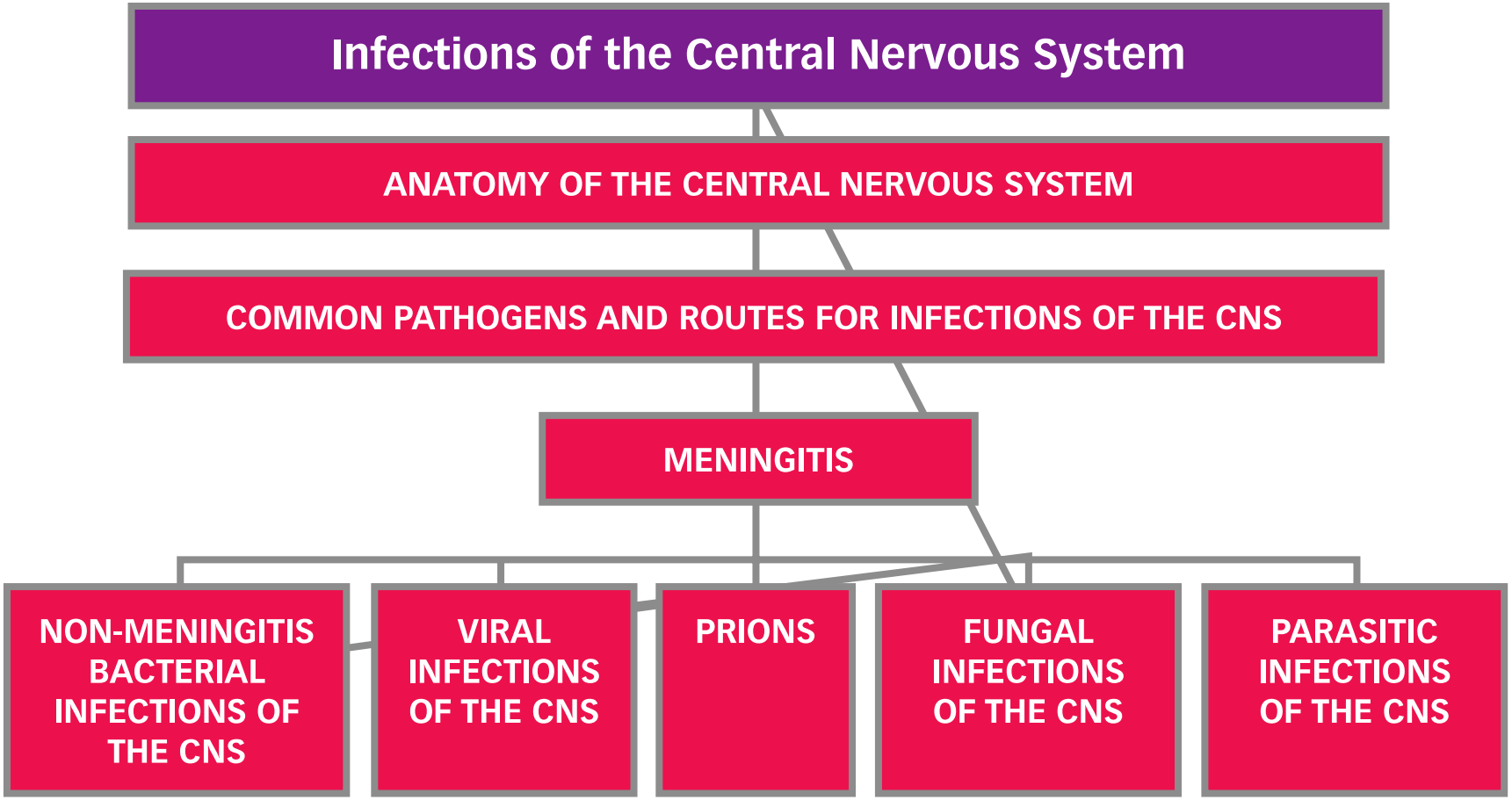
CHAPTER 24
INFECTIONS OF THE CENTRAL NERVOUS SYSTEM

OVERVIEW

- In some cases, the CNS is the main target
- In others, the CNS is a secondary target
- Infections of CNS can be caused by:
  - Bacteria, viruses, fungi, and parasites, like other body systems
  - Infectious proteins, called prions, that only infect the CNS

OVERVIEW


Infections of the Central Nervous System
ANATOMY OF THE CENTRAL NERVOUS SYSTEM
COMMON PATHOGENS AND ROUTES FOR INFECTIONS OF THE CNS
MENINGITIS
NON-MENINGITIS BACTERIAL INFECTIONS OF THE CNS
VIRAL INFECTIONS OF THE CNS
PRIONS
FUNGAL INFECTIONS OF THE CNS
PARASITIC INFECTIONS OF THE CNS

ANATOMY OF THE CNS

- CNS has two major parts
  - Brain
  - Spinal cord
- Both surrounded by three layers of connective tissue – meninges
- Cerebrospinal fluid is found in the subarachnoid space
- The brain and spinal cord are protected from the body by the blood-brain barrier
  - Protects against infectious disease
  - Some pathogens can pass through the blood-brain barrier

ANATOMY OF THE CNS

- No room for swelling in the CNS
- Inflammation is one of the first and most formidable responses
  - Always causes swelling
- Vasogenic edema – swelling caused by inflammatory response in the subarachnoid space
- Cytotoxic edema – swelling from toxic substances produced by bacteria and neutrophil invasion

ANATOMY OF THE CNS

- Infection can also affect proper brain function through:
  - Acidosis
  - Hypoxia
  - Destruction of neurons
- Effects of infection can be profound and irreversible
- Blood-brain barrier can make it difficult to treat CNS infections

COMMON PATHOGENS AND ROUTES FOR CNS INFECTIONS

- Organisms reach the brain and spinal cord in a variety of ways
- Organisms in blood can enter the cerebrospinal fluid and cause meningitis
- Infections in the sinuses and mastoid air spaces eventually cause erosion of the skull bone
  - Pathogens can then enter the brain and cause abscesses
- Most CNS infections result from the passage of pathogens across the blood-brain barrier

COMMON PATHOGENS AND ROUTES FOR CNS INFECTIONS

- CNS infections can be caused by:
  - Normal bacterial flora
  - Pathogens acquired through ingestion
  - Pathogens acquired during the birthing process
  - Contamination of shunts

COMMON PATHOGENS OF THE CNS

- Bacterial meningitis usually caused by:
  - *H. influenzae*
  - *N. meningitidis*
  - *S. pneumoniae*
  - *L. monocytogenes*
  - *Staphylococcus*
- Group B streptococci often involved in meningitis in newborns
  - Acquired through the birthing process

COMMON PATHOGENS OF THE CNS

- Deep fungal mycoses *Cryptococcus neoformans* and *Coccidioides immitis*

COMMON PATHOGENS OF THE CNS

- Most common viral causes of acute CNS infections:
  - Enterovirus
  - Herpes simplex virus
  - HIV
  - Epstein-Barr virus
  - Also several arthropod-borne viruses
- Viral infections manifest as aseptic meningitis, encephalitis, and poliomyelitis

COMMON PATHOGENS AND ROUTES FOR CNS INFECTIONS

- Initial source of a CNS infection is either:
  - Occult – infection of mononuclear phagocytic system cells
  - Overt – from complications of other infections
    - Pneumonia
    - Pharyngitis
    - Skin abscesses
    - Infectious endocarditis

COMMON PATHOGENS AND ROUTES FOR CNS INFECTIONS

- The infection site can be close to or in direct contact with the CNS
- Pathogens can enter the CNS through:
  - Defects in the structures that encase the CNS
  - Opening left by surgical, traumatic, or congenital developmental abnormalities

COMMON PATHOGENS AND ROUTES FOR CNS INFECTIONS

- Intraneural pathways are the least common route to the CNS
- Exceptions are:
  - Rabies virus – uses peripheral sensory nerves
  - Herpesvirus – uses trigeminal nerve

COMMON PATHOGENS AND ROUTES FOR CNS INFECTIONS

- Brain abscesses are relatively rare, but present a special problem
- They can be found in:
  - Subdural space
  - Epidural space
  - Directly in the brain tissue
- Commonly formed by bacteria or fungi from a distant site
- Also result from:
  - Extensions of pathogens located at the site of mastoiditis or sinusitis
  - Surgical complications

GENERAL TREATMENT OF CNS INFECTIONS

- Bacterial and fungal infections require prompt and aggressive treatment
- Treatment periods vary depending on the type of infection
  - 10 days to 12 months for uncomplicated cases
  - Longer if the infection is caused by *M. tuberculosis*
  - Treatment of fungal infections can last for years
  - Treatment of viral infections is mostly supportive

MENINGITIS

- Broad category of infections of the fluid surrounding spinal cord and brain
- Usually caused by virus or bacteria – important to know which
  - Severity of illness differs
  - Treatments differ

MENINGITIS: Bacterial

- Bacterial meningitis can be severe and cause:
  - Brain damage
  - Hearing loss
  - Learning disability
- Important to know type of bacterium
  - Antibiotic therapy can prevent its spread

MENINGITIS: Bacterial

- Some forms of bacterial meningitis are contagious
  - Spread by exchange of respiratory and throat secretions
  - Not as contagious as the common cold
- *N. meningitidis* can spread to other people via close or prolonged contact
  - Bacterial meningitis concern for daycare centers and schools

MENINGITIS: Viral

- Viral meningitis is generally less severe:
  - Usually resolves without treatment
- Caused by several types of virus:
  - 90% of cases by enterovirus
  - Also herpesvirus and mumps virus
- Viral meningitis rarely fatal if there is a competent immune system:
  - Patient usually recovers completely

MENINGITIS: Diagnosis and Treatment

- Patients with any symptoms of meningitis should see a doctor immediately
- Diagnosis of the bacterial strain is usually made by growing bacteria from spinal fluid
  - Identification helps in selecting the most effective antibiotic therapy
- Early antibiotic therapy limits risk of death to 15%
- Viral meningitis is also diagnosed using spinal fluid
  - No antibiotic therapy
  - Bed rest, plenty of fluids, medicines to relieve fever and headache

NON-MENINGITIS BACTERIAL INFECTIONS OF THE CNS

- Tetanus and botulism infections affect the CNS in different ways
  - Produce exotoxins with an affinity for CNS tissue
  - Antibiotic therapy is ineffective once the exotoxin has been produced

TETANUS
(CLOSTRIDIUM TETANI)

- Tetanus is caused by *Clostridium tetani*
  - Gram-positive
  - Anaerobic
  - Rod shaped
  - Produces a terminal spore

TETANUS
(CLOSTRIDIUM TETANI)

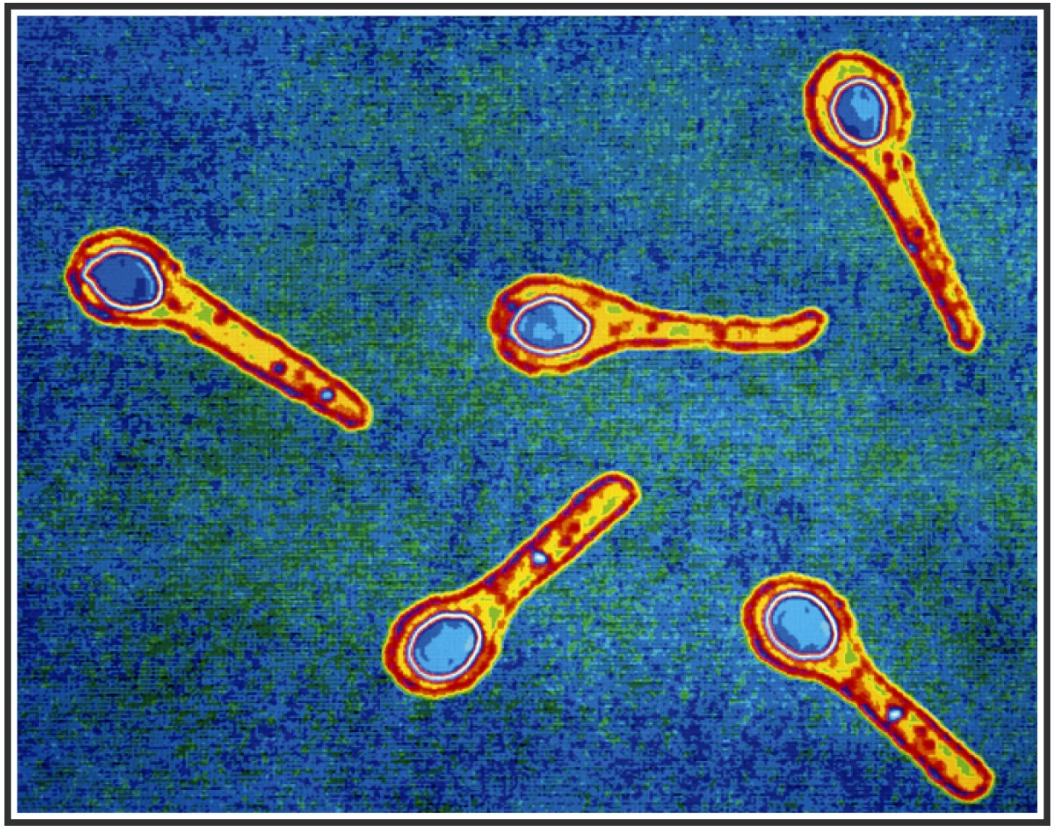


Figure 24.5 Microbiology: A Clinical Approach 2e (© Garland Science 2016)

TETANUS
(CLOSTRIDIUM TETANI)

- *C. tetani* is a strict anaerobe
  - Cannot survive in the presence of oxygen
- Commonly found in the soil
  - Spores can survive there for years
  - Gets into wounds via contaminated soil
- Spores are very resistant to disinfectants and can withstand boiling

TETANUS
(CLOSTRIDIUM TETANI)

- Toxin produced by *C. tetani* is neurogenic
  - Affinity for and targets nervous tissue
- Called tetanospasmin or tetanus toxin
- Acts by enzymatically degrading proteins required for normal physiology

TETANUS: Pathogenesis

- Tetanus spores require areas of low oxygen to germinate
  - Area of necrosis around tissue injury is perfect
  - Spores germinate and *Clostridium* begins to grow
- Bacteria do not cause damage to the tissue where they reside
  - Produce their neurogenic toxin
  - Toxin enters the presynaptic terminals of the lower motor neurons
  - From there, it gets into the CNS

TETANUS: Pathogenesis

- Toxin acts at the anterior horn cells in the spinal cord
  - Blocks postsynaptic inhibition of the spinal motor reflexes
- Produces spasmodic contraction of the muscles
  - Occur locally at first
  - May extend up and down the spinal cord

TETANUS: Pathogenesis

- Incubation period can vary between 4 days and several weeks
  - The shorter the incubation period, the more severe the infection
- Tetanus toxin is systemic for muscles
  - Masseter muscle of the jaw usually first to be affected
    - Mouth cannot be opened (sometimes called lockjaw)
  - Muscles for respiration and swallowing can eventually be compromised
  - Severe cases can suffer from opisthotonos
    - Head and heels move toward each other

TETANUS: Pathogenesis

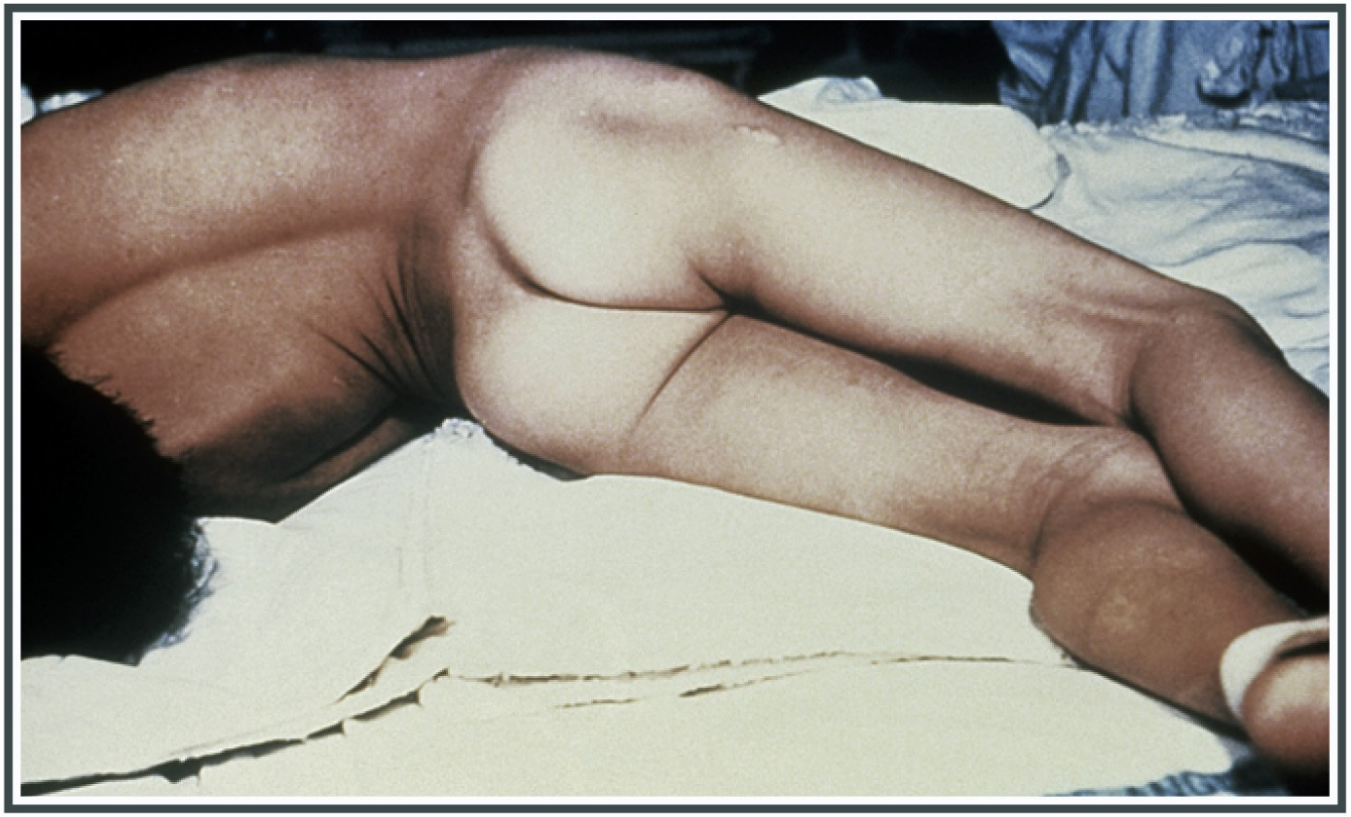


Figure 24.6 Microbiology: A Clinical Approach 2e (© Garland Science 2016)

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TETANUS: Pathogenesis

- Death results from exhaustion and respiratory failure
  - Mortality for untreated tetanus is 15 – 60%
- Several factors affect mortality:
  - Location of lesion
  - Incubation period
  - Age
    - Mortality is highest in infants and the elderly

TETANUS: Treatment

- Antibiotics are not effective once toxin is produced
- Neutralization of the toxin with human tetanus immunoglobulin is important
- Additional supportive measures are:
  - Maintenance of a dark, quiet environment
  - Sedation
  - Provision of an adequate airway for breathing

BOTULISM
(CLOSTRIDIUM BOTULINUM)

- Etiologic agent is *Clostridium botulinum*
  - Gram-positive
  - Anaerobic
  - Spore-forming
  - Rod-shaped
- Found naturally in soil and sediments of ponds and lakes

BOTULISM
(CLOSTRIDIUM BOTULINUM)

- Spores contaminate food under anaerobic conditions
  - Spores convert to the vegetative state and begin to produce toxin.
- Contamination of food with botulinum toxin does not affect the smell, taste, or color
  - Commonly seen in cases of home canning
- Botulinum toxin is among the most poisonous toxins in the world

BOTULISM: Pathogenesis

- Begins with cranial nerve palsy
  - Develops into a descending symmetrical motor paralysis
  - May involve the respiratory muscles
- No fever or inflammation
- No obvious sign of infection

BOTULISM: Pathogenesis

- Time course of the infection depends on:
  - Amount of toxin
  - Whether toxin was ingested in a preformed state, or produced in the intestinal tract

BOTULISM: Pathogenesis

- Foodborne botulism is classified as intoxication not infection
- Toxin is absorbed directly through the intestinal tract
  - Reaches a neuromuscular junction via bloodstream
  - Binds and inhibits the release of acetylcholine
    - Causes muscular paralysis

BOTULISM: Pathogenesis

- Symptoms depend on which nerves are damaged
  - Damage is permanent
- Foodborne botulism usually starts 12-36 hours after ingestion of toxin
  - First symptoms are nausea, dry mouth, and sometimes diarrhea
- Nervous system dysfunction starts later
  - Includes blurred vision, pupillary dilation, and rapid eye movements

BOTULISM: Pathogenesis

- Symmetrical paralysis begins with ocular, laryngeal, and respiratory muscles
  - Spreads to trunk and extremities
- Most serious complication is complete respiratory paralysis
  - Mortality rates are 10 – 20%

BOTULISM: Pathogenesis

- Two other forms of botulism:
  - Infant form
  - Wound form
- Infant botulism is the most commonly diagnosed form

BOTULISM: Pathogenesis

- Infant botulism occurs in infants between 3 weeks and 8 months old
  - Organism introduced on weaning or through dietary supplements, particularly honey
  - Multiplies in colon
  - Toxin is absorbed into the blood
- Symptoms are constipation, poor muscle tone, lethargy, and feeding problems
  - Severe cases can cause vision problems and paralysis

BOTULISM: Pathogenesis

- Wound botulism is very rare
  - Usually seen in intravenous drug users
- Symptoms are similar to those of food poisoning
  - Usually begin with muscle weakness in extremities used for injection

BOTULISM: Treatment

- Single most important determinant in survival is availability of intensive support measures, particularly mechanical ventilation
  - Mortality is less than 10% with proper ventilation
- Antibiotic therapy is only given to patients with the wound form

VIRAL INFECTIONS OF THE CENTRAL NERVOUS SYSTEM

- Viruses can cause encephalitis
- Viruses can also cause other symptoms
- Such viral CNS infections can be split into:
  - Acute
  - Persistent

RABIES

- Rabies is an acute and fatal viral CNS infection
- Can affect all mammals
- Transmitted by infected secretions (usually through a bite)
- Virus is large and bullet-shaped
  - Glycoproteins cover the entire virion

RABIES: Pathogenesis

- Rabies involves severe neurological symptoms
- CNS abnormalities include:
  - Relentless progression of excess motor activity
  - Agitation
  - Hallucinations
- Also overproduction of saliva
  - Can be an inability to swallow

RABIES: Pathogenesis

- Rabies exists in two forms:
  - Urban
  - Sylvatic
- Urban form is associated with unimmunized dogs and cats
- Sylvatic form is seen in wild animals
- Infection in humans incidental
  - Does not contribute to maintenance or transmission of infection

RABIES: Pathogenesis

- First event of rabies infection is introduction of the virus
  - Usually through the epidermis via an animal bite
  - Also through inhalation of heavily contaminated material such as bat droppings

RABIES: Pathogenesis

- Virus replicates at the site of infection
  - Immunization immediately after infection keeps virus from migrating into the nervous tissue
- Without intervention, virus moves into peripheral nervous system
  - Spreads into the CNS
  - Replicates exclusively in gray matter

RABIES: Pathogenesis

- After replication, virus moves into other tissues
  - Adrenal medulla, kidneys, lungs, and salivary glands
- Lymphocytes and plasma cells infiltrate into the CNS
  - Destroy nerve cells
  - Primary lesion is the Negri body

RABIES: Pathogenesis

- Incubation period varies from 10 days to as long as a year, depending on:
  - Amount of virus initially introduced
  - Amount of tissue infected
  - Host's immune response
  - Innervation at the site
  - Distance virus must travel to reach CNS

RABIES: Pathogenesis

- Rabies presents as acute, fatal encephalitis
  - Once symptoms appear the infection is irreversibly fatal
- Illness begins with nonspecific fever, headache, malaise, nausea, and vomiting
- Onset of encephalitis is marked by:
  - Periods of excessive motor activity
  - Agitation accompanied by hallucinations
  - Combativeness
  - Muscle spasms
  - Seizures followed by coma

RABIES: Pathogenesis

- There can also be:
  - Excessive salivation
  - Dysfunction of brain and cranial nerves
  - Double vision, facial palsy, and difficulty in swallowing
- Involvement of respiratory centers causes respiratory paralysis
  - Major cause of death
- Median survival after the onset of symptoms is 4 days

RABIES: Treatment

- Prevention is the best cure
- Treatment consists of a course of injections
  - Only beneficial if administered before the onset of symptoms
- Mortality for rabies is 90%

POLIO

- Condition first known as infantile paralysis
  - Risk of paralysis actually increases with age
- Poliomyelitis is essentially nonexistent in most modern countries
  - There is an effective vaccine
- Still a major problem in underdeveloped countries

POLIO: Pathogenesis

- Virus is an enterovirus with an affinity for the CNS
  - Normally crosses the blood-brain barrier
  - Can also use axons or the perineural sheath of the peripheral nervous system
- Motor neurons are particularly vulnerable

POLIO: Pathogenesis

- Various levels of neuronal destruction cause:
  - Necrosis of neural tissue
  - Infiltration by mononuclear cells, primarily lymphocytes
- 90% of poliomyelitis infections are very mild and subclinical
- Incubation time varies from 4 to 35 days
  - Average is about 10 days

POLIO: Pathogenesis

- Three types of polio infection:
  - Abortive poliomyelitis
  - Nonparalytic poliomyelitis (aseptic meningitis)
  - Paralytic poliomyelitis

POLIO: Pathogenesis

- Abortive poliomyelitis:
  - Nonspecific febrile illness
  - Lasts two to three days
  - No signs or symptoms

POLIO: Pathogenesis

- Nonparalytic poliomyelitis (aseptic meningitis):
  - Characterized by meningeal irritation, stiff neck, back pain, and back stiffness
  - Rapid and complete recovery

POLIO: Pathogenesis

- Paralytic poliomyelitis:
  - Occurs in 2% of persons infected
  - Characterized by asymmetric flaccid paralysis
    - Extent varies from case to case
  - Temporarily damaged neurons can regain function
    - Recovery can take six months
  - Paralysis persisting after this period is permanent

POLIO: Prevention

- Polio vaccine essentially wiped out this infection
- Two types of vaccine:
  - Inactive form
  - Live attenuated form

VIRAL ENCEPHALITIS

- Neurological infections classified as viral encephalitis are caused by arboviruses
  - Not a microbial taxonomic group
  - There is a variety of clinical types
  - These viruses are common in US
    - Increased occurrence of infections in summer months due to increased number of mosquitoes

VIRAL ENCEPHALITIS

- Infections range in severity from subclinical symptoms to rapid death
- Infections are all characterized by chills, headache, and fever
  - Can lead to mental confusion and coma
- Survivors can subsequently develop permanent neurological disease

VIRAL ENCEPHALITIS

- Both horses and people are affected by arboviruses:
  - Eastern equine encephalitis (EEE)
  - Western equine encephalitis (WEE)
    - Both cause severe infection in humans
- St. Louis encephalitis is the most common form of arbovirus encephalitis
  - Less than 1% show clinical symptoms

VIRAL ENCEPHALITIS

- West Nile virus is an emerging encephalitis infection
  - Mostly affects birds
  - Can also infect humans and horses
    - Most human cases are subclinical
    - Some can be a severe infection with rapid death in elderly

PERSISTENT VIRAL CNS INFECTIONS

- Progressive neurological diseases in both humans and animals are caused by viruses
  - Termed slow viral disease
  - Better term is persistent viral infection
    - Long period between infection and illness
    - Prolonged period of illness

PERSISTENT VIRAL CNS INFECTIONS

- Subacute sclerosing panencephalitis:
  - Rare chronic measles infection
  - Occurs in children
  - Produces progressive neurological disease
  - Insidious onset of personality change, progressive intellectual deterioration, and dysfunction of the autonomic nervous system

PERSISTENT VIRAL CNS INFECTIONS

- AIDS dementia complex
  - Part of pathology of HIV infection
  - In asymptomatic AIDS patients
  - Varies from mild to severe progressive dementia

PERSISTENT VIRAL CNS INFECTIONS

- Persistent enterovirus infection:
  - Seen in patients with congenital or acquired immunodeficiency
  - Chronic CNS infection
  - Characterized by headache, confusion, lethargy, seizures, and increased numbers of mononuclear cells in CNS
  - Caused by both echoviruses and enteroviruses

PRIONS

- Prions (infectious proteins) cause five fatal CNS infections in mammals
- Prions do not elicit inflammatory or immune responses in a host
- Pathogenesis of these infections is not well understood but they have similar features
  - Loss of neurons
  - Proliferation of astrocytes
  - Vacuoles seen in the brain cortex and cerebellum

PRIONS

- Incubation period can be from months to years
- Course of infection is protracted and always fatal
- Prions are very hard to destroy:
  - Remain viable in brain tissue after years of being immersed in formalin
  - Resistant to ionizing radiation and many common disinfectants

PRION INFECTIONS: Kuru

- Subacute progressive neurological disease
  - Discovered 1957 in the cannibalistic Fore people of New Guinea
- Symptoms are failure of muscular coordination, hyperactive reflexes, and muscular spasms
- Leads to progressive dementia and death
- Causes diffuse neuronal degeneration and spongiform change of the cerebral cortex and basal ganglia

PRION INFECTIONS: Fatal Familial Insomnia

- Presents as a difficulty in sleeping followed by increasingly progressive dementia
- Occurs in people between 35-61 years
- Always fatal
  - Death occurs between 13-25 months after diagnosis

PRION INFECTIONS: Creutzfeld-Jacob disease

- Progressive fatal infection often seen in patients aged 60-70 years
- Initially presents as a change in cerebral function
  - Often mistaken for a psychiatric disorder
  - Patient exhibits forgetfulness and disorientation
  - Progresses to overt dementia

PRION INFECTIONS: Creutzfeld-Jacob disease

- Progression can last 4 – 7 months and involve changes in gait, involuntary movements, and seizures
- There is eventual paralysis, wasting, pneumonia, and death
- Infection seen throughout the world
  - One case per million people is reported each year

PRION INFECTIONS: Creutzfeld-Jacob disease

- Mode of transmission is essentially unknown but could include:
  - Contaminated dura mater grafts and corneal transplants
  - Contact with contaminated instruments used in neurosurgical procedures
- Transmission has also been linked to contaminated growth hormone
- No evidence of transmission by direct contact or airborne spread

PRION INFECTIONS: Creutzfeld-Jacob disease

- Incubation period is anywhere from 3-20 years
- Pathology identical to that seen in kuru
  - High levels of prions are found in the brain
- Examination of brain tissue is the only way to confirm the disease
- There is no treatment

PRION INFECTIONS: Bovine Spongiform Encephalopathy

- BSE (mad cow disease) was first identified in the UK in 1986
  - Source of prions traced to cattle feed containing bonemeal from sheep that had scrapie
  - Cows ate the feed and became infected
  - The infection passed to humans who ate infected beef
- Infection in humans is known as variant Creuztfeld-Jacob disease (vCJD)
  - Cases frequently present in young adults
  - Presents as psychiatric problems progressing to dementia
  - Average life expectancy after diagnosis is 14 months

FUNGAL INFECTIONS OF THE CNS

- Primarily opportunistic
- Usually seen in immunocompromised patients

CRYPTOCOCCOSIS

- Cryptococcosis is the most important fungal CNS infection
- Caused by *Cryptococcus neoformans*
  - Encapsulated form of yeast
  - Capsule production varies with the strain and environmental conditions
  - Found throughout world, especially in soil contaminated with bird droppings
    - Birds are not sick from this fungus

CRYPTOCOCCOSIS: Pathogenesis

- Causes a chronic form of meningitis
  - Slow, insidious onset
  - Symptoms include low-grade fever and headache
  - Progresses to altered mental status and seizures

CRYPTOCOCCOSIS: Pathogenesis

- Infection usually seen in immunocompromised patients
  - Common in AIDS patients
- Infection begins with inhalation of the yeast cells
- Each yeast cell begins to overproduce its capsule
  - Capsule is anti-phagocytic
  - Can bind to complement components
    - Reduces opsonization
  - Can interfere with the presentation of antigens to T cells
    - Inhibits the adaptive immune response

CRYPTOCOCCOSIS: Pathogenesis

- After inhalation, yeast cells multiply outside the lungs and move into the nervous system
- Initial symptoms can continue for weeks or months
  - Intermittent headache, dizziness, and difficulty with complex cerebral function
- Later stages of the infection show:
  - Seizures, cranial nerve damage, and papilledema (edema of the optic nerve)
  - Dementia and decreased levels of consciousness
- Progression of disease is accelerated in patients with AIDS

CRYPTOCOCCOSIS: Treatment

- Amphotericin B and fluconazole are effective
- 75% patients with cryptococcal meningitis initially respond to treatment
  - Significant portion relapse when therapy is stopped
- Patients with chronic infection require repeated courses
- Residual neurological damage occurs in more than half of cured patients

PARASITIC INFECTIONS OF THE CENTRAL NERVOUS SYSTEM

- Free living amebas can infect the CNS
  - Cause primary amebic meningoencephalitis
- Infections are rare and usually fatal

PRIMARY AMEBIC MENINGOENCEPHALITIS

- Caused by free-living amebas of two genera
  - *Naegleria*
  - *Acanthamoeba*
- *Naegleria* is found in large numbers in shallow freshwater ponds, especially in warm weather
  - Acquired by swimming in fresh water
  - Infection seen in children and young adults
- *Naegleria* infection is infrequent and almost always fatal

PRIMARY AMEBIC MENINGOENCEPHALITIS

- *Acanthamoeba* causes a sub-acute or chronic illness
  - Almost always fatal
- *Acanthamoeba* found in soil and fresh brackish water
  - Most occur in the southeastern US
  - Patients typically fall ill during the summer after swimming or water skiing in small shallow freshwater lakes
- *Acanthamoeba* is also found in the oropharynx of asymptomatic humans

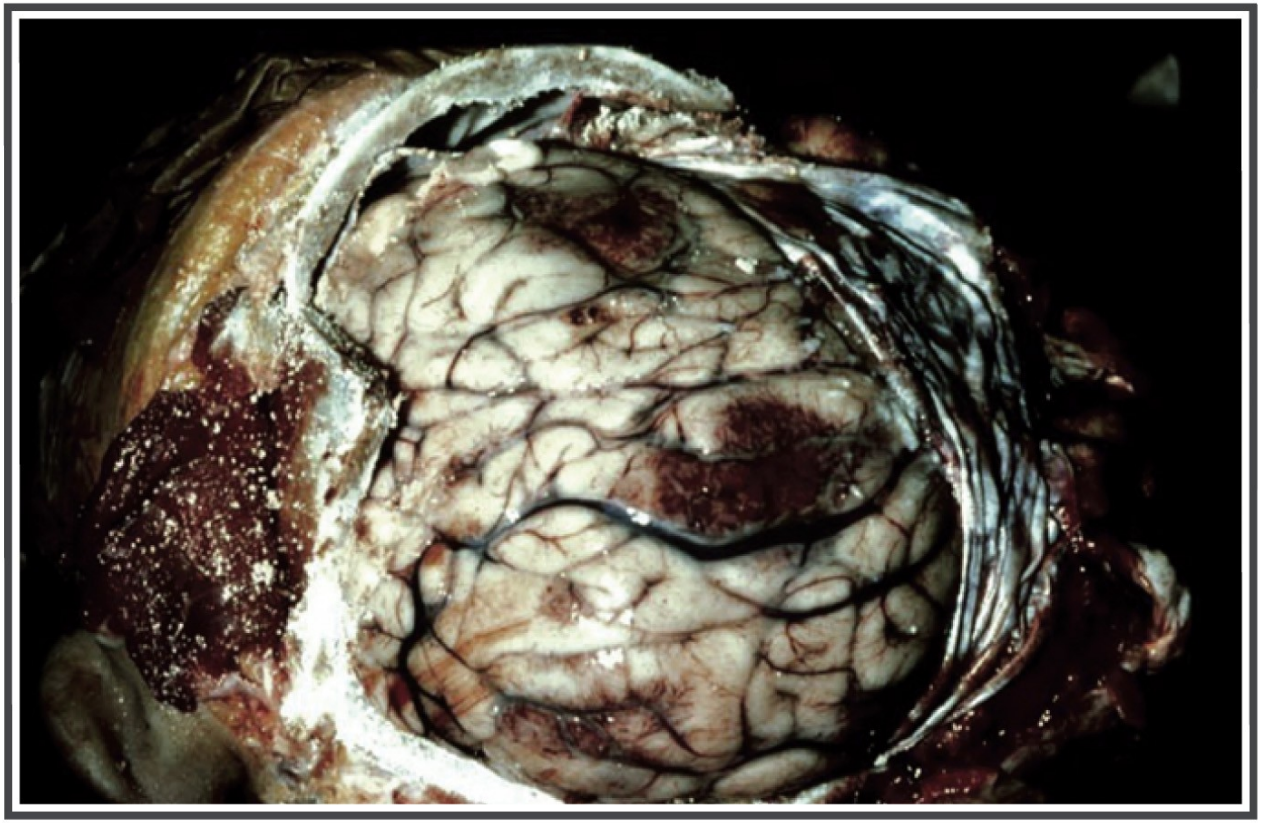
AMEBIC MENINGOENCEPHALITIS: Pathogenesis

- *Naegleria* enters the CNS by traversing the nasal mucosa and cribriform plate
- In the CNS produces a purulent, hemorrhagic inflammatory reaction
  - Extends from the olfactory bulb to other regions of the brain
- Characterized by rapid onset of severe bifrontal headache and seizures
  - Occasionally abnormal sense of taste and smell
- Progresses to coma and death within days
- Wet mounts of cerebrospinal fluid reveal trophozoite forms of the parasite

AMEBIC MENINGOENCEPHALITIS: Pathogenesis

- Epidemiology of *Acanthamoeba* encephalitis is not clearly defined
  - Known to involve the elderly and immunocompromised
- Thought that the ameba reaches the brain by hematogenous dissemination
  - Site of infection is unknown, possibly respiratory, eye, or skin
- Infection produces diffuse necrotizing granulomatous encephalitis

AMEBIC MENINGOENCEPHALITIS: Pathogenesis



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Courtesy of Dr. Andrew Bollen and Dr. Walter Finkbeiner.

AMEBIC MENINGOENCEPHALITIS: Pathogenesis

- Both cysts and trophozoites can be found in lesions
- AIDS patients can have:
  - Cutaneous ulcers and hard nodules containing amebas
  - Amebas in the cerebrospinal fluid
- Clinical course of *Acanthamoeba* infection is more prolonged that that of *Naegleria*
- *Acanthamoeba* occasionally ends in spontaneous recovery

AMEBIC MENINGOENCEPHALITIS: Treatment

- Few patients have ever survived infection with *Naegleria*
  - All were diagnosed early
  - Treated with high doses of amphotericin B with rifampin