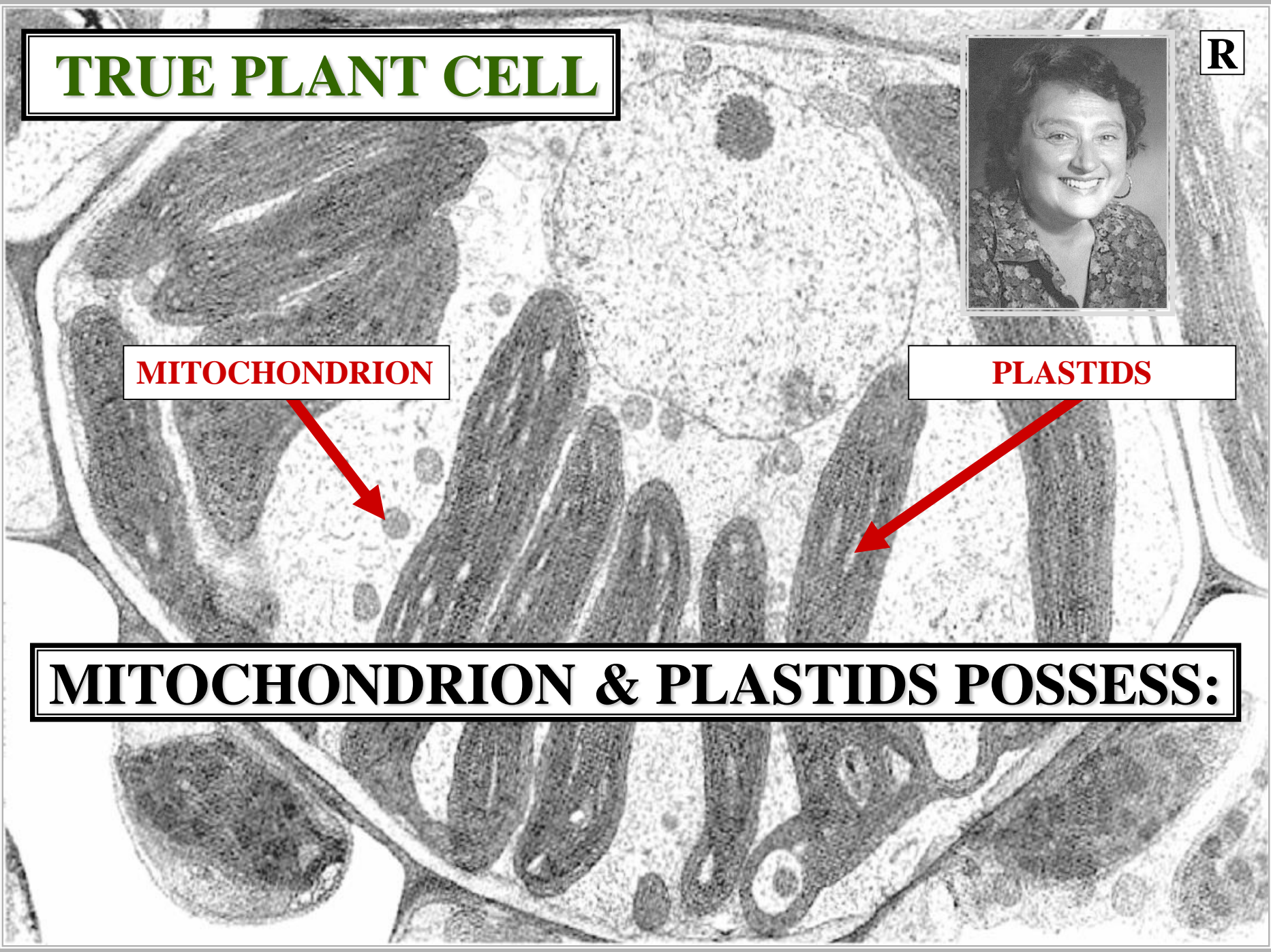
**MITOCHONDRION**



**PLASTIDS**



**MITOCHONDRION & PLASTIDS POSSESS:**





# TRUE PLANT CELL

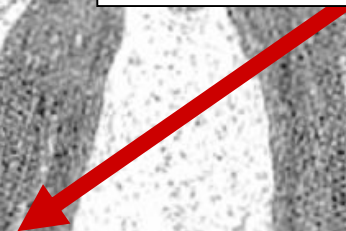
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MITOCHONDRION



PLASTIDS



MITOCHONDRION & PLASTIDS POSSESS:

RIBOSOMES

# TRUE PLANT CELL

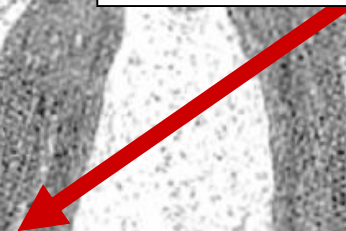
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MITOCHONDRION



PLASTIDS



MITOCHONDRION & PLASTIDS POSSESS:

RIBOSOMES PROKARYOTE-LIKE



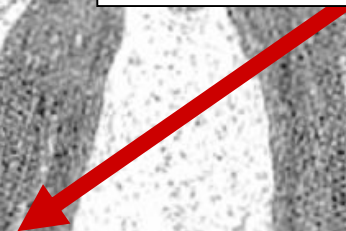
# TRUE PLANT CELL



**MITOCHONDRION**



**PLASTIDS**



**RIBOSOMES PROKARYOTE-LIKE**

**RIBOSOMES: SMALL**

This electron micrograph shows several large, dark, roughly spherical ribosomes. They have a granular, textured surface and are scattered across the field of view. One large ribosome is particularly prominent in the center-left, oriented vertically.

***RIBOSOMES***  
***SMALL SIZE***

**PROKARYOTES**

This electron micrograph shows a large, complex eukaryotic cell. The cell is filled with various organelles, including a nucleus with a prominent nucleolus, rough endoplasmic reticulum with ribosomes on its surface, and mitochondria. The ribosomes are much smaller and more numerous than those in the prokaryotic image, appearing as small dark dots. A small white box with a black triangle is located in the top right corner.

***RIBOSOMES***  
***LARGE SIZE***

**EUKARYOTES**



# TRUE PLANT CELL

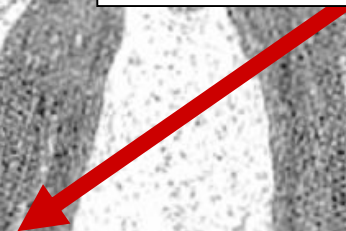
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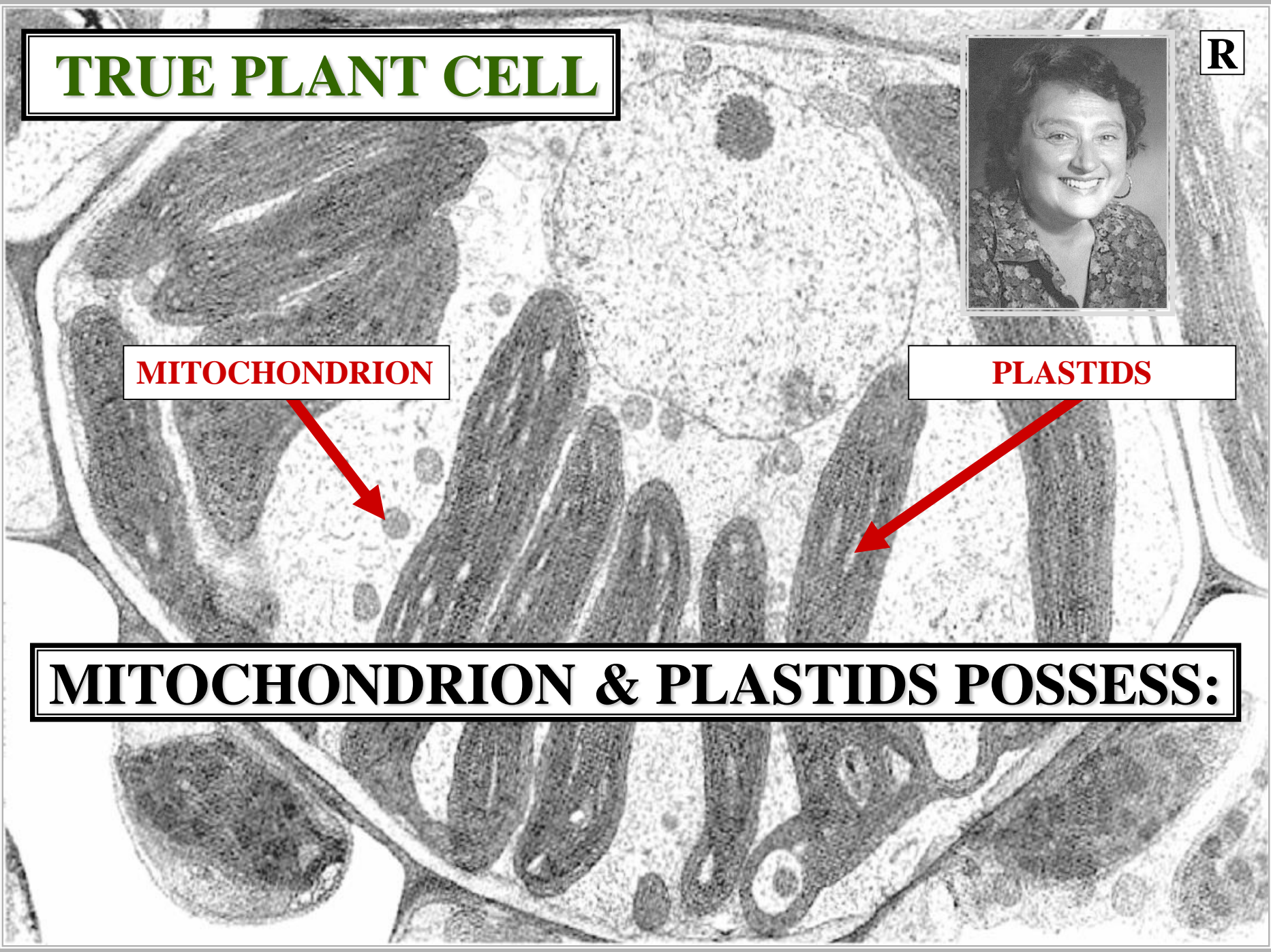
**MITOCHONDRION**



**PLASTIDS**



**MITOCHONDRION & PLASTIDS POSSESS:**



# TRUE PLANT CELL

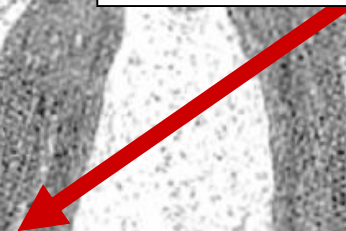
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MITOCHONDRION



PLASTIDS



MITOCHONDRION & PLASTIDS POSSESS:

REPRODUCTION



# TRUE PLANT CELL

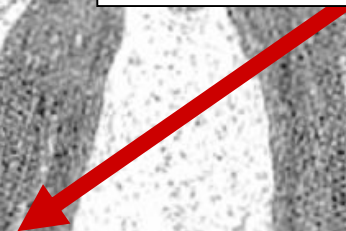
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MITOCHONDRION



PLASTIDS



MITOCHONDRION & PLASTIDS POSSESS:

REPRODUCTION PROKARYOTE-LIKE

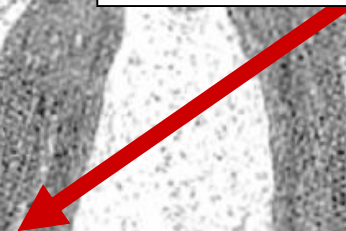
# TRUE PLANT CELL



**MITOCHONDRION**



**PLASTIDS**



**REPRODUCTION PROKARYOTE-LIKE**

**REPRODUCTION: BINARY FISSION**



An electron micrograph showing several rod-shaped prokaryotic cells. The cells have a thick, textured outer layer and a granular interior. One cell in the center is particularly prominent, showing a clear internal structure.

***REPRODUCTION  
BINARY FISSION  
PRESENT***

**PROKARYOTES**

An electron micrograph showing a cross-section of a eukaryotic cell. The cell is large and contains various organelles, including a nucleus with a nucleolus, mitochondria with cristae, and endoplasmic reticulum. A small box with a question mark is in the top right corner.

***REPRODUCTION  
BINARY FISSION  
ABSENT***

**EUKARYOTES**

# QUESTION

DOES THIS EVIDENCE  
SUPPORT OR REFUTE  
THE  
ENDOSYMBIOTIC  
THEORY?

# QUESTION





# TRUE PLANT CELL



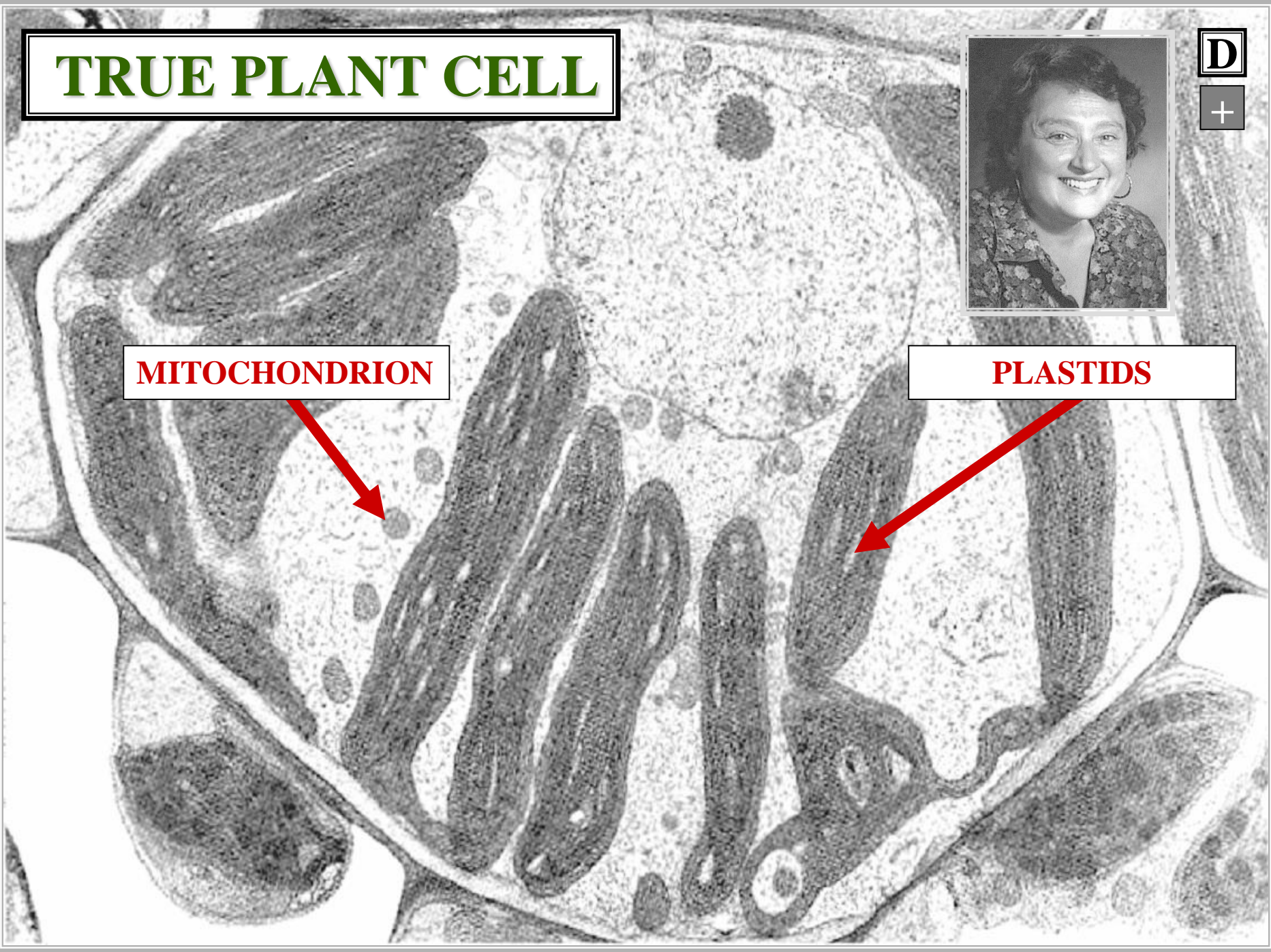
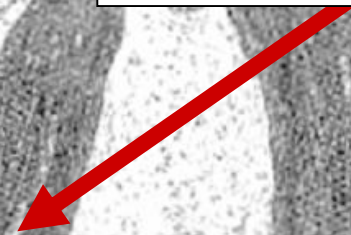
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MITOCHONDRION



PLASTIDS





# TRUE PLANT CELL

R

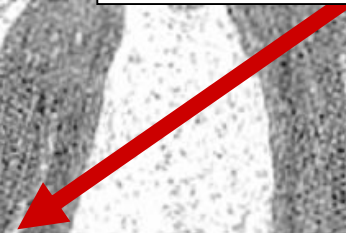
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MITOCHONDRION



PLASTIDS



DNA PROKARYOTE-LIKE

# TRUE PLANT CELL

R

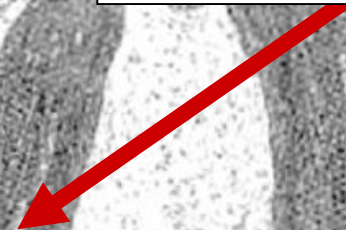
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MITOCHONDRION



PLASTIDS



DNA PROKARYOTE-LIKE

RIBOSOMES PROKARYOTE-LIKE



# TRUE PLANT CELL

?

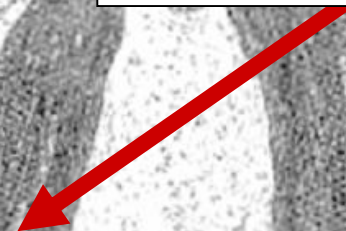
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**MITOCHONDRION**



**PLASTIDS**



**DNA PROKARYOTE-LIKE**

**RIBOSOMES PROKARYOTE-LIKE**

**REPRODUCTION PROKARYOTE-LIKE**

# QUESTION

DOES THIS EVIDENCE  
SUPPORT OR REFUTE  
THE  
ENDOSYMBIOTIC  
THEORY?

# QUESTION



S

**ANSWER**

**EVIDENCE SUPPORTS  
ENDOSYMBIOTIC  
THEORY**

**ANSWER**

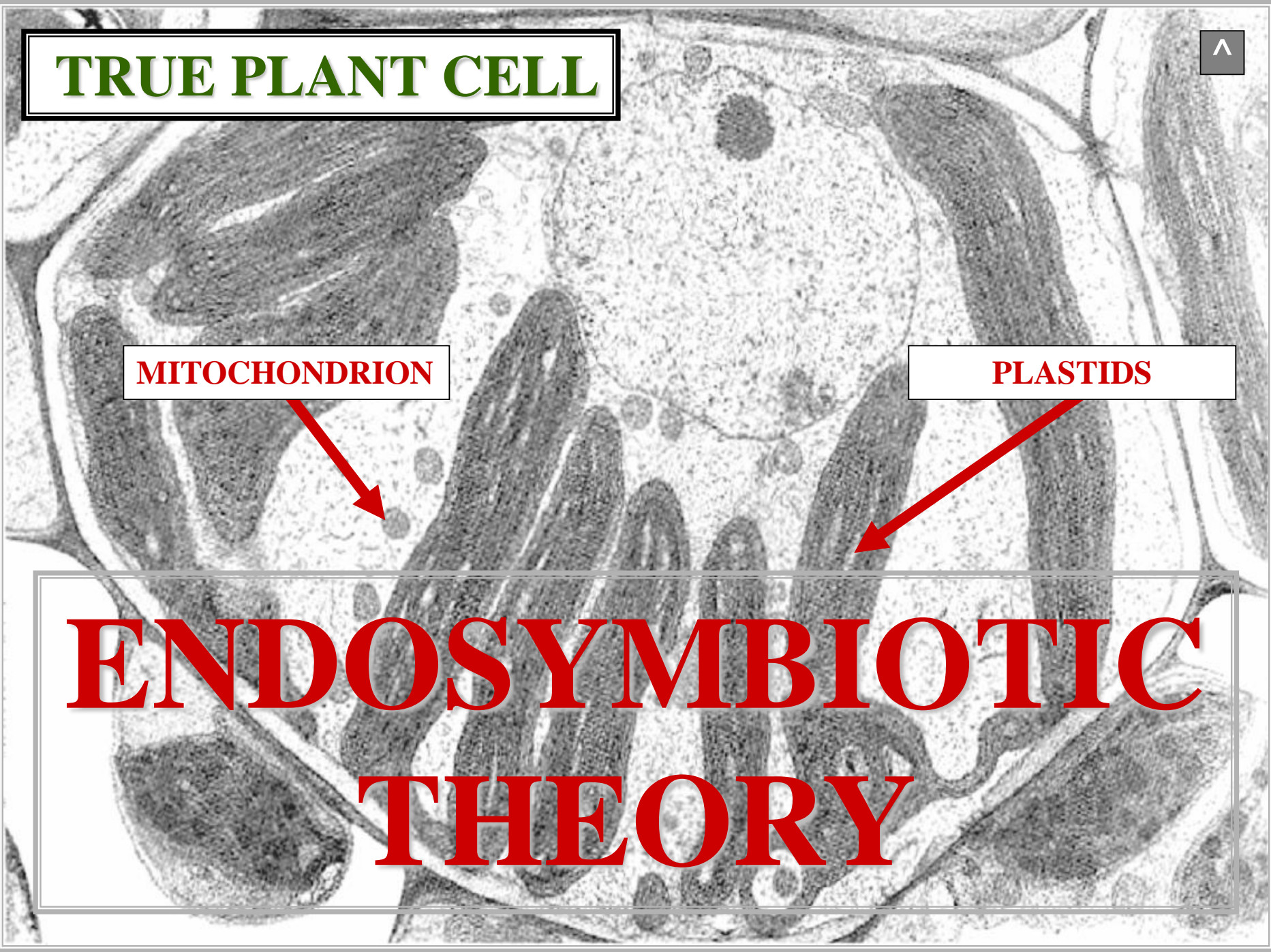


# TRUE PLANT CELL

MITOCHONDRION

PLASTIDS

# ENDOSYMBIOTIC THEORY



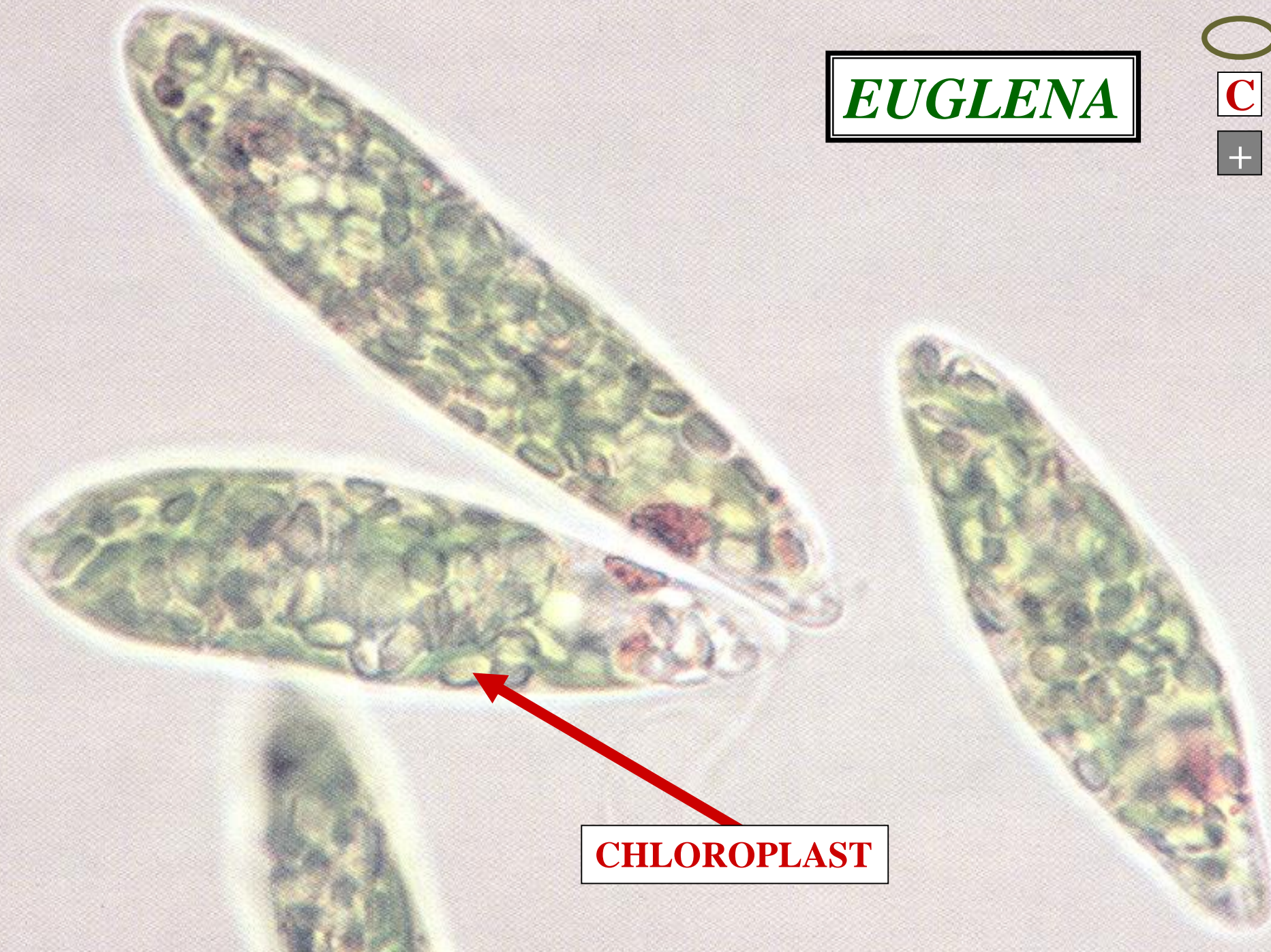
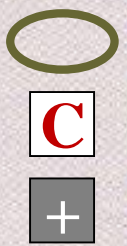


*Euglena*

**TRUE PLANT  
EXCLUSION**

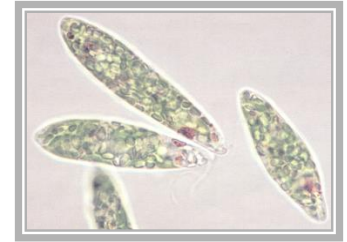


# *EUGLENA*

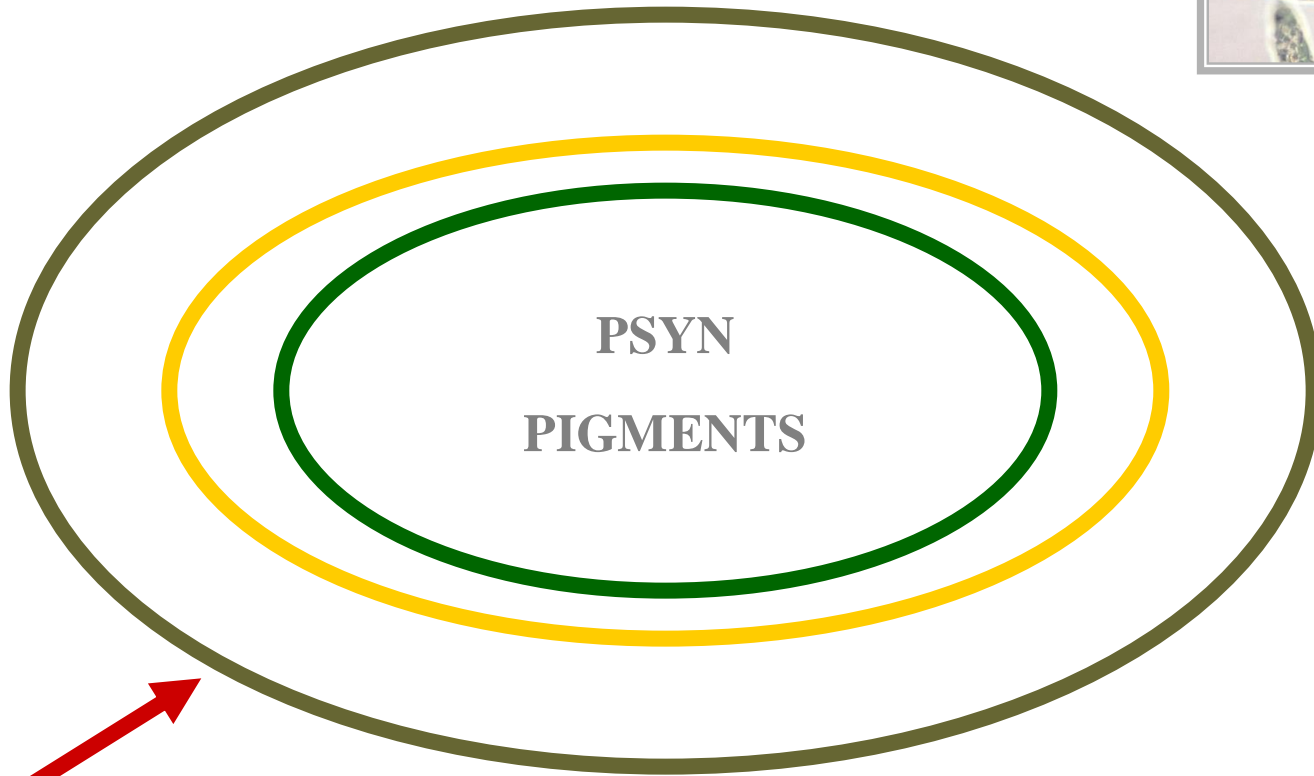


**CHLOROPLAST**

# *EUGLENA*

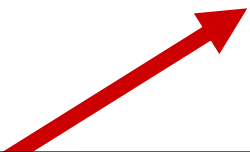


**A&B**

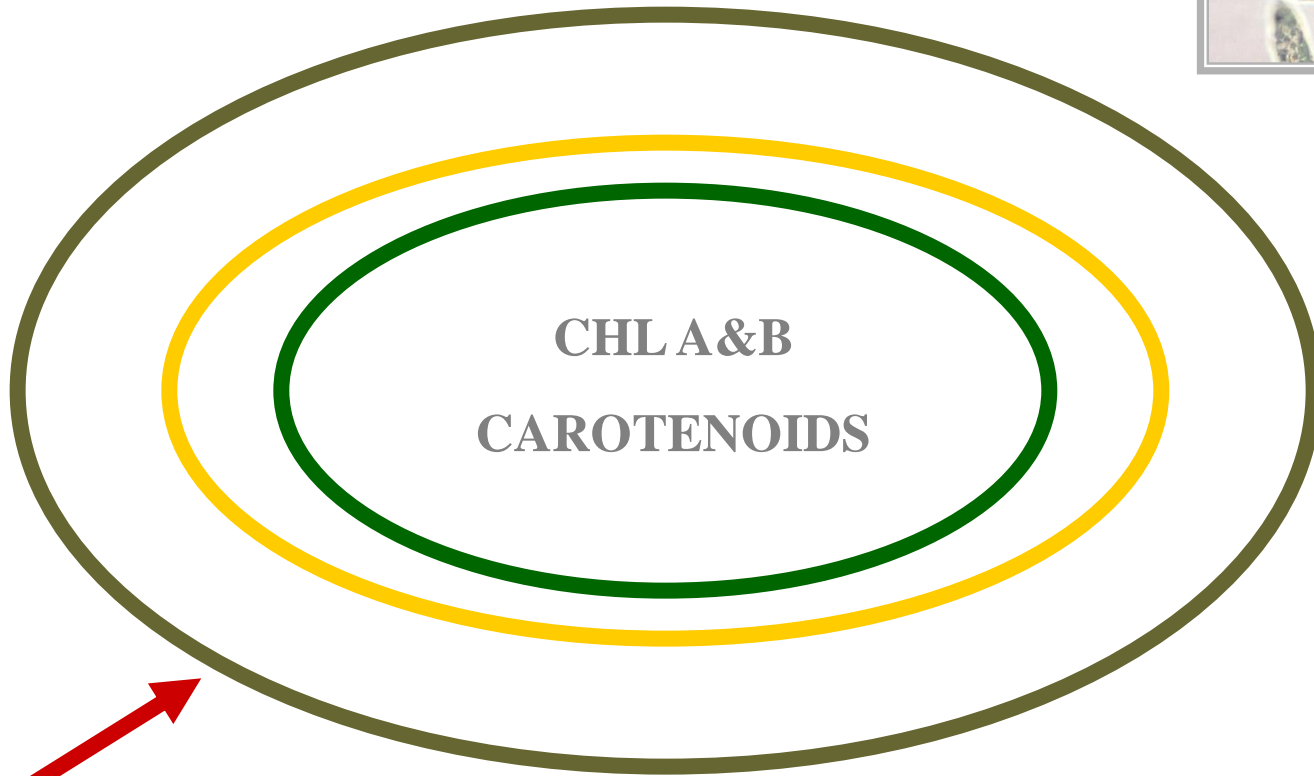
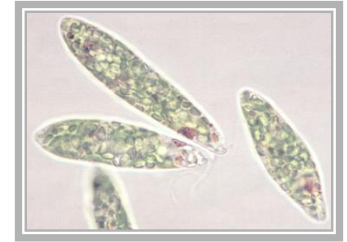


PSYN  
PIGMENTS

**CHLOROPLAST**



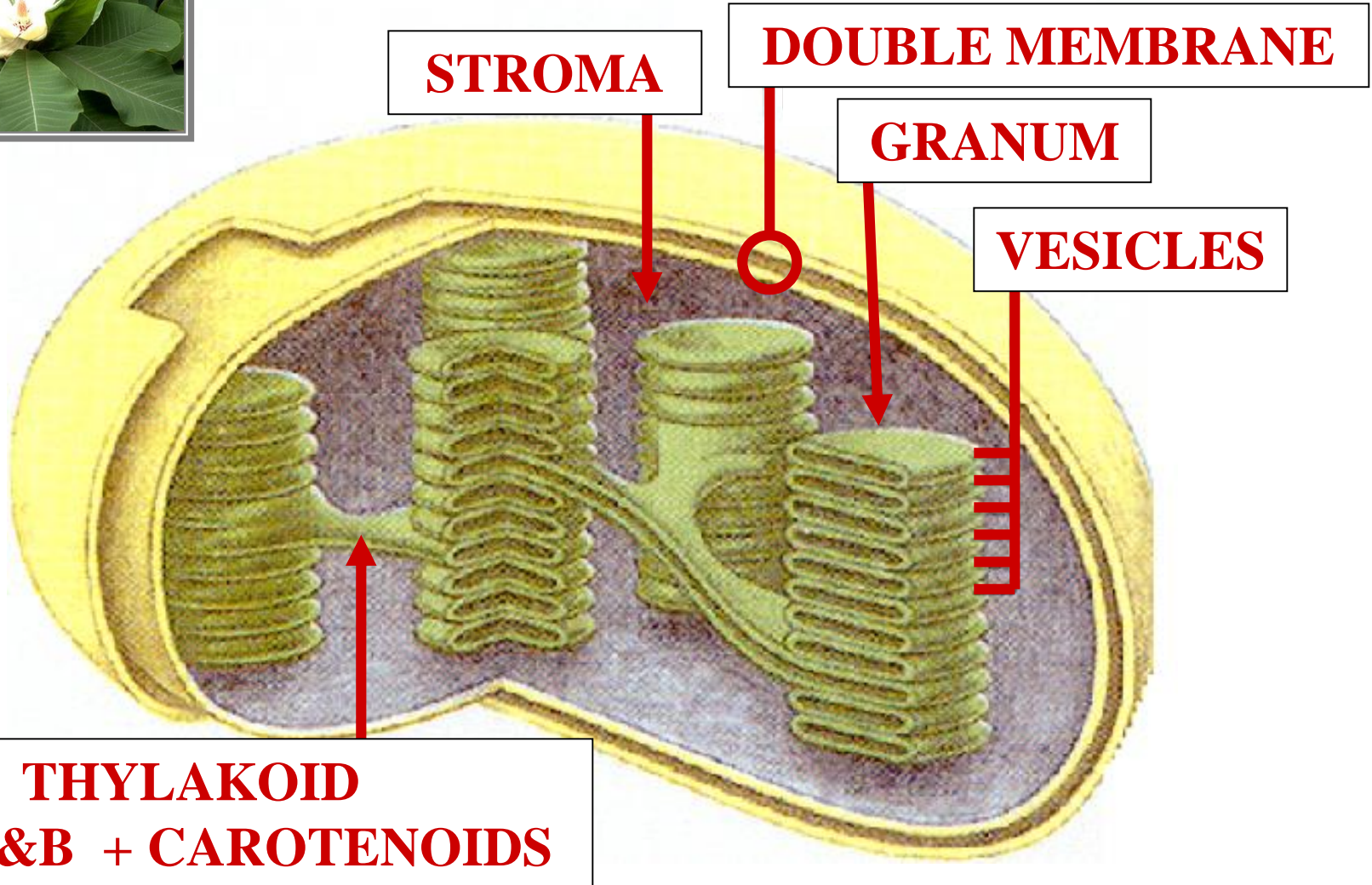
# *EUGLENA*



**CHLOROPLAST**



# TRUE PLANT CHLOROPLAST ULTRASTRUCTURE



**STROMA**

**DOUBLE MEMBRANE**

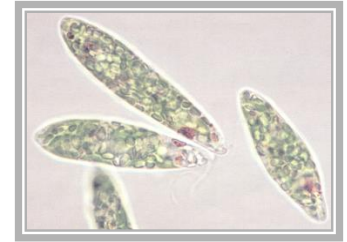
**GRANUM**

**VESICLES**

**THYLAKOID**

**CHLA&B + CAROTENOIDS**

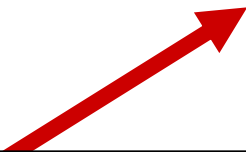
# *EUGLENA*



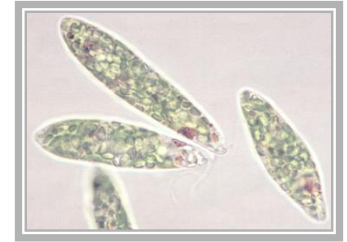
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CHL A&B  
CAROTENOIDS

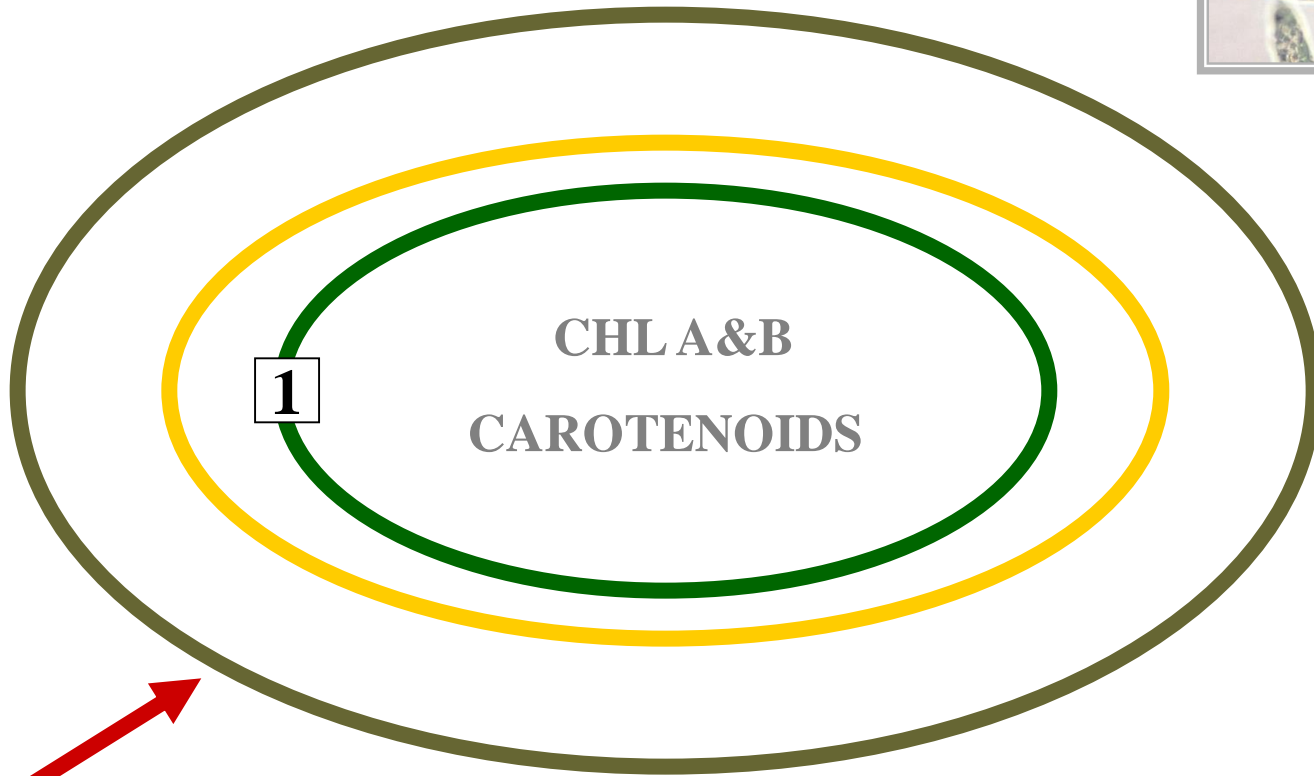
**CHLOROPLAST**



# *EUGLENA*



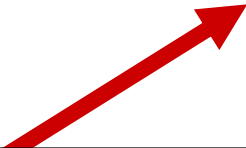
2



1

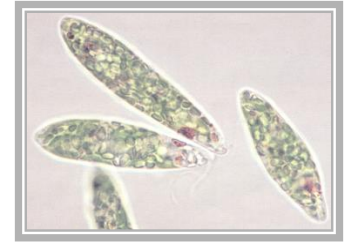
CHL A&B  
CAROTENOIDS

CHLOROPLAST

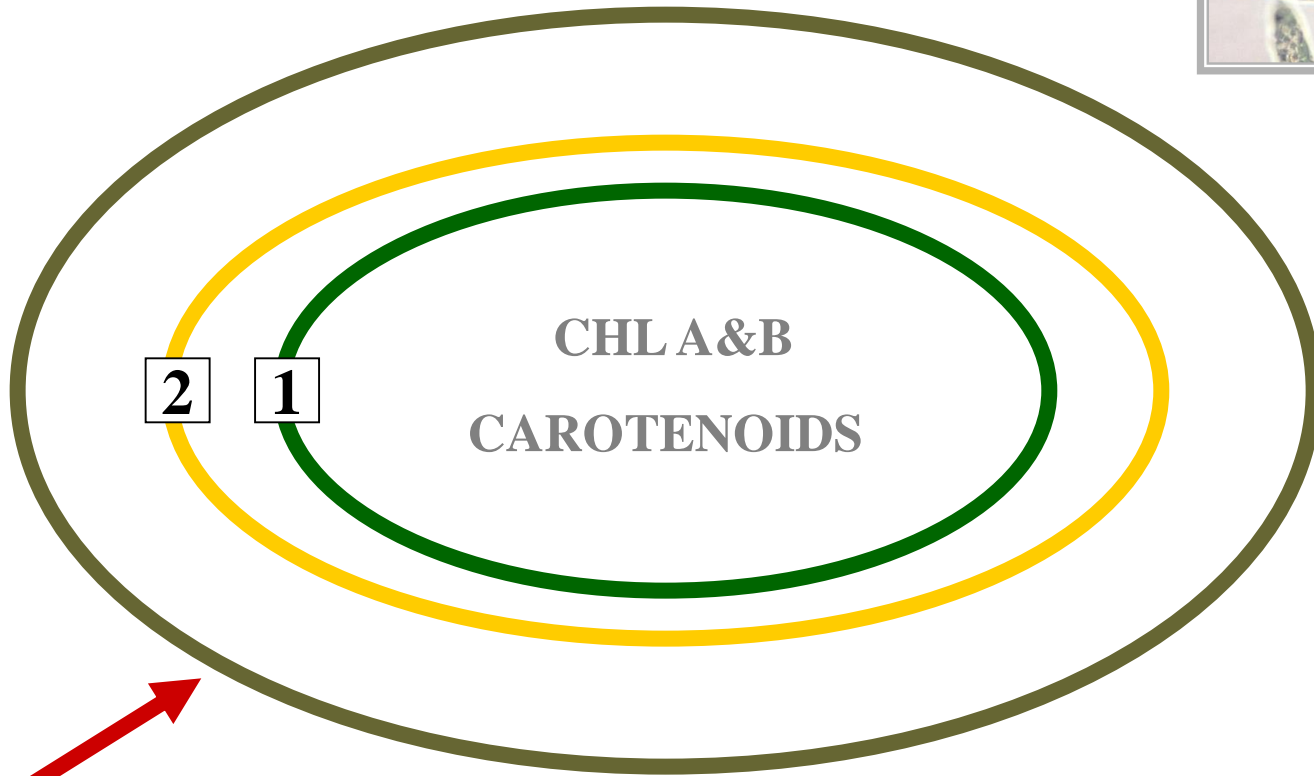




# *EUGLENA*



3



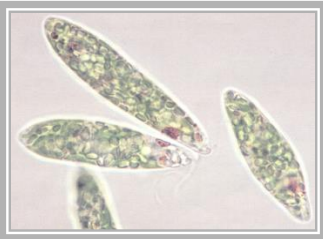
2

1

CHL A&B  
CAROTENOIDS

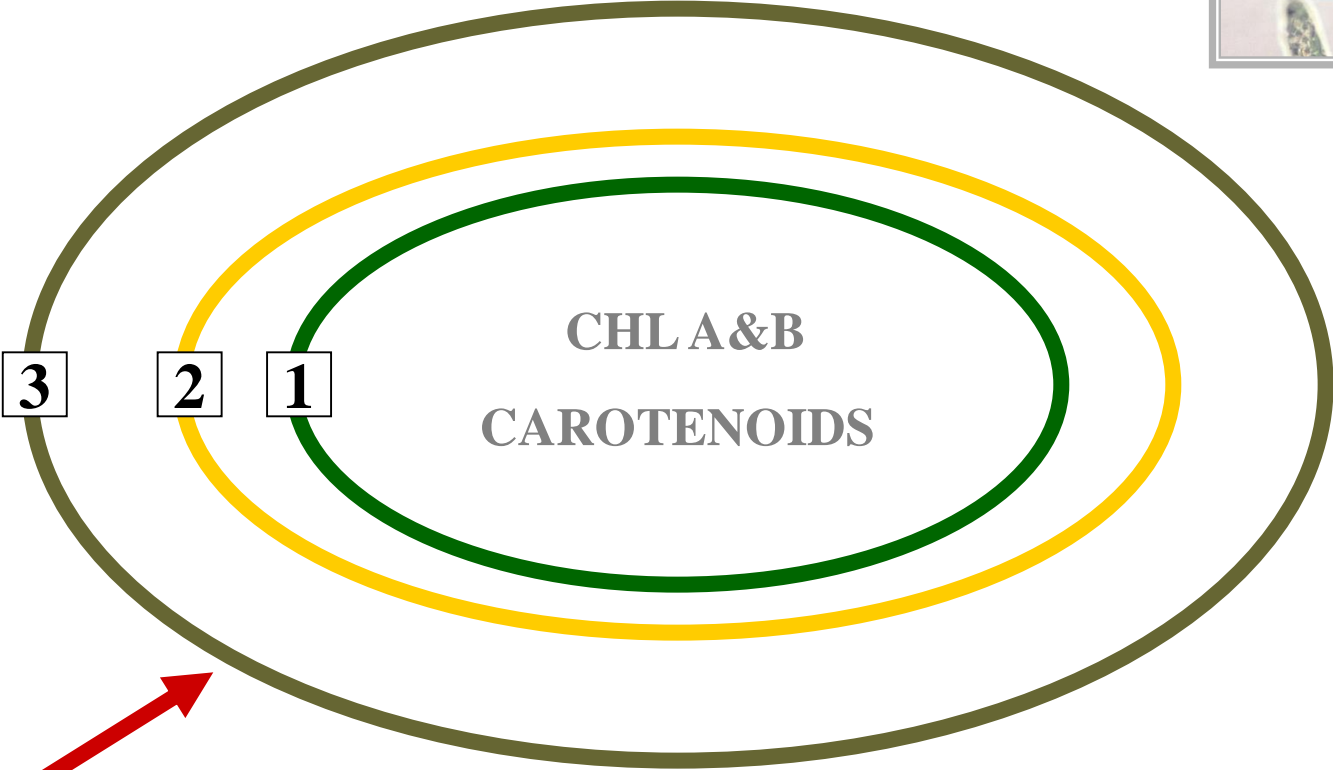
CHLOROPLAST

# *EUGLENA*



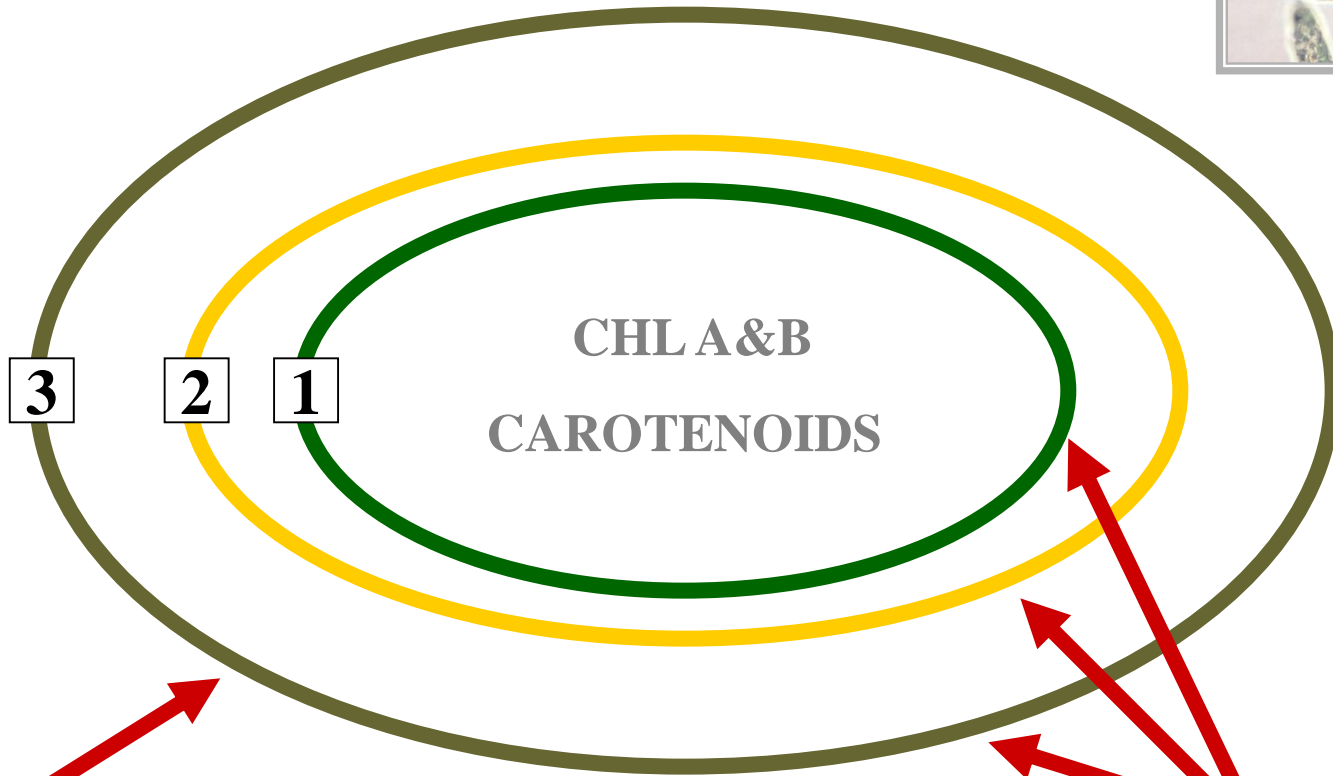
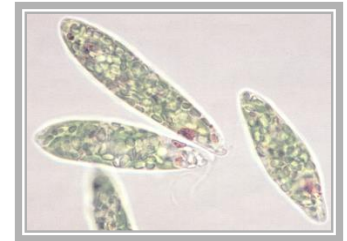
**T**

**+**



**CHLOROPLAST**

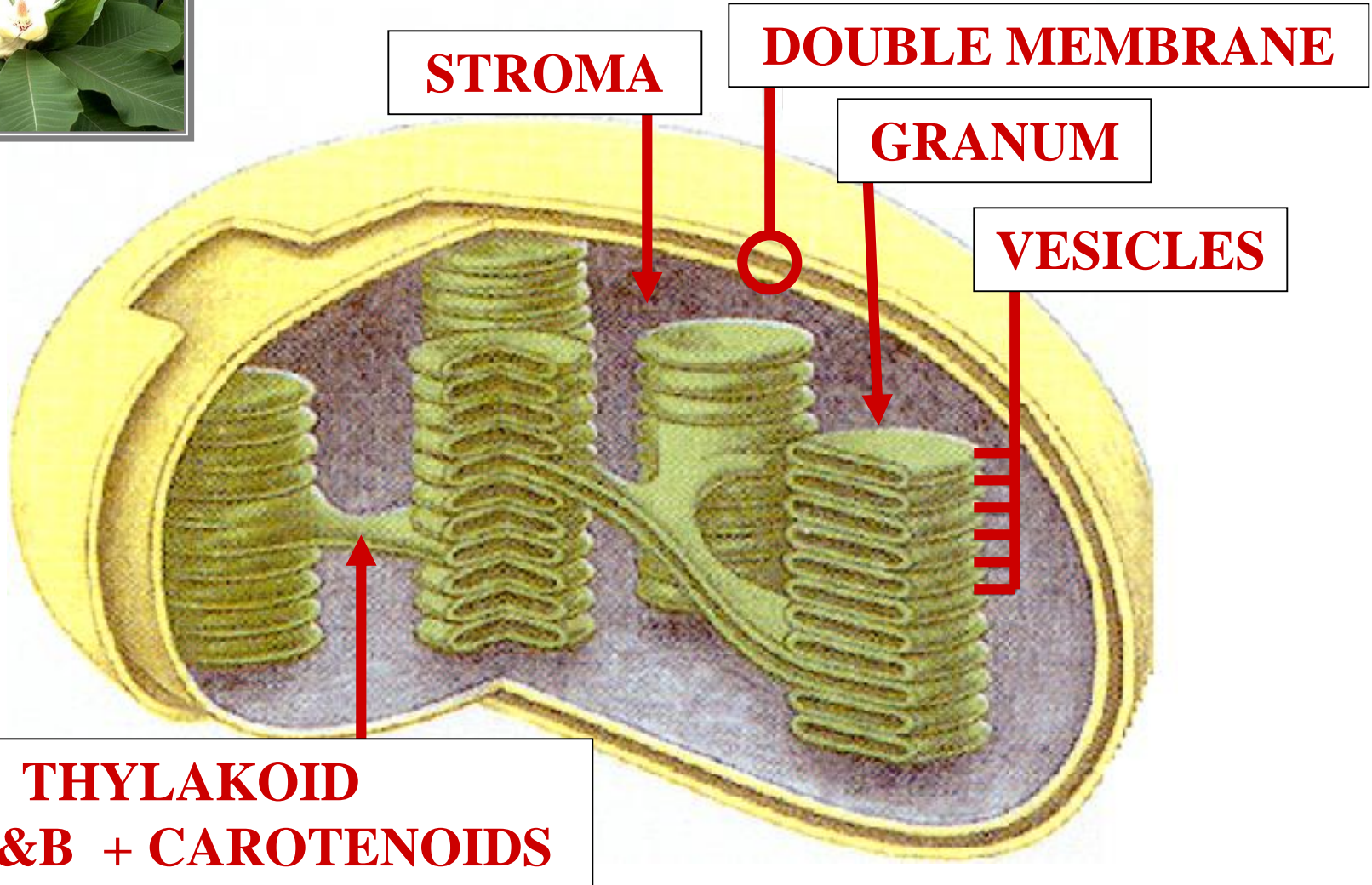
# *EUGLENA*



**CHLOROPLAST**

**TRIPLE MEMBRANE**

# TRUE PLANT CHLOROPLAST ULTRASTRUCTURE



**STROMA**

**DOUBLE MEMBRANE**

**GRANUM**

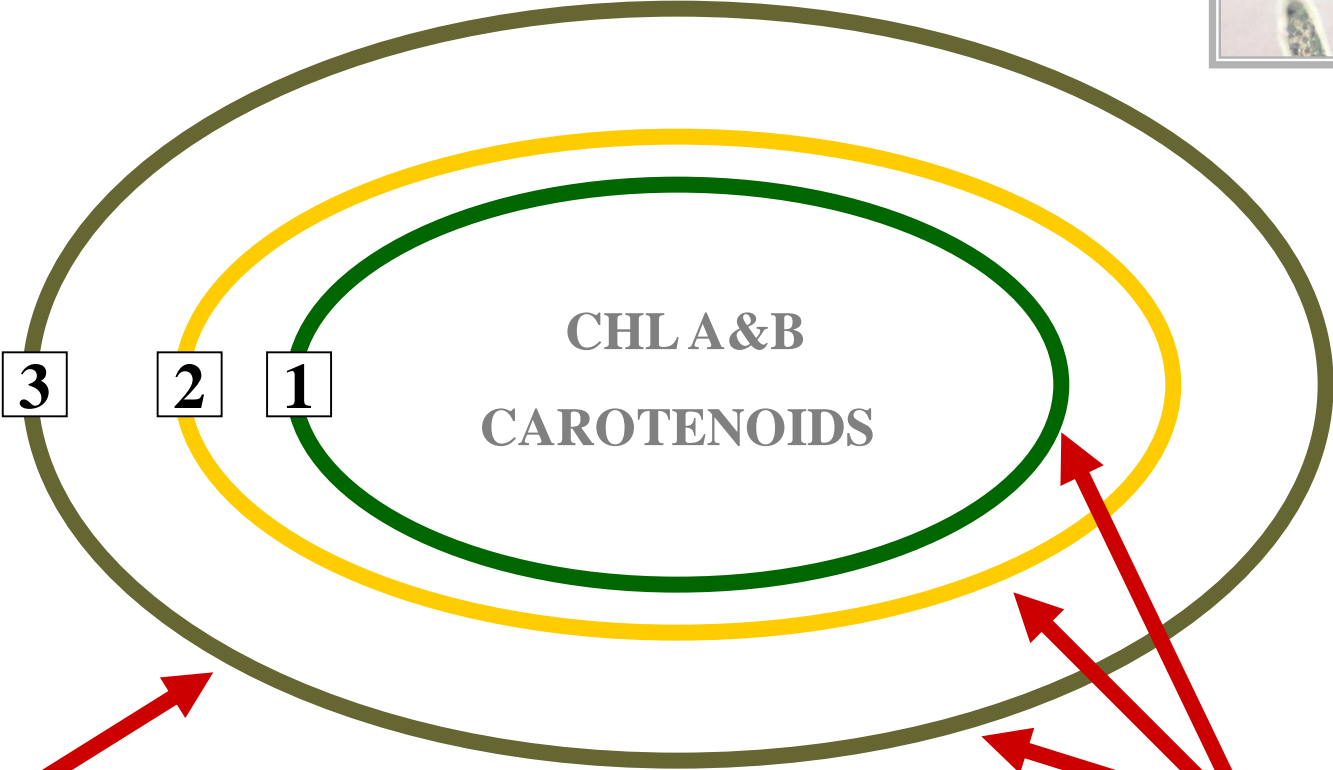
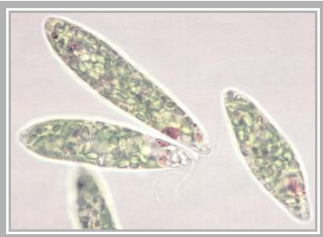
**VESICLES**

**THYLAKOID**

**CHLA&B + CAROTENOIDS**



# *EUGLENA*



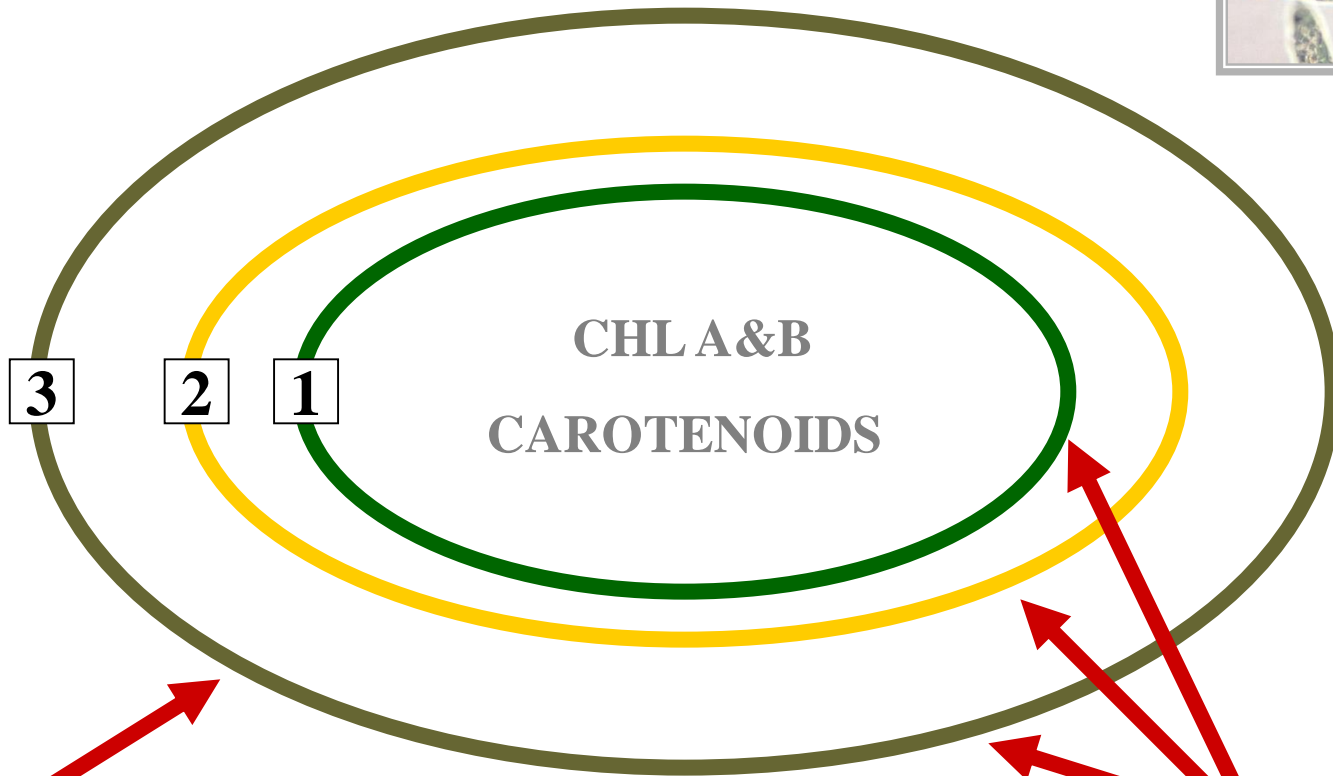
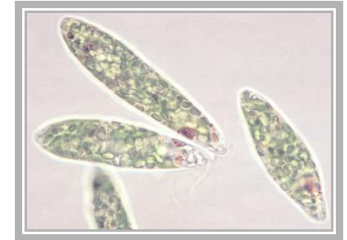
~2

?

**CHLOROPLAST**

**TRIPLE MEMBRANE**

# *EUGLENA*



**CHLOROPLAST EVOLVED VIA  
SECONDARY ENDSYMBIOSIS**

**TRIPLE MEMBRANE**



# SECONDARY ENDOSYMBIOSIS

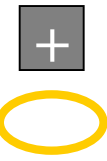
**PRIMARY  
ENDOSYMBIOSIS**



**PRIMARY  
ENDOSYMBIOSIS**

**PROKARYOTE  
UNDERGOES  
ENDOSYMBIOSIS**

**PRIMARY  
ENDOSYMBIOSIS**



# PRIMARY ENDOSYMBIOSIS

**HETEROTROPHIC  
HOST CELL**

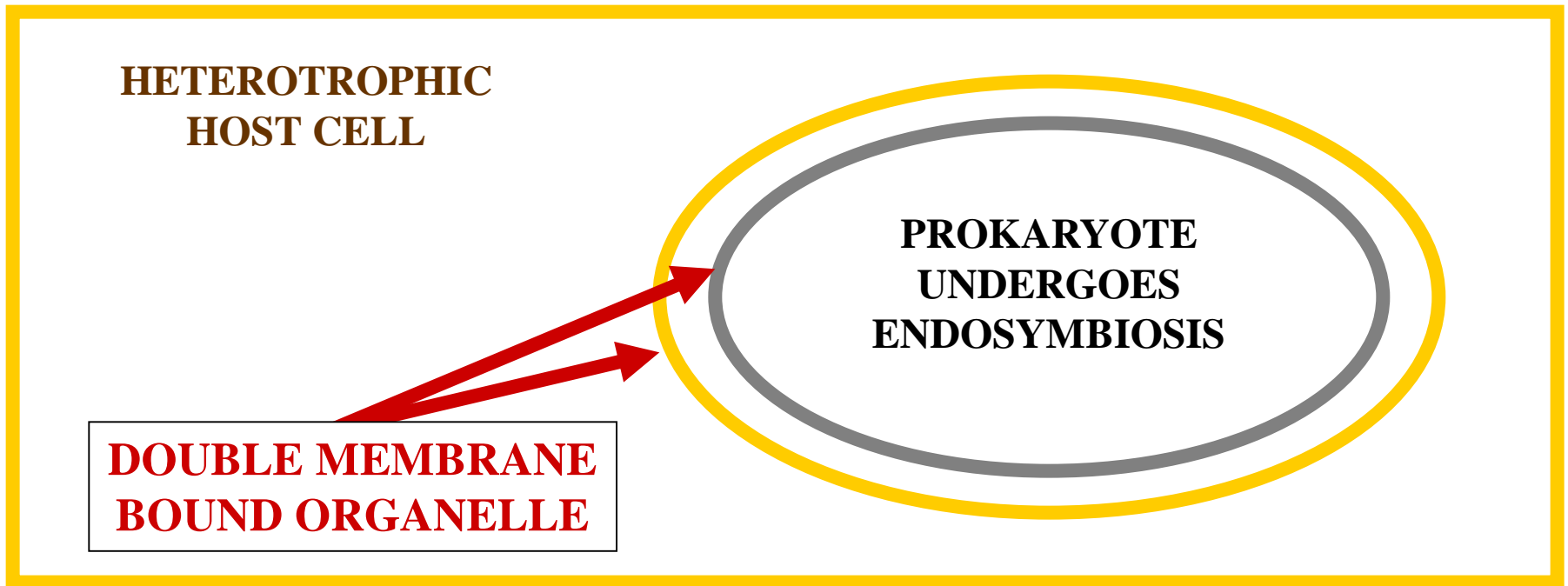


**PROKARYOTE  
UNDERGOES  
ENDOSYMBIOSIS**

The diagram illustrates the process of primary endosymbiosis. It features a large yellow rectangular border representing the heterotrophic host cell. Inside this border, there is a gray oval representing a prokaryote. The text 'PROKARYOTE UNDERGOES ENDOSYMBIOSIS' is centered within the gray oval. The text 'HETEROTROPHIC HOST CELL' is positioned to the left of the gray oval, within the yellow border.

# PRIMARY ENDOSYMBIOSIS

# PRIMARY ENDOSYMBIOSIS



# PRIMARY ENDOSYMBIOSIS

# **SECONDARY ENDOSYMBIOSIS**



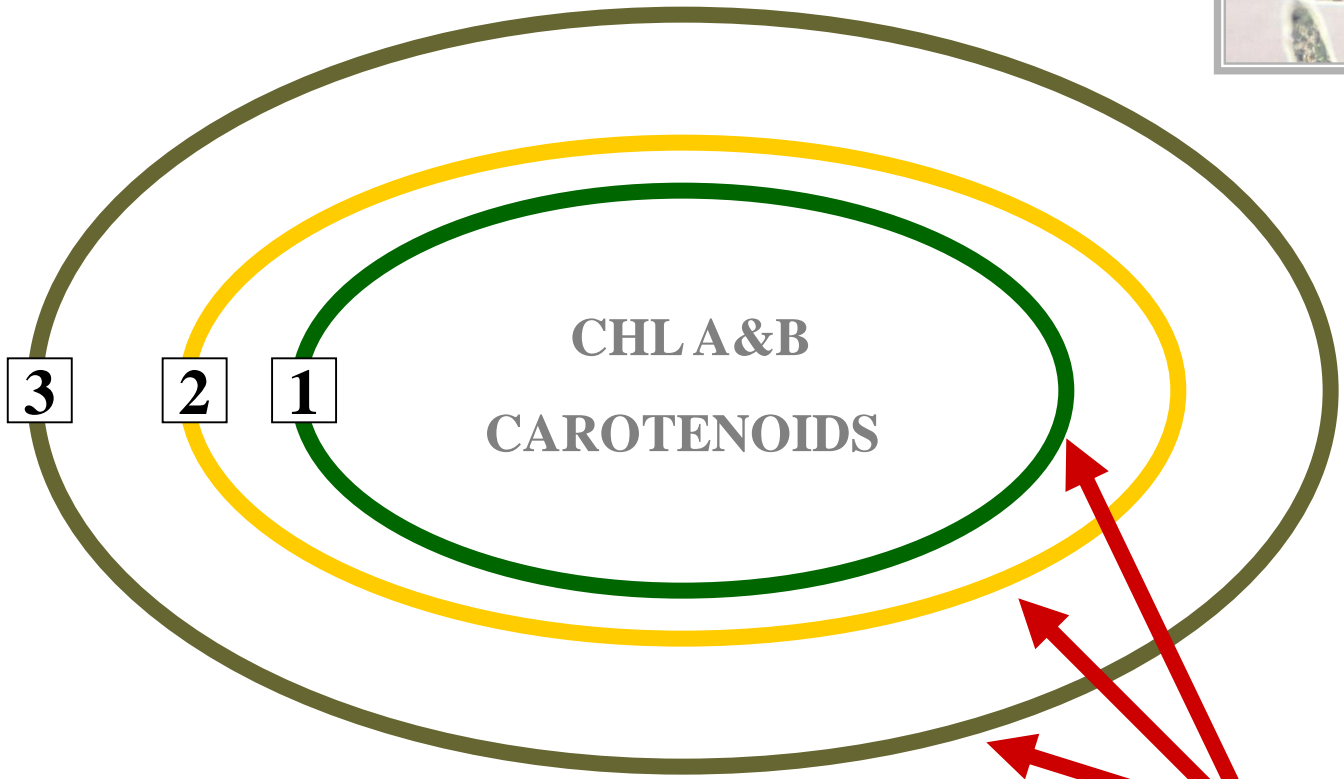
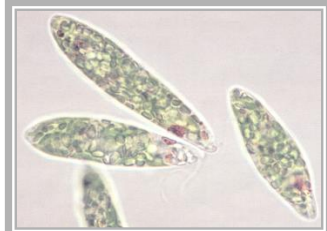
**SECONDARY  
ENDOSYMBIOSIS**



**EUKARYOTE  
UNDERGOES  
ENDOSYMBIOSIS**

**SECONDARY  
ENDOCYTOSIS**

# *EUGLENA*



**SECONDARY ENDOSYMBIOSIS**

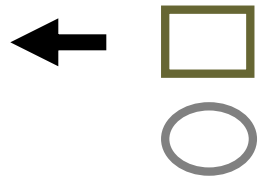
**TRIPLE MEMBRANE BOUND ORGANELLE**



*Euglena*

**PLASTID**

**EVOLUTION**



*Euglena*

PLASTID

EVOLUTION

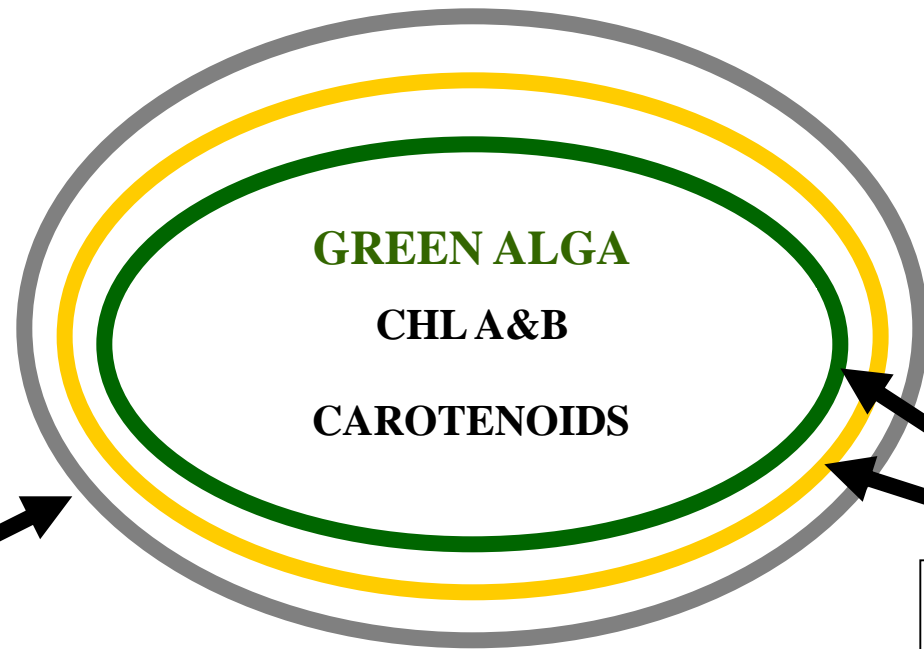
HYPOTHETICAL

SCENARIO



**HETEROTROPHIC  
EUGLENOID  
HOST CELL**

**EUGLENOID  
MEMBRANE**



**CELL  
MEMBRANE**

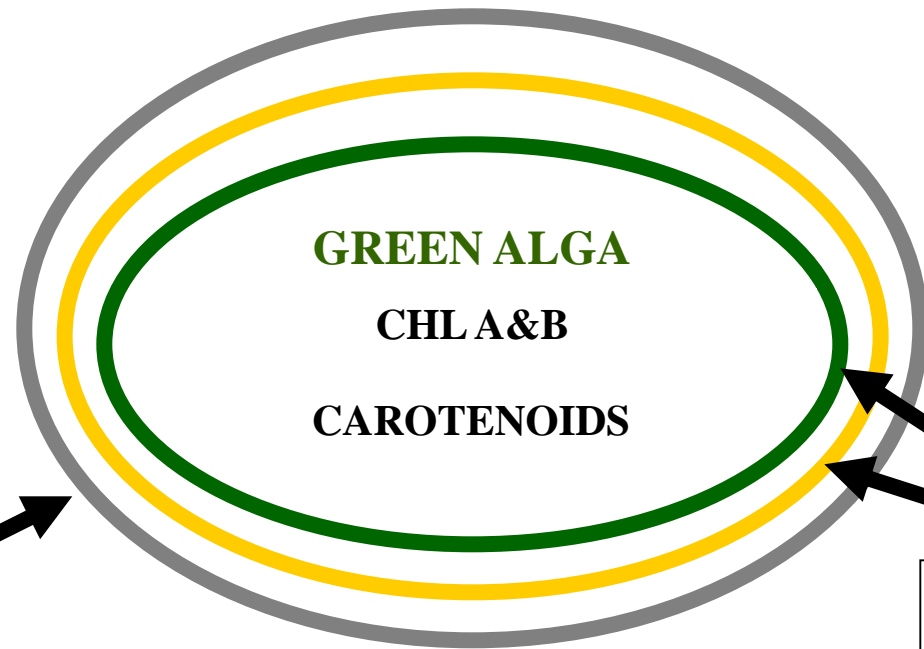
**AUTOTROPHIC EUKARYOTE**

**CHLOROPLAST  
DOUBLE  
MEMBRANE**

**HETEROTROPHIC  
EUGLENOID  
HOST CELL**

**SAME HABITAT**

**EUGLENOID  
MEMBRANE**



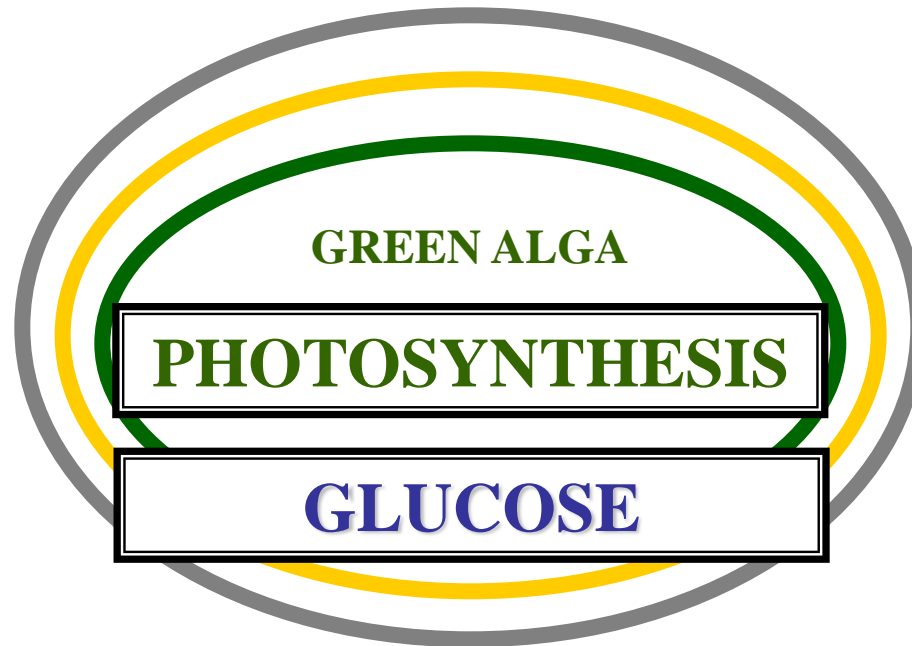
**CELL  
MEMBRANE**

**AUTOTROPHIC EUKARYOTE**

**CHLOROPLAST  
DOUBLE  
MEMBRANE**

**HETEROTROPHIC  
EUGLENOID**

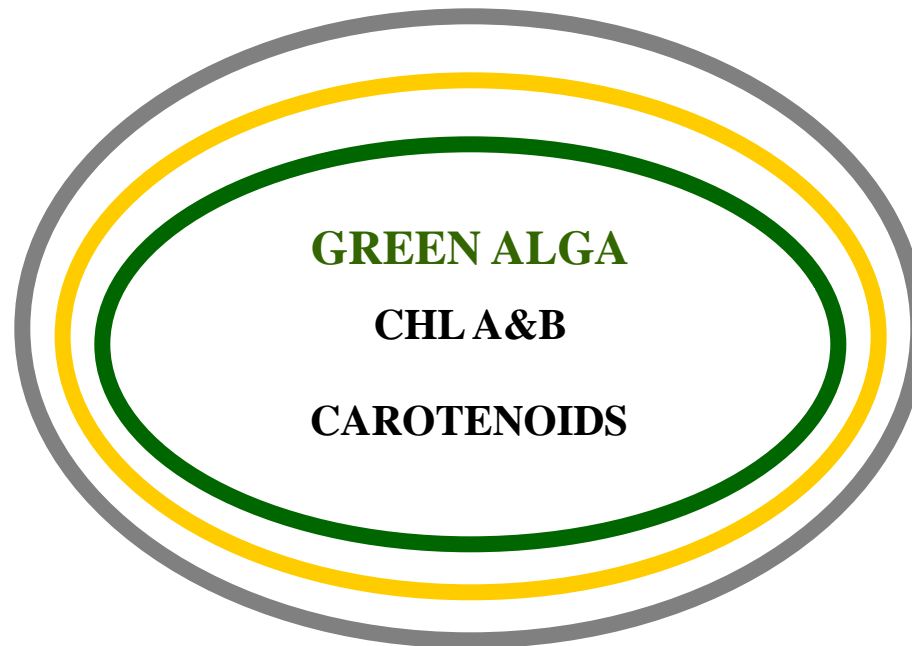
***CANNOT DERIVE* GLUCOSE**



**AUTOTROPHIC EUKARYOTE**

**HETEROTROPHIC  
EUGLENOID**

**CONSUMES AUTOTROPHIC GREEN ALGA**

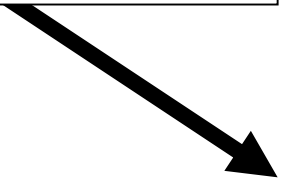


**AUTOTROPHIC EUKARYOTE**

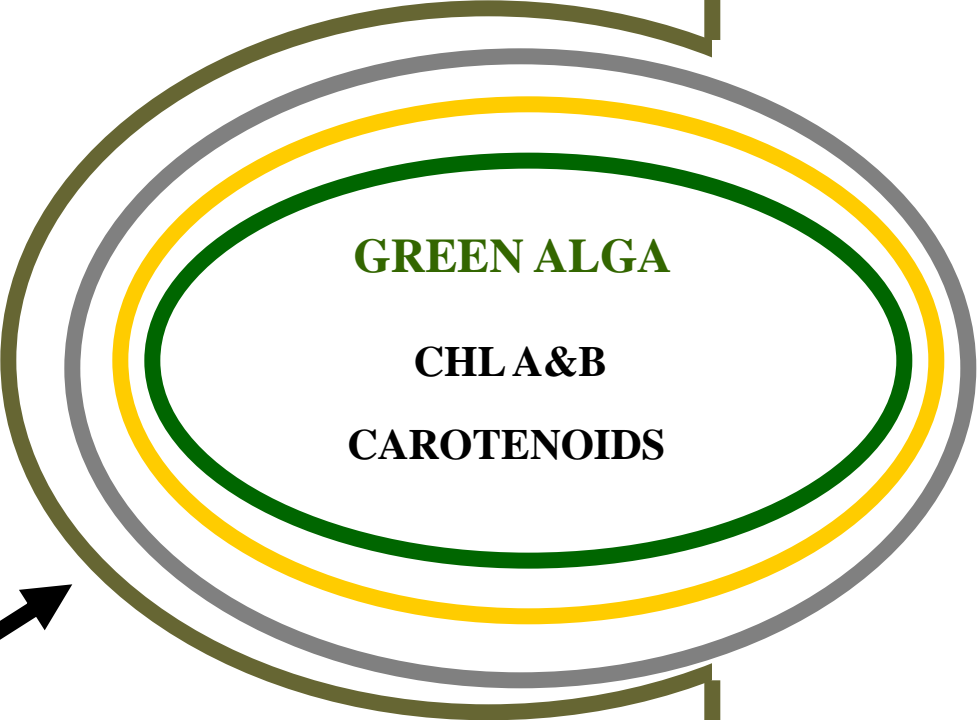
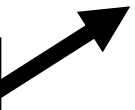


**EUGLENOID  
HOST CELL**

**CELL MEMBRANE**



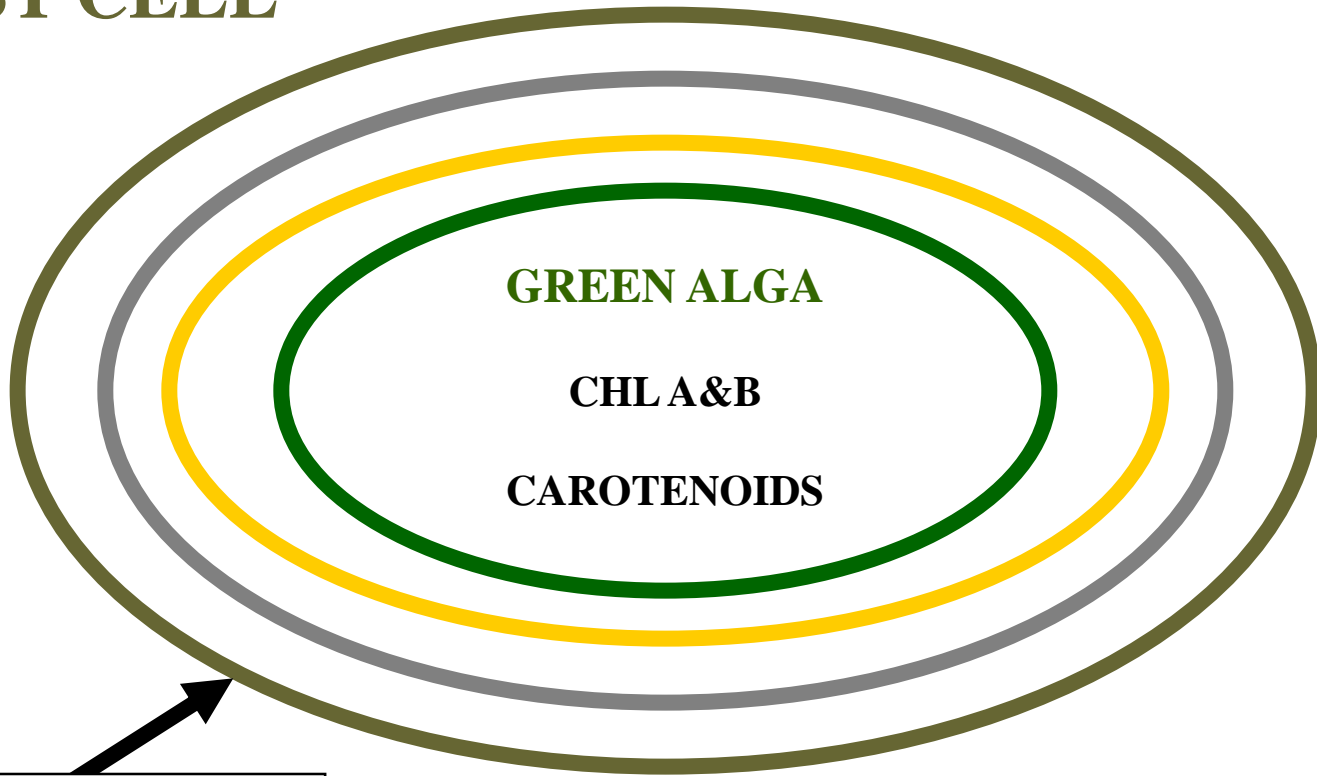
**ENDOCYTOSIS**



**GREEN ALGA**  
**CHL A&B**  
**CAROTENOIDS**

# GREEN ALGA WITHIN FOOD VACUOLE

EUGLENOID  
HOST CELL



GREEN ALGA

CHL A&B

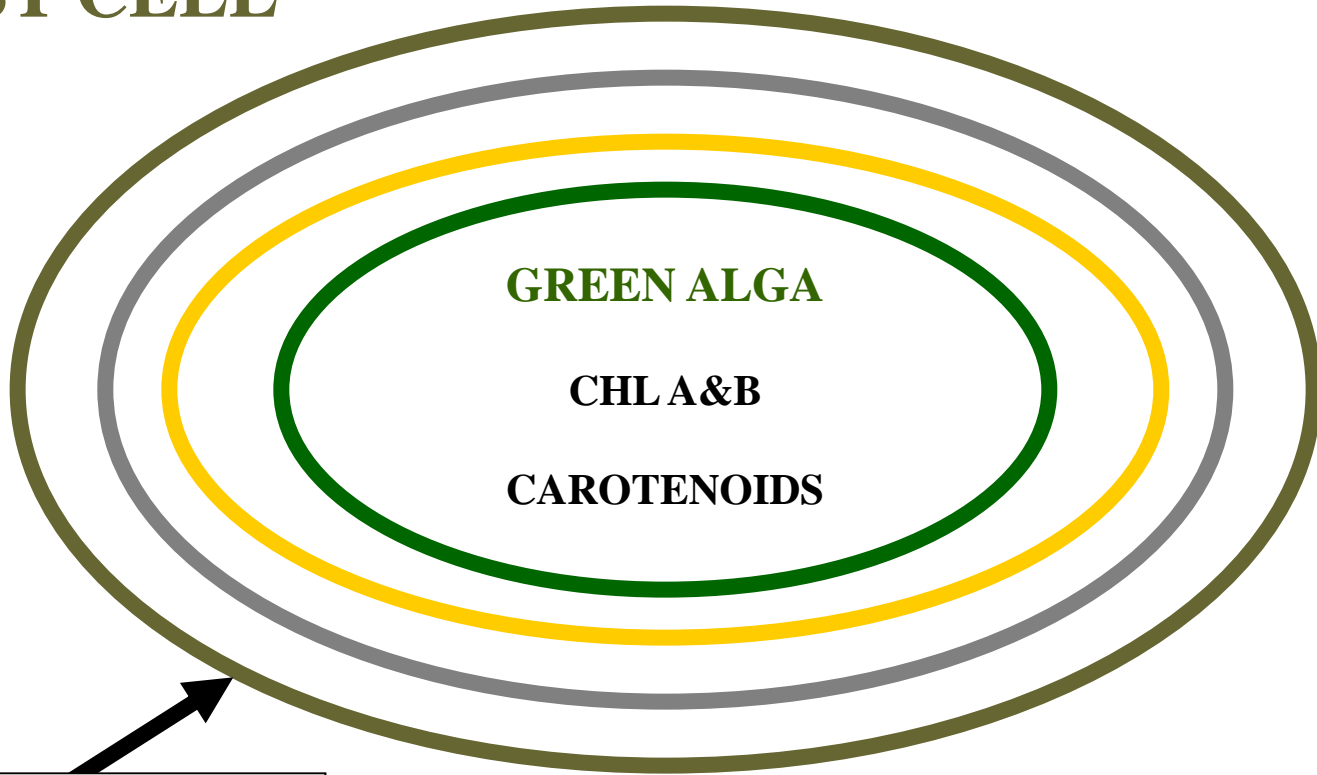
CAROTENOIDS

FOOD VACUOLE

# INITIALLY EUGLENOID DIGESTS GREEN ALGA



**EUGLENOID  
HOST CELL**



**GREEN ALGA**

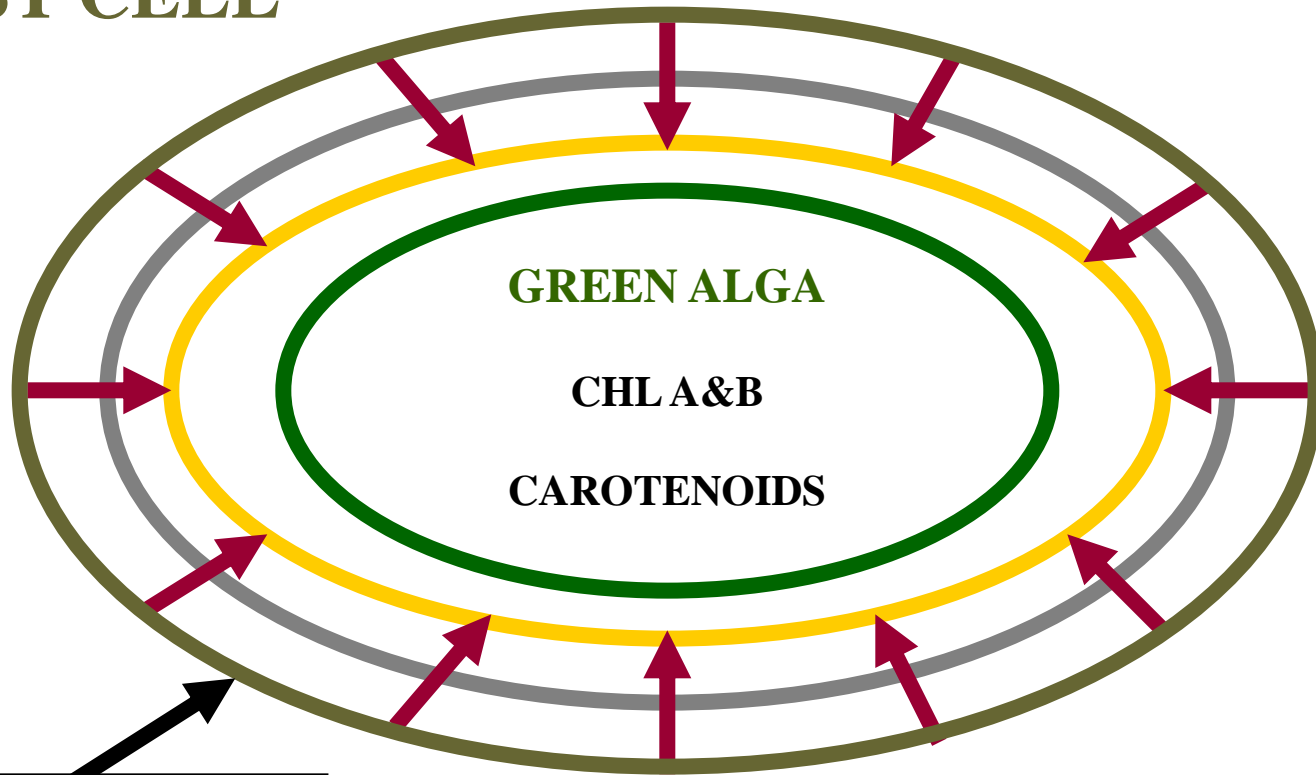
**CHL A&B**

**CAROTENOIDS**

**FOOD VACUOLE**

# INITIALLY EUGLENOID DIGESTS GREEN ALGA

EUGLENOID  
HOST CELL



GREEN ALGA

CHL A&B

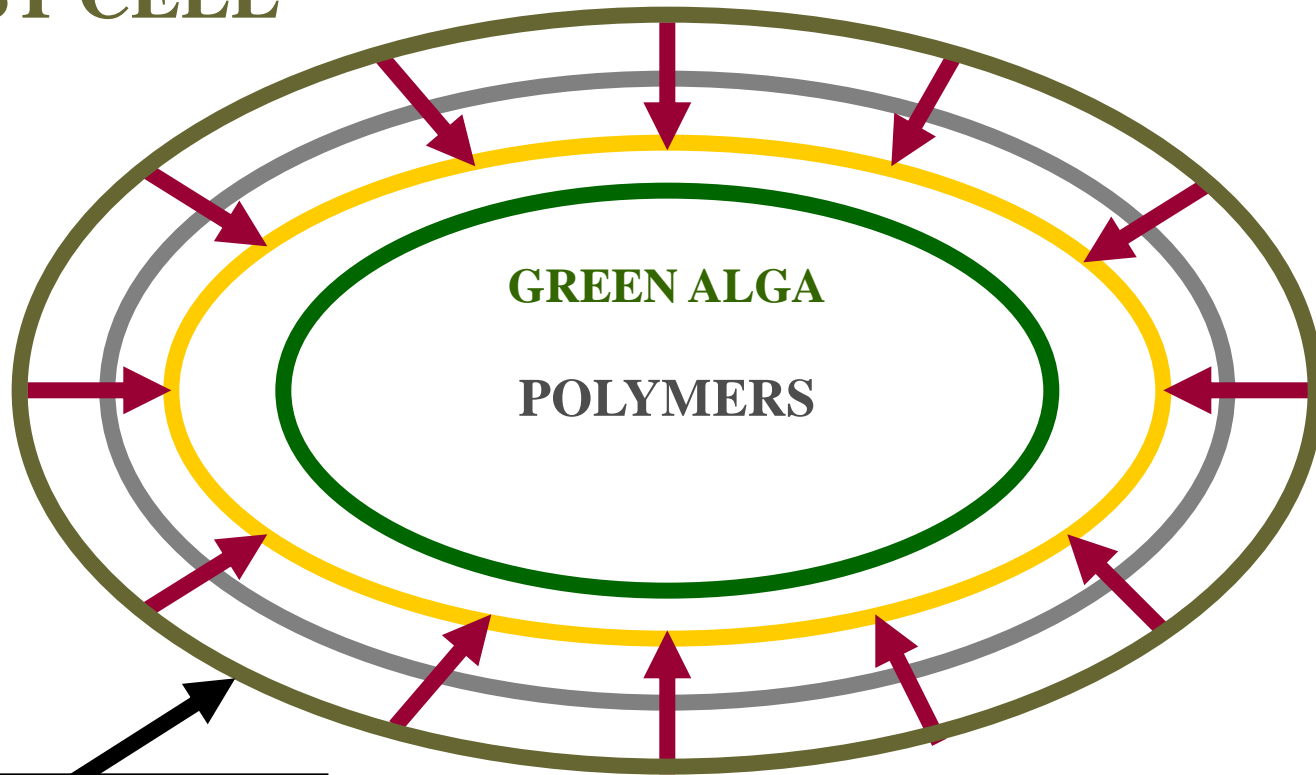
CAROTENOIDS

FOOD VACUOLE

→ = ENZYMES

# INITIALLY EUGLENOID DIGESTS GREEN ALGA

EUGLENOID  
HOST CELL



FOOD VACUOLE

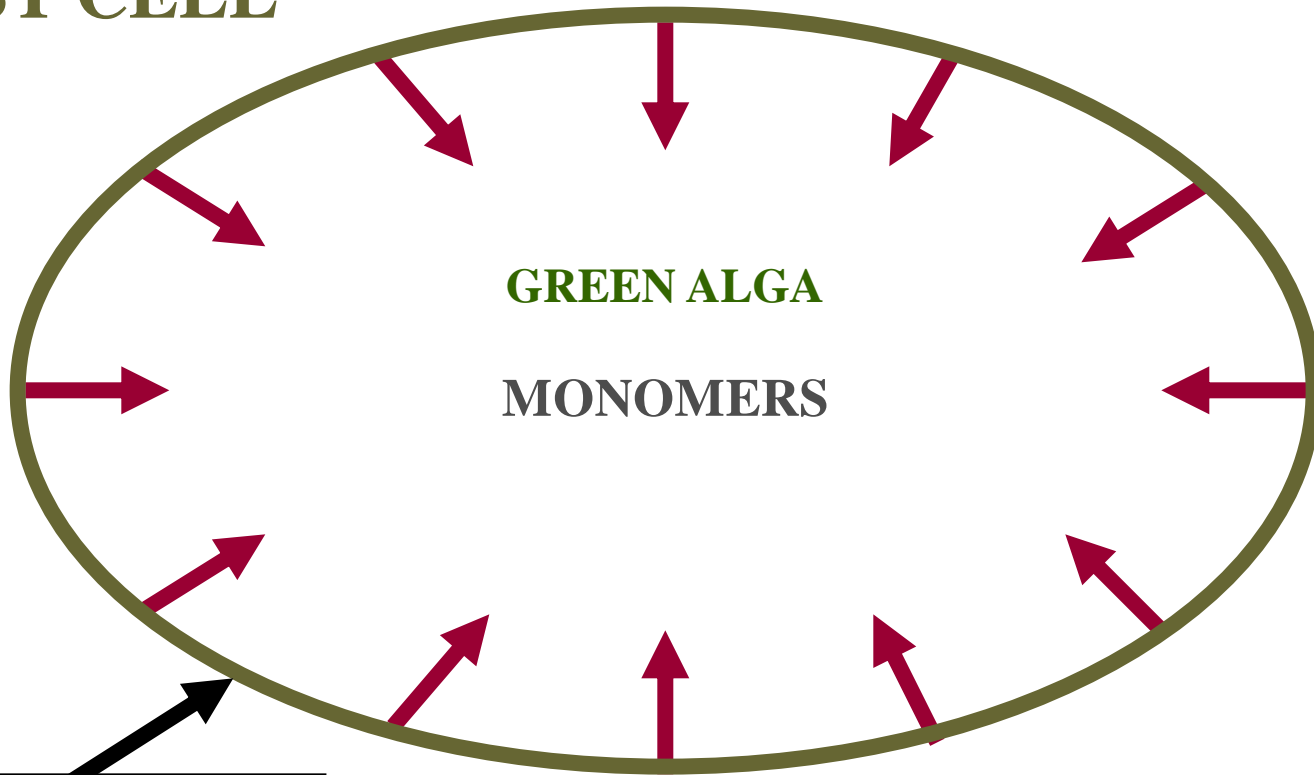
→ = ENZYMES



# INITIALLY EUGLENOID DIGESTS GREEN ALGA



**EUGLENOID  
HOST CELL**



**GREEN ALGA  
MONOMERS**

**FOOD VACUOLE**

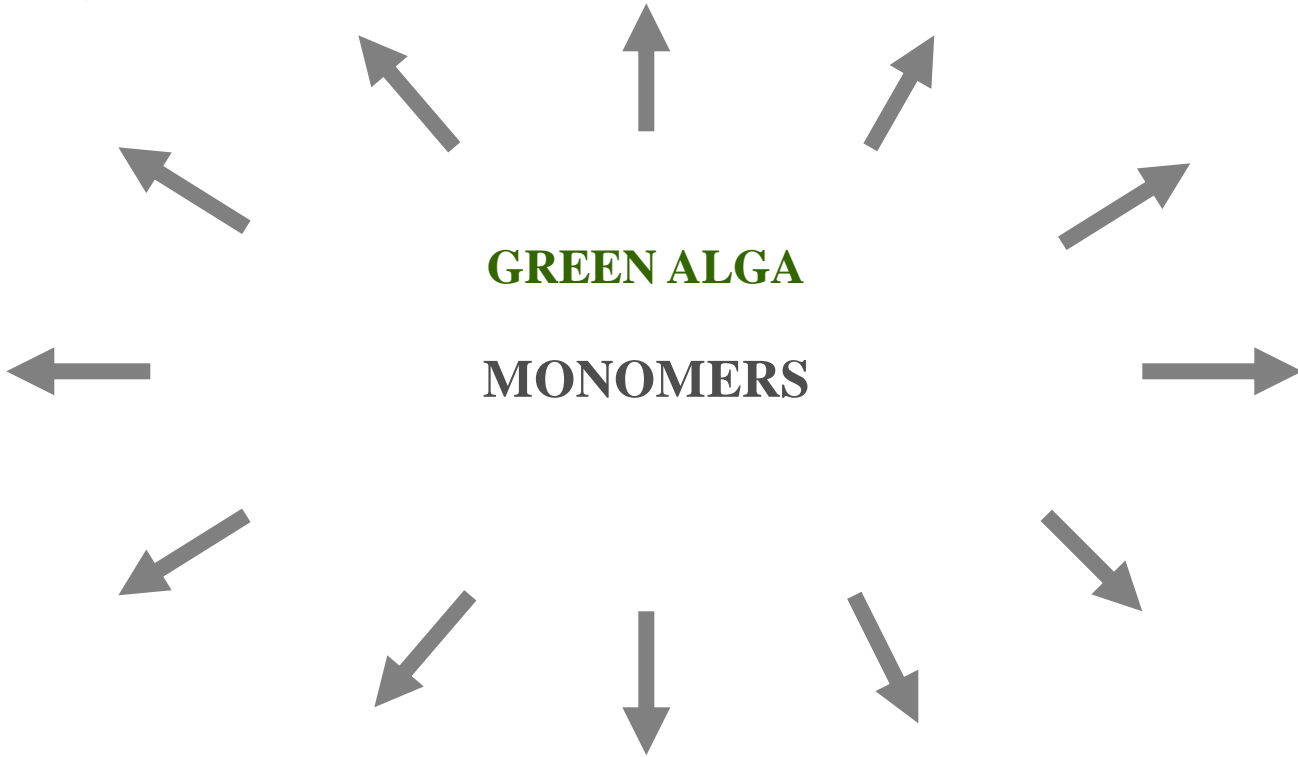
**→ = ENZYMES**

# INITIALLY EUGLENOID DIGESTS GREEN ALGA

**EUGLENOID  
HOST CELL**

**GREEN ALGA  
MONOMERS**

**CYTOSOL**



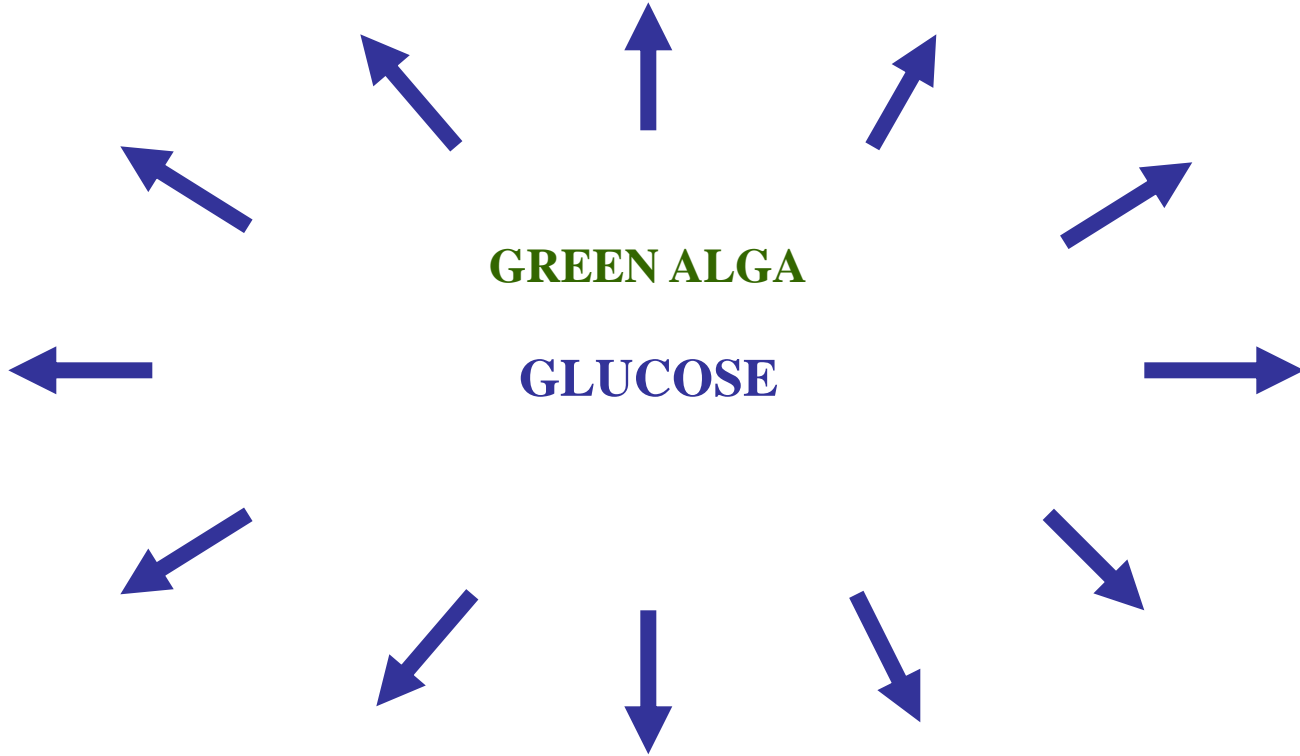
# INITIALLY EUGLENOID DIGESTS GREEN ALGA

**EUGLENOID  
HOST CELL**

**GREEN ALGA**

**GLUCOSE**

**CYTOSOL**



# INITIALLY EUGLENOID DIGESTS GREEN ALGA

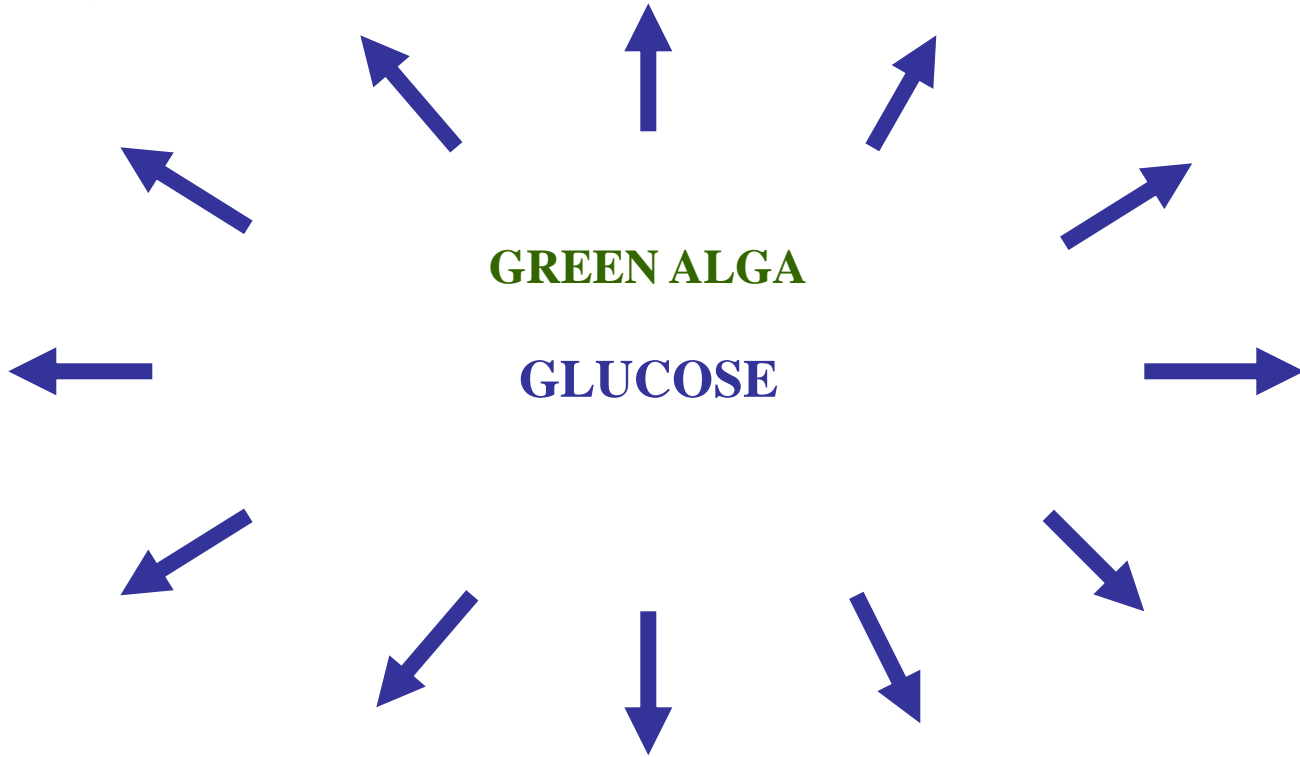
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**EUGLENOID  
HOST CELL**

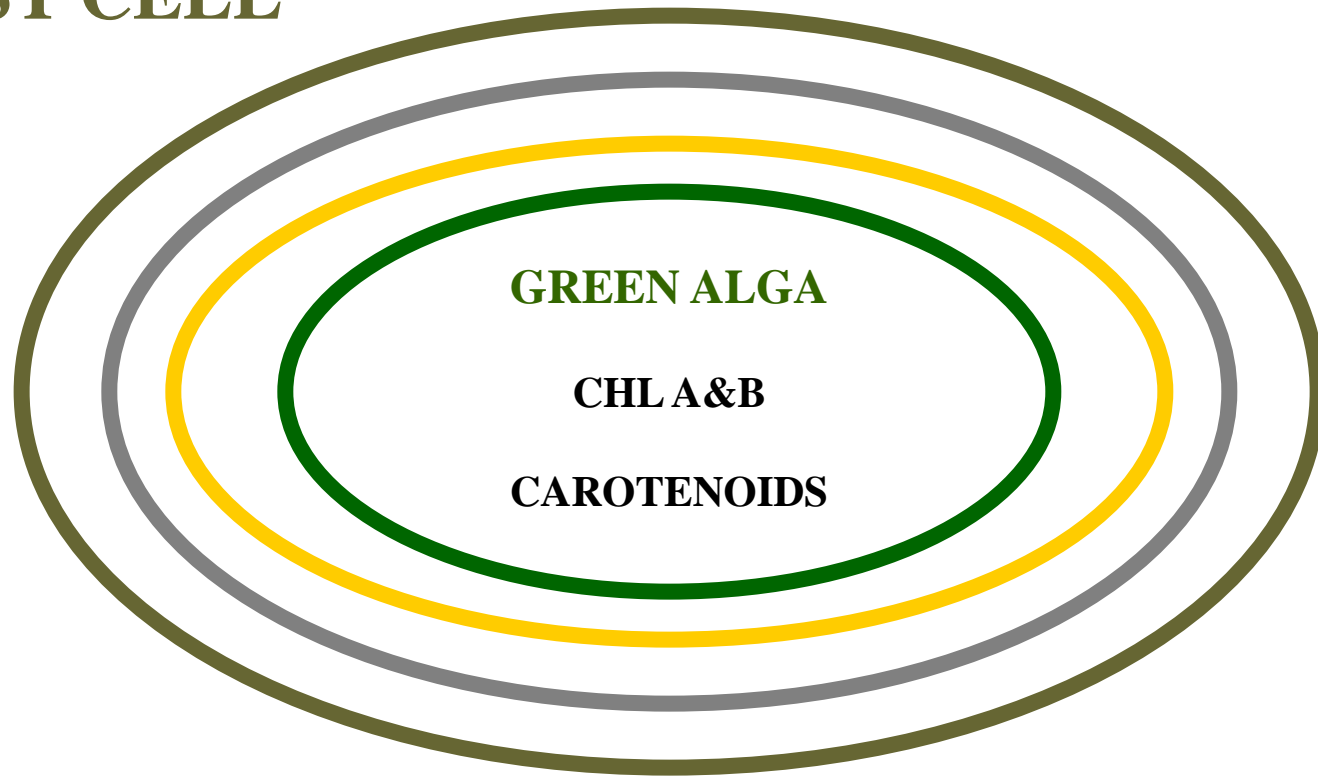
**GREEN ALGA**

**GLUCOSE**

**METABOLISM**



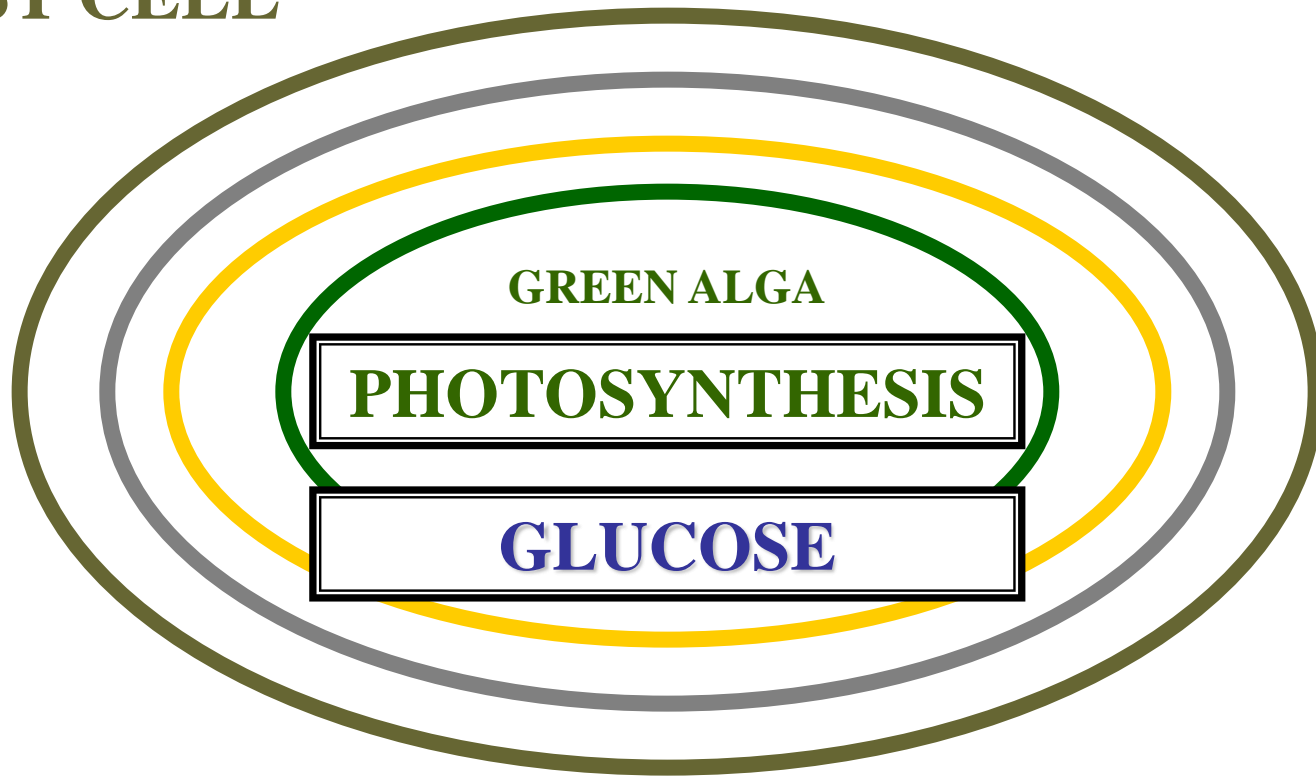
**EUGLENOID  
HOST CELL**



**“DAWNS ON EUGLENOID”**



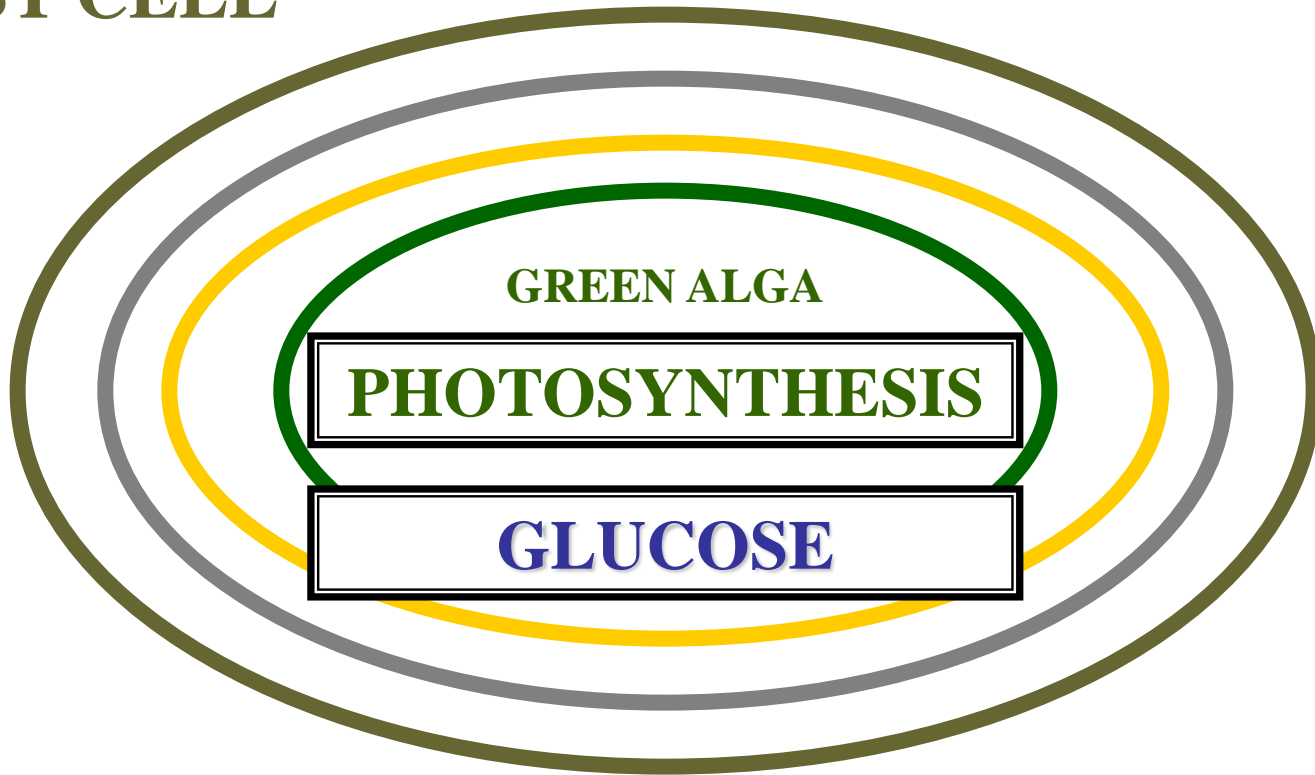
EUGLENOID  
HOST CELL



**“DAWNS ON EUGLENOID”**

EUGLENOID  
HOST CELL

GLUCOSE



GREEN ALGA

PHOTOSYNTHESIS

GLUCOSE

**“DAWNS ON EUGLENOID”**