Chapter 11

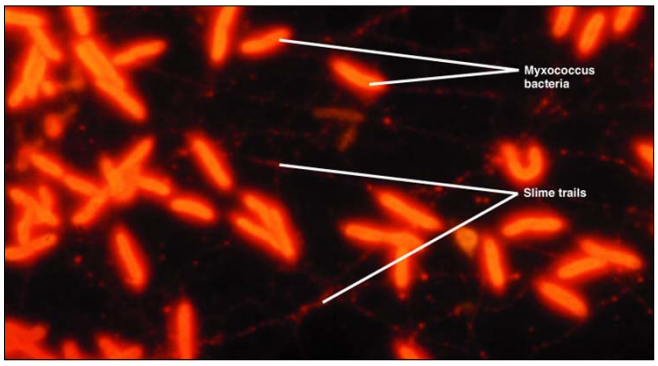
Objectives: Students should be able to….

1. **Ch. 11:** From a modern laboratory setting, explain **4 methods to distinguish** between **proteobacteria**, **firmicutes**, **actinobacteria**, and **archaea**
   - (review Chs. 1 & 4)

Chapter 11

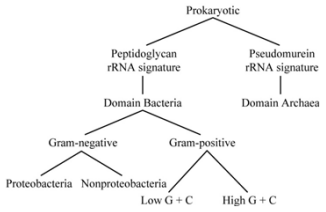
The Prokaryotes:

Domains Bacteria & Archaea



The Prokaryotes: Domains Bacteria & Archaea

1. One circular chromosome, not in a membrane
2. No histones on DNA
3. No organelles
4. Peptidoglycan (bact.) cell walls
5. Binary fission, ….



1) Major classes separated by rRNA sequences.
- ***Hybridization or PCR (see Ch. 9!) detect slight differences in rDNA (ribosomal RNA genes) between major classes of proks.***

2) GC-content (%age) in chromosomal DNA.

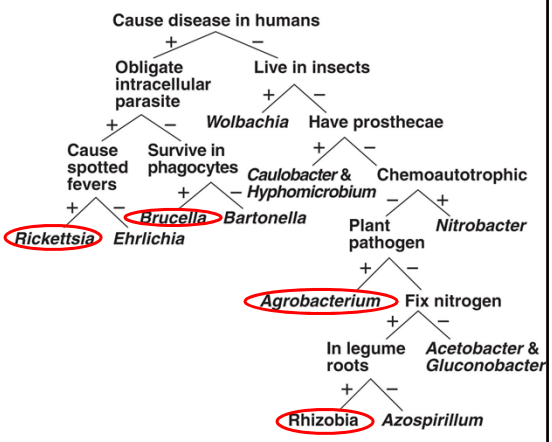
3) Archaea have different cell wall and PM. (biochem. Anal.)

Domain Bacteria: *Dichotomous Keys*

11.1) Proteobacteria

Proteobacteria

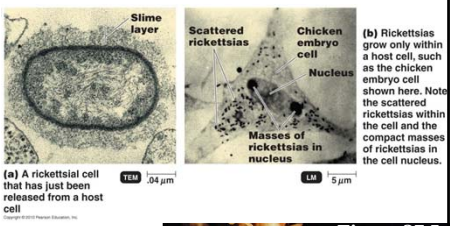
- Mythical Greek god, Proteus, could assume many shapes
- ***Diverse forms!!***
- Gram-negative
- Common photosynthetic ancestor



A. The α (alpha) Proteobacteria

1. **Human pathogens:**
   - *Bartonella henselae* - Cat-scratch disease
   - *Brucella* – Brucellosis (milk products, animals)
2. **Obligate intracellular parasites:**
   - ***Rickettsia***. Arthropod-borne, spotted fevers; ind phagocytosis!!
     - *R. prowazekii* = Epidemic typhus
     - *R. typhi* = Endemic murine typhus
     - *R. rickettsii* = Rocky Mountain Spotted Fever
3. **Plant pathogen:**
   - ***Agrobacterium***
4. Chemoautotrophic:
   - Oxidize nitrogen for energy
   - Fix CO_2
     - ***Nitrobacter***. $NH_3^+ \rightarrow NO_2^-$
     - ***Nitrosomonas***. $NO_2^- \rightarrow NO_3^-$
5. **Nitrogen-fixing bacteria:**
   - ***Azospirillum*** (free-living)
     - Grow in soil, using nutrients excreted by plants
     - Fix nitrogen
   - ***Rhizobium*** (endosymbionts)
     - Fix nitrogen in the roots of plants

•*Grow with little nutrients; stalks & buds morphology*



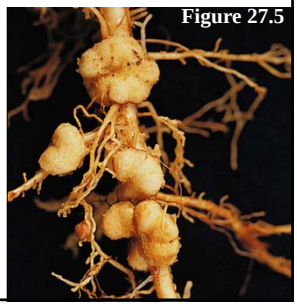


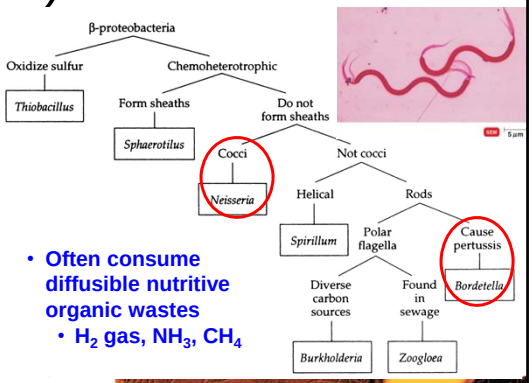
Figure 27.5

B. The β (beta) Proteobacteria

1. Thiobacillus
- Chemo***auto***trophic, oxidize sulfur:
- $H_2S \rightarrow SO_4^{2-}$

2. Neisseria –
- Chemo*hetero*trophic, cocci
- *N. meningitidis*
- *N. gonorrhoeae*

3. Bordetella
- Chemoheterotrophic, rods
- *B. pertussis*



- **Often consume diffusible nutritive organic wastes**
  - **H_2 gas, NH_3, CH_4**

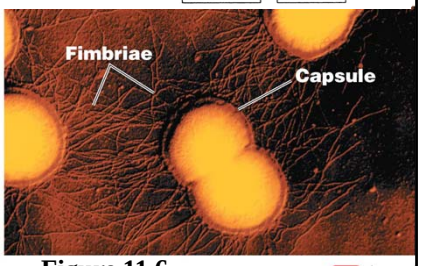
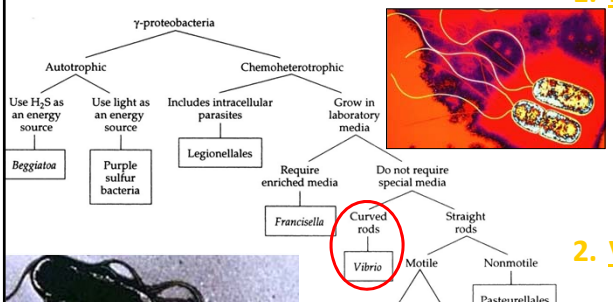
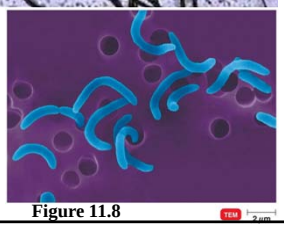
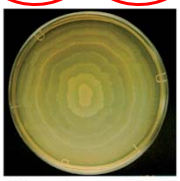


Figure 11.6

C. γ (gamma) Proteobacteria





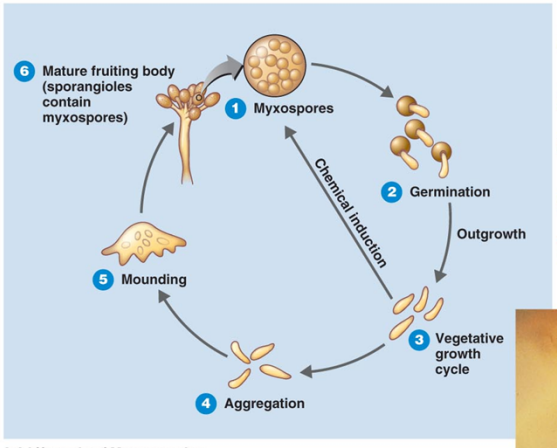


(b) A swarming colony of *Proteus mirabilis*, showing concentric rings of growth

Figure 11.8

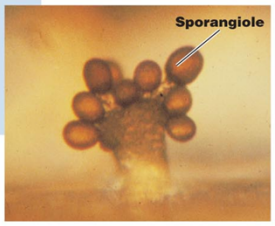
1. **Pseudomonadales:**
   - ***Pseudomonas***
     - Opportunistic pathogens
     - Metabolically diverse
     - Polar flagella
   - ***Azotobacter*** and ***Azomonas-***
     - Nitrogen fixing
2. **Vibrionales:**
   - Found in coastal water
     - ***Vibrio cholerae*** causes cholera
     - ***V. parahaemolyticus*** causes gastroenteritis
3. **Enterobacteriales (*enterics*):**
   - Peritrichous flagella, facultatively anaerobic
     - ***Enterobacter; Erwinia***
     - ***Escherichia; Klebsiella***
     - ***Proteus; Salmonella***
     - ***Serratia; Shigella; Yersinia***

D. δ (delta) Proteobacteria



(a) Life cycle of Myxococcales

1. Myxospores are produced by a fruiting body or by chemical induction of vegetative cells.
2. Myxospores germinate and form gram-negative vegetative cells, which divide to reproduce.
3. Vegetative myxobacteria are motile by gliding, forming visible slime trails.
4. Under certain conditions, the vegetative cells swarm to central locations, forming an aggregation.
5. Aggregations of cells heap up into a mound, an early fruiting body.
6. Mounds of myxobacteria differentiate into a fruiting body, which produces myxospores packed within sporangioles.

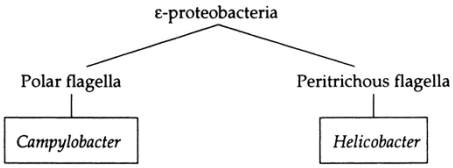


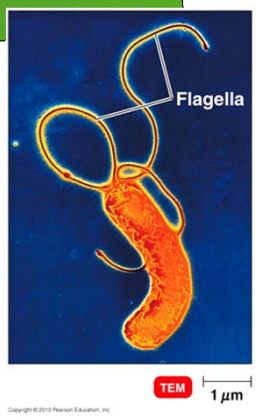
(b) A myxobacterium fruiting body; the sporangioles contain myxospores

Figure 11.1b

- **Myxobacteria**
  - "nasal mucus"
  - Move by gliding along a trail of slime
  - conidiospores

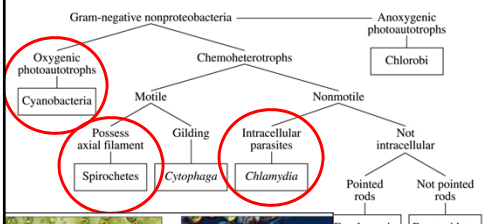
E. ε (epsilon) Proteobacteria

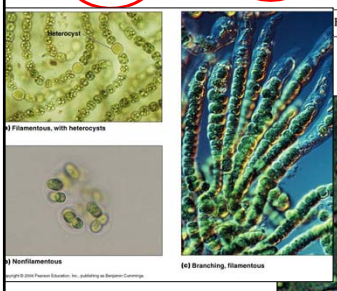




- ***Campylobacter*** *(jejuni)*
  - Bipolar flagella
    - Gastroenteritis (major!)
- ***Helicobacter*** *(pylori)*
  - Multiple flagella
    - Peptic ulcers
    - Stomach cancer

F. Nonproteobacteria Gram-Negative Bacteria





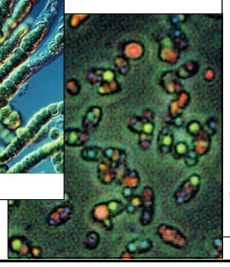


Figure 11.12a-c

1. Cyanobacteria

- *Oxygenic* photosynthesis
- Gliding motility
- Fix nitrogen

$$2H_2O + CO_2 \xrightarrow{\text{light}} (CH_2O) + H_2O + O_2$$ *oxygenic*

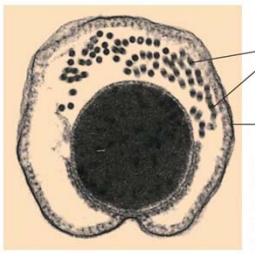
2. Purple & Green Photosynthetic Bacteria

- ***Anoxygenic*** photosynthesis
- Purple and green sulfur bacteria

$$2H_2S + CO_2 \xrightarrow{\text{light}} (CH_2O) + H_2O + 2S^0$$ *anoxygenic*

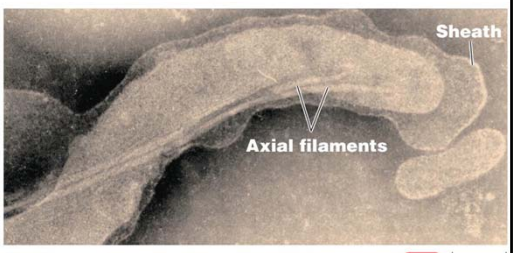
3. Spirochaetes

- ***Borrelia*** – Lyme disease



(a) This cross section of a spirochete shows numerous axial filaments between the dark cell and the outer sheath.

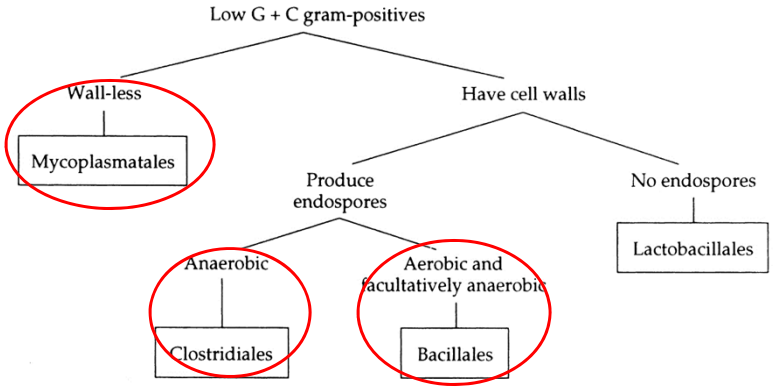
- ***Treponema*** – syphilis



(b) This micrograph of a portion of *Treponema pallidum* shows the sheath, which has shrunk away from the cell, and two axial filaments attached near one end of the cell under the sheath.

11.2) Gram +: Firmicutes

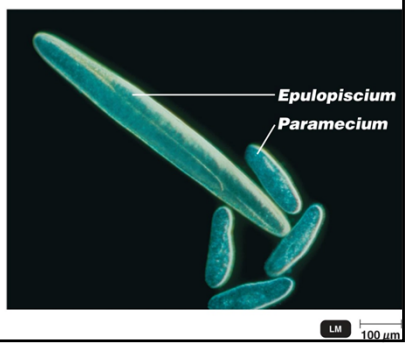
- **Low G + C (~20-40%)**
- Gram-positive



A. Clostridiales

- ***Clostridium*** *(botulinum, tetani, perfringens)*
  - Endospore-producing
  - Obligate anaerobes

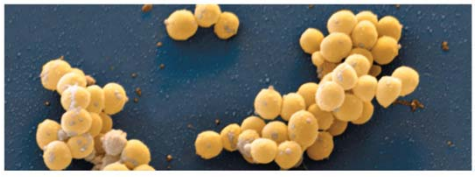
- ***Epulopiscium***
  - Giant! (80 um x 600 um)
  - In fish gut

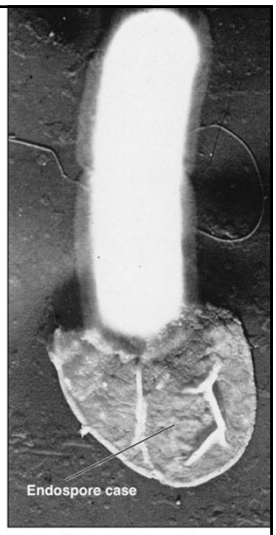


B. Bacillales

- ***Bacillus*** *(anthracis, thuringensis)*
  - Endospore-producing rods
  - Mammalian, insect pathogens

- ***Staphylococcus*** *(aureus)*
  - **enterotoxin, TSS** (toxic shock syndrome)
  - Cocci in clusters





(b) *Bacillus cereus germinating*

C. Lactobacillales !!

- Generally **aerotolerant anaerobes**, lack an electron-transport chain…..
  - ***Lactobacillus***
  - ***Streptococcus***
  - *Enterococcus*
  - *Listeria*

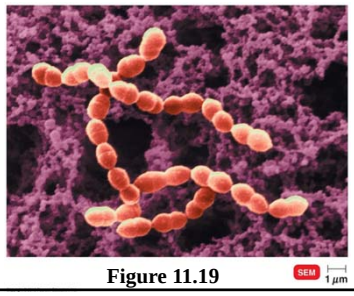
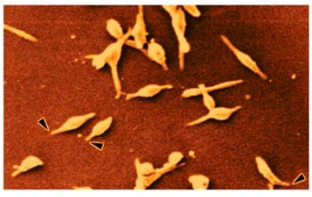


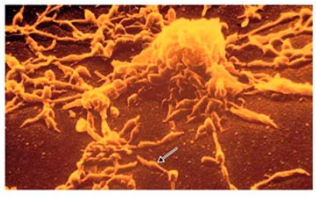
Figure 11.19

D. Mycoplasmatales

- **Wall-less, pleomorphic**
  - ***Not really Gram +, but related by rRNA & G + C content.***
- **0.1 - 0.24 µm!!**
  - Smallest known cellular organisms
- ***M. pneumoniae***



(a) Individual cells of *M. pneumoniae*. Arrowheads indicate terminal structures that probably aid in attachment to eukaryotic cells, which then become infected.

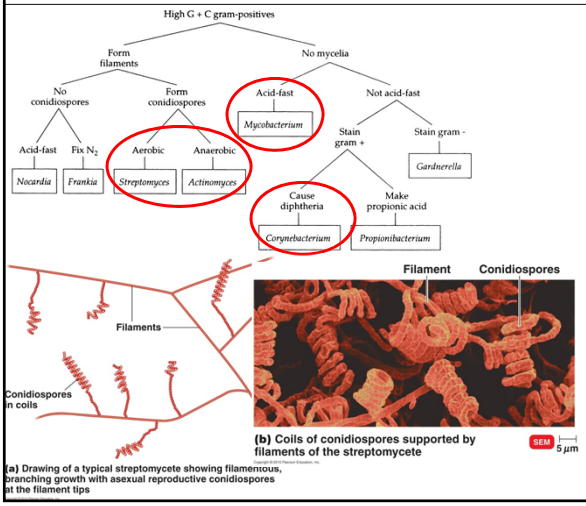


(b) This micrograph shows the filamentous growth of *M. pneumoniae*. Some individual cells can also be seen (arrow). The organism reproduces by fragmentation of the filaments at the bulges.

Figure 11.20

11.3) Gram +: Actinobacteria

- **High G + C**; Gram-positive; radiating filaments
- Many *filamentous* → antibiotics
- ***Nonfilamentous*** = pathogens; lipoidal cell walls



(a) Drawing of a typical streptomycete showing filamentous, branching growth with asexual reproductive conidiospores at the filament tips

(b) Coils of conidiospores supported by filaments of the streptomycete

1. ***Corynebacterium***
   - ***diptheria***
2. ***Frankia***
   - ***N-fixation***
3. ***Mycobacterium***
   - ***Tuberculosis; leprosy***
4. ***Propionibacterium***
   - ***Propionic acid,***
     - ***Swiss cheese***
5. ***Streptomyces***
   - ***antibiotics***

11.4) Domain Archaea***

1. No peptidoglycan wall, or wall-less
2. Ether-linked, branched PM lipids
3. ***Extremophiles!!***

- Hyperthermophiles
  - ***Pyrodictium abyssi***
  - *Sulfolobus*
- Methanogens
  - *Methanobacterium*
- Extreme halophiles
  - *Halobacterium*

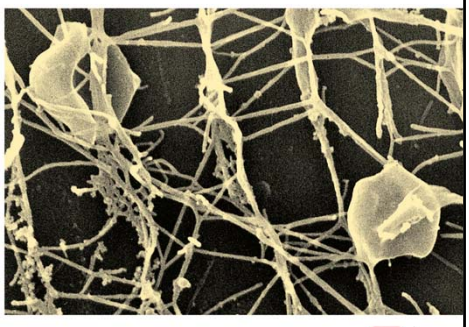


Figure 11.27

Pyrodictium abyssi

11.5) Microbial Diversity

- Bacteria size range:
  - ***Thiomargarita*** (750 µm) –
    - NO_3 vacuoles
    - Sulfur pearl of Namibia (*T. namibiensis)*
    - Gamma proteobact.
  - to **Nanobacteria**?? -- (0.02 µm); in rocks

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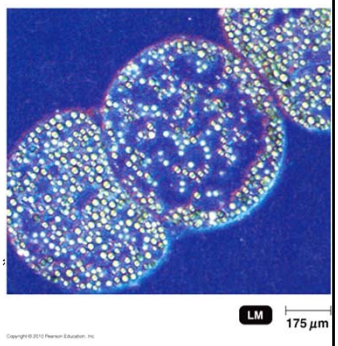

- PCR indicates up to **10,000 bacteria/gm of soil**.

- Many bacteria haven't been identified or characterized b/c they:
  1. ***Haven't been cultured (>99%!?)***
  2. Need special nutrients….
  3. Are part of complex food chains requiring the products of other bacteria...
  4. *Need to be cultured to understand their metabolism and ecological role.*

Ch. 11 Summary

1. Gram Negative Bacteria: Proteobacteria
   a) Alpha – little nutrients; rickettsia, agrobacterium, rhizobium
   b) Beta – consume diffusible wastes; Thiobac., Neisseria, Bordatella
   c) Gamma – pseudomonads, enterobacteria, vibrios
   d) Delta – myxobacteria; gliding, conidia
   e) Epsilon – campylobacter, helicobacter (gastroenteritis)
2. Nonproteobacteria gram- : cyanobact./photosyn, spirochaetes
3. Gram Positive:
   a) Firmicutes: Low GC – clostridium, mycoplasma, bacillus, lactobacillus
   b) Actinobacteria: High GC – (antibiotics) actinomyces, streptomyces, mycobact.
4. Archaea: extremophiles (thermo-, halo-), methanogens
   - Ether-linked, branched phospholipids; No PG cell wall
5. Diversity: 0.2um – 750 µm; 10,000/gm soil