Viral classification, structures and replication

Tutor

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Viral Classification

- 1. Nucleic Acid
- 2. Morphology
- 3. Strategy for replication
The Baltimore classification system

Based on genetic contents and replication strategies of viruses. According to the Baltimore classification, viruses are divided into the following seven classes:

1. dsDNA viruses
2. ssDNA viruses
3. dsRNA viruses
4. (+) sense ssRNA viruses (codes directly for protein)
5. (-) sense ssRNA viruses
6. RNA reverse transcribing viruses
7. DNA reverse transcribing viruses

where "ds" represents "double strand" and "ss" denotes "single strand".
Virus Classification I
- the Baltimore classification

- All viruses must produce mRNA, or (+) sense RNA
- A complementary strand of nucleic acid is (−) sense

- The Baltimore classification has + RNA as its central point

- Its principles are fundamental to an understanding of virus classification and genome replication, but it is rarely used as a classification system in its own right
Virus classification II - the Classical system

- This is based on three principles -
  
  - 1) that we are classifying the virus itself, not the host
  - 2) the nucleic acid genome
  - 3) the shared physical properties of the infectious agent (e.g. capsid symmetry, dimensions, lipid envelope)
Virus classification III - the genomic system

• More recently a precise ordering of viruses within and between families is possible based on DNA/RNA sequence

• By the year 2000 there were over 4000 viruses of plants, animals and bacteria - in 71 families, 9 subfamilies and 164 genera
CLASSIFICATION
NUCLEIC ACID

• RNA or DNA
• segmented or non-segmented
• linear or circular
• single-stranded or double-stranded
• if single-stranded RNA
  – is genome mRNA (+) sense or complementary to mRNA (-) sense
Genome

• The genome of a virus can be either DNA or RNA

• DNA-double stranded (ds): linear or circular
  Single stranded (ss) : linear or circular

• RNA- ss:segmented or non-segmented
  ss:polarity+(sense) or polarity –(non-sense)

  ds: linear (only reovirus family)
Viral genome strategies

• dsDNA (herpes, papova, adeno, pox)
• ssDNA (parvo)
• dsRNA (reo, rota)
• ssRNA (+) (picorna, toga, flavi, corona)
• ssRNA (-) (rhabdo, paramyxo, orthomyxo, bunya, filo)
• ssRNA (+/-) (arena, bunya)
• ssRNA (+RTase) (retro, lenti)
All families shown are icosahedral except for poxviruses.
DNA viruses

DNA

Icosahedral

Naked

ss linear (+) or (−)

ds circular

ds linear

Enveloped

ds circle gapped

ds linear

Naked/Env. (cytoplasmic)

Enveloped (cytoplasmic)

Helical

Complex

ds linear (x linked)

Parvo

Papova

Adeno

Hepadna

Herpes

Irido

Baculo

Pox

(−)

(−)

(−)

(+)

(−)

(−)

(−)

(+)

18–26

45–55

70–90

42

150–200

125–300

60 × 300

170–200 × 300–450

5

5–8

36–38

3.2

120–200

150–350

100

130–280
RNA viruses

### Classification criteria

- **Symmetry of capsid**
  - Icosahedral
  - Helical

- **Naked or enveloped**
  - Naked
  - Enveloped

- **Genome architecture**
  - ds 10–18 seg.
  - ds 2 seg.
  - (+) ss cont.
  - (−) ss cont.
  - (+) ss cont. 2 copies

- **Baltimore class**
  - III
  - III
  - IV
  - IV
  - IV
  - IV
  - VI
  - V
  - V
  - V
  - V

### Properties

- **Family name**
  - Reo
  - Birna
  - Calici
  - Picorna
  - Flavi
  - Toga
  - Retro
  - Corona
  - Filo
  - Rhabdo
  - Bunya
  - Orthomyxo
  - Paramyx
  - Arena

- **Virion polymerase**
  - (+)
  - (+)
  - (−)
  - (−)
  - (−)
  - (+)
  - (−)
  - (+)
  - (+)
  - (−)
  - (+)
  - (+)
  - (+)

- **Virion diameter (nm)**
  - 60–80
  - 60
  - 35–40
  - 28–30
  - 40–50
  - 60–70
  - 80–130
  - 80 x 790–14,000
  - 70–85 x 130–380
  - 90–120
  - 90–120
  - 150–300
  - 50–300

- **Genome size (total in kb)**
  - 22–27
  - 7
  - 8
  - 7.2–8.4
  - 10
  - 12
  - 3.5–9
  - 16–21
  - 12.7
  - 13–16
  - 13.5–21
  - 13.6
  - 16–20
  - 10–14
Viral Structure - Overview

Fig 1. Schematic overview of the structure of animal viruses

** does not exist in all viruses
5 BASIC TYPES OF VIRAL STRUCTURE

ICOSAHEDRAL

ENVELOPED ICOSAHEDRAL

HELICAL

ENVELOPED HELICAL

ICOSAHEDRAL NUCLEOCAPSID

HELICAL NUCLEOCAPSID

COMPLEX

NUCLEOCAPSID

NUCLEIC ACID

CAPSID

CAPSOMERES (PROTEIN)

NUCLEIC ACID

PROTEIN (MONOMERIC UNITS)

NUCLEOCAPSID

LIPID BILAYER

GLYCOPROTEIN SPIKES = PEPLOMERS
**RNA Viruses**

- **Picornavirus**
  - Genomes: $C = 32$
  - Sizes: 22-30 nm

- **Astrovirus**
  - Genomes: $C = 32^?$
  - Sizes: 30-35 nm

- **Calicivirus**
  - Genomes: $C = 32$ (holes)
  - Sizes: 35-39 nm

- **Flavivirus**
  - Genomes: Icosahedral
  - Sizes: 45-50 nm

- **Togavirus**
  - Genomes: Icosahedral
  - Sizes: 70 nm

- **Coronavirus**
  - Genomes: Pleomorphic
  - Sizes: 120-160 nm

- **Retrovirus**
  - Genomes: Icosahedral
  - Sizes: 90-120 nm

- **Reovirus**
  - Genomes: 10-12 segments
  - Sizes: 60-80 nm

- **Bunyavirus**
  - Genomes: Helical
  - Sizes: 90-120 nm

- **Orthomyxovirus**
  - Genomes: Helical, Pleomorphic
  - Sizes: 80-120 nm

- ** Arenavirus**
  - Genomes: Pleomorphic
  - Sizes: 110-130 nm

- **Filovirus**
  - Genomes: Helical
  - Sizes: 80x800-2500 nm

- **Rhabdovirus**
  - Genomes: Helical
  - Sizes: 60x180 nm

- **Paramyxovirus**
  - Genomes: Helical, Pleomorphic
  - Sizes: 150-300 nm

**DNA Viruses**

- ** Circovirus**
  - Genomes: Icosahedral
  - Sizes: 17-22 nm

- ** Parovirus**
  - Genomes: $C = 12$
  - Sizes: 18-26 nm

- **Hepadnavirus**
  - Genomes: $C = 180$, Icosahedral
  - Sizes: 40-48 nm

- **Papovavirus**
  - Genomes: $C = 72$
  - Sizes: 45/55 nm

- **Adenovirus**
  - Genomes: Icosahedron
  - Sizes: 252
  - Sizes: 75-80 nm

- **Herpesvirus**
  - Genomes: $C = 162$
  - Sizes: 150-200 nm

- **Poxvirus**
  - Genomes: Complex
  - Sizes: 240x300 nm
Viral Structure

• Varies in size, shape and symmetry
• VIP for classification
• 3 types of capsid symmetry:
  – Cubic (icosahedral)
    • Has 20 faces, each an equilateral triangle. Eg. adenovirus
  – Helical
    • Protein binds around DNA/RNA in a helical fashion eg. Coronavirus
  – Complex
    • Is neither cubic nor helical eg. poxvirus
Icosahedral capsids

(a) Crystallographic structure of a simple icosahedral virus.

(b) The axes of symmetry
Cubic or icosahedral symmetry
Helical symmetry
Helical

- California Encephalitis Virus
- Coronavirus
- Hantavirus
- Influenza Virus (Flu Virus)
- Measles Virus (Rubeola)
- Mumps Virus
- Para Influenza Virus
- Rabies Virus
- Respiratory Syncytial Virus (RSV)
Enveloped helical virus

Enveloped icosahedral virus
Properties of naked viruses

• Stable in hostile environment
• Not damaged by drying, acid, detergent, and heat
• Released by lysis of host cells
• Can sustain in dry environment
• Can infect the GI tract and survive the acid and bile
• Can spread easily via hands, dust, fomites, etc
• Can stay dry and still retain infectivity
• Neutralizing mucosal and systemic antibodies are needed to control the establishment of infection
Naked viruses (Non Enveloped)

- Adeno-associated Virus (AAV)
- Adenovirus
- B19
- Coxsackie virus - A
- Coxsackie virus - B
- Echovirus
- Hepatitis A Virus (HAV)
- Hepatitis E Virus (HEV)
- Norwalk Virus
COMPLEX SYMMETRY

POXVIRUS FAMILY

White, DO and Fenner, FJ. Medical Virology, 4th Ed. 1994

Dr. T.V. Rao MD
ENVELOPE

• OBTAINED BY BUDDING THROUGH A CELLULAR MEMBRANE (except poxviruses)
• POSSIBILITY OF EXITING CELL WITHOUT KILLING IT
• CONTAINS AT LEAST ONE VIRALLY CODED PROTEIN
  – ATTACHMENT PROTEIN
• LOSS OF ENVELOPE RESULTS IN LOSS OF INFECTIVITY
BASIC STEPS IN VIRAL LIFE CYCLE

• ADSORPTION
• PENETRATION
• UNCOATING AND ECLIPSE
• SYNTHESIS OF VIRAL NUCLEIC ACID AND PROTEIN
• ASSEMBLY (maturation)
• RELEASE
<table>
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<th>RECEPTOR</th>
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<tr>
<td>ICAM-1</td>
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<tr>
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<td>HVEM</td>
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<tr>
<td>Sialic acid</td>
<td>Influenza, reo, corona</td>
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Virus Replication

1. Virus attachment and entry
2. Uncoating of virion
3. Migration of genome nucleic acid to nucleus
4. Transcription
5. Genome replication
6. Translation of virus mRNAs
7. Virion assembly
8. Release of new virus particles
• TEMPERATURE INDEPENDENT
• REQUIRES VIRAL ATTACHMENT PROTEIN
• CELLULAR RECEPTORS
PENETRATION
- ENVELOPED VIRUSES

• FUSION WITH PLASMA MEMBRANE
• ENTRY VIA ENDOSONES
PENETRATION

herpesviruses, paramyxoviruses, HIV
PENETRATION
- ENVELOPED VIRUSES

• FUSION WITH PLASMA MEMBRANE
• ENTRY VIA ENDOsomES, FUSION WITH ACIDIC ENDOsOME MEMBRANE
entry directly across plasma membrane:
Replicative cycle

• As obligate intracellular parasites, Virus must enter and replicate in living cells in order to “reproduce” themselves. This “growth cycle” involves specific attachment of virus, penetration and uncoating, nucleic acid transcription, protein synthesis, maturation and assembly of the virions and their subsequent release from the cell by budding or lysis.
UNCOATING

• NEED TO MAKE GENOME AVAILABLE

• ONCE UNCOATING OCCURS, ENTER ECLIPSE PHASE

• ECLIPSE PHASE LASTS UNTIL FIRST NEW VIRUS PARTICLE FORMED
SYNTHESIS OF VIRAL NUCLEIC ACID AND PROTEIN

• MANY STRATEGIES
• NUCLEIC ACID MAY BE MADE IN NUCLEUS OR CYTOPLASM
• PROTEIN SYNTHESIS IS ALWAYS IN THE CYTOPLASM
ASSEMBLY AND MATURATION

- NUCLEUS
- CYTOPLASM
- AT MEMBRANE
RELEASE

• LYSIS
• BUDDING THROUGH PLASMA MEMBRANE
• NOT EVERY RELEASED VIRION IS INFECTIOUS
Transmission of Viruses

- Respiratory transmission
  - Influenza A virus
- Faecal-oral transmission
  - Enterovirus
- Blood-borne transmission
  - Hepatitis B virus
- Sexual Transmission
  - HIV
- Animal or insect vectors
  - Rabies virus
Viruses enter the body of the host in a variety of ways, for example...
The commonest forms of transmission are via...

INHALED DROPLETS in sneezing of coughing for example the COMMON COLD or INFLUENZA VIRUSES.
or by...

drinking water or
eating raw food, for example,
HEPATITIS A and POLIOVIRUS.
also...

vertical transmission - from mother to baby for example HIV, HEPATITIS B and RUBELLA...
also...

bites of vector arthropods such as mosquitoes for example YELLOW FEVER, RIFT VALLEY FEVER and DENGUE.
Most viral infections... do not lead to such serious complications and the host...
A bacteriophage

- A bacteriophage is any one of a number of viruses that infect bacteria. They do this by injecting genetic material, which they carry enclosed in an outer protein capsid. The genetic material can be ssRNA, dsRNA, ssDNA, or dsDNA ('ss-' or 'ds-' prefix denotes single-strand or double-strand) along with either circular or linear arrangement.
Sub-viral agents

- **Satellites**
  - Contain nucleic acid
  - Depend on co-infection with a helper virus
  - May be encapsidated (satellite virus)
  - Mostly in plants, can be human e.g. hepatitis delta virus
  - If nucleic acid only = virusoid

- **Viroids**
  - Unencapsidated, small circular ssRNA molecules that replicate autonomously
  - Only in plants, e.g. potato spindle tuber viroid
  - Depend on host cell polIII for replication, no protein or mRNA

- **Prions**
  - No nucleic acid
  - Infectious protein e.g. BSE