

## Chapters 13-14

### Viruses

## Viral epidemics

- 1918 & 1919 - Spanish flu (swine flu)  
(read page 619)
- 1940s & 50s - polio
- 1970s & 1990s - Ebola
- 1980s & 1990s - HIV
- 1996 & 1997 - hepatitis, dengue fever, yellow fever, Ebola, Lassa fever, and polio
- Others - hantavirus,

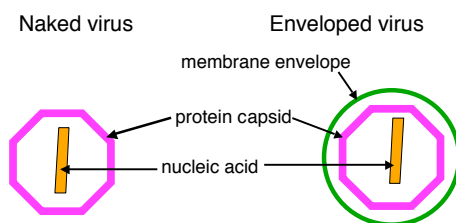
## Viruses

- Too small to see with the light microscope
- No cell nucleus
- No organelles
- No cytoplasm
- Obligate intracellular parasites??

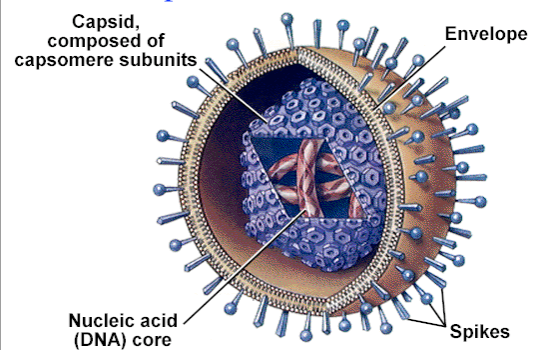
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**Table 13.1 Comparison Between Viruses and Cells**

	Viruses	Cells
<b>Size</b>	10-500 nm	Bacteria: 1,000 nm Animal: 200,000 nm Plant: 400,000 nm
<b>Multiplication</b>	Multiply only within cells; outside the cell they are metabolically inert; protein coat and nucleic acid separate prior to multiplication	Most are free-living and multiply in the absence of other cells; entire cell remains intact during multiplication
<b>Nucleic Acid Content</b>	Contain either DNA or RNA, but never both	Always contain both DNA and RNA
<b>Enzyme Content</b>	Contain very few, if any, enzymes	Contain many enzymes
<b>Internal Components</b>	Lack ribosomes and enzymes for generating energy	Contain ribosomes and enzymes for generating energy

## Viruses





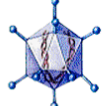

## Viral components (virion)



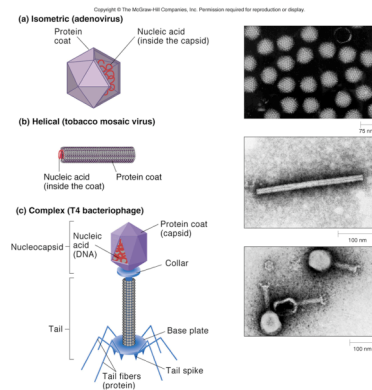
## Classification of viruses

- Nucleic acids
- Size and shape
- Host and Specificity (disease)

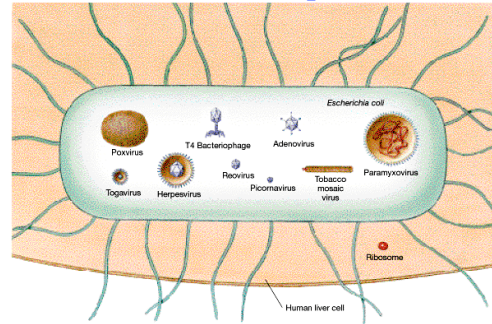
Viruses can have DNA or RNA as the for their genome

	DNA viruses	RNA viruses
Enveloped	 <p>Herpesvirus</p>	 <p>Retrovirus</p>
Naked	 <p>Adenovirus</p>	 <p>Picornavirus</p>

## Common shapes of viruses

















## Relative sizes and shapes of viruses

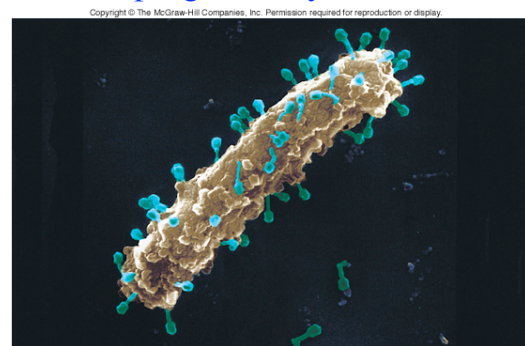


Many shapes - Spherical to icosahedral

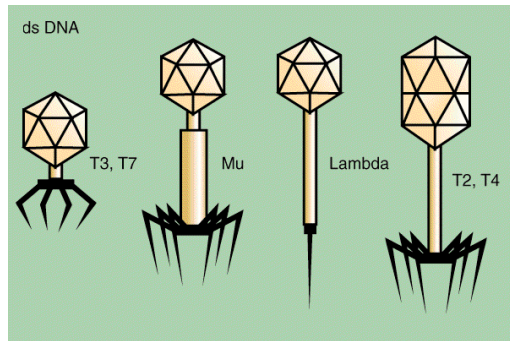
### RELATIVE SIZES AND SHAPES OF DIFFERENT VIRUSES

DNA VIRUSES	     
RNA VIRUSES	       

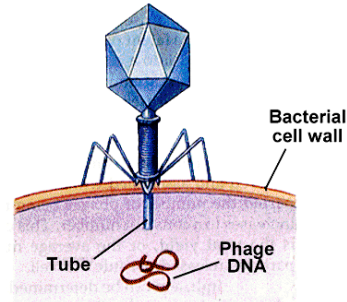
## Bacteriophages (ready to eat)



## Bacteriophages



## Bacteriophage injecting genome



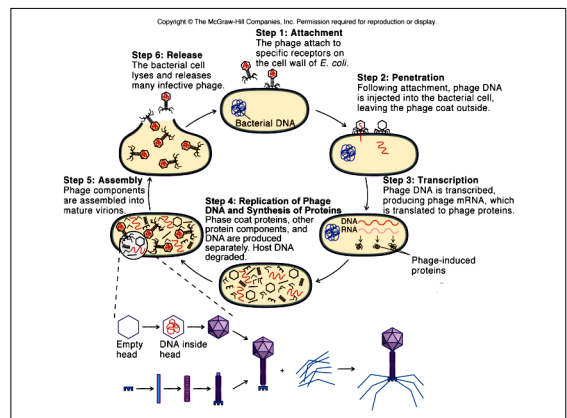
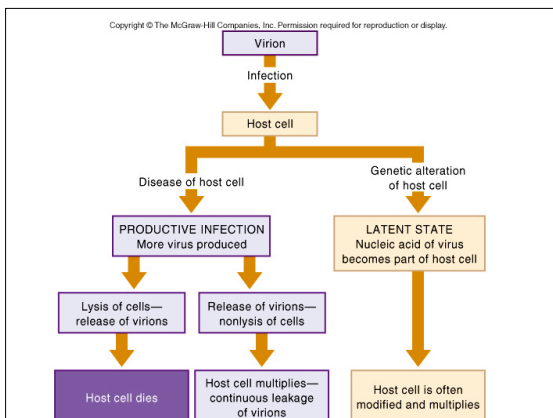
## Host Range and specificity

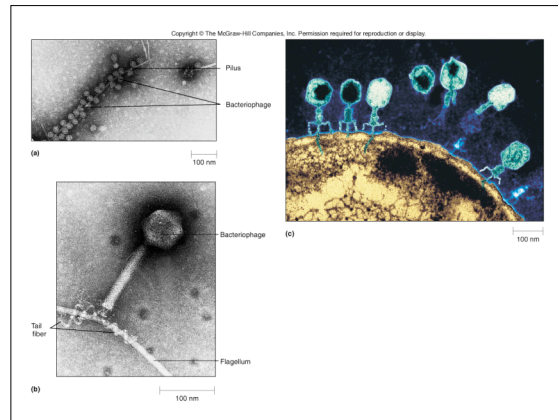
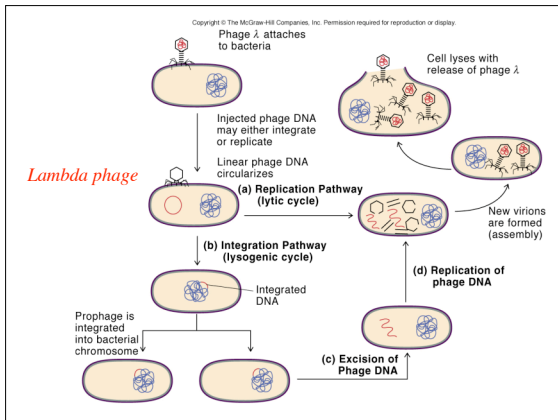
- Most viruses are specific to the host they attack.
  - Bacteria, fungi, algae, protozoa, plants and vertebrates.
  - Polio - only humans
  - Rabies - many warm blooded animals
- Many are specific to the cells they attack
  - Human papillomavirus (warts) - skin cells
  - Cytomegalovirus (CMV)- salivary glands, liver, lungs, and other tissues

Table 13.2 Representative Important Bacteriophages

Bacteriophage	Host	Shape	Genome Structure*	Relationship to Host Cell
T4, T1-T7	<i>Escherichia coli</i>	Complex	ds DNA	Lytic
M13, fd	<i>Escherichia coli</i>	Filamentous	ss DNA	Exit by extrusion
φ174	<i>Escherichia coli</i>	Isohedral	ss DNA	Lytic
Lambda (λ)	<i>Escherichia coli</i>	Complex	ds DNA	Latent
MS2, Qβ	<i>Escherichia coli</i>	Isohedral	ss RNA	Lytic
Beta (β)	<i>Corynebacterium diphtheriae</i>	Isohedral	ds DNA	Latent; codes for diphtheria toxin

\*ds, double-stranded; ss, single-stranded.





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**TABLE 13.4 Features of Interactions of Phage with Host Cells**

Phage	Type of Interaction	Type of Nucleic Acid*	Result of Interaction
T4	Productive	ds DNA	Cell lyses
MS2, Q $\beta$	Productive	ss RNA	Cell lyses
Lambda ( $\lambda$ )	Latent	ds DNA	Phage and host live in harmony
M13, fd	Productive	ss DNA	Phage extrudes from cell, which continues to multiply
$\phi$ X174	Productive	ss DNA	Cell lyses

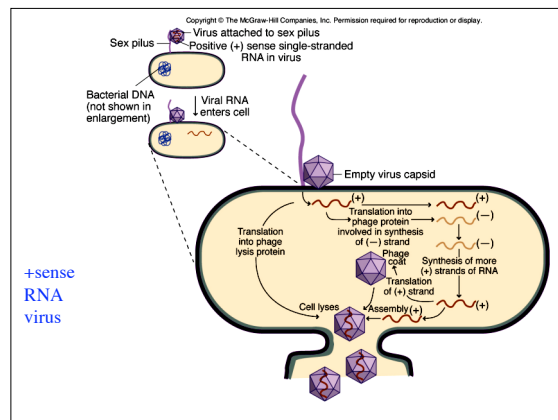
\*ds, double-stranded; ss, single-stranded.

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**Table 13.3 Some Properties Conferred by Prophage**

Microorganism	Medical Importance	Property Coded by Phage
<i>Corynebacterium diphtheriae</i>	Causes diphtheria	Synthesis of diphtheria toxin
<i>Clostridium botulinum</i>	Causes botulism	Synthesis of botulinum toxin
<i>Streptococcus</i> ( $\beta$ -hemolytic)	Causes scarlet fever, strep throat, nephritis	Erythrogenic toxin responsible for scarlet fever
<i>Salmonella</i>	Causes food poisoning	Modification of lipopolysaccharide of cell wall
<i>Vibrio cholerae</i>	Causes cholera	Synthesis of cholera toxin

- + sense RNA viruses**
- Picornaviridae
    - Polio, rhinoviruses (common cold), hepatitis A
  - Togaviridae
    - Rubella virus
  - Flaviviridae
    - Yellow fever, Hepatitis C
  - Retroviridae (reverse transcriptase)
    - Adult leukemia, HIV(AIDS)



### - sense RNA viruses

- Paramyxoviridae
  - Mumps, measles, viral pneumonia
- Rhabdoviridae
  - Rabies
- Orthomyxoviridae
  - Influenza
- Filoviridae
  - Marburg, Ebola
- Bunyaviridae
  - Hanta, LaCross virus

### Double-stranded RNA viruses

- Reoviridae
  - Respiratory and gastrointestinal infections
    - Rotavirus - diarrhea in children
    - Bluetongue virus - sheep

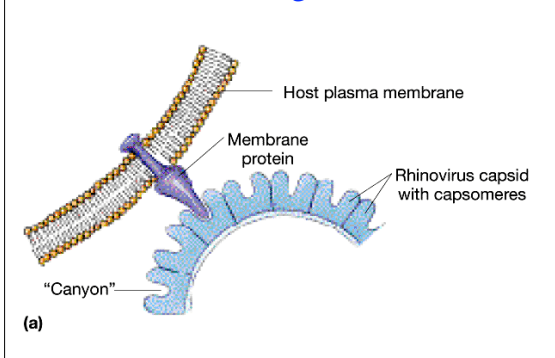
### DNA viruses

- Adenoviridae
  - Respiratory infections
- Herpesviridae
  - Oral and genital herpes
- Poxviridae
  - Smallpox
- Papovaviridae
  - Human papilloma viruses (warts), cervical and penile cancers
- Hepadnaviridae
  - Hepatitis B

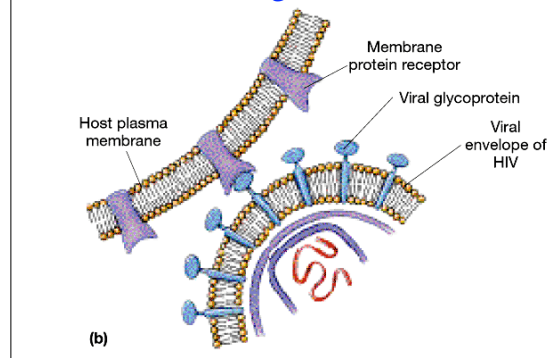
### Viral replication

- Adsorption
  - The attachment of the viruses to the cells
- Penetration
  - The entry of the virion (or the genome)
- Synthesis
  - New nucleic acids, capsid proteins, & other viral components
- Maturation
  - Assembly of viral components
- Release
  - Release generally, but not always kills the cell

### Cold virus attaching

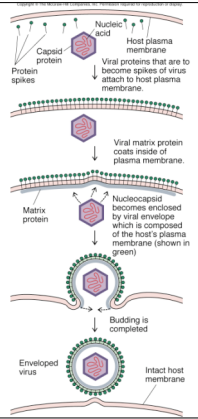


### HIV virus binding



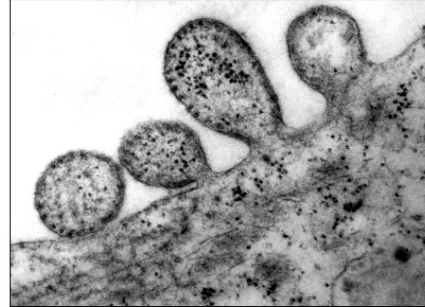


## Release of the virus - budding



## Budding

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(b)

100 nm

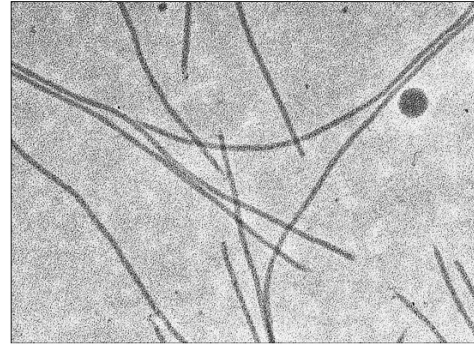
TABLE 14.5 Relationship of Virus Size to Dependency on Host Cell Enzymes for DNA Replication

Virus*	Increasing Size of Virus	Dependence on Host Cell DNA Synthetic Enzymes
Parvovirus ss DNA	↓	Depends totally on host cell enzymes.
Polyomavirus ds DNA		Codes for a protein that is involved in the start of DNA synthesis; rest depends on host enzymes.
Adenovirus ds DNA		Codes for proteins involved in initiation of DNA synthesis and also DNA polymerase.
Poxvirus ds DNA		Is totally independent of host cell enzymes.
Herpesvirus ds DNA		

\* ss, single-stranded; ds, double-stranded.

## fd phage

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## Animal viruses

- Genome structure
  - DNA or RNA, Single or double-stranded, segmented or single molecule
- Virus particle structure
  - Isometric (icosahedral), helical (rod), or pleomorphic (irregular in shape)
- Presence or absence of a viral envelope

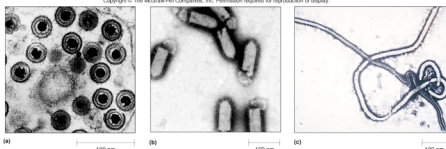












TABLE 14.1 Classification of RNA Viruses Infecting Vertebrates

Family	Drawing of Virion	Virion Structure	Genome Structure*	Characteristics and Representative Pathogenic Members
Picornaviridae (pic, micro, rna, ribonucleic acid)		Naked isometric	1 molecule, ss RNA	Poliovirus, rhinovirus
Caliciviridae (calic, cup)		Naked isometric	1 molecule, ss RNA	Rotavirus; many members cause gastroenteritis
Togaviridae (toga, cloak)		Lipid-containing envelope	1 molecule, ss RNA	Many multiply in arthropods and vertebrates; encephalitis in humans
Flaviviridae (flava, yellow)		Lipid-containing envelope	1 molecule, ss RNA	Yellow fever virus; dengue virus
Coronaviridae (corona, crown)		Lipid-containing envelope	1 molecule, ss RNA	Cold and respiratory tract infections
Rhabdoviridae (rhabdo, rod)		Bullet-shaped; lipid-containing envelope	1 molecule, ss RNA	Rabies virus
Filoviridae (filo, threadlike)		Long filamentous; lipid-containing envelope	1 molecule, ss RNA	Marburg virus; ebola virus
Paramyxoviridae (para, by the side of; myxo, mucus)		Pleomorphic; lipid-containing envelope	1 molecule, ss RNA	Mumps virus; parainfluenza virus
Orthomyxoviridae (ortho, straight; myxo, mucus)		Pleomorphic; lipid-containing envelope	7-8 segments of linear ss RNA	Influenza virus
Bunyaviridae (Bunyamena, a locality in Uganda)		Lipid-containing envelope	3 molecules of ss RNA	Hantaan virus
Arnaviridae (arava, sand)		Pleomorphic; lipid-containing envelope	2 molecules of ss RNA with hydrogen-bonded ends	Lassa virus

**TABLE 14.1 Classification of RNA Viruses Infecting Vertebrates**

<b>Roviridae</b> (respiratory enteric, organ virus)		Naked virion	Linear ds RNA divided into 10, 11, or 12 segments	Diarthera in animals
<b>Birnaviridae</b> (B1, hsw)		Naked virion; icosahedral	2 segments of linear ds RNA	No human pathogen; diseases in chickens and fish
<b>Retroviridae</b> (retro, backwards)		Icosahedral; lipid-containing envelope	2 identical molecules ss RNA	HIV

**TABLE 14.2 Classification of DNA Viruses Infecting Vertebrates**

Family	Drawing of Virion	Virion Structure	Genome Structure*	Characteristics and Representative Pathogenic Members
<b>Hepadnaviridae</b> (hepa, liver, dna, deoxythymosic acid)		Lipid-containing envelope	1 molecule, mainly ds DNA but with a single-stranded gap	Hepatitis B virus
<b>Parvoviridae</b> (parvo, small)		Naked	1 molecule, ss DNA	Outbreaks of gastroenteritis following eating of shellfish
<b>Papovaviridae</b> (papilloma, polyoma, vacuolating agent)		Naked	1 molecule, circular ds DNA	Human papillomaviruses associated with genital and oral carcinomas
<b>Adenoviridae</b> (adeno, gland)		Naked	1 molecule, ds DNA	Some cause tumors in animals
<b>Herpesviridae</b> (herpes, creeping)		Enveloped with surface projections	1 molecule, ds DNA	Herpes simplex virus; cytomegalovirus
<b>Poxviridae</b> (pox, pustule)		Enveloped; large brick-shaped	ds DNA, covalently closed ends	Smallpox virus; vaccinia virus
<b>Iridoviridae</b> (irid, rainbow)		Enveloped	1 molecule, ds DNA	No known human pathogens; only animal pathogens

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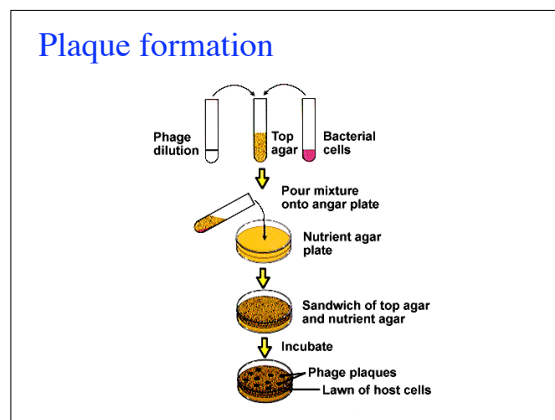
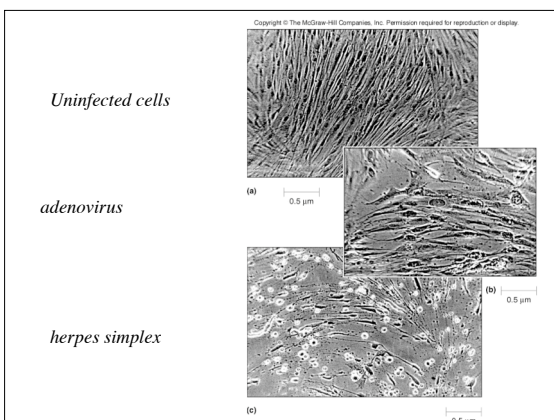
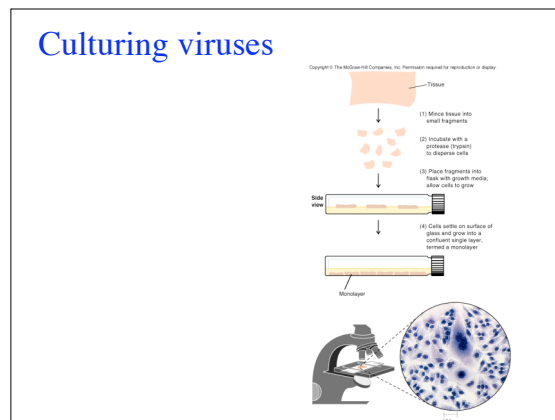
**TABLE 14.3 Classification of Human Picornaviruses**

Family	Genus	Species
<i>Picornaviridae</i>	<i>Enterovirus</i>	Polioviruses 1–3 Coxsackieviruses A1–A24 (no A23), B1–B6 Echoviruses 1–34 (no 10 or 28) Enteroviruses 68–71
	<i>Rhinovirus</i>	Rhinoviruses 1–100
	<i>Hepatovirus</i>	Hepatitis A virus

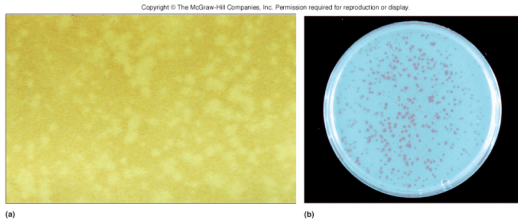
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**TABLE 14.4 Grouping of Human Viruses Based on Route of Transmission**

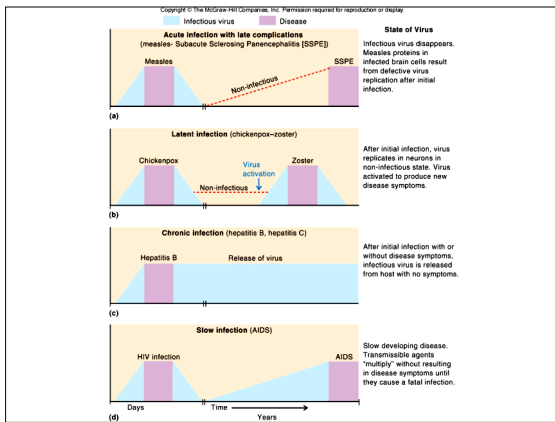
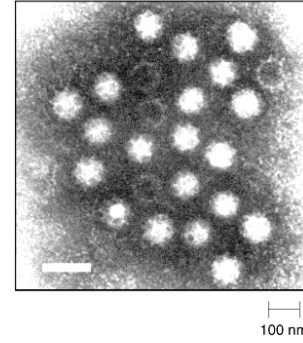
Virus Group	Mechanism of Transmission	Common Viruses Transmitted
Enteric	Fecal-oral route	Enteroviruses (polio, coxsackie B); rotaviruses (diarrhea)
Respiratory	Respiratory or salivary route	Influenza; measles; rhinoviruses (colds)
Zoonoses	Vector (such as arthropods) Animal to human directly	Sandfly fever; dengue Rabies; toxoplasmosis
Sexually transmitted	Sexual contact	Herpes simplex virus-2 (genital herpes); HIV



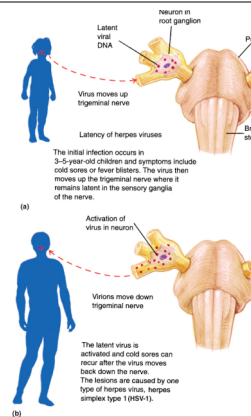
## Plaques (polio an bacteriophage)



## Electron micrograph of *Calicivirus*



## Herpes simplex 1



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**TABLE 14.7 Examples of Latent Infections**

Virus	Primary Disease	Recurrent Disease	Cells Involved in Latent State
Herpes Simplex Virus			
HSV-1	Primary oral herpes	Recurrent herpes simplex	Neurons of sensory ganglia
HSV-2	Genital herpes	Genitalis	Neurons of sensory ganglia
Varicella-zoster virus (herpesvirus family)	Chicken pox	Herpes zoster (shingles)	Satellite cells of sensory ganglia
Cytomegalovirus (CMV, herpesvirus family)	Usually subclinical except in fetus or immunocompromised host	CMV pneumonia, eye infections, mononucleosis-like symptoms	Salivary glands, kidney epithelium, leukocytes
Epstein-Barr virus (herpesvirus family)	Mononucleosis	Burkitt's lymphoma	B cells, which are involved in antibody production

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**TABLE 14.8 Examples of Chronic Infections**

Virus	Site of Infection	Location of Infectious Virions in Carrier State	Disease
Hepatitis B	Liver	Plasma, saliva, genital secretions	Hepatitis, cirrhosis, carcinoma
Hepatitis C	Liver	Plasma, saliva, genital secretions	Hepatitis, cirrhosis, carcinoma
Rubella virus	Many organs	Urine, saliva	Congenital rubella syndrome

**TABLE 14.10 Some Oncogenes Associated with Tumors**

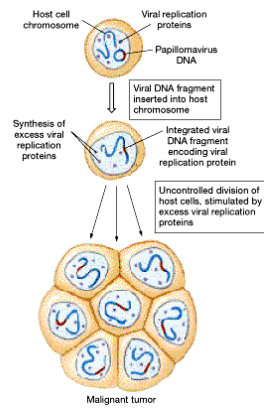
Oncogene	Virus	Function of Oncogene
<i>src</i>	Rous sarcoma	Tyrosine protein kinase*
<i>ffps</i>	Fujinami sarcoma virus (chickens)	Tyrosine protein kinase
<i>H-ras</i>	Mouse sarcoma virus	Mutant guanosine triphosphate-binding protein
<i>raf</i>	Mouse sarcoma virus	Serine protein kinase
<i>jun</i>	Avian sarcoma virus	Mutant sequence-specific gene activator
<i>skv</i>	Sloan-Kettering virus	Mutant sequence-specific DNA-binding protein

Oncogenes identified in different retroviruses. Each of these oncogenes corresponds to a proto-oncogene in the host.  
 \*An enzyme that adds a phosphate molecule to tyrosine in a regulatory protein modifying the activity of the protein.

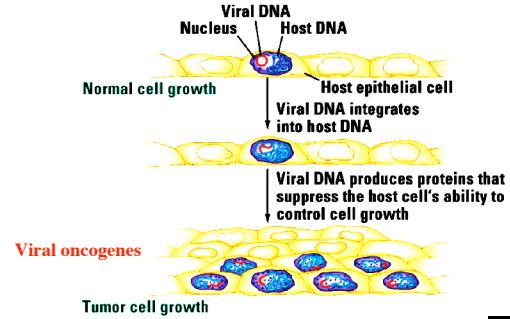
**TABLE 14.11 Viruses Associated with Cancers in Humans**

Virus	Type of Nucleic Acid	Kind of Tumor
Human papillomaviruses (HPV)	DNA	Different kinds of tumors, including squamous cell and genital carcinomas, caused by different HPV types
Hepatitis B virus	DNA	Hepatocellular carcinoma
Epstein-Barr virus	DNA	Burkitt's lymphoma; nasopharyngeal carcinoma; B-cell lymphoma
Hepatitis C virus	DNA	Hepatocellular carcinoma
Human herpes, virus 8	DNA	Kaposi's sarcoma
HTLV-1	RNA (retrovirus)	Adult T-cell leukemia (rare)

## Tumor formation



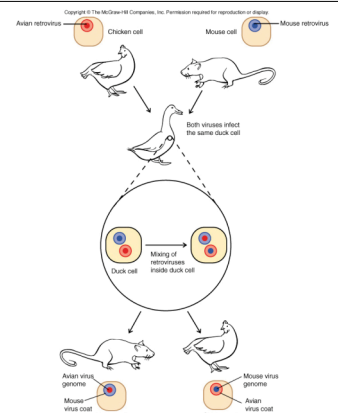
## Virus life cycle



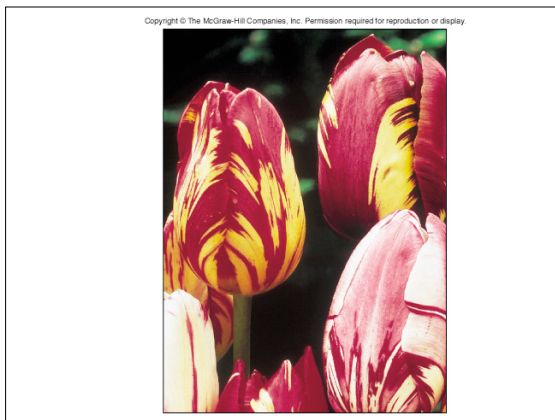
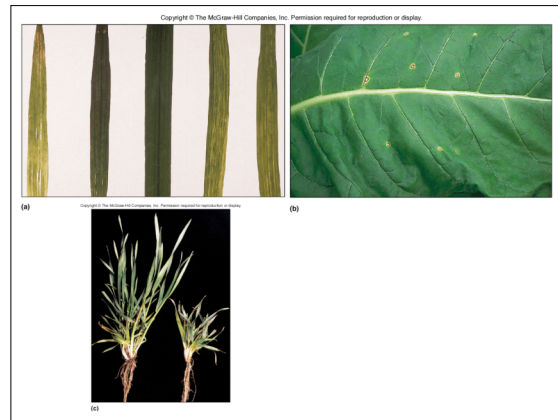
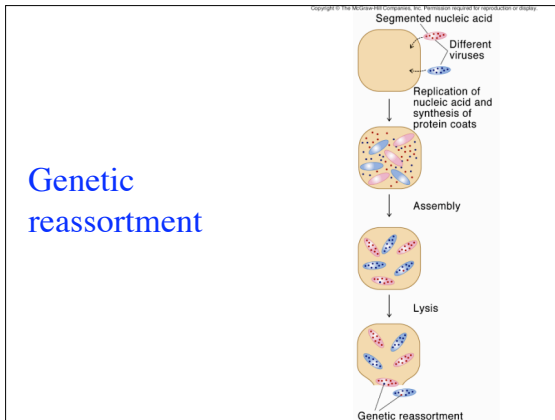
## Kaposi's sarcoma



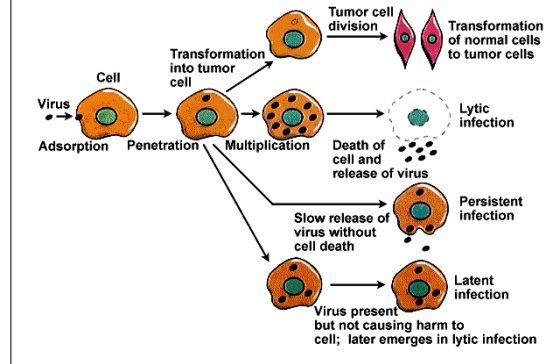
## Phenotype mixing



## Genetic reassortment



## Four effects on host cells



## Viroids and Prions

- Viroids (plants - stunt disease)
  - Low molecular weight circular RNA molecule
  - Exist without capsid or envelope
  - Do not require a helper virus
  - Do not produce proteins
- Prions (Creutzfeldt-Jakob disease CJD, kuru, scrapie, BSE)
  - Resist heating to 90°C
  - Insensitive to radiation treatment
  - Not destroyed by nucleases
  - Are sensitive to protein-denaturing agents