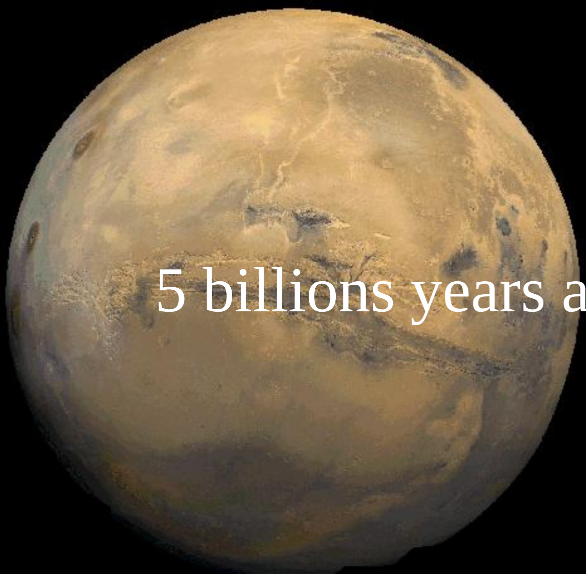
Chapter 1

Basics of Microbiology

Objectives

- How microorganisms are classified (taxonomy)
- What they look like (morphology)
- The major divisions among microorganisms based upon their function in the environment (trophic groups)
- The biochemical reactions that they mediate (metabolism)

- Taxonomy: Science of classification
  - Observable phsyical properties:
    - Morphology
    - Reaction with specific dyes
    - Convert a chemical into another
- Phylogeny: detects differences in m.o. Based upon genetic characteristics



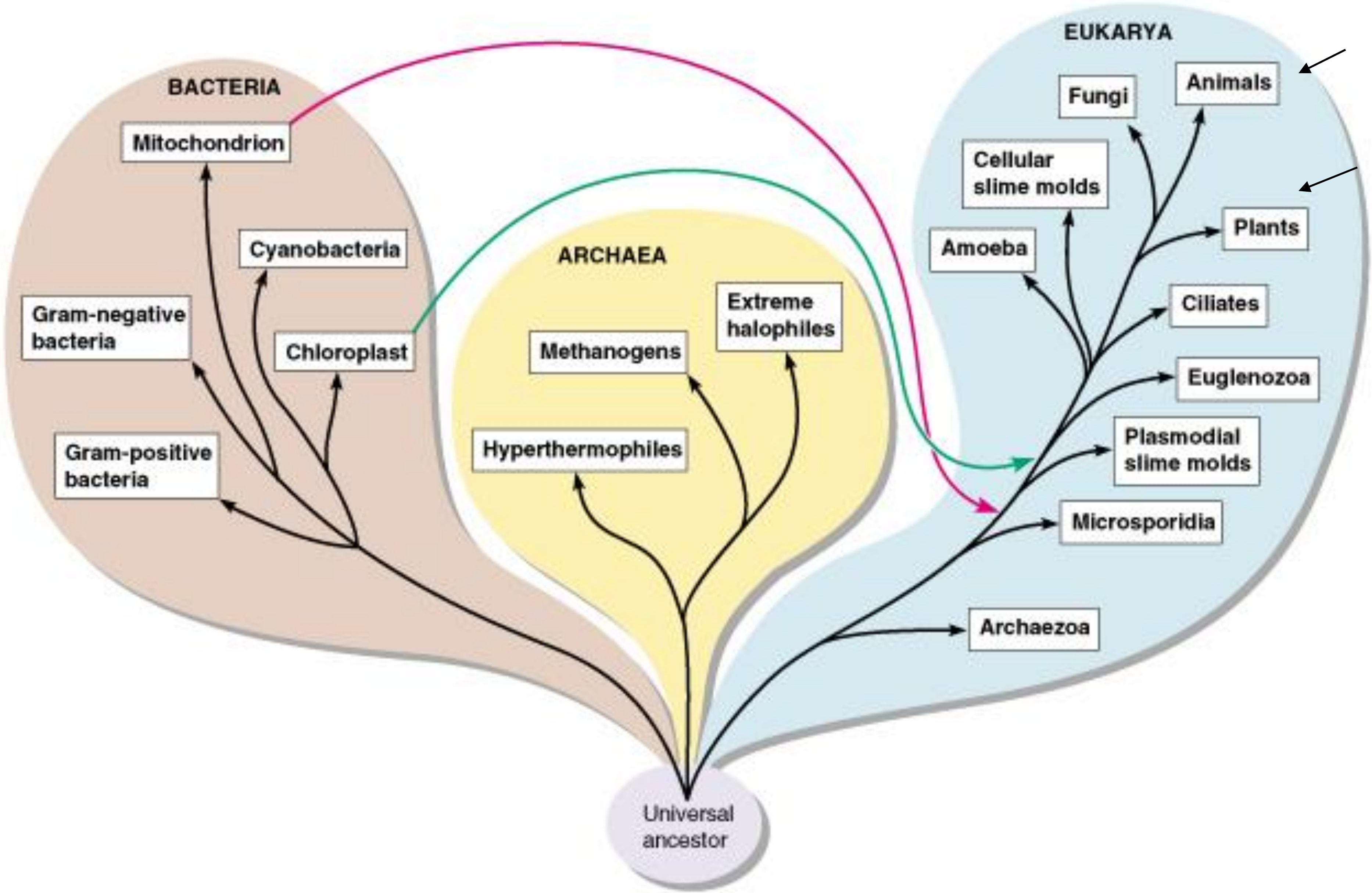
5 billions years ago

Life begins around 1.5 billion years

Extreme environment, high temperature, volcanic eruptions, no $O_{2,}$ “Mars like”

Present day earth [Biosphere]:

•O_2, water, temperature 0 -100

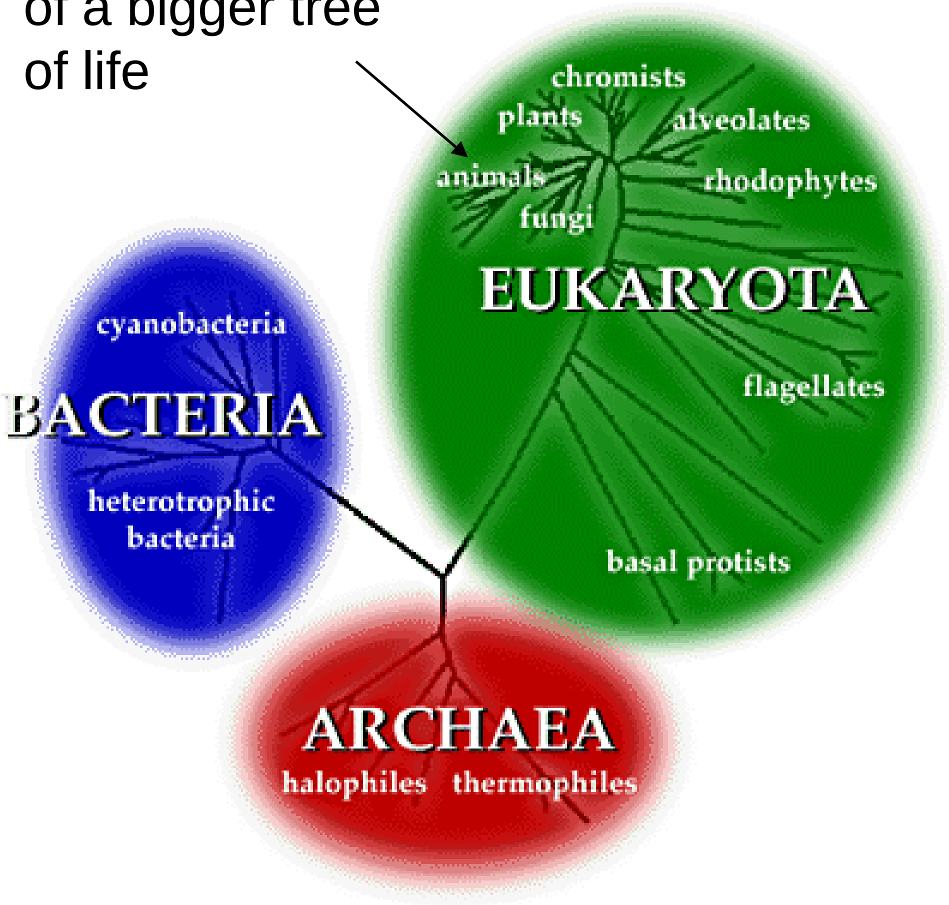

BACTERIA
Mitochondrion
Cyanobacteria
Gram-negative bacteria
Chloroplast
Gram-positive bacteria
ARCHAEA
Methanogens
Extreme halophiles
Hyperthermophiles
EUKARYA
Fungi
Animals
Cellular slime molds
Plants
Amoeba
Ciliates
Euglenozoa
Plasmodial slime molds
Microsporidia
Archaezoa
Universal ancestor

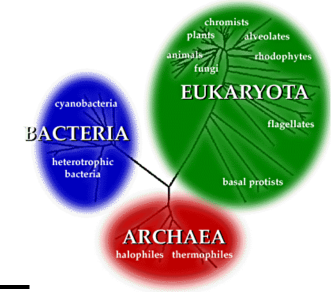
The Larger Context of Life

There are three great "domains" of life. Two of these "domains" are prokaryotic, and one is eukaryotic.

Animals arose from single-celled eukaryotes.

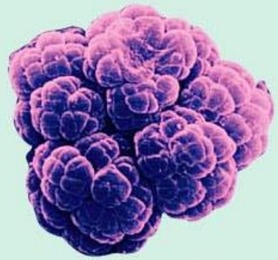
animals are part of a bigger tree of life



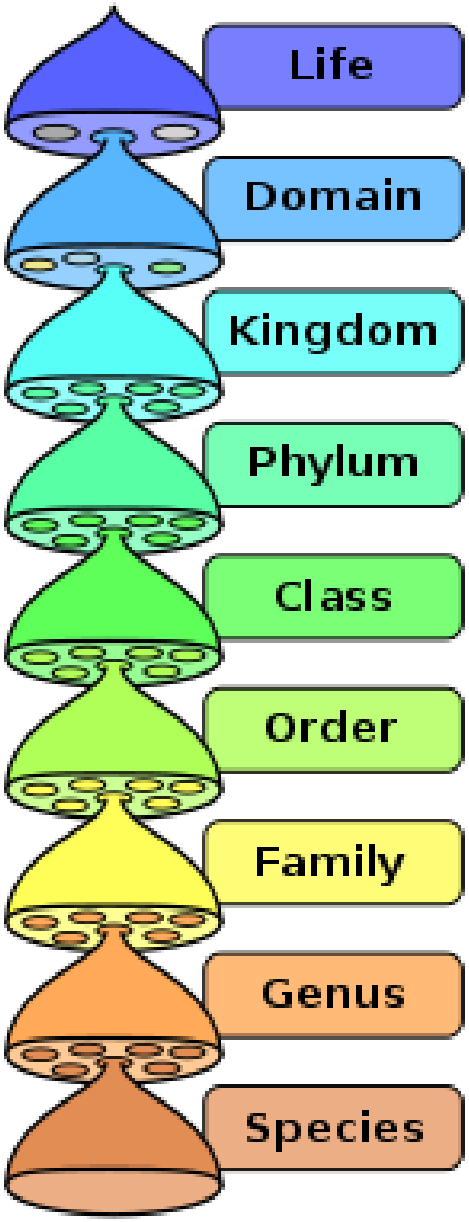


Properties of	Bacteria,	Archaea &	Eukarya
Nuclear envelope	No	No	Yes
Organelles in membrane	No	No	Yes
Mitochondria/chloroplasts	No	No	Yes
Chromosomes	1 circular	1 circular	>1 linear
Peptidoglycan in cell wall	Yes - some	No	No
Membrane lipids	Unbranched	Some branched	Unbranched

TABLE 10.1 Some Characteristics of Archaea, Bacteria, and Eukarya

	Archaea	Bacteria	Eukarya
	 *Methanosarcina* SEM 10 μm	 *E. coli* SEM 1 μm	 *Amoeba* SEM 10 μm
Cell Type	Prokaryotic	Prokaryotic	Eukaryotic
Cell Wall	Varies in composition; contains no peptidoglycan	Contains peptidoglycan	Varies in composition; contains carbohydrates
Membrane Lipids	Composed of branched carbon chains attached to glycerol by ether linkage	Composed of straight carbon chains attached to glycerol by ester linkage	Composed of straight carbon chains attached to glycerol by ester linkage
First Amino Acid in Protein Synthesis	Methionine	Formylmethionine	Methionine
Antibiotic Sensitivity	No	Yes	No
rRNA Loop*	Lacking	Present	Lacking
Common Arm of tRNA†	Lacking	Present	Present

*Binds to ribosomal protein; found in all bacteria.
†A sequence of bases in tRNA found in all eukaryotes and bacteria: guanine-thymine-pseudouridine-cytosine-guanine.



Hierarchy of biological classification

- The basic taxonomic unit is the *species*
- Microrganisms are generally given a genus and species name
  - *Escherichia coli*

Genus Species

Nomenclature

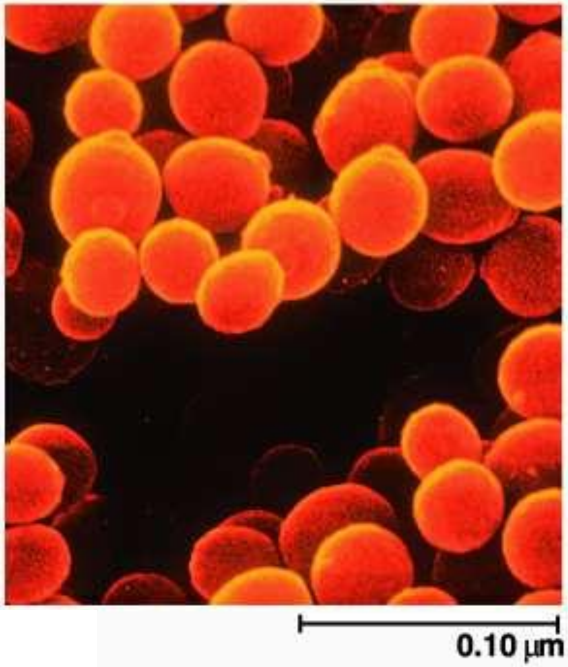
- Scientific name (Systematic Name) Binomial System of Nomenclature
  - Genus name + species name
    - Italicized or underlined
    - Genus name is capitalized and may be abbreviated
    - Species name is never abbreviated
    - eg: *Bacillus subtilis*
      B. subtilis

Prokaryotes

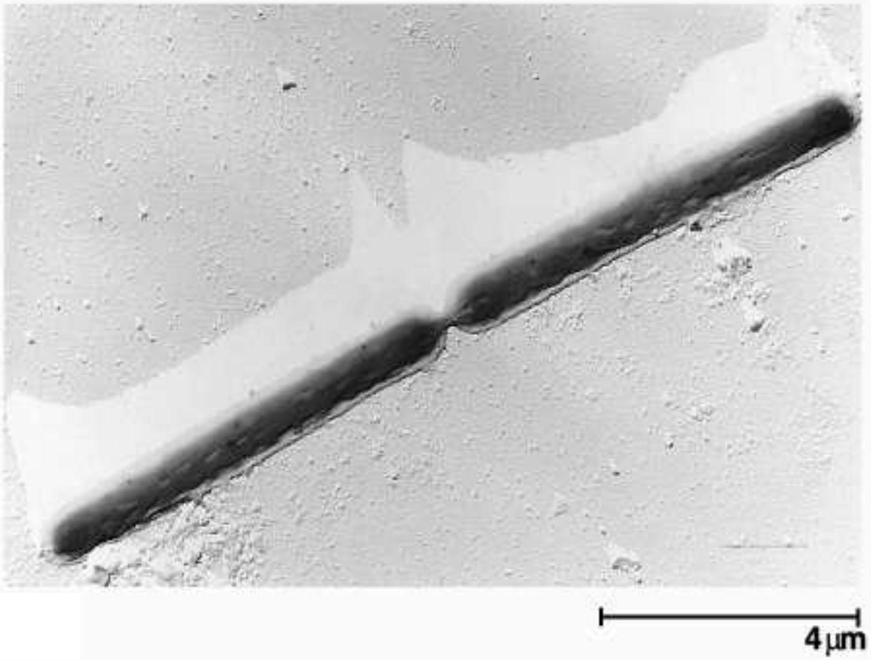
- Until the development of genetic phylogeny, bacteria and archaea was simply called bacteria.
  - They often are found together
  - Anaerobic degradation of organic matter

3 common bacterial shapes:

Cocci- spheres

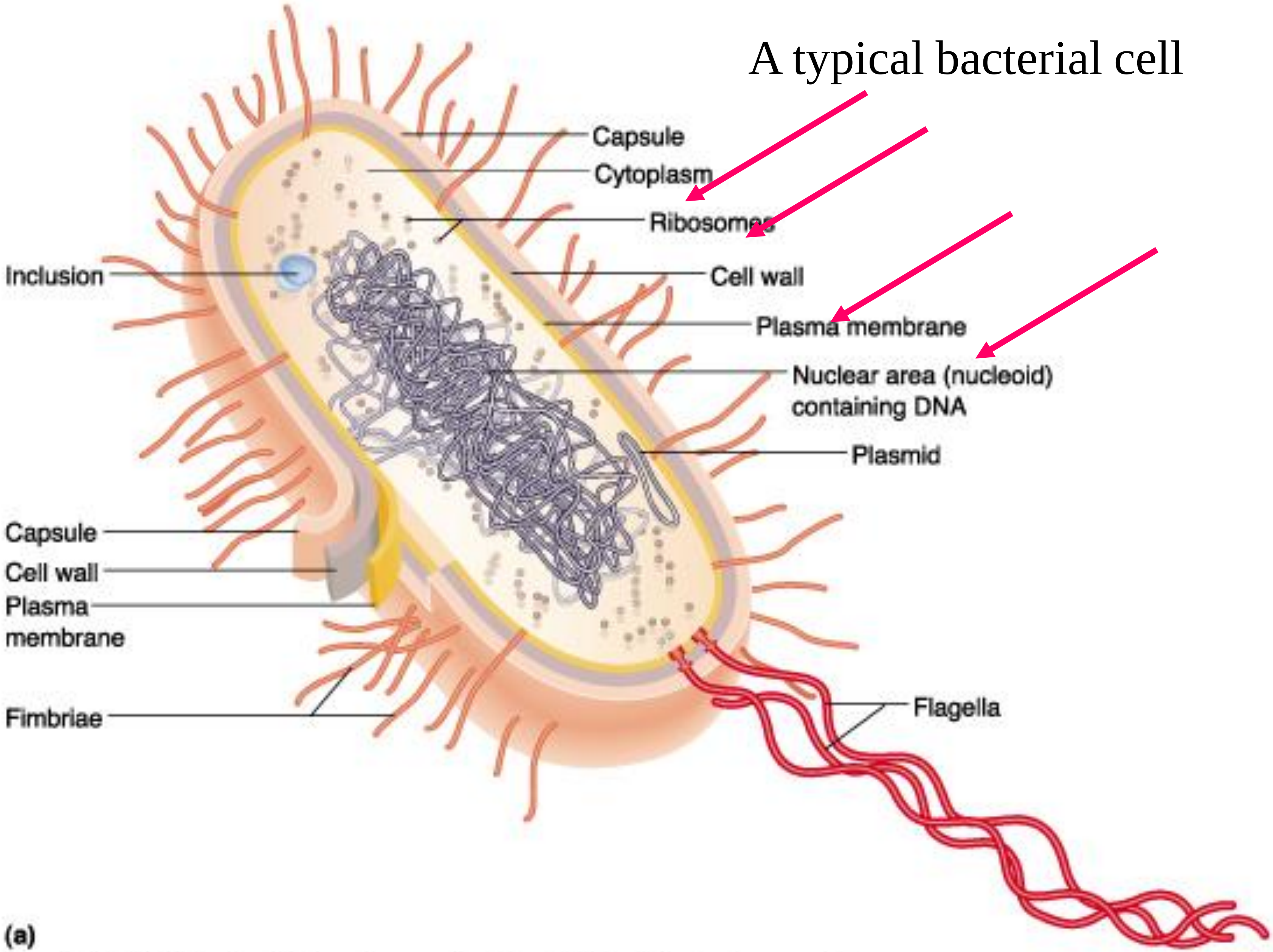


Bacilli- rods

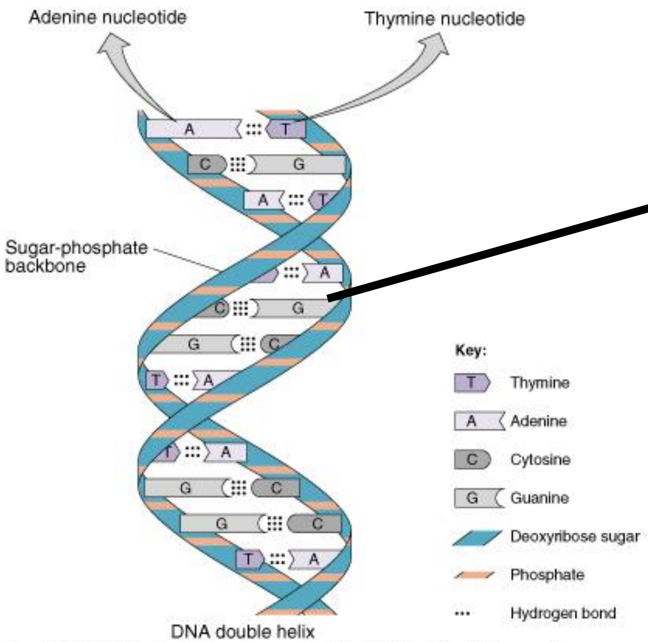


Spirilli- spirals

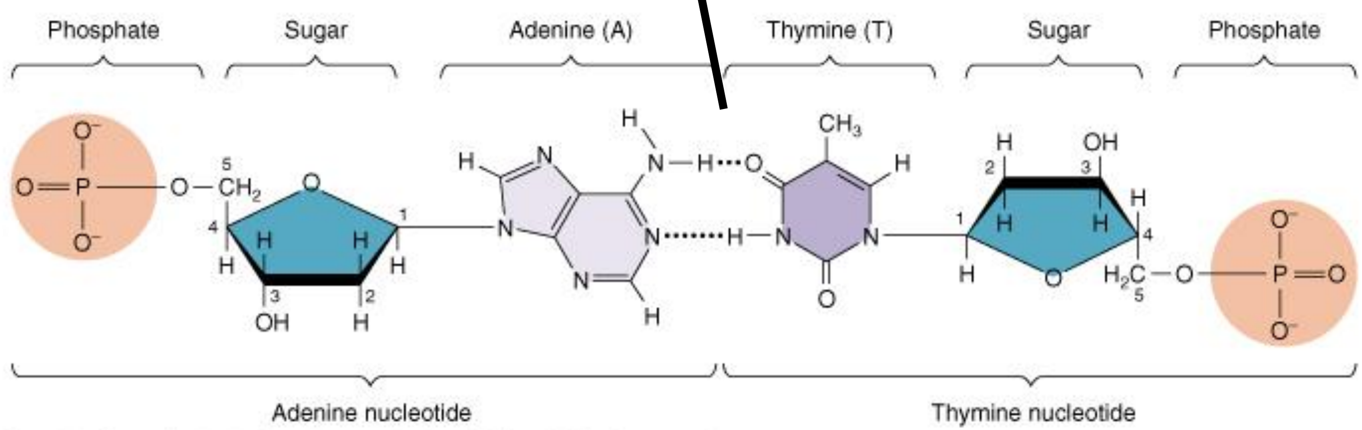
A typical bacterial cell



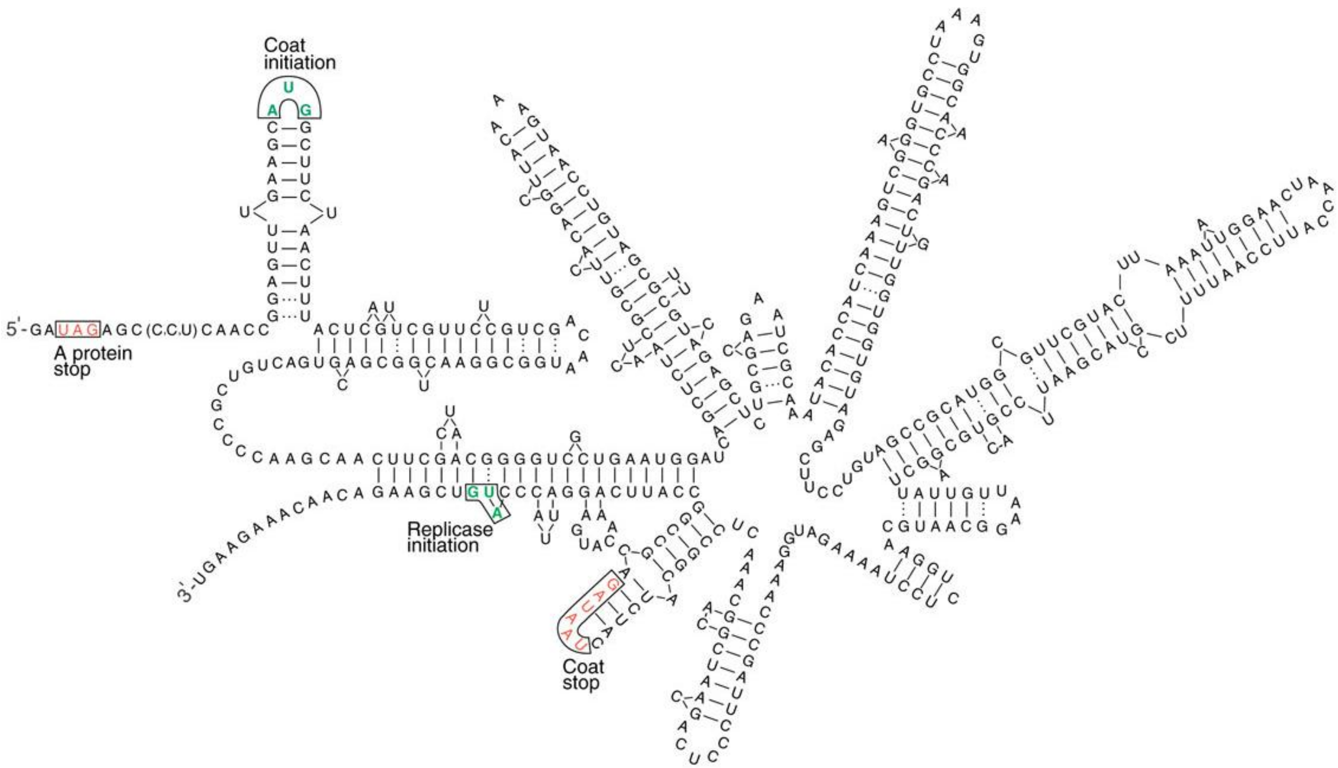
Nucleic acid



base-pairing



RNA: Structure



1. RNA can be single or double stranded
2. G-C pairs have 3 hydrogen bonds
3. A-U pairs have 2 hydrogen bonds
4. Single-stranded, double-stranded, and loop RNA present different surfaces

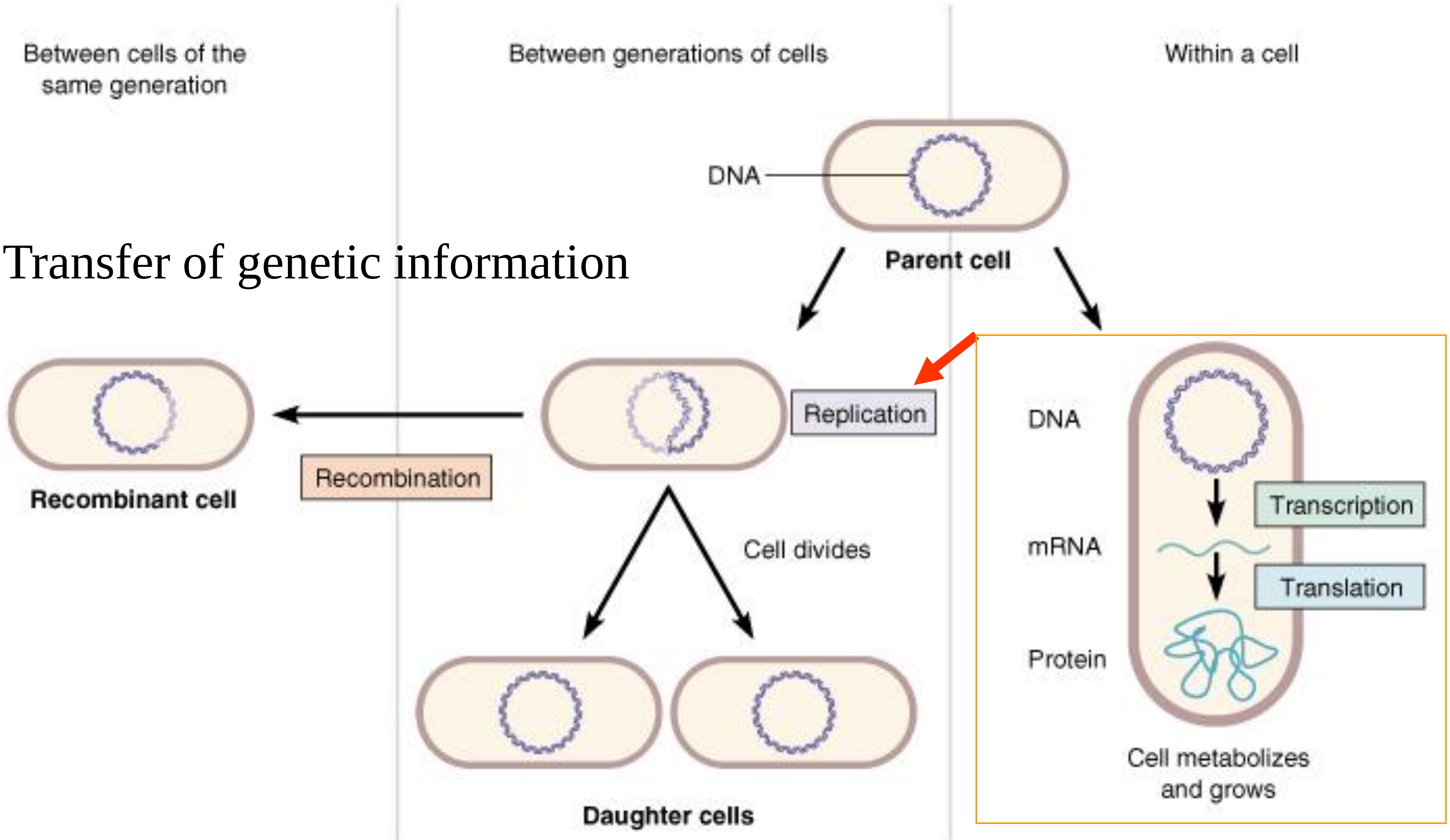
Central Dogma

- DNA carries the genetic code and transcribes an RNA copy of the code
- The RNA copy is translated by ribosomes to make protein

DNA $\xrightarrow[\textit{Transcription}]{1}$ ***RNA*** $\xrightarrow[\textit{Translation}]{2}$ ***Protein***

Central dogma

Transfer of genetic information

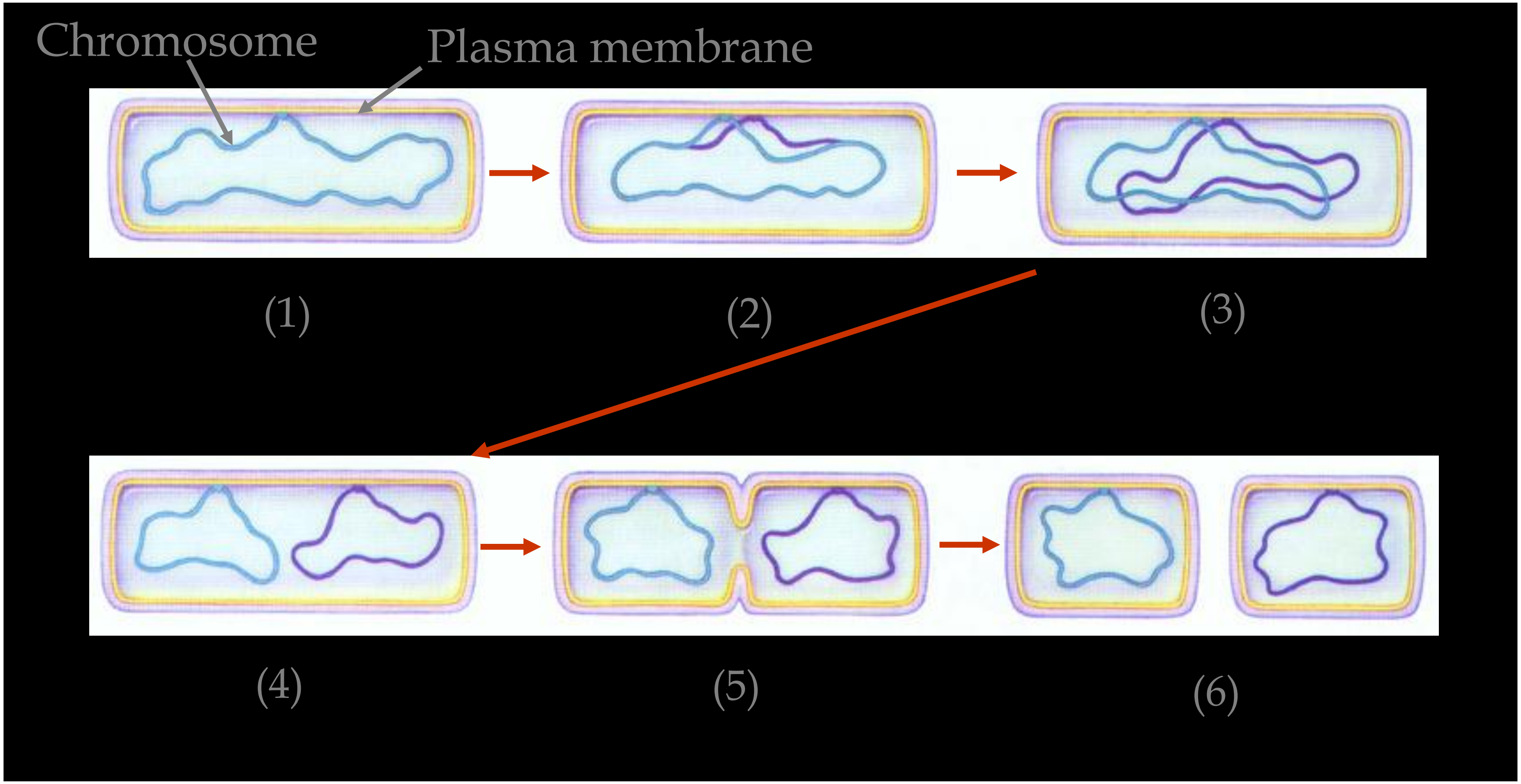


Chemical Composition of Bacteria

Constituent	Percentage
Water	75
Dry Matter	25
Organic	90
C	45-55
O	22-28
H	5-7
N	8-13
Inorganic	10
P_2O_5	50
K_2O, Na_2O, MgO, CaO, SO_3	50

Reproduction of Bacteria

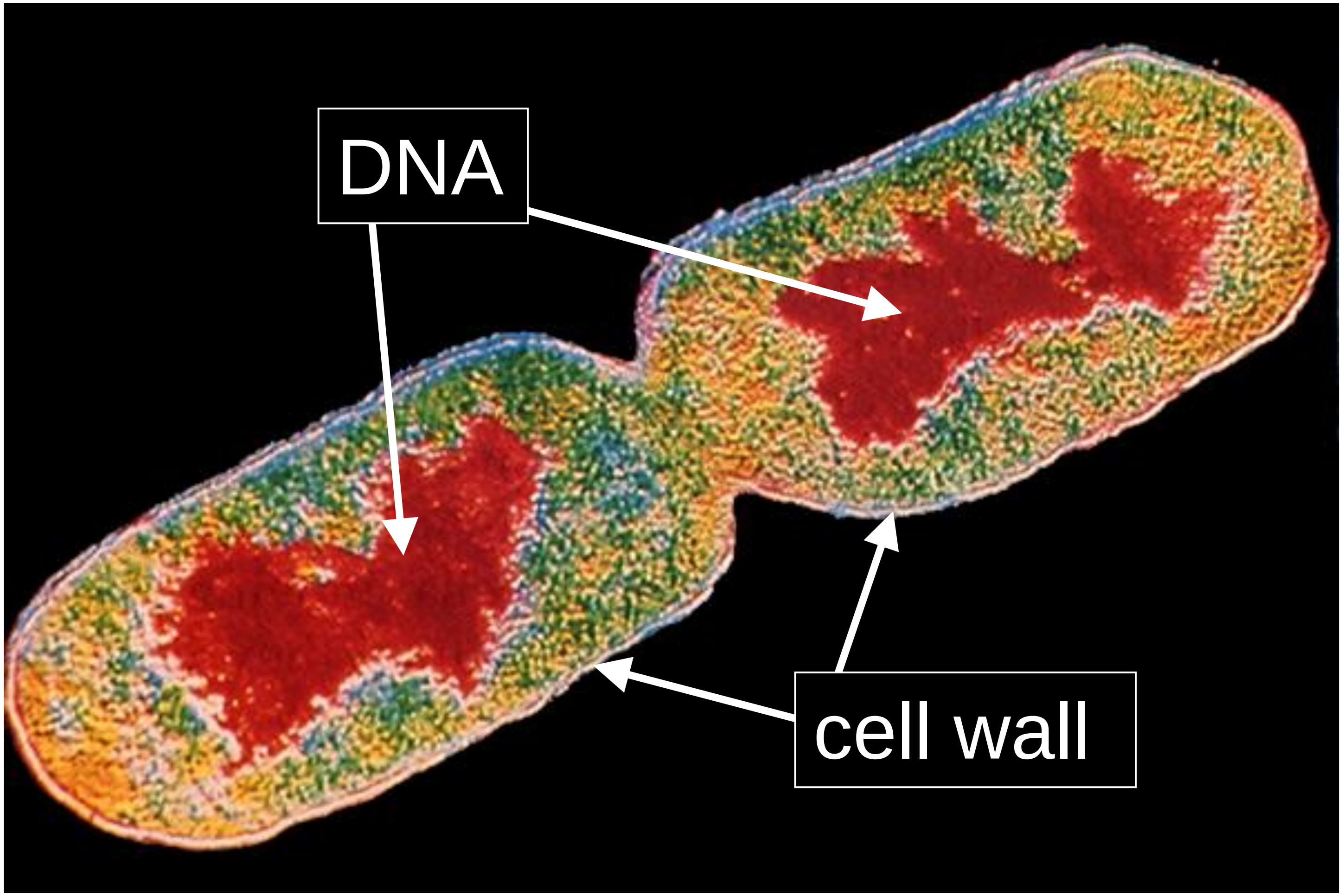
Daughter cells are identical copies



Binary fission

Binary fission

E. coli



Carbon sources & Energy sources

Suffix - Carbon sources:

1. **Heterotroph** (*hetero* = others, *troph* = to feed) = eating preexisting organic compounds. All animals, & humans, many microscopic organisms
2. **Autotroph** (self feeding) = cells that get carbon directly from the environment - carbon dioxide from air or disolved in water (trees, most plants)

TABLE 5.1 *Metabolic Classifications of Living Organisms*

Metabolic Classification	*Carbon Source*	*Energy Source*	*Examples*
Photoautotroph	carbon dioxide	sunlight	plants, photosynthetic bacteria
Chemoautotroph	carbon dioxide	inorganic chemicals (e.g., iron, sulfur, ammonia)	some bacteria and archaea, especially in extreme environments
Photoheterotroph	organic compounds	sunlight	some bacteria and archaea
Chemoheterotroph	organic compounds	organic compounds	animals, many microbes

Prefix: Energy sources to make ATP:

1. ***Photo*** - Sunlight - photosynthesis (plants)
2. ***Chemo*** - Organic compounds (eat food) - chemical reactions
3. ***Chemo*** - Inorganic chemicals from the environment (that do not contain carbon) - chemical reactions

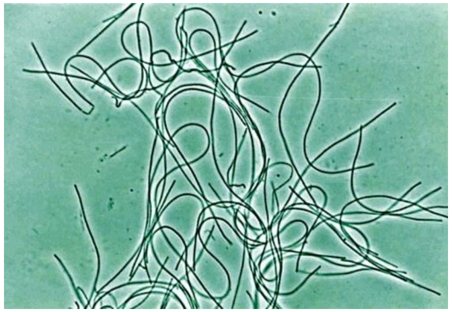
Carbon sources & Energy sources

A **chemoheterotroph** gets is energy from chemical reactions and its carbon from food.

Humans, animals, many microorganisms.

A **photoheterotroph** gets its energy from the Sun and its carbon from food.

Rare - some prokayotes - bacteria Chloroflexus (carbon from other bacteria and energy from photosynthesis - lakes, rivers, hot springs, aquatic environments high in salts)



Chloroflexux photomicrograph from the Joint Genome Institute of the United States Department of Energy

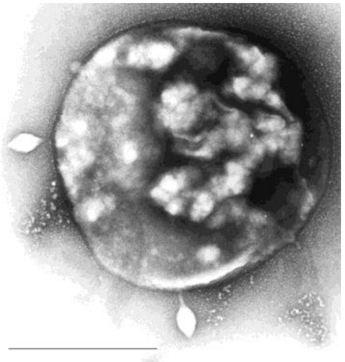
A **photoautotroph** gets its energy from the Sun and its carbon from the inorganic carbon.

Plants, algae, and some microorganisms.

A **chemoautotroph** gets its energy from chemical reactions and its carbon from the inorganic carbon.

Amazing organisms - archae - Sulfolobus - volcanic springs obtain energy from chemical reactions involving sulfur compounds.

Found in environments where most organisms could not survive! Most likely to be found on other worlds with harsher conditions for life!



Cell of Sulfolobus infected by virus STSV1 observed under microscopy were isolated in an acidic hot spring in Yunnan Province, China.

All organisms require a source of energy & carbon

Autotrophs can obtain all their C from CO_2

Table 27.1 Major Nutritional Modes

Mode of Nutrition	Energy Source	Carbon Source	Types of Organisms
Autotroph			
Photo-autotroph	Light	CO_2	Photosynthetic prokaryotes, including cyanobacteria; plants; certain protists (algae)
Chemo-autotroph	Inorganic chemicals	CO_2	Certain prokaryotes (for example, *Sulfolobus*)
Heterotroph			
Photo-heterotroph	Light	Organic com-pounds	Certain prokaryotes
Chemo-heterotroph	Organic com-pounds	Organic com-pounds	Many prokaryotes and protists; fungi; animals; some parasitic plants

All organisms require a source of energy & carbon

Heterotrophs require at least one organic nutrient, *e.g.*, glucose

Table 27.1 Major Nutritional Modes

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Heterotroph			
Photo-heterotroph	Light	Organic com-pounds	Certain prokaryotes
Chemo-heterotroph	Organic com-pounds	Organic com-pounds	Many prokaryotes and protists; fungi; animals; some parasitic plants

All organisms require a source of energy & carbon

Phototrophs obtain their energy from the sun

Table 27.1 Major Nutritional Modes

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Autotroph			
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Chemo-heterotroph	Organic com-pounds	Organic com-pounds	Many prokaryotes and protists; fungi; animals; some parasitic plants

All organisms require a source of energy & carbon

Chemotrophs obtain their energy from chemical compounds

Table 27.1 Major Nutritional Modes

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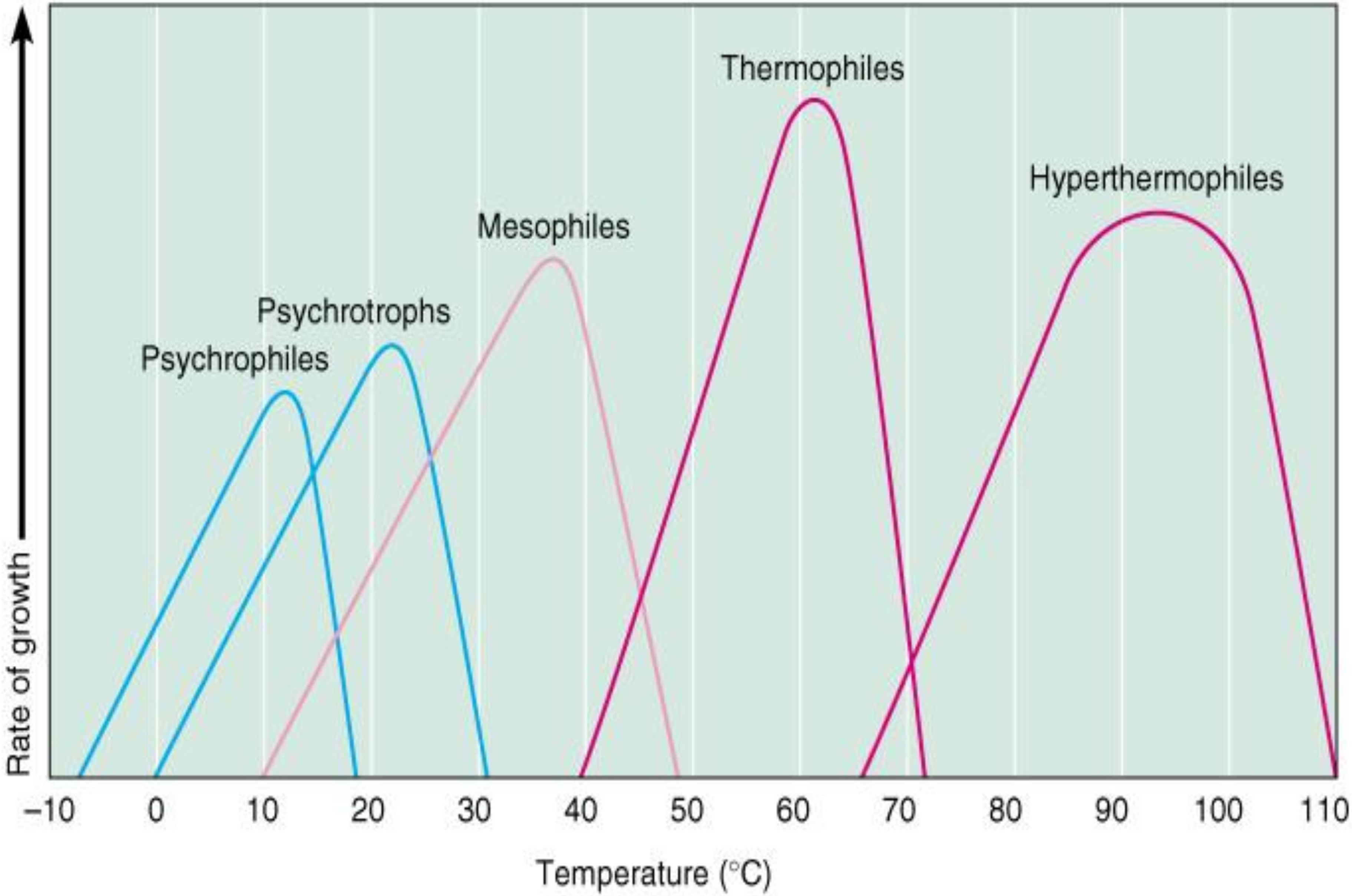
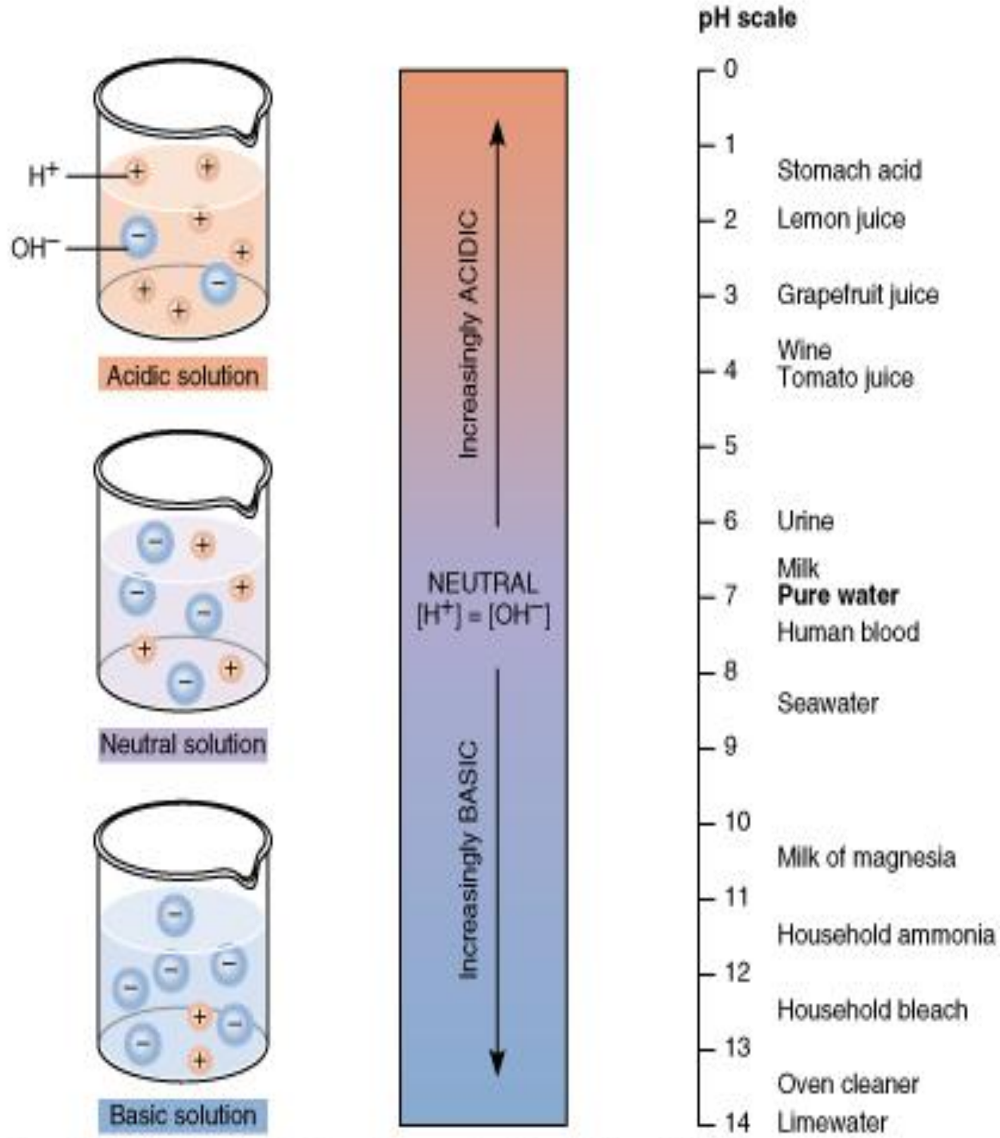
Heterotroph			
Photo-heterotroph	Light	Organic compounds	Certain prokaryotes
Chemo-heterotroph	Organic compounds	Organic compounds	Many prokaryotes and protists; fungi; animals; some parasitic plants

Environmental Conditions for Growth

- Temperature
  - Affects rate of growth
  - Growth rate roughly double for each 10^{o}C rise.
  - At temperatures above the normal range→key enzymes destroyed
- pH
  - For most bacteria pH: 6-8 optimum
- Oxygen partial pressure
- Osmotic pressure


Thermophiles
Hyperthermophiles
Mesophiles
Psychrotrophs
Psychrophiles
Rate of growth
–10
0
10
20
30
40
50
60
70
80
90
100
110
Temperature (°C)

pH = -log[H+]



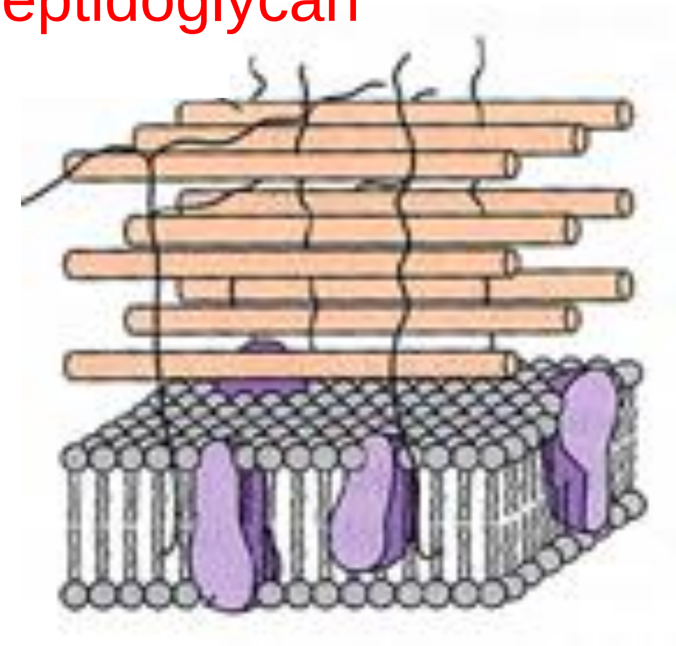
acidophiles

neutrophiles

alkaliphiles

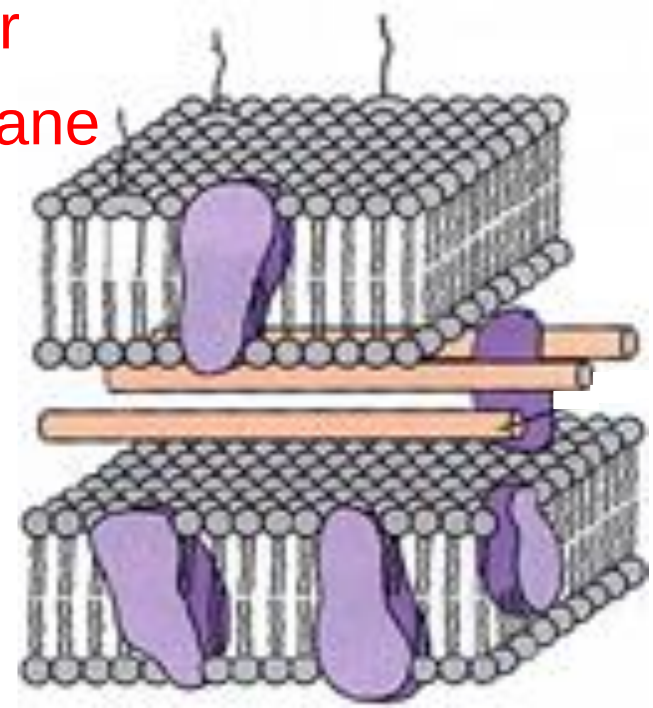
Two biochemical groups of bacteria:

peptidoglycan



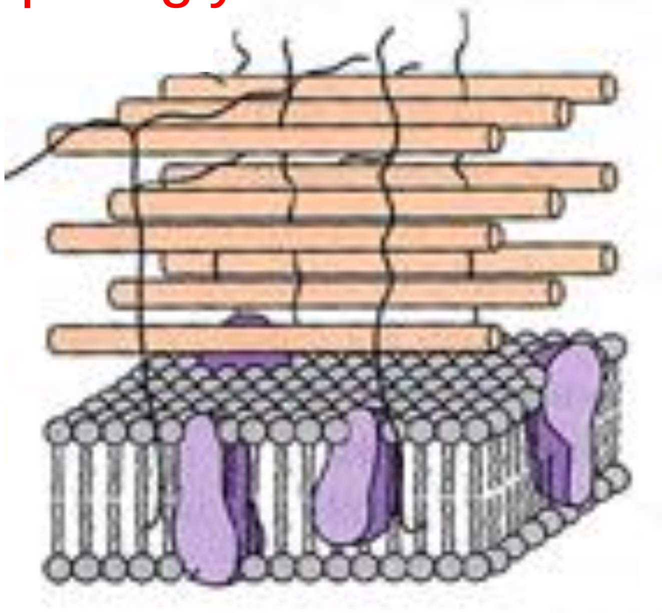
outer

membrane



Two biochemical groups of bacteria:

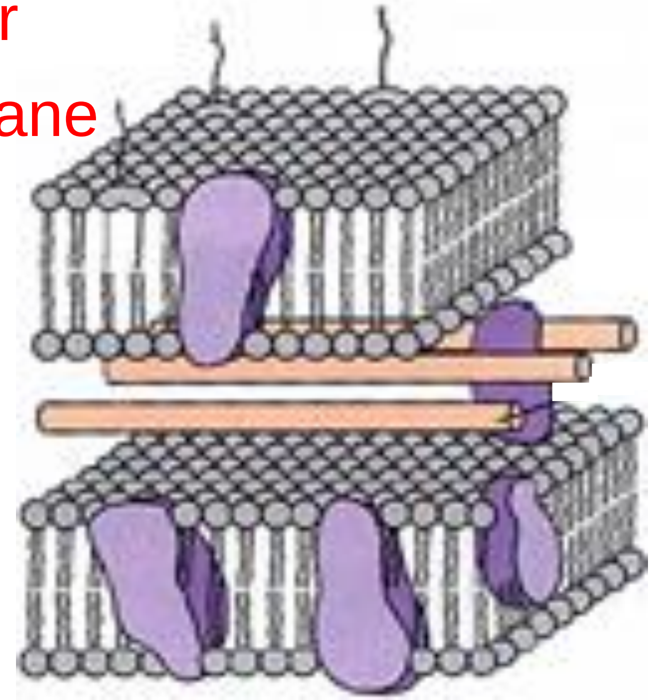
peptidoglycan



will stain

Gram positive bacteria

outer membrane



will not stain

Gram negative bacteria

Archaea

- Usually extremophiles
  - Methanogens
  - Thermophiles
  - Halophiles

Extreme Thermophiles
“Heat-loving” *Archaea*

Extreme Halophiles
"Salt-loving" *Archaea*

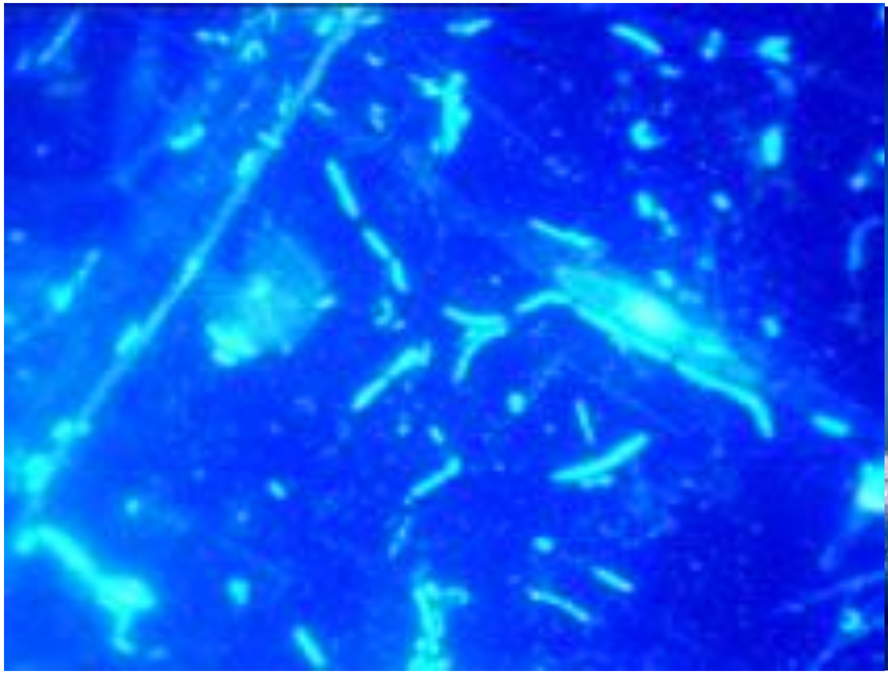
Australian Salt Lake

Methanogens
Methane-generating *Archaea*

Occur in oxygen-free habitats

***E.g.*, swamp mud, anerobic treatment**

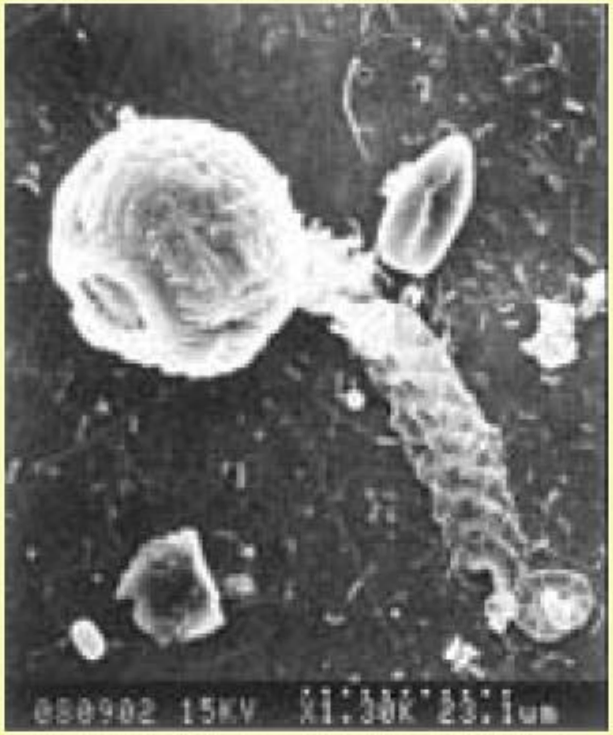
Ice Bacteria & Archaea

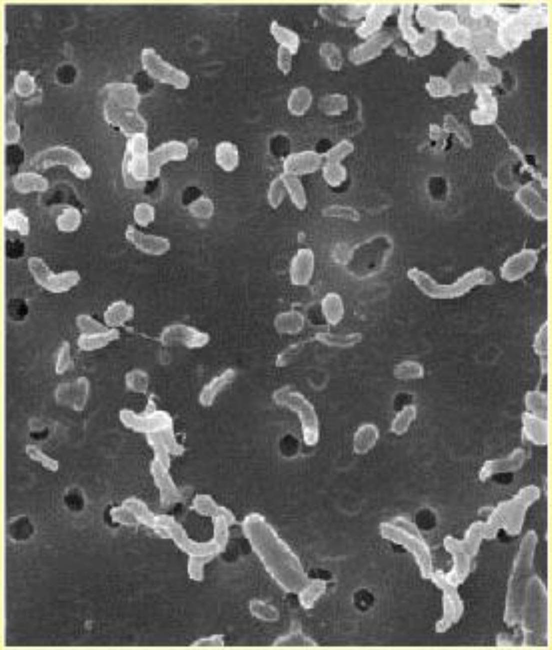


Cave Bacteria

Sometimes reaching acidity of pH 0.5

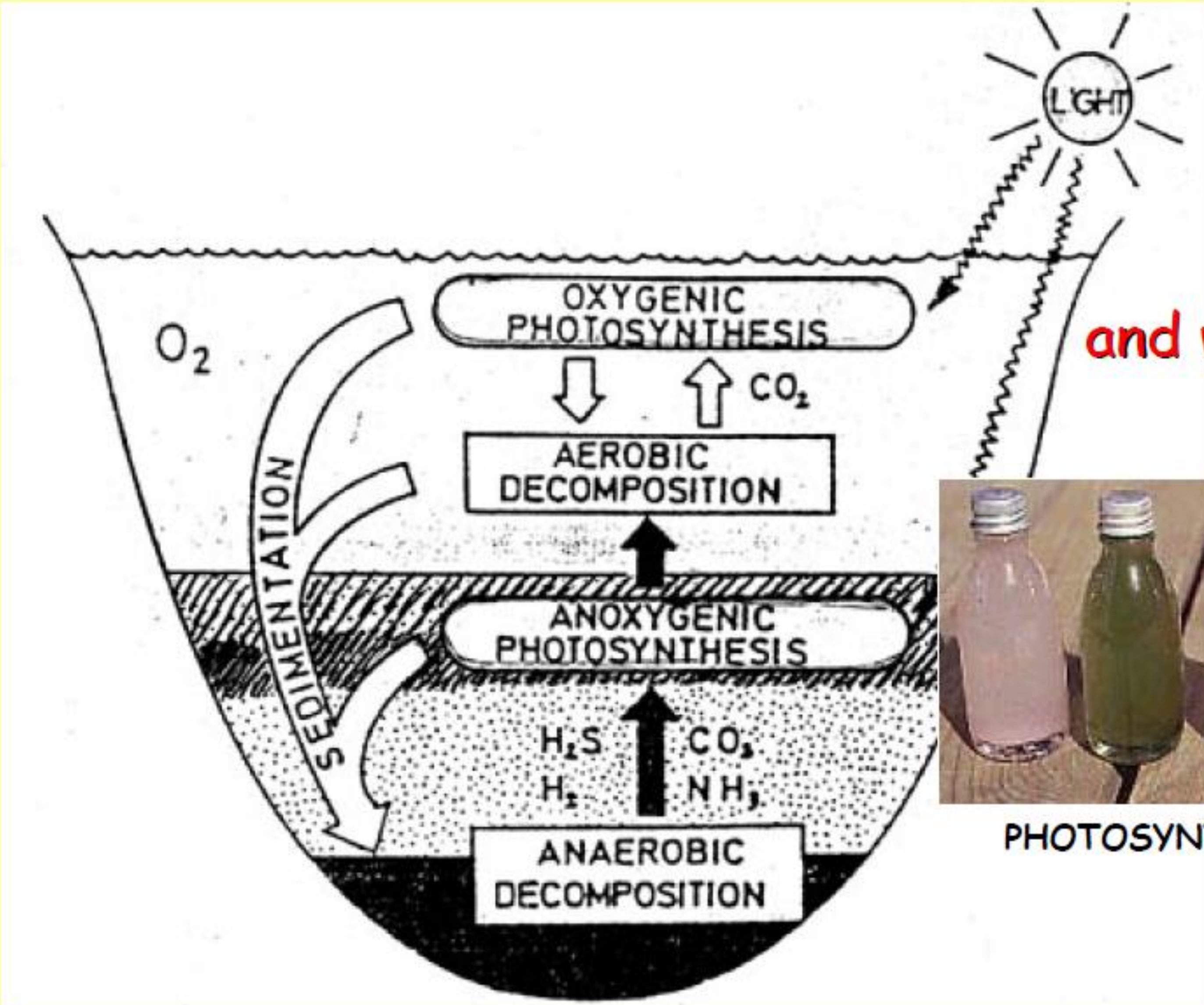
Microbes are small





but…

sometimes they have conspicuous colors in pure cultures...

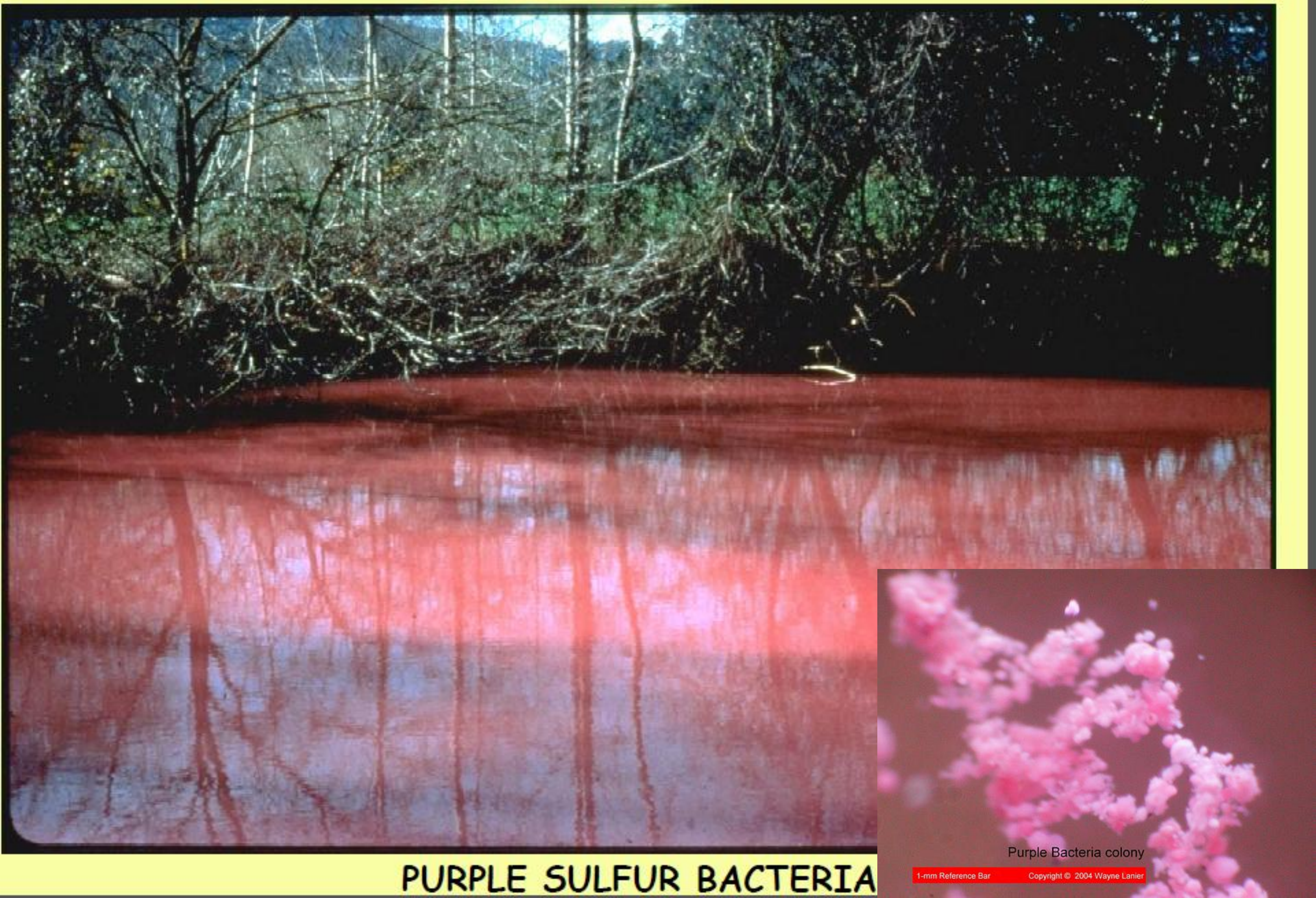


and we can see them easily ...

PHOTOSYNTHETIC SULFUR BACTER

...making visible the invisible!

LAKE CISO, SPAIN



PURPLE SULFUR BACTERIA

Formation of zones in a typical lake or pond

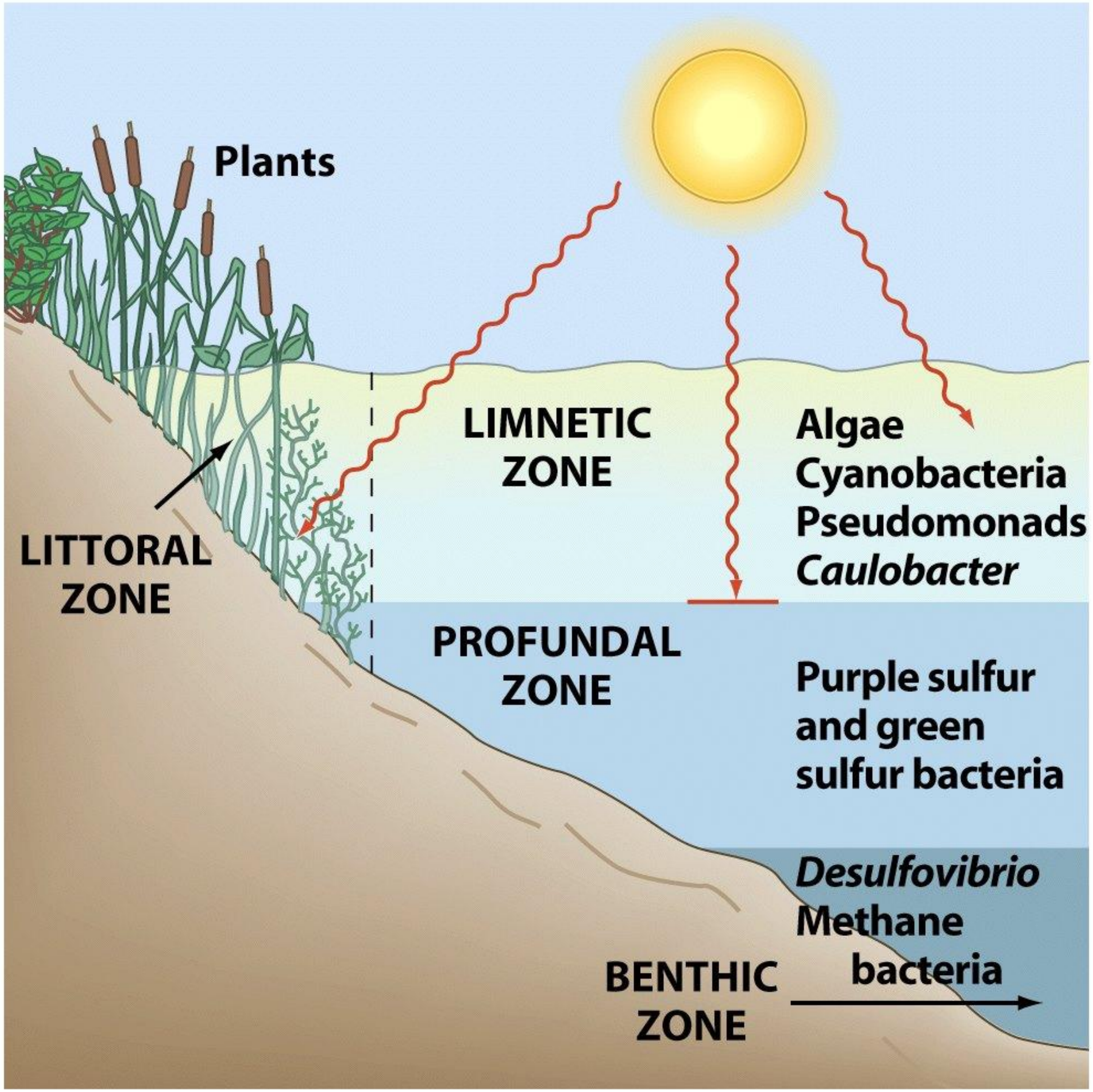


Figure 25-14 Microbiology, 6/e

...making visible the invisible!

RIO TINTO, SPAIN

IRON BACTERIA

Sometimes we cannot see them, but we can count them

Biomass of Microbes in the Biosfere

Habitat	Population size (cells)
Oceans	1.2×10^{29}
Soil	2.6×10^{29}
*Subsurface	4.9×10^{30}
Global	5×10^{30}

Whitman et al. PNAS 1998

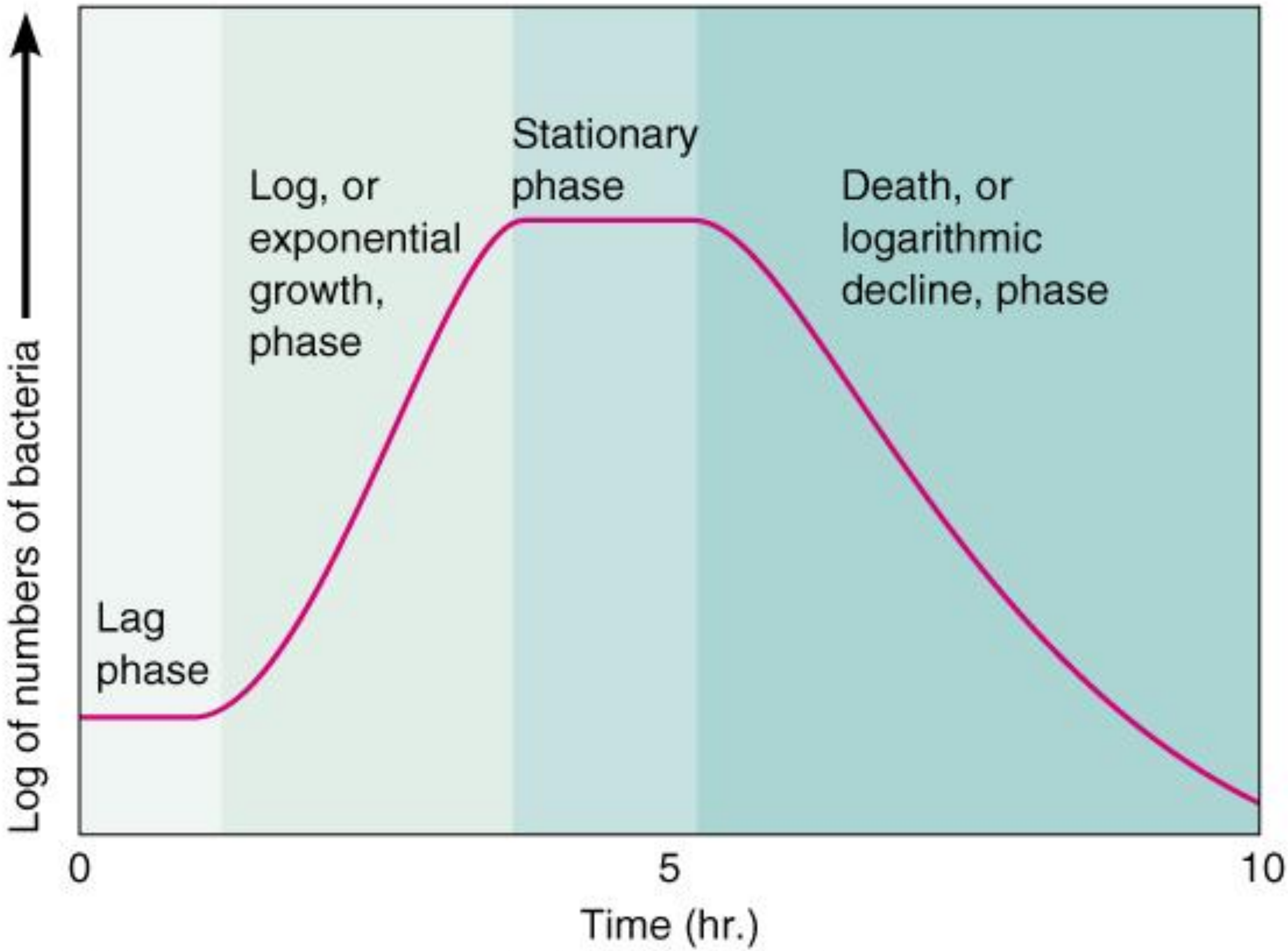
*terrestrial habitats below 8 m (grounwater included) and marine sediments below 10 cm

Biomass of Microbes in the Biosphere

Habitat	Population size (cells)	Biomass (Pg of C)	Plant Biomass (Pg of C)
Oceans	1.2×10^{29}	4	0
Soil	2.6×10^{29}	26	560
Subsurface	4.9×10^{30}	325-520	0
Global	5×10^{30}	**350-545**	**562**

Whitman et al. PNAS 1998

1 Pg = 10^{15} g


Log of numbers of bacteria
Lag phase
Log, or exponential growth, phase
Stationary phase
Death, or logarithmic decline, phase
0
5
10
Time (hr.)

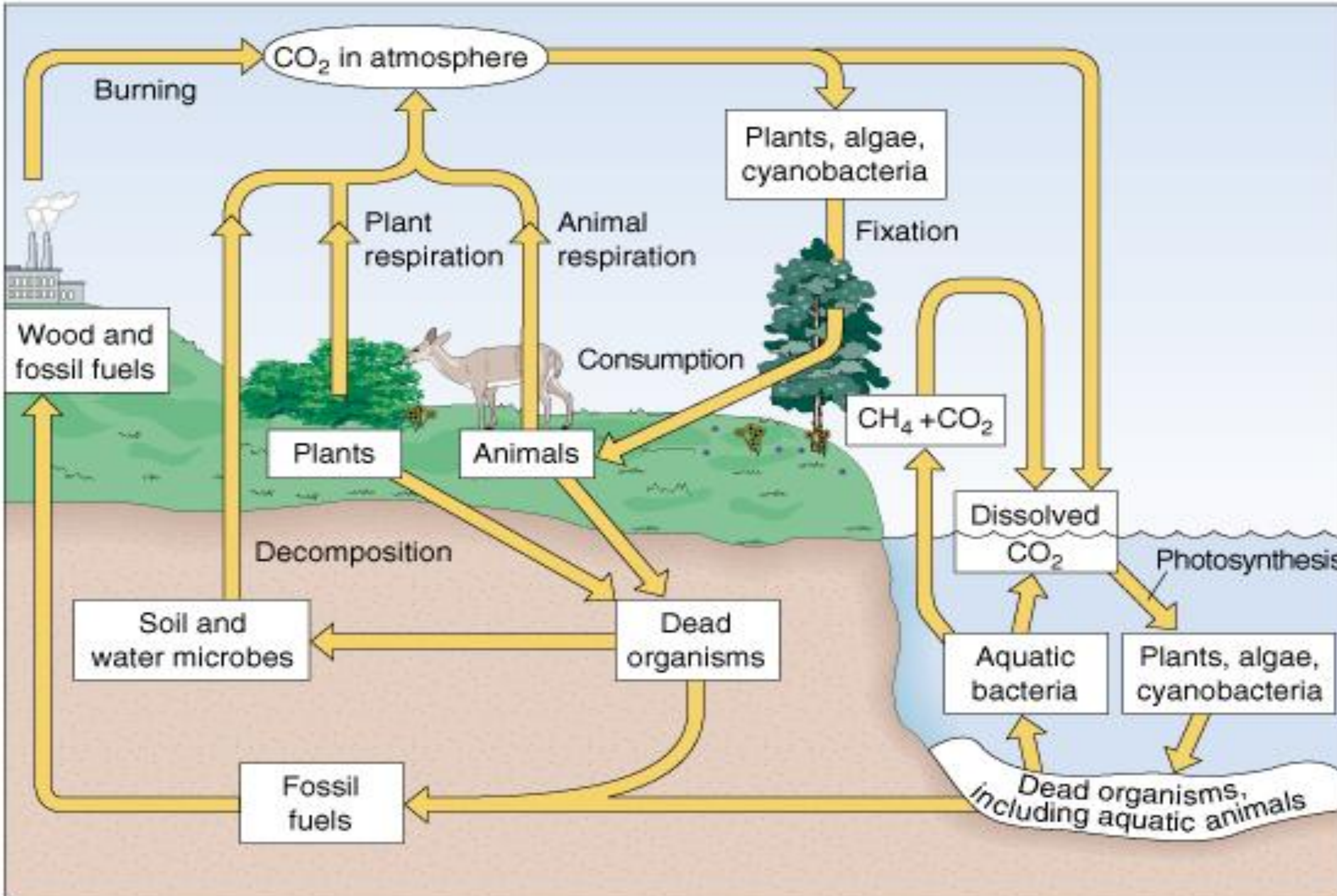
Bacterial Growth Curve

- ***Lag-phase*** During this phase bacteria become acclimated to their new surroundings. They are digesting food, developing enzymes and other things required for growth.
- ***Accelerated Growth-phase*** The bacteria are growing as fast as they can, since there is an excess of food. The cells are mostly dispersed, not sticking together.
- ***Declining Growth-phase*** Reproduction slows down because there is not an excess of food. A lot of food has been eaten and there are now a large number of bacteria to compete for remaining food, so the bacteria do not have enough remaining food to keep the growth rate at a maximum.

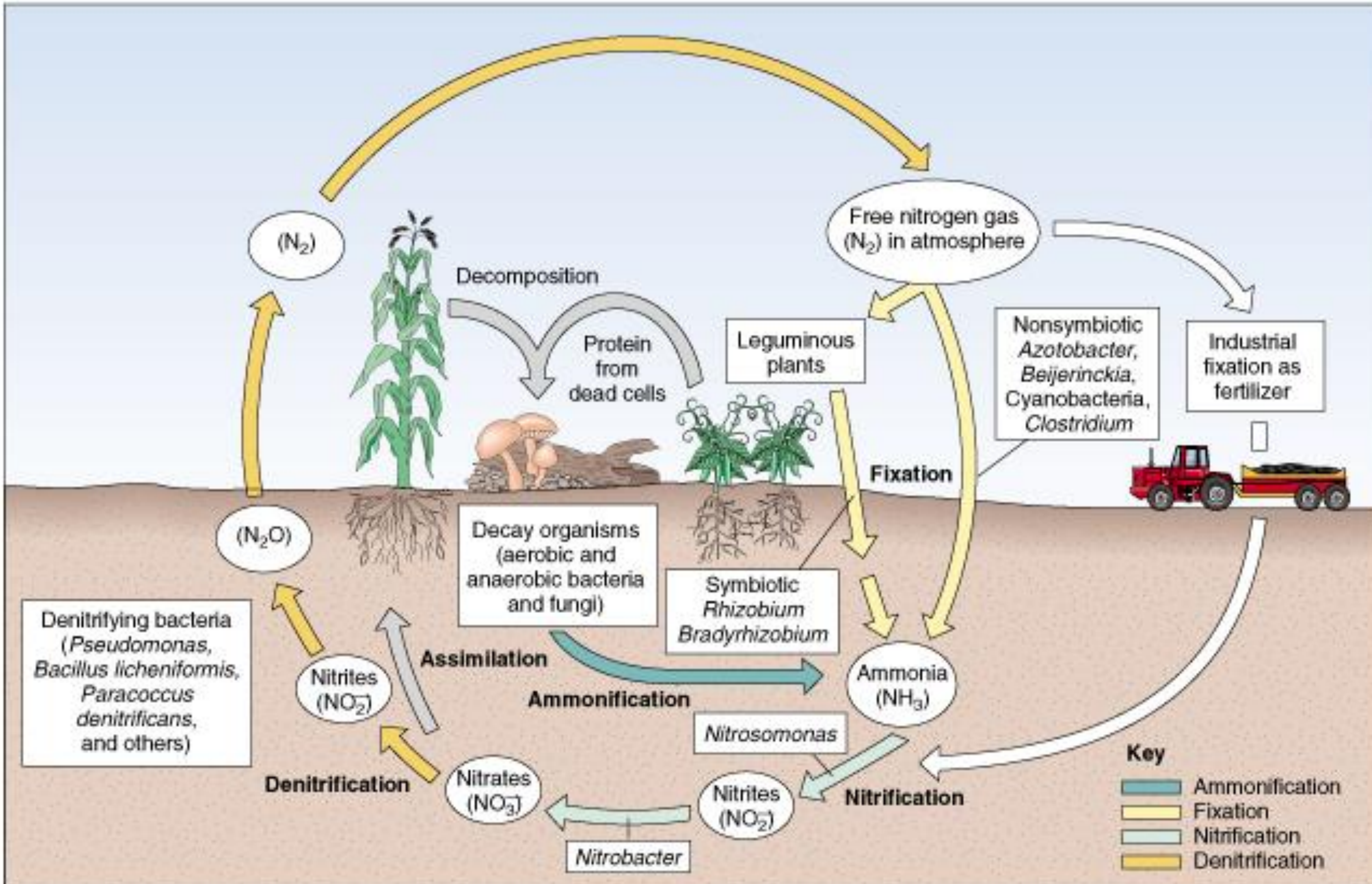
Bacterial Growth Curve

- ***Stationary-phase*** The number of bacteria is the highest possible, but not much food is left, so the bacteria cannot increase in number. There is some reproduction, but some cells are also dying, so the numbers of bacteria remain relatively constant. The bacteria have now lost their flagella and have a sticky substance covering the outside of the cell, allowing them to agglomerate into floc. In fact, the floc gets big enough that if aeration and mixing were stopped, the floc could settle to the bottom.
- ***Death-phase*** The death rate increases with very little if any growth occurring. Therefore, the total number of living bacteria keeps reducing. The bacteria are just trying to keep alive.

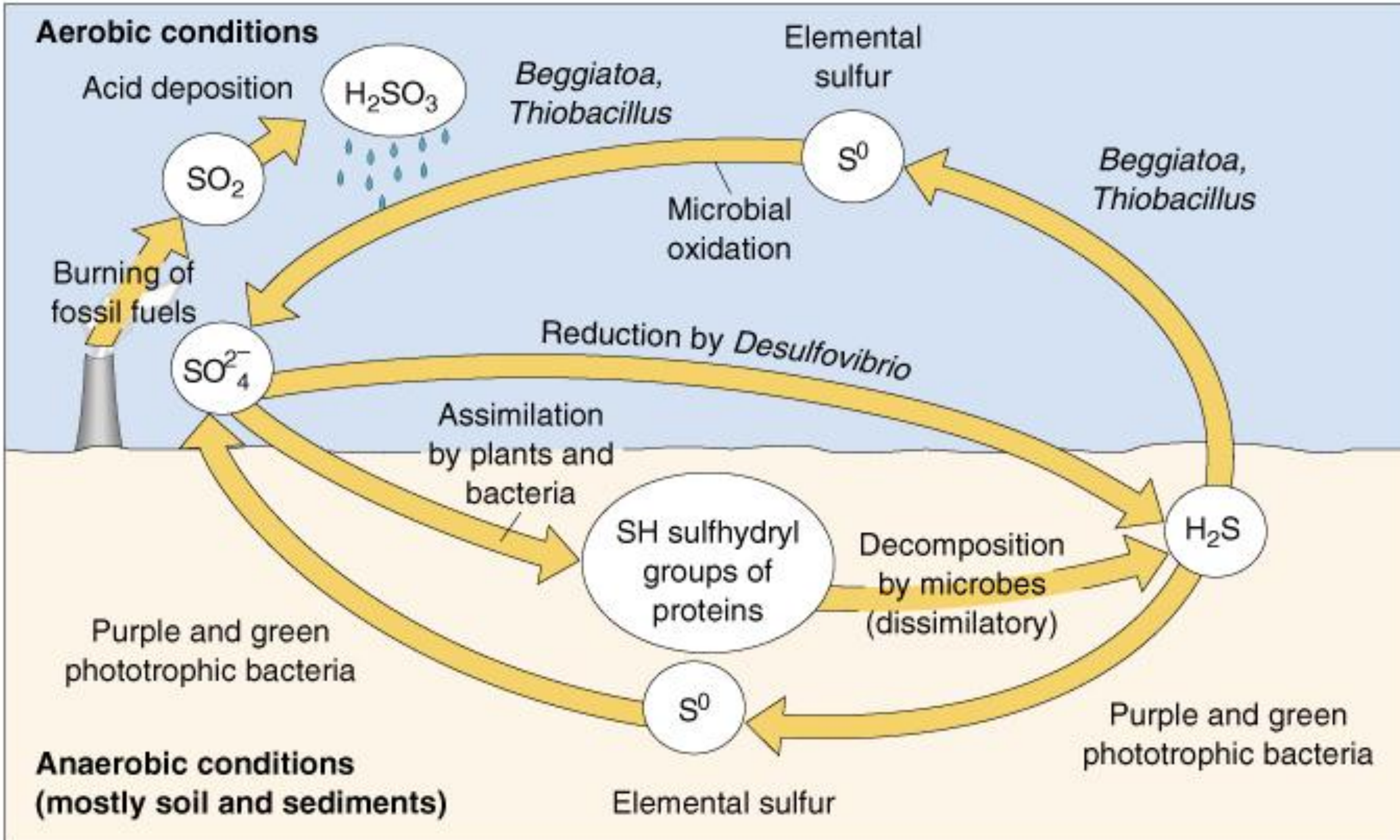
Carbon cycle/recycle

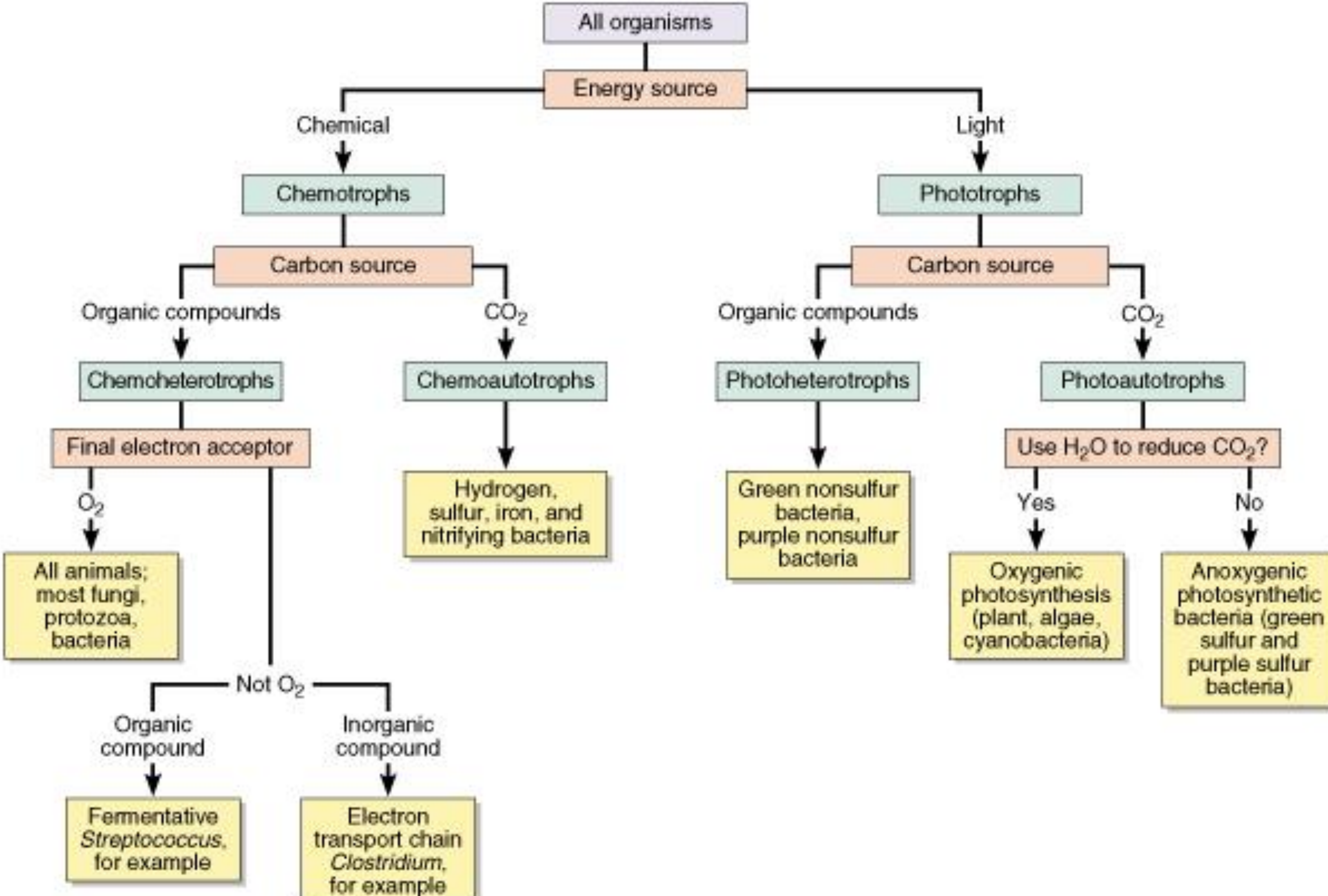


Nitrogen Cycle/Recycle



Sulfur Recycle




All organisms
Energy source
Chemical
Light
Chemotrophs
Phototrophs
Carbon source
Carbon source
Organic compounds
CO_2
Organic compounds
CO_2
Chemoheterotrophs
Chemoautotrophs
Photoheterotrophs
Photoautotrophs
Final electron acceptor
Use H_2O to reduce CO_2?
O_2
Yes
No
Hydrogen, sulfur, iron, and nitrifying bacteria
Green nonsulfur bacteria, purple nonsulfur bacteria
All animals; most fungi, protozoa, bacteria
Oxygenic photosynthesis (plant, algae, cyanobacteria)
Anoxygenic photosynthetic bacteria (green sulfur and purple sulfur bacteria)
Not O_2
Organic compound
Inorganic compound
Fermentative *Streptococcus*, for example
Electron transport chain *Clostridium*, for example