BIO 2500	AUTOTROPHIC PROKARYOTES
SA #16-17	Stern, Chapter 17

LOOKING BACK: Although *botany* is largely the study of "plants," we have learned that classification of "plants" has undergone many changes over the past three centuries. What had been a two-kingdom classification of all of life (Plantae and Animalia) has split into six kingdoms. Autotrophic, or plant-like species now occupy four of the six kingdoms–Plantae, Protista, Bacteria, and Archaea. We have studied some of the challenges faced by both evolutionary and creationist biologists in developing a natural classification of life. Now, we begin our survey of plant-like organisms using the contemporary six-kingdom system.

READING: Read Chapter 17; pp. 292-308. First, study the Chapter Outline, p. 292 and the Summary, p. 314. We will not include "Viruses." Use the **EMPHASIS** and **Study Outline** below for orientation.

EMPHASIS: This Study Assignment in Chapter 17 will examine the following themes:

1. Distinguish Kingdoms Bacteria and Archaea from Eukaryota and from each other.
2. What forms of nutrition, metabolism, and reproduction are represented in the prokaryotes?
3. Evaluate the claim that prokaryotes are simple forms of life that are closely related to the primordial cells that first appeared on Earth.

STUDY QUESTIONS: – Answer Questions 1 - 3 as prerequisite to Question #4.

1. Why do botanists claim the Bacteria, Archaea, and Protista even though they are not true "plants?"

2. Name three groups of the Archaea (Archaebacteria) and discuss their metabolism, habitats, and their ecological and economic significance.

3. The chapter discusses three major groups – Eukaryotes, Bacteria, and Archaebacteria. To which group do each of the following belong: (a) Cyanobacteria (e.g. *Anabaena, Nostoc*), (b) *Methanococcus* (a methane bacterium), (c) Protozoa (*e.g.* ciliates such as *Paramecium*) and (d) Algae (*e.g. Spirogyra*)?

4. DISCUSSION–APPLICATION QUESTIONS: [Come prepared for Group Discussion]

   a. **Evolution Postulate: All life evolved from one (or a few) simple kind(s) of organism(s). Possible "simple" ancestoral forms**: Cyanobacteria (*e.g. Anabaena*), the Prochlorobacteria (*e.g. Prochloron*) , and Methanobacteria (e.g. *Methanococcus*) are considered by evolutionary biologists to be "simple" or "primitive" organisms more closely related to the original primordial forms of life on Earth. ➤Analyze this position based upon what you are learning about metabolism and structure of each of these prokaryotes, and present an alternative view. See text and resources in Study Outline.

   b. **Origin of Eukaryotes, Bacteria, and Archaebacteria?** "The data shows these three cannot be placed into an ancestor-descendant relationship. (ReMine, 1993. *The Biotic Message*, p263) "They are basically too different for any one to have evolved directly from any of the others. And yet they go about their business in a sufficiently similar fashion, as to suggest beyond doubt that all three learned it from one teacher. (Edey and Johanson, 1989. *Blueprints: Solving the Mystery of Evolution*, p. 321). ➤Present support (or opposition) to the above claims from what you are learning about (a) *Methanococcus*, (b) Prochlorobacteria and *Prochlorococcus* (Box, page 17.4 and Figure, page 17.5).

STUDY OUTLINE: Chapter 17 Kingdom Bacteria and Kingdom Archaea

I. INTRODUCTION:

A. WHY DO BOTANISTS CLAIM KINGDOMS BACTERIA and ARCHAEA

1. Evolution Perspective -- they are viewed as closely related to evolutionary ancestors of plants
2. Creation Perspective: What can we learn from phylogenetic classification?
   a. Phylogenetic model organizes plant forms according to morphology (convenient for study)
   b. Phylogenetic classification can be tested by what we learn from fossil and current species

B. OUR APPROACH -- General Survey -- more detail in Microbiology

II. CLASSIFICATIONOF PROKARYOTES – **Click on "Internet Botany –** (also linked to "Schedule" Page):

A. KINGDOM ARCHAE – *archae* = "primitive" {as in archaic}

1. METHANOGENIC -- anaerobic methane-generating (O_2 kills them!)

   a. H_2 gas + CO_2 --> CH_4 + Energy a. "swamp gas" -- combusts at 5-6%
      b. "greenhouse gas" -- rice paddies, feedlots, wetlands
      c. organic waste digesters --> methane as fuel

   b. *Methanococcus* -- ocean floor geothermal vents

2. HALOPHILIC -- live in salt-evaporation ponds
   -- Photosynthetic; have bacterial rhodopsin pigment

3. THERMOPHILIC (Sulfolobus bacteria); hot sulfur springs; *Thermus aquaticus* used in PCR tech.

B. KINGDOM BACTERIA (or EUBACTERIA) – *eu* = "true" (true bacteria)

1. Bacteria – common bacteria (e.g. our "microflora";and, parasites and photosynthetic bacteria)
2. Cyanobacteria – blue-green bacteria ("blue-green algae"); *e.g. Anabaena, Prochlorococcus*, *Nostoc*
3. Prochlorobacteria – prokaryotic "green bacteria" – e.g. *Prochloron*

C. BASIS FOR CLASSIFICATION

1. CHEMICAL COMPOSITION
   a. CELL WALL COMPOSITION – Do they have +N-acetylmuramic acid (a peptidoglucan)?
   b. PIGMENTS – e.g. photosynthetic pigments
   c. GRAM STAIN – + or - depending upon whether lipid covering on cell wall prevents uptake of stain (Gram negative) or absence of lipid permits stain to enter (Gram positive)
2. NUTRITION – saprophytic, parasitic (secrete toxins), mutualistic, photosynthetic, chemosynthetic
3. MORPHOLOGY – cell shape (see III. A. 2.) and projections (flagella or pili; Figure 17.3)
4. +/- SPORE FORMATION -- *e.g. Clostridium* can survive boiling in improperly canned food

III. CHARACTERISTICS OF PROKARYOTES (See Internet Links)

A. COMMON FEATURES

1. GENETIC ASPECTS:
   a. No nuclear membrane (or other organelles)
   b. No chromosomes with histones -- instead, a *nucleoid* (1 circular, DNA molecule)
   c. No mitosis or meiosis – instead, *fission* (DNA replication and cytoplasmic division)
   d. *Plasmids* – smaller circular DNA molecules
   e. Ribosomes – smaller (70 to nearly 80S) than Eukaryotic cells (80S)

2. MORPHOLOGY
   a. Cell shape used in classification – *coccus, bacillus, spirillum*
   b. Unicellular, clusters, or colonies (not multicellular)

3. ASEXUAL REPRODUCTION – Fission, Fragmentation, or Budding

4. GENETIC RECOMBINATION
   a. *Conjugation* -- exchange of DNA of plasmids via *pilus*
   b. *Transformation* -- DNA taken up by cells from medium
   c. *Transduction* -- virus introduces bacterial DNA from previous host cell
      NOTE*: Lateral gene transfer* (among species!) as in a. – c. above has major implications.
      Question: Can you suggest one implication?
   d. *Mutation* -- one in every 200,000 genes; evidenced in antibiotic resistance

B. DIFFERENCES between BACTERIA and ARCHAEA , compared to Eukaryotic Kingdoms

Characteristic	BACTERIA	ARCHAEA	EUKARYOTA
Cell walls have Peptidoglycans (e.g. muramic acid)	YES	NO	
RNA Polymerase	Unique	Similar	
Introns (non-coding DNA seq.)	Absent	Present	
Ribosomes	70S; shape not unique	>70–<80S; unique shape [1]	80S;shape not unique [1]
Unique Genes	No	Yes [2]	No

[1] Eukaryotic ribosomes are heavier because they have 1 extra RNA sequence on each of their 2 subunits; Archaea ribosomes are between 70S and 80S because they have only 1 of the 2 additional RNA sequences present in Eukaryota. The ribosomes of Bacteria are lightest because they lack both sequences.

[2] *Methanococcus* (see II. A. p. 17.2) – 56% of the 1,738 genes of its genome that are unique to biological science.

IV. CYANOBACTERIA

A. LOCATIONS – in freshwater systems, they are similar to "green algae" in habitat
– more so in stagnant pools, gutters, birdbaths; favored when N is limiting factor [Why?]
– in marine ecosystems, see the following excerpt:

> In open ocean ecosystems, carbon fixation is dominated by the closely related marine cyanobacteria *Prochlorococcus* and *Synechococcus.* Together they have been shown to contribute between 32 and 80% of the NPP in the oligotrophic oceans. *Prochlorococcus*, discovered...[in 1988], is an extremely small, **Chl b-containing cyanobacterium** that sometimes constitutes up to 50% of the photosynthetic biomass in the oceans. Various *Prochlorococcus* strains are known to have significantly different conditions for optimal growth and survival. Strains which dominate the surface waters [down to ~100 m], for example, have an irradiance optimum for photosynthesis (i.e. PAR) of 200 μmol/m^2/sec , whereas those that dominate the deeper waters [100-200 m] photosynthesize optimally at 30–50 μmol/m^2/sec . Isolates with a high Chl b2/a2 ratio (high B/A ecotype) are much more efficient at utilizing low light than those with a low Chl b2/a2 ratio (low B/A ecotype) but are incapable of growth at higher irradiances.
>
> – Sallie Chisholm's Lab at MIT *Photos. Research* 70: 53–71, 2001.

B. DISTINCTIONS:

1. PIGMENTS -- Chlorophyll *a* + Carotenoids (like algae and plants) [But see Box above.]
-- Phycobilins ----phycoerythrin (red) + phycocyanin (blue)
2. PHOTOSYNTHESIS – *oxygenic* (*i.e.* produce O_2 as product)
3. N_2 FIXATION (some) -- *heterocysts* (cell "differentiation" to separate two metabolisms)
-- separates O_2-producing photosynthesis from N_2 fixation

> Summary Reaction: $N_2 + 3\ H_2$ --nitrogenase--> $2\ NH_3$
>
> > NOT SIMPLE METABOLISM!! -- Complex enzymes and pathways
>
> *e.g.* NITROGENASE enzyme has m.w. = 300,000; two components
>
> Component I = 220,000 with 32 Fe atoms and 2 Mo atoms
>
> Component II = 60,000 with 4 Fe atoms
>
> Some N-fixing bacteria have leghemoglobin (Why would this be beneficial?)

C. REPRODUCTION

1. Fragmentation and Fission – no (known) sexual reproduction
2. akinetes -- resistant for surviving unfavorable environments

VII. PROCHLOROBACTERIA -- "Green Bacteria"

A. PIGMENTS: -- Chlorophyll *a, b*, carotenoids, BUT no phycobilins

1. Same pigments as Kingdom Plantae!!
2. Origins implications?

B. ENDOSYMBIONT HYPOTHESIS:

CLAIM: Chloroplasts and other organelles are descended from "captured" prokaryotic cells

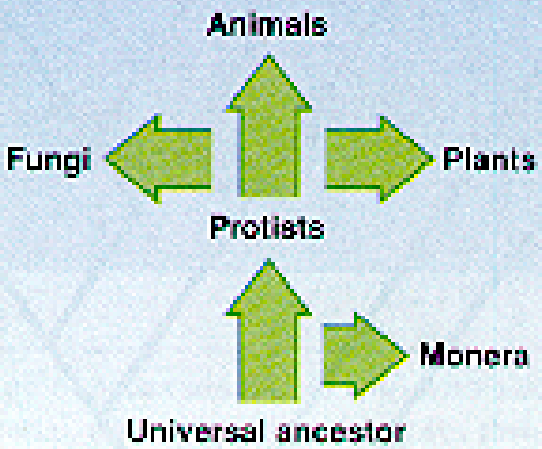
EVIDENCE: Prokaryotic cells (e.g. Prochloron) have similar DNA, ribosomes, and size as chloroplasts

1. Evolution -- Is this the origin of eukaryotic cells?
2. Creation -- Is this an example of multiple usage of components by intelligent designer?

AN UPDATED TREE OF LIFE

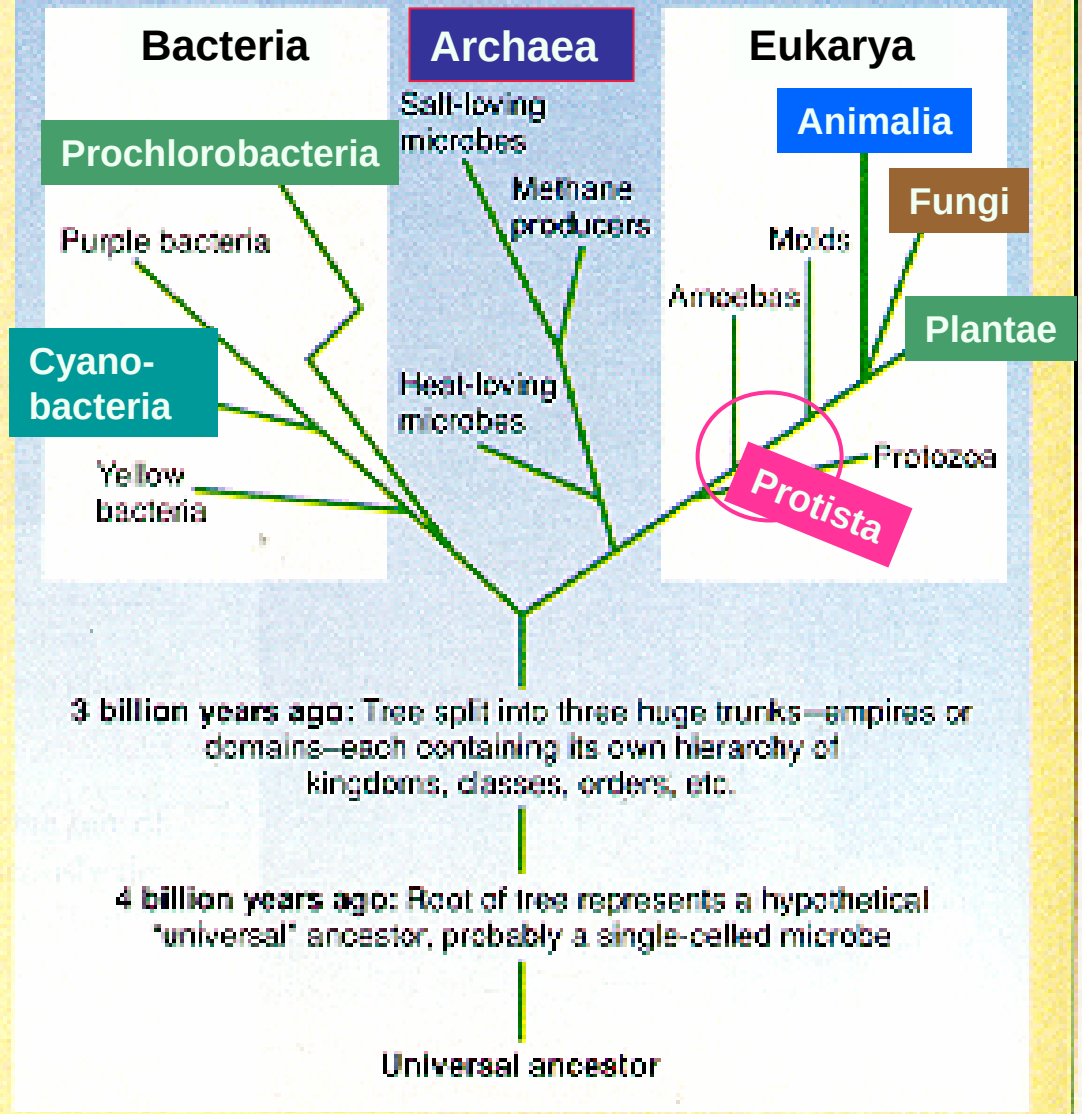
The animal and plant kingdoms, were once thought to contain all living things, but are now seen as just the tips of one branch of a more complex tree of life. Here's how the old and new trees compare:

Old Tree of Life



See also Figure 16.4

New Tree of Life



Source: Biological Sciences and Carl Woese, University of Illinois

General Botany **BIO 2500** **Stewardship & Progress Quiz #4**

NAME(S) of those in attendance: _____

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4. DISCUSSION–APPLICATION QUESTIONS: Use group knowledge, open notes/text (10 min):

Evolution Postulate: All life evolved from one (or a few) simple kind(s) of organism(s).
Possible "simple" ancestoral forms?
Cyanobacteria (*e.g. Anabaena*), the Prochlorobacteria (*e.g. Prochloron*) ; and Archaebacteria such as Methanobacteria (e.g. *Methanococcus*) are considered by evolutionary biologists to be "simple" or "primitive" organisms more closely related to the primordial forms of life.
➤Analyze this position by addressing three of the following specific contentions based upon your study of the text, SA #16-17 Study Outline, and lecture slides if available on the S:\drive:

i. The prokaryotic cell has less complex membrane structure than eukaryotic cells

ii. The Kingdom Archae, have representatives such as *Methanococcus* and *Thermus aquaticus* that occupy very stressful conditions on planet Earth.

iii. Cyanobacteria are evolutionarily "primitive" and close to ancestoral autotrophs because they lack cell differentiation and lack complex matabolic processes

iv. Prochlorobacteria, as their name implies are seen as "early or first-chlorophyll-bearing bacteria," would be expected to have primitive light-absorbing pigments.