

## Introduction to the Lectures, Fall, 2009 -

These Lectures consist of the overhead notes used for the oral lectures in the 2009 version of MCDB 4350/5350, "Microbial Diversity and the Biosphere." Each "Lecture" is not a single lecture, but a series, to address a general topic. The notes can be downloaded from the class Web site. In some cases the class notes will contain material added at the last moment, and may not be reflected in the Web-available text. In general the Lectures will be provided as PDFs. If you have questions/suggestions on how to better provide the information, please bring them up.

### Lecture 1: Introduction to Microbial Diversity

- Please tell us who you are:

On paper slips: list: -Name  
-E-mail address  
-Year  
-Major  
-Professional intent

Note -- Schedule is a projected outline, unlikely to be the real thing since presentation times and discussions are hard to judge

-- Examination times are fixed unless by class consensus.

---

**Read: Text, Chapter 1 for background, pp. 26-33 on visualizing microbes and the consequences of small (really small!) size. Note that the "resolution" (what means?) of the light microscope is only ~0.2 microns. Note in passing for future reference:**

- historical roots (remarkably recent in history);
- "Koch's Postulates" (what if you can't culture?);
- critical importance of culture to microbiology;
- Gram stain method (lots of medical importance).

1. “Microbial diversity” reflects the different ways in which microbial organisms:

- Obtain energy and nutrients
- Respond to the environment and other organisms
- Regulate genes and metabolism
- Grow and divide, and just tick-over
- Survive adverse conditions – resting states
- Differ evolutionarily and relate to one another

A. Microbial organisms have the same needs as large organisms - “mAcrobes”. Indeed, most of biological diversity (**what means??**) is microbial in nature; historical focus aside, most eucaryotes are microbial, as well.

B. Note the differing biological strategies manifest by large (e.g. plants and animals) macrobial and microbial phenotypes:

1. Large creatures are comprised of different cell-types, differentiated from a **common genome**, that collectively and **interdependently** form the functioning community (the macroorganism). I.e. you get the same organism again and again.
2. The constituents of communities of microbial organisms are selected upon by the local chemistry and physical properties, and collectively and interdependently form the functioning community (e.g. a "biofilm"). The microbial world is usually not “single-celled”.

C. In the mAcro case the genome of the particular organism carries the information for the required cell-types; in the micro case the environment selects from the global “metacommunity” for the suite of required cell-types. Hence the composition of a microbial community has a very large stochastic component – and all differ at least subtly – and they all are continuously changing – and they never reset.

2. Traditional large-organism biology has focused on organism shape and isolated cells: general biology texts usually paint “procaryotes” (Bad Word!) as simple cells:

A. Common descriptions:


rods (bacilli, s. bacillus; note contrast with *Bacillus*, a “genus” name)

cocci (s. coccus)

“spirals” (misnomer—really helices)

“vibrios” (partial helices)

Chains (strepto-, e.g. streptococci)

Tetrads (  ) and higher regular clusters

Rosettes



e.g. *Planctomyces*

B. But many other forms occur—e.g.: (Slides)

--Long filaments (> 100  $\mu\text{m}$  = 0.1 mm common, e.g. *Beggiatoa*, *Thioploca*)

- Branched filaments (e.g. *Streptomyces*)
- Star-shaped (*Stella*)
- Amorphous-shaped (e.g. *Sulfolobus*)
- Flat-looking (e.g. *Haloarcula*)

(Be sure that you can sketch the conspicuous cell types.)

3. General texts often emphasize individual cells, but aggregates are the common theme in nature; as in the large creature world (ours), most biomass is stuck to a surface of some sort (note marine/water exception – but how is it that life stuck to a surface [e.g. landmass] can develop so much more profusely than in the planktonic state?)
4. Seldom do organisms in nature occur in isolation, “free-living” cell-types: Microbes form complex “**communities**” (ensembles of different organisms—in contrast to a “**population**,” which refers to a collection of the same type of organism)
5. Most microbes in nature are attached to surfaces and associated with communities—“**biofilms**” and “**mats**”—containing interdependent (“syntrophic”) suites of organisms (“syntrophs”) that often cannot be grown in pure culture. (Just like it is hard/impossible to culture most human differentiated cell lines.)

Note differentiated states vary in environment-dependent ways, e.g. *Saccharomyces cerevisiae*, the “budding yeast”, when starved for N becomes filamentous rather than “yeast” in form.

6. Highly variable in size: commonly 1-10 $\mu\text{m}$  in diameter, but some are visible to the naked eye (e.g. *Epulopiscium* gets to 100 $\mu\text{m}$  x 700 $\mu\text{m}$ ! Pic on p. 69). Others (ca. 50% of what you see in the environment by microscope) are only 0.1 - 0.3 $\mu\text{m}$  in diameter (note that volume scales with  $r^3$ !) — are they starved “normal” cells, or truly small? How to find out?

A. Communities of microbes are commonly large: e.g. meter-size blobs and strata in sediments; diffuse colonies in soils are little documented but potentially very large. In general the structures of microbial communities are little characterized, but expected to be dictated by local chemical and physical conditions rather than geography – and they are always blowing around with winds, waters and geological action.

B. “Stromatolites” are fossil manifestations of ancient microbial communities.

7. Size-terminology funky, nonstandard:

a. “nannobacteria” (sic) = “really small”

b. Planktonic terminology:

microplankton, 20-200 microns dia.

nanoplankton, 2-20 microns

picoplankton, 0.2-2 microns

etc.

c. I'll use the term "ultrasmall". No definition, but you know it when you see it (e.g. hydrothermal vent community, slides).

## 8. Structural diversity

A. Many types of cell walls— some terms you should know:

"Gram negative": Double-membrane, thin peptidoglycan wall,  
**periplasm.**

"Gram positive": Single-membrane, thick peptidoglycan wall (complex mesh probably periplasm-like in many regards)

"S-Layers," others.

(NOTE: For historical reference you need to be familiar with the "Gram reaction" - see BBM 12<sup>th</sup> pp. 27-28 (58-59 in 10<sup>th</sup>) if you are not. For all the historical import, however, it doesn't have much "phylogenetic" significance. The commonly used term "typical Gram negative" organism is an oxymoron - more on that in due course. (People who use that term are usually referring to a representative of the bacterial phylogenetic (relatedness) division/phylum now called "Proteobacteria").

B. Many different external structures, e.g.:

Flagella, pili, stalks and holdfasts, capsules, sheaths (sometimes with multiple types of organisms), etc.

C. Many different internal structures, e.g.:

“Nucleoid” (bacterial nucleus), spores, “inclusions” of energy -- reserves (e.g. sulfur, poly beta-hydroxybutyrate, glycogen, etc).

10. Metabolic diversity - switch-hitters common, capable of markedly different metabolisms. E.g. some do photosynthesis when the sun is out and eat organics at night. Traditional microbial classification has focused on metabolic traits.

Terminology (we will return-to; microbial diversity is very much chemical diversity):

A. “Chemoorganotroph” a.k.a. “Chemoheterotroph” - obtain energy and carbon from reduced organics, e.g. *Escherichia*, *Bacillus*

B. Chemolithotroph” a.k.a. “Chemoautotroph” - energy from reduced inorganics (e.g. H<sub>2</sub>S, *Beggiatoa*; Fe<sup>2+</sup>, *Gallionella*); carbon by “fixing” CO<sub>2</sub>

C. “Photoorganotroph” aka “Photoheterotroph” - carbon from organics, energy from light (e.g. *Rhodobacter*)

D. Photoautotroph” - carbon from CO<sub>2</sub>, energy from light (cyanobacteria, plants [the chloroplast is a cyanobacterium!])

11. Ecological diversity: Microbial phenotypes can occupy lots of places and conditions that might seem bizarre:

- A. Extremes of ionic strength—distilled H<sub>2</sub>O to NaCl-saturated brines (south SF Bay, Dead Sea, e.g. *Haloarcula*)
- B. Extremes of temperature—ca. -30°C to 120°C
- C. pH -- pH <0 to 11
- D. All over the planet -- from deep-subsurface to clouds in the sky, any place there is liquid water and an energy gradient

## 12. Behavioral diversity

- A. Motility and taxis -- chemotaxis, phototaxis, magnetotaxis
- B. Developmental processes -- sporulation (*Bacillus*), developmental growth phases (*Caulobacter*), metabolic differentiation (*Anabaena* “heterocysts” for N<sub>2</sub>-fixation)
- C. Communication -- between like cells (“Quorum-sensing”) and unlike (symbioses, antibiotics)

## 13. Evolutionary diversity -- the basis of it all

- A. For all the differences between different organisms, the underlying biochemistries are pretty much the same:

DNA/RNA-based information transfer

ATP / NAD(P) chemiosmosis-based energy

same (general) pathways for carbon-metabolism and biosynthesis

B. All life (on Earth) is related ancestrally.