Study Guide
MICROBIAL DIVERSITY
Brock Ch. 12, I-II

Brock Chapter 12 is about 100 pages long – and even so, it's hardly enough to cover the spectacular diversity embodied by the domain Bacteria. We will take this chapter in pieces. This study guide covers parts I and II (pages 353-398): the phylogeny of bacteria, and the proteobacteria.

1. How many major lineages of bacteria are currently known? What are these lineages called?

2. What is the most phylogenetically ancient lineage?

    a. Why is it not surprising that this lineage contains **hyperthermophilic chemolithotrophs?**

3. Note that on the tree, the proteobacteria are part of a clade that contains several other phyla: the cyanobacteria, the gram-positive bacteria, and the genus *Nitrospira*.

4. The proteobacteria contain five clades and comprise a tremendous diversity of species. These organisms do share two main characteristics: they are **gram-negative**, and they have SSU rDNA sequences that place them together, and divide them into five groups.

THUS…all of the taxa described below are GRAM-NEGATIVE.

WE WILL HIGHLIGHT A FEW OF THE MOST INTERESTING GROUPS IN THIS STUDY GUIDE AND IN CLASS; YOU WILL BE RESPONSIBLE FOR THE INFORMATION BELOW, EVEN IF YOU DON'T HAVE TO FILL IN AN ANSWER ON THIS STUDY GUIDE.

5. Look at the list of key genera under heading 12.2 (the purple phototrophic bacteria). Compare that list to Table 12.1. What subdivision(s) is/are represented by the four 'key genera'?

Based on your answer to the question above, are the purple phototrophic bacteria monophyletic? Do the purple phototrophic bacteria represent a phylogenetic or a functional grouping?

The PPB share several characteristics. Define or explain each one below.

a. Anoxygenic photosynthesis (define)

- Name a lineage of bacteria that carries out oxygenic photosynthesis.

b. A purple, red, or brown color, which is due to…(name components)

There are two major types of PPB: the purple sulfur bacteria, which are in the gamma proteobacteria, and the purple nonsulfur bacteria (which are alpha and beta proteobacteria). Here are the important points about each, which you should know for Exam 2:

a. The purple sulfur bacteria, which are in the gamma proteobacteria, use H_2S (hydrogen sulfide) as an electron donor in photosynthesis. This yields elemental sulfur, which is stored inside the cell until it is oxidized to sulfate. The only exception are groups like *Ectothiorhodospira*, which do not store elemental sulfur inside the cell. (You can remember this exception because 'ecto' refers to 'outside'.) The purple sulfur bacteria are often found in aquatic habitats such as sulfur springs and meromictic lakes. Define meromictic here:

b. The purple nonsulfur bacteria were originally thought to no not use sulfide in photosynthesis, but most of these bacteria actually can use sulfide in this way. They just use it at much smaller concentrations than do the purple sulfur bacteria. Many of the purple nonsulfur bacteria can use organic compounds as an electron donor in photosynthesis. What's amazing about these bacteria is that they practice **photoheterotrophy**: they use light for energy, but their carbon from organic molecules. This is sort of the best of both worlds and is thought to account for the great diversity of these groups. These are easily cultured from just about any environment. They are members of the alpha and proteobacteria; thus they are not monophyletic.

Use the information above to fill in the following table: put 'Y' (for 'yes') where appropriate.

Characteristic	**PSB**	**PNSB**
Member of the proteobacteria		
Can photosynthesize		
Produce oxygen		
Some can grow in the absence of light		
In the gamma proteobacteria		
In the alpha and beta proteobacteria		
Use highly concentrated H_2S as electron donor		
Typically accumulate elemental sulfur in cells		
Engage in photoheterotrophy		
Common in meromictic lakes		
Common in most environments and easily cultured		

6. Nitrifying bacteria are chemolithotrophs that make a living off various forms of nitrogen. One group, the nitrosifyers, oxide ammonia. The second group, the true nitrifyers, oxidize nitrite. The nitrifying bacteria represent **multiple subdivisions of proteobacteria** (see Table 12.4), and one additional lineage outside of the proteobacteria: the genus *Nitrospira*. *Nitrospira* is sister to the proteobacteria.

7. Sulfur-oxidizing bacteria are chemolithotrophs that use sulfur, under acid or alkaline conditions, as a source of energy, and their reactions for oxidizing sulfur **release tremendous amounts of energy** and **release a large amount of sulfuric acid**. Some of these species can switch to a chemoorganotrophic lifestyle under certain conditions. Organisms that rely on both chemolithotrophy and chemoorganotrophy are said to be **mixotrophic**. The genus *Beggiatoa* is mixotrophic.

    Describe *Beggiatoa* a bit more. It's a mixotrophic, sulfur-oxidizing member of the gamma proteobacteria. Name one of its habitats, and one of the ways in which it's important ecologically or to humans. What does it look like?

8. Hydrogen-oxidizing bacteria occur among multiple lineagese of proteobacteria and also outside of the proteobacteria (in the gram-positive bacteria). One well studied genus is *Ralstonia*, in the beta proteobacteria. Interestingly, many flourish in the presence of nickel, and some can grow on carbon monoxide.

9. Use the information above and from the chapter to fill in this table:

	Electron donor(s)	Multiple lineages of Proteobacteria?	Example
Nitrifying bacteria			
Sulfur-oxidizing bacteria			
Iron-oxidizing bacteria			
Hydrogen-oxidizing bacteria			

10. Name a few places in which methane is common.

11. Methanotrophs make a living by oxidizing methane, and they are one example of bacteria that can use one-carbon compounds (bacteria that can use one-carbon compounds are called methylotrophs). These compounds lack carbon-carbon bonds, which means that the bacteria have to synthesize new carbon-carbon bonds in the course of their metabolism. Methantrophy occurs among multiple lineages of proteobacteria.

    a. Describe a marine symbiosis between a methanotroph and a eukaryote. (Don't worry about what a 'type 1' methanotroph is; we will not go to this level of detail.)

12. *Pseudomonas* and the Pseudomonads are a group of proteobacteria that are represented in **multiple subdivisions**, but which share (1) the absence of gas formation from glucose, and (2) the positive oxidase test. We'll talk about these later. They are able to use a wide variety of organic compounds as carbon sources, but they lack enzymes needed to break down polymers. They follow the **Entner-Doudoroff pathway** in metabolizing glucose. Many pseudomonads are pathogenic, and are known for resistance to antibiotics (especially *Pseudomonas aeruginosa*, which is common in hospitals). Several species are also pathogenic on plants. Another group of Pseudomonads, *Zymomonas,* is used in fermentation in many countries. For example, *pulque* (in Mexico) is not fermented with yeast, but with *Zymomonas*).

13. Acetic acid bacteria produce acetic acid from ethanol. If your bottle of wine turns to vinegar, blame these bacteria. In fact, they are common in beer, and they're used to produce vinegar.

    a. How can you distinguish between the two major genera of acetic acid bacteria? Give the name and characteristics of each genus.

14. There are several different groups of bacteria that fix nitrogen. Some live in soil; these are called the free-living nitrogen fixers, and they are aerobic. These can be found in multiple divisions of proteobacteria (including alpha or gamma proteobacteria). These use nitrogenase to fix nitrogen (an enzyme).

15. Enteric bacteria: this is the 'poster' group of gamma proteobacteria. Many strains of enteric bacteria are pathogenic to animals or plants. Typical genera include *Escherichia* and *Salmonella.* These are closely related genera.

    a. What diseases are frequently caused by *Salmonella*?

    b. *Proteus* is in the same group. What disease does *Proteus* cause in humans?

    c. What's distinctive about the behavior of *Proteus*?

16. The next group is a group of rod-shaped, facultative aerobes that have a fermentative metabolism: *Vibrio* and *Photobacterium*. *Vibrio cholerae* causes cholera in humans, as described in the Tree of Life chapter we read for Exam 1. We also learned about quorum sensing in *Vibrio (V. fischeri*) for exam one (remember the glowing squid?).

17. The Rickettsias are primarily **obligate intracellular parasites with small genomes**. They are famous because they cause what diseases in humans? (Name two)

Their cells are very small, and they don't survive long outside the host (they are typically transmitted by arthropod vectors).

One amazing genus in the Rickettsia group is *Wolbachia*, which has the remarkable effect of influencing the expression of gender among insects. The bacterium can induce **parthenogenesis** *(convert male eggs to female eggs, yielding all-female offspring*, which give rise to more female offspring), can cause **feminization** (cause males to develop as females via hormone manipulation), or can be **male-killers** (somehow killing males preferentially). This leads insect populations to follow very distinctive evolutionary trajectories without being able to interbreed. Thus, it's thought that *Wolbachia* may underlie the tremendous diversity of insects.

18. *Spirilla* are spiral-shaped proteobacteria that are represented in multiple subdivisions. Some show **magnetotaxis**; define that here:

    What organism in this group is responsible for peptic ulcers in humans?

    What lineage of protobacteria does that organism represent?

19. In addition to the familiar single-celled forms of bacteria, the clade has some other growth forms.

    a. Some proteobacteria are **encased in sheaths**. These filamentous, **beta** proteobacteria form flagellated, swarmer cells within a long tube or sheath. Some interfere with the settling of sewage in sewage treatment; *Sphaerotilus*, one genus in this group, often forms a filamentous slime on rocks in streams that receive sewage outflow.
    b. Some proteobacteria are **stalked or have appendages**; the appendages, which contain cytoplasm and are encased by the cell wall, are called **prosthecae**. Bacteria in this group don't divide by binary fission, but instead undergo budding from a mother cell. These bacteria also generate their cell wall from a single initiation point, instead of more or less simultaneously forming the cell wall about the entire cell.

        i. Describe two possible functions of prosthecae.

        ii. State and draw the five ways in which bacterial cells reproduce. Be sure that you can also explain each way in words.

20. Many of the proteobacteria we've discussed so far move via flagella; however, some proteobacteria can glide (move without flagella when in contact with a surface). There is some neat variety of motility in the **delta proteobacteria**. The **myxobacteria** do this, and in fact, they glide in a coordinated fashion to produce multicellular fruiting bodies. This is the most complex behavior known among prokaryotes and it's not surprising that myxobacteria have a large chromosome (large genome). Check out the awesome pictures on pp. 394-395. In the life cycle, cells of myxobacteria aggregate, likely due to chemical communication, and cells migrate toward one another to form mounds of heaps. The mound of cells then differentiates into a stalk (primarily slime) and a head (where cells differentiate into myxospores).

21. Another interesting group within the delta proteobacteria are the **sulfate- and sulfur-reducing** bacteria, which produce H_2S from sulfate or sulfur under anaerobic conditions. Examples of this group all have names that start with *Desulfo*: *Desulfovibrio*, *Desulfobacter*, etc.

22. Use the information above to highlight an interesting group of…

	Name of example	**Why interesting?**
Alpha proteobacteria		
Beta proteobacteria		
Gamma proteobacteria		
Delta proteobacteria		
Epsilon proteobacteria		

Note: A recurring theme throughout this portion of the chapter is that a given **ecological or functional role** often is spread across many lineages of proteobacteria. This is interesting: did each role evolve many separate times across the proteobacteria? Is the SSU rDNA tree wrong? Or is there widespread horizontal gene transfer for ecological function? This is a rhetorical query for now; we will address this in detail later.