23 VIRUSES

PRESENTATION FORMAT

NOTES

I. Introduction

A. Characteristics

1. Not cellular
2. Cannot carry on metabolic activities independently
3. Contain either DNA or RNA, not both (true cells contain both)
4. Lack ribosomes and enzymes necessary for protein synthesis
5. Reproduce only within cells they infect

B. Classification

1. Because of first two characteristics above, viruses are not classified in any of the five kingdoms
2. No system of classification has been agreed upon
3. Viruses are usually grouped according to size, shape, presence or absence of an outer envelope, and whether they contain DNA or RNA and whether it is single-stranded or double-stranded
4. Sometimes classified according to the diseases they cause or their mode of transmission

II. Structure of a Virus

■ **A VIRUS IS A TINY PARTICLE (VIRION) CONSISTING OF A CORE OF DNA OR RNA SURROUNDED BY A PROTEIN COAT (CAPSID).**

A. Virus — tiny particle consisting of a nucleic acid core surrounded by a protein coat (capsid)

B. Virion — a single, infective virus particle

C. Envelope — membranous layer surrounding some viruses; contains proteins, lipids, carbohydrates, and traces of metals

D. Nucleic acid core is either RNA or DNA *(Fig 23-1)*

■ **VIRUSES ARE MUCH SMALLER THAN BACTERIA.**

E. Smallpox virus can be seen with the light microscope; all others require the electron microscope

F. Viral shape

1. Determined by the organization of protein subunits (capsomeres) that make up the capsid

■ **VIRUSES ARE HELICAL, POLYHEDRAL, OR A COMBINATION OF BOTH SHAPES.**

2. Either helical, polyhedral, or a combination *(Fig 23-2)*
   a. Helical viruses appear as long rods or threads
   b. Polyhedral viruses appear somewhat spherical in shape

III. Bacteriophages

■ **BACTERIOPHAGES ARE VIRUSES THAT INFECT BACTERIA.**

A. Definition: complex viruses that infect bacteria *(Fig 23-2d)*

B. Also called phages
C. Structure
   1. Most common — long nucleic acid molecule coiled within a polyhedral head
   2. Most utilize DNA as their genetic material *(Fig 23-3)*
   3. A tail attaches to the head of most phages; fibers extending from the tail may be used to affix the phage to a bacterium
D. There are many varieties, each usually specific for one species or strain of bacterium
E. Easily cultured (See *Focus on Culturing viruses*)

■ **SOME PHAGES ARE VIRULENT (LYTIC).**

F. Virulent (lytic) bacteriophages cause lytic infections; after the viruses multiply they lyse and destroy the host cell

■ **SOME PHAGES ARE TEMPERATE (LYSOGENIC).**

G. Temperate (lysogenic) viruses may or may not destroy their host cells; some integrate their nucleic acid into the host's DNA and multiply whenever the host does

IV. Viral Replication in Lytic Infections *(Fig 23-4)*

■ **VIRAL INFECTION INCLUDES ATTACHMENT TO THE HOST CELL, PENETRATION, REPLICATION, ASSEMBLY, AND RELEASE.**

A. Attachment — phage attaches to receptor sites on bacterial cell wall
B. Penetration — nucleic acid is injected through cell membrane into cytoplasm of host cell; capsid remains outside cell
C. Replication — virus takes over host's metabolic machinery and replicates its own macromolecules; viral genes contain all information necessary to produce new viruses
D. Assembly — viral components are assembled into new viruses

■ **IN A LYTIC INFECTION THE VIRUS PRODUCES A LYSOZYME, WHICH CAUSES THE HOST CELL TO LYSE, RELEASING THE NEW VIRUSES.**

E. Release — lysozyme produced by viruses degrades host cell wall, causing release of about 100 phages *(Fig 23-5)*

V. DNA Integration in Lysogenic Infections

■ **IN LYSOGENIC INFECTIONS, TEMPERATE VIRUSES INTEGRATE THEIR DNA INTO THE HOST DNA.**

A. Some temperate viruses integrate their DNA into the DNA of their bacterial host
B. When bacterial DNA replicates, the viral DNA (prophage) also replicates *(Fig 23-6)*
C. Viral genes for structural proteins may be repressed indefinitely
D. Lysogenic host cells — those carrying prophages

■ **NUCLEIC ACID INTEGRATION MAY CONFER NEW PROPERTIES ON THE HOST CELL.**

E. Lysogenic conversion — the display of new properties by bacterial cells containing temperate viruses; toxins are only produced by many disease-causing bacteria when infected with phage

F. Under certain conditions, the phage nucleic acid enters a lytic phase, releasing new phages

■ **PHAGES RELEASED FROM LYSOGENIC CELLS MAY CONTAIN A PORTION OF BACTERIAL DNA, WHICH CAN LEAD TO TRANSDUCTION IN A NEW HOST CELL.**

G. Transduction

1. When a lysogenic bacterium lyses, the released phages may contain some host DNA in place of their own genetic material
2. When the released phage infects a new bacterium, this DNA is introduced into the genome of the host
3. Permits genetic recombination in the new host cell *(Fig 23-7)*
4. An important phenomenon for recombinant DNA studies

VI. Another Form of Coexistence

■ **IN SOME VIRAL INFECTIONS, THE HOST CELL CONTINUES ITS METABOLIC ACTIVITIES, AND VIRUSES ARE SLOWLY ASSEMBLED AND RELEASED WITH MINIMAL DAMAGE TO THE HOST CELL.**

A. A few bacterial and animal viruses release new viruses slowly without destroying the host cell *(Fig 23-8)*
B. The host cell carries on its own metabolic activities, using some energy to produce new viruses
C. Viruses appear to exit from the cell in a process that may be the reverse of penetration

VII. Plant Viruses and Viroids

A. Tobacco mosaic virus *(Fig 23-9)*

1. Consists only of an RNA core surrounded by a protein capsid
2. Is elongate and lacks an outer envelope
3. Attaches to host's ribosomes and is translated like mRNA
4. Many other plant viruses belong to this group

■ **PLANT VIRUSES CAUSE SERIOUS AGRICULTURAL LOSSES.**

B. Plant viruses cause serious agricultural losses

1. Cures are not known; infected plants are commonly burned
2. Virus-resistant strains of crop plants are being developed

C. Modes of transmission

1. Insects
2. Inherited by way of infected seeds or by asexual propagation
3. Spreads through a plant by passing through plasmodesmata

■ **PLANTS MAY BE INFECTED BY VIROIDS, WHICH ARE SMALLER AND SIMPLER THAN VIRUSES.**

D. Viroids — infective agents that are smaller and simpler than viruses

1. Consists of a short strand of RNA that may be sufficient to code for a single medium-sized protein
2. Have no associated proteins and no protective coat *(Fig 23-10)*
3. Host enzymes used to replicate viroid's RNA
4. Generally found within the nucleus
5. Cause disease either by interfering with intron splicing or by interfering with the regulation of the host's genes

6. Only known to infect plants, although suspected of causing certain animal diseases

VIII. Viruses That Infect Animals

A. General

1. Hundreds of different viruses attack humans and other animals
2. Virtually every type of cell is susceptible to viral infection
3. Most viruses cannot survive long outside a living cell

B. Infection by animal viruses

1. Receptor sites
   a. Receptor molecules on the surface of a virus aid in chemical attachment to a host cell and determine what type of cell the virus can infect
   b. Some viruses have specialized structures for attachment to host cells
      (1) Some have fibers projecting from the capsid
      (2) Others are surrounded by a lipoprotein envelope with projecting glycoprotein spikes that serve as receptors
   c. Receptor sites vary with each species and sometimes with each type of tissue
      (1) Some viruses can infect only humans
      (2) Some infect many types of tissues
      (3) Some infect only certain tissue cells
2. Cell entry

■ **UNENVELOPED ANIMAL VIRUSES ENTER THE HOST CELL BY A PROCESS SIMILAR TO PHAGOCYTOSIS.**

   a. Unenveloped virus — engulfed by cell and transported into cytoplasm in a process resembling phagocytosis

■ **ENVELOPED VIRUSES FUSE TO THE HOST CELL MEMBRANE AND THEN PASS INTO THE CELL.**

   b. Enveloped virus — fuses with host cell membrane and passes into cytoplasm

■ **CAPSIDS ARE REMOVED WITHIN THE HOST CELL, AND THE VIRIONS REPLICATE AND PRODUCE NEW VIRIONS.**

3. Replication
   a. Viral nucleic acid is replicated and viral proteins are synthesized that inhibit host DNA, RNA, and protein synthesis
   b. Process by which a virus's DNA and proteins are synthesized is similar to that of the host
   c. Most RNA viruses — transcription takes place with the help of an RNA polymerase
   d. Some RNA viruses (e.g., the AIDS virus and some tumor-causing viruses) — transcription takes place with the help of a DNA polymerase (reverse transcriptase)
      (1) This enzyme catalyzes the synthesis of a complementary DNA strand, using the viral RNA as a template

(2) This DNA acts as a template for production of its complement, producing a double-stranded DNA molecule
(3) This double-stranded DNA is then used to synthesize copies of the viral RNA

e. Structural proteins are synthesized and the capsid is produced

4. Exiting the cell

a. Unenveloped viruses exit by cell lysis
b. Enveloped viruses

(1) Receive lipoprotein envelopes as they pass through the plasma (or nuclear) membrane
(2) Are released slowly by a process called budding
(3) Host cell is not destroyed

5. Causes of damage to host cells

a. Viral proteins may alter permeability of the cell membrane
b. Viral proteins may inhibit synthesis of host nucleic acids or proteins
c. Sheer number of virus particles may damage or kill host cells

■ **ANIMAL CELLS PRODUCE INTERFERONS IN RESPONSE TO VIRAL INFECTION.**

6. Host cell defense — viral infected cells may produce interferons, proteins that interfere with viral replication

C. Viral diseases in animals *(Fig 23-11, Table 23-1)*

■ **HUMAN VIRAL INFECTIONS MAY BE ACUTE, CHRONIC, LATENT, OR SLOW.**

1. Acute infections — disease is short-lived
2. Latent infections — viruses remain quietly in the body for years before becoming active
3. Chronic infections — virus is present even though the carrier may be symptomless; virus can be transmitted
4. Slow infections — cause slow, progressive degeneration of the tissues involved; often lead to death

D. Viruses and cancer

■ **VIRUSES CAUSE CANCERS IN MANY TYPES OF ANIMALS, AND THEY MAY CAUSE CERTAIN HUMAN CANCERS.**

1. Both RNA and DNA viruses cause cancer
2. Viral nucleic acid becomes integrated into the DNA of host cells, transforming them into cancer cells
3. Viral nucleic acid probably codes for enzymes that change important proteins in the host cell
4. Oncogenes

a. Viral oncogenes — genes in some cancer viruses that are responsible for transforming infected cells into cancer cells
b. Cellular oncogenes — genes in cells that code for many different kinds of proteins (e.g., growth factors), membrane receptors, and protein kinases; when maintained in an active state of transcription, these genes appear to promote cancer

(1) Such an active state of transcription can apparently result from infection by a retrovirus, mutation, and other unknown factors
(2) Viruses lacking oncogenes may activate cellular oncogenes

5. Retroviruses
   a. Cancer-causing RNA viruses are retroviruses containing reverse transcriptase
   b. Human retroviruses
      (1) HTLV — linked to certain leukemias
      (2) HIV — the virus that causes AIDS
6. DNA viruses have not been isolated from human tumors, but several are linked with human cancers
   a. Epstein-Barr virus — a type of herpesvirus thought to cause Burkitt's lymphoma (a lymphatic cancer), infectious mononucleosis, and nasopharyngeal carcinoma among persons of Chinese ancestry
   b. Herpes simplex virus type 2 — linked with cervical cancer
   c. Hepatitis B virus — associated with liver cancer
   d. DNA viruses may play a role in other cancers as well

E. Prions
1. Definition: infectious particles, smaller than viroids, appearing to consist only of a glycoprotein
2. Polymerize in infected tissue, forming rods
3. Thought to be associated with two rare CNS diseases in humans

F. Treating viral infections
1. Vaccines help prevent viral infection
2. Antibiotics kill bacteria, but not viruses
3. Effective antiviral drugs to treat infections have yet to be developed
4. Acyclovir, used in the treatment of genital herpes, is the most effective antiviral drug to date; it doesn't cure, but speeds healing

IX. The Origin of Viruses

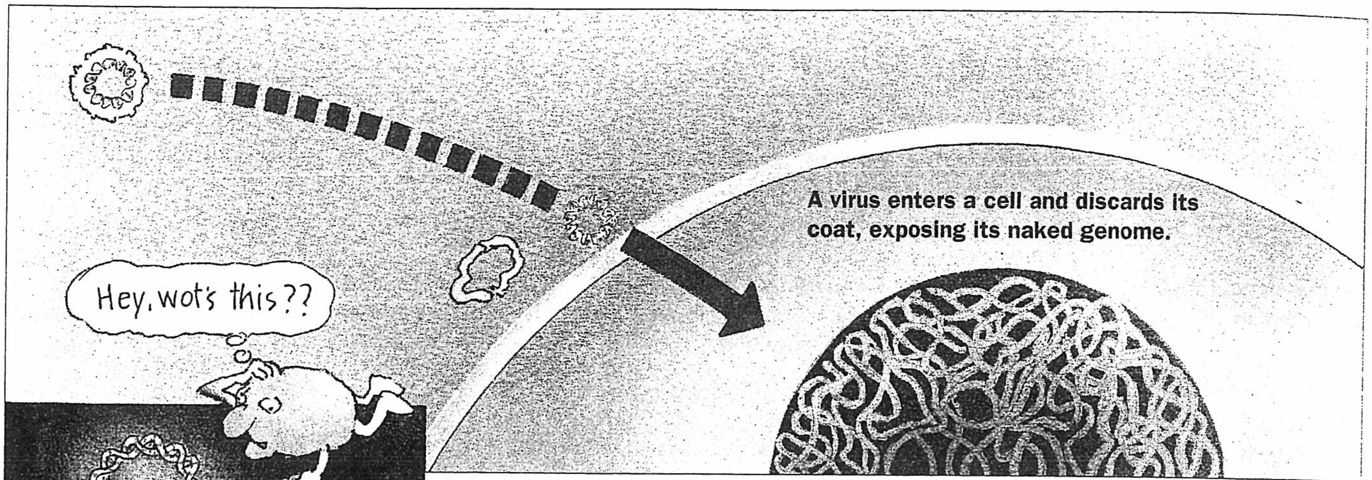
A. Hypothesis 1
1. Ancestors were primitive, free-living heterotrophs that evolved in the primordial sea, feeding upon organic nutrients
2. Some became autotrophs, others adapted the parasitic lifestyle of the viruses

B. Hypothesis 2 — ancestors were cellular organisms that lost all cellular components but the nucleus, becoming highly specialized as parasites

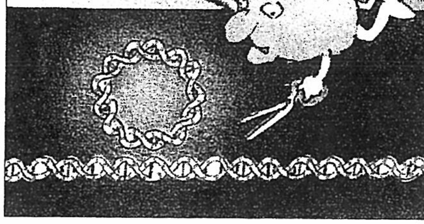
■ **VIRUSES ARE THOUGHT TO HAVE HAD A MULTIPLE EVOLUTIONARY ORIGIN.**

C. Hypothesis 3 (most likely)
1. Viruses are bits of nucleic acid that "escaped" from cellular organisms
2. The origin of some modern viruses can be traced to animal cells, others to plant cells, and still others to bacterial cells

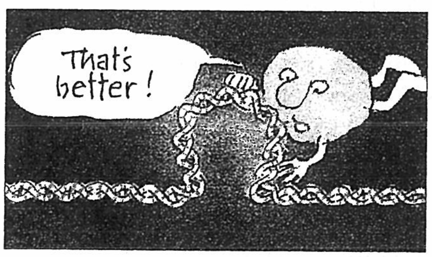
Viruses



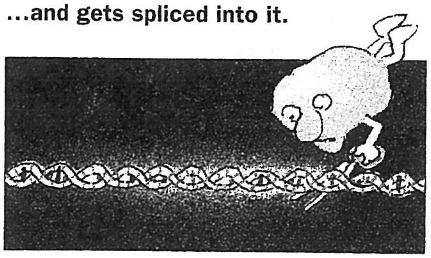
A virus enters a cell and discards its coat, exposing its naked genome.



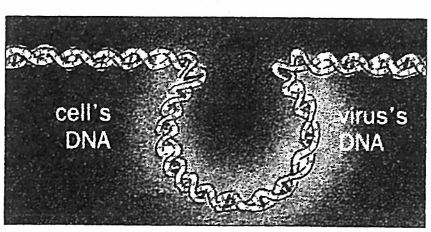
It approaches a location on the unsuspecting host's genome...



...and gets spliced into it.



When it departs many cell generations later...



...it may take some of the host's genes along with it.

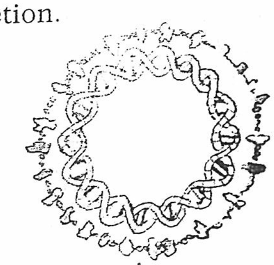
The Uninvited Guest

Certain independently reproducing pieces of genetic information have become obstreperous over the course of evolutionary history. These plasmids have evolved the ability to use the host cell's ATP and ribosome machinery to make protein coats for themselves — to become viruses. Shielded by their protective coats and making use of certain enzymes they produce, viruses make their escape from the host cell. From there, they invade *other* cells, take over their machinery, and make many more copies of themselves. Viruses can make cells sick (as with the common cold) or destroy their function (as with AIDS, which is caused by HIV, the human immunodeficiency virus). Alternatively, viruses may unobtrusively splice their genes into their victims' DNA, thereby subtly changing the infected cells' genetic character. And when they subsequently cut themselves out of the host's DNA, they may "kidnap" some of the host's genes. Then, as these viruses hop from one infected cell to another, they can transfer normal cell genes along with their own genetic material.

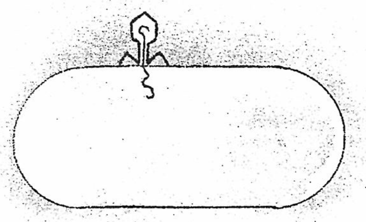
It appears, then, that viruses originally arose from cells and have interacted with cells throughout evolution — sometimes to the cells' detriment when they cause disease, although sometimes in ways that produce evolutionary advantages. Viruses are thus a genetic shuttle between all forms of life.

All this shuffling of genes inside cells and among cells means that life's information is constantly being reorganized. Simple mutations, gene transpositions, sexual recombination, and the existence of plasmids and viruses all contribute to enriching the ocean of variation fished by natural selection.

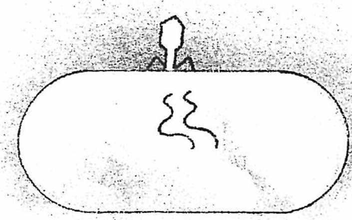
In this way, viruses carry new information from cell to cell.



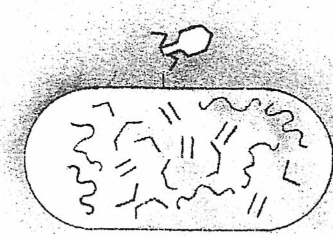
The Bacterium's Nemesis



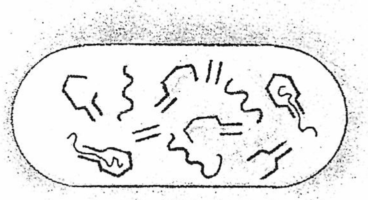
A virus injects its DNA into a bacterium.



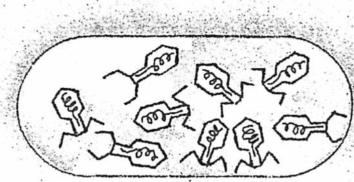
The invading viral DNA orders the cell's machinery to make multiple copies of it...



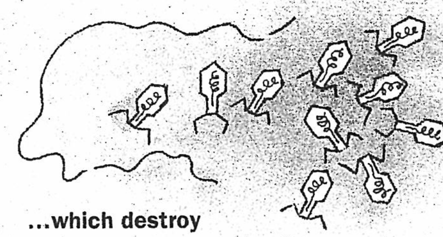
...which, in turn, are used to make multiple copies of the virus's proteins...



...which spontaneously assemble...



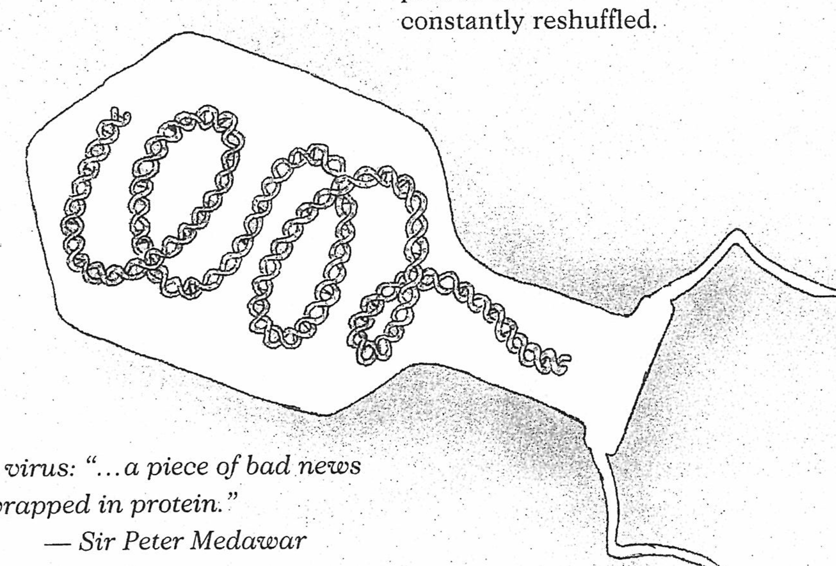
...into new viruses...



...which destroy the bacterium and escape.

Scientists have learned a lot about the relationship between viruses and their hosts by studying the behavior of a peculiar sort of virus called a bacteriophage (literally, "bacterium eater"). Phages (for short) are tiny DNA-filled syringes with protein coats. These marauders go on a take-over mission, attaching themselves to bacterial cells with spider-like "feet" and then injecting their DNA. Information in the phage's DNA prevents the bacterium from using its own protein-making machinery and diverts it to the construction of proteins for the phage. After about 20 minutes, the bacterium is chock full of 100 or so brand-new DNA-filled phages. In the ultimate insult, the phages instruct the bacterium to make an enzyme that breaks open the bacterium's wall. This kills the bacterium and releases the phages to go on to infect other cells!

Occasionally, after a phage has injected its DNA into a bacterium, nothing appears to happen; the bacterium goes right on growing. The phage's DNA, in this case, has spliced itself directly into the bacterium's DNA, where it lies dormant. Many bacterial generations later, the phage's DNA may emerge, subvert the bacterium's protein-making machinery to make new viruses, and then burst out of the bacterium to hunt for the next victim. Sometimes, when this happens, the phage carries along with it some of the bacterium's genes, transferring them to the next bacterium it attacks. Thus, all bacteria seem to be connected by viruses in an immense gene pool in which information is constantly reshuffled.



A virus: "...a piece of bad news wrapped in protein."
— Sir Peter Medawar