Prokaryotes and the basic needs of organisms

1. **The basic needs and ecological roles of organisms**
2. **Prokaryotic cell structure (and comparison with eukaryotes)**
3. **Evolutionary history of prokaryotes; importance of cyanobacteria and photosynthesis**
4. **Diversity and abundance of modern prokaryotes**
   - **Cyanobacteria**
   - **Archaeabacteria**

- **Cell membranes….**

Table 2.1 Naturally Occurring Elements in the Human Body

- **The top 4 (O, C, H, and N) make up 96% of living matter on earth**
- **25 of the 92 natural elements are essential for life**
- **In addition to essential chemical elements (the building blocks), all organisms need a source of energy (to power cellular processes, including molecular construction), and a liquid medium for chemical reactions**

Table 2.1 Naturally Occurring Elements in the Human Body

Symbol	Element	Atomic Number (See p. 34)	Percentage of Human Body Weight
O	Oxygen	8	65.0
C	Carbon	6	18.5
H	Hydrogen	1	9.5
N	Nitrogen	7	3.3
Ca	Calcium	20	1.5
P	Phosphorus	15	1.0
K	Potassium	19	0.4
S	Sulfur	16	0.3
Na	Sodium	11	0.2
Cl	Chlorine	17	0.2
Mg	Magnesium	12	0.1

Trace elements (less than 0.01%): boron (B), chromium (Cr), cobalt (Co), copper (Cu), fluorine (F), iodine (I), iron (Fe), manganese (Mn), molybdenum (Mo), selenium (Se), silicon (Si), tin (Sn), vanadium (V), and zinc (Zn).

The three basic requirements of life

1. Energy source
2. Organic (carbon-based) molecules
3. Liquid medium

Metabolic relationships to oxygen

- Obligate aerobe-need oxygen
- Facultative aerobes-can do both (use O_2 if it is present, or fermentation)
- Obligate anaerobes-cannot have oxygen

- Early prokaryotes were obligate anaerobes. What happened to them as photosynthesis became common?

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General characteristics of prokaryotes

- Binary fission
- Budding or fragmentation
- Rapid mutation rate
- Conjugation: prokaryotic 'sex' – passing genetic material
- Transformation: they Can take up free naked DNA from environment (probably rare due to instability of free DNA)
- Transduction: via a virus, passes DNA to another bacteria

Prokaryote characteristics

- Small cells (1-10 um) (though one is 700 um!)
- Unicellular
- Can form colonies
- Cell walls generally made of peptidoglycan rather than cellulose and/or chitin
- Capsule is around the cell wall and is generally composed of polysaccarhides or proteins

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Some major episodes in the history of life. One very important one: the evolution of photosynthesis in prokaryotes.

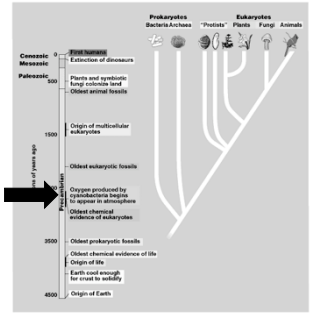
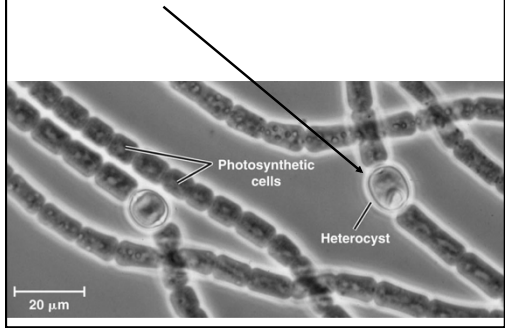
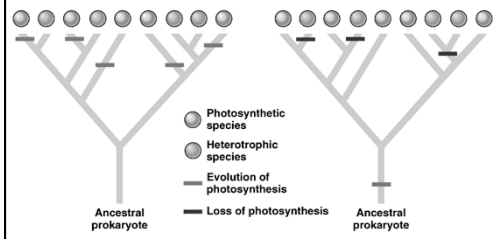


Figure 27.10 One of the most independent organisms on earth: Cyanobacteria (*Anabaena*). This bacterium is colonial, with some cells specialized for specific functions, such as heterocysts for nitrogen fixation.



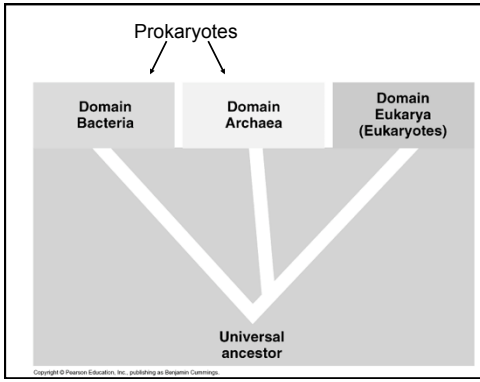
Contrasting hypotheses for the taxonomic distribution of photosynthesis among prokaryotes. Which hypothesis is most likely?



Hypothesis (a): Photosynthesis evolved many times.

Hypothesis (b): Photosynthesis evolved once.

parsimony



Cyanobacteria: a critical change factor on Earth

Photosynthetic bacteria come in two general groups: Cyanobacteria and Purple/ Green Bacteria

Cyanobacteria are Important in global carbon and nitrogen cycles

About 7500 species – only about 200 non symbiotic

Cyanobacteria

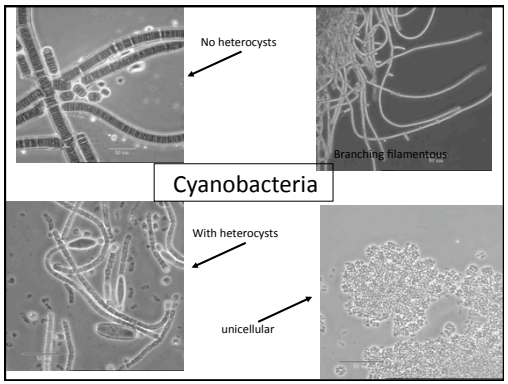
- Chlorophyll a and Phycobilins: phycocyanin (blue), phycoerythrin (red)
- Storage product *glycogen*
- Within the cell are layers of membranes - photosynthetic *thylakoids*. Look like chloroplasts, and same size *(10 um). Cyanobacteria probably gave rise to eukaryotic chloroplasts (those without cell walls)
- Very similar in biochemistry and structure to chloroplasts of red algae
- Color due to a mucilaginous sheath to bind cells/filaments together – sheath is pigmented. Cells are independent within sheath

Cyanobacteria

- Some can move by gliding, away from parent colony
- Some have gas vesicles (eg. Plankton – buoyancy)
- Some can fix nitrogen gas to ammonium – can occur within heterocysts-big cells with thick walls containing glycolipid which impedes O2 diffusion into cell. N2 fixation is an *anaerobic* process.
- Can also form *akinetes*-spores resistant to heat, drought etc.

Cyanobacteria

- Growth forms:
  - –Single cells
  - –Branched filaments (most common)
  - –Plates (uncommon) or irregular colonies
  - –Stromatolites: when colonies bind CaCo3 into domed structures



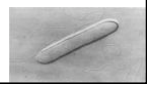
Cyanobacteria

- Stromatolites
  - –Geol record of 2.7 billion yrs!
  - –Form when cyanobacteria bind CaCo3 rich sediments
  - –Now they form in shallow pools in hot/dry climates (eg. Australia)
  - –Abundant in early earth – played an imp role in elevating free O2 in atmosphere.

Cyanobacteria

- Lifestyle
  - Can live in very inhospitable environments
  - Hot springs to Antarctica
  - Most are symbiotic (endosymbionts) – sponges, lichens etc.
  - Some live inside the hollow hairs of polar bears! Giving them a yellowish/greenish color – especially in zoos.

Purple and Green Bacteria



- Photosynthetic process and pigments differ from cyanobacteria
- No O2 during photosynthesis (anoxygenic)
- Some use sulfer as electron donors
- Only one photosystem
- Probably gave rise to photosystems I and II in cyanobacteria, algae and plants

Many Archaea are extremophiles

•Halophiles, thermophiles, methanogens

• Key members of oceanic picoplankton (<1 micrometer), outnumbering all other oceanic organisms!

Archaea

•**Halophiles:** great salt lake and dead sea

•**Methanogens** – prokaryotes (archaea) that make natural gas (anaerobic). Cows have them in their gut (help degrade cellulose); cows belch 50 liters of methane per day! Common in sewage treatment plants and in the deep sea

•**Thermophiles** are anaerobes, use sulfer, live at 110 degreesC! Also live in hydrothermal vents in the deep sea.