Overview: A Borrowed Life

- Viruses called bacteriophages can infect and set in motion a genetic takeover of bacteria, such as *Escherichia coli*
- Viruses lead "a kind of borrowed life" between life-forms and chemicals
- The origins of molecular biology lie in early studies of viruses that infect bacteria

Concept 19.1: A virus consists of a nucleic acid surrounded by a protein coat

- Viruses were detected indirectly long before they were actually seen

The Discovery of Viruses: *Scientific Inquiry*

- Tobacco mosaic disease stunts growth of tobacco plants and gives their leaves a mosaic coloration
- In the late 1800s, researchers hypothesized that a particle smaller than bacteria caused the disease
- In 1935, Wendell Stanley confirmed this hypothesis by crystallizing the infectious particle, now known as tobacco mosaic virus (TMV)

Structure of Viruses

- Viruses are not cells
- A **virus** is a very small infectious particle consisting of nucleic acid enclosed in a protein coat and, in some cases, a membranous envelope

Viral Genomes

- Viral genomes may consist of either
  - Double- or single-stranded DNA, or
  - Double- or single-stranded RNA
- Depending on its type of nucleic acid, a virus is called a DNA virus or an RNA virus

Capsids and Envelopes

- A **capsid** is the protein shell that encloses the viral genome
- Capsids are built from protein subunits called *capsomeres*
- A capsid can have various structures
- Some viruses have membranous envelopes that help them infect hosts
- These **viral envelopes** surround the capsids of influenza viruses and many other viruses found in animals
- Viral envelopes, which are derived from the host cell's membrane, contain a combination of viral and host cell molecules
- **Bacteriophages**, also called **phages**, are viruses that infect bacteria
- They have the most complex capsids found among viruses
- Phages have an elongated capsid head that encloses their DNA
- A protein tail piece attaches the phage to the host and injects the phage DNA inside

Concept 19.2: Viruses replicate only in host cells

- Viruses are obligate intracellular parasites, which means they can replicate only within a host cell
- Each virus has a **host range**, a limited number of host cells that it can infect

General Features of Viral Replicative Cycles

- Once a viral genome has entered a cell, the cell begins to manufacture viral proteins
- The virus makes use of host enzymes, ribosomes, tRNAs, amino acids, ATP, and

other molecules
- Viral nucleic acid molecules and capsomeres spontaneously self-assemble into new viruses

Replicative Cycles of Phages
- Phages are the best understood of all viruses
- Phages have two reproductive mechanisms: the lytic cycle and the lysogenic cycle

The Lytic Cycle
- The **lytic cycle** is a phage replicative cycle that culminates in the death of the host cell
- The lytic cycle produces new phages and lyses (breaks open) the host's cell wall, releasing the progeny viruses
- A phage that reproduces only by the lytic cycle is called a **virulent phage**
- Bacteria have defenses against phages, including **restriction enzymes** that recognize and cut up certain phage DNA

The Lysogenic Cycle
- The **lysogenic cycle** replicates the phage genome without destroying the host
- The viral DNA molecule is incorporated into the host cell's chromosome
- This integrated viral DNA is known as a **prophage**
- Every time the host divides, it copies the phage DNA and passes the copies to daughter cells
- An environmental signal can trigger the virus genome to exit the bacterial chromosome and switch to the lytic mode
- Phages that use both the lytic and lysogenic cycles are called **temperate phages**

Replicative Cycles of Animal Viruses
- There are two key variables used to classify viruses that infect animals
  - DNA or RNA?
  - Single-stranded or double-stranded?

Viral Envelopes
- Many viruses that infect animals have a membranous envelope
- Viral glycoproteins on the envelope bind to specific receptor molecules on the surface of a host cell
- Some viral envelopes are formed from the host cell's plasma membrane as the viral capsids exit
- Other viral membranes form from the host's nuclear envelope and are then replaced by an envelope made from Golgi apparatus membrane

RNA as Viral Genetic Material
- The broadest variety of RNA genomes is found in viruses that infect animals
- **Retroviruses** use **reverse transcriptase** to copy their RNA genome into DNA
- **HIV (human immunodeficiency virus)** is the retrovirus that causes **AIDS (acquired immunodeficiency syndrome)**
- The viral DNA that is integrated into the host genome is called a **provirus**
- Unlike a prophage, a provirus remains a permanent resident of the host cell
- The host's RNA polymerase transcribes the proviral DNA into RNA molecules
- The RNA molecules function both as mRNA for synthesis of viral proteins and as genomes for new virus particles released from the cell

Evolution of Viruses

- Viruses do not fit our definition of living organisms
- Since viruses can replicate only within cells, they probably evolved as bits of cellular nucleic acid
- Candidates for the source of viral genomes are plasmids, circular DNA in bacteria and yeasts, and transposons, small mobile DNA segments
- Plasmids, transposons, and viruses are all mobile genetic elements
- Mimivirus, a double-stranded DNA virus, the largest virus yet discovered, is the size of a small bacterium
- There is controversy about whether this virus evolved before or after cells

Concept 19.3: Viruses, viroids, and prions are formidable pathogens in animals and plants

- Diseases caused by viral infections affect humans, agricultural crops, and livestock worldwide
- Smaller, less complex entities called viroids and prions also cause disease in plants and animals, respectively

Viral Diseases in Animals

- Viruses may damage or kill cells by causing the release of hydrolytic enzymes from lysosomes
- Some viruses cause infected cells to produce toxins that lead to disease symptoms
- Others have molecular components such as envelope proteins that are toxic
- **Vaccines** are harmless derivatives of pathogenic microbes that stimulate the immune system to mount defenses against the harmful pathogen
- Vaccines can prevent certain viral illnesses
- Viral infections cannot be treated by antibiotics
- Antiviral drugs can help to treat, though not cure, viral infections

Emerging Viruses

- Emerging viruses are those that suddenly become apparent
- Recently, a general outbreak (**epidemic**) of a flu-like illness appeared in Mexico and the United States, caused by an influenza virus named H1N1
- Flu epidemics are caused by new strains of influenza virus to which people have little immunity
- Viral diseases in a small isolated population can emerge and become global
- New viral diseases can emerge when viruses spread from animals to humans
- Viral strains that jump species can exchange genetic information with other viruses to which humans have no immunity
- These strains can cause **pandemics**, global epidemics
- The 2009 flu pandemic was likely passed to humans from pigs; for this reason it was originally called the "swine flu"

Viral Diseases in Plants

- More than 2,000 types of viral diseases of plants are known and cause spots on leaves and fruits, stunted growth, and damaged flowers or roots
- Most plant viruses have an RNA genome
- Plant viruses spread disease in two major modes
  - Horizontal transmission, entering through damaged cell walls
  - Vertical transmission, inheriting the virus from a parent

Viroids and Prions: The Simplest Infectious Agents

- **Viroids** are small circular RNA molecules that infect plants and disrupt their growth
- **Prions** are slow-acting, virtually indestructible infectious proteins that cause brain diseases in mammals
- Prions propagate by converting normal proteins into the prion version
- Scrapie in sheep, mad cow disease, and Creutzfeldt-Jakob disease in humans are all caused by prions