Chapter 13 Characterizing and Classifying Viruses, Viroids, and Prions
Characteristics of Viruses

- Viruses
  - Minuscule, acellular, infectious agent having either DNA or RNA
  - Cause infections of humans, animals, plants, and bacteria
  - Cause most of the diseases that plague the industrialized world
  - Cannot carry out any metabolic pathway
  - Neither grow nor respond to the environment
  - Cannot reproduce independently
  - Recruit the cell's metabolic pathways to increase their numbers
  - No cytoplasmic membrane, cytosol, organelles
  - Have extracellular and intracellular state
Characteristics of Viruses

- **Extracellular state**
  - Called **virion**
  - Protein coat (capsid) surrounding nucleic acid
  - Nucleic acid and **capsid** also called nucleocapsid
  - Some have phospholipid **envelope**
  - Outermost layer provides protection and recognition sites for host cells

- **Intracellular state**
  - Capsid removed
  - Virus exists as nucleic acid
Characteristics of Viruses

• **Genetic Material of Viruses**
  - Show more variety in nature of their genomes than do cells
  - Primary way scientists categorize and classify viruses
  - May be DNA or RNA, but never both
    - Can be dsDNA, ssDNA, dsRNA, ssRNA
  - May be linear and segmented or single and circular
  - Much smaller than genomes of cells
Characteristics of Viruses

• **Hosts of Viruses**
  • Most viruses infect only particular host's cells
    • Due to affinity of viral surface proteins for complementary proteins on host cell surface
  • May be so specific they only infect particular kind of cell in a particular host
  • Generalists infect many kinds of cells or many different hosts
  • All types of organisms are susceptible to some virus
Characteristics of Viruses

• **Capsid Morphology**
  • Capsids
    • Provide protection for viral nucleic acid
    • Means of attachment to host's cells
    • Composed of proteinaceous subunits called **capsomeres**
      • Capsomere may be made of single or multiple types of proteins

• **Viral Shapes**
  • Viruses can be classified by virion shape
  • Three basic types of viral shapes:
    • Helical
    • Polyhedral
    • Complex
Figure 13.5 The shapes of virions.

(a) Enveloped capsid
(b) Fiber layer
(c) Cell's vesicle
(d) TEM
Characteristics of Viruses

• **The Viral Envelope**
  - Acquired from host cell during viral replication or release
    - Envelope is portion of membrane system of host
  - Composed of phospholipid bilayer and proteins
    - Some proteins are virally coded glycoproteins (spikes)
  - Envelope proteins and glycoproteins often play role in host recognition
  - Enveloped viruses are more fragile than naked viruses
Classification of Viruses

- Virus classification based on:
  - Type of nucleic acid
  - Presence of an envelope
  - Shape
  - Size
- Viral genera have only been organized into families
- Relationship among viruses is not well understood by taxonomists
Viral Replication

- Dependent on hosts' organelles and enzymes to produce new virions
- Lytic replication
  - Viral replication usually results in death and lysis of host cell
  - Five stages of lytic replication cycle:
    - Attachment
    - Entry
    - Synthesis
    - Assembly
    - Release
Figure 13.12 Three mechanisms of entry of animal viruses.

(a) Direct penetration

1. Viral genome inside capsid
2. Empty capsid
3. Receptors on cytoplasmic membrane

(b) Membrane fusion

1. Viral genome
2. Viral glycopolproteins
3. Envelope
4. Receptors on cytoplasmic membrane of host
5. Viral genome
6. Uncoating capsid

(c) Endocytosis

1. Viral genome
2. Viral glycopolproteins remain in cytoplasmic membrane
3. Cytoplasmic membrane of host engulfs virus (endocytosis)
4. Envelope
5. Viral genome
6. Uncoating capsid
Viral Replication

- Replication of Animal Viruses
  - Synthesis of DNA Viruses of Animals
    - Each type of animal virus requires different strategy depending on its nucleic acid
    - DNA viruses often enter the nucleus
    - RNA viruses often replicate in the cytoplasm
  - Must consider
    - How mRNA is synthesized
    - What serves as template for nucleic acid replication
Viral Replication

• Synthesis of DNA Viruses of Animals
  • dsDNA viruses
    • Similar to replication of cellular DNA
      • Viral genome replicated in the nucleus
      • Viral proteins are made in the cytoplasm
    • Some exceptions
      • Hepatitis B viruses replicate DNA from an RNA intermediary
  • ssDNA viruses
    • Cells do not use ssDNA
    • Parvoviruses have ssDNA genomes
      • DNA strand folds back on itself to form dsDNA, which is replicated by cellular DNA polymerase
      • Newly replicated strand is released as ssDNA
Figure 13.13 Synthesis of proteins and genomes in animal RNA viruses.

(a) Positive-sense ssRNA virus

(b) Negative-sense ssRNA virus

(c) Double-stranded RNA virus

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Viral Replication

- Replication of Animal Viruses
  - Assembly and Release of Animal Viruses
    - Most DNA viruses assemble in nucleus
    - Most RNA viruses develop solely in cytoplasm
    - Number of viruses produced depends on type of virus and size and initial health of host cell
  - Enveloped viruses cause persistent infections
  - Naked viruses are released by exocytosis or lysis

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Viral Replication

• Replication of Animal Viruses
  • Latency of Animal Viruses
    • When animal viruses remain dormant in host cells
    • Viruses are called latent viruses or proviruses
    • May be prolonged for years with no viral activity
    • Incorporation of provirus into host DNA is permanent
The Role of Viruses in Cancer

• Cell division is under strict genetic control
  - Genes dictate that some cells can no longer divide at all
  - Cells that can divide are prevented from unlimited division
  - Genes for cell division "turned off" or genes inhibiting division "turned on"

• Neoplasia
  - Uncontrolled cell division in multicellular animal
  - Mass of neoplastic cells is tumor

• Benign versus malignant tumors
  - Malignant tumors also called cancers
  - Metastasis occurs when tumors spread
The Role of Viruses in Cancer

- *Protooncogenes* promote cell growth and division
- Uncontrolled activation of oncogenes can lead to cancer
- Environmental factors that contribute to the activation of oncogenes:
  - Ultraviolet light
  - Radiation
  - Carcinogens
  - Viruses
Figure 13.16 The oncogene theory of the induction of cancer in humans.

Normal state:
DNA
Protooncogene
Gene for repressor
Represses mRNA
Repessor
Result: No cancer

First "hit":
Virus inserts promoter
DNA
Oncogene
Gene for repressor
Represses mRNA
Repessor
Result: Still no cancer

Second "hit":
Virus inserts into repressor gene
DNA
Oncogene
Gene for repressor
No repressor protein because gene is segmented
mRNA
Protein Causes cell division
Result: Cancer
The Role of Viruses in Cancer

- Viruses cause 20–25% of human cancers
  - Some carry copies of oncogenes as part of their genomes
  - Some promote oncogenes already present in host
  - Some interfere with tumor repression
  - Specific viruses are known to cause some human cancers:
    - Burkitt's lymphoma
    - Hodgkin's disease
    - Kaposi's sarcoma
    - Cervical cancer
Other Parasitic Particles: Viroids and Prions

- **Characteristics of Viroids**
  - Extremely small, circular pieces of ssRNA that are infectious and pathogenic in plants
  - Similar to RNA viruses, but lack capsid
  - Viroid RNA does not code for proteins
  - Viroid RNA adheres to complementary plant RNA
    - Plant enzyme degrades the dsRNA
    - Results in a disease state
Other Parasitic Particles: Viroids and Prions

• Characteristics of Prions
  • Proteinaceous infectious agents
  • *Cellular PrP*
    • Made by all mammals
    • Normal, functional structure has α-helices
  • *Prion PrP*
    • Disease-causing form has β-sheets
    • Prion PrP causes cellular PrP to refold into prion PrP
Prions: Overview

prion-infected meat
Prions: Characteristics

α-helix

β-pleated sheet

cell membrane

PLAY

Prions: Characteristics
Other Parasitic Particles: Viroids and Prions

- Characteristics of Prions
  - Prion diseases
    - Spongiform encephalopathies
      - Large vacuoles form in brain
        - Characteristic spongy appearance
      - BSE, scrapie, kuru, CWD, vCJD
    - Transmitted by ingestion, transplantation, or contact of mucous membranes with infected tissues
  - No standard treatment for any prion disease
Other Parasitic Particles: Viroids and Prions

• Characteristics of Prions
  • Normal sterilization procedures do not deactivate prions
  • Prions destroyed by incineration or autoclaving in concentrated sodium hydroxide
  • European Union recently approved use of enzymes to remove prions from medical equipment
<table>
<thead>
<tr>
<th>Human Prion Diseases</th>
<th>Animal Prion Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creutzfeldt-Jakob disease</td>
<td>Scrapie</td>
</tr>
<tr>
<td>Gerstmann-Straussler-Scheinker syndrome</td>
<td>Transmissible mink encephalopathy</td>
</tr>
<tr>
<td>Fatal familial insomnia</td>
<td>Chronic wasting disease</td>
</tr>
<tr>
<td>Kuru</td>
<td>Bovine spongiform encephalopathy (&quot;mad cow disease&quot;)</td>
</tr>
</tbody>
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**Central nervous system**

**Brain**
Viral Diseases of the Skin and Wounds

- **Herpes Infections**
  - Signs and symptoms
    - Slow-spreading skin lesions
      - Herpetic gingivostomatitis, whitlow, herpes gladiatorum
    - Recurrence of lesions is common
  - Pathogens and virulence factors
    - Caused by human herpesviruses 1 and 2
    - Produce various proteins that act as virulence factors
  - Pathogenesis
    - Painful lesions caused by inflammation and cell death
    - Fusion of infected cells forms syncytia
Figure 19.12 Sites of events in herpesvirus infections.

- Trigeminal (V) nerve ganglion, site of viral latency
- Ophthalmic branch
- Ocular herpes
- Maxillary branch
- Mandibular branch
- Brachial ganglia, site of viral latency
- Fever blisters
- Sacral ganglia, site of viral latency
- Genital herpes
- Whitlow
Viral Diseases of the Skin and Wounds

• **Herpes Infections**
  
  • Epidemiology
    
    • Spread between mucous membranes of mouth and genitals
    
    • Herpes infections in adults are not life threatening
    
    • Neonatal infections can be fatal
  
  • Diagnosis, treatment, and prevention
    
    • Diagnosis is made by presence of characteristic lesions
    
    • Immunoassay reveals presence of viral antigens
    
    • Chemotherapeutic drugs help control the disease but do not cure it
    
    • Health care workers can wear gloves to limit exposure
Viral Diseases of the Skin and Wounds

- **Warts**
  - **Signs and symptoms**
    - Benign epithelial growths on the skin or mucous membranes
    - Can form on many body surfaces
  - **Pathogens and virulence factors**
    - Various papillomaviruses cause warts
    - Some strains trigger oncogenes in host chromosome
  - **Pathogenesis**
    - Warts develop several months after infection
    - Most warts are harmless
    - Papillomaviruses may precipitate some cancers
Figure 19.13 Various kinds of warts—lesions caused by papillomaviruses.
Viral Diseases of the Skin and Wounds

• Warts

  • Epidemiology
    • Transmitted via direct contact and fomites
    • Individuals can spread viruses among locations on their own body
  
  • Diagnosis, treatment, and prevention
    • Diagnosed by observation
    • Various techniques to remove warts
      • New warts can develop as a result of latent viruses
Viral Diseases of the Skin and Wounds

• **Chickenpox and Shingles** - Varicella-zoster virus (VZV) causes both diseases
  
  • Signs and symptoms
    
    • Chickenpox
      
      • Highly contagious infectious disease
      
      • Characterized by lesions on the back and trunk that spread across body
      
      • Virus becomes latent within sensory nerves
    
    • Shingles
      
      • Occurs following reactivation of the virus
      
      • Lesions are localized to skin along an infected nerve
      
      • Pain may last after lesions have healed
Viral Diseases of the Skin and Wounds

- **Chickenpox and Shingles**
  - Pathogenesis
    - Infection spreads from the respiratory tract to the skin via blood and lymph
    - Infected dermal cells cause characteristic rash of chickenpox
    - Chickenpox is usually a mild disease
    - Virus becomes latent in nerve ganglia
      - Reactivated VZV causes shingles
Viral Diseases of the Skin and Wounds

• Chickenpox and Shingles
  • Epidemiology
    • Chickenpox occurs mostly in children
    • VZV infected 90% of children prior to immunization
    • Disease is more severe in adults
    • ~20% of people who have had chickenpox develop shingles
    • Risk of shingles increases with age
  • Diagnosis, treatment, and prevention
    • Diagnosis based on characteristic lesions
    • Treatment based on relief of symptoms
    • Vaccine available against chickenpox
Viral Diseases of the Skin and Wounds

- **Other Viral Rashes** - B19 virus
  - Erythema infectiosum
    - Also referred to as *fifth disease*
    - Respiratory disease that manifests as a rash
    - Adults may also develop anemia and joint pain
  - Roseola - human herpesvirus 6 (HHV-6)
    - Endemic disease of children
    - Caused by Characterized by a rose-colored rash
  - Hand-foot-mouth disease – Coxsackie A virus