General structure and classification of viruses

THE CONCEPT OF VIRUS:
✓ Edward Jenner (1798), introduced the term virus in microbiology.
✓ Virus in Greek means poison.
✓ Edward Jenner noticed that milk maids who infected with cowpox develop immunity against smallpox.
✓ He inoculated a boy with the vesicle fluid taken from the hand of infected maid.
✓ The boy developed sustained immunity against smallpox.
✓ Edward Jenner assumed that the vesicle fluid that has been taken from the hand of the milk maid contained a poison (virus), that was responsible for immunity.

GENERAL CHARACTERISTICS & STRUCTURE OF VIRUSES:
✓ Viruses are smaller than bacteria, they range in size between 20-300 nanometer (nm). (MCQ)
✓ Viruses contain only one type of nucleic acid, either DNA or RNA, but never both. (MCQ very imp.)
✓ Viruses consist of nucleic acid acid surrounded by a protein coat called capsid.
✓ The capsid is composed of small structural units called capsomeres.
✓ The capsid protects nucleic acid from inactivation by the outer physical conditions.
✓ Some viruses have additional lipoprotein envelope, composed of virally coded protein and host lipid.
✓ The viral envelope is covered with glycoprotein spikes.
✓ Some viruses have enzymes inside the virion.
✓ All ss- RNA viruses with negative polarity have the enzyme transcriptase (RNA dependent RNA polymerase) inside virions. (MCQ)
✓ Retroviruses (الايدز) and hepatitis B virus contain the enzyme reverse transcriptase. (MCQ)
✓ Viruses lack cellular organelles, such as mitochondria and ribosomes.
✓ Viruses are obligate cellular parasite (they replicate only inside living cells)
✓ Viruses replicate through replication of their nucleic acid and synthesis of the viral protein.
✓ Viruses do NOT multiply in chemically defined media. (MCQ)
✓ Viruses do NOT undergo binary fission. (MCQ)

TERMINOLOGY:
Virion: The complete virus particle.
Capsid: The protein coat that surrounds nucleic acid.
Nucleocapsid: The nucleic acid plus the capsid.
Capsomeres: The structural protein units that made up the capsid.
Defective virus: the virus cannot replicate by its own, it requires helper virus.
Nanometer: milli-micron.

Fig-1: Structure of icosahedral unenveloped virus

Fig-2: Structure of icosahedral enveloped virus

Fig-3: Structure of viruses

Fig-4: Enveloped viruses (Rabies viruses (1) influenza virus (2) & herpes viruses (3))

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Viruses are divided into three groups, based on the morphology of the nucleocapsid and the arrangement of capsomeres.

1. **Cubic symmetry:**
   - The virus particle is *icosahedral* in shape (almost spherical particle) and the nucleic acid contained inside the capsid.
   - The icosahedron particle is composed of 20 equilateral triangles, 12 vertices and has 2,3,5 rotational symmetry.
   - **Viral families with cubic (icosahedral) symmetry:**
     | Picornaviridae | Caliciviridae | Astroviridae |
     | Reoviridae     | Herpesviridae | Adenoviridae |

Fig-6- Cubic symmetry

Fig-7- Cubic symmetry (herpes & adeno viruses).

Fig-5- Unenveloped viruses (Adenoviruses).
2. **Helical symmetry**:  
   - The virus particle is elongated or pleomorphic (**not spherical**), and the **nucleic acid is spiral**. Caposomeres are arranged round the nucleic acid.
   - The following virus families have helical symmetry:
     - *Orthomyxoviridae*, *paramyxoviridae*, *rhabdoviridae*, *filoviridae*.

![Helical symmetry](image)

**Fig-9**- helical symmetry

**Fig-10**- Helical symmetry (influenza & rabies viruses)

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3. **complex symmetry:**
   - The virus particle does not confirm either cubic or helical symmetry.
   - It has a complex structure.
   - Family: **Poxviridae**

![Complex symmetry diagram](image)

**Fig-11- Complex symmetry (Poxviruses)**

### Classification of Viruses:
- Viruses are divided into two large groups:
  1. RNA containing viruses.
  2. DNA containing viruses.
- **Baltimore classification**
  - Viruses were divided into six groups based on their nucleic acid and m-RNA production.
  - A. ds-DNA viruses.
  - B. ss-DNA viruses.
  - C. ds-RNA viruses.
  - D. ss-RNA viruses with positive strands (positive polarity).
  - E. ss-RNA viruses with negative strands (negative polarity).
  - F. ss-RNA viruses associated with the enzyme reverse transcriptase.
  - G. ds-DNA viruses associated with the enzyme reverse transcriptase.

<table>
<thead>
<tr>
<th>ds–DNA with reverse transcriptase enzyme</th>
<th>Ds-DNA</th>
<th>ss-DNA</th>
<th>Ds-RNA</th>
<th>ss-RNA(–) with transcriptase enzyme</th>
<th>ss-RNA(+)</th>
<th>ss-RNA with reverse transcriptase enzyme</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hepatitis B only (HBV)</strong></td>
<td>Poxviridae</td>
<td>Paroviridae</td>
<td>Reoviridae</td>
<td>Orthomyxoviridae</td>
<td>Picornaviridae</td>
<td>Retroviruses</td>
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<td>Flaviviridae</td>
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</tbody>
</table>

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**Notes:**
- **ss-RNA(+)**: The viral genome acts directly as m-RNA.
- **ss-RNA(-)**: The viral genome does not act as m-RNA. It must be transcribed by the viral enzyme transcriptase into m-RNA.
- **Retroviruses**: These viruses replicate through ds-DNA intermediate.
  - The viral genome is reverse transcribed into a complementary DNA strand using the enzyme reverse transcriptase.
- **HBV** is a unique virus, it has small partially circular ds-DNA genome.
  - The viral genome is transcribed into a full length genome m-RNA.
  - This m-RNA is then reverse transcribed into a complementary DNA strand.
  - The complementary strand is converted to ds-DNA.

**Steps in Virus Replications:**

1- Adsorption (attachment).
2- Penetration.
3- uncoating.
4- Replication of the viral genome.
5- Transcription of the viral genome into m-RNA.
6- Translation of m-RNA into viral proteins.
7- protein synthesis,
8- Viral assembly.

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1- **Adsorption (attachment).**

- Viruses must recognize and bind to specific cellular receptors on the surface of the infected cell via particular glycoproteins.

2—**Penetration(VERY IMPORTANT MCQ)**

(A). Enveloped viruses:

1. Enveloped viruses that **has the ability to form syncytia** (multi-nucleated giant cell) enter the cell through **fusion of the viral envelope with cell plasma membrane** (eg. Paramyxovirus and herpes viruses).

2. **The remaining** enveloped viruses enter the cell through **endocytosis**.

(B). Unenveloped viruses:

enter the cell either by **endocytosis** (endosome lyses as with adenoviruses) or by **forming a pore in the membrane of the cell**. The viral RNA is then released inside the cell (picornaviruses).
Fig-12-Entry of enveloped viruses, fusion of the viral envelope.

Fig-13-Penetration of adenoviruses (lyses of endosomes).

**Endocytosis:**

- involves invagination of the cell membrane to form vesicles in the cell cytoplasm.
- Infected viruses are then engulfed inside these vesicles.
- Each vesicle fuses with a lysosome to form lysosomal vesicle.
- The viral envelope fuses with lysosomal membrane and the viral nucleocapsid is expelled into the cytoplasm.

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3- **Uncoating.**
   - Release of the viral genome from its protective capsid to enable the viral nucleic acid to replicate.

4- **Transcription:**
   - Synthesis of m-RNA.

5- **Translation:**
   - The viral genome is translated using cell ribosomes into structural and non-structural proteins.

6- **Replication of the viral nucleic acid.**

7- **Assembly**
   - New virus genomes and proteins are assembled to form new virus particles.

8- **Release (MCQ) very imp.**
   - Enveloped viruses are released by budding from the infected cells.
   - Unenveloped viruses are released by rupture of the infected cells.
Lab diagnosis of viral infection:

1- Detection of IgM antibody:
   - IgM is a marker of recent infection.
   - It is the first Immunoglobulin (Ig) that appears in circulation.
   - It appears early in the acute phase of the disease.
   - Usually, it disappears after 8–12 weeks.
   - In contrast, IgG is a marker of immunity.
   - It is the second Ig that appears in circulation.
   - IgG persists for several years.

2- Detection of the total antibody (IgM & IgG):
   - This method is limited only to HIV, HTLV, and HCV.
   - In case of HIV and HTLV, there is no immunity nor recovery.
   - Presence of antibody to these two viruses mean infection.
   - In case of HCV, 80% of the infected will develop chronic hepatitis C infection.
   - Only 20% will recover.

3- Detection of the viral antigen in the patient specimens:
   - Rota, astro, enteric adenoviruses are shed freely in stool.
   - Respiratory syncytial virus (RSV), influenza, parainfluenza, and adenoviruses can be detected inside infected cells of the nasopharyngeal aspirate.

4- Detection of the viral nucleic acid in the patient specimen using PCR:
   - PCR is recommended to all life threatening conditions.

5- Isolation of the virus in tissue culture followed by identification of the isolated virus.

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The End of the 1st lecture

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