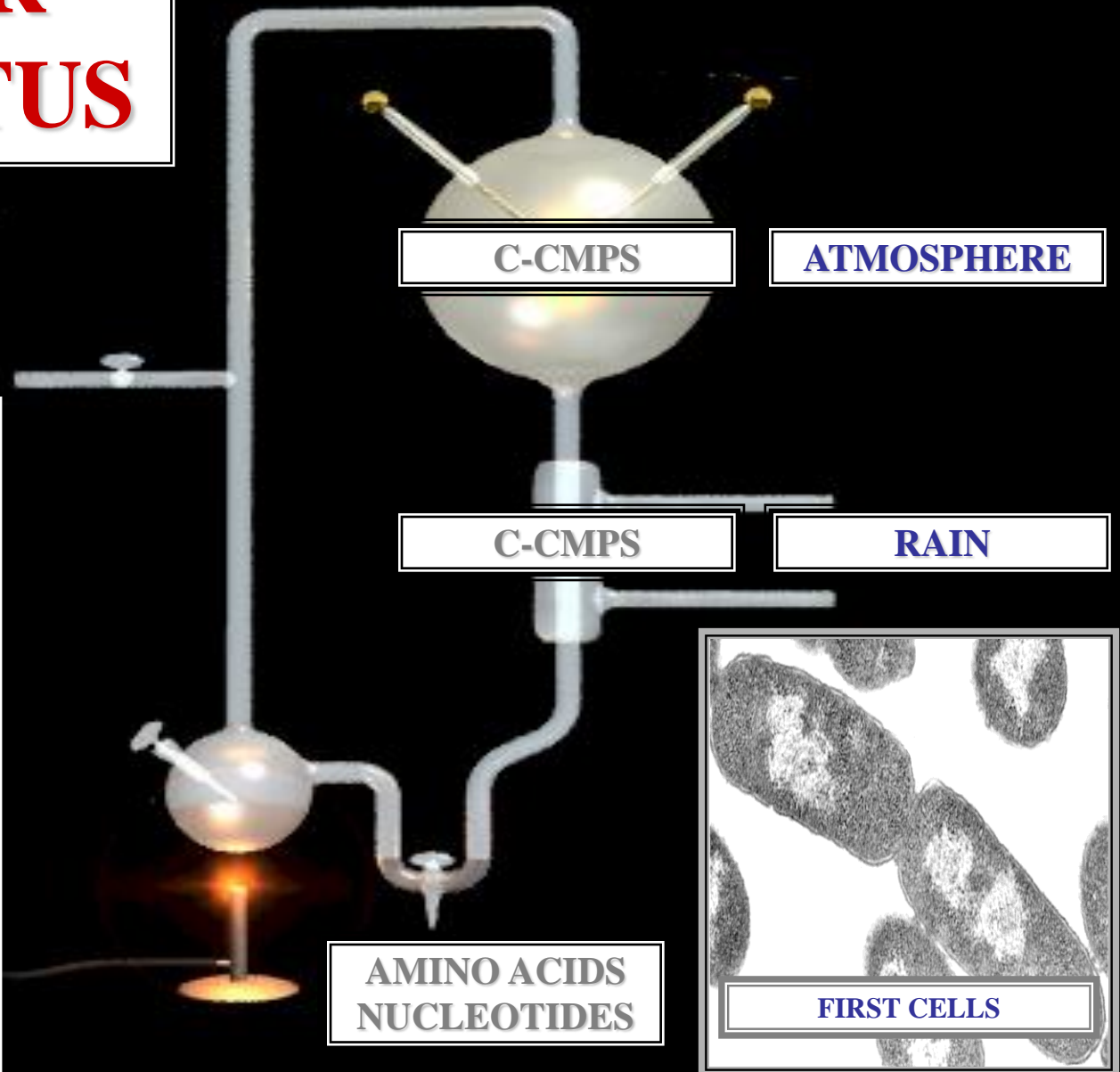
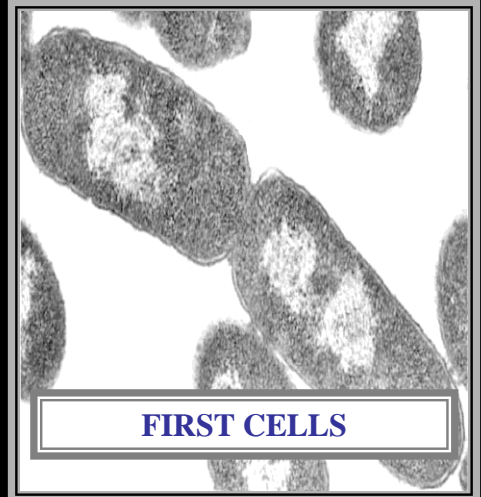


MILLER APPARATUS

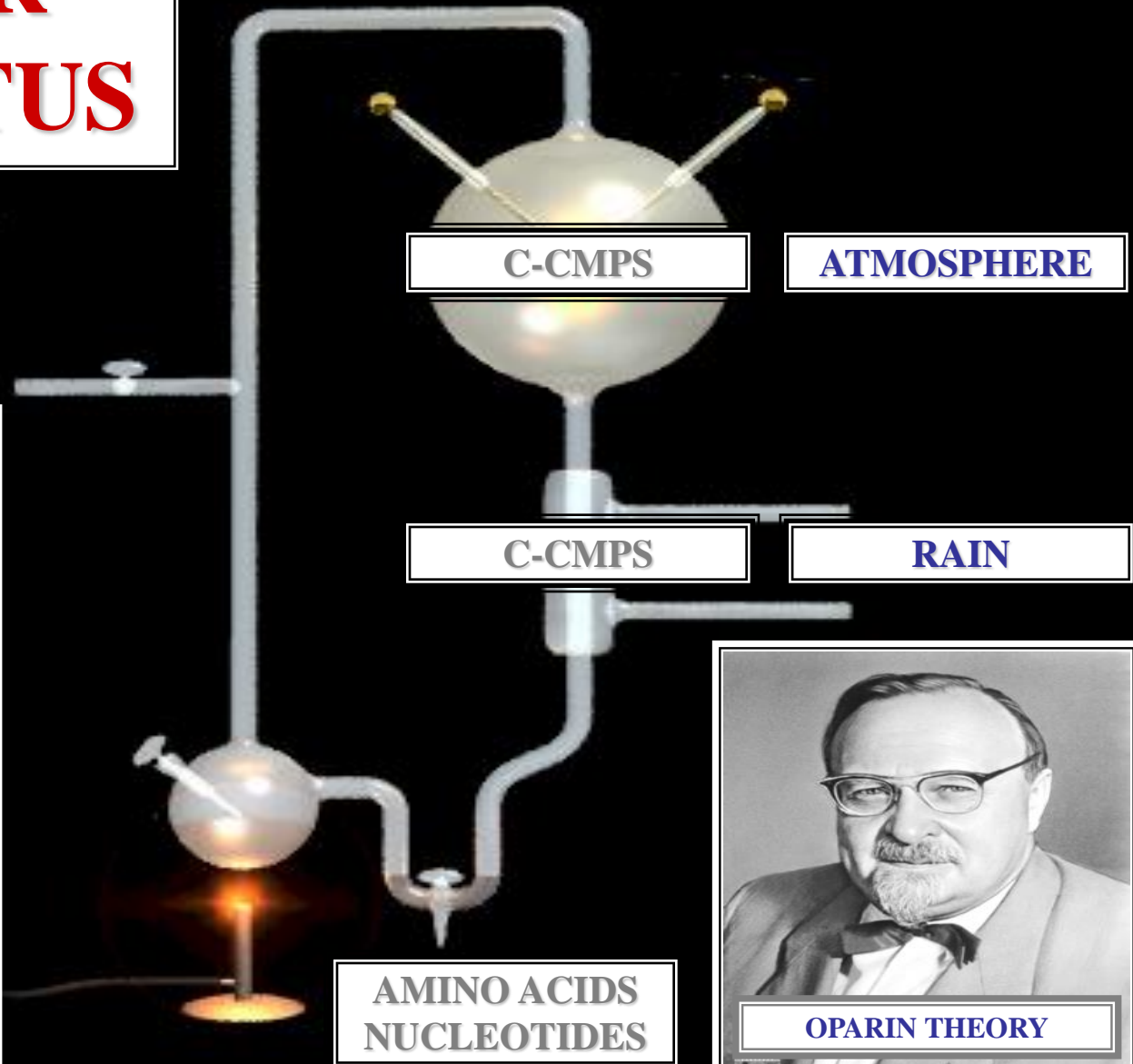
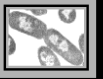


STANLEY MILLER

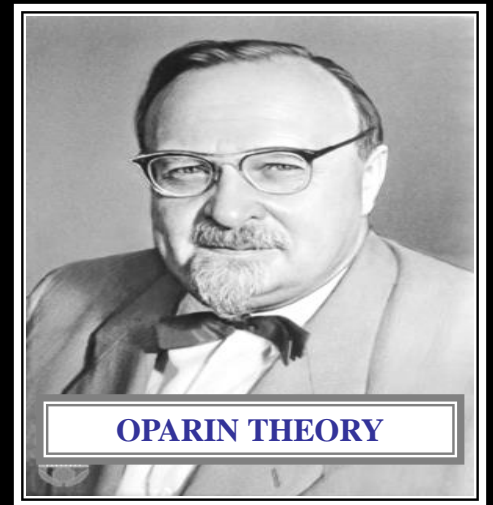


FIRST CELLS

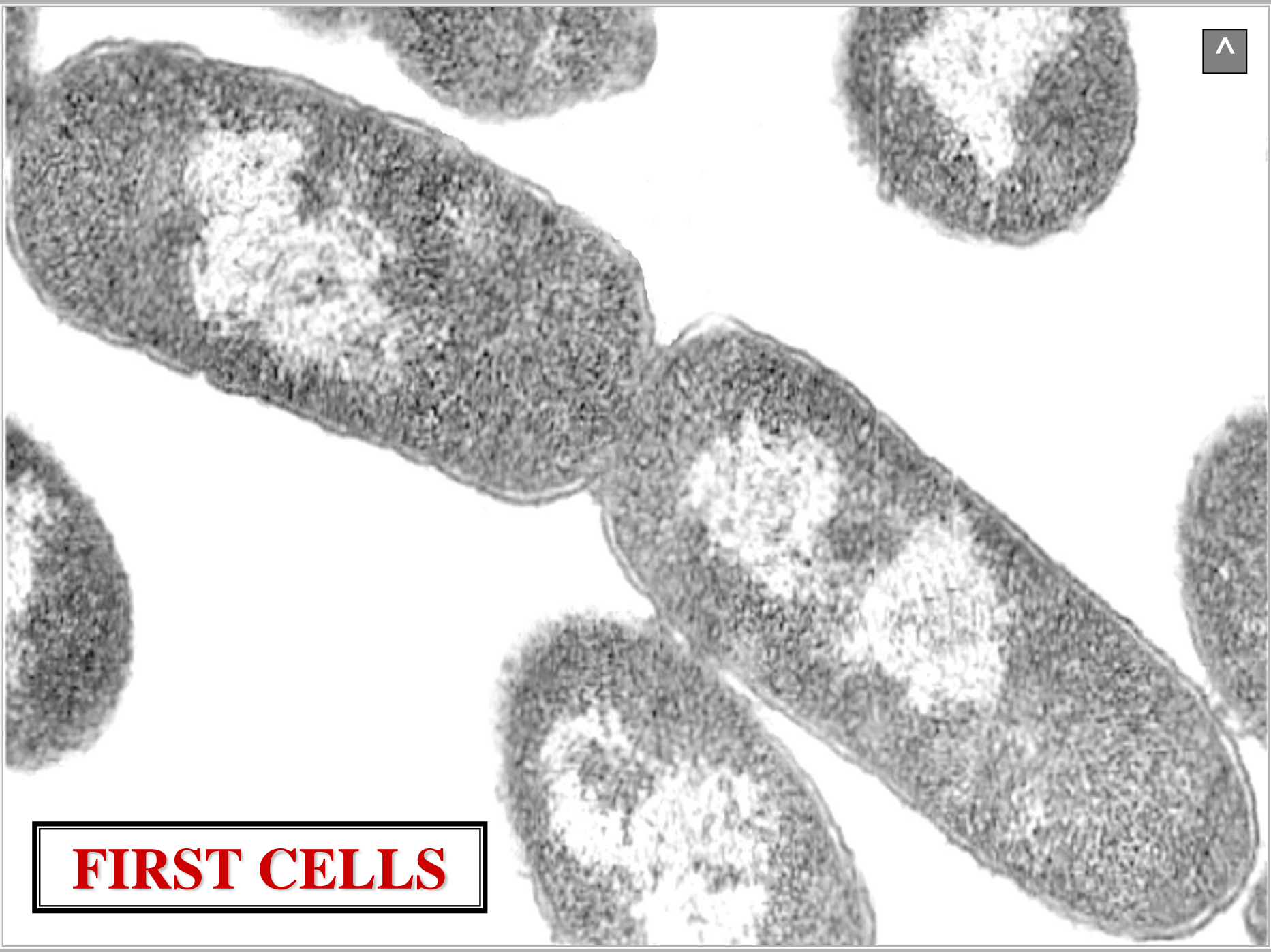
MILLER APPARATUS



STANLEY MILLER



OPARIN THEORY



FIRST CELLS

BIOLOGICAL EVOLUTION

BIOLOGICAL EVOLUTION



BIOLOGICAL EVOLUTION

BIO-DIVERSITY

VIA

MUTATION

NATURAL SELECTION

SPECIATION

BIOLOGICAL EVOLUTION

QUESTION

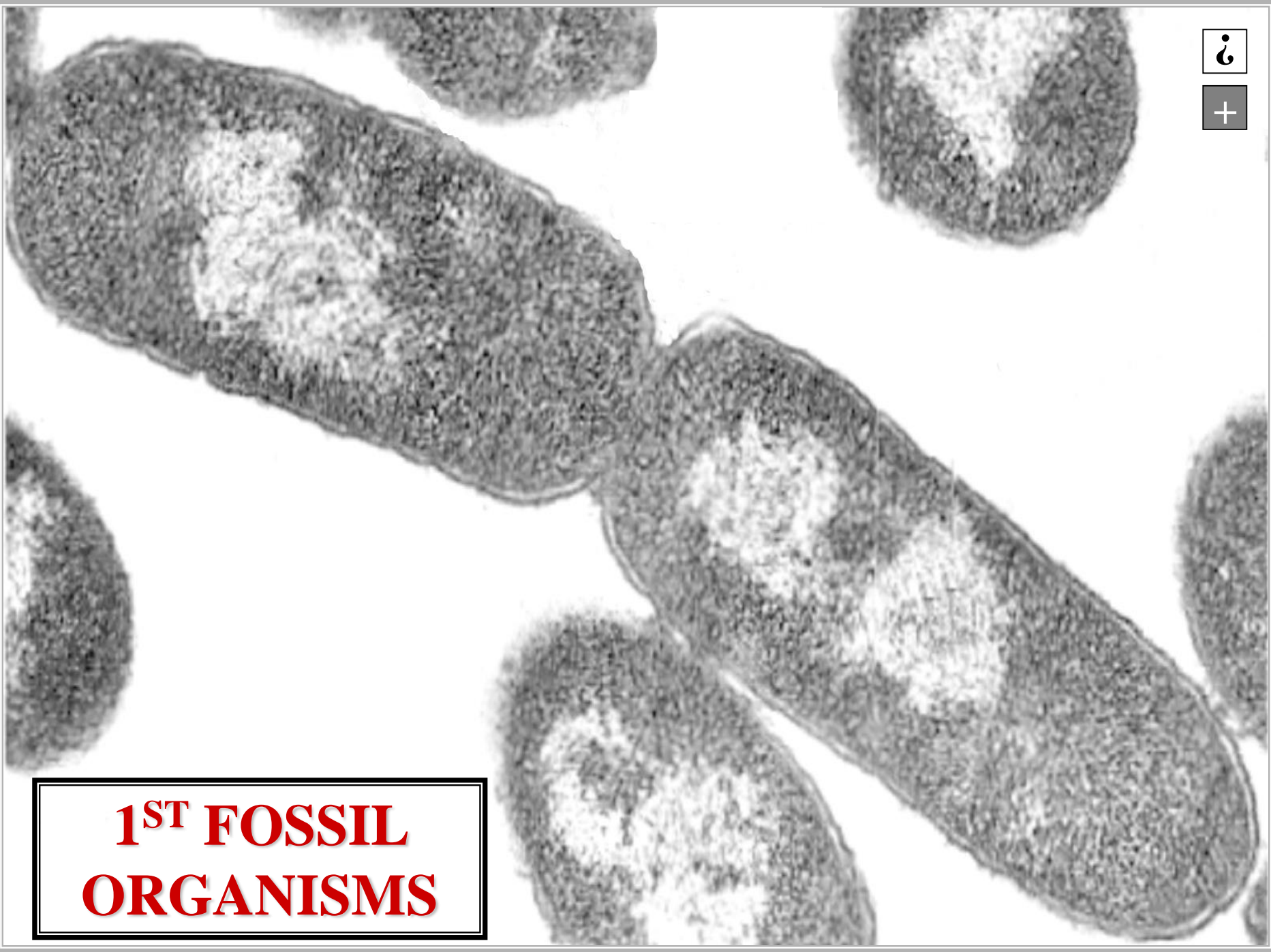
HOW OLD IS LIFE?

QUESTION

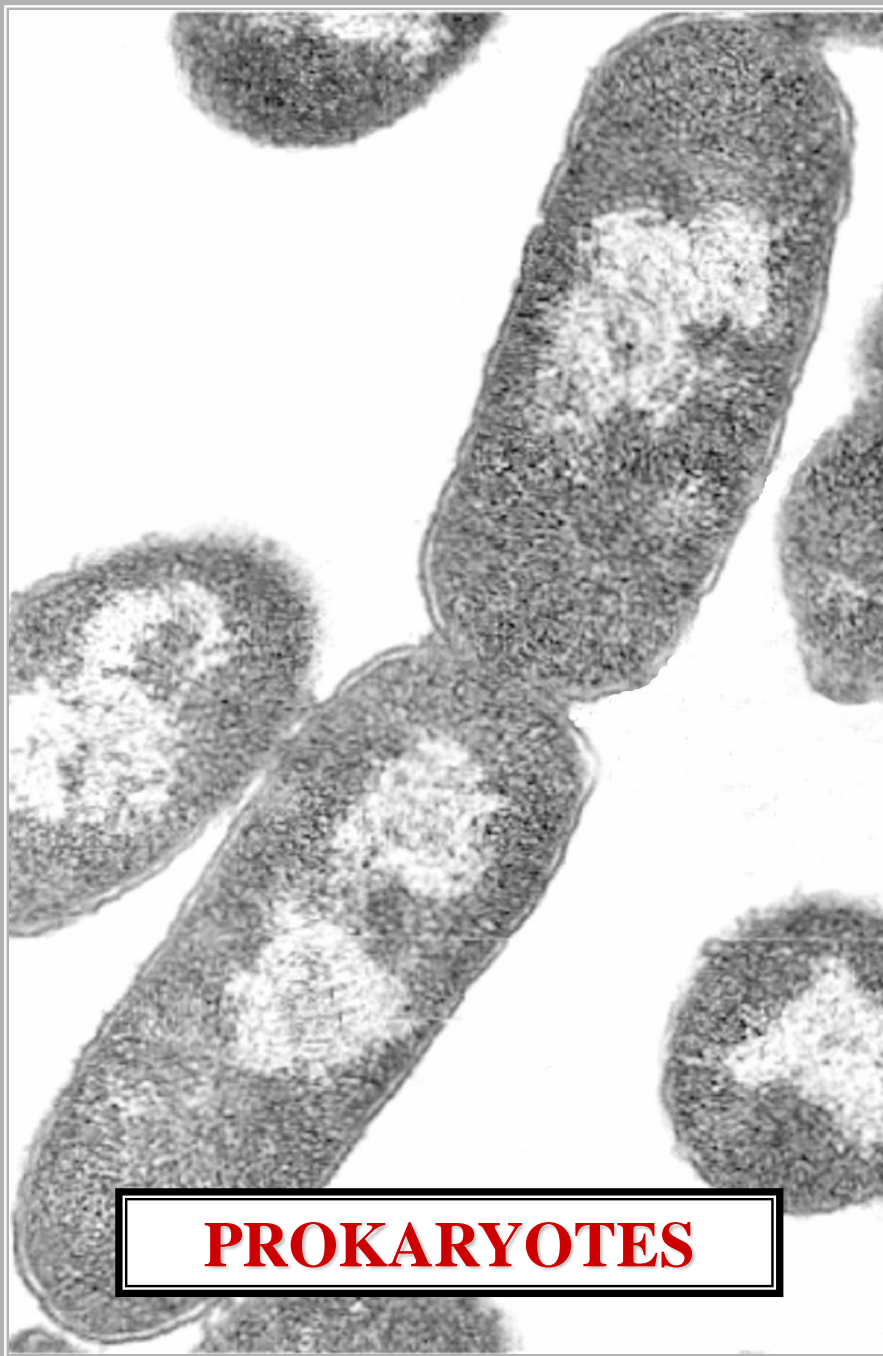


1

~3.5
BILLION YEARS



**1ST FOSSIL
ORGANISMS**

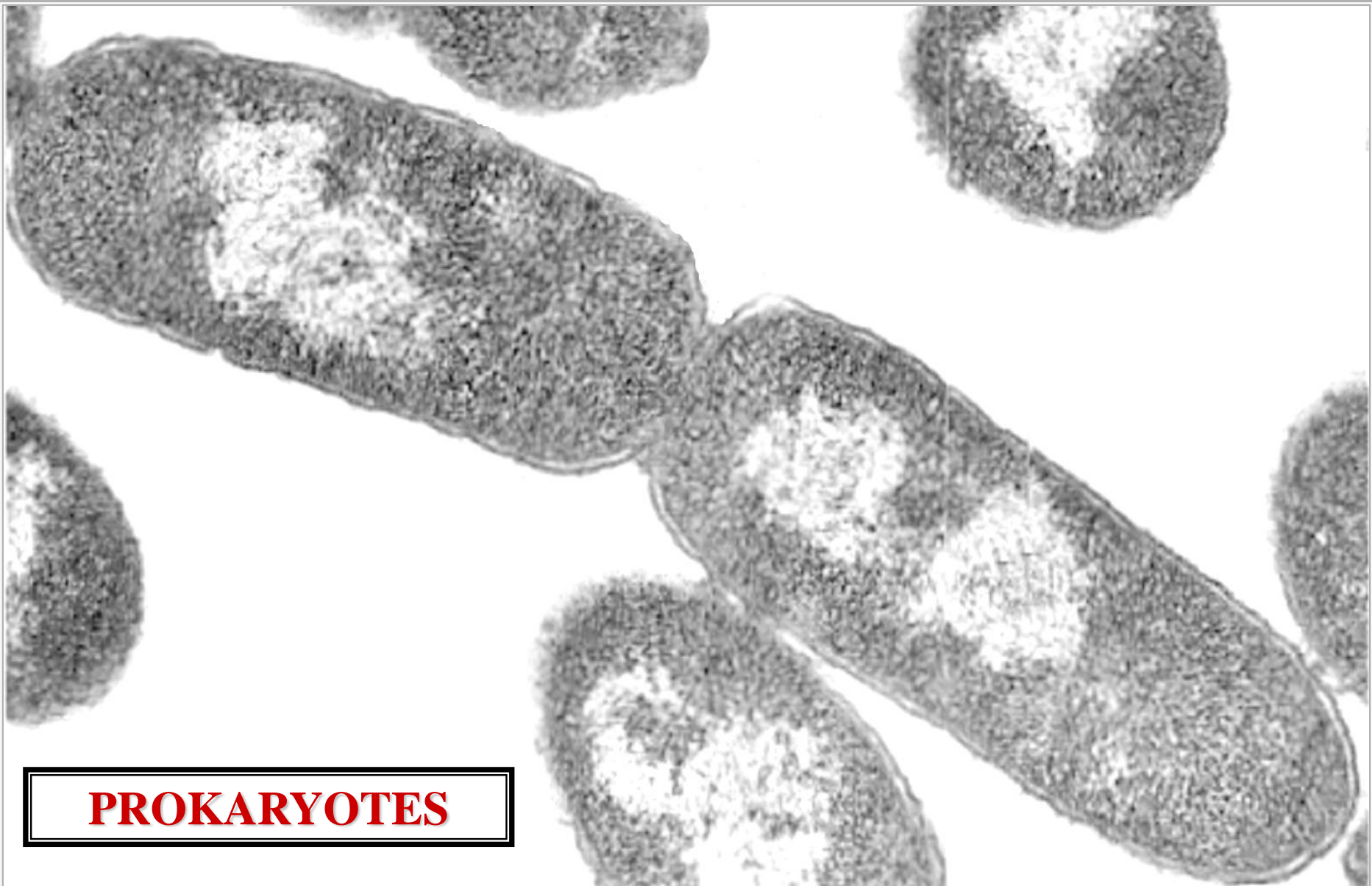


PROKARYOTES

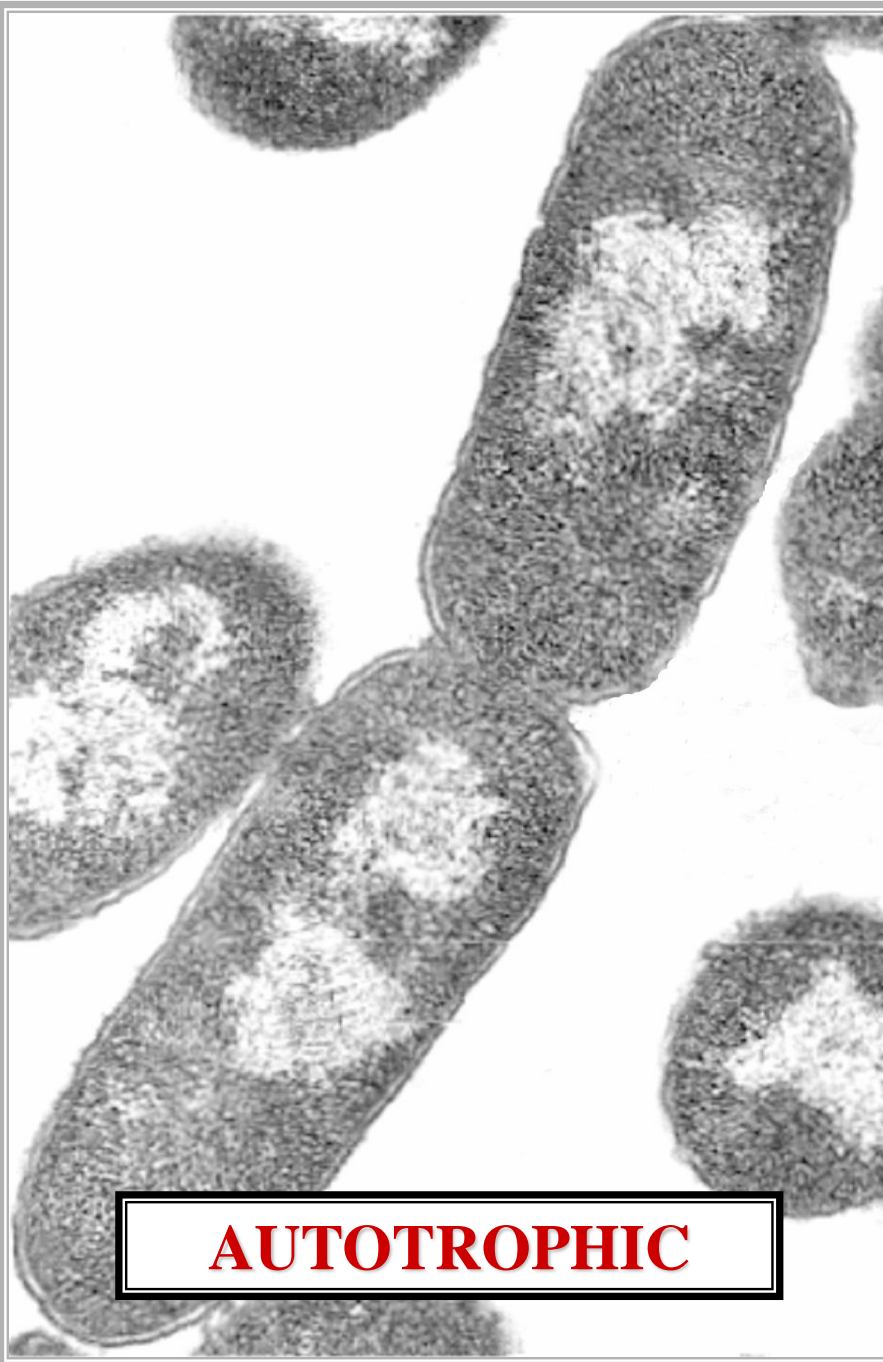


EUKARYOTES

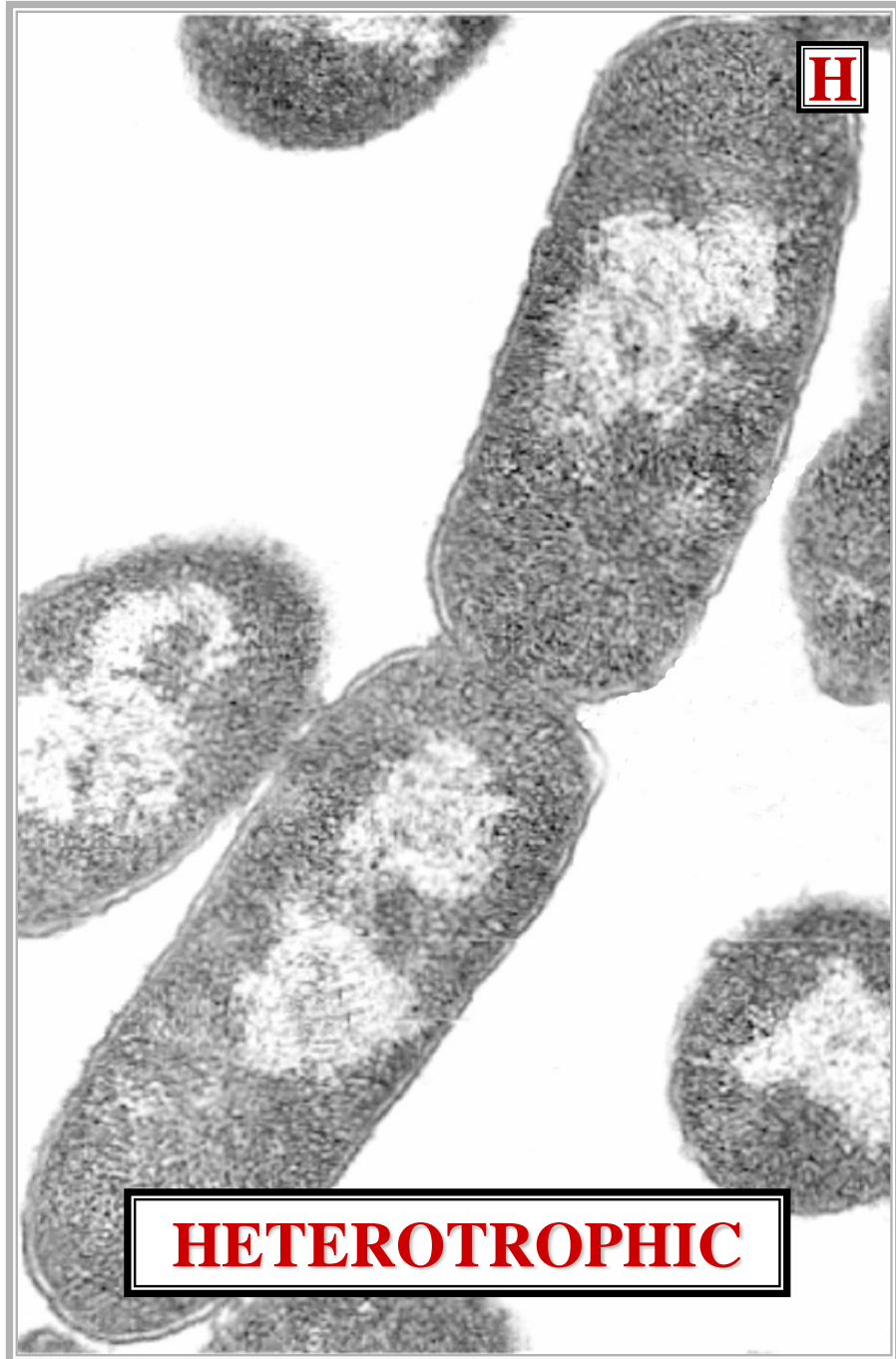
PROKARYOTES



PROKARYOTES

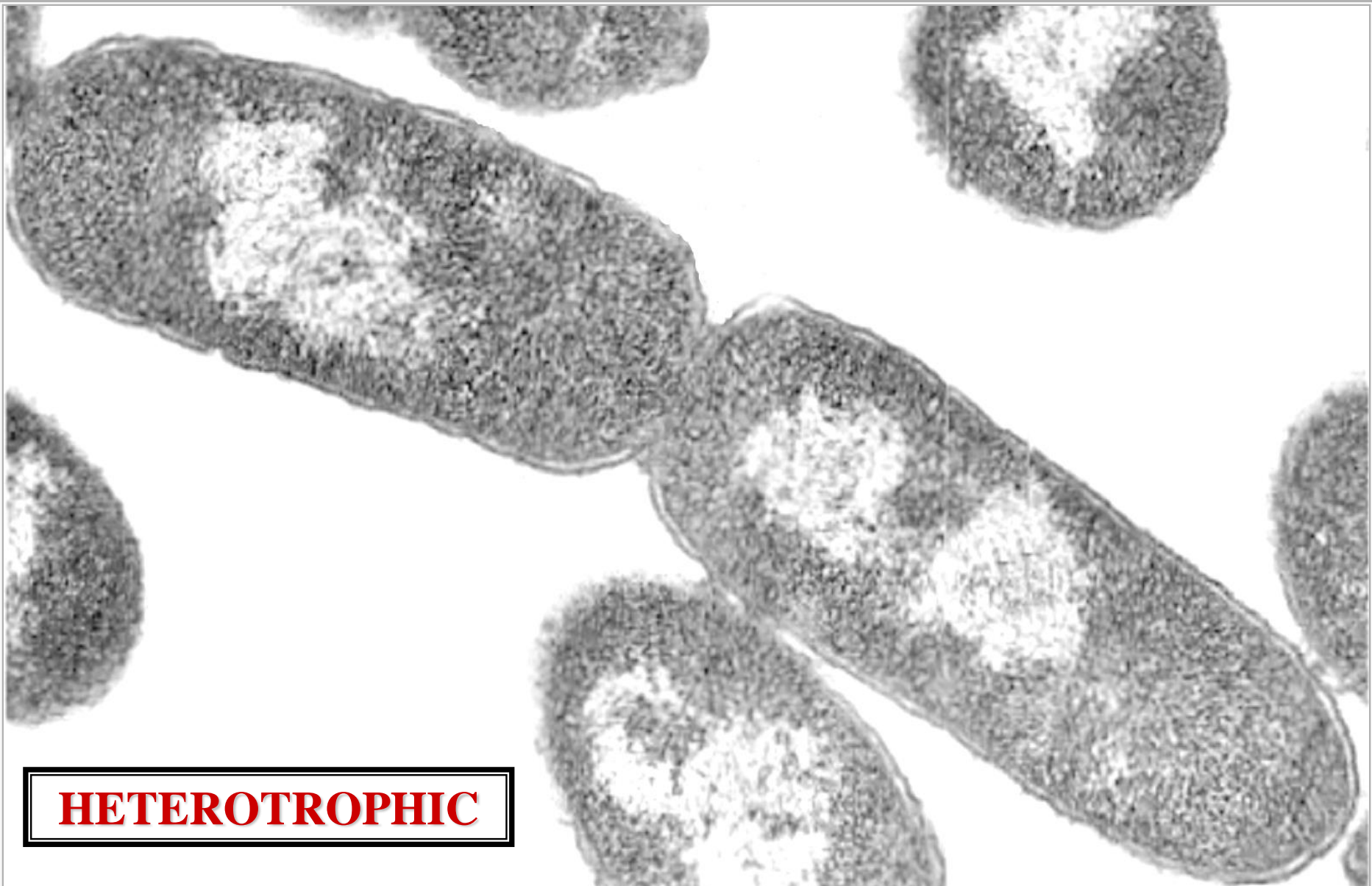


AUTOTROPHIC



HETEROTROPHIC

PROKARYOTES



HETEROTROPHIC

PRIMORDIAL EARTH OCEANS



“PRIMORDIAL SOUP”

C-CMP

C-CMP

C-CMP

C-CMP

C-CMP

C-CMP

C-CMP

C-CMP

C-CMP

C-CMP

C-CMP

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C-CMP

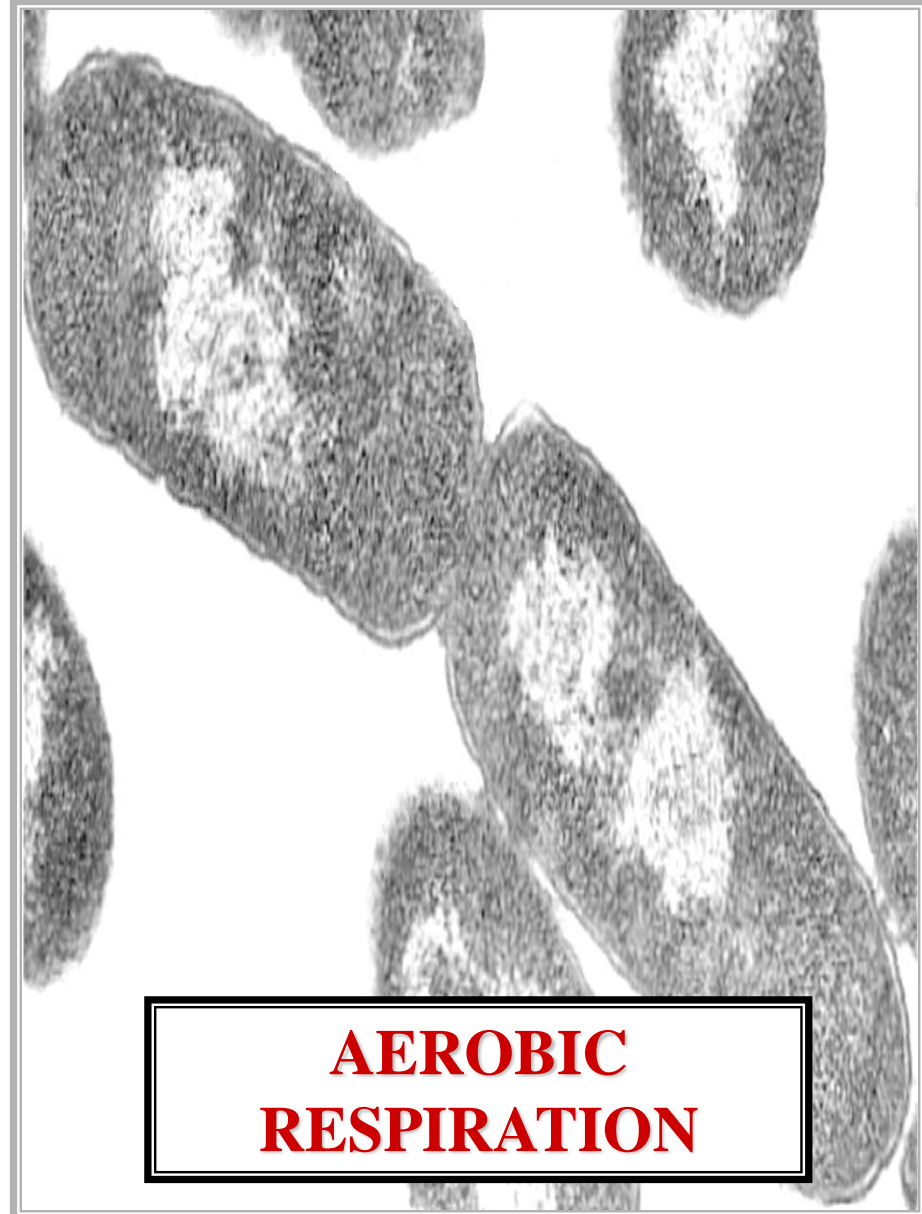
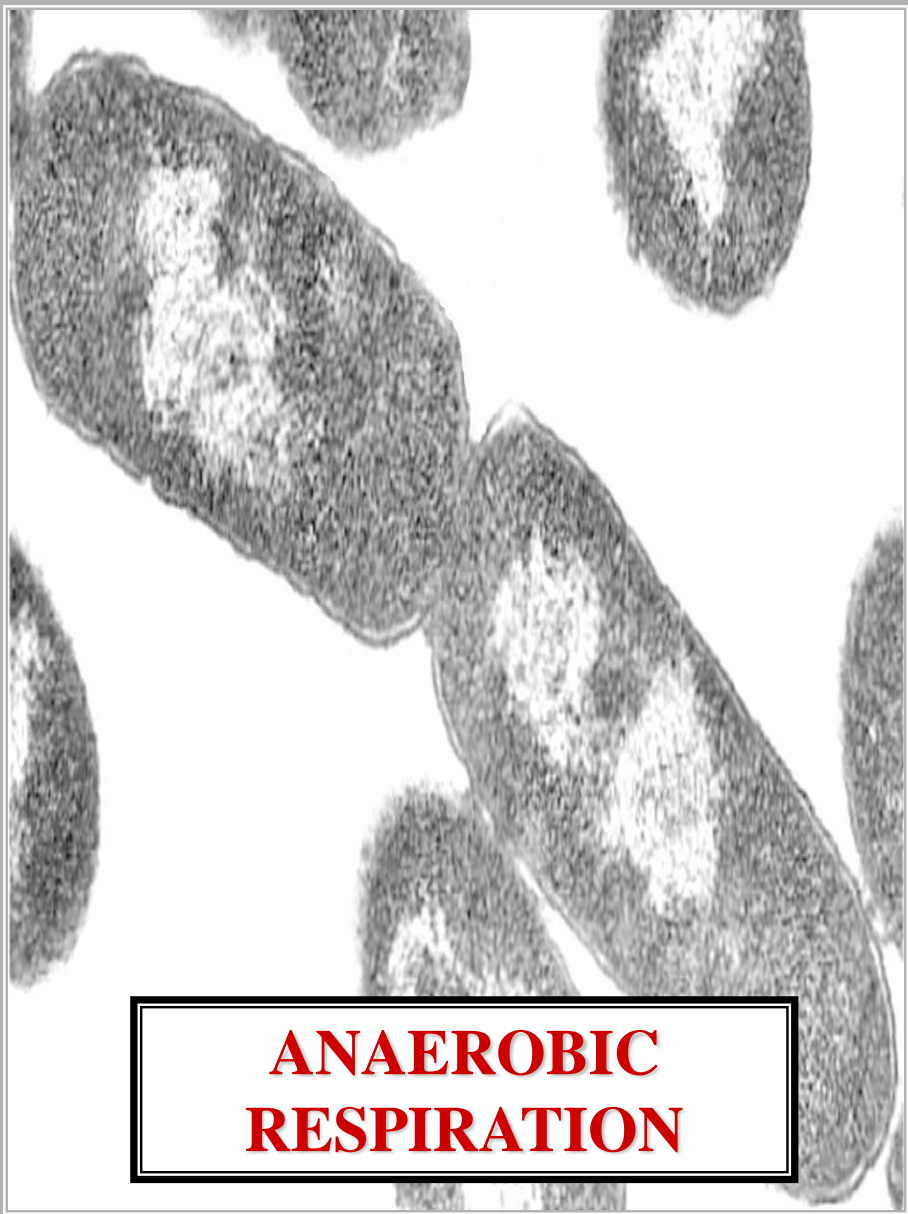
C-CMP

C-CMP

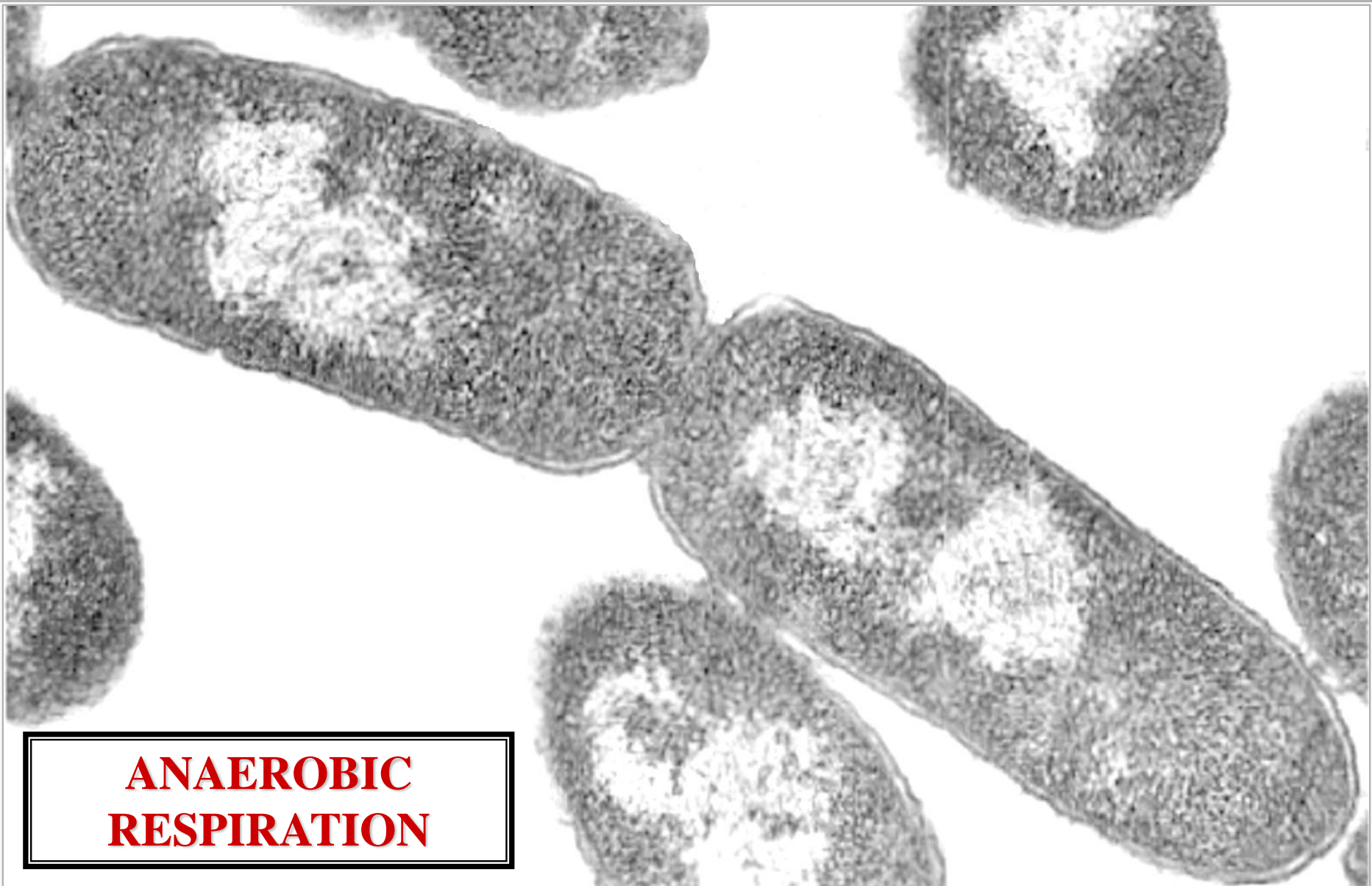
C-CMP

C-CMP

PROKARYOTES



PROKARYOTES



**ANAEROBIC
RESPIRATION**

?

ENVIRONMENT

PRIMORDIAL EARTH



**ANAEROBIC
ENVIRONMENT**

?

A

OXYGEN ABSENT

PRIMORDIAL EARTH

PROKARYOTES

A grayscale electron micrograph showing several rod-shaped prokaryotic cells. The cells have a thick, textured outer layer and a granular internal structure. The text is overlaid on this image.

**ANAEROBIC
RESPIRATION
ATP NET**

? ATP

**ANAEROBIC
RESPIRATION**

PROKARYOTES

A grayscale electron micrograph showing several rod-shaped prokaryotic cells. The cells have a textured, granular appearance, likely representing internal cellular structures. The text is overlaid on this image.

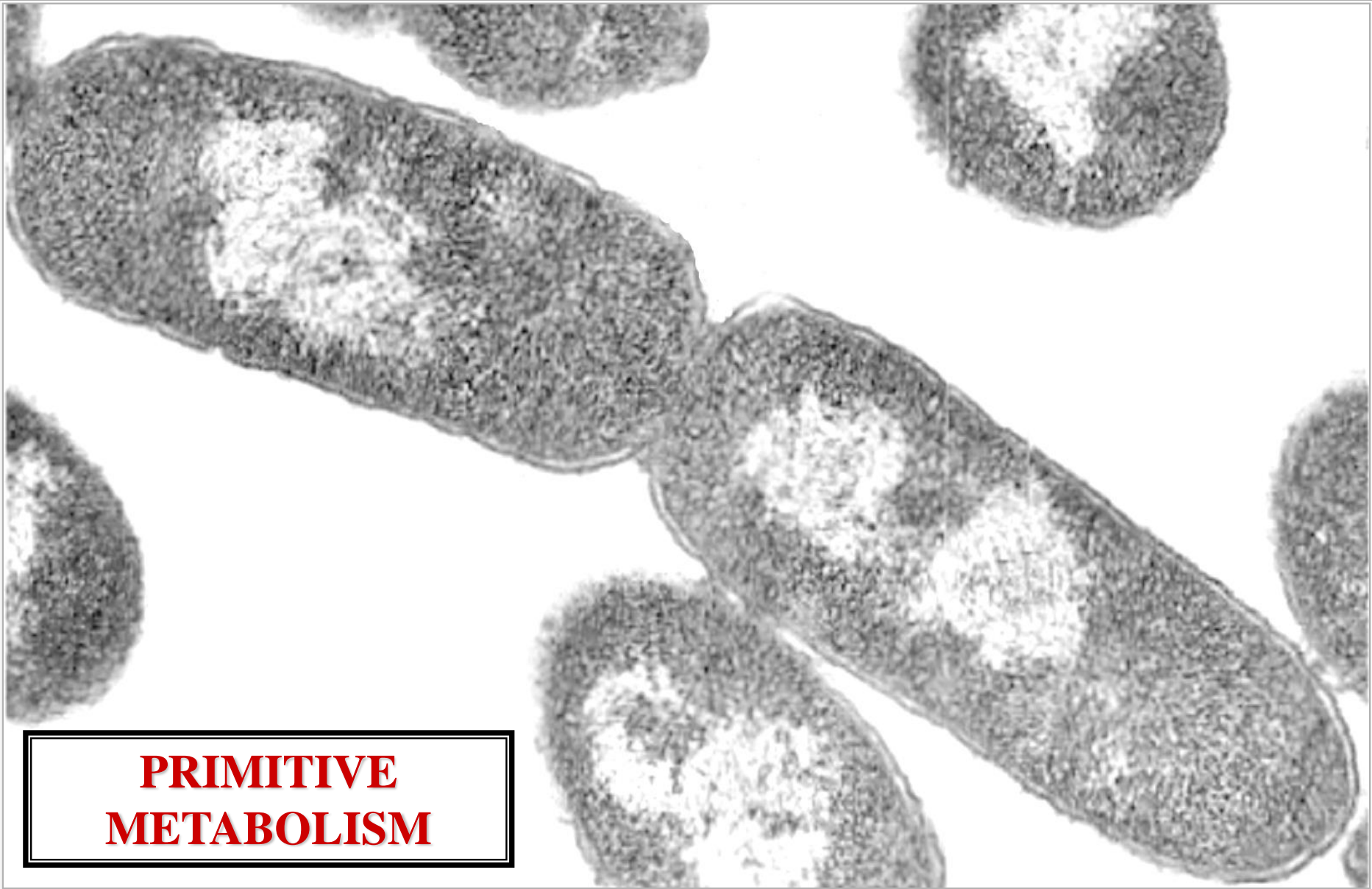
**ANAEROBIC
RESPIRATION
ATP NET**

2 ATP

**ANAEROBIC
RESPIRATION**

PROKARYOTES

S



**PRIMITIVE
METABOLISM**



SUPPORTING EVIDENCE



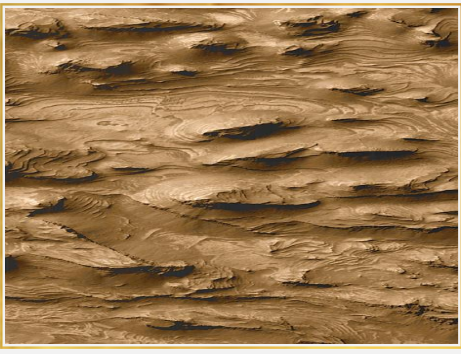
SEDIMENTARY ROCK ~3.5 BYA

SCANNING ELECTRON MICROSCOPE



SEDIMENTARY ROCK ~3.5 BYA

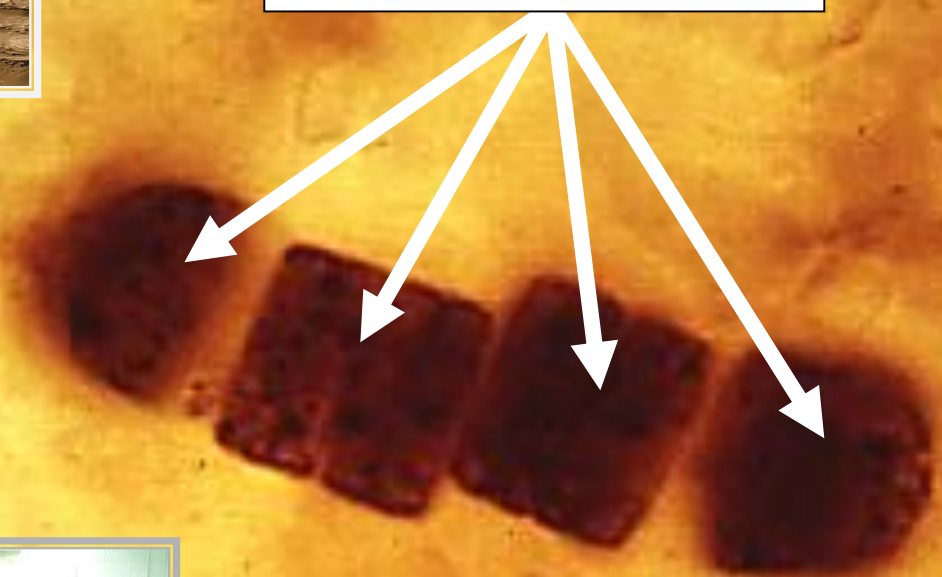
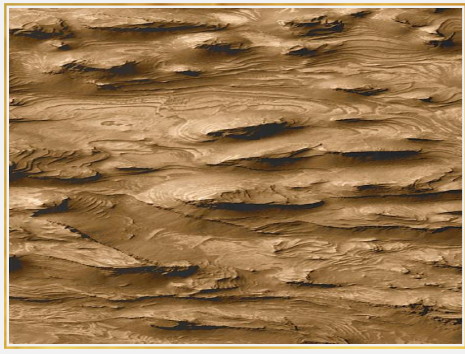
H



SEDIMENTARY ROCK ~3.5 BYA

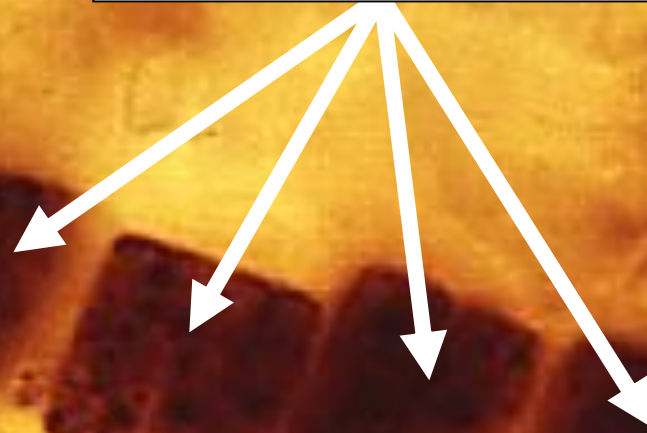
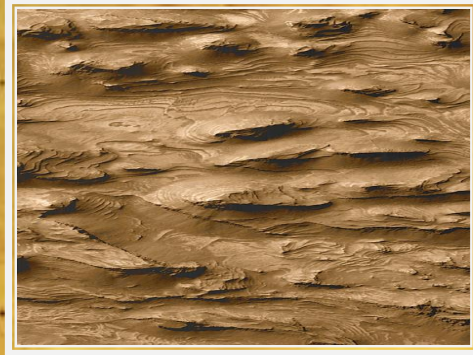
HIGH ORGANIC
CONTENT

F



SEDIMENTARY ROCK ~3.5 BYA

**HIGH ORGANIC
CONTENT**



**FOSSIL
PROKARYOTES**



~3.4

BILLION YEARS

PRIMORDIAL EARTH OCEANS



O

C-CMP

C-CMP

C-CMP

C-CMP

C-CMP

C-CMP

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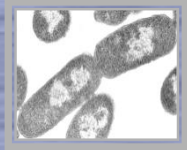
C-CMP

PRIMORDIAL EARTH OCEANS

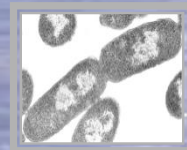


ORGANIC COMPOUNDS BECOME SCARCE

C-CMP



C-CMP

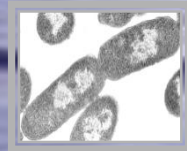


C-CMP

C-CMP

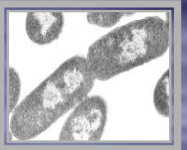


C-CMP

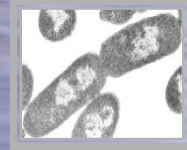


C-CMP

C-CMP

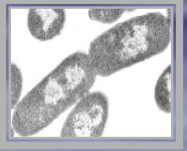


C-CMP

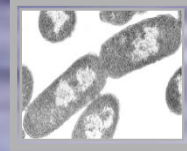


C-CMP

C-CMP

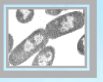


C-CMP

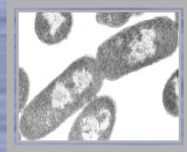
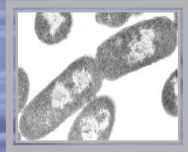


C-CMP

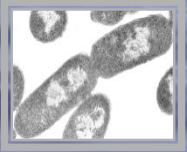
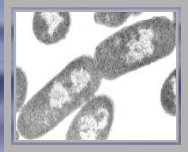
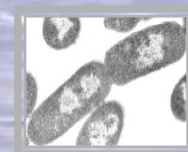
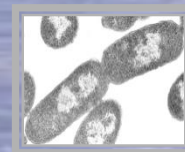
PRIMORDIAL EARTH OCEANS



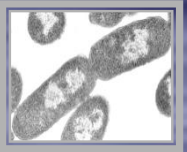
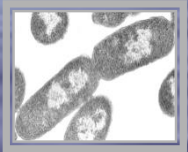
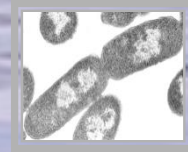
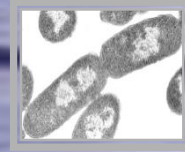
ORGANIC COMPOUNDS BECOME SCARCE



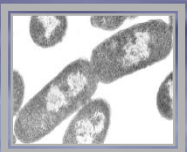
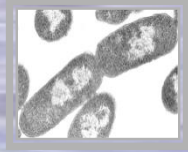
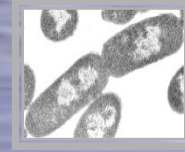
C-CMP



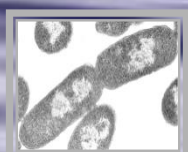
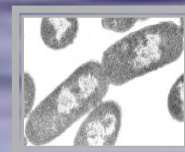
C-CMP



C-CMP



C-CMP



PROKARYOTES



ORGANIC COMPOUNDS
BECOME SCARCE
“FOOD SHORTAGE”

HETEROTROPHIC

HETEROTROPHIC

PROKARYOTES

ORGANIC COMPOUNDS
BECOME SCARCE
“FOOD SHORTAGE”



HETEROTROPHIC

A black and white micrograph showing several rod-shaped prokaryotic cells. The cells are arranged in a somewhat diagonal line, with some overlapping. They have a textured, granular appearance, suggesting internal structures like ribosomes or a nucleoid region. The background is light and slightly out of focus.



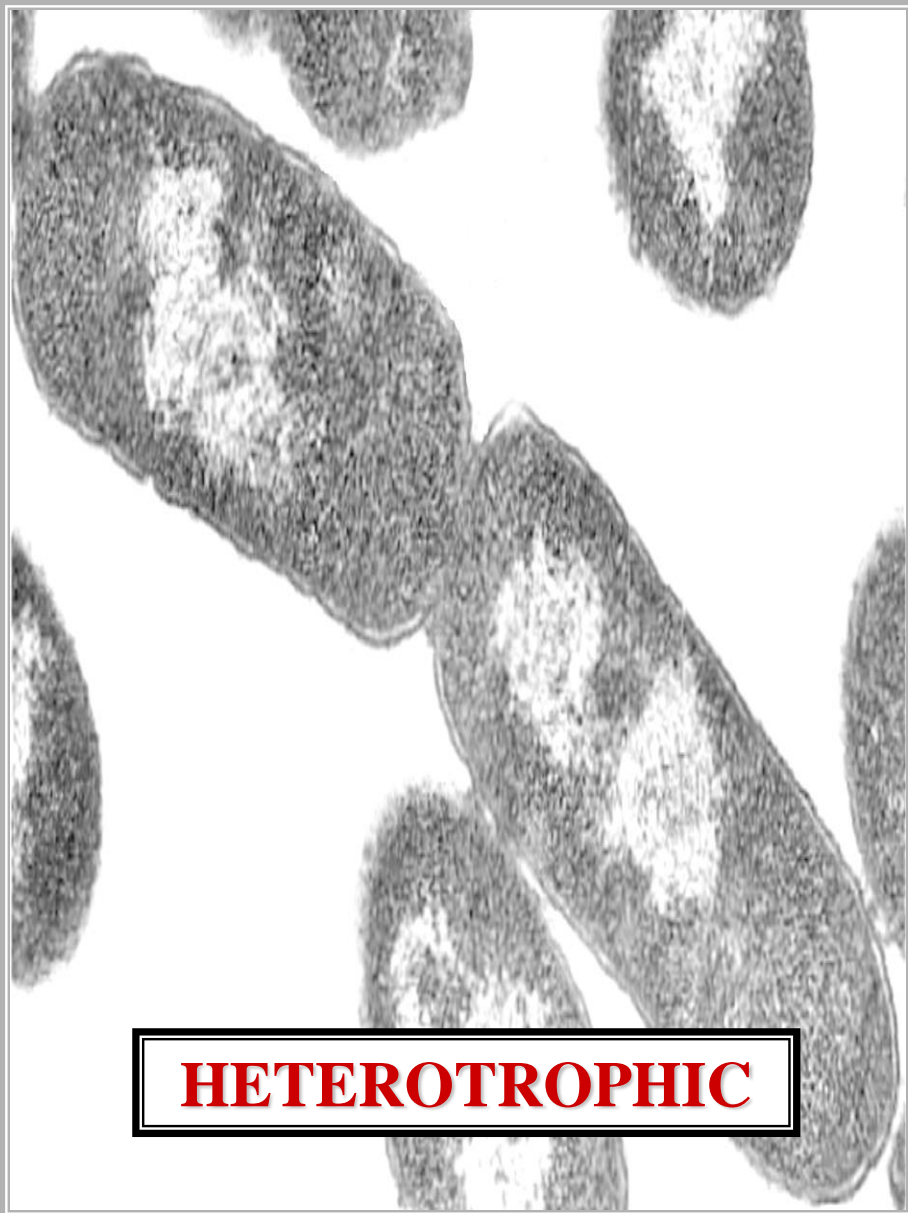
AUTOTROPHIC

A color micrograph showing numerous rod-shaped prokaryotic cells, likely cyanobacteria, arranged in several parallel chains. The cells are greenish-yellow, indicating the presence of photosynthetic pigments. The chains are somewhat irregular and vary in length. The background is a light, yellowish-green color.

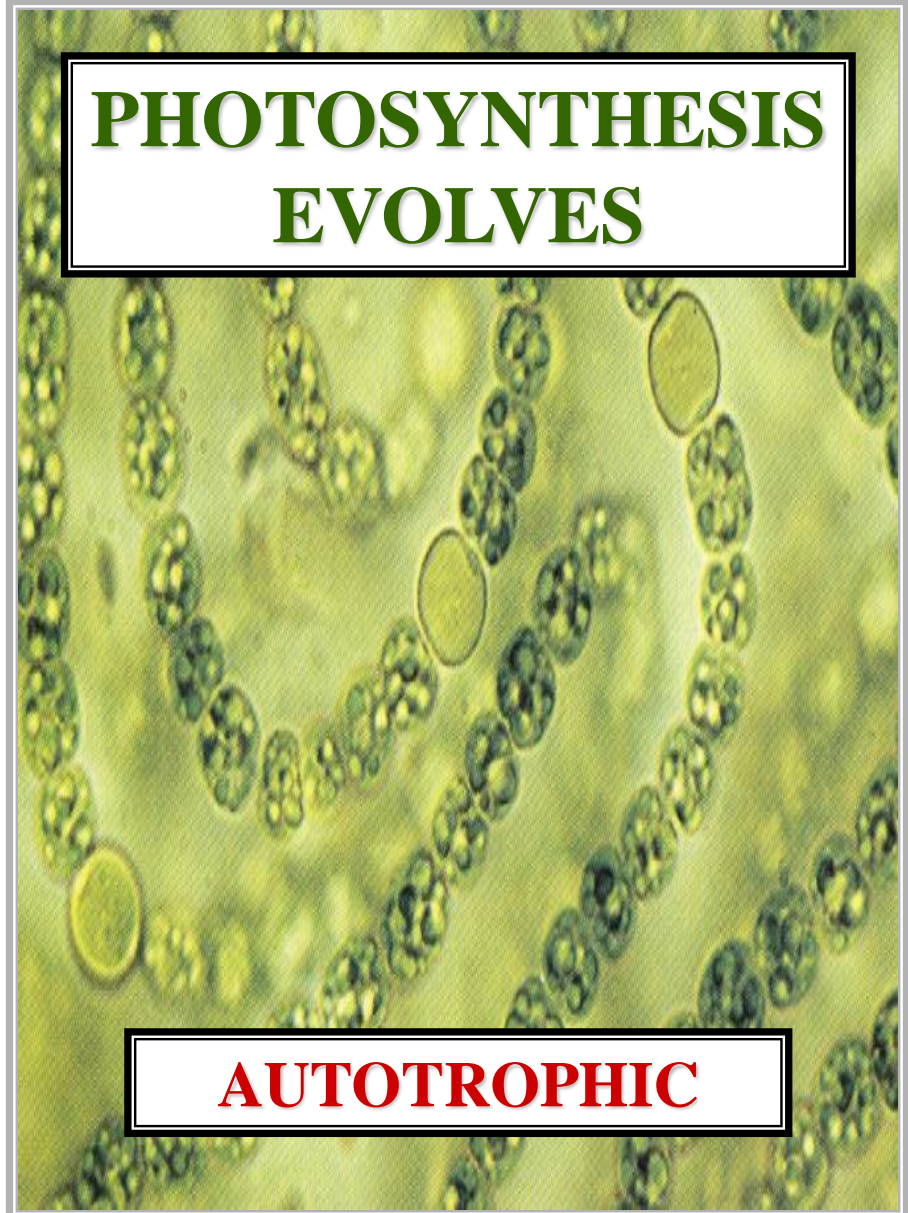
PROKARYOTES

?

P



HETEROTROPHIC

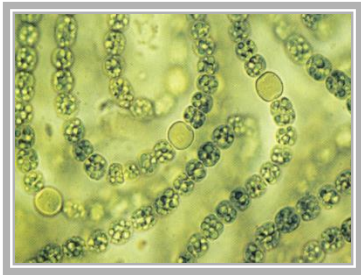


**PHOTOSYNTHESIS
EVOLVES**

AUTOTROPHIC

PHOTOSYNTHESIS

L



WATER

CO₂

LIGHT ENERGY

PHOTO

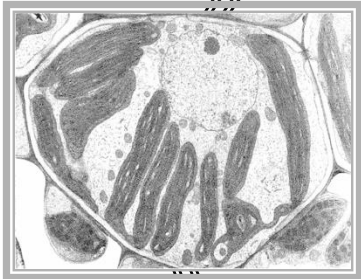
ATMOSPHERE

E-

PHOTOLYSIS

CHEMICAL ENERGY

?



?

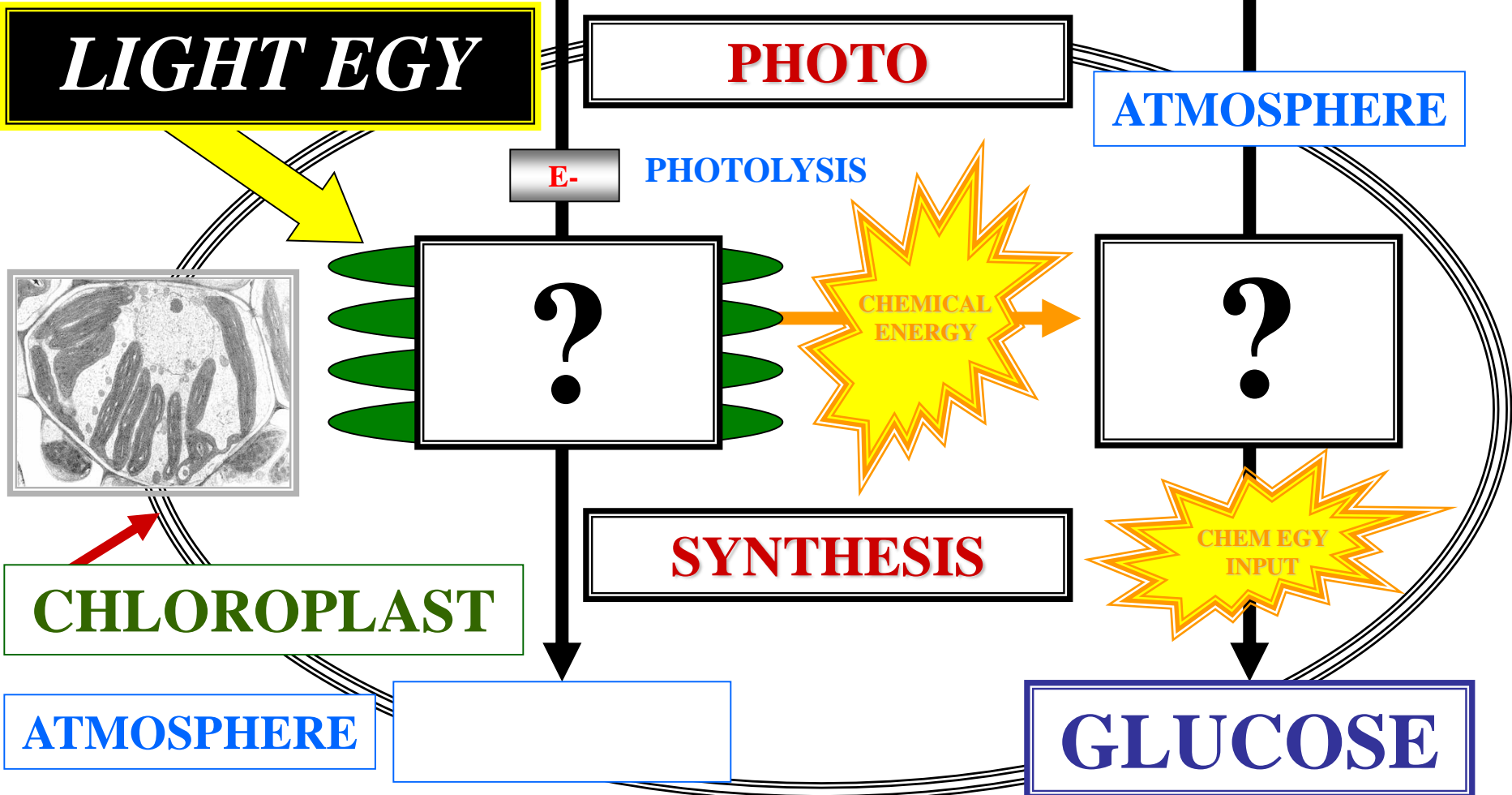
SYNTHESIS

CHEMICAL ENERGY INPUT

CHLOROPLAST

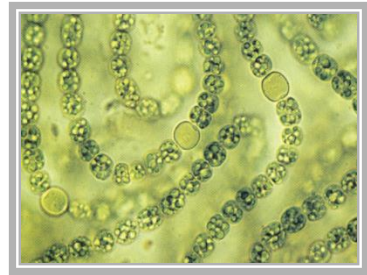
ATMOSPHERE

GLUCOSE



PHOTOSYNTHESIS

D



WATER

CO₂

LIGHT ENERGY

PHOTO

ATMOSPHERE

E-

PHOTOLYSIS

LT RXT

THYLAKOID

CHEMICAL ENERGY

?

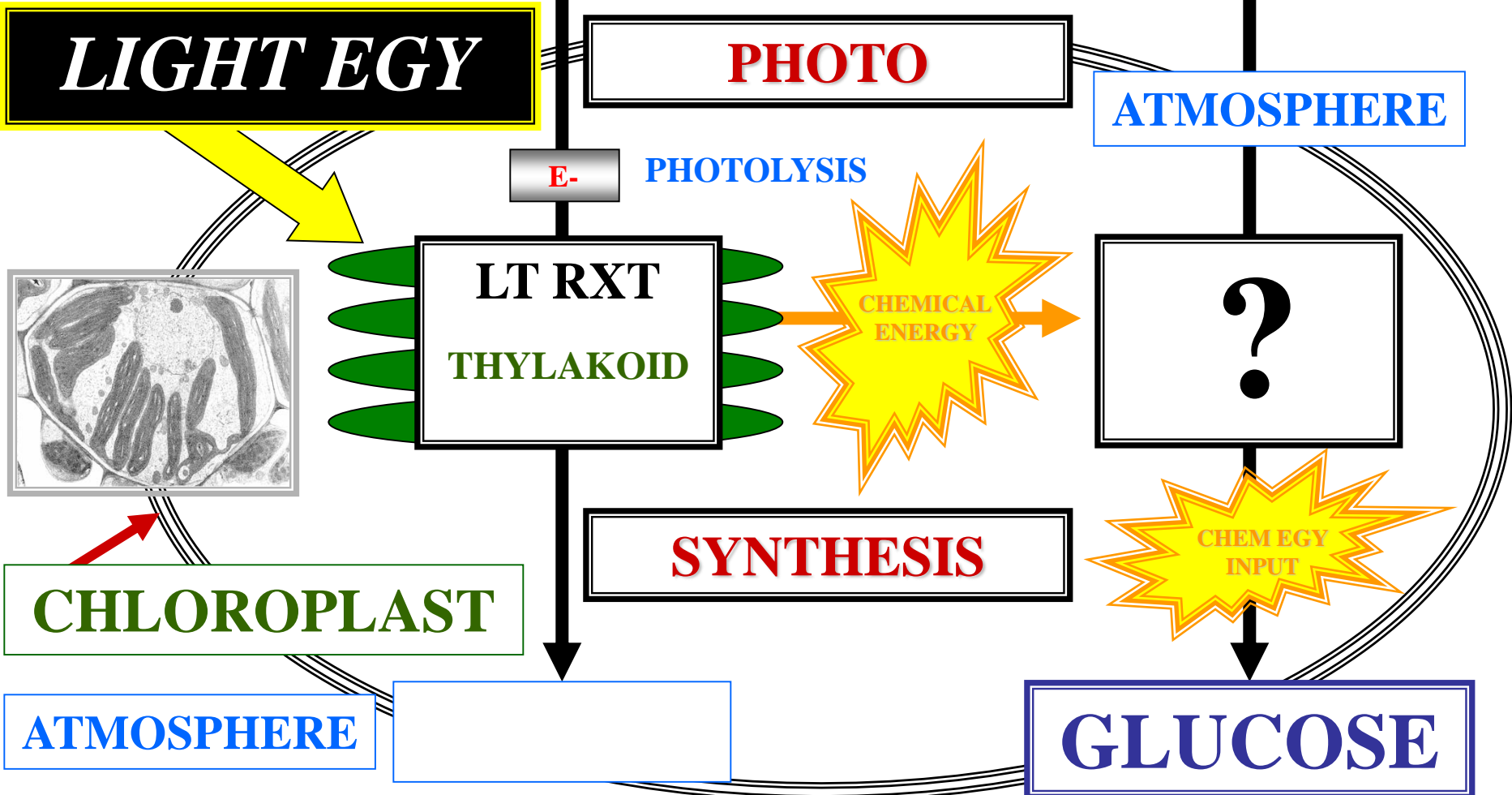
CHEMICAL ENERGY INPUT

SYNTHESIS

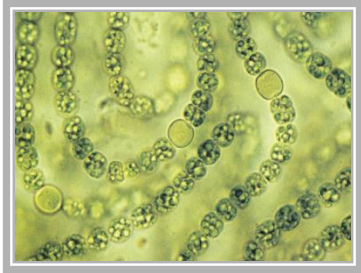
CHLOROPLAST

ATMOSPHERE

GLUCOSE



PHOTOSYNTHESIS



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WATER

CO₂

LIGHT ENERGY

PHOTO

ATMOSPHERE

E-

PHOTOLYSIS

LT RXT

THYLAKOID

CHEMICAL ENERGY

DK RXT

STROMA

SYNTHESIS

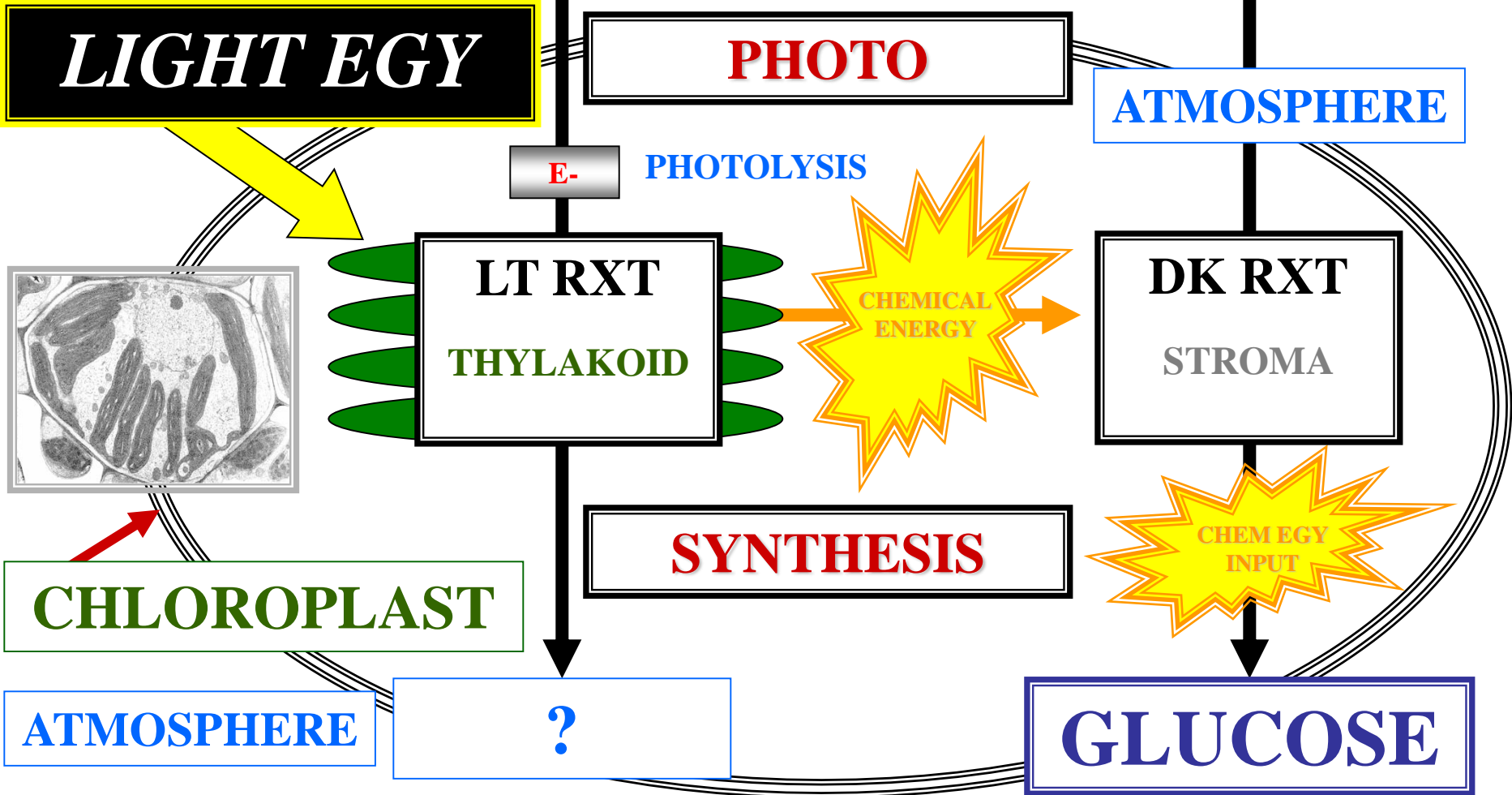
CHEMICAL ENERGY INPUT

CHLOROPLAST

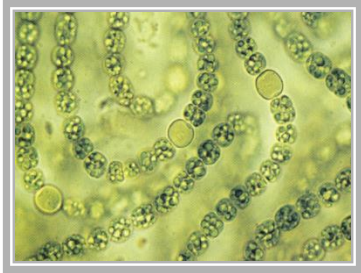
ATMOSPHERE

?

GLUCOSE



PHOTOSYNTHESIS



WATER

CO₂

LIGHT ENERGY

PHOTO

ATMOSPHERE

E-

PHOTOLYSIS

LT RXT

THYLAKOID

CHEMICAL ENERGY

DK RXT

STROMA

SYNTHESIS

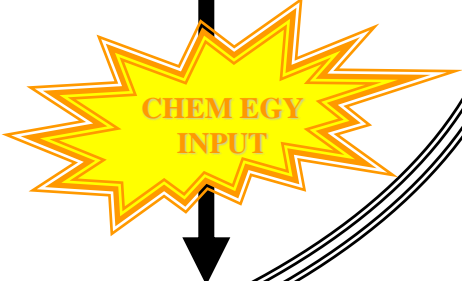
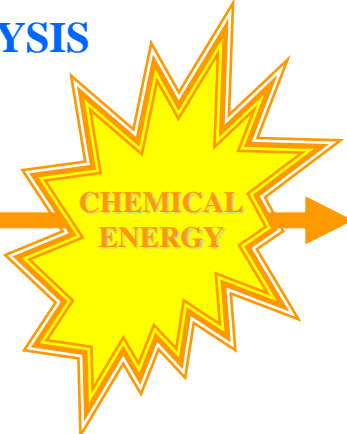
CHEMICAL ENERGY INPUT

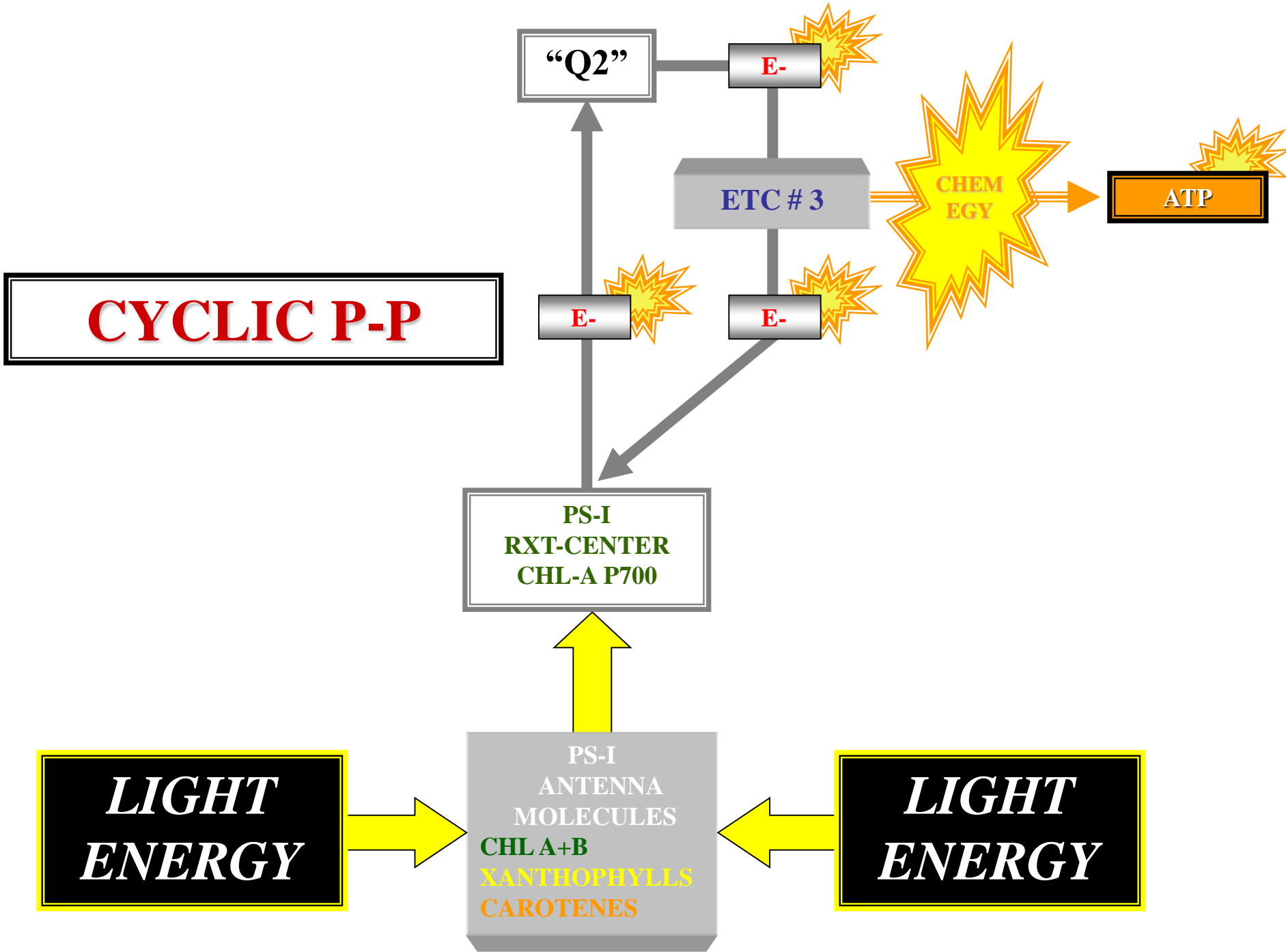
CHLOROPLAST

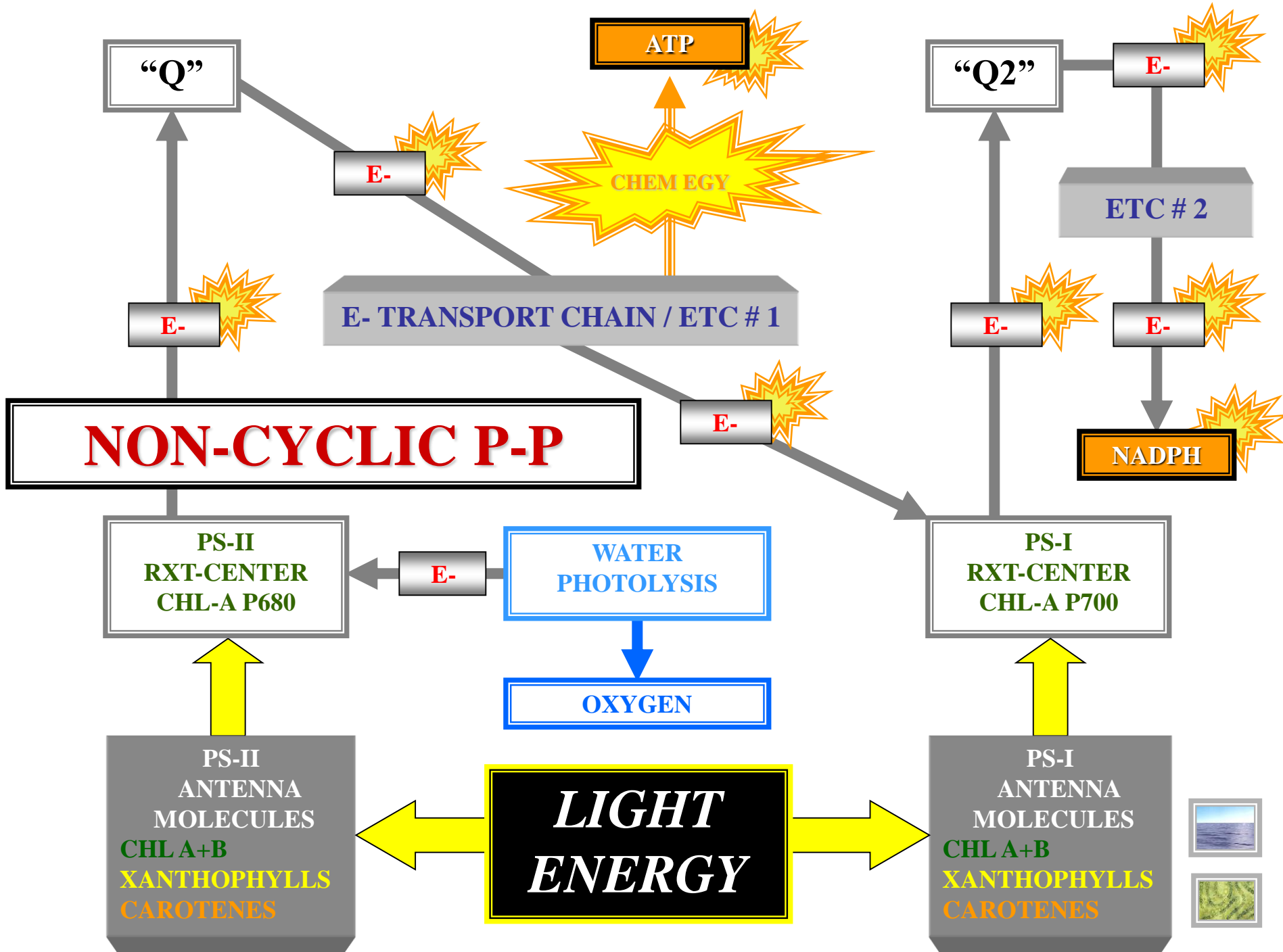
ATMOSPHERE

OXYGEN

GLUCOSE

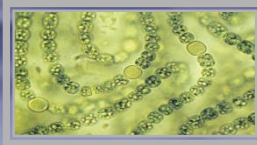
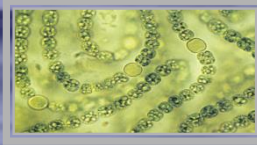
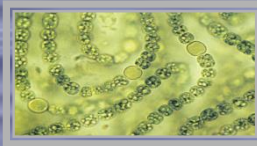
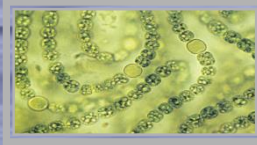






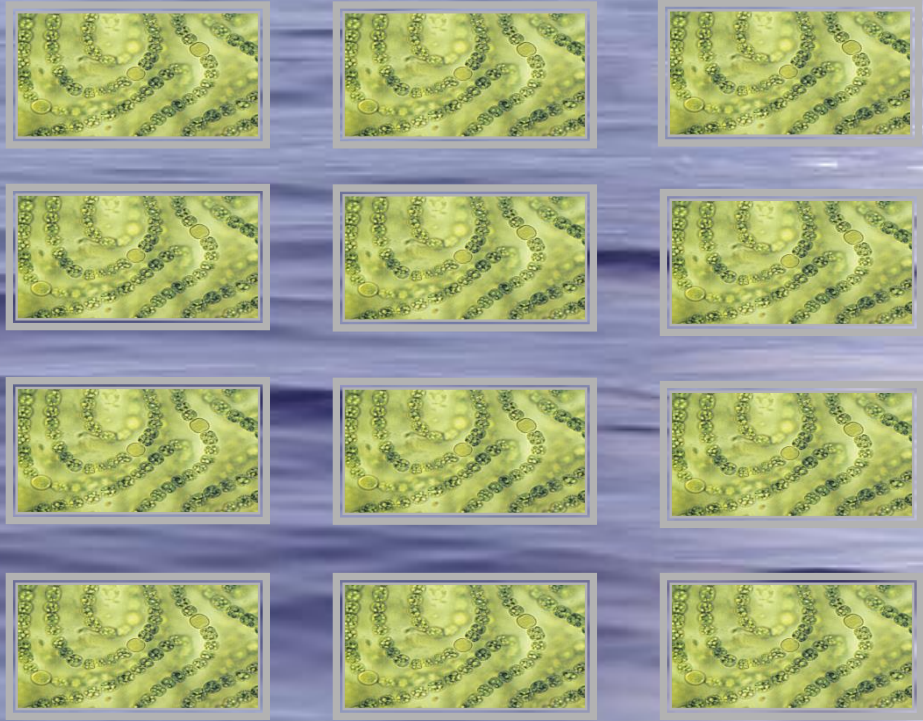
PRIMORDIAL EARTH OCEANS

PHOTOSYNTHESIS: PHOTOLYSIS



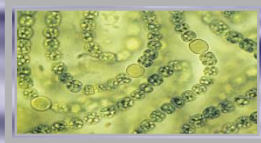
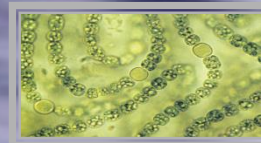
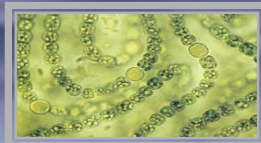
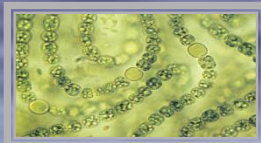
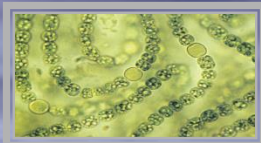
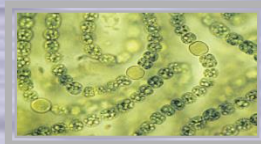
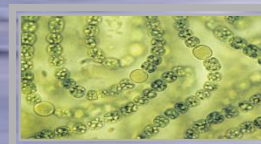
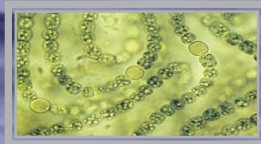
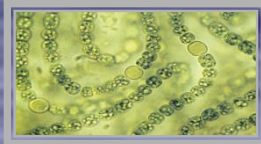
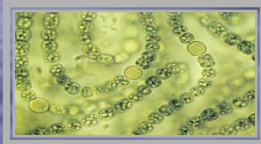
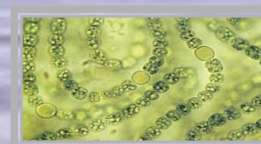
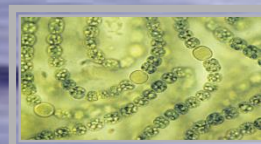
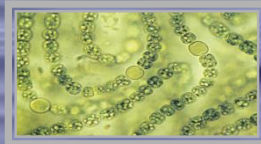
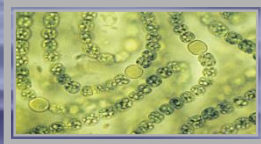
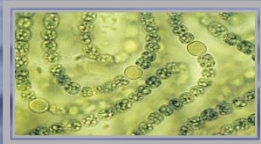
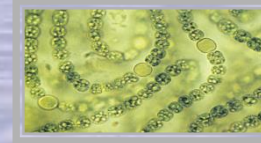
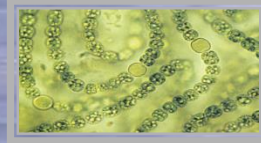
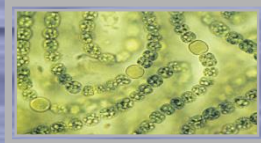
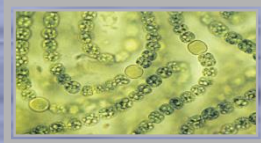
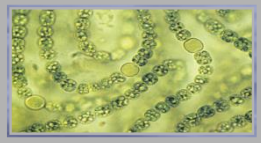
PRIMORDIAL EARTH OCEANS

PHOTOSYNTHESIS: PHOTOLYSIS



PRIMORDIAL EARTH OCEANS

PHOTOSYNTHESIS: PHOTOLYSIS



PRIMORDIAL EARTH OCEANS

PHOTOSYNTHESIS: PHOTOLYSIS



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PRIMORDIAL EARTH OCEANS



PHOTOSYNTHESIS: PHOTOLYSIS

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PRIMORDIAL EARTH OCEANS

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PHOTOSYNTHESIS: PHOTOLYSIS

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SUPPORTING EVIDENCE

PRIMORDIAL EARTH OCEANS



PHOTOSYNTHESIS: PHOTOLYSIS

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PRIMORDIAL EARTH OCEANS

PHOTOSYNTHESIS: PHOTOLYSIS

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PRIMORDIAL EARTH OCEANS



PHOTOSYNTHESIS: PHOTOLYSIS

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PRIMORDIAL EARTH OCEANS



PHOTOSYNTHESIS: PHOTOLYSIS

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IRON-OXIDE FORMATION

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IRON-OXIDE





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BILLION YEARS

CYANOBACTERIA EVOLVE

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CYANOBACTERIA EVOLVE



SUPPORTING EVIDENCE



STROMATOLITE FOSSILS

PRIMORDIAL EARTH OCEANS

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STROMATOLITES

STROMATOLITE

STROMATOLITE

**CALCIUM CARBONATE
MOUND**

STROMATOLITE

STROMATOLITE

**CALCIUM CARBONATE
MOUND**

**CYANOBACTERIA
DEPOSITED**

STROMATOLITE



STROMATOLITE

STROMATOLITE

FOSSILS

CYANOBACTERIA

FOSSILS WITHIN

STROMATOLITE

STROMATOLITES



CYANOBACTERIA DEPOSITED



CYANOBACTERIA



CYANOBACTERIA

CYANOBACTERIA DEPOSITED

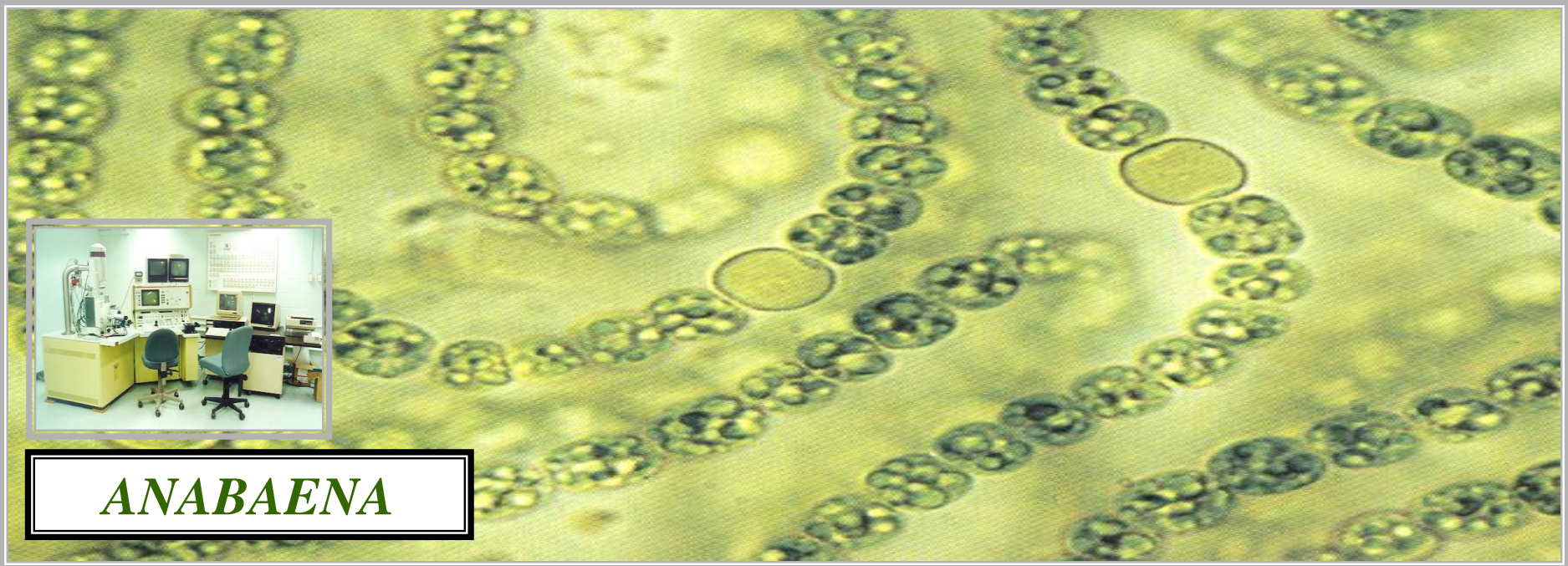
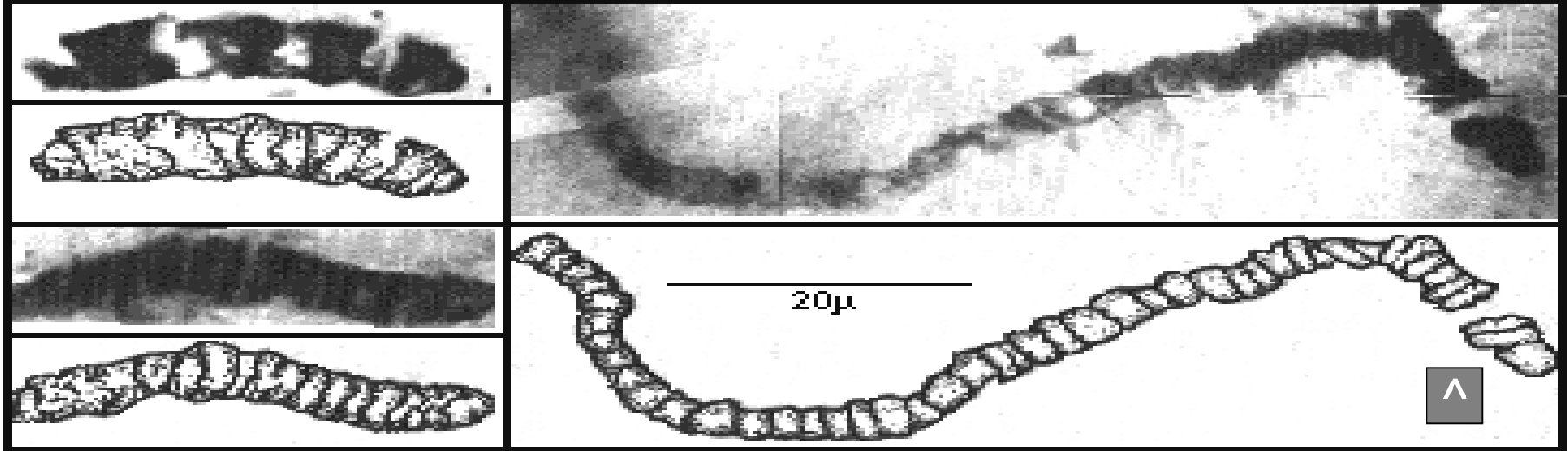
FOSSIL STROMATOLITE



SCANNING ELECTRON MICROSCOPE



STROMATOLITE CYANOBACTERIA FOSSILS



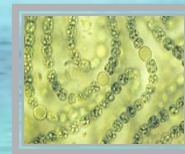
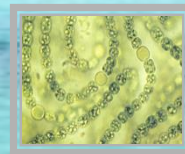
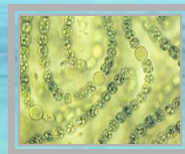
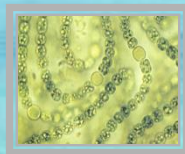
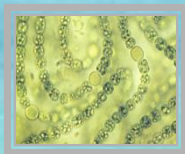
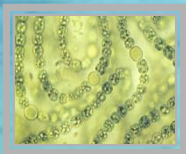


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BILLION YEARS

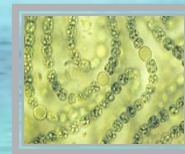
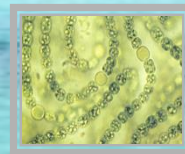
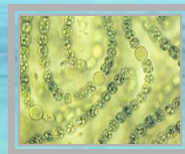
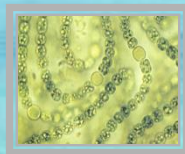
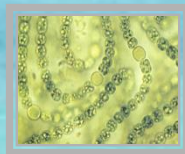
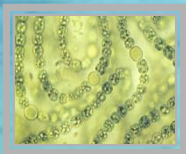
ANAEROBIC ATMOSPHERE

CYANOBACTERIA



ANAEROBIC ATMOSPHERE

PHOTOSYNTHESIS



ANAEROBIC ATMOSPHERE

OXYGEN SATURATED OCEANS

PHOTOLYSIS

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AEROBIC ATMOSPHERE

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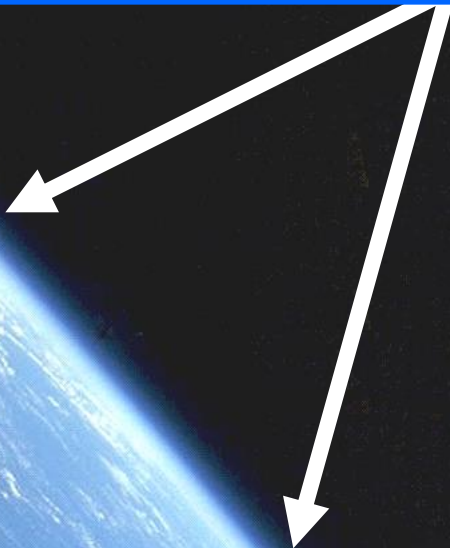
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**AEROBIC
ATMOSPHERE**

A satellite-style photograph of Earth from space, showing the curvature of the planet and the atmosphere. The atmosphere is depicted as a thin blue layer. A yellow arrow in the top right corner points left towards the atmosphere. A white box with a blue border at the top center contains the text 'OZONE LAYER'. Two white arrows point from this box down to the blue atmospheric layer. A white box with a blue border at the bottom left contains the text 'AEROBIC ATMOSPHERE'.

OZONE LAYER

**AEROBIC
ATMOSPHERE**

A diagram of Earth's atmosphere from space. The Earth's surface is visible at the bottom left, showing blue oceans and white clouds. The atmosphere is depicted as a blue layer above the surface. A white box with a blue border in the upper left contains the text 'OZONE LAYER'. A white box with a black border in the upper right contains the text 'FILTERS HARMFUL RADIATION'. A yellow arrow points from this box towards the atmosphere. Several yellow arrows point from the right towards the atmosphere, representing radiation being filtered. A white box with a blue border in the lower left contains the text 'AEROBIC ATMOSPHERE'.

OZONE LAYER

**FILTERS
HARMFUL
RADIATION**

**AEROBIC
ATMOSPHERE**

OZONE LAYER

**FILTERS
HARMFUL
RADIATION**



**AEROBIC
ATMOSPHERE**





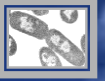
**ADDITIONAL
HABITATS
OPEN**

EARTH



DIVERSE PROKARYOTE BIOTA

EARTH



AEROBIC ENVIRONMENT

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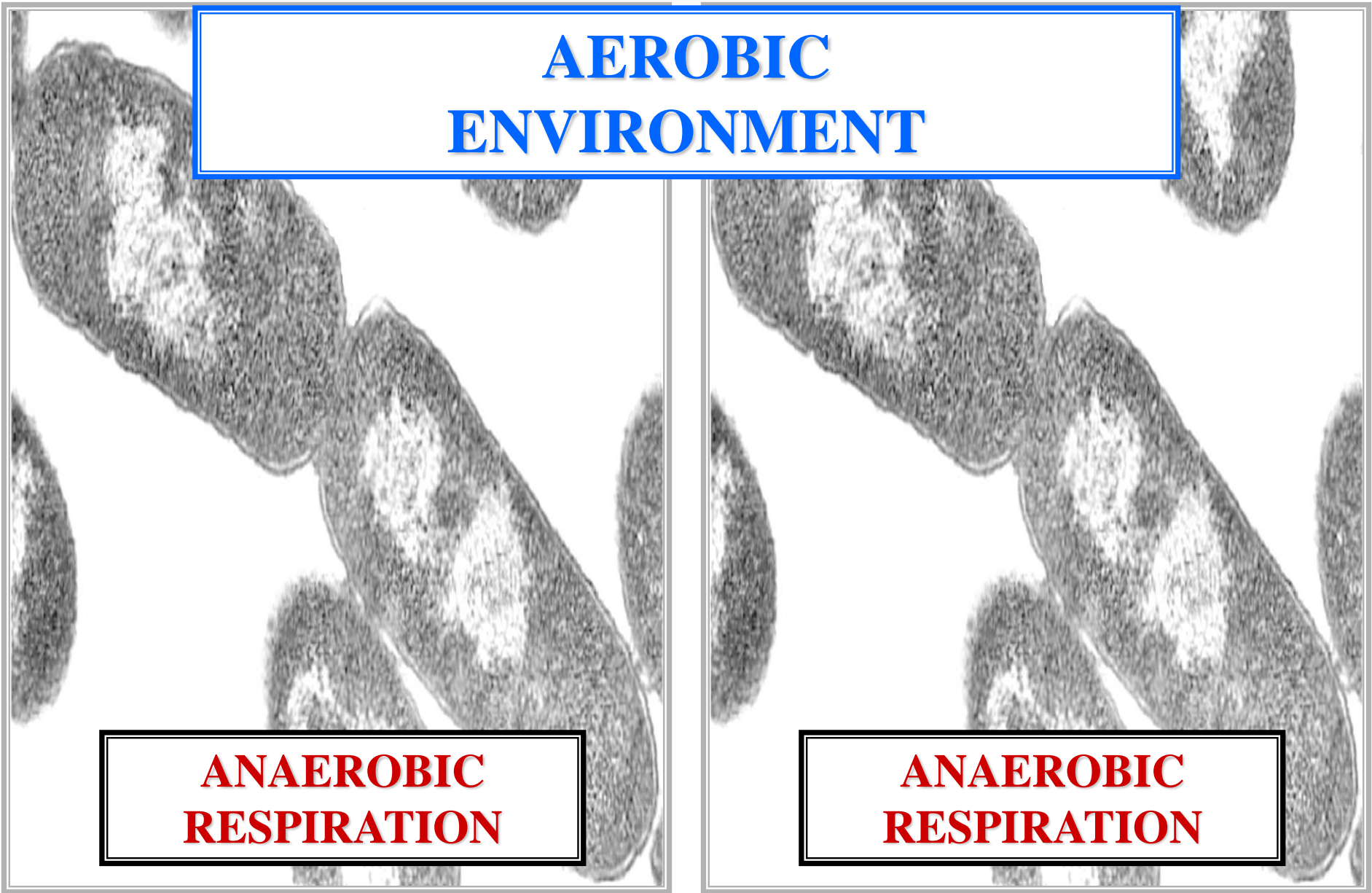
PROKARYOTES



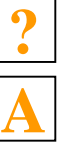
**AEROBIC
ENVIRONMENT**

**ANAEROBIC
RESPIRATION**

**ANAEROBIC
RESPIRATION**



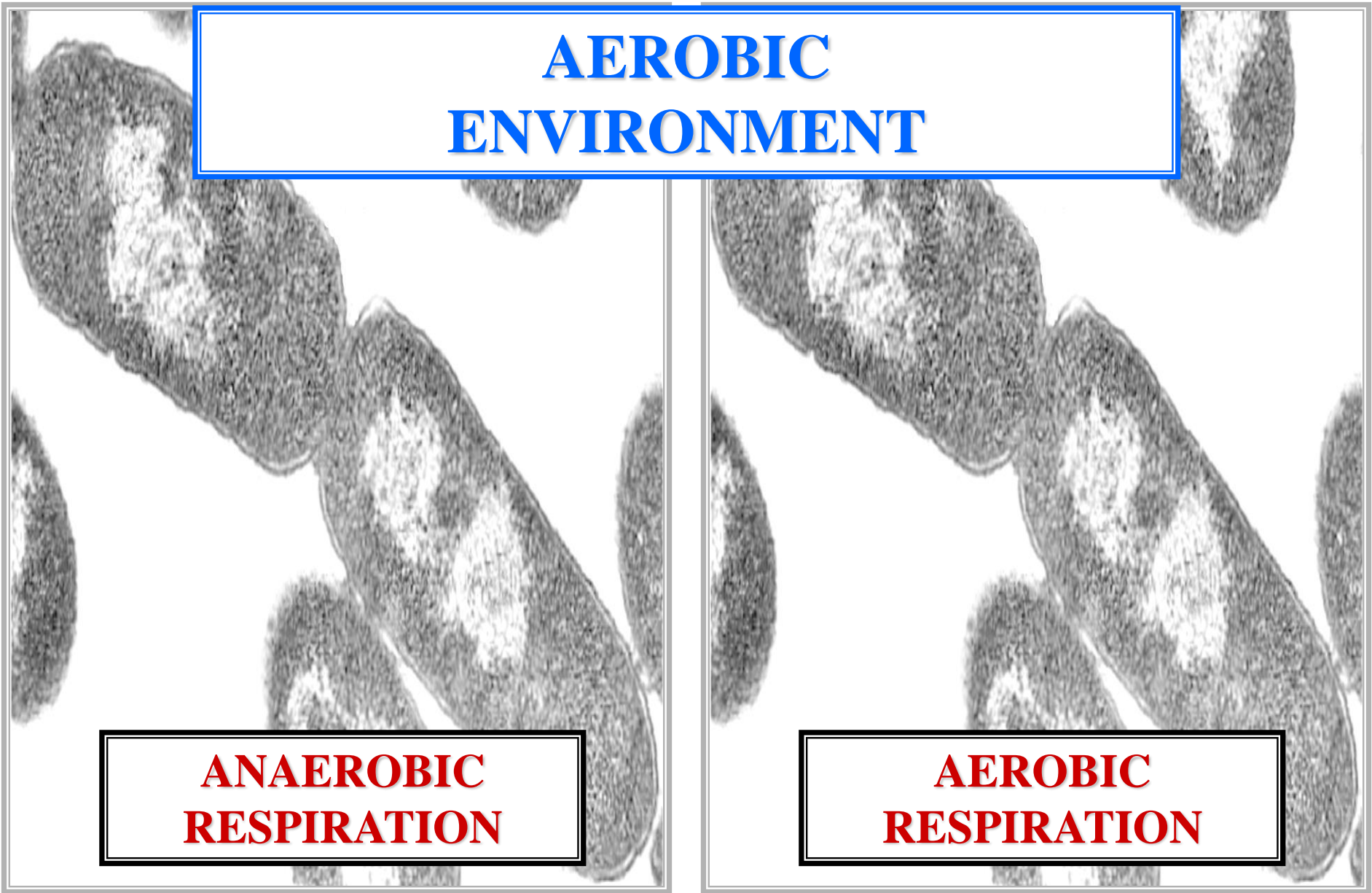
PROKARYOTES



**AEROBIC
ENVIRONMENT**

**ANAEROBIC
RESPIRATION**

**AEROBIC
RESPIRATION**



PROKARYOTES

3

A grayscale micrograph showing several rod-shaped prokaryotic cells. The cells have a textured, granular appearance. Overlaid on the image is the text 'AEROBIC RESPIRATION' and 'ATP NET' in large, bold, black letters. Below this, the text '? ATP' is written in a large, bold, orange font. In the bottom left corner, there is a black-bordered box containing the text 'AEROBIC RESPIRATION' in red.

**AEROBIC
RESPIRATION**

ATP NET

? ATP

**AEROBIC
RESPIRATION**

PROKARYOTES

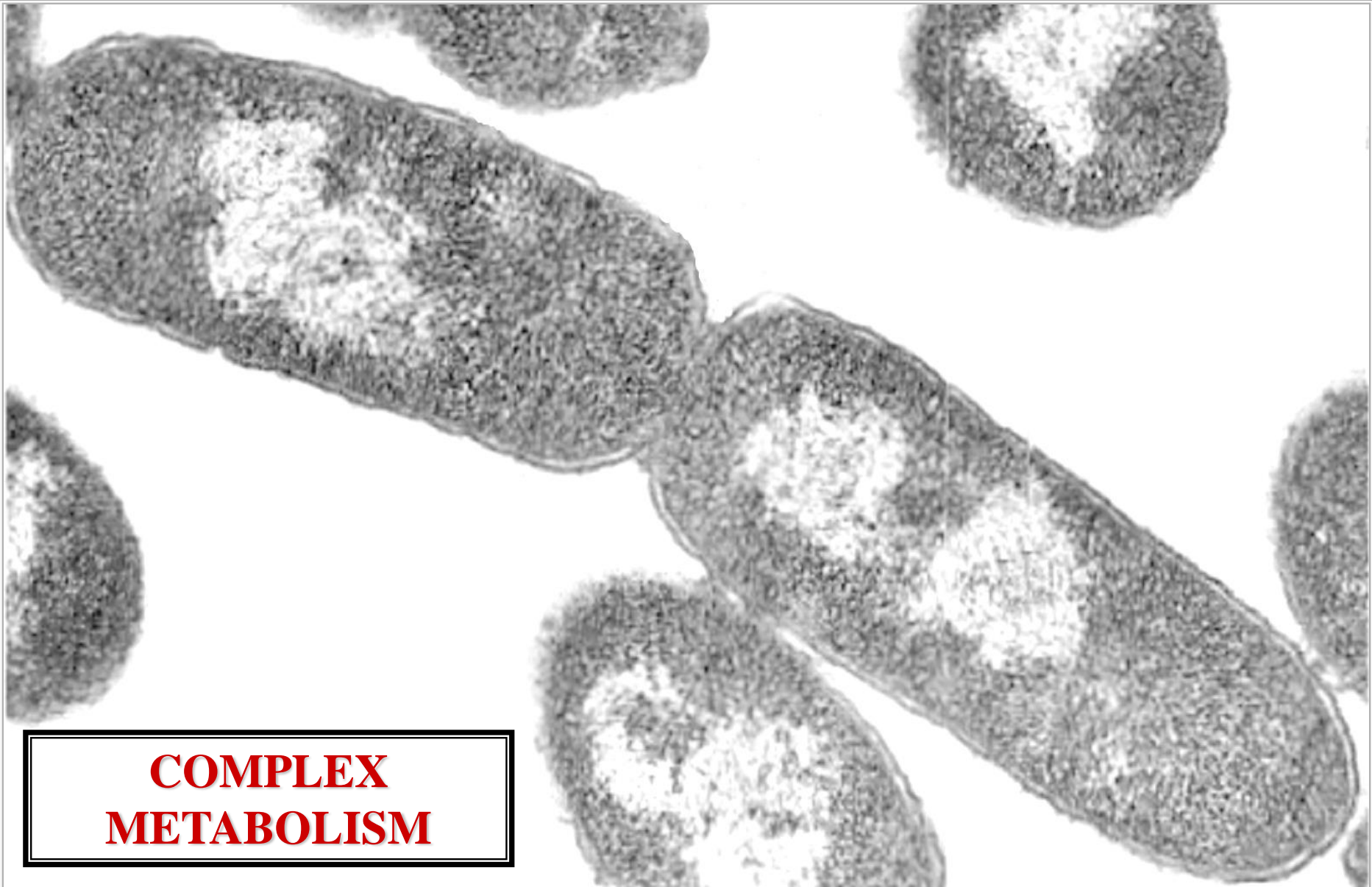
A grayscale electron micrograph of several prokaryotic cells, likely bacteria, showing internal structures like ribosomes and possibly flagella. The text is overlaid on this image.

AEROBIC RESPIRATION ATP NET

36-38 ATP

**AEROBIC
RESPIRATION**


PROKARYOTES



**COMPLEX
METABOLISM**

**ADDITIONAL
HABITATS
OPEN**

EARTH

A high-resolution satellite image of Earth from space, showing the Western Hemisphere. The image captures the curvature of the planet, with the blue oceans, brown and green landmasses, and white cloud patterns. A white double-line border is superimposed over the center of the image, framing the text.

DIVERSE PROKARYOTE BIOTA

The word "EARTH" is centered at the bottom of the image. It is enclosed within a white double-line rectangular border, which is slightly offset from the main border of the image.

EARTH



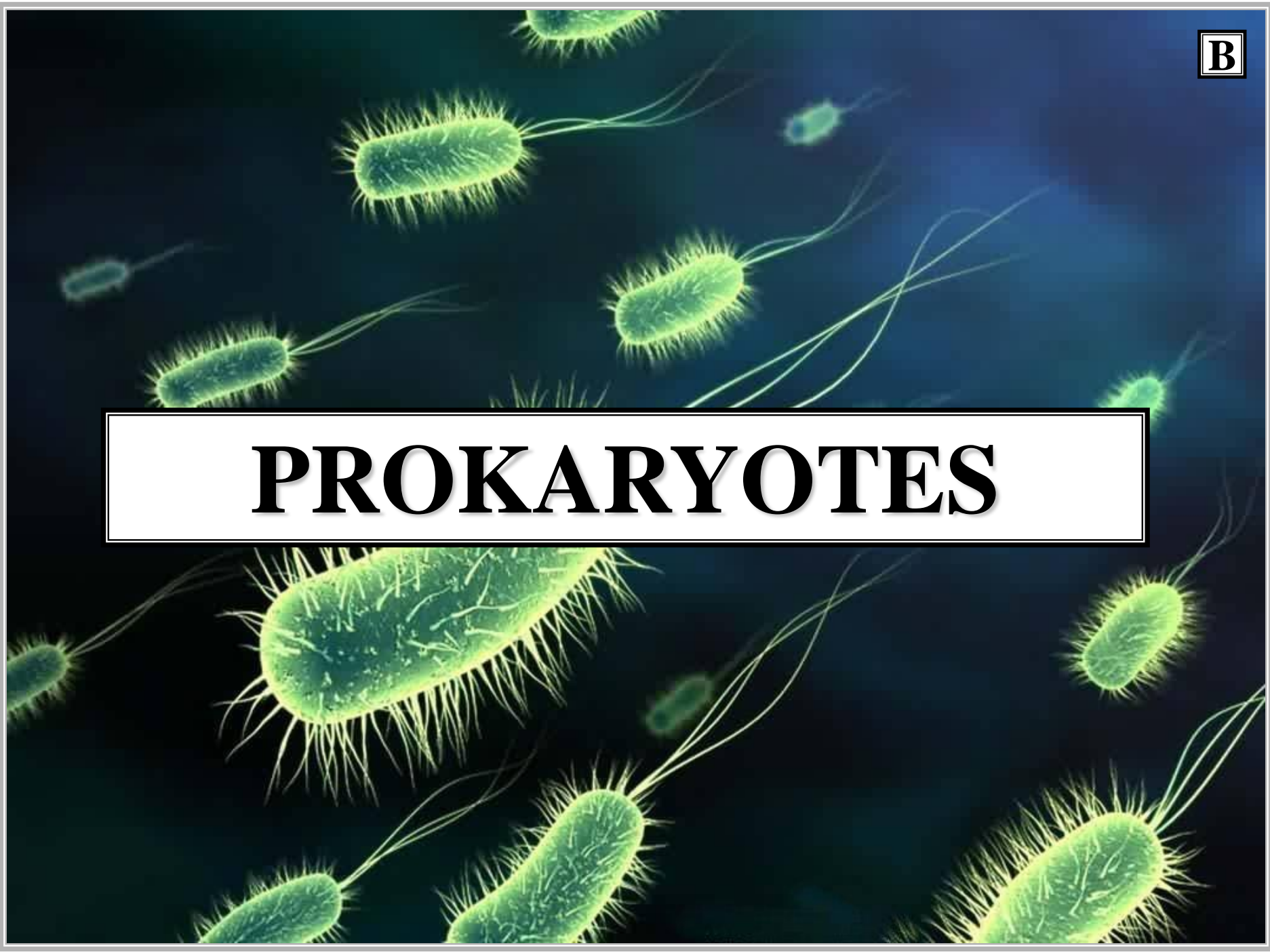
INTRODUCTION

PROKARYOTES



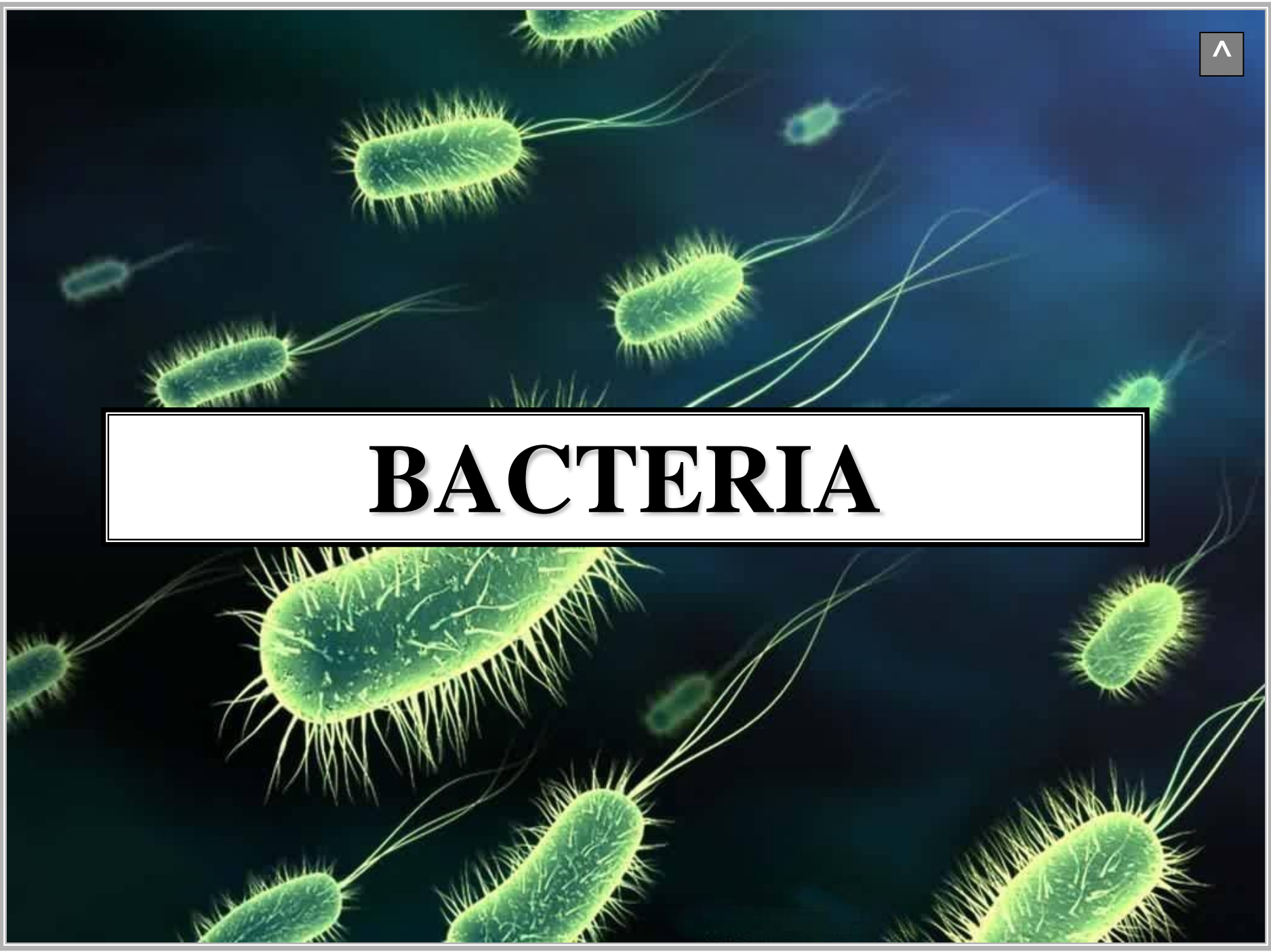
PROKARYOTE COMMON NAME

PROKARYOTES





BACTERIA



PROKARYOTE DIVERSITY



~5,000 SPECIES

EARTH



PROKARYOTE DISTRIBUTION



COSMOPOLITAN

EARTH

COSMOPOLITAN



COSMOPOLITAN

**WORLDWIDE
DISTRIBUTION**

COSMOPOLITAN



PROKARYOTE HABITAT

UBIQUITOUS

EARTH

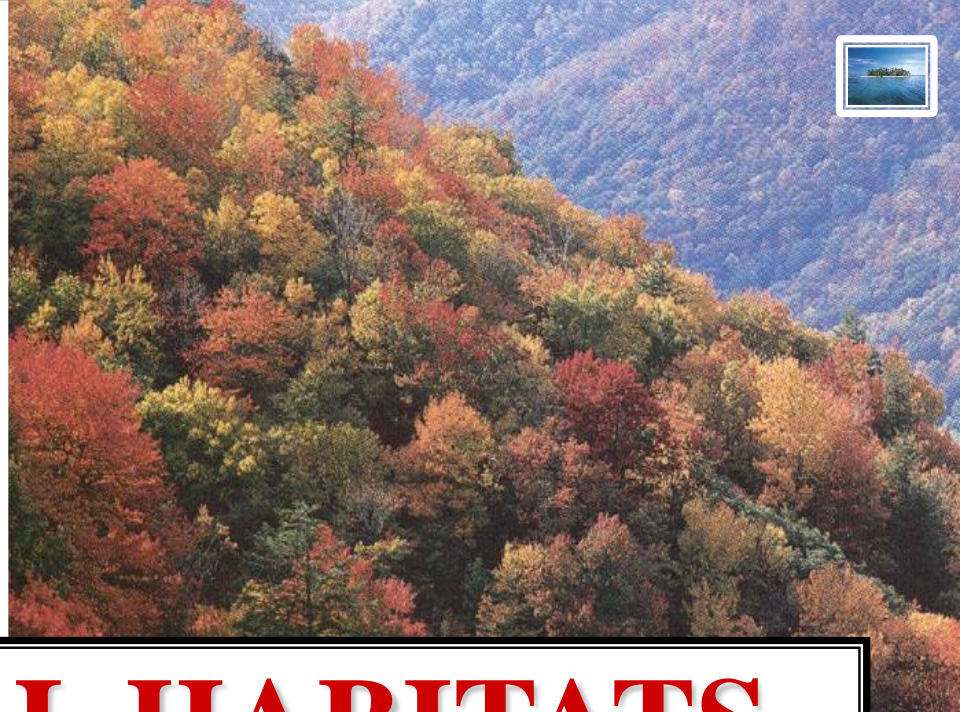
UBIQUITOUS

UBIQUITOUS



ALL HABITATS

UBIQUITOUS



TERRESTRAL HABITATS

