I. Gram-Positive Cocci  (gram positives are grouped by G+C ratio)

A. *Staphylococcus*

1. Morphology - Occur in grapelike clusters

2. Example - *Staphylococcus aureus* – Named for golden color

3. Causes many diseases such as food poisoning and toxic shock syndrome

4. Characteristics
   a) *Grow under high osmotic pressure and low moisture.*
      *Grows on Mannitol salt agar and Staph aureus ferments mannitol.*
   b) *Produce toxins that contribute to pathogenicity* –
      *Enterotoxin involved in food poisoning.*
   c) *Facultative anaerobe (both aerobic and anaerobic growth)*

B. *Streptococcus*

1. Morphology - Appear in chains with as few as from 4-6 cocci or as many as 50. One species *Streptococcus pneumoniae* occurs in pairs.

2. Metabolism - Do not use oxygen although most are aerotolerant. See smaller colonies.

3. Classification - Based on action of blood agar.
   a) *Alpha-hemolytic* - Produces an alpha-hemolysin that reduces hemoglobin (red) to methemoglobin (green).
      *Causes a greenish zone to surround the colony. Streptococcus pneumoniae*
   b) *Beta-hemolytic* - Produces hemolysin- forms a clear zone of hemolysis on blood agar. *Strep pyogenes*
   c) *Gamma-hemolytic* - No hemolysis – *Enterococcus faecalis*
4. Characteristics
   a) *Produce products that destroy phagocytic cells*
   b) *Produce enzymes that digest connective tissue*

5. Examples
   a) *Streptococcus pyogenes* - scarlet fever
   b) *Streptococcus pneumoniae* – pneumonia
   c) *Streptococcus mutans* - dental caries
   d) Many species.

II. Gram-Negative Cocci (most gram negatives are in the Proteobacteria group, the largest taxonomic group of bacteria)

A. *Usually inhabit mucous membranes*

B. *Diplococci – Some look like short fat rods*

C. *Examples -*

1. *Neisseria gonorrhoea* – Gonorrhea
   a) *Aerobic but requires CO₂ and Chocolate Agar for Growth*
   b) *Attaches via fimbriae*

2. *Neisseria meningitidis* – Meningitis
   a) Will grow on blood agar

3. *Moraxella catarrhalis* – Pneumonia
   a) *Moraxella are strictly aerobic and shaped like coccobacilli*

4. *Moraxella lacunata* – Pink eye - conjunctivitis

5. *Veillonella* (not in text)
   a) *Anaerobe*
b) Component of dental plaque

c) Part of normal flora of mouth

III. Endospore-Forming Gram-Positive Rods

A. **Bacillus - Rods** *Common environmental inhabitants*

1. Aerobes or facultative anaerobes
2. Large straight sided rods
3. Example - *Bacillus anthracis* - Anthrax

B. **Clostridium - Rods**

1. Anaerobe (obligate)
2. Examples
   a) *Clostridium tetani* causes Tetanus
   b) *Clostridium botulinum* causes Botulism
   c) *Clostridium perfringens* causes Gas Gangrene.

IV. Nonsporing Gram-Positive Rods

A. **Lactobacillus**

1. Metabolism - Lack a cytochrome system and are unable to use oxygen as an electron acceptor. But are aerotolerant and produce lactic acid from simple carbohydrates. Acidity creates an ecological niche by inhibiting competing organisms.
2. Site - In humans are found in vagina, oral cavity and intestinal tract.
3. Industrially – examples: Sauerkraut, pickles, & yogurt

B. **Listeria monocytogenes**

1. Psychrotroph - Can survive refrigerator temperature. Also can survive inside phagocytic cells
2. Involved in food contamination, mainly dairy products
3. Threat of still birth or serious damage to fetus

C. Corynebacteria (club shaped cells)
   1. Morphology - Tend to be pleomorphic cell shape
   2. Metabolism - May be aerobic, anaerobic, or microaerophiles
   3. Example - *Corynebacterium diphtheriae* - Diphtheria

D. Anaerobic Diphtheroid - *Propionibacterium acnes* found in skin causes acne.

E. Actinomyces sp. - Filamentous anaerobic bacteria
   1. Fragment into Coryneform cells
   2. *Actinomyces israeli* – Actinomycosis affecting the head, neck, or lungs.

V. Fermenting Gram-Negative Rods

A. *Enterobacteriaceae (Enterics, Enterobacteriales)*
   1. Can’t distinguish one from the other on the basis of gram stains. Are straight and short sided – some bipolar staining.
   2. Facultatively Anaerobic
   3. Most inhabit the intestinal tract of humans and animals.
   4. Some present only as agents of disease
   5. Active fermenters of glucose and other carbohydrates, oxidase negative, nitrate +
   6. Many techniques for isolation and identification because of clinical importance
   7. Include motile (peritrichous) and non-motile species; some have fimbriae (adherence), and pili (genetic exchange).
8. Among important genera are Escherichia, Salmonella, Klebsiella, Serratia, Proteus, Yersinia, and Enterobacter

a) *Escherichia coli*. Examples: used as an indicator of fecal contamination, UTI’s, Food Contamination (O157:H7), common gut inhabitant

9. Each of these can cause a wide variety of infections or some, such as *Salmonella typhi*, cause a specific disease called typhoid fever.

VI. Non-fermenting Gram Negative Rods

A. *Pseudomonas aeruginosa*

1. Aerobe

2. Slender rod on gram stain. Has polar flagella.

3. Causes a wide variety of infections – UTI’s, wounds, burns. Cause 1 in 10 nosocomial infections.

4. Excrete extra cellular, water soluble pigments

5. Common in soil and can grow at refrigerator temperature (food spoilage and medication contamination).

6. Large genetic capacity allows for many unusual traits. Able to decompose chemicals such as pesticides in soil, can grow in antiseptic solutions, soap, cap-liner adhesives, etc, very resistant to antibiotics.

7. Resistant to antibiotics.

VII. Other Gram Negative Rods (Unusual, Fastidious, Anaerobic)

A. *Pasteurellaceae (Pasteurellales)*

1. Facultative anaerobes

2. Example - *Pasteurella multocida* - isolated from dog and cat bites. Really a pathogen of domestic animals

3. Example - *Hemophilus influenza* - Inhabitant of upper respiratory tract and causes of variety of diseases such as
meningitis in children and pneumonia in adults.

B. **Bacteroides sp.**

1. Anaerobe
2. Live in human intestinal tract (1 billion per gram of feces), oral cavity, and genital tract.
3. Cause deep wound infections, especially from punctures and bowel perforations.

C. **Fusobacterium sp.**

1. Anaerobe
2. Long slender pointed rods (spindle shaped)
3. Causes some dental abscesses.

VIII. Spirochetes

A. **Morphology** - Long, thin, helical cells that move by means of axial filament (endoflagella). Wound around the body of the cell between an outer sheath and the body. Cell moves by rotating filament like a corkscrew.

B. **Examples**

1. *Treponema pallidum* - Syphilis
2. *Borrelia burgdorferi* - Lyme Disease transmitted by a tick

IX. Aerobic/Microaerophilic, Motile, Helical/Vibrioid Gram-Negative Bacteria

A. **Morphology** - Helical but lack an axial filament. Do not have a complete turn. Has a single flagella at one or both ends. Are rigid helices or curved rods.

B. **Examples** - *Campylobacter jejuni* - Diarrheal Diseases and *Helicobacter pylori* - Ulcers.

C. *Vibrio*
1. Morphology - Slightly curved rod

2. Found mostly in aquatic environment

3. Example - Pathogen *Vibrio cholerae* causes cholera and *Vibrio parahaemolyticus* causes gastroenteritis from raw and under cooked shellfish.

X. Rickettsias and Chlamydias and Related

A. Metabolism - Both are obligate intracellular (as are viruses) parasites – Resemble and are classified as bacteria. Main difference between the two is mode of transmission.

B. Rickettsias

1. Morphology - Rod-shaped bacteria or coccobacilli (0.8-2.0 µm long). Pleomorphic. Gram negative and divide by binary fission.

2. Transmission - Ticks and fleas

3. Examples – Several that cause fevers. Have to use serology to differentiate
   a) *Rickettsia rickettsii* - Rocky Mountain spotted fever.
   b) *Rickettsia typhi* – Endemic murine typhus
   c) *Rickettsia prowazekii* – Epidemic typhus
   d) *Coxiella burnetii* – Q-fever

C. Chlamydias

1. Have a developmental cycle – The infectious form, elementary body attaches to a host cell and is phagocytized and housed in a cell vacuole. Within the host cell the body becomes a larger less infective reticulate body that divides successively. Eventually these condense into infective elementary bodies that are released to infect surrounding cells.

2. Morphology - Gram-negative coccoid bacteria (0.2-1.5 µm)

3. Transmission - Interpersonal contact or airborne
respiratory routes (Do not require ticks or fleas)

4. Examples

a) *Chlamydia trachomatis* - trachoma – blindness, nongonococcal urethritis (NGU), lymphogranuloma venereum (sexually transmitted diseases)

b) *Chlamydia psittaci* – psittacosis- From parrots and other birds (Parrot fever)

XI. Mycoplasmas

1. Morphology - Do not form cell walls and so are very pleomorphic. Can form filaments that resemble fungi. Small, ranging from 0.1-0.25 μm.

2. Will not readily grow on artificial media. To grow, sterols must be provided.

3. Example

a) *Mycoplasma pneumoniae* - Cause of “walking pneumonia”. Also called PAP – Primary Atypical Pneumonia

XII. Mycobacteria

A. Aerobic, non-spore forming rods.

B. “Myco” suggests fungus because occasionally has filamentous growth.

C. Have a distinctive gram negative like cell wall – outermost lipopolysaccharide layer is replaced with mycolic acid that forms a waxy, water-resistant layer. Resistant to stress of drying, acts as barrier to antimicrobials, pathogenic mechanism.

D. Stains acid-fast

E. Examples

1. *Mycobacteria tuberculosis* - Causes TB
2. **Mycobacteria leprae** - Causes leprosy

XIII. Norcardia (Resemble Actinomyces morphologically but are aerobic)

A. **Aerobic**

B. **Reproduction - Produce rudimentary filaments which fragment into short rods**

C. **Cell Wall - Resembles that of Mycobacteria therefore are acid-fast.**

1. Example - **Norcardia asteroides** - Mycetoma - a localized destructive infection of feet or hands