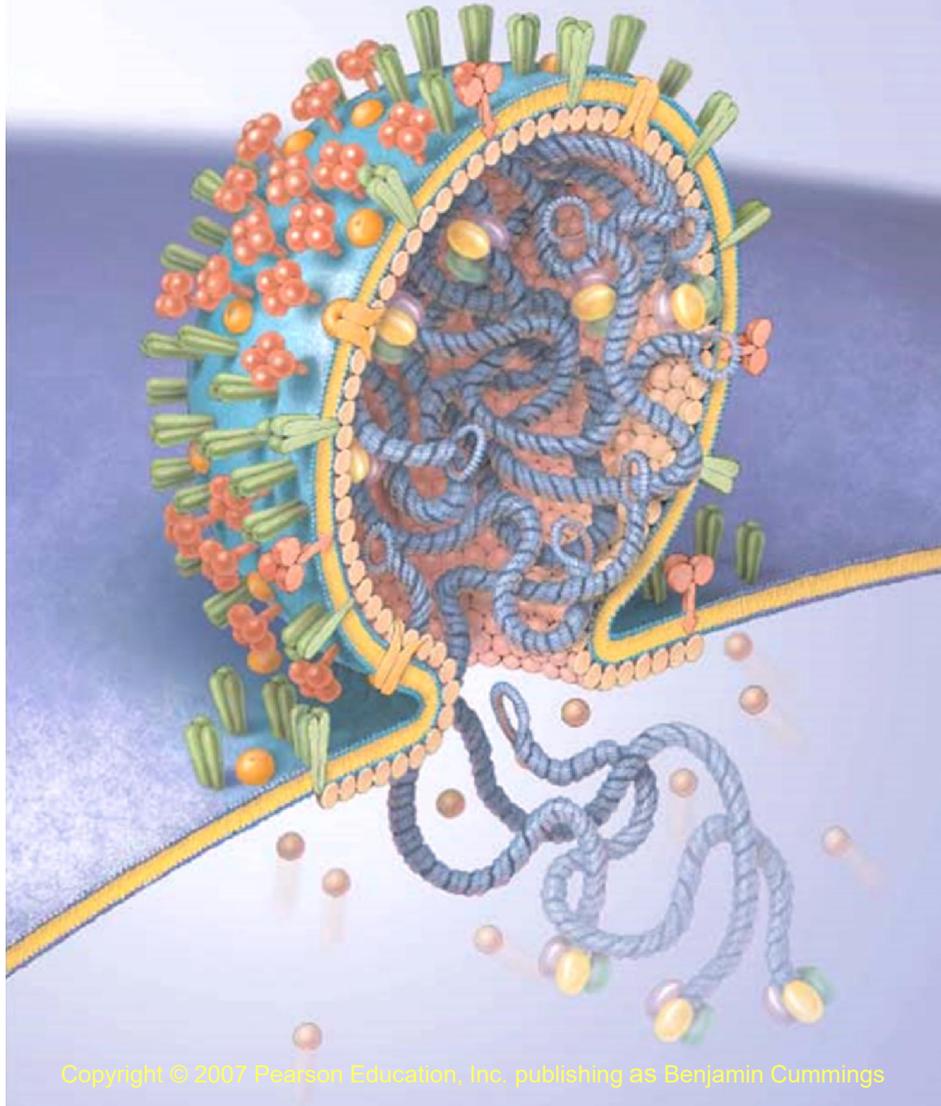


Microbiology

With Diseases by Taxonomy

Second Edition



Copyright © 2007 Pearson Education, Inc. publishing as Benjamin Cummings

PowerPoint® Lecture Slides

Pathogenic
Gram-Positive
Cocci and
Bacilli

Gram-Positive Pathogens

- Stain purple when gram-stained
- Can be categorized into two major groups based on their DNA
 - Low G + C organisms
 - Genera of cocci-shaped organisms – *Staphylococcus*, *Streptococcus*, and *Enterococcus*
 - Genera of bacilli-shaped organisms – *Bacillus*, *Clostridium*, and *Listeria*
 - High G + C organisms
- Genera of bacilli-shaped organisms – *Corynebacterium*, *Mycobacterium*, *Propionibacterium*, *Nocardia*, and *Actinomyces*

Staphylococcus

- Normal members of every human's microbiota
- Can be opportunistic pathogens

Staphylococcus



SEM

1 μ m

Figure 19.1

Structure and Physiology

- Gram-positive cocci, nonmotile, facultative anaerobes
- Cells occur in grapelike clusters because cells division occurs along different planes and the daughter cells remain attached to one another
- Salt-tolerant – allows them to tolerate the salt present on human skin
- Tolerant of desiccation – allows survival on environmental surfaces (fomites)

Structure and Physiology

- Two species are commonly associated with staphylococcal diseases in humans
 - *Staphylococcus aureus* – the more virulent strain that can produce a variety of conditions depending on the site of infection
 - *Staphylococcus epidermidis* – normal microbiota of human skin that can cause opportunistic infections in immunocompromised patients or when introduced into the body

Pathogenicity

- “Staph” infections result when staphylococci breach the body’s physical barriers
- Entry of only a few hundred bacteria can result in disease
- Pathogenicity results from three features
 - Structures that enable it to evade phagocytosis
 - Production of enzymes
 - Production of toxins

Structural Defenses Against Phagocytosis

- Protein A coats the cell surface
 - Interferes with humoral immune responses by binding to class G antibodies
 - Inhibits the complement cascade
- Bound coagulase
 - Converts the soluble blood protein fibrinogen in insoluble fibrin molecules that form blood clots
 - Fibrin clots hide the bacteria from phagocytic cells

Structural Defenses Against Phagocytosis

- Synthesize loosely organized polysaccharide slime layers (often called capsules)
 - Inhibit chemotaxis of and phagocytosis by leukocytes
 - Facilitates attachment of Staphylococcus to artificial surfaces

Enzymes

- Cell-free coagulase
 - Triggers blood clotting
- Hyaluronidase
 - Breaks down hyaluronic acid, enabling the bacteria to spread between cells
- Staphylokinase
 - Dissolves fibrin threads in blood clots, allowing *S.aureus* to free itself from clots

Enzymes

- Lipases
 - Digest lipids, allowing staphylococcus to grow on the skin's surface and in cutaneous oil glands
- β -lactamase
- Breaks down penicillin
 - Allows the bacteria to survive treatment with β -lactam antimicrobial drugs

Toxins

- *Staphylococcus aureus* produces toxins more frequently than *S.epidermidis*
- Cytolytic toxins
 - Disrupts the cytoplasmic membrane of a variety of cells
 - Leukocidin can lyse leukocytes specifically
- Exfoliative toxins
 - Causes the patient's skin cells to separate from each other and slough off the body

Toxins

- Toxic-shock-syndrome toxin
 - Causes toxic shock syndrome
- Enterotoxins
 - Stimulate the intestinal muscle contractions, nausea, and intense vomiting associated with staphylococcal food poisoning

Staphylococcal Diseases

- Three categories
 - Noninvasive disease
 - Food poisoning from the ingestion of enterotoxin-contaminated food
 - Cutaneous disease
 - Various skin conditions including scalded skin syndrome, impetigo, folliculitis, and furuncles

Staphylococcal Diseases

- Systemic disease
 - Toxic shock syndrome – TSS toxin is absorbed into the blood and causes shock
 - Bacteremia – presence of bacteria in the blood
 - Endocarditis – occurs when bacteria attack the lining of the heart
 - Pneumonia – inflammation of the lungs in which the alveoli and bronchioles become filled with fluid
 - Osteomyelitis – inflammation of the bone marrow and the surrounding bone

Diagnosis, Treatment, and Prevention

- Diagnosis
 - Detection of Gram-positive bacteria in grapelike arrangements isolated from pus, blood, or other fluids
- Treatment
 - Methicillin is the drug of choice to treat staphylococcal infections
 - Is a semisynthetic form of penicillin and is not inactivated by β -lactamase

Diagnosis, Treatment, and Prevention

- Prevention
 - Hand antisepsis is the most important measure in preventing nosocomial infections
 - Also important is the proper cleansing of wounds and surgical openings, aseptic use of catheters or indwelling needles, an appropriate use of antiseptics

Streptococcus

- Gram-positive cocci, arranged in pairs or chains, that are facultative anaerobes
- Often categorized based on the Lancefield classification
 - Divides the streptococci into serotype groups based on the bacteria's antigens
 - Lancefield groups A and B include the significant streptococcal pathogens of humans

Group A Streptococcus: *Streptococcus Pyogenes*

- *S. pyogenes* forms white colonies surrounded by zone of beta-hemolysis on blood agar plates
- Pathogenic strains often form a capsule
- Group A streptococci generally only cause disease in certain situations
 - Normal microbiota are depleted
 - Large inoculum enable the streptococci to establish themselves before antibodies are formed against them
 - Specific immunity is impaired

Pathogenicity

- Structural components
 - Protein M, which interferes with opsonization and lysis of the bacteria and a hyaluronic acid capsule, which acts to camouflage the bacteria
- Enzymes
 - Streptokinases, deoxynucleases, and C5a peptidase all facilitate the spread of streptococci through tissues
- Pyrogenic toxins that stimulate macrophages and helper T cells to release cytokines
- Streptolysins lyse red blood cells, white blood cells, and platelets

Group A Streptococcal Diseases

- Pharyngitis (“strep throat”) – inflammation of the pharynx
- Scarlet fever – rash that begins on the chest and spreads across the body
- Pyoderma – confined, pus-producing lesion that usually occurs on the face, arms, or legs
- Streptococcal toxic shock syndrome – bacteremia and severe multisystem infections

Necrotizing Fasciitis



Group A Streptococcal Diseases

- Necrotizing fasciitis – toxin production destroys tissues and eventually muscle and fat tissue
- Rheumatic fever – inflammation that leads to damage of heart valves muscle
- Glomerulonephritis – inflammation of the glomeruli and nephrons which obstruct blood flow through the kidneys

Diagnosis, Treatment, and Prevention

- Diagnosis
 - Observation of Gram-positive bacteria in short chains or pairs or immunological tests that identify the presence of group A streptococcal antigens
 - Streptococci are normally in the pharynx so their presence in a respiratory sample is of little diagnostic value

Diagnosis, Treatment, and Prevention

- Treatment
 - Penicillin is very effective
- Prevention
 - Antibodies against M protein provide long-term protection against future infection of *S. pyogenes*, but only if it is the same strain

Group B Streptococcus: *Streptococcus agalactiae*

- Gram-positive cocci that divide to form chains
- Distinguished from group A streptococcus by its buttery colonies and smaller zone of beta-hemolysis on blood agar plates and its resistance to bacitracin
- Normally colonizes the lower gastrointestinal, genital, and urinary tracts

Pathogenicity and Diseases

- Pathogenicity
 - Often infects newborns who have not yet formed type-specific antibodies and whose mothers are uninfected (and so do not provide passive immunity)
 - Produces various enzymes whose roles in causing disease is not yet understood
- Diseases
 - Most often associated with neonatal bacteremia, meningitis, and pneumonia
 - Immunocompromised older patients are at risk from group B streptococcal infections

Diagnosis, Treatment, and Prevention

- Diagnosis
 - Agglutination and ELISA test utilizing antibodies directed against the bacteria's distinctive cell wall polysaccharide
 - Incubation of the bacteria with bacitracin which inhibits its growth
- Treatment
 - Penicillin G, sometimes in combination with an aminoglycoside

Diagnosis, Treatment, and Prevention

- Prevention
 - Prophylactic administration of penicillin at birth to children whose mothers' urinary tracts are colonized with group B streptococci
 - Immunization of women against group streptococci to prevent infection of future children

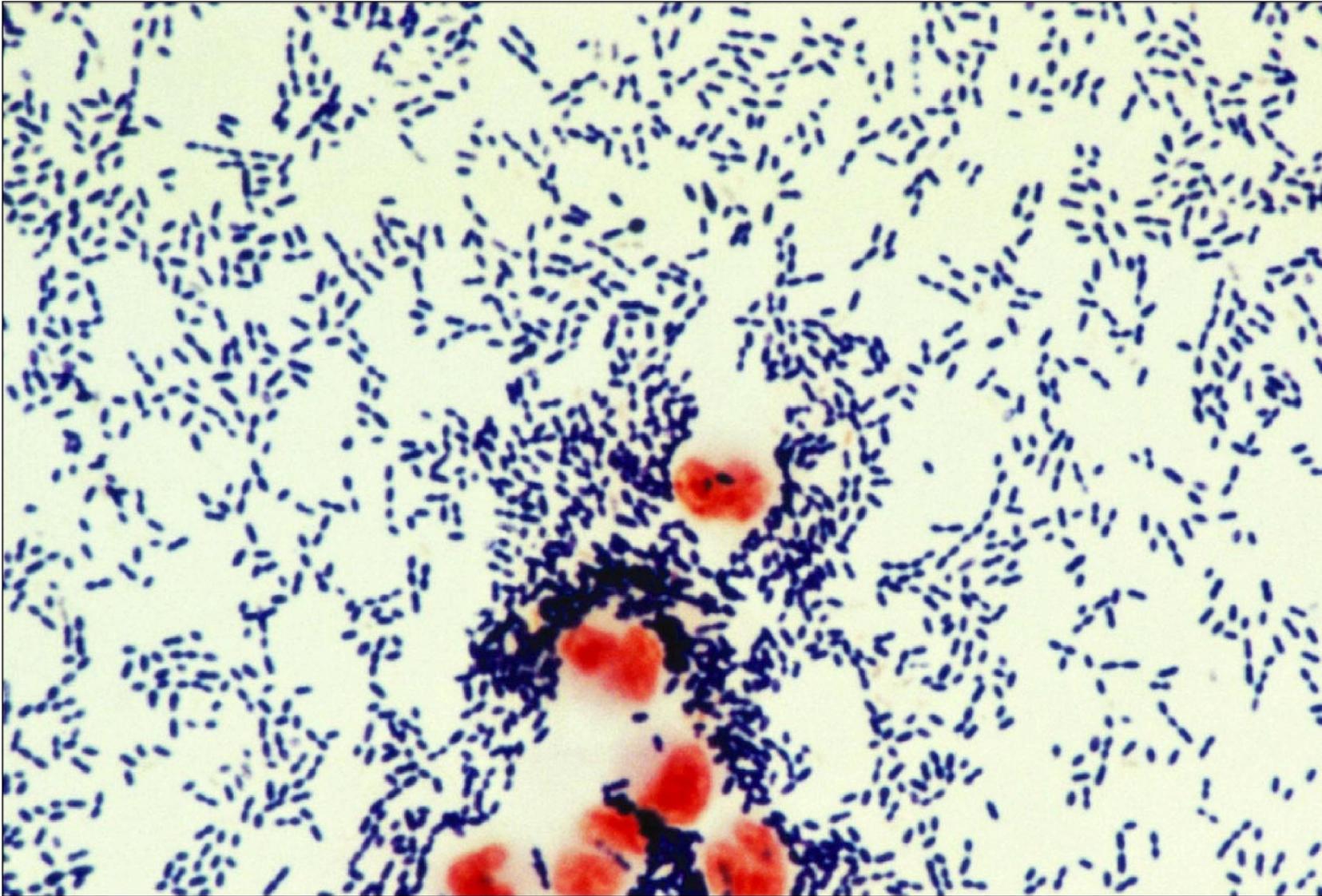
Alpha-Hemolytic Streptococci: The Viridans Group

- Lack group-specific carbohydrates and cannot be grouped by the Lancefield system
- Many produce a green pigment when grown on blood media
- Normally inhabit the mouth, pharynx, GI tract, genital tract, and urinary tract
- One of the causes of dental caries and dental plaques
- If enter the blood can cause meningitis and endocarditis

Streptococcus pneumoniae

- Gram-positive cocci that most commonly forms pairs but may also form chains
- Forms unpigmented, alpha-hemolytic colonies when grown on blood agar (anaerobic incubation produces beta-hemolytic colonies)
- Normally colonizes the mouths and pharynx but can cause disease if travels to the lungs
- Disease is highest in children and the elderly

Streptococcus pneumoniae



LM

10 μ m

Figure 19.9

Pathogenicity

- Phosphorylcholine – stimulates cells to phagocytize the bacteria
- Polysaccharide capsule – protects the bacteria from digestion after endocytosis
- Protein adhesin – mediates binding of the cells to epithelial cells of the pharynx
- Secretory IgA protease – destroys IgA
- Pneumolysin – lyses epithelial cells and suppresses the digestion of the endocytized bacteria

Diseases

- Pneumococcal pneumonia – bacteria multiply in the alveoli of the lower lung causing damage to the alveolar lining and producing an inflammatory response
- Sinusitis and otitis media – bacteria invade the sinuses or middle ear, often following a viral infection
- Bacteremia and endocarditis – bacteria in the bloodstream or in the lining of the heart
- Pneumococcal meningitis – bacteria that have spread to the meninges

Diagnosis, Treatment, and Prevention

- Diagnosis
 - Gram-stain of sputum smears
 - Quellung reaction – anti-capsular antibodies cause the capsule to swell, confirming the presence of bacteria
- Treatment
 - Penicillin
- Prevention
 - Vaccine made from purified capsular material
 - Provides long lasting immunity in normal adults but is not as effective in children, the elderly, or AIDS patients

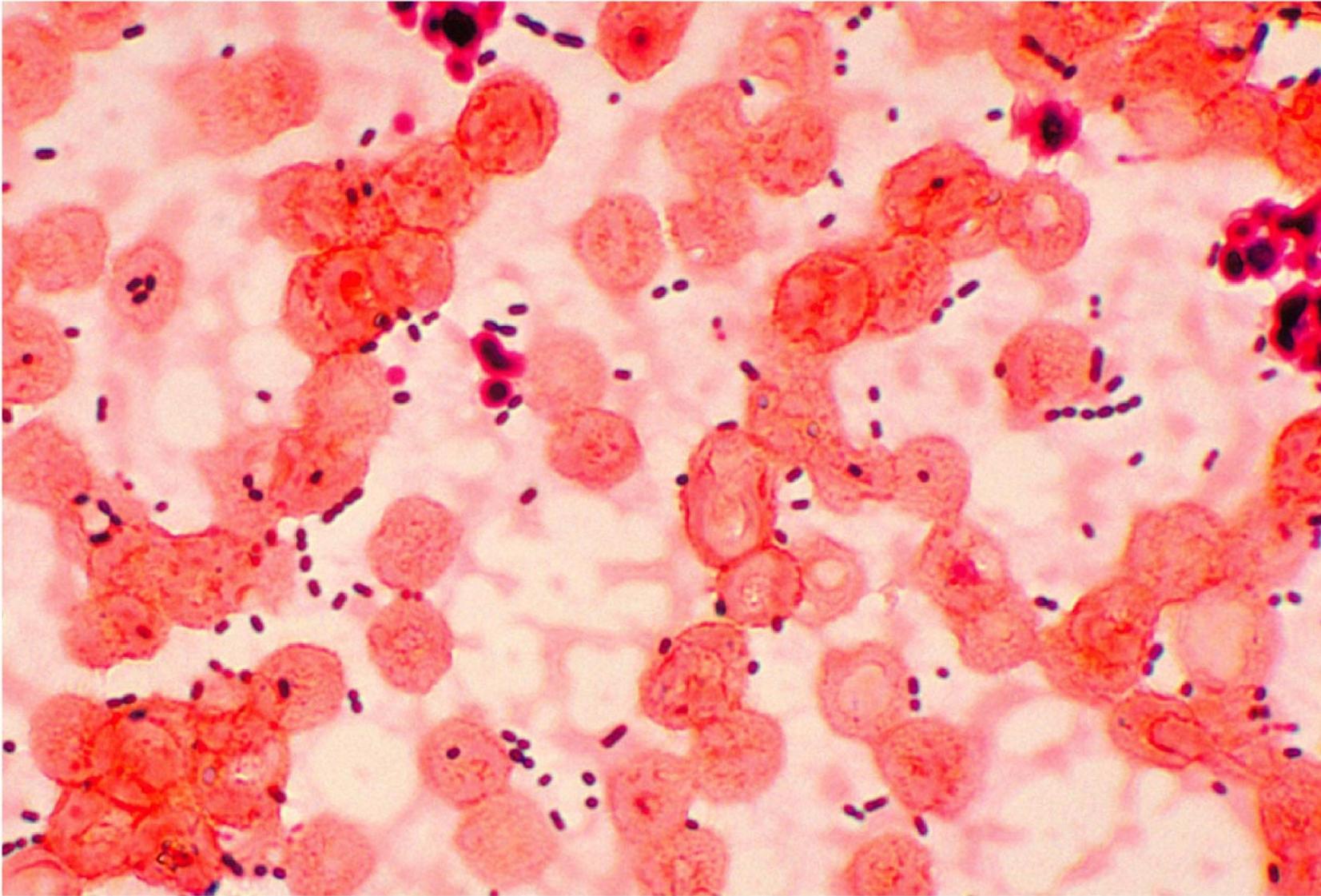
Enterococcus

- Previously classified as group D streptococci but differed enough to be reclassified as a separate genus
- Form short chains and pairs and lack a capsule
- Found in the human colon but are rarely pathogenic at this site
- Can cause disease if they are introduced into other parts of the body, such as the urinary tract or bloodstream

Enterococcus

- Important cause of nosocomial infections
- Treatment is difficult because enterococci are often resistant to antimicrobials
- Prevention is difficult, especially in a health care setting, where patients' often have weakened immune systems

Enterococcus



LM

10 μ m

Figure 19.10

Bacillus

- Gram-positive bacilli, that occurs singly, in pairs, or in chains
- Forms endospores
- *Bacillus anthracis* is a strict pathogen of animals and humans
 - Primarily a disease of herbivores, but humans can contract the disease from infected animals
 - Humans contract the bacteria via one of three routes
 - Inhalation of spores
 - Inoculation of spores into the body through a break in the skin
 - Ingestion of spores

Bacillus anthracis



SEM

3 μ m

Pathogenicity and Diseases

- Pathogenicity
 - Anthrax toxin
- Diseases
 - Anthrax is the only disease caused by *Bacillus anthracis*
 - Anthrax can have three clinical manifestations
 - Gastrointestinal anthrax
 - Rare in humans
 - Intestinal hemorrhaging and eventually death

Pathogenicity and Diseases

- Cutaneous anthrax
 - Produces a ulcer called an eschar and toxemia
- Inhalation anthrax
 - Rare in humans
 - Spores germinate in the lungs and secrete toxins that are absorbed into the bloodstream
 - High mortality rate

Diagnosis, Treatment, and Prevention

- Diagnosis
 - Presence of large, nonmotile, Gram-positive bacilli in clinical samples of the lungs or skin
- Treatment
 - Ciproflaxacin and many other antimicrobials are effective against *B.anthraxis*
- Prevention
 - Control the disease in animals
 - An anthrax vaccine is available but requires multiple doses and boosters

Clostridium

- Gram-positive, anaerobic, endospore-forming bacillus
- Ubiquitous in soil, water, and the gastrointestinal tracts of animals and humans
- The presence of endospores allows for survival in harsh conditions

Clostridium perfringens

- Commonly grows in the digestive tracts of animals and humans
- Produces 11 toxins that have various effects on the body and can result in irreversible damage

Clostridium perfringens

- Diseases
 - Food poisoning
 - Benign disease characterized by abdominal cramps and watery diarrhea
 - Gas gangrene
 - Endospores are introduced into the body through some traumatic event
 - The endospores germinate and cause necrosis that is often accompanied by foul-smelling gaseous bacterial waste products

Diagnosis, Treatment, and Prevention

- Diagnosis
 - The presence of more than 10^5 bacteria in a gram of food or 10^6 cells per gram of feces indicates the involvement of *Clostridium* in food poisoning
 - Gas gangrene is usually diagnostic by itself
- Treatment
 - Food poisoning is self-limited
 - Gas gangrene is treated by removing the dead tissue and administering large doses of antitoxin and penicillin

Diagnosis, Treatment, and Prevention

- Prevention
 - Difficult to prevent because it is so common
 - Proper cleaning of wounds can often prevent gas gangrene

Clostridium difficile

- Common member of the intestinal microbiota
- Opportunistic pathogen in patients treated with broad-spectrum antimicrobial drugs
 - Minor infections can result in a self-limiting explosive diarrhea
 - Serious cases can cause pseudomonas colitis
 - Can result in perforation of the colon, leading to massive internal infection by fecal bacteria and eventual death

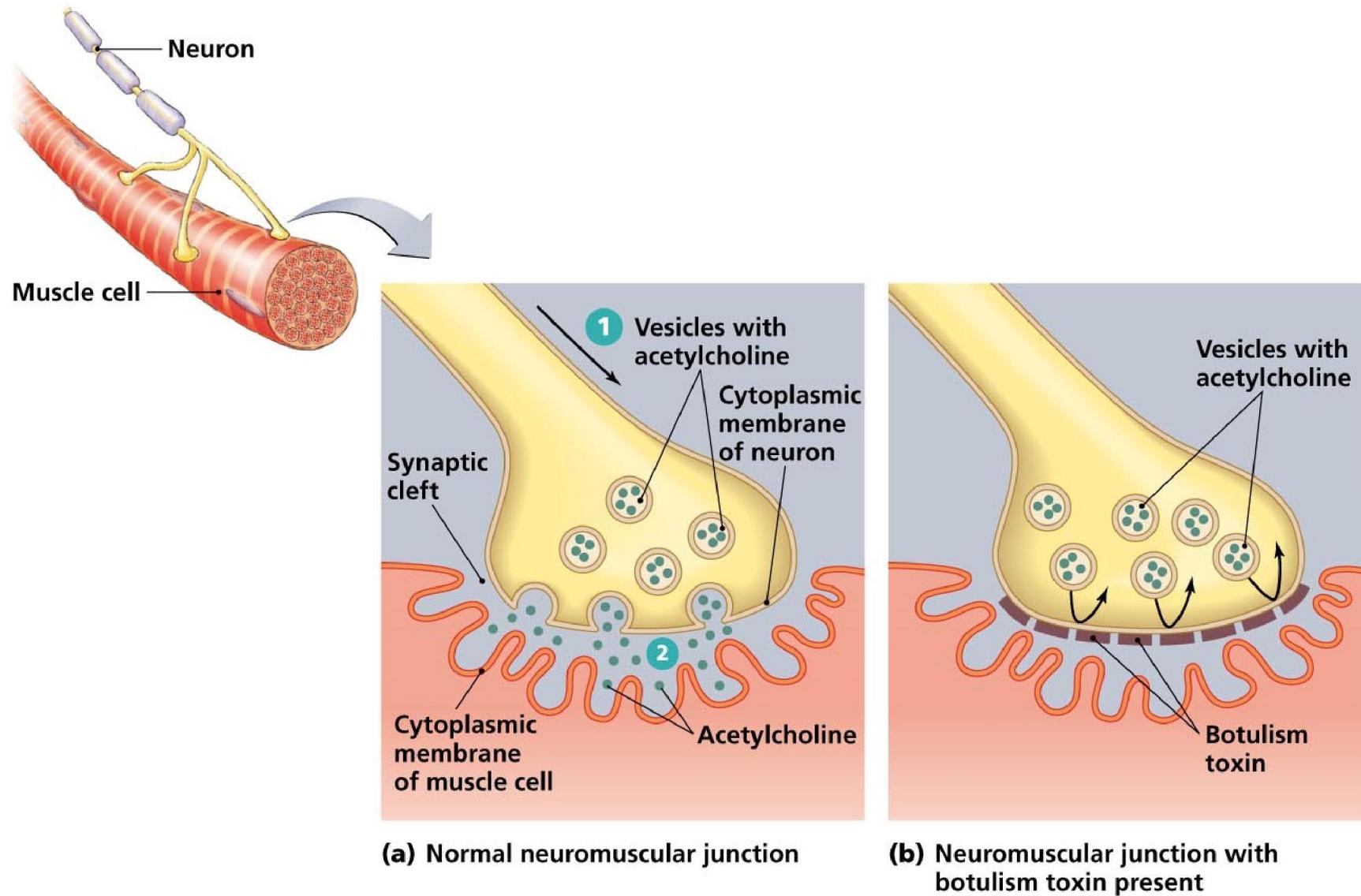
Clostridium difficile

- Diagnosed by isolating the organism from feces or by demonstrating the presence of toxins via immunoassay
- Minor infections are usually resolved by discontinuing use of the antimicrobial drug in use
- Serious cases are treated with antibiotics
- Proper hygiene is critical for limiting nosocomial infections

Clostridium botulinum

- Anaerobic, endospore-forming, Gram-positive bacillus
- Common in soil and water
- Botulism results when the endospores germinate and produce botulism toxin
- The different botulism toxins are among the deadliest toxins known

Botulism Toxin



Diseases

- Botulism is not an infection, but an intoxication caused by the botulism toxin
- Three forms of botulism
 - Food-borne botulism
 - Usually occurs due to the consumption of toxin in home-canned foods or preserved fish
 - Can result in a progressive paralysis that results in death due to the inability to inhale

Diseases

- Infant botulism
 - Results from the ingestion of endospores, which germinate, and colonize the infant's gastrointestinal tract due to the lack of sufficient numbers of normal microbiota
 - Symptoms include constipation and “failure to thrive”; paralysis and death are rare
- Wound botulism
 - Wound becomes contaminated with endospores
 - Symptoms are the same as with food-borne botulism

Diagnosis, Treatment, and Prevention

- Diagnosis
 - Symptoms of botulism are diagnostic
 - Confirm diagnosis by culturing the organism from food, feces, or the patient's wound
- Treatment
 - Can involve three approaches
 - Repeated washing of the intestinal tract to remove *Clostridium*
 - Administer antibodies against botulism toxin to neutralize toxin in the blood before it can bind to neurons
 - Administer antimicrobials drugs to kill clostridia in infant botulism cases

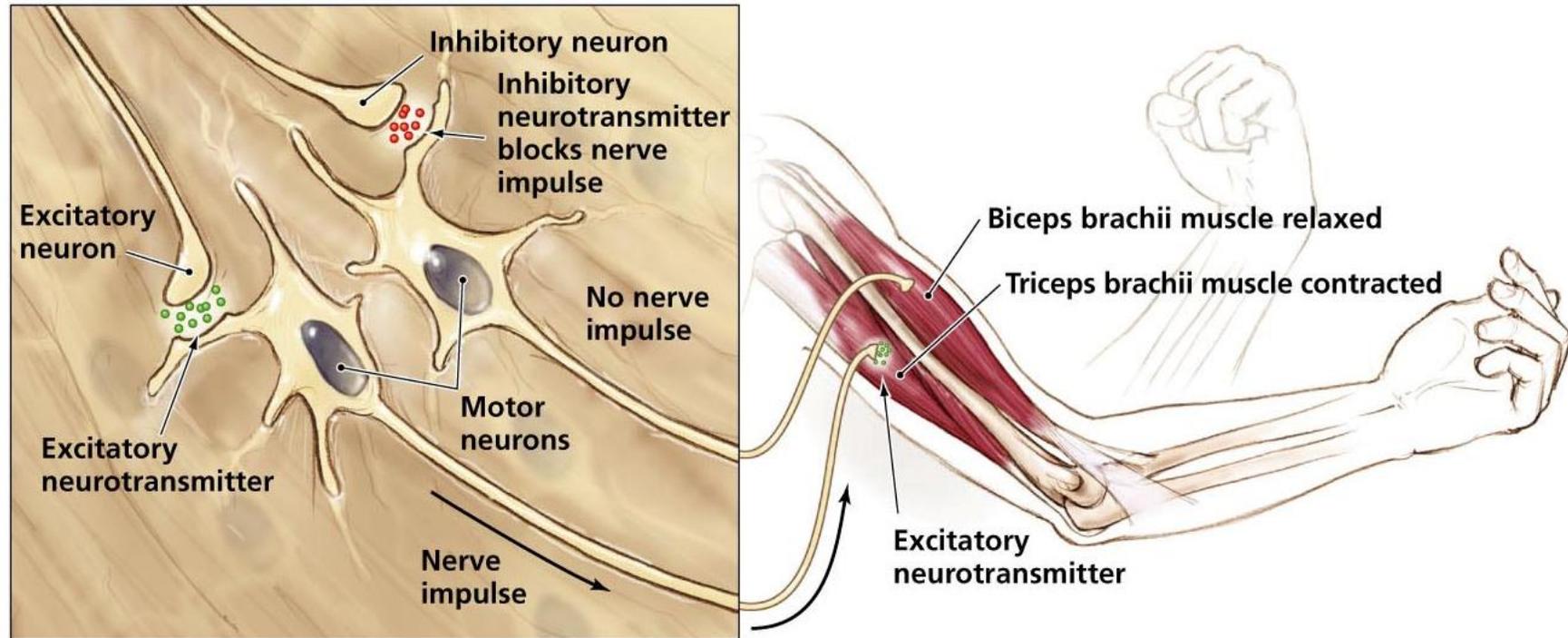
Diagnosis, Treatment, and Prevention

- Prevention
 - Proper canning of food to prevent contamination
 - Infants should not consume honey under the age of 1

Clostridium tetani

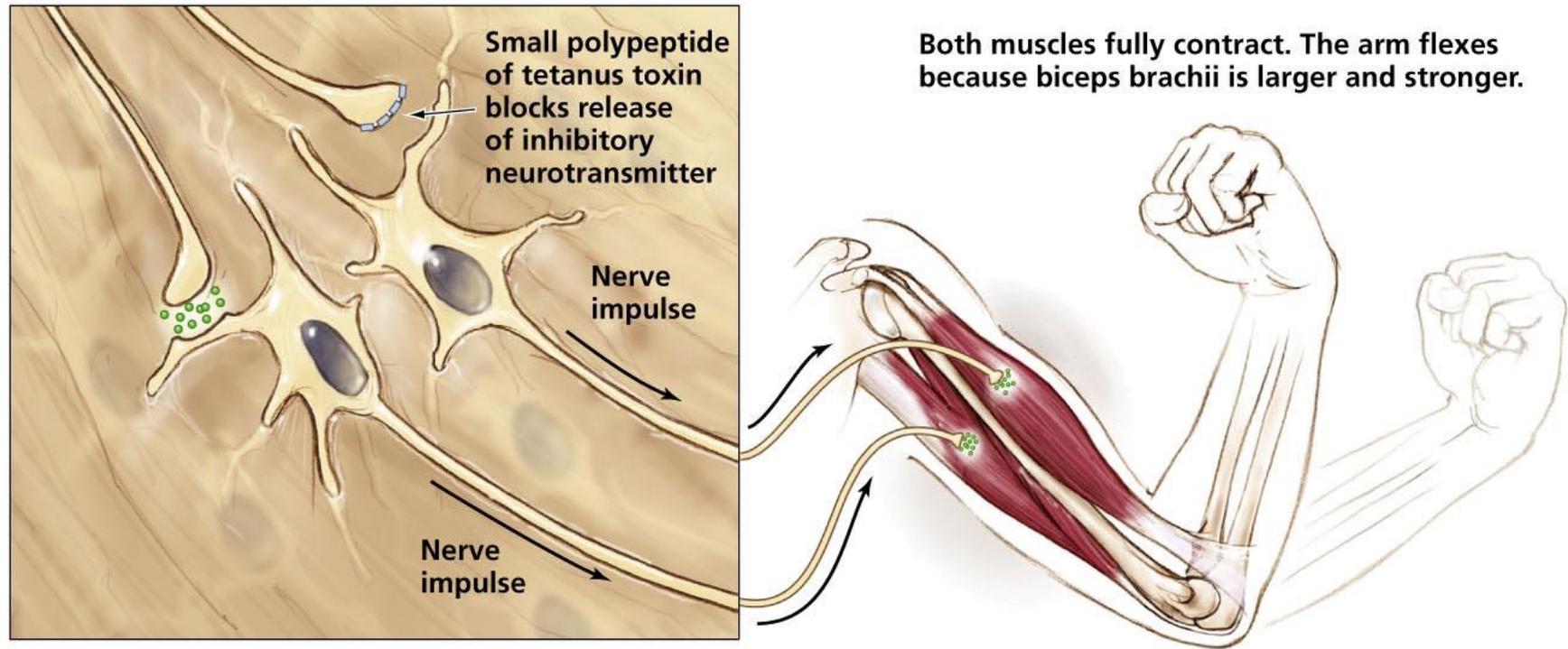
- Endospore-forming, obligately anaerobic, Gram-positive bacilli
- Ubiquitous in soil, dust, and the GI tract of animals and humans
- Tetanus results when the bacterial endospores germinate and produce tetanus toxin
- Tetanus results in spasms and contractions that can result in death because patients can't exhale

Tetanus Toxin



(a)

Tetanus Toxin



(b)

Patient with Tetanus



Diagnosis, Treatment, and Prevention

- Diagnosis
 - Characteristic muscular contraction
 - The bacteria is rarely isolated from clinical samples because it grows slowly and is sensitive to oxygen
- Treatment
 - Thorough cleaning of wounds to remove endospores
 - Passive immunization with immunoglobulin directed against the toxin
 - Administration of antimicrobials
 - Active immunization with tetanus toxoid

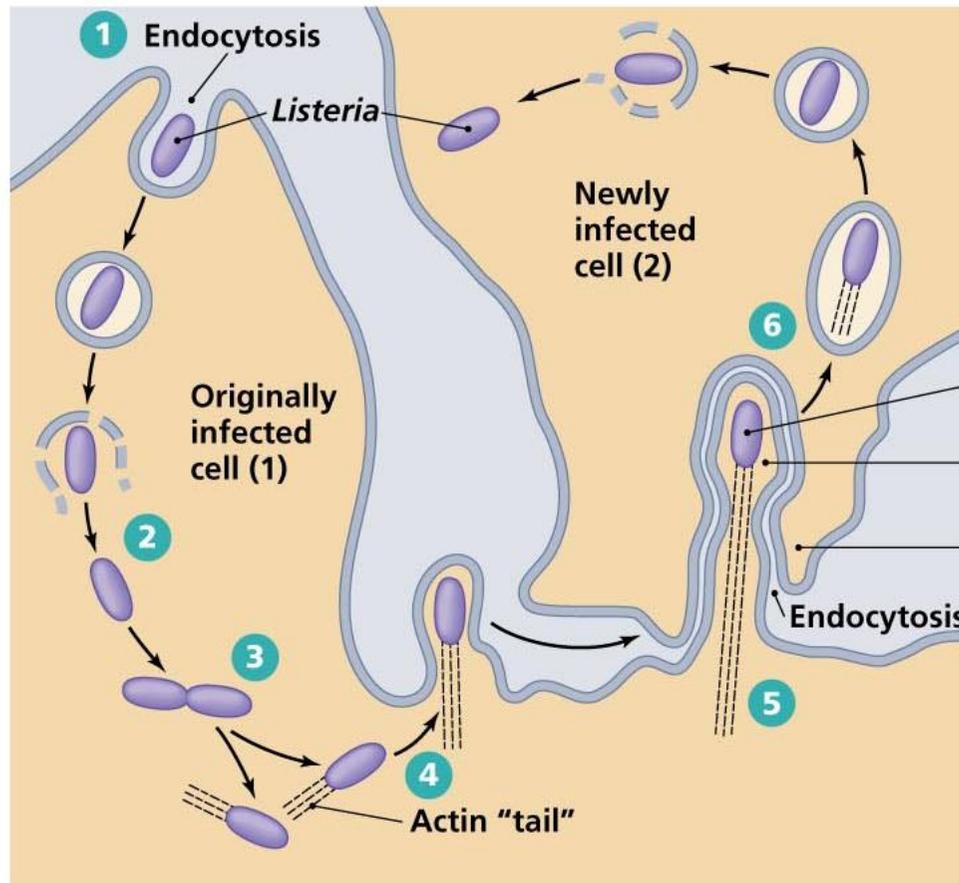
Diagnosis, Treatment, and Prevention

- Prevention
 - Immunization with tetanus toxoid

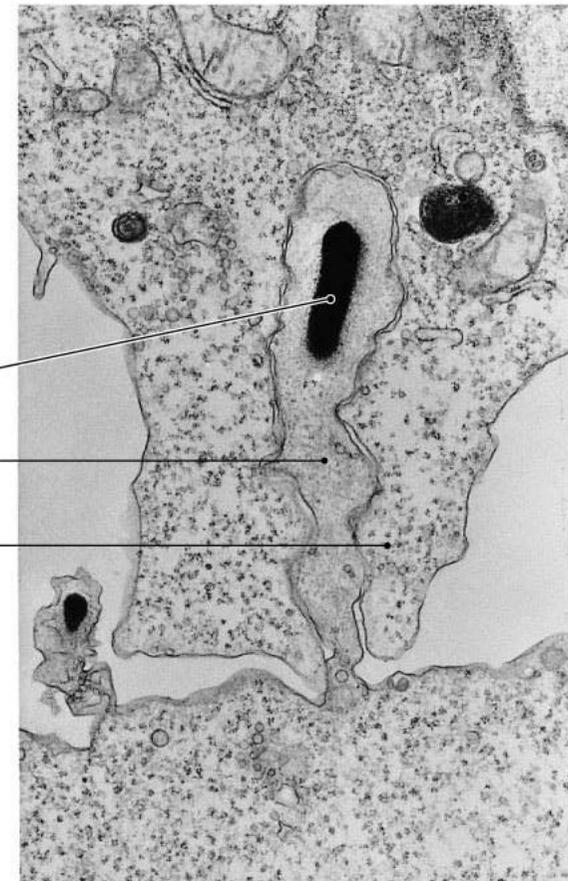
Listeria

- Gram-positive non-spore-forming, coccobacillus
- Found in soil, water, mammals, birds, fish, and insects
- Enters body in contaminated food and drink
- *Listeria* produces no toxins or enzymes
- Virulence is directly related to the bacteria's ability to live within cells

Listeria



(a)



(b)

TEM 2 μm

Diagnosis, Treatment, and Prevention

- Diagnosis
 - Presence of the bacteria in the cerebrospinal fluid
 - Rarely seen by Gram-staining because so few *Listeria* cells are required to produce disease
- Treatment
 - Most antimicrobial drugs inhibit *Listeria*
- Prevention
 - Difficult because the organism is ubiquitous
 - At risk individuals should avoid undercooked vegetables, unpasteurized milk, undercooked meat, and all soft cheeses

Corynebacterium

- Ubiquitous on plants and in animals and humans
- Colonizes the skin and the respiratory, gastrointestinal, urinary, and genital tract
- *Corynebacterium diphtheriae*, the cause of diphtheria, is the most widely known
 - Transmitted from person to person via respiratory droplets or skin contact
 - Endemic in poor parts of the world that lack adequate immunization
 - Diphtheria toxin is responsible for the signs and symptoms of diphtheria

Disease

- Diphtheria toxin inhibits polypeptide synthesis which results in cell death
- Infections are asymptomatic or produce mild respiratory disease in immune or partially immune individuals

Disease

- Severe respiratory infections of nonimmune patients produce the signs and symptoms of diphtheria
 - Pseudomembrane results from fluid that has thickened and adheres throughout the respiratory tract
 - The pseudomembrane can completely occlude the respiratory passages and cause suffocation
- Cutaneous diphtheria causes cell death and formation of a pseudomembrane on the skin

Diagnosis, Treatment, and Prevention

- Diagnosis
 - Initial diagnosis is based on the presence of pseudomembrane
 - Absolute identification is based on the Elek test
 - Antibodies against the toxin react with toxin in a sample of fluid from the patient
- Treatment
 - Administration of antitoxin to neutralize toxin before it binds to cells
 - Penicillin and erythromycin kills the bacteria

Diagnosis, Treatment, and Prevention

- Prevention
 - Immunization with the DPT vaccine

Mycobacterium

- Cell wall contains a waxy lipid called mycolic acid
- The unusual cell wall results in a number of unique characteristics
 - Slow growth
 - Protection from lysis once the bacteria are phagocytized
 - Capacity for intracellular growth
 - Resistance to Gram-staining, detergents, many antimicrobial drugs, and dessication

Mycobacterium

- Three main mycobacterial diseases
 - Tuberculosis
 - Leprosy
 - Opportunistic infections in AIDS patients

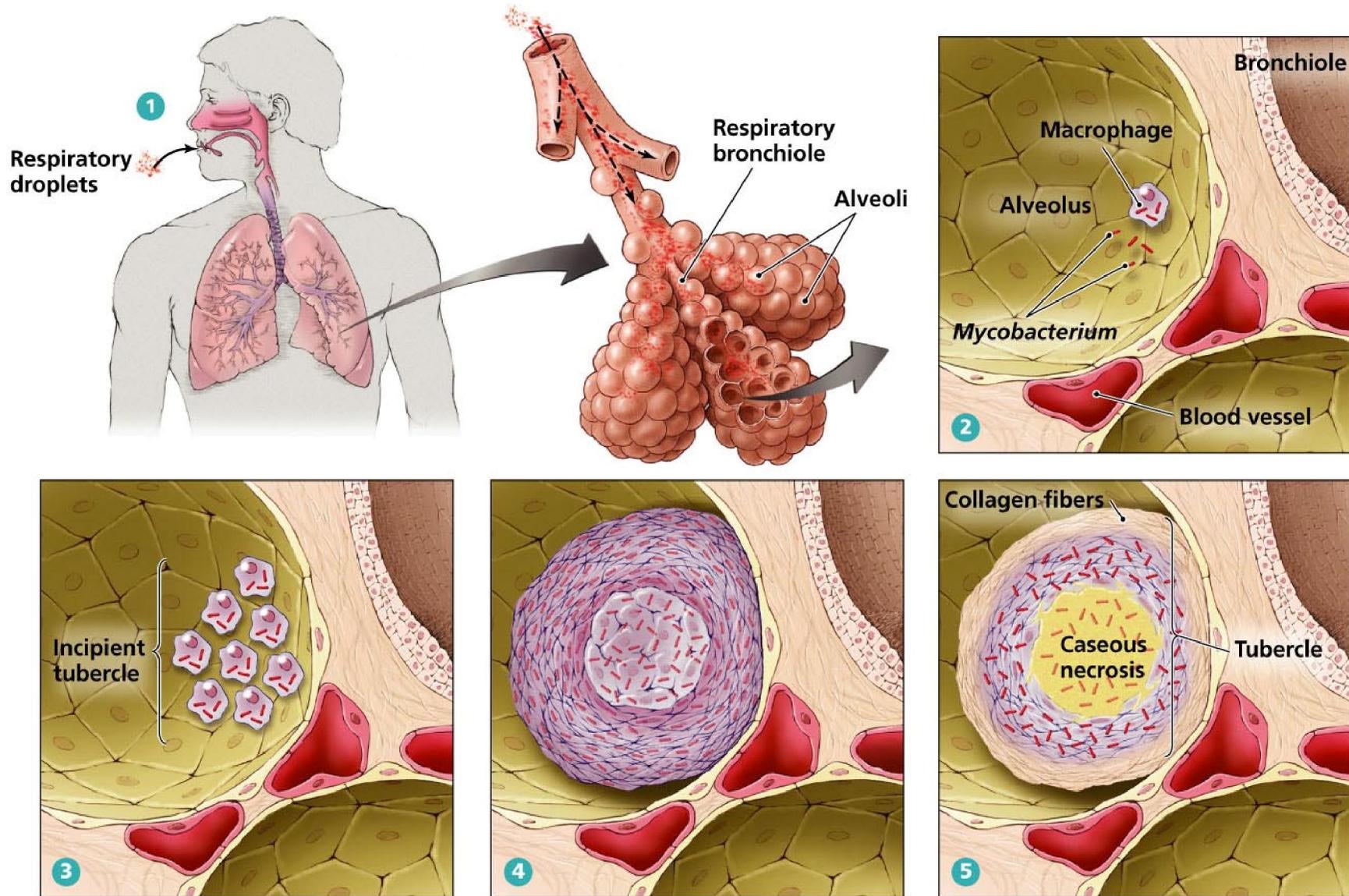
Tuberculosis (TB)

- Respiratory disease cause by *Mycobacterium tuberculosis*
- Cases are declining in the United States but it is pandemic in other parts of the world
- Virulent strains of *M.tuberculosis* contain the cell wall component, cord factor, that is necessary to cause disease

Tuberculosis (TB)

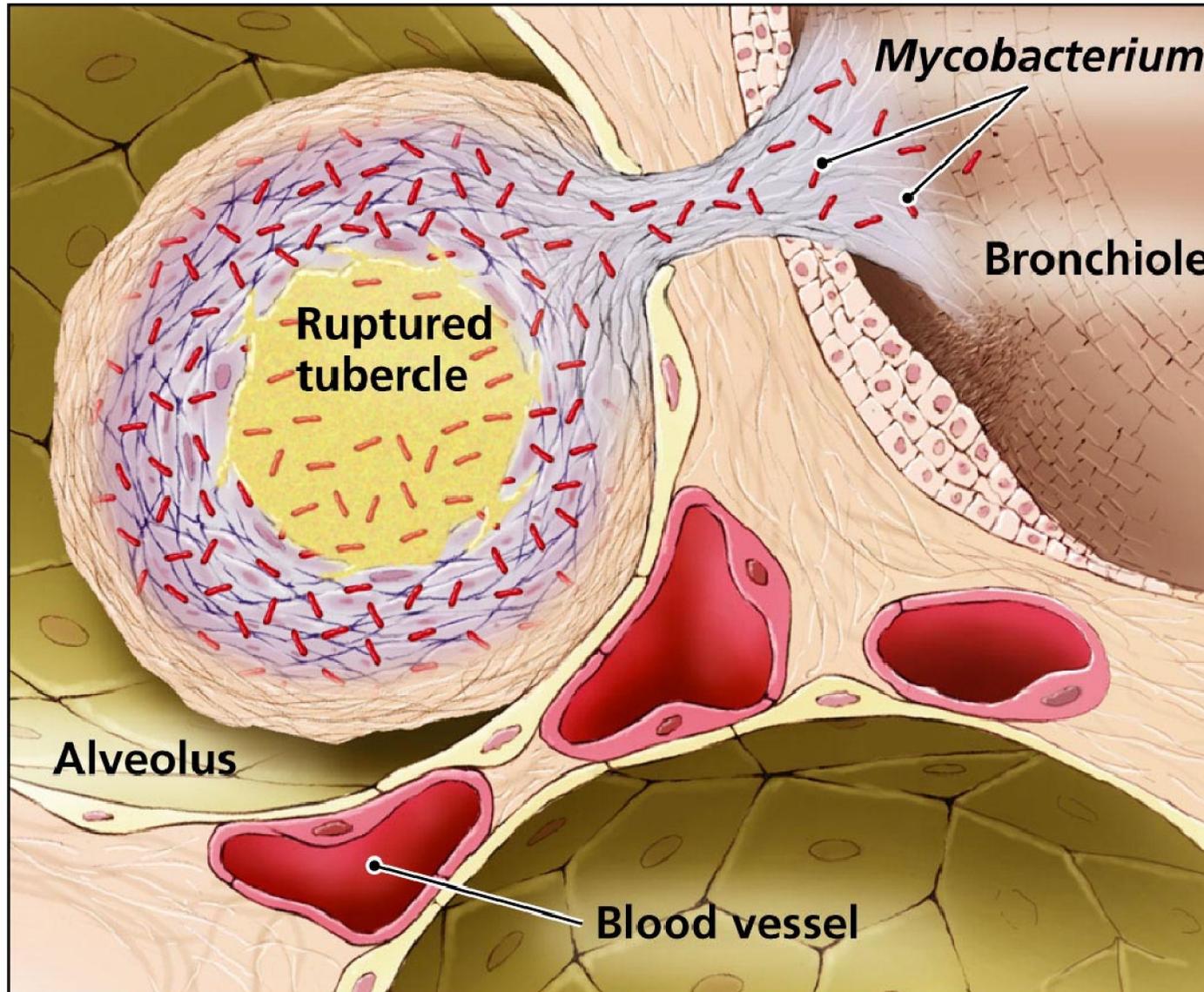
- Three types of tuberculosis
 - Primary TB
 - Results from the initial infection with *M.tuberculosis*
 - Secondary TB
 - Reestablishment of an active infection after a period of dormancy
 - Disseminated TB
 - Results when the infection spreads throughout the body

Primary Tuberculosis



(a) Primary tuberculosis infection

Secondary Tuberculosis



(b) Secondary or reactivated tuberculosis

Diagnosis, Treatment, and Prevention

- Diagnosis
 - Tuberculin skin test identifies individuals with previous exposure to *M. tuberculosis* by the presence of a hard, red swelling at the test site
 - Chest x-rays are used to identify individuals with active disease
- Treatment
 - Treatment with common antimicrobials is difficult because the bacteria grow slowly and can live within macrophages
 - Combination therapy must be used for a number of months to treat the disease

Diagnosis, Treatment, and Prevention

- Prevention
 - Prophylactic use of antibacterial drugs is used to treat patients who have shown a conversion from a negative to a positive skin test or were exposed to active cases of tuberculosis
 - Immunization with BCG vaccine is used in countries where TB is common

Leprosy

- Caused by *Mycobacterium leprae*
- Bacteria have never been grown in cell-free culture
- Cases of leprosy are becoming relatively rare
- Transmission is via person-to-person contact or through a break in the skin

Leprosy

- Two different forms of disease
 - Tuberculoid leprosy
 - Nonprogressive disease that is characterized by loss of sensation in regions of the skin
 - Lepromatous leprosy
 - Produces gradual tissue destruction that results in the loss of facial features, digits, and other body structures

Diagnosis, Treatment, and Prevention

- Diagnosis
 - Based on the signs and symptoms of the disease
 - Loss of sensation in skin lesions in the case of tuberculoid leprosy
 - Disfigurement in the case of lepromatous leprosy
- Treatment
 - Treatment with a combination of antimicrobial drugs
 - Lifelong treatment is sometimes needed

Diagnosis, Treatment, and Prevention

- Prevention
 - Primarily prevented by limiting exposure to the pathogen
 - BCG vaccine provides some protection

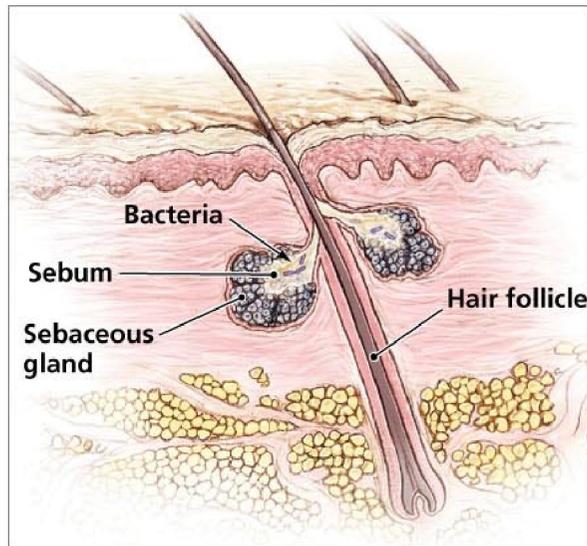
Mycobacterial Infections in AIDS Patients

- Mycobacterium avium-intracellulare is the most common mycobacterial infection among AIDS patients in the United States
- Infections are a result of ingestion of contaminated food or water
- Infections can simultaneously affect almost every organ and result in massive organ failure
- Treatment is difficult due to the disseminated nature of the infection

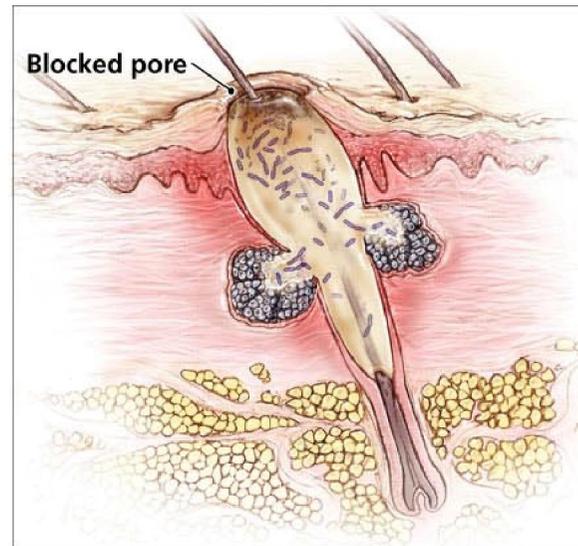
Propionibacterium

- Small, Gram-positive rods that are often found on the skin
- *Propionibacterium acnes* is the species most commonly involved in human infections
- Causes much of the acne of adolescents and young adults
- May also be an opportunistic pathogen
- Treatment often involves the use of antimicrobial drugs though many cases require no treatment

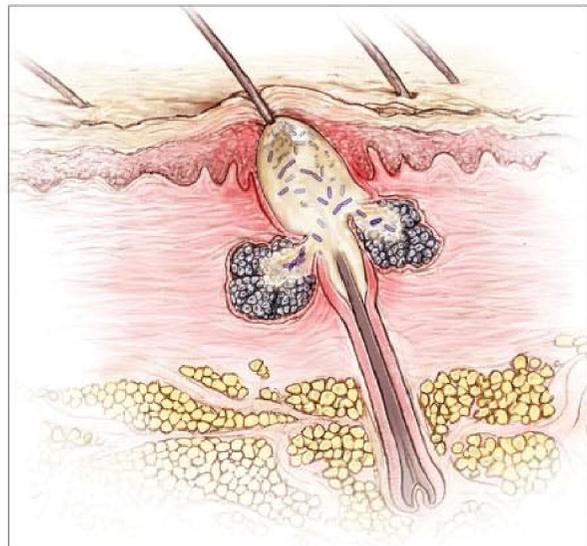
Development of Acne



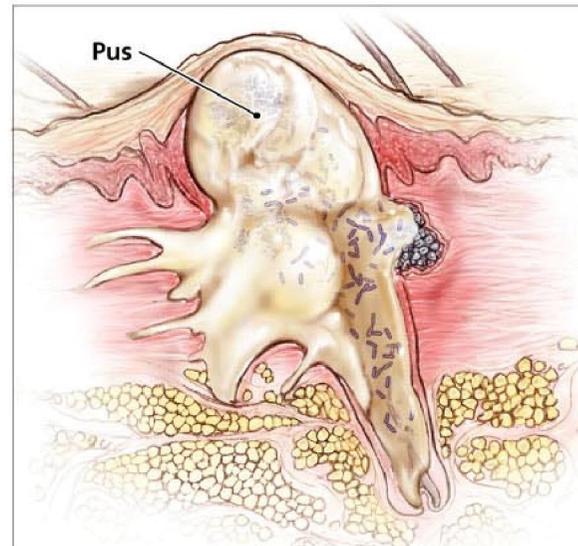
1 Normal skin



3 Blackhead



2 Whitehead



4 Pustule formation (cystic acne)

Nocardia asteroides

- Common inhabitant of soils rich in organic matter
- Produces opportunistic infections in numerous sites
 - Pulmonary infections
 - Develop from inhalation of the bacteria
 - Produce pneumonia
 - Cutaneous infections
 - Result from introduction of the bacteria into wounds
 - Produce mycetoma, a painless, long-lasting infection characterized by swelling, pus production, and draining sores

Nocardia asteroides

- Central nervous system infections
 - Result from the spread of the bacteria in the blood
- Prevention of nocardial disease involves avoiding exposure to the bacterium in soil

Actinomyces

- Normal member of the surface microbiota of human mucous membranes
- Produces opportunistic infections of the respiratory, gastrointestinal, urinary, and female genital tracts
- Actinomycosis results when the bacteria enters breaks in the mucous membrane
 - Disease is characterized by the formation of many abscesses connected by channels in the skin or mucous membranes
- Diagnosis of actinomycosis can be difficult because other organisms cause similar diseases