

Microbial Dz of the Nervous System

CCV
Microbiology

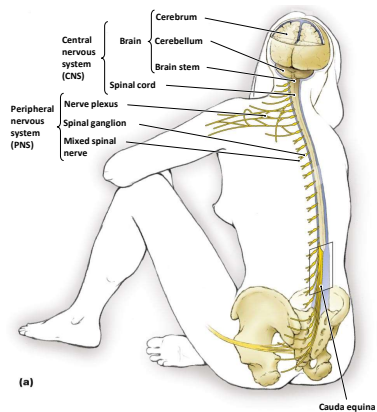
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Structure of the Nervous System

- **Divided into two parts**
 - Central nervous system (CNS)
 - Peripheral nervous system (PNS)

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Figure 20.1a The nervous system.



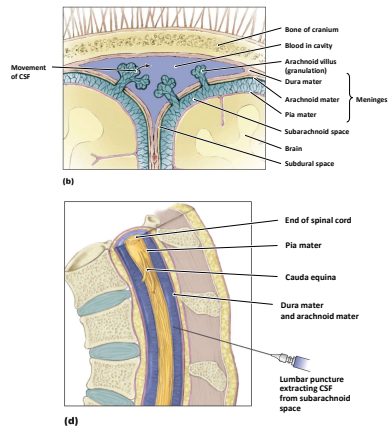
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Structure of the Nervous System

- **Structures of the Central Nervous System**
 - **Composed of the brain and spinal cord**
 - Brain has several main parts
 - Cerebrum controls voluntary muscles, perception, and "thinking"
 - Cerebellum controls many involuntary body movements
 - Brain stem controls breathing, heart rate, blood pressure
 - Spinal cord
 - Extends from the brain stem to the lumbar region

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Figure 20.1b-d The nervous system.



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Structure of the Nervous System

• Structures of the Peripheral Nervous System

- Nerves transfer commands from CNS to muscles and glands
- Cranial nerves extend from brain through holes in the cranial bones
- Spinal nerves extend from spinal cord through vertebral gaps
- Three types of nerves
 - Sensory nerves: carry signals toward the CNS
 - Motor nerves: carry signals away from the CNS
 - Mixed nerves: carry signals toward and away from the CNS

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Structure of the Nervous System

• Cells of the Nervous System

- Two basic cell types
 - Neuroglia
 - Provide support, insulation, nutrients
 - Phagocytize microbes
 - Neurons
 - Carry nerve impulses
 - Nucleus lies in a region called the *cell body*
 - Ganglion is collection of many neurons' cell bodies
 - Dendrites and axons extend from the cell body

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Structure of the Nervous System

• Cells of the Nervous System

- Synapse
 - Junction at the terminal ends of axons
 - Mediates signal transfer to postsynaptic cell
 - Synaptic cleft stops transmission of electrical signals
- Neurotransmitters
 - Chemical signal between cells
 - May be either stimulatory or inhibitory

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Structure of the Nervous System

• Portals of Infection of the Central Nervous System

- CNS is an axenic environment
 - It has no normal microbiota
- Pathogens may access the CNS several ways
 - Breaks in the bones and meninges
 - Medical procedures
 - Travel in peripheral neurons to the CNS
 - Infect and kill cells of the meninges, causing meningitis
 - Inflammation can alter the permeability of the blood-brain barrier



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Bacterial Diseases of the Nervous System

• Bacteria Cause Disease in Two Ways

- Infect cells of the nervous system
 - Meningitis
 - Leprosy
- Bacteria growing elsewhere release toxins that affect neurons
 - Botulism
 - Tetanus



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Bacterial Diseases of the Nervous System

• Bacterial Meningitis

- Signs and symptoms
 - Sudden high fever, severe meningeal inflammation, and increased white blood cells in the CSF
 - Inflammation causes most signs and symptoms
 - Infection of the brain causes encephalitis
 - Can result in behavioral changes, coma, and death
 - Can develop rapidly



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Bacterial Diseases of the Nervous System

• Bacterial Meningitis

- Pathogens and virulence factors
 - Five species cause 90% of bacterial meningitis cases
 - *Neisseria meningitidis*
 - *Streptococcus pneumoniae*
 - *Haemophilus influenzae*
 - *Listeria monocytogenes*
 - *Streptococcus agalactiae*
 - Opportunistic members of the normal microbiota can also cause meningitis



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Bacterial Diseases of the Nervous System

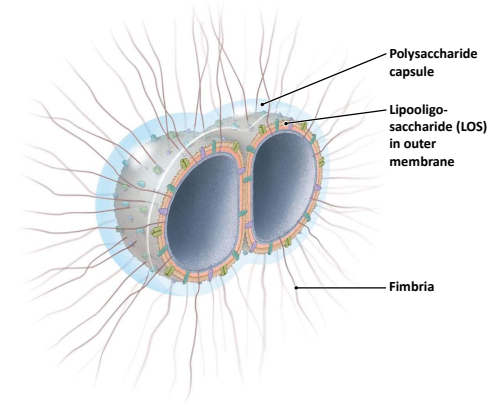
• Bacterial Meningitis

- Pathogens and virulence factors
 - *Neisseria meningitidis*
 - Gram-negative cocci
 - Known as meningococcus
 - Fimbriae, capsule, and lipooligosaccharide help the bacteria attach to cells
 - *Neisseria* cells without these structures are avirulent
 - Capsule protects bacteria from phagocytic lysis
 - Blebbing releases lipid A into the body
 - Triggers fever, inflammation, shock, and clotting



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Figure 20.2 Artist's rendition of diplococci of *Neisseria meningitidis*.



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Bacterial Diseases of the Nervous System

• Bacterial Meningitis

- Pathogens and virulence factors
 - *Streptococcus pneumoniae*
 - Gram-positive coccus
 - Leading cause of meningitis in adults
 - Capsule protects bacteria from digestion by phagocytes
 - Enzymes and toxins enable bacteria to counteract immune defenses
 - Phosphorylcholine triggers endocytosis by cells



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Figure 20.3 Cells of *Streptococcus pneumoniae* are typically arranged in pairs.



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Bacterial Diseases of the Nervous System

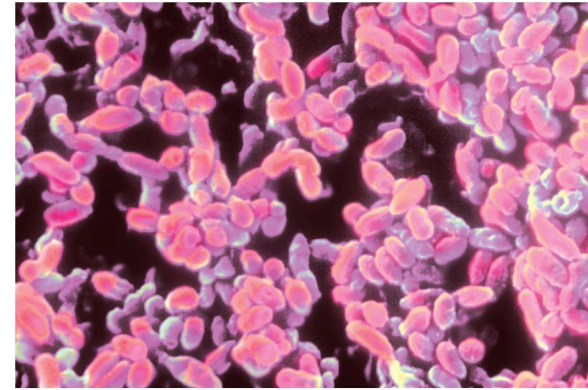
• Bacterial Meningitis

- Pathogens and virulence factors
 - *Haemophilus influenzae*
 - Pleomorphic bacillus
 - Obligate parasite of humans and some animals
 - Presence of capsule resists phagocytosis
 - Different *Haemophilus* strains distinguished by capsular antigens
 - Prior to vaccination most disease caused by *H. influenzae* type b



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Figure 20.4 The pleomorphic bacilli of *Haemophilus influenzae* in a Gram-stained smear.



SEM 1.5 µm



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Bacterial Diseases of the Nervous System

• Bacterial Meningitis

- Pathogens and virulence factors
 - *Listeria monocytogenes*
 - Gram-positive coccobacillus
 - Enters the body in contaminated food or drink
 - Rarely pathogenic in healthy adults
 - Meningitis can occur in pregnant women, fetuses, newborns, and the elderly or immunocompromised
 - Production of listeriolysin O protects the bacteria from phagocytic digestion



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Bacterial Diseases of the Nervous System

• Bacterial Meningitis

- Pathogens and virulence factors
 - *Streptococcus agalactiae*
 - Lancefield group B streptococcus
 - Normal vaginal microbiota in some women
 - Capsule allows bacteria to evade phagocytosis
 - Causes bacteremia, pneumonia, and meningitis in newborns



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Bacterial Diseases of the Nervous System

• Bacterial Meningitis

- Pathogenesis
 - *S. agalactiae* is acquired during birth
 - *Listeria* is transmitted via contaminated food
 - Other species are transmitted via respiratory droplets
 - Bacteria usually spread via the blood to the meninges
 - Head or neck trauma may allow entry of bacteria into the meninges



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Bacterial Diseases of the Nervous System

• Bacterial Meningitis

- Epidemiology
 - *H. influenzae* was leading cause of bacterial meningitis prior to vaccination
 - *S. pneumoniae* and *N. meningitidis* are now most prevalent
 - *S. agalactiae* is leading cause of meningitis in newborns
 - Not spread by casual contact
 - Meningococcal meningitis can become epidemic
 - Spreads among individuals in barracks and dorms
 - *Listeria* is not transmitted among humans except from mother to fetus



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Bacterial Diseases of the Nervous System

• Bacterial Meningitis

- Diagnosis, treatment, and prevention
 - Diagnosis is based on symptoms and culturing of bacteria from CSF
 - Treated with intravenous antimicrobial drugs
 - Vaccines available for *S. pneumoniae*, *H. influenzae* type b, and *N. meningitidis*
 - Administration of penicillin at birth reduces neonatal meningitis due to *S. agalactiae*
 - Individuals at risk for listeriosis should avoid high-risk foods



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Bacterial Diseases of the Nervous System

• Hansen's Disease (Leprosy)

- Signs and symptoms
 - Tuberculoid leprosy
 - Nonprogressive form of the disease
 - Strong cell-mediated immune response
 - Lepromatous leprosy
 - More virulent form of the disease
 - Weak cell-mediated immune response
 - Death from leprosy is rare



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Figure 20.5 Lepromatous leprosy can result in severe deformities.



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Bacterial Diseases of the Nervous System

• Hansen's Disease (Leprosy)

- Pathogen and virulence factors
 - *Mycobacterium leprae* is the causative agent
 - Gram-positive bacillus
 - Mycolic acid in the cell wall is responsible for several characteristics of the bacterium
 - Slow growth rate
 - Protection from phagocytic lysis
 - Growth within phagocytes
 - Resistance to many antimicrobial drugs

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Bacterial Diseases of the Nervous System

• Hansen's Disease (Leprosy)

- Pathogenesis
 - *M. leprae* grows best in cooler regions of the body
 - *M. leprae* can live inside infected cells for years
 - Cellular immune response eventually attacks infected cells
 - May destroy nerves and other tissues
- Epidemiology
 - Lepromatous leprosy is becoming rare
 - Transmitted by person-to-person contact or breaks in the skin

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Bacterial Diseases of the Nervous System

• Hansen's Disease (Leprosy)

- Diagnosis, treatment, and prevention
 - Diagnosis is based on the signs and symptoms
 - Confirmed by presence of acid-fast bacilli in samples
 - Treated with multiple antimicrobials
 - Treatment may be lifelong for some patients
 - BCG vaccine provides some protection
 - Prevent infections by avoiding exposure to the pathogen

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Bacterial Diseases of the Nervous System

• Botulism

- Signs and symptoms
 - Botulism is an intoxication with three manifestations
 - Foodborne botulism
 - Progressive paralysis on both sides of the body
 - Slow recovery from growth of new nerve cell endings
 - Infant botulism
 - Results from the ingestion of endospores
 - Nonspecific symptoms
 - Wound botulism
 - Contamination of a wound by endospores
 - Symptoms are similar to those of foodborne botulism



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Bacterial Diseases of the Nervous System

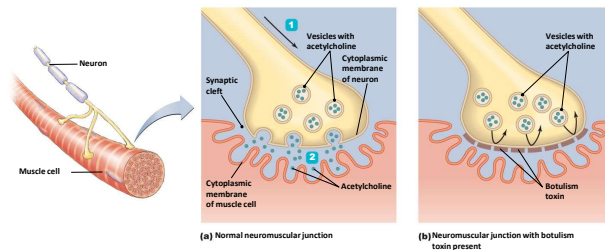
• Botulism

- Pathogen and virulence factors
 - *Clostridium botulinum* is the causative agent
 - Gram-positive, endospore-forming bacillus
 - Common worldwide in soil and water
 - Different strains produce one of seven neurotoxins



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Figure 20.6 How botulism toxin acts at a neuromuscular junction.



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Bacterial Diseases of the Nervous System

• Botulism

- Epidemiology
 - ~30 cases of foodborne and wound botulism per year in U.S.
 - Infant botulism most common form in U.S.
- Diagnosis, treatment, and prevention
 - Three approaches to treatment
 - Washing of intestinal tract to remove *Clostridium*
 - Administration of botulism immune globulin
 - Treatment with antimicrobial drugs
 - Prevented by destroying endospores in contaminated food



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Bacterial Diseases of the Nervous System

• Botulism

- Diagnosis, treatment, and prevention
 - Symptoms are diagnostic
 - Four approaches to treatment
 - Maintain open and functional airways
 - Wash intestinal tract to remove *Clostridium*
 - Administer botulism immune globulin
 - Treat with antimicrobial drugs
 - Prevented by destroying endospores in contaminated food
 - Infants under 1 year old should not consume honey



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Bacterial Diseases of the Nervous System

• Tetanus

- Signs and symptoms
 - Tightening of the jaw (lockjaw)
 - Spasms and contractions may spread to other muscles
 - Irregular heartbeat and blood pressure and profuse sweating may occur
- Pathogen and virulence factors
 - *Clostridium tetani* is causative agent
 - Found in soil, dust, and the intestines of humans and animals
 - Produce neurotoxin called *tetanospasmin*



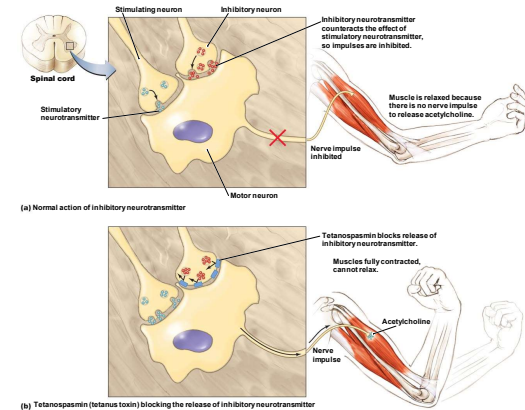
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Figure 20.7 A patient with tetanus.



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Figure 20.8 The action of tetanus toxin on a pair of antagonistic muscles.



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Bacterial Diseases of the Nervous System

• Tetanus

- Pathogenesis
 - Can acquire through break in skin or mucous membrane
 - Distance of infection from CNS determines incubation period
- Epidemiology
 - Mortality rate is ~50% if left untreated
 - Incidence has decreased worldwide
 - Most cases occur where immunization or adequate medical is unavailable



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Bacterial Diseases of the Nervous System

• Tetanus

- Diagnosis, treatment, and prevention
 - Diagnosis is based on characteristic muscle contraction
 - Treatment involves several steps
 - Thorough wound cleaning
 - Passive immunotherapy
 - Administration of antimicrobials
 - Active immunization
 - Vaccine is available against tetanus



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Viral Diseases of the Nervous System

- Viruses more readily cross the blood-brain barrier
- Occur more frequently than bacterial and fungal infections
- Include meningitis, polio, rabies, and encephalitis



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Viral Diseases of the Nervous System

• Viral Meningitis

- Signs and symptoms
 - Similar to those of bacterial meningitis
 - Usually milder than those of bacterial or fungal meningitis
- Pathogens and virulence factors
 - 90% of cases caused by RNA viruses in the genus *Enterovirus*
 - *Coxsackie A virus*, *Coxsackie B virus*, *Echovirus*
 - Spread via fecal contamination of food, water, or hands
 - Spread by the bloodstream to other organs following ingestion



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Viral Diseases of the Nervous System

• Viral Meningitis

- Pathogenesis
 - Damage to cells in the meninges triggers meningitis
- Epidemiology
 - More common than bacterial and fungal meningitis
 - Spread via respiratory droplets and feces
- Diagnosis, treatment, and prevention
 - Diagnosed by characteristic signs and symptoms in the absence of bacteria in the CSF
 - No specific treatment exists
 - Difficult to prevent the spread of enteroviruses



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Viral Diseases of the Nervous System

• Poliomyelitis

- Epidemics of polio were common in the past
- May become second human disease to be eradicated
- Signs and symptoms
 - Asymptomatic infections: almost 90% of cases
 - Minor polio: nonspecific symptoms
 - Nonparalytic polio: muscle spasms and back pain
 - Paralytic polio: produces paralysis
 - Postpolio syndrome can be debilitating
- Pathogen and pathogenesis
 - Poliovirus is the causative agent
 - Transmitted most often by drinking contaminated water



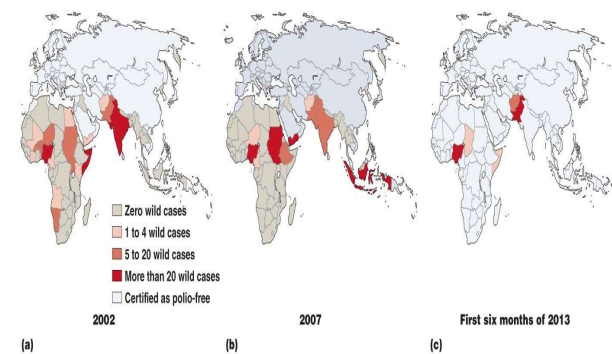
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Figure 20.9 A hospital ward filled with "iron lungs."



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Figure 20.10 Reports of naturally occurring polio.



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Viral Diseases of the Nervous System

• Poliomyelitis

- Epidemiology
 - Polio currently exists in a few countries in Africa and Asia
 - Difficult to control in these regions because of several factors
 - Political and religious tensions
 - Poor sanitation
 - High population density
- Diagnosis, treatment, and prevention
 - Diagnosed by identification of virus in the throat or feces
 - No specific treatment exists
 - Two effective vaccines are available



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TABLE 20.1 Comparison of Polio Vaccines

	Advantages	Disadvantages
Salk vaccine: Inactivated polio vaccine (IPV)	Effective; inexpensive; stable during transport and storage; poses no risk of vaccine-related disease	Requires booster to achieve lifelong immunity; must be injected; requires higher community immunization rate than does OPV
Sabin vaccine: Attenuated, oral polio vaccine (OPV)	Provides lifelong immunity without boosters; triggers secretory antibody response similar to natural infection; easy to administer; results in herd immunity	Less stable than IPV; can mutate to disease-causing form; poses risk of polio developing in immunocompromised contacts of those vaccinated



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Viral Diseases of the Nervous System

• Rabies

- Signs and symptoms
 - Characteristic neurological signs if virus reaches CNS
 - Hydrophobia, seizures, hallucination, paralysis
- Pathogen and virulence factors
 - Rabies virus (ssRNA virus)
- Pathogenesis
 - Transmitted via bite or scratch from an infected animal
 - Virus replicates in muscle cells and then moves into neurons



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Viral Diseases of the Nervous System

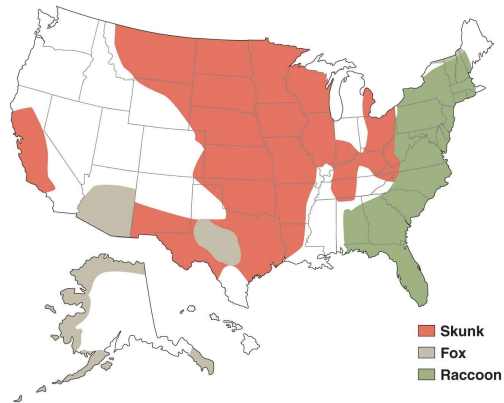
• Rabies

- Epidemiology
 - Zoonotic disease
- Diagnosis, treatment, and prevention
 - Diagnosis by unique neurological symptoms
 - Postmortem detection of Negri bodies in the brain
 - Treated with human rabies immunoglobulin, vaccine injections, and cleansing infection site
 - Prevented by controlling rabies in domestic animals
 - Vaccine is available for at-risk individuals



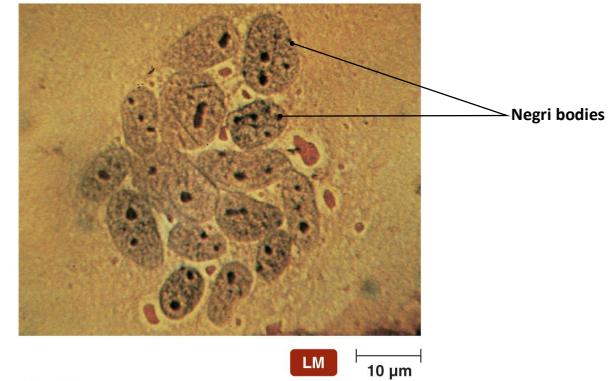
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Figure 20.11 Portions of the United States in which skunks, foxes, or raccoons are the predominant wildlife reservoirs for rabies.



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Figure 20.12 Negri bodies, characteristic of rabies infection, in cells of the cerebellum.



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Viral Diseases of the Nervous System

• Arboviral Encephalitis

- Arboviruses are *arthropod-borne viruses*
 - Transmitted via blood-sucking arthropods (e.g., mosquitoes)
- Mosquito-borne arboviruses can cause arboviral encephalitis
- As zoonotic diseases, they rarely affect humans

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Viral Diseases of the Nervous System

• Arboviral Encephalitis

- Signs and symptoms
 - Arboviruses usually cause mild, coldlike symptoms
 - Can cause encephalitis if cross the blood-brain barrier
 - Arboviruses infect many different animals
 - Six arboviruses cause most cases of viral encephalitis in Americans
 - West Nile virus is the most significant cause in the United States

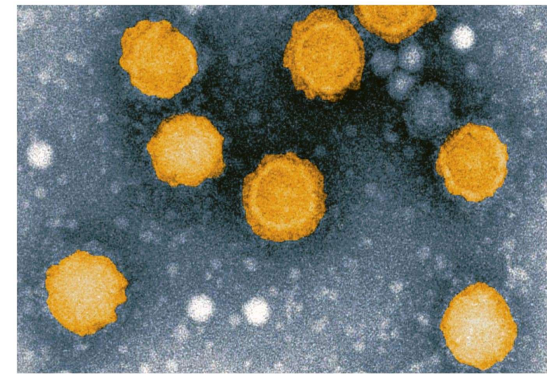
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TABLE 20.2 Characteristics of Arboviral Encephalitis Diseases and Viruses in the United States

Name of Disease and Virus	Distribution	Vector	Natural Hosts	Number of Human Cases in 2009 in U.S. (Mean Human Mortality)	Special Groups at Risk
Togaviridae					
Eastern equine encephalitis (EEE)	Eastern seaboard, Gulf coast, Great Lakes states	Aedes and Culex mosquitoes	Birds	4 (35%)	Horses; humans over age 50 or under age 15
Western equine encephalitis (WEE)	States west of Mississippi River	Culex and Culiseta mosquitoes	Birds	0 (3%)	Horses; children under age 1
Venezuelan equine encephalitis (VEE)	Texas	Aedes and Culex mosquitoes	Rodents	0 (unknown)	Horses; children
Flaviviridae					
St. Louis encephalitis	Lower 48 states except MA, ME, NH, RI, SC, and VT	Culex mosquito	Birds	10 (5%)	Humans over age 50
West Nile encephalitis	Lower 48 states except ME and NH	Culex mosquito	Birds	360 (<1%)	Humans over age 50
Bunyaviridae					
California (LaCrosse) encephalitis	Eastern and central states	Aedes mosquito	Small mammals	39 (<1%)	Children under age 16



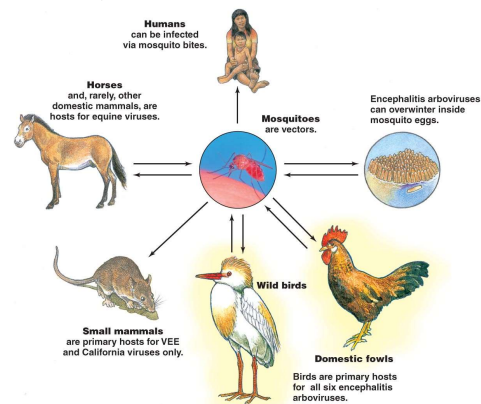
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Figure 20.13 Togaviruses.

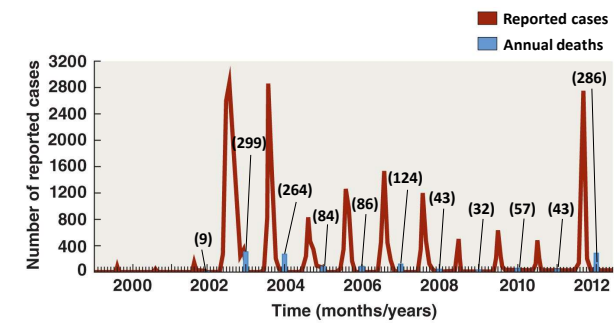
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Figure 20.14 Transmission of six encephalitis arboviruses.

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Figure 20.15 Human West Nile virus encephalitis in the United States.

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Viral Diseases of the Nervous System

• Arboviral Encephalitis

- Diagnosis, treatment, and prevention
 - Diagnosis based on signs and symptoms
 - Confirmed by presence of arbovirus-specific antibodies in CSF
 - Treatment is supportive
 - Prevention involves limiting contact with mosquitoes
 - Use netting and insect repellents
 - Eliminate stagnant water
 - Vaccines for horses available against EEE, WEE, VEE, and WNV



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Mycoses of the Nervous System

• Mycoses of the Nervous System

- Mycoses are fungal diseases
- Spread from the lungs to the CNS via the blood
- Mushroom toxins can produce hallucinations and neurological problems
- May also produce fungal meningitis



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Mycoses of the Nervous System

• Cryptococcal Meningitis

- Signs and symptoms
 - Similar to those of bacterial meningitis
 - Loss of vision and coma may occur in later stages
- Pathogen and virulence factors
 - *Cryptococcus neoformans* is causative agent
 - Two variants of the yeast found worldwide
 - Resists phagocytosis by defensive cells



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Mycoses of the Nervous System

• Cryptococcal Meningitis

- Pathogenesis and epidemiology
 - Infections follows inhalation of spores or dried yeast cells
 - Occurs in terminal AIDS patients and in transplant recipients
- Diagnosis, treatment, and prevention
 - Diagnosed by detection of fungal antigen in CSF
 - Treated with intravenous antifungal drugs
 - Hospitals try to prevent entry of *Cryptococcus*-contaminated air



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Protozoan Diseases of the Nervous System

- Protozoan infections of the nervous system are rare
- Two diseases caused by protozoa
 - African sleeping sickness
 - Meningoencephalitis



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Protozoan Diseases of the Nervous System

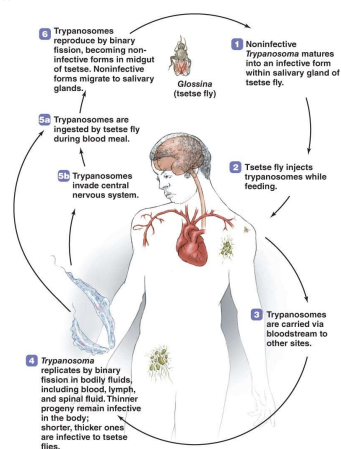
• African Sleeping Sickness

- Signs and symptoms
 - Three clinical stages
 - Site of bite becomes lesion
 - Parasites in the blood create fever, lymph node swelling, and headache
 - Protozoa invade CNS, causing meningoencephalitis
 - Characterized by cyclic waves of parasitemia
- Pathogen and virulence factors
 - Caused by *Trypanosoma brucei*
 - Evades immune system by changing surface glycoproteins



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Figure 20.16 The life cycle of *Trypanosoma brucei*.



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Protozoan Diseases of the Nervous System

• African Sleeping Sickness

- Diagnosis, treatment, and prevention
 - Diagnosed by microscopic observation of trypanosomes in blood, lymph, spinal fluid, or tissue biopsy
- Treatment based on disease stage
 - Must begin soon after infection to be successful
- Insecticide application can help reduce occurrence



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Protozoan Diseases of the Nervous System

• **Primary Amebic Meningoencephalopathy**

- Signs and symptoms
 - Same as those of meningitis and encephalitis caused by other microbes
- Pathogen, pathogenesis, and epidemiology
 - Caused by *Acanthamoeba* and *Naegleria*
 - Enter host through abrasions on the skin or the eyelid or by inhalation of contaminated water
 - Rare but almost always fatal
- Diagnosis, treatment, and prevention
 - Detect amoebae in sample from the eye or brain, or in CSF
 - Drugs have limited success
 - Prevented by avoiding contaminated water supplies



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Prion Disease

- A prion is an infectious protein
- Spongiform encephalopathies
 - A class of diseases that includes scrapie and "mad cow" disease
 - Leave the brains of victims full of holes
 - Can occur spontaneously in the elderly
 - Humans can contract by eating meat from infected cattle



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Prion Disease

• **Variant Creutzfeldt-Jakob Disease**

- Signs and symptoms
 - Insomnia, weight loss, and memory failure
 - Progressive worsening of muscle control
- Pathogen, pathogenesis, and epidemiology
 - Caused by abnormal form of prion protein
 - Turn normal prions into abnormal form
 - Medical procedures can spread the disease
 - Prions may remain dormant for many years
 - vCJD can occur in young people



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Prion Disease

• **Variant Creutzfeldt-Jakob Disease**

- Diagnosis, treatment, and prevention
 - Diagnosed by characteristic signs and symptoms
 - Can be confused with other forms of dementia in elderly
 - No treatment is available
 - Destruction of prions outside the body is difficult
 - Prevented by avoiding prion-contaminated meat



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Microbial Diseases of the Eye

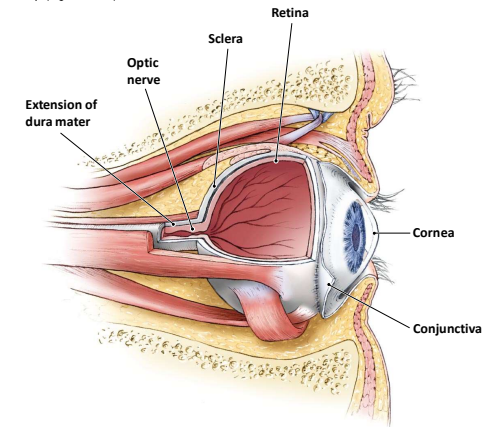
• Microbial Diseases of the Eye

- Senses are important part of the nervous system
- Vision comprises almost half of the function of the cerebrum



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Figure 20.17 The eye (sagittal section).



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Microbial Diseases of the Eye

• Trachoma

- Leading cause of nontraumatic blindness
- Signs and symptoms
 - Scarring of the conjunctiva and cornea
- Pathogen, pathogenesis, and epidemiology
 - Caused by *Chlamydia trachomatis*
 - Multiplies in the conjunctiva
 - Purulent discharge causes deformed eyelids
 - Scarring can lead to blindness
 - Typically affects children



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Figure 20.18 An eyelid afflicted with trachoma.



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Microbial Diseases of the Eye

- **Trachoma**

- Diagnosis, treatment, and prevention
 - Diagnosed by identifying bacteria at site of infection
 - Treated with antimicrobials
 - Surgery can correct eyelid deformities



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Microbial Diseases of the Eye

- **Other Microbial Diseases of the Eye**

- Bacterial infections of skin and reproductive tract can affect the eyes
- Sties
 - Infections of the sebaceous glands near the eye
- Ophthalmia neonatorum
 - Inflammation of the conjunctiva and cornea of a newborn
- Conjunctivitis
 - Inflammation of the conjunctiva
- Keratitis
 - Inflammation of the cornea



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