

Bacteria

Taxonomy

- ✓ Classification of organisms
 - Establish criteria for identification
 - Arrange related organisms into groups
 - Provide information about evolution

Binomial nomenclature

- ✓ “two-name” system
 - Genus
 - species
- ✓ Strains are subgroups of species
 - *Escherichia coli* 0157:H7

Microbe names

NAME OF MICROORGANISM	MEANING OF NAME
<i>Entamoeba histolytica</i>	Ent = intestinal, amoebae = shape and means of movement, histo = tissue, lytic = lysing, or digesting, tissue
<i>Escherichia coli</i>	Named after Theodor Escherich in 1888; found in the colon
<i>Haemophilus ducreyi</i>	Hemo = blood, phil = love; named after Augusto Ducrey in 1889
<i>Neisseria gonorrhoeae</i>	Named after Albert L. Neisser in 1879; causes the disease gonorrhoea

Bacterium vs human taxonomy

TAXONOMIC CATEGORY	HUMAN	BACTERIUM THAT CAUSES SYPHILIS
Kingdom	Animalia	Monera (Prokaryotae)
Division/Phylum	Chordata	Gracilicutes
Subphylum	Vertebrata	
Class	Mammalia	Scotobacteria
Order	Primate	Spirochaetales
Family	Hominidae	Spirochaetaceae
Genus	Homo	Treponema
Specific epithet	sapiens	pallidum

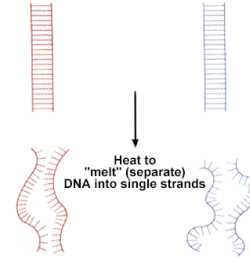
A dichotomous key

- 1a. Prokaryotic MONERA
- 1b. Eukaryotic see 2a
- 2a. Strictly unicellular PROTISTA
- 2b. Either uni-or multicellular see 3a
- 3a. Nutrition by photosynthesis PLANTAE
- 3b. Nutrition by absorption or ingestion see 4a
- 4a. Reproduce primarily sexually ANIMALIA
- 4b. Reproduce either sexually or asexually FUNGI

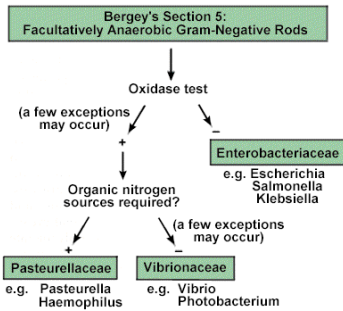
Bacterial Key

1a Gram-positive	Go to 2
1b Not gram-positive	Go to 3
2a Cells spherical in shape	Gram-positive cocci
2b Cells not spherical in shape	Go to 4
3a Gram-negative	Go to 5
3b Not gram-negative (lack cell wall)	Mycoplasma
4a Cells rod-shaped	Gram-positive bacilli
4b Cells not rod-shaped	Go to 6
5a Cells spherical in shape	Gram-negative cocci
5b Cells not spherical in shape	Go to 7
6a Cells club-shaped	Corynebacteria
6b Cells variable in shape	Propionibacteria
7a Cells rod-shaped	Gram-negative bacilli
7b Cells not rod-shaped	Go to 8
8a Cells helical with several turns	Spirochetes
8b Cells comma-shaped	Vibrioids

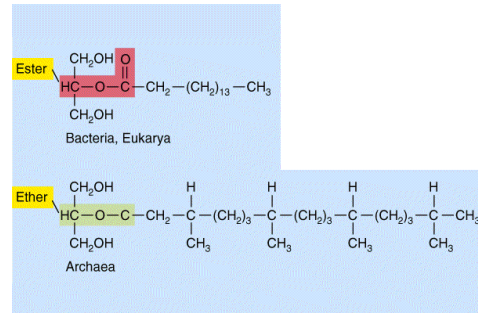
DNA hybridization



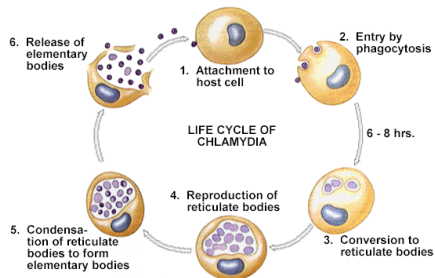
Bergey's manual



Eubacteria vs Archaeobacteria



Rickettsiae and Chlamydiae present special problems



Differential staining

1. Primary stain
2. Mordant (fixes the primary dye)
3. Decolorizing rinse --critical step
4. Counter stain

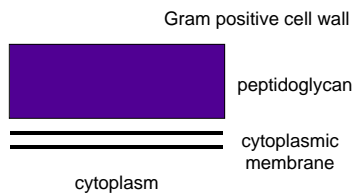
Gram stain

1. Crystal violet
2. Iodine
3. Alcohol rinse
4. Safranin

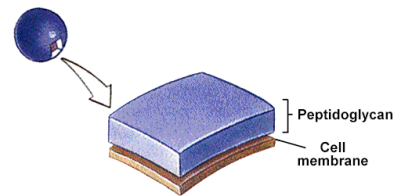
Gram reaction

Step	Positive	Negative
Crystal violet		
Iodine		
Alcohol		
Safranin		

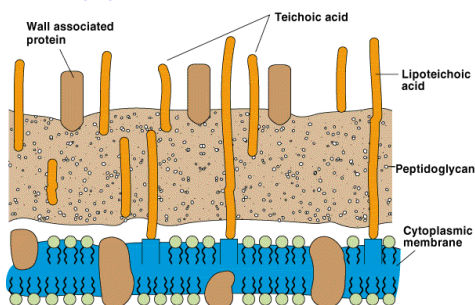
Gram positive



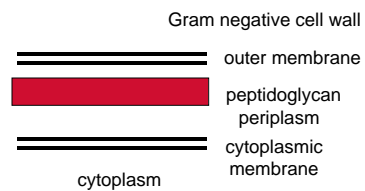
Gram (+)



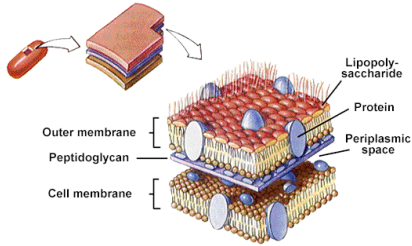
Gram (+) cell wall



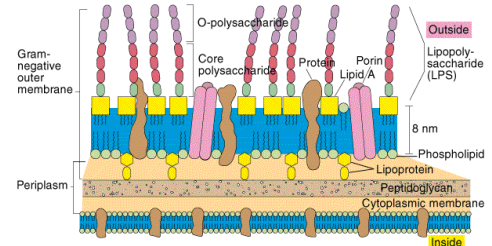
Gram negative



Gram (-)



Gram (-) cell wall

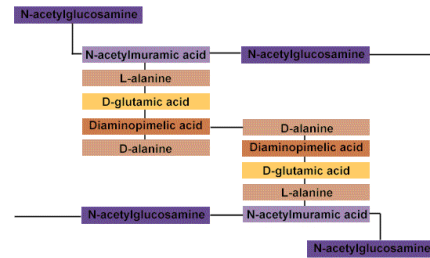


Peptidoglycan

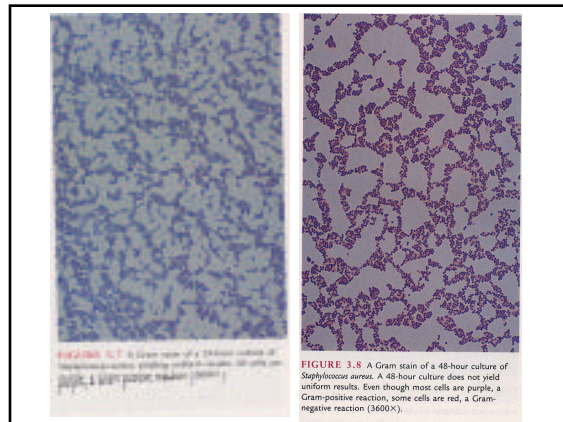
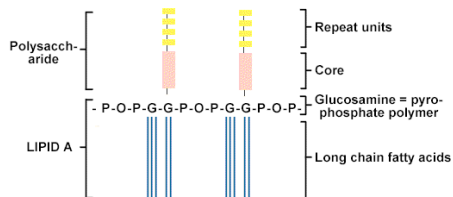
peptidoglycan contains cross-linked modified sugar subunits:

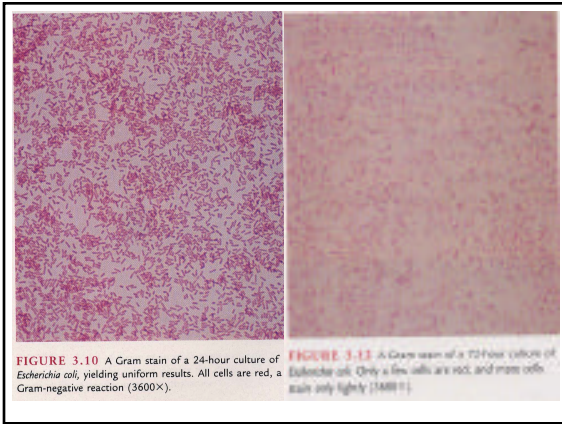
N-acetylglucosamine (NAG)
N-acetylmuramic acid (NAM)

Gram (-) peptidoglycan



Lipopolysaccharide (endotoxin)





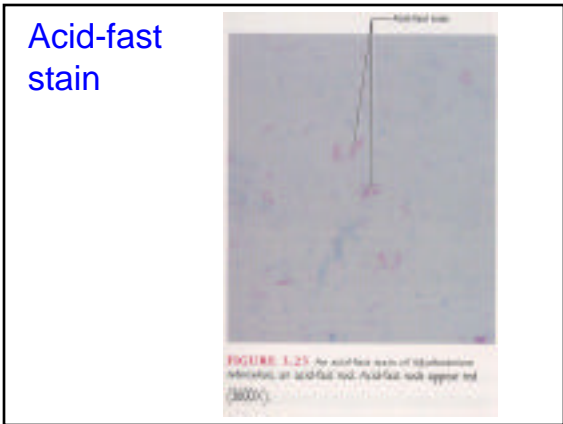
Acid fast reaction

Step	Positive	Negative
Carbolfuchsin		
Acid alcohol		
Methylene blue		

Acid fast bacteria

Carbolfuchsin gets into the cytoplasm and resists decoloration by the acid alcohol

Lipid layer
Peptidoglycan
Cell membrane



- ### Special Stains
- ✓ Endospore stain
 - ✓ Flagella stain
 - ✓ Negative stain
 - ✓ Capsule stain



Negative stain (bacillus)



FIGURE 3.5 A negative stain of the rod *Bacillus* (3600 \times).

Diplobacilli



FIGURE 2.16 A 24-hour culture of *Bacillus cereus*. Many cells are undergoing binary fission and appear as diplobacilli (4000 \times).

Diplococci

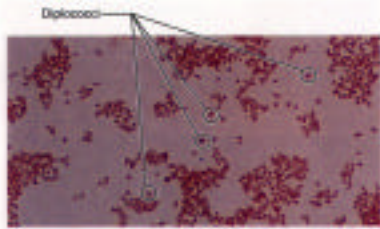


FIGURE 2.18 *Neisseria gonorrhoeae*, a diplococcus, is the causative agent of gonorrhea. The paired cocci have flattened sides that lie adjacent to each other (3600 \times).

Staphylococci

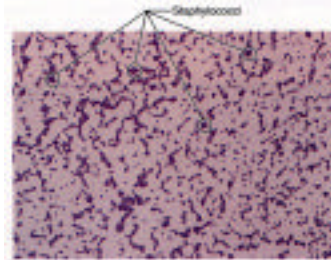
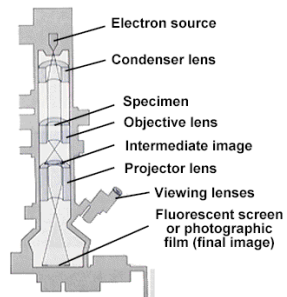


FIGURE 2.22 Cocci in clusters (staphylococci) in *Staphylococcus aureus*. These clusters are due to cell division occurring in more than three planes (2500 \times).

Electron Microscope



Electron microscopy

Electrons are generated, condensed, and focused onto an object. An image is created and magnified on a fluorescent screen.

Staining for electron microscopy

1. Heavy metals
2. Radioactive materials

Why?

It is difficult for electrons to pass through very dense materials.

26.1 The Three Domains of Life on Earth

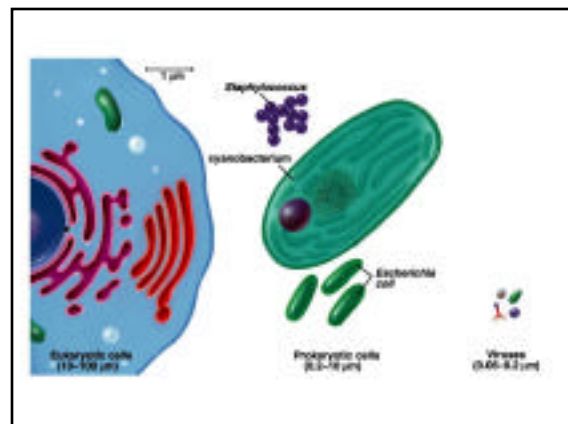
CHARACTERISTIC	BACTERIA	DOMAIN EUKARIA	DOMAIN ARCHAEA
Membrane-enclosed nucleus	Absent	Absent	Present
Membrane-enclosed organelles	Absent	Absent	Present
Peptidoglycan in cell wall	Present	Absent	Absent
Membrane lipids	Ester-linked Unbranched	Ether-linked Branched	Ester-linked Unbranched
Ribosomes ^a	70S	70S	80S
Initiator tRNA	Formylmethionine	Methionine	Methionine
Operons	Yes	Yes	No
Plasmids	Yes	Yes	Rare
RNA polymerases	One	Several	Three
Similar to chlamydomonas and streptococcus	Yes	No	No
Ribosomes sensitive to chloramphenicol	No	Yes	Yes
Some are methanogens	No	Yes	No
Some fix nitrogen	Yes	Yes	No
Some conduct chlorophyll-based photosynthesis	Yes	No	Yes

^a70S denotes an order that 90S denotes

LIFE: THE SCIENCE OF BIOLOGY, Seventh Edition, Figure 26.1

26.2 How Organisms Obtain Their Energy and Carbon

NUTRITIONAL CATEGORY	ENERGY SOURCE	CARBON SOURCE
Photoautotrophs	Light	Carbon dioxide
Photoheterotrophs	Light	Organic compounds
Chemoautotrophs	Inorganic substances	Carbon dioxide
Chemoheterotrophs	Organic compounds	Organic compounds



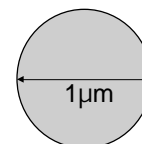
Cell shapes



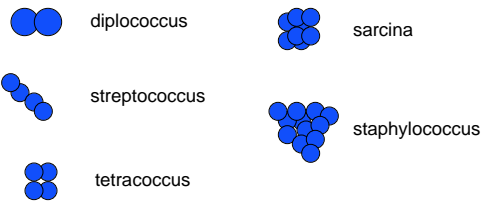
FIGURE 2.3 Cell shapes in bacteria. These drawings are intended for comparisons only and are not drawn to scale.

Cocci

One coccus, many cocci.

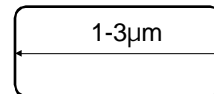


Arrangements of cocci

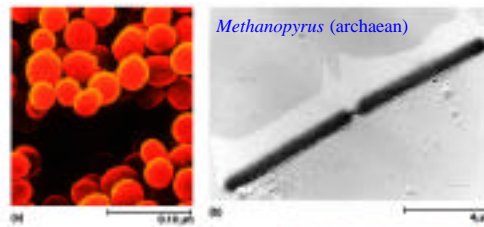
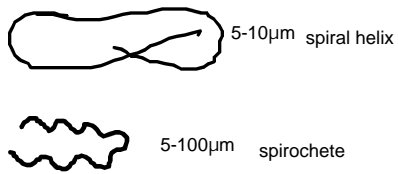


Bacilli

One bacillus, many bacilli.



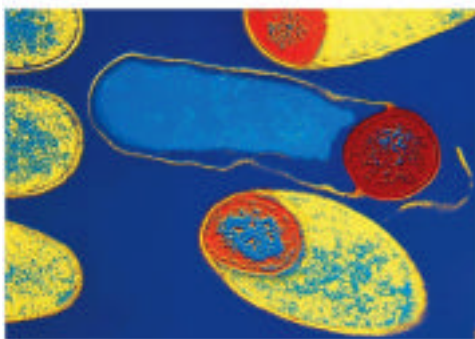
Spirals



Micrococcus

Leptospira interrogans

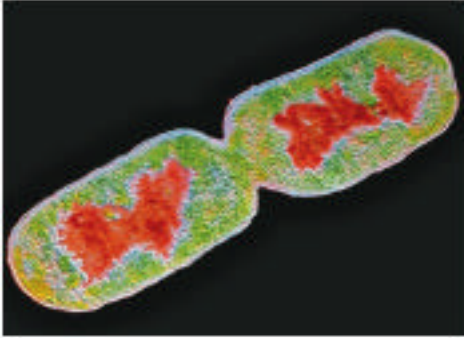
Clostridium endospores



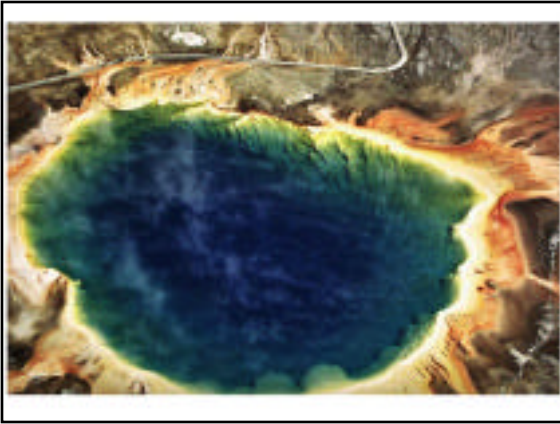
Aqiofex (archaeon)



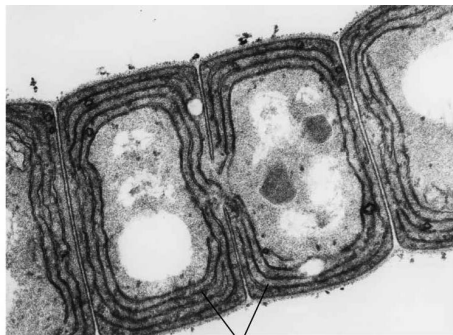
Binary fission



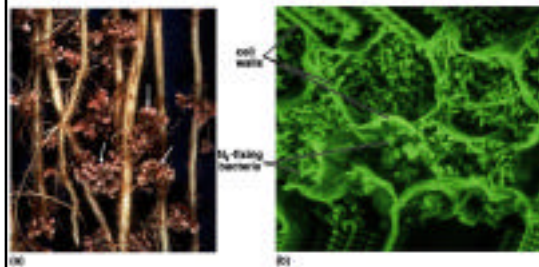
Conjugation



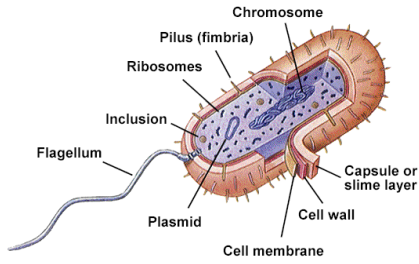
Oscillatoria (chlorophyll in membranes)



Nitrogen fixing bacteria



Prokaryotic cell



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Major Group	Typical Examples
Archaeobacteria	Methanogens, thermophiles, halophiles
Actinomycetes	Streptomyces, Actinomyces
Chemoautotrophs	Sulfur bacteria, Nitrobacter, Nitrosomonas
Cyanobacteria	Anabaena, Nostoc

Bacteria (1)

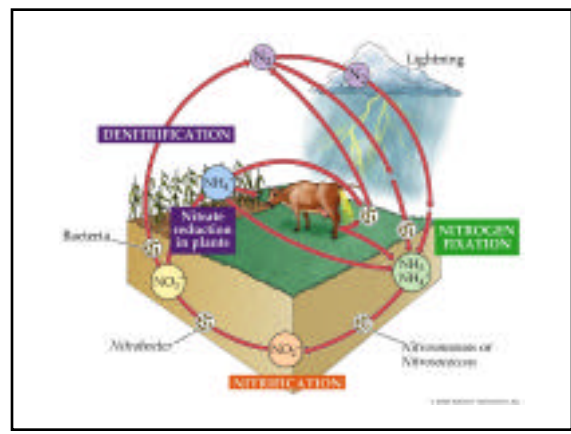
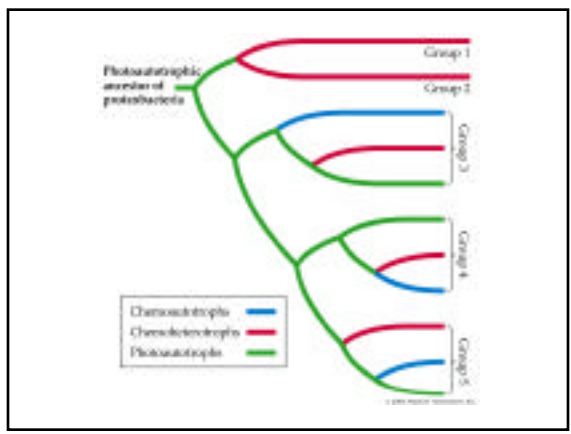
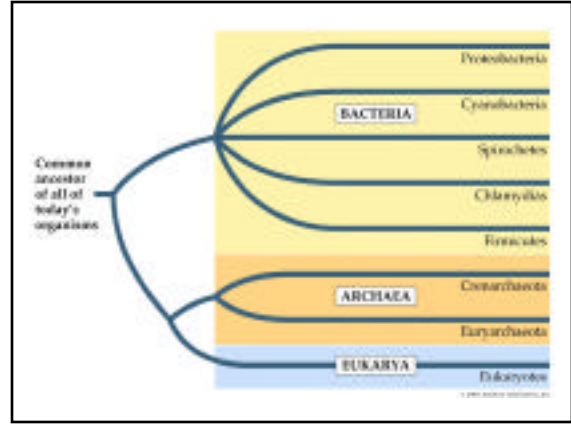
Illustrations of various bacterial groups: purple spherical clusters (Archaeobacteria), a branching filamentous structure (Actinomycetes), yellow rod-shaped bacteria (Chemoautotrophs), and a green filamentous structure (Cyanobacteria).

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Major Group	Typical Examples
Enterobacteria	Escherichia coli, Salmonella, Vibrio
Gliding and budding bacteria	Myxobacteria, Chondromyces
Pseudomonads	Pseudomonas
Rickettsias and chlamydias	Rickettsia, Chlamydia
Spirochaetes	Treponema

Bacteria (2)

Illustrations of various bacterial groups: a red rod-shaped bacterium (Enterobacteria), a red budding structure (Gliding and budding bacteria), green rod-shaped bacteria (Pseudomonads), red and white structures (Rickettsias and chlamydias), and a red spiral bacterium (Spirochaetes).



Envelops of archaeobacteria

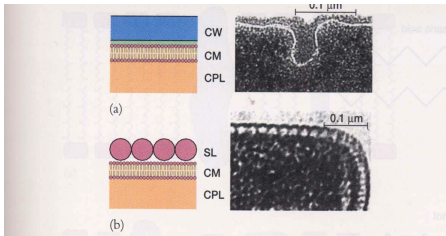


Figure 20.1 Cell Envelopes of Archaeobacteria. Schematic representations and electron micrographs of (a) *Methanobacterium formicicum*, a typical gram-positive organism, and (b) *Thermoproteus tenax*, a gram-negative archaeobacterium. CW, cell wall; SL, surface layer; CM, cell membrane or plasma membrane; CPL, cytoplasm.

Membranes of archaeobacteria

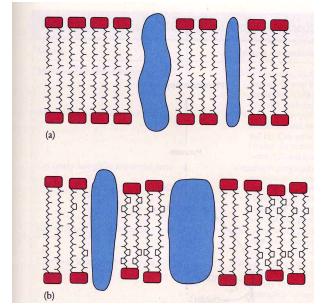


Figure 20.5 Examples of Archaeobacterial Membranes. (a) A membrane composed of integral proteins and a bilayer of C_{20} diethers. (b) A rigid monolayer composed of integral proteins and C_{26} tetraethers.

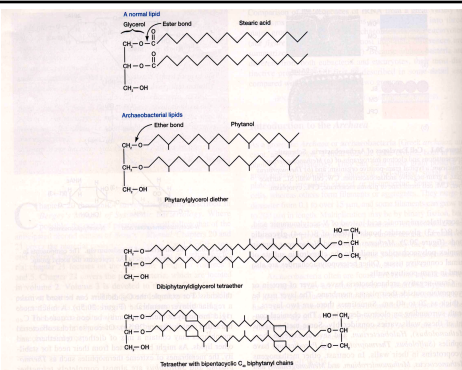
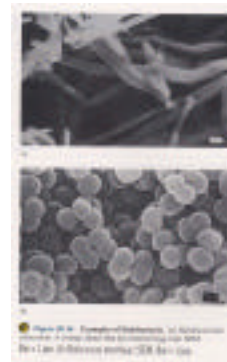


Figure 20.3 Archaeobacterial Membrane Lipids. An illustration of the difference between archaeobacterial lipids and those of other bacteria. Archaeobacterial lipids are derivatives of isoprenyl glycerol ethers rather than the usual glycerol fatty acid esters. Three examples of common archaeobacterial glycerolipids are given.

Halobacteria



Thermophilic

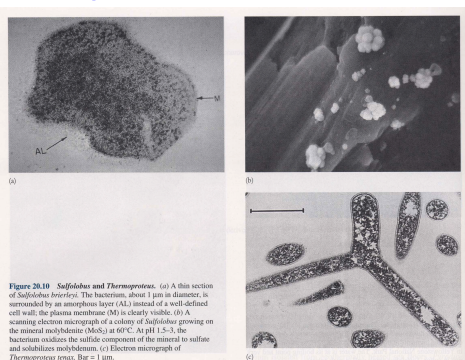
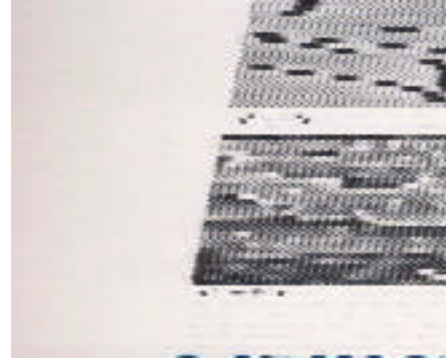
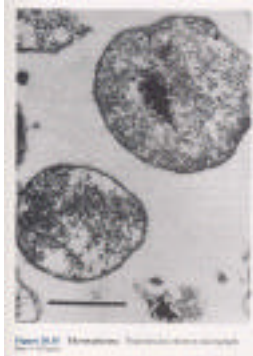


Figure 20.10 Sulfobobus and Thermoproteus. (a) A thin section of *Sulfobobus overlying*. The bacterium, about 1 μm in diameter, is surrounded by an amorphous layer (AL) instead of a well-defined cell wall; the plasma membrane (PM) is clearly visible. (b) A scanning electron micrograph of a colony of *Sulfobobus* growing on the mineral molybdenite (MoS_2) at 60°C. At pH 1.5-3, the bacterium oxidizes the sulfide component of the mineral to sulfate and solubilizes molybdenum. (c) Electron micrograph of *Thermoproteus tenax*. Bar = 1 μm.

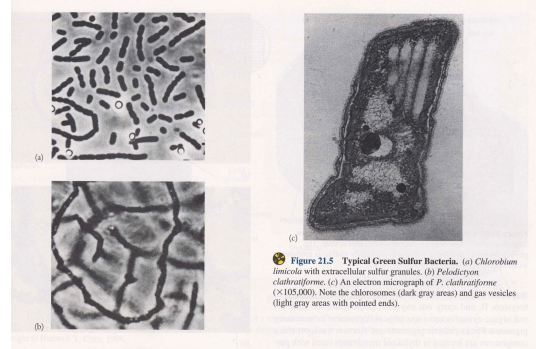
Methanogenic



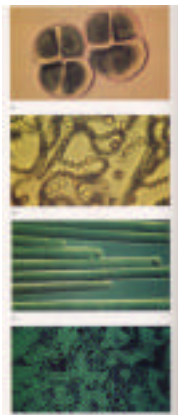
Thermoplasma



Green sulfur bacteria



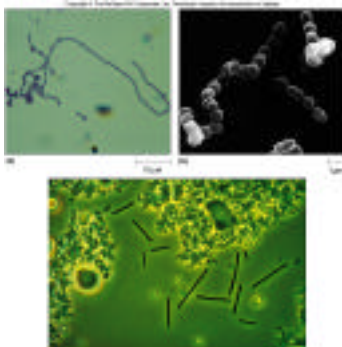
Cyanobacteria



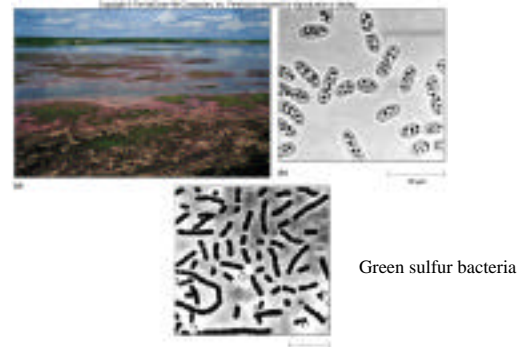
Myxobacteria



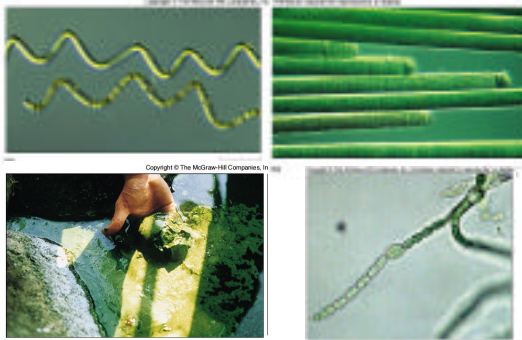
Streptococcus and Lactobacillus



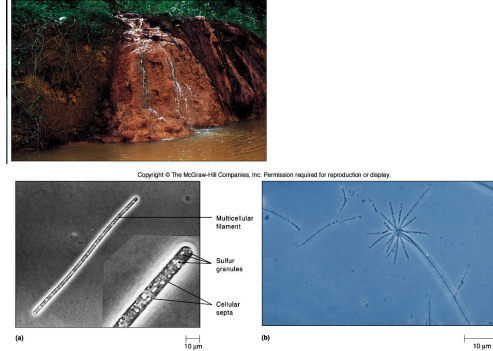
Purple sulfur bacteria



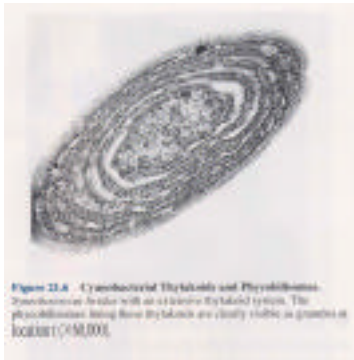
Oxygenic phototrophs



Aerobic chemolithotrophs



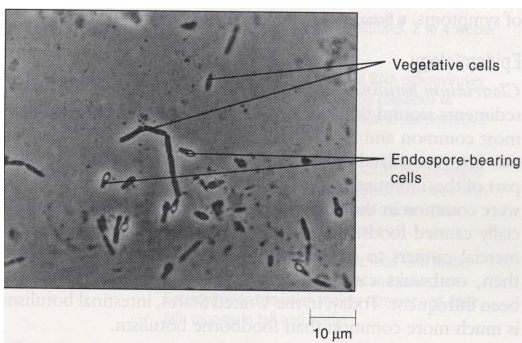
Thylacoids



Botulism

- ✓ *Botulus*
 - Sausage
- ✓ Causative agent
 - *Clostridium botulinum*
 - ☐ Endospore forming bacillus
 - ☐ Obligate anaerobe
 - ☐ Produces a very potent neurotoxin
 - (exotoxin)
 - ☐ Found in the soil

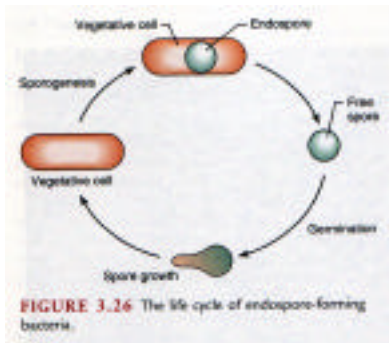
Clostridium botulinum



C. botulinum endospores



Endospore formation



Growth in thioglycollate medium

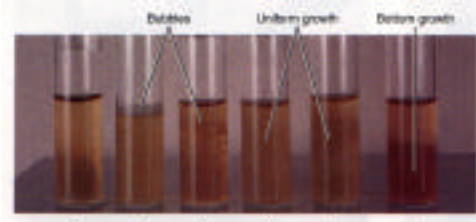


FIGURE 4.47 Bacterial growth patterns in thioglycollate broth tubes. Bubbles (tubes 2 and 3) are indicative of gas-producing bacteria; uniform growth (tubes 4 and 5) is indicative of facultatively anaerobic bacteria; and bottom growth (tube 6) is indicative of anaerobic bacteria. Tube 1 was left unassociated.

Types of botulism

- ✓ Foodborne botulism
 - Ingestion of the toxin
 - No infection necessary
- ✓ Infant botulism
 - Germination of endospores in immature digestive tracts
 - "Floppy baby" syndrome (up to 12 months)
- ✓ Wound botulism
 - Deep, crushing wounds

Foodborne botulism



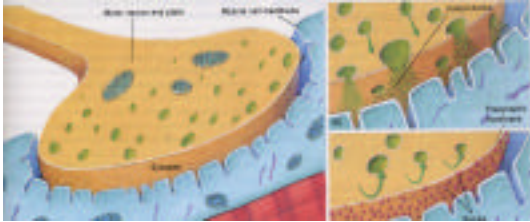
Symptoms/signs of botulism

- ✓ Relaxes muscles
 - Double vision
 - Speaking difficulties
 - Swallowing
 - breathing
 - No fever

Toxin characteristics

- ✓ Most potent toxin known
- ✓ Exotoxin?
- ✓ Heat labile
 - Destroyed by heat

Botulinum toxin blocks acetylcholine release at neuronal junctions



Treatment

- ✓ Polyvalent antitoxin immediately
- ✓ Respiratory help
- ✓ Antibiotics?
 - Amoxicillin
 - Penicillin

Prevention

- ✓ Can food properly/avoid damaged cans
- ✓ Boiling home canned food for 10 minutes
- ✓ Avoid giving honey to infants
- ✓ Clean deep wounds properly
- ✓ Avoid dirty needles

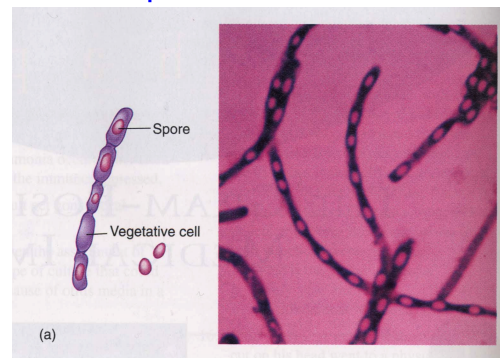
Causative agent

- ✓ *Bacillus anthracis*
 - Gram + bacteria
 - Endospore forming
 - Rod shaped
 - Encapsulated

Bacillus anthracis
colony



Anthrax spores



Bacillus anthracis



Bacillus anthracis endospore

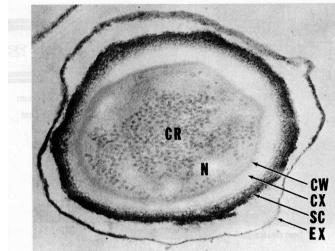
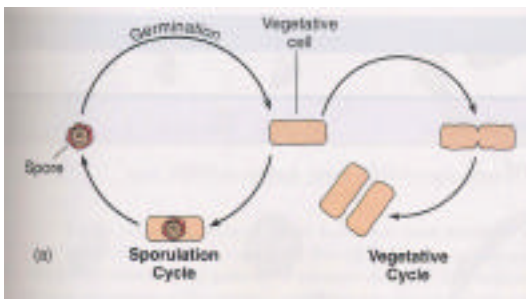


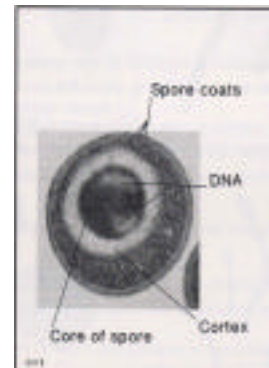
Figure 3.45 Endospore Structure. *Bacillus anthracis* endospore ($\times 151,000$). Note the following structures: exosporium, EX; spore coat, SC; cortex, CX; core wall, CW; and the protoplast or core with its nucleoid, N, and ribosomes, CR.

Sporulation



Spores

Dipicolinic acid
Low water
Low metabolism

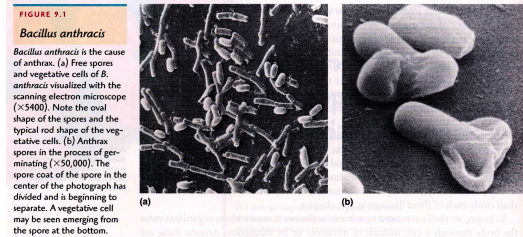


Spores

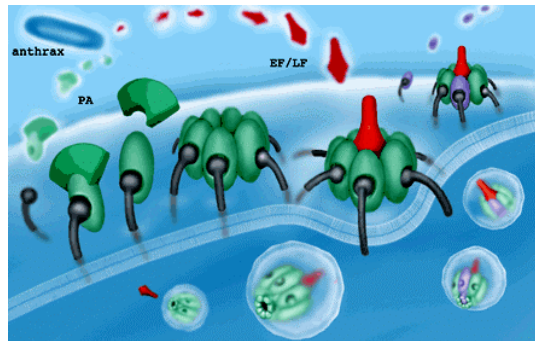


Figure 11.17 Endospore-Formers (a) Endospores forming in the midportion of the cells of *Bacillus anthracis*. (b) Endospores forming at the ends of the cells in *Clostridium tetani*. Both of these species can cause fatal disease, but many other species of endospore-formers are harmless.

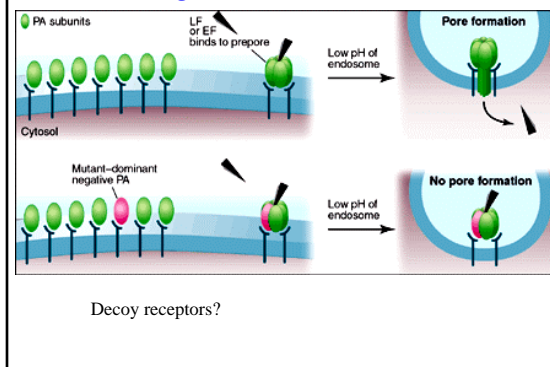
Spore formation and germination



Anthrax toxin



Preventing anthrax?



Vaccines

✓ First vaccine in the 1930s

• Livestock

- Attenuated bacteria
- Pasteur first to attenuate the organism

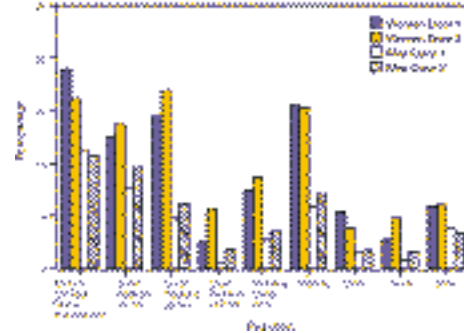
• Human

- Cell culture extracts that contain the PA protein

✓ New? -- DNA vaccine with the PA and LF genes on a plasmid

Vaccine side effects

FIGURE 1. Side effects associated with the anthrax vaccine. (United States Food and Drug Administration, October 2008)



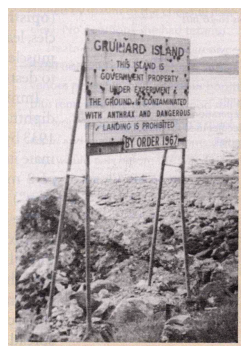
Grainard Island

In 1941

60 sheep

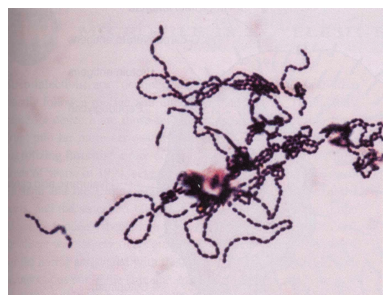
1971 - still anthrax spores
Spread by earthworms

1981 - notes led government officials to 10 lbs of soil
1986 - the island was decontaminated
1987 - sheep were on the island again

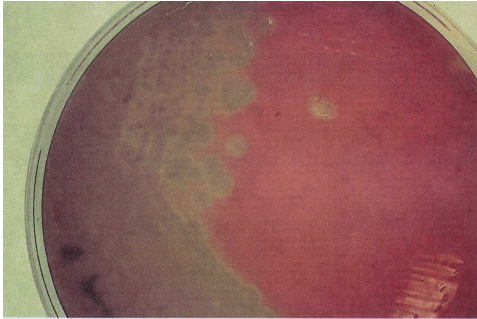


Strept throat (streptococcal pharyngitis)

Causative agent: *Streptococcus pyogenes*



-hemolysis (usually *S. pneumonia*)



Complications

- ✓ Scarlet fever
- ✓ Streptococcal toxic shock syndrome
- ✓ Necrotizing fasciitis
- ✓ Glomerulonephritis
- ✓ Rheumatic fever
- ✓ Chorea

Necrotizing fasciitis



Prevention/treatment

- ✓ Avoid crowds
 - Adequate ventilation
- ✓ Penicillin (10 days)
- ✓ Erythromycin (10 days)

Causative organism

- ✓ *Neisseria gonorrhoeae*
 - Gram (-) cocci
 - Diplococcus
 - Fastidious
 - Chocolate agar - enriched
 - Thayer-Martin medium - selective
 - Vancomycin - inhibits Gram (+)
 - Colistin & trimethoprim lactate - inhibits Gram (-) rods
 - Nystatin - inhibit fungi

Transmission

- ✓ Direct contact
 - Vaginal sex
 - Oral sex
 - Birth canal - neonates
 - Anal sex
 - Fomites - towels, laundry, sheets

Pathogenesis

- ✓ Pili attach to epithelial cells
- ✓ Pili evade phagocytosis
- ✓ Other surface antigens help attach
- ✓ Endotoxin, proteases, phospholipases
 - Cleave IgA antibodies
- ✓ Hitch rides on sperm?

Diagnosis

- ✓ *Neisseria gonorrhoeae* identification
 - Cultures (Thayer-Martin medium)
 - Gram stain of culture and discharge
 - ↳ Gram(-) diplococci
 - An ELISA test (antibody)
 - Nucleic acid probe

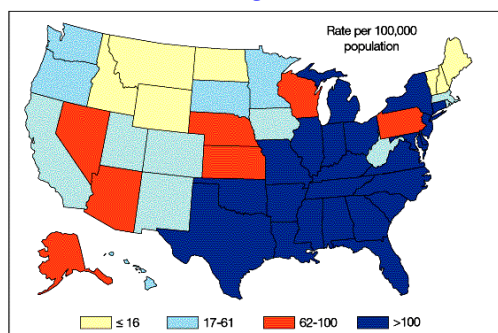
Treatment

- ✓ IM Ceftriaxone
- ✓ Penicillin
- ✓ Tetracycline
- ✓ Combination of ceftriaxone and tetracycline (doxycycline) or azithromycin

Prevention

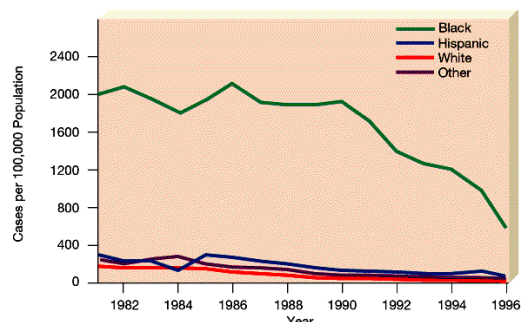
- ✓ No sexual contact
- ✓ Monogamous relationship
 - Condoms

US incidence of gonorrhea



(a)

Gonorrhea by ethnicity



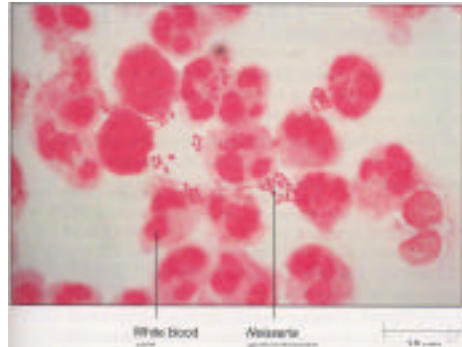
(b)

Streak plate of *Neisseria gonorrhoeae*



FIGURE 9.16 Streak plate on chocolate agar of *Neisseria gonorrhoeae*, the causative agent of gonorrhea.

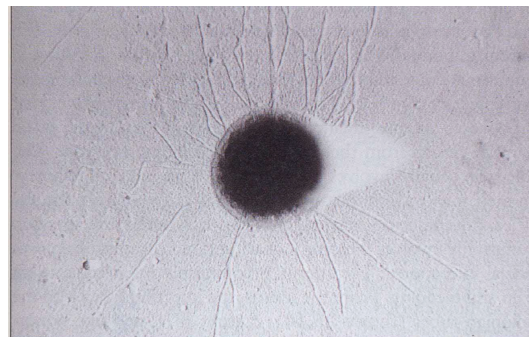
Discharge with *N. gonorrhoeae*



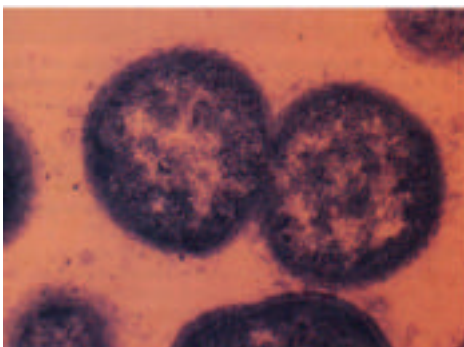
WBC with *N. gonorrhoeae*



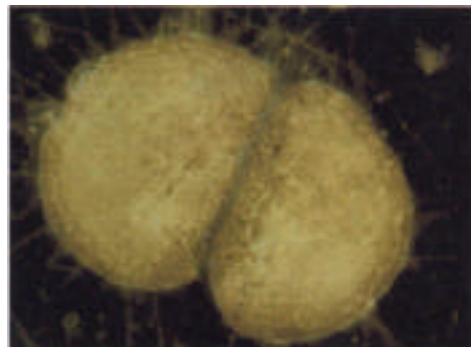
Pili of *N. gonorrhoeae*



Diplococcus



Diplococcus

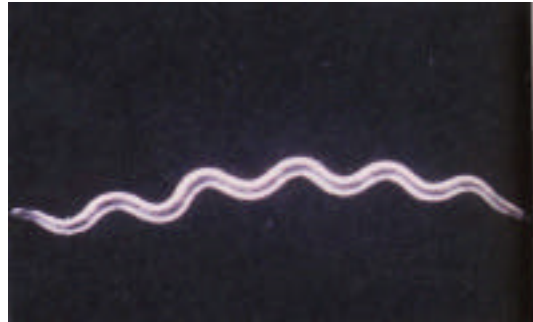


Causative agent

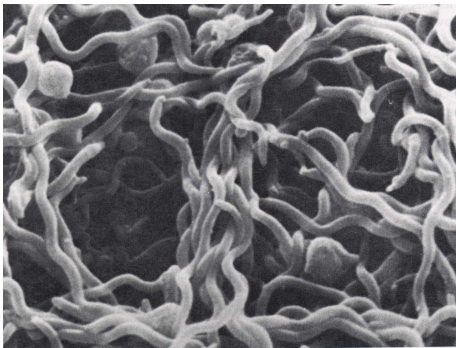
✓ *Borrelia burgdorferi*

- Bacterium
- Large spirochete
- 11 to 25 μm
- Linear genome (multiple copies)

Borrelia burgdorferi



Borrelia burgdorferi



Transmission

- ✓ Bite of an infected tick
- ✓ *Borrelia burgdorferi* reproduce and spread radially
- ✓ No transmission to other people

- ✓ Major reservoir
 - White footed mouse
 - White tailed deer

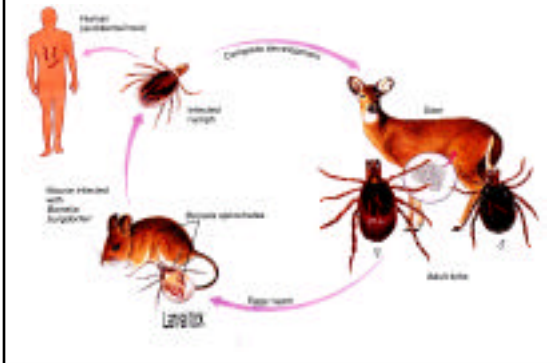
Vector

- Black-legged tick
- *Ixodes scapularis*
- Deer tick

Ixodes scapularis (Black legged tick)



Life-cycle



Signs/symptoms

✓ Stage 1 - one week

- Bull's-eye rash develops at bite site
 - Ring-like - up to 6 inches
- Fever, malaise, headache, and body aches
 - Flu-like

Signs/symptoms

✓ Stage 2 & 3

- Acute - 2-8 weeks -
 - heart and nervous system
 - Paralysis of the face, pacemaker, impairment of arm and leg movement, fatigue, severe headache,
- Chronic - 6 months -
 - Arthritis, joint pain, swelling, tenderness in joints

Bull's-eye rash



Bull's-eye rash



Bull's-eye rash



Lyme Disease

- ✓ Clinical symptoms
 - Rash - sometimes
 - Arthritis - most cases
- ✓ Antibody test

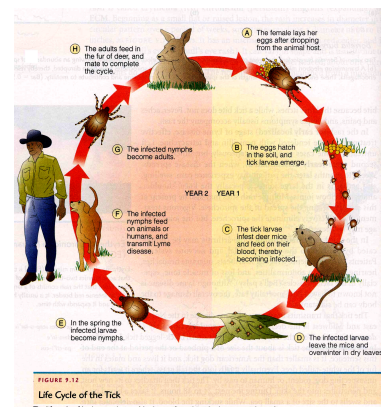
Lyme disease

- ✓ Treatment
 - Doxycycline
 - Amoxicillin
 - Ampicillin
 - Ceftriaxone
- ✓ Prevention
 - Protective clothing, tick repellents
 - Vaccine (4/5 people it works)
 - Parasitic wasp against black-legged ticks

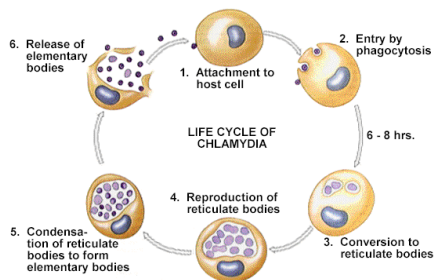
Lyme disease distribution



FIGURE 7-10
Lyme Disease in the United States, 1997



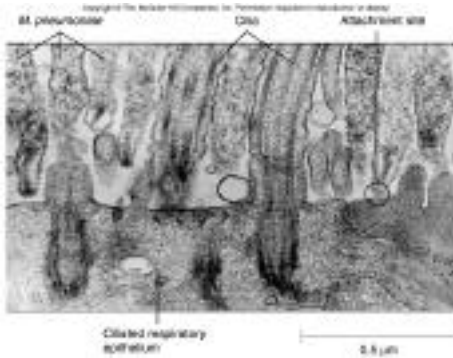
Rickettsiae and Chlamydiae present special problems



Mycoplasma pneumoniae



Mycoplasma pneumonia



Causative agent

- ✓ *Mycobacterium tuberculosis*
- ✓ *Mycobacterium bovis*
- ✓ *Mycobacterium avium*

- ✓ Acid fast bacillus bacterium
- ✓ Obligate aerobe
- ✓ Slow grower
 - Generation time = 12 hours

Mycobacterium diseases

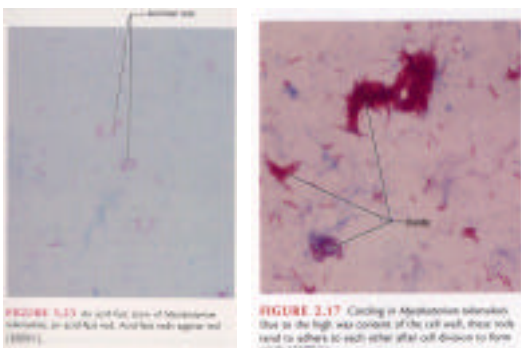
SPECIES	DISEASE
<i>M. tuberculosis</i>	Tuberculosis
<i>M. avium</i>	Tuberculosislike disease in humans, transmitted from birds and swine
<i>M. bovis</i>	Tuberculosis, transmitted from cattle; could be transmitted from subhuman primates
<i>M. fortuitum</i> complex	Wound infections
<i>M. kansasii</i>	Tuberculosislike disease
<i>M. leprae</i>	Hansen's disease (leprosy)
<i>M. marinum</i>	Cutaneous lesions in humans, tuberculosis in fish
<i>M. ulcerans</i>	Ulcerative lesions

Acid fast and staining

- ✓ Lipid layer - mycolic acid
 - Prevents drying
 - Prevents staining with most dyes

- Carbofuchsin - red (positive)
- Methylene blue - blue (negative)

Acid fast staining



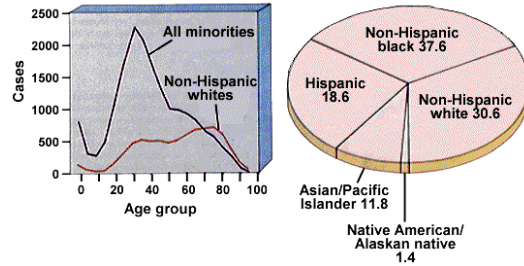
Transmission

- ✓ Aerosol droplets
 - 10 or fewer cells cause disease
 - Coughing
 - Ventilation
 - Crowding
 - Families
 - Schools
 - Hospitals
 - Elderly homes

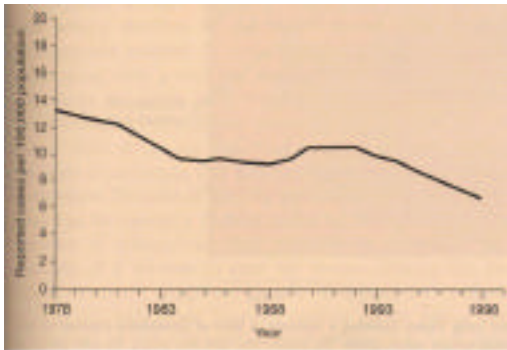
Signs/symptoms

- ✓ Slight fever
- ✓ Chronic cough
- ✓ Sweating at night
- ✓ Weight loss
- ✓ Blood streaked sputum

US incidence of TB



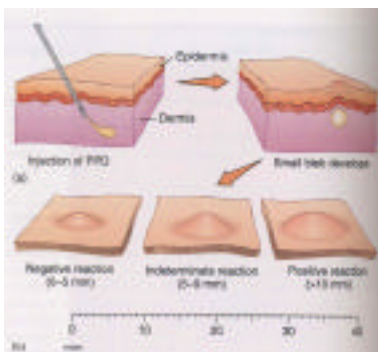
Incidence of tuberculosis



Tuberculin or Mantoux test

- ✓ Inject under the skin the purified protein
 - PPD - purified protein derivative
- ✓ If infected
 - Redness and firmness develops
 - 48-72 hr
- ✓ T-cell delayed hypersensitivity response
- ✓ Positive test - infected or exposed to *Mycobacterium tuberculosis*

PPD skin test



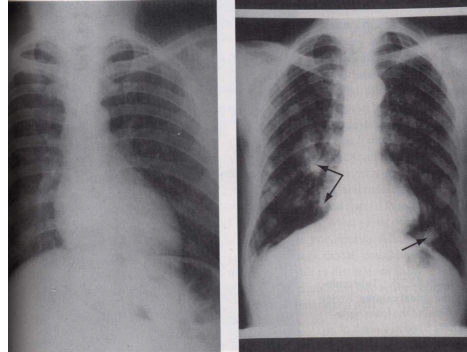
Positive skin test



Diagnosis

- ✓ Sputum culture
 - Slow - 8 weeks
- ✓ Genetic probes
 - Fast
- ✓ Chest x-rays
- ✓ Skin test

X-rays

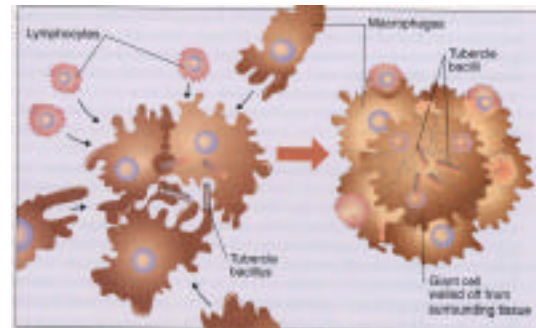


Treatment

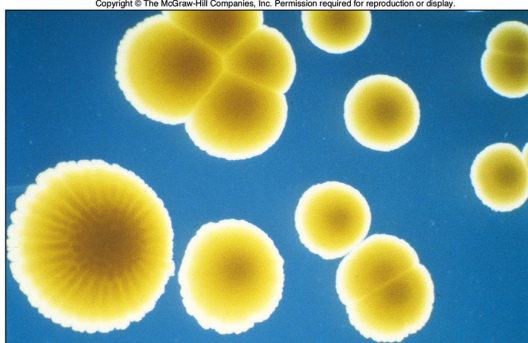
- ✓ Isoniazid & rifampin
 - Six months or more
- ✓ Other drugs...

- ✓ GCG vaccine
 - Discouraged in US
 - Living attenuated bacteria

Growth of *M. tuberculosis*



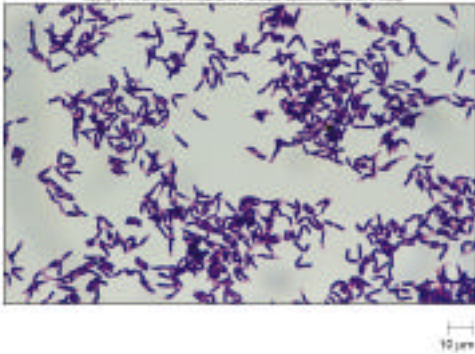
Micrococcus



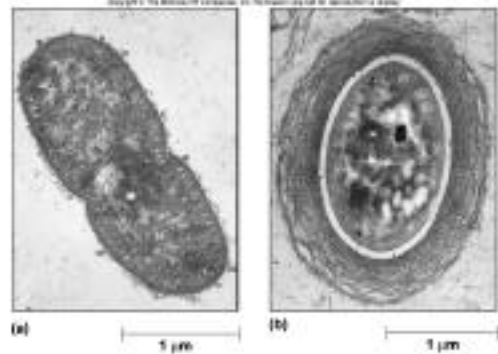
Pseudomonas



Corynebacteria



Azotobacter



Myxobacteria



Actinomycetes (*Streptomyces*)



Coxiella and *Chlamydia*

