SACRAMENTO STATE
Leadership begins here.

Chapter 10: Viruses

Lecture Exam #3 Wednesday, November 22nd
(This lecture WILL be on Exam #3)

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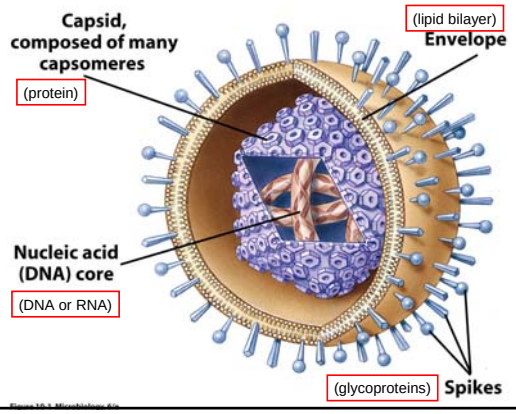
Office Hours: MW 9-10 AM

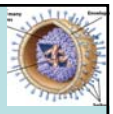
Viruses

- Too small to see with a light microscope
  - Visible with electron microscopy
- Not cells: no nucleus, organelles, or cytoplasm
- Obligate intracellular parasites
  - Can only reproduce inside a living cell
- Viruses are on the border between living & nonliving things
- Have *either* DNA *or* RNA, never both
- Often cause death of the host cell
- Genus/species names *not* used in viral classification

Compenents of a virus

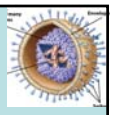


Viral components: **Nucleic Acid**



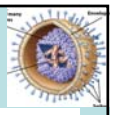
- Viral genomes can be **either DNA or RNA**
- This genome, once inside a host cell, directs synthesis of new viral proteins, and also replication of new viral genomes
- ★Viral genomes come in **all kinds**:
  - Single- or double-stranded, RNA or DNA
  - Linear or circular
  - One piece or segmented (in several fragments)

★ Viral components: **Capsid**



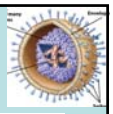
- A protein shell that surrounds & protects the nucleic acid
- Determines the shape of the virus
- Made up of many subunits called **capsomeres**
  - Capsomeres may be all the same, or virus may have several different proteins in its capsid
  - Composition & arrangement of capsomeres is characteristic of each virus (use for identification)

Viral components: **Envelope**



- Not all viruses have an envelope
  - **Enveloped virus**: has one
  - **Naked virus**: does NOT have an envelope
- ★Envelope is a **Lipid bilayer membrane**
  - acquired from a host cell membrane when virus "buds" (plasma membrane) or passes through a membrane-bound organelle (such as the nucleus)
  - Composition of envelope resembles that of the cell membrane from which it came
- Some envelopes have **spikes**
  - **Glycoproteins** (proteins bound to carbohydrates) that stick out from the envelope
  - Spikes often are important for **attachment** to host cells

Viral components: **Envelope**



Enveloped viruses: Advantages

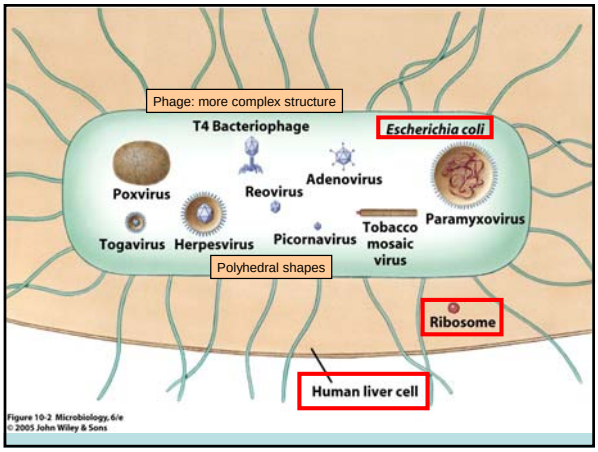
- Membrane "looks" like cell, **hides virus** from the immune system
- ★ Helps virus **infect** new cells by **membrane fusion** with a new host cell

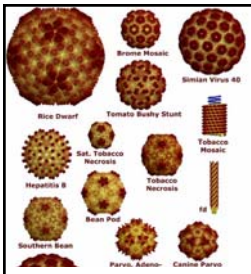
Enveloped viruses: Disadvantage

- Enveloped viruses are **fragile**
  - Conditions that damage membranes, will damage the envelope (heat, freezing, pH change, lipid solvents, chemical disinfectants like chlorine & hydrogen peroxide)
- Naked viruses are generally tougher

Viruses: Size & Shape

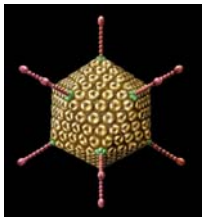
- Like bacteria, viruses come in a range of sizes & shapes
  - though they are *all* very small, average about 100 nm
- Shape is determined by the capsid or envelope, often beautifully symmetric
  - Enveloped viruses tend to be roughly spherical

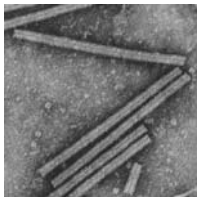




Right: coronavirus

Below: T4 phage; Marburg virus; tobacco mosaic virus





Virus host range & specificity

By now you are getting the idea that at the very small level of life, molecular interactions tend to be highly specific. This is especially true for viruses.

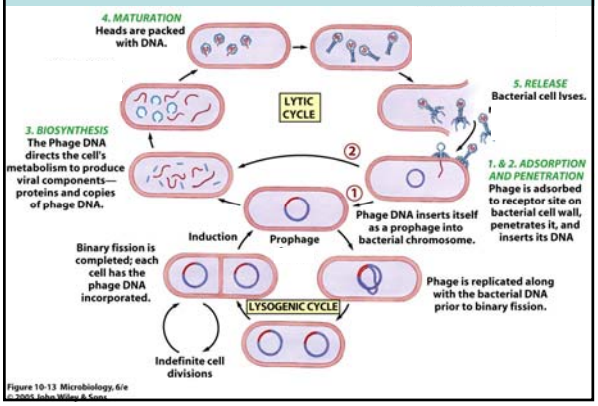
★ **Host range**: *all* life gets infected by some kind of virus, but each virus type can only infect a specific range of **host organisms**.

- Some viruses infect only one host; others have a broader range

Viral specificity: molecules on the surface of a virus determine whether it can attach to a **particular cell type**; cell must have correct surface receptors, plus other internal factors, for virus to infect it.

- Some viruses infect only one cell type in a single host species; others can infect many cell types

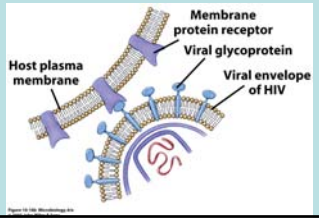
Replication of bacteriophages (virulent & temperate/lysogenic)



Animal viruses work somewhat differently

1. Attachment (adsorption) of virus to target cell

★
- Bacteriophage: "tail" clings to bacterial cell wall
- Animal virus: spikes, capsid, or envelope bind to proteins in the plasma membrane of target cell

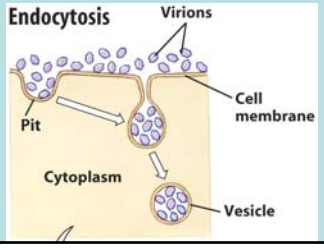


Animal viruses work somewhat differently

2. Penetration

★
- Bacteriophage: DNA gets injected into the cell
- Animal virus: **virus genome + capsid enters the cell by endocytosis** (naked virus) or **fusion** (enveloped virus)

Naked viruses: **Endocytosis**



Penetration by enveloped viruses:

★Envelope **membrane fuses** with a membrane of the cell
- either Plasma membrane, or
- Vesicle membrane after endocytosis

Animal viruses work somewhat differently

3. Uncoating

★
- Bacteriophage: DNA is already exposed
- Animal virus: **genome must be released from the capsid** (protein coat)

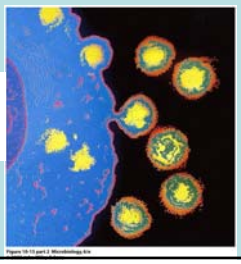
4. *Both* bacterial & animal virus genomes then hijack the cell to manufacture & assemble new virus particles (proteins & genomes)

Animal viruses work somewhat differently

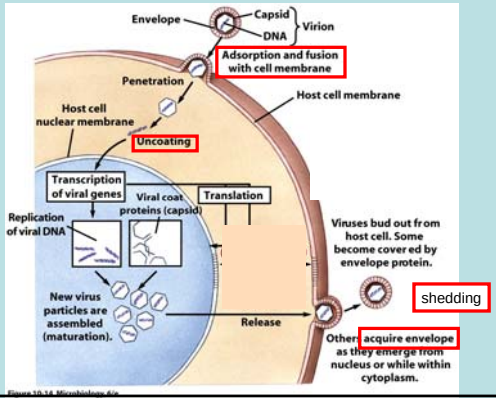
5. Release of new virus
- Bacteriophage: cell lysis

★ Animal virus: **lysis *or* shedding (budding)**

Enveloped viruses budding / being shed from a cell



Replication of an enveloped animal virus (dsDNA)



Viral genomes can be made of…

1. + sense ssRNA
2. - sense ssRNA (antisense)
3. dsRNA
4. dsDNA
5. ssDNA

ss = single stranded
ds = double stranded

The cells viruses infect use DNA to make DNA (replication) & ssRNA (transcription).

★ •Any other reactions must be catalyzed by **enzymes provided by the infecting virus itself!**

★ + and – sense RNA genomes

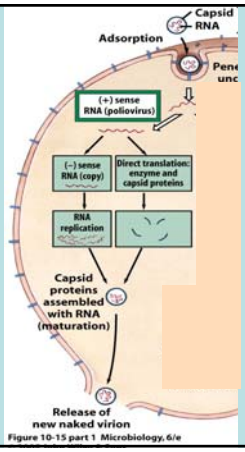
+ sense RNA: acts like mRNA; can be directly translated by ribosomes

-- (negative) sense RNA: the *complementary* sequence; acts as a template for synthesis of + sense RNA

- Cells do NOT make RNA from RNA templates
- Cells do NOT have RNA-dependent RNA polymerases
- Virus must bring a **pre-made RNA polymerase molecule** with it when it infects

★ Replication of a + sense RNA virus

1. + sense RNA acts like mRNA, gets directly translated into viral proteins
2. To make new copies of the virus genome, a complementary RNA is made (-- sense) from + RNA
   - requires a viral enzyme
3. -- sense RNA is template for synthesis of many copies of the + sense RNA genome that goes into the new viruses

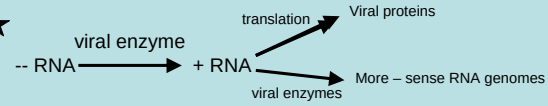


Replication of -- sense RNA viruses:

Inside the infecting virus capsid is the **RNA genome AND a transcriptase** that makes + sense RNA from the – sense genome.

The + sense RNA then:
- •acts like mRNA to direct protein synthesis
- •serves as a template for synthesis of many new copies of the original – sense RNA genome

★



Retroviruses: Human Immunodeficiency Virus (**HIV**)

HIV is a ***retrovirus*** that cause **AIDS** (acquired immunodeficiency syndrome)

Retroviruses:

★ + sense RNA genome

does NOT act like mRNA!!

Retroviruses: HIV

HIV +sense RNA genome is ***reverse transcribed*** into DNA

★ **Reverse transcriptase**
(enzyme is brought with the virus)

RNA ⟶ DNA

Reverse transcriptase is a very **inaccurate** DNA polymerase; it makes lots of mistakes.

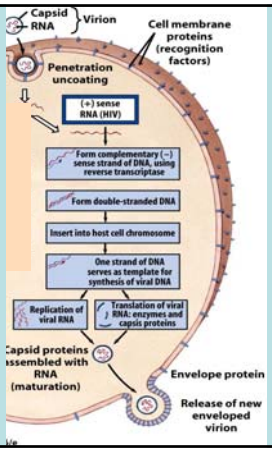
High mutation rate causes HIV to constantly change, a serious problem for making a vaccine.

Retroviruses: HIV

Reverse transcribed viral DNA
moves to the host cell nucleus &
gets incorporated into a host chromosome.

Integrated viral genome is called a
provirus

Replication of a retrovirus (HIV)



Growing viruses

- Obligate intracellular parasites: can't just grow on nutrient-rich agar like bacteria
- Must provide cells for them to infect
- Some viruses can be grown in cell culture
  - e.g., cancer cells growing on the bottom of a dish
    - Malignant cells are "immortal"
- Some viruses must be grown in animals, or **embryonated chicken eggs**
  - **Influenza virus vaccines** are made in chicken egg embryos

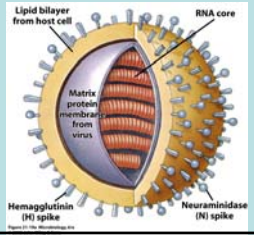
Influenza A viruses

- Influenza is a *respiratory* infection
  - spread by inhalation of virus-containing droplets, or indirect contact with infectious secretions
  - appears seasonally in the winter
- Influenza A:
  - Enveloped RNA virus
  - **Can infect MANY species**; many reservoirs of infection
    - Humans, birds, pigs

Influenza A viruses

Two important surface antigens (markers) on the envelope:

★ **Hemagglutinin** (H)
Neuraminidase (N)



Influenza A

- Virus frequently changes
  - Immune system recognizes one version, fails to provide protection against a new version

2 kinds of change

★ **Antigenic drift**:
mutations in the H & N genes

- Accounts for typical annual variation
- Each year's "flu shot" contains the H & N antigens expected to circulate that season

Influenza A

★ **Antigenic Shift**

- Major, sudden change in genetic makeup of the virus
- Usually causes a pandemic
- Gene reassortment between two different viruses which infected the same cell

The concern with avian influenza H5N1 is that it will infect a bird or human simultaneously infected with a flu that can spread person-to-person, and acquire the genes to do so itself.

- Ch. 10 p. 264-268; p. 271 (+/- sense RNA); 276-278 (emerging viruses); 281-282 (plaque assay from lab); 283-287 (replication of animal viruses); 288 cell culture; p. 273 retroviruses
- Ch. 21 p. 628-634 (influenza; also SARS, hantavirus in next lecture)