About the Nervous System
• Divided into two parts
  – Central nervous system (CNS)
  – Peripheral nervous system (PNS)

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
Structure of the Nervous System

• Structures of the Peripheral Nervous System
  – Composed of nerves that transfer commands from CNS to muscles and glands
  – Cranial nerves extend from the brain through holes in the cranial bones
  – Spinal nerves extend from the spinal cord through gaps between the vertebrae
  – 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

Structure of the Nervous System – Main Cell Types

• 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
      – A collection of many neurons’ cell bodies is called a ganglion
    – Dendrites and axons extend from the cell body

How do they get in?

• 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
    – Traveling in peripheral neurons to the CNS
    – Infecting and killing cells of the meninges resulting in meningitis
How do they cause disease?

- Bacteria cause disease in two ways
  - Infect cells of the nervous system
    - Meningitis
    - Leprosy
  - Bacteria growing elsewhere release toxins that affect neurons
    - Botulism
    - Tetanus

Bacterial Diseases of the Nervous System

- Bacterial Meningitis
  - Signs and symptoms
    - Sudden high fever and severe meningeal inflammation
    - Inflamed cranial meninges – severe headache, vomiting, pain
    - Inflamed spinal meninges – stiff neck, altered muscle control
    - Infection of the brain, or encephalitis, can result in behavioral changes, coma, and death
    - All may develop rapidly

Bacterial Diseases – Bacterial Meningitis

- Bacterial Meningitis
  - Pathogens and virulence factors
    - Five species cause 90% of bacterial meningitis cases
      - *Streptococcus pneumoniae* – leading cause in adults
      - *Neisseria meningitidis* – due to fimbria, capsule, and lipooligosaccharide
      - *Haemophilus influenzae* – leading cause prior to vaccine
      - *Listeria monocytogenes* – disease in fetuses, pregnant women, and immunocompromised individuals
      - *Streptococcus agalactiae* – causes most cases of newborn meningitis
Bacterial Diseases of the Nervous System – Strep Pneumonia

Bacterial Disease – Neisseria Diplococci
- Fimbriae

Bacterial Diseases – Haemophilus Influenza
- Pleomorphic Bacteria
Bacterial Diseases of the Nervous System

- Listeria Invasion – evading the cell

Bacterial Diseases of the Nervous System

- Bacterial Meningitis
  - Pathogenesis
    - *S. agalactiae* acquired during birth
    - *Listeria* transmitted via contaminated food
    - Other species transmitted via respiratory droplets
  - Epidemiology
    - *S. pneumoniae* present in throat of 75% of humans without causing harm
    - Not spread by casual contact
    - Meningococcal meningitis is the only form that becomes epidemic

Bacterial Diseases of the Nervous System

- Bacterial Meningitis
  - Diagnosis, treatment, and prevention
    - **Diagnosis** made based on symptoms and culturing of bacteria from CSF from a spinal tap
    - **Treat** with various antimicrobial drugs
    - **Vaccines** available for *S. pneumoniae*, *H. influenzae* type b, and *N. meningitidis*
    - Individuals at risk for listeriosis should avoid high-risk foods (milk, cheeses, undercooked meat)
Bacterial Diseases of the Nervous System

• Hansen’s Disease (Leprosy)
  – Signs and symptoms manifest in two forms
    – Tuberculoid leprosy – nonprogressive
    – Lepromatous leprosy – progressive tissue destruction
  – Pathogen and virulence factors
    – Mycobacterium leprae is the causative agent
      – Gram-positive bacillus with mycolic acid in cell wall
    – Pathogenesis
      – M. leprae grows best in cooler regions of the body
Bacterial Diseases of the Nervous System

• Botulism
  – Signs and symptoms
    – Caused by intoxication from ingested toxin
  – Three forms
    – Food-borne botulism – progressive paralysis of all voluntary muscles
    – Infant botulism – bacteria grow in the intestines, producing non-specific symptoms
    – Wound botulism – symptoms like those of food-borne botulism
  – Pathogen and virulence factors
    – Clostridium botulinum is the causative agent
    – Different strains produce one of seven neurotoxins

Bacterial Diseases of the Nervous System - Botulism

• How Botulism Toxin Works

Clostridium

• Botulism
  – Epidemiology
    – Rare, roughly 50 cases of food-borne 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
    – Prevention involves destroying endospores in contaminated food through proper canning techniques
Bacterial Diseases: Clostridium Botulinum (Flaccid Paralysis)

- Baby intakes or ingests C. botulinum endospores, particularly in honey.
- Endospores germinate in anaerobic environments, converting into vegetative forms, grow, reproduce, and release botulinum toxin.
- Poison is absorbed into blood and circulates throughout body.
- Botulinum toxin produces characteristic and marked effects.
- Gradually the toxin paralyzes muscles, including neck muscles and the diaphragm.

Bacterial Diseases -- Typical Clostridium Spores

- Clostridium spores are typically oval and can be seen in this image.
- Dimensions: 10 μm.

Bacterial Diseases of the Nervous System: Tetanus

- Symptoms include spasms, rigidity, and stiffness.
- Treatment: Antitetanus therapy, including tetanus immunoglobulin (if available) and tetanus toxoid (if not previously immunized).
- Prevention: Vaccination is crucial for preventing tetanus.
- Tetanus is more severe in infants and young children.
Bacterial Diseases – Tetanus Toxin & Antagonistic Pairs

Viral Diseases of the Nervous System – In General
- Viruses more readily cross the blood-brain barrier
- Viral infections of the nervous system occur more frequently than bacterial and fungal infections
- Viral diseases of the nervous system include meningitis, polio, rabies, and encephalitis

Viral Diseases - Viral Meningitis
- Signs and symptoms
  - Similar to bacterial meningitis
  - Usually milder than bacterial or fungal meningitis
- Pathogens and virulence factors
  - 90% of cases caused by viruses in the genus Enterovirus
- Pathogenesis
  - Damage to cells in the meninges triggers meningitis
Viral Diseases - Viral Meningitis (cont)
- Epidemiology
  - More common than bacterial and fungal meningitis
  - Spread via respiratory droplets and feces
- Diagnosis, treatment, and prevention
  - Characteristic signs and symptoms that occur in the absence of bacteria in the CSF
  - No specific treatment exists

Viral Diseases – Polio
• Poliomyelitis
  - Signs and symptoms – four conditions may result
    - Asymptomatic infections – almost 90% of cases
    - Minor polio – nonspecific symptoms
    - Nonparalytic polio – muscle spasms and back pain
    - Paralytic polio – produces paralysis
  - Pathogen and pathogenesis
    - Poliovirus is the causative agent
    - Transmitted most often by drinking contaminated water

Viral Diseases – Polio Iron Lung Ward
Viral Diseases Polio World Map – Look! India is now Polio-Free!

- World Wide Polio Cases

- 2012- Eradicated!

Viral Diseases & Polio Vaccines

- Comparison of Vaccines

<table>
<thead>
<tr>
<th>Table 20.1</th>
<th>Comparison of Polio Vaccines</th>
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- Rabies Virus

Viral Diseases – Rabies – TEM

- Rabies Virus
Viral Diseases – Rabies (cont.)

- Rabies
  - Pathogen and virulence factors
  - Rabies virus
  - Pathogenesis
    - Virus replicates in muscle cells and then moves across neuromuscular junctions into neurons
  - Epidemiology
    - Zoonotic disease
      - Transmitted via bite or scratch from an infected animal

Viral Diseases Rabies Distribution

Viral Diseases – Cell changes due to Rabies in Cerbellum
Viral Diseases – Arboviral Encephalitis

In General:
– Arboviruses are arthropod-borne viruses
– Transmitted via blood-sucking arthropods (ex. mosquitoes)
– Mosquito-borne arboviruses cause various types of arboviral encephalitis
– As zoonotic diseases they rarely affect humans
– Arboviruses usually cause mild, cold-like symptoms
– Arboviruses that cross the blood-brain barrier can cause encephalitis with symptoms similar to meningitis

Viral Diseases – Overview of Arboviral Encephalitis in the US

<table>
<thead>
<tr>
<th>Table 20.2 Characteristics of Arboviral Encephalitis: Diseases and Viruses in the United States</th>
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<tbody>
<tr>
<td>Disease Name</td>
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<tr>
<td>Eastern equine encephalomyelitis (EEE)</td>
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<td>St. Louis encephalitis</td>
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<td>California encephalitis</td>
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Viral Diseases – Togavirus TEM (false color)
**Viral Diseases – Transmission of Encephalitic Arboviruses**

![Diagram showing the transmission cycle of arboviruses]

**Viral Diseases – Incidence of Human West Nile Virus in the US**

![Graph showing the incidence of West Nile Virus cases from 2001 to 2007]

**Viral Diseases – Arboviral Encephalitis – How to...**

- **Diagnosis** based on signs and symptoms and positive test for antibodies against specific arboviruses in the CSF
- **Treatment** is supportive
- **Prevention** involves limiting contact with mosquitoes
  - Use netting and insect repellants
  - Reduce mosquito numbers by eliminating stagnant water
- **Vaccines** for horses available against EEE, WEE, VEE, and WNV
Mycoses of the Nervous System – What are they?

- Mycoses are fungal diseases
- Mycoses may spread from the lungs to the CNS via the blood
- Poisoning from mushroom toxins can produce neurological problems and hallucinations
- Fungi may also produce fungal meningitis

Mycoses – Cryptococcus Neoformans in Brain

- Capsules
- In Brain
Protozoan Diseases of the Nervous System

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

Protozoan Diseases -- Trypanosomiasis

- African Sleeping Sickness
  - Signs and symptoms – three clinical stages
    - Site of bite becomes lesion with necrotic tissue
    - Parasites in the blood create fever, lymph node swelling, and headache
    - Meningoencephalitis upon invasion of the CNS
  - Pathogen and virulence factors
    - Caused by the trypanosome *Trypanosoma brucei*
    - Evades host's immune system by changing surface glycoproteins

Protozoan Diseases – *Trypanosoma brucei* Life Cycle

- *T. brucei*
- Tsetse fly
- rhythmic
Protozoan Diseases – Trypanosomiasis how to…

• African Sleeping Sickness
  – Diagnosed from microscopic observation of trypanosomes in the blood, lymph, or spinal fluid, or by tissue biopsy
  – Treatment includes various drugs that are administered based on how the disease has progressed
  – Insecticide application can help reduce occurrence

Protozoan Diseases – Amoebic Infection

• Primary Amebic Meningoencephalopathy – what is it?
  – Signs and symptoms
  – Same as for meningitis and encephalitis caused by bacteria, viruses, and fungi
  – Pathogen, pathogenesis, and epidemiology
    – Caused by Acanthamoeba and Naegleria
    – Enter host through cuts or scrapes on the skin, the eyelid, or through inhaling contaminated water
  – Diagnosis, treatment, and prevention
    – Drugs have limited success
    – Prevent by avoiding possibly contaminated water supplies

Prion Disease – what are they?

• 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
  – Humans can contract by eating meat from infected cattle
Prion Disease

Characteristic holes

Microbial Diseases of the Eye

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

Microbial Diseases of the Eye -- Trachoma

- Pathogen, treatment, and prevention
  - Caused by Chlamydia trachomatis that multiplies in the conjunctiva
  - Results in discharge and deformed eyelids
  - Can lead to blindness
  - Typically affects children, but certain strains can affect adults
- Diagnosis, treatment, and prevention
  - Diagnose by identifying bacteria at site of infection
  - Treat with antimicrobials and surgery
Microbial Diseases – Trachoma (Chlamydia trachomatis)

Other Microbial Diseases of the Eye

- Bacterial infections of the skin and reproductive tract can affect the eyes
- Sties – infections of the sebaceous glands near the eye
- Ophthalmic neonatorum – inflammation of the conjunctiva and cornea of a newborn
- Conjunctivitis – inflammation of the conjunctiva
  - Haemophilus influenzae is common bacterial cause
- Keratitis – inflammation of the cornea