# NAME OF THE COURSE WORK
# VIROLOGY

## UNIT-I
## GENERAL VIROLOGY

## NAME OF THE COURSE TEACHER
## Dr. V. RAJESH KANNAN

- **What is virus?**
- **Early development & Discovery of viruses**
- **Virus structure**
- Taxonomy of Virus
- Nomenclature
- Classification
- Host, nucleic acid
- Evolution & Origin of viruses
- Databases of viruses

| | Growth on artificial media | Division by binary fission | Contain DNA and RNA | Contain protein synthesis machinery | Contain muramic acid | Sensitive to antibiotics |
|---|---|---|---|---|---|---|
| **Bacteria** | **often** | **yes** | **yes** | **yes** | **often** | **yes** |
| **Viruses** | **never** | **no** | **Either DNA or RNA** | **no*** | **no** | **no** |

# What is Virus?

- Virus - “poison”
- Small (nanometers)
- Infectious
- Obligate intracellular parasite
- Genome (either DNA or RNA) never both. Surrounded by productive protein coat & some animal viruses have a phospholipid envelope surrounding the virus
- Replicate only in the presence of a specific host.
- Outside host cells, viruses are in dormant stages where they exist between the living and nonliving.

❖ Exit in two distinct states – When not in contact with a suitable host cell & they remain entirely dormant;

❖ Virions - nonliving state viruses are referred to as virions;

❖ When the virion comes into contact with an appropriate host it becomes active, then referred to as a virus.

- Size
  - 17 nm – 3000 nm diameter

- Basic shape
  - Rod-like
  - “Spherical”

- Protective Shell - Capsid
  - Made of many identical protein subunits
  - Symmetrically organized
  - 50% of weight
  - Enveloped or non-enveloped
- Genomic material
  - DNA or RNA
  - Single- or double-stranded

# Discovery of Virus

Ancients period did not understand the nature of their illnesses, in fact some evidence that the great epidemics of AD 165-180 & 251-266. which severely weakened the Roman Empire & aided its decline may have been caused by measles & smallpox viruses.

❖In 1717, Mary Montagu, the wife of an English ambassador to the Ottoman Empire, observed local women inoculating their children against Smallpox.

❖ In the late 18th century, Edward Jenner (1798) observed and studied Miss Sarah Nelmes, a milkmaid who had previously caught Cowpox and was subsequently found to be immune to Smallpox, a similar virus.

Louis Pasteur, (1885) French chemist used the same principle of Jenner's to develop vaccines against rabies.
He used inoculated the weakened infected tissues against rabies was successful. But he was unaware about the causative agent of rabies.

In 1892 Dimitrii Ivanovsky, a Russian scientist observed the causative agent of tobacco mosaic virus can able to pass through the filters which retains bacteria.
He found that filtered extracts of infected plants in turn caused disease in uninfected plants

- The term *virus* was coined by the Dutch microbiologist Martinus Beijerinck.
- His experiments showed that viruses were different from bacteria, yet they could also cause disease in living organisms.

- In 1898, Friedrich Loeffler and Paul Frosch observed the causative agent of foot and mouth disease, was also filterable.

- Frederick Twort in 1915 and Felix d'Herelle in 1917 described viruses also infect bacteria and lyse bacteria (bacteriophages) on the surface of agar plates results in plaque formation.

- Finally, in 1935 Wendell Stanley crystallized the tobacco mosaic virus and found it to be mostly protein. A short time later the virus was separated into protein and nucleic acid parts.

- During the 1950s, Hershey and Chase made important discoveries on the replication of DNA during their studies on a bacteriophage called T2.

- Together with Delbruck they were jointly awarded the 1969 Nobel Prize in Physiology or Medicine "for their discoveries concerning the replication mechanism and the genetic structure of viruses".

- Since then, the study of bacteriophages has provided insights into the switching on and off of genes, and a useful mechanism for introducing foreign genes into bacteria and many other fundamental mechanisms of molecular biology.

- The second half of the 20th century was the golden age of virus discovery and most of the 2,000 recognized species of animal, plant, and bacterial viruses were discovered during these years.
- In 1946, Bovine virus diarrhea was discovered, which is still possibly the commonest pathogen of cattle throughout the world.
- In the 1950s, improvements in virus isolation and detection methods resulted in the discovery of several important human viruses that cause the common cold.
- In the 1960s more viruses were discovered. In 1963, the hepatitis B virus was discovered by Baruch Blumberg (b. 1925), and in 1965, Howard Temin (1934–1994) described the first retrovirus.
- In 1983 Luc Montagnier (b. 1932) and his team at the Pasteur Institute in France, first isolated the retrovirus now called HIV.
- In 1989 Michael Houghton's team at Chiron Corporation discovered Hepatitis C. New viruses and strains of viruses were discovered in every decade of the second half of the 20th century.
- These discoveries have continued in the 21st century as new viral diseases such as SARS and nipah virus have emerged.
- Despite scientists' achievements over the past one hundred years, viruses continue to pose new threats and challenges.

- In the 1960 and subsequent years, many improved detection methods

- Complement fixation test
- Radioimmunoassays
- Immunoflourescence
- Enzyme Linked Immunosorbent Assay
- Radioimmune precipitation
- Western Blot Assay

# Study of Viral structure

Can be considered under 3 methods

Physical methods
Chemical methods
Electron microscopy

1. Physical methods

- Filtration in 1930s – pore sizes (rather inaccurate)
- Sedimentation properties in 1960s – Ultracentrifuges
- Spectroscopy – light scattering properties; examine the nucleic acid content of the particle
- Electrophoresis – intact virus particles
- X-ray diffraction – Crystallography – most important method
- Nuclear magnetic resonance (NMR) – to determine the atomic structure of all kinds of molecules, including proteins and nucleic acid.

2. Chemical methods

Reagents interaction on protein bound,
Electrostatic interaction – eluted by addition of ionic salts or alteration of pH
Hydrophobic interaction – eluted by reagents such as urea
Lipid components – eluted by non-ionic detergents or organic solvents

3. Electron microscopy

(Ernst Ruska,1931; constructed the first electron microscope: TEM & SEM)

SEM: Beautiful images with 3-dimensional appearance

TEM: practical investigations & higher magnification achievable.

Two fundamental types of information can be obtained

- the absolute number of virus particles present in any preparation (total count)
- the appearance/structure of the particles

# Virus morphology

Viruses, as viewed through the electron microscope, come in a variety of shapes (i.e., *morphologies*) that may be divided into:

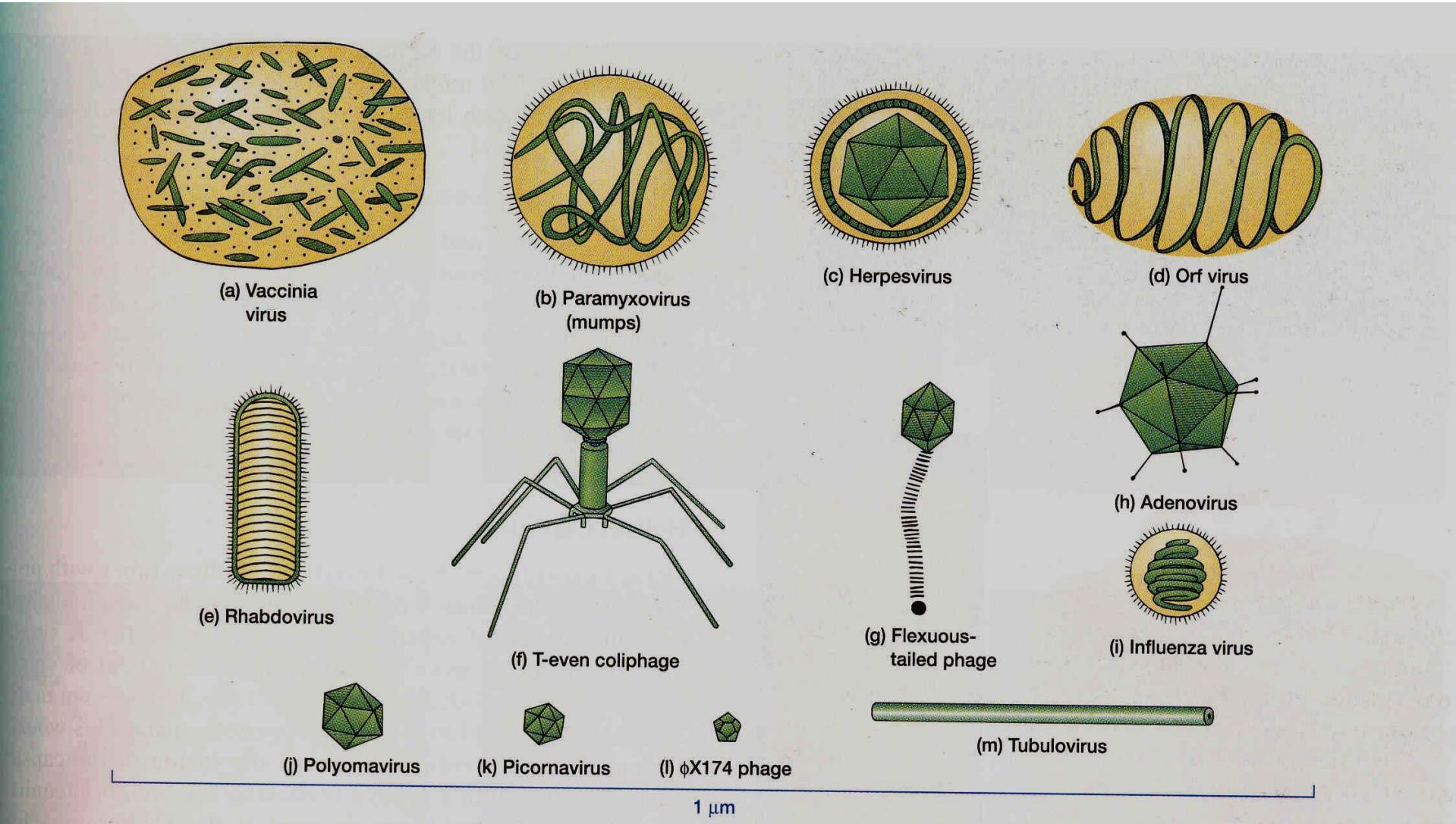



**Figure 16.10 The Size and Morphology of Selected Viruses.** The viruses are drawn to scale. A 1 μm line is provided at the bottom of the figure.

- **HELICAL:** Rod shaped, varying widths and specific architectures; no theoretical limit to the amount of nucleic acid that can be packaged.

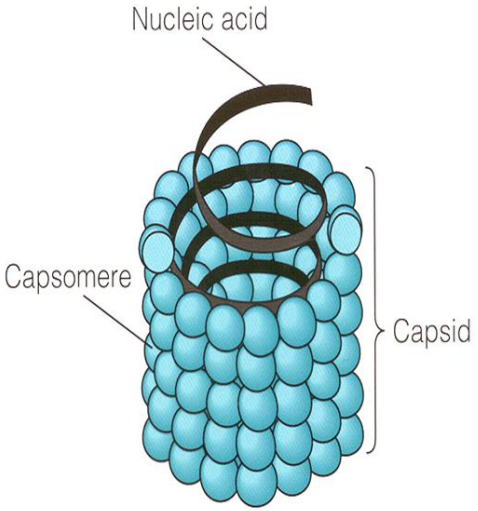
- **CUBIC *(Icosahedral)*:** Spherical, amount of nucleic acid that can be packaged is limited by the of the particle.

# Principles of basic virus structure

- Nucleoprotein must be stable but dis-associatable
- Capsid is held together by non-covalent, reversible bonds: hydrophobic, salt, hydrogen bonds
- Capsid is a polymer of identical subunits

## HELICAL VIRUSES

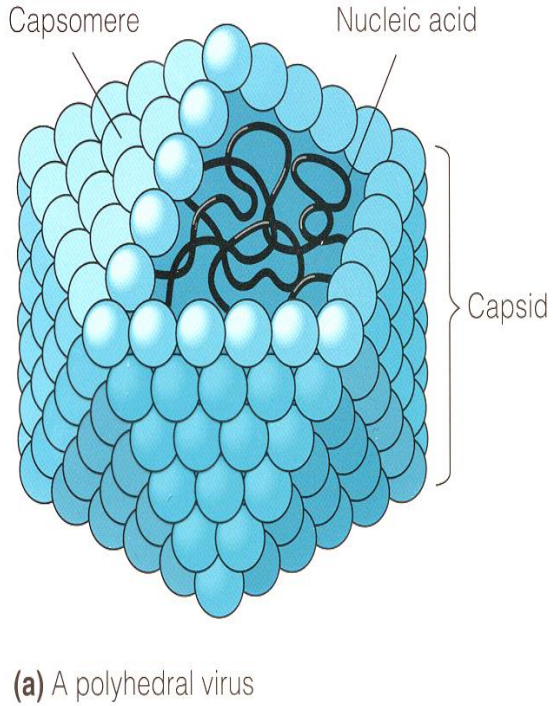
- Resemble long rods.
- May be rigid or flexible.
- Viral Genome found inside a hollow cylindrical capsid.
- E.G.: Ebola virus and Rabies virus.




(a) A helical virus

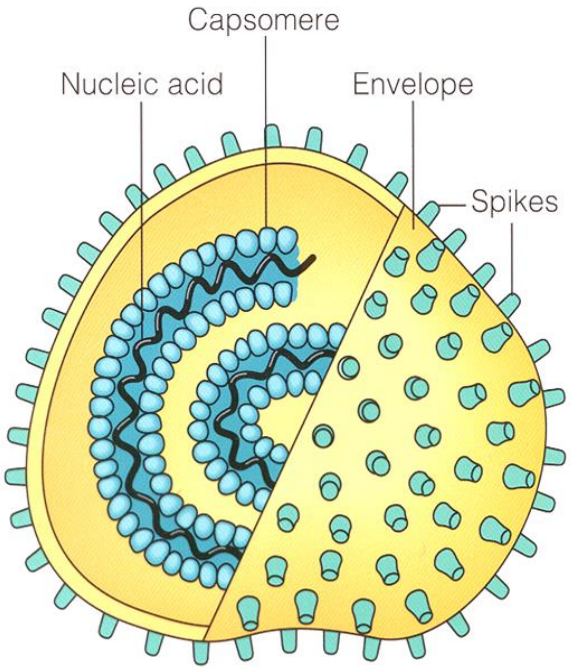
## POLYHEDRAL VIRUSES

- Many-sided Capsid is in the shape of icosahedron (a polyhedral with 20 triangular faces).
- E.G.: Adenovirus, and poliovirus.



(a) A polyhedral virus

## ENVELOPED VIRUSES



(a) An enveloped helical virus

- Roughly Spherical
- Enveloped helical or eneveloped polyhedral viruses.
- Enveloped helical=Influenza virus.
- Enveloped Polyhedral= Herpes simplex virus

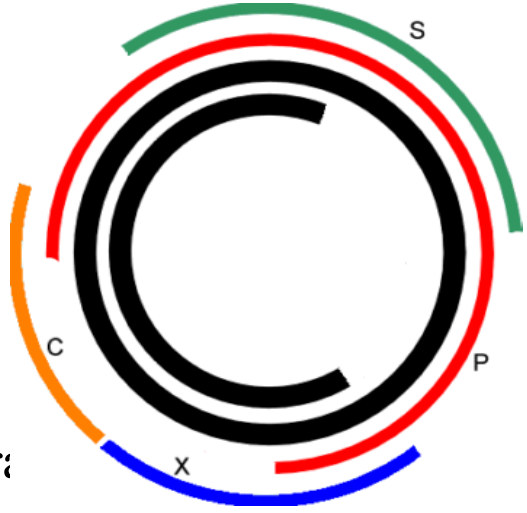
# COMPLEX VIRUSES

- Bacteriophage.
- Capsid (head) is polyhedral, tail sheath is helical.
- Tail fibers, plate and pin.

# Genome structural variation

- Beyond whether a virus has an RNA or DNA genome, viruses differ in the structure of their genomes.
- Below is a list of viral structural permutations:

RNA or DNA genome
may be short or long
may be haploid or diploid
may be segmented or not segmented
may be linear or circular
may be single - or double-stranded
if single stranded, may be plus-stranded or minus-str




Number of genes tends to be a function of length which, in turn, determines the degree of complexity displayed by viruses.

Note that very few viruses have diploid genomes.

Segmented means broken up into more than on section.

The strand from which mRNA is template (i.e., transcribed ) is called the *minus* or antisense strand. The complementary strand is equivalent to, or in some cases actually is the mRNA (and is called the *plus* or sense strand).

## DNA Viruses may be large genomes

- PolyDNAvirus (PDV) - contain many DNA segments
- Mimivirus - larger than small bacteria

## RNA Genomes

- Sense (positive-sense, negative-sense, ambisense - an ambisens genome is a genome which both nucleic acid strands encode for proteins)
- Presence or absence of 5‘ - terminal cap or 5‘ - covalently-linked protein
- Presence or absence of 3‘ - terminal poly (A) tract
- Retroviruses - Replication strategy

# GROWING VIRUSES IN THE LAB

- Plaque method: Bacteriophages.
- Living animals: Animal viruses.
- Embryonated eggs: Animal viruses.
- Cell cultures: Animal viruses (CPE).
- Primary cell lines, Diploid cell lines, and continuous cell lines.

# VIRAL MULTIPLICATION

- Viruses are nonliving particles that reproduce only inside specific host cells.
- Exhibit many patterns of viral life cycle, but they generally include:
- Co-opting host cell's resources to:
- Manufacture capsid protein;
- Assemble newly produced viral nucleic acid and capsomeres.
- Several mechanisms used to infect host cells with viral DNA.
- For Example, T- phages uses an elaborate tail piece to inject DNA into the host cell.
- Once the viral genome is inside its host cell, it commandeers the host's resources and re-programs the cell to copy the viral genes and manufacture capsid protein.

## Three possible patterns of viral genome replication

1. DNA---->DNA: If viral DNA is double-stranded, DNA replication resembles that of cellular DNA, and the virus uses DNA polymerase produced by the host.

2. RNA----->RNA: Since host cells lack the enzyme to copy RNA, most RNA viruses contain a gene that codes for RNA replicase.

- RNA replicase is an enzyme that uses viral RNA as a template to produce complementary RNA.

3. RNA----->DNA----->RNA: Some RNA viruses encode reverse transcriptase, an enzyme that transcribes DNA from an RNA template.

# Taxonomy

What is the purpose of classification?

*To make order*

- Effective organization schemes facilitate and focus study

*To be able to communicate with each other*

- The better the classification system, the fewer explanatory words are needed

*To assemble like members with each other*

- It is important to identify the qualities that are considered in a classification scheme

In 1966, established by International congress of Microbiology in Moscow, International Committee on Nomenclature of Viruses (ICNV)

1973, the ICNV became the ICTV

Today, the ICTV operates under the virology Division of the International Union of Microbiological Societies (IUMS)

ICTV has 6 subcommittees; 45 study groups & 400 participating virologist

# Classification, nomenclature, and orthography

- 7th Report of the ICTV was published in 2000
  - 56 families, 9 subfamilies, 233 genera, and 1550 virus species
  - Includes retrotransposons (2 families), satellites, viroids, prions
- Rules of orthography changed in 1999 to require italics, but no true binomial – only modified binomial e.g.
  - Family *Reoviridae*
    - Genus *Orbivirus*
      - Species *Bluetongue virus* (24 named strains: BTV-1 to BTV-24)
- Criteria for species demarcation vary for different families

# Problems with virus classification and nomenclature

- Some systems don't lend themselves easily to rational hierarchical classification
  - High recombination among bacteriophages in natural settings is problematic
- Many journals are unaware of or ignore rules of orthography
- Many virologists are unaware of or ignore rules of orthography

## Rules for taxa

- A species name must provide an appropriately unambiguous identification of the species. Numbers, letters or combinations therefore may be used as species epithets
- A virus genus - group of related species that share some significant properties differ in host range and virulence.
- A genus name must be a single word ending in virus.

A subfamily - group of genera shares common characters.

A subfamily name must be a single word ending in *virinae*.

A family - group of genera, whether or not these are organized into subfamilies, sharing certain common characters.

A family name must be a single word ending in viridae.

An order - group of families sharing certain common characters.

An order name must be a single word ending in *virales*.

# Virus classification involves naming and placing into a taxonomic system

a ) Morphological taxonomy

-Host range aside & traditionally are distinguished by their morphologies (in the present of electron microscopy era);

b) Genomic taxonomy

-Viruses are also differentiated by similarities & differences in their genomes.

# CLASSIFICATION

- BASIC STRUCTURE AND MOLECULAR BIOLOGY
  - particularly important as diagnostic and therapeutic abilities expand

- NUCLEIC ACID
- CAPSID
- PRESENCE OF ENVELOPE
- REPLICATION STRATEGY

## 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

## CAPSID

- symmetry
  - icosahedral, helical, complex
- number of capsomers if icosahedral
- enveloped or non-enveloped

# Virus Nomenclature

a) Common name nomenclature

- Virus sps. names have not been established, consequently virus are described by their common names.
- Common names are not italicized. Ex. Influenza virus

b) Subspecies nomenclature

- Virus subspecies are often described by adding numbers to the common name. ex. HIV 1

❖ The ICTV's essential principles of virus nomenclature are:

- Stability
- To avoid or reject the use of names which might cause error or confusion
- To avoid the unnecessary creation of names

❖ The name of a taxon has no status until it has been approved by ICTV

**International Congress on Taxonomy of Viruses**
**http://www.ncbi.nlm.nih.gov/ICTV/**

- **Morphology**
  - virion size
  - enveloped or naked nucleocapsid
  - capsid symmetry and structure
- **Genome characteristics**
- **Replication strategy**
- **Antigenic Properties**

# Virus classification

Virus classification is based mainly on phenotypic characteristics, including morphology, nucleic acid type, mode of replication, host organisms, and the type of disease.

**I. Classification system**

- **a) Baltimore system**
- **b) ICTV system**
- **c) Classical System**

**II. Genome based classification**

- **a) DNA viruses**
- **b) RNA viruses**
- **c) Reverse transcribing viruses**

**III. Host based classification**

- **a) Animal Viruses**
- **b) Plant Viruses**
- **c) Viruses of fungi & algae**
- **d) Insect viruses**

# Baltimore classification

- David Baltimore, a Nobel Prize-winning biologist, devised the Baltimore classification system, which places viruses into one of seven groups based on their mode of replication, and genome type.

Group I: Double-stranded DNA viruses (ex. Adenoviruses) dsDNA

Group II: Single-stranded DNA viruses (ex. Parvoviruses) ssDNA

Group III: Double-stranded RNA viruses (ex. Reoviruses) dsRNA

Group IV: Positive-sense single-stranded RNA viruses (ex. Picornaviruses) +ssRNA

Group V: Negative-sense single-stranded RNA viruses (ex. Orthomyxoviruses) -ssRNA

Group VI: Reverse transcribing Diploid single-stranded RNA viruses (ex. Retroviruses)

Group VII: Reverse transcribing Circular double-stranded DNAviruses (ex. Hepadnaviruses)

# ICTV classification

- The ICTV classification system is used in conjunction with the Baltimore classification system in modern virus classification.

- The International Committee on Taxonomy of Viruses devised and implemented several rules on the naming and classification of viruses early in the 1990's.

- To this day they oversee the naming and placement of viral species into the framework. The system shares many features with the classification system of cellular organisms, such as taxon structure.

- Viral classification starts at the level of order and follows as thus, with the taxon suffixes given in italics:

  Order (*-virales*)
  Family (*-viridae*)
  Subfamily (*-virinae*)
  Genus (*-virus*)
  Species (*-virus*)

- However, this system of nomenclature differs from other taxonomic codes on several points.
- A minor point is that names of orders and families are italicized, as in the *ICBN*.
- Most notably, species names generally take the form of *[Disease] Virus*.

# Classical System

- In 1962, Lwoff, Robert W.Horne, and Paul Tournier classified all virus under Linnaean hierarchical system.
- The general structure is: Order (-*virales*)
  Family (-*viridae*)
  Subfamily (-*virinae*)
  Genus (-*virus*)
  Species (-*virus*)

- Four characteristics used were:
  Nature of nucleic acid,
  Symmetry of the protein shell
  Presence or absence of envelope
  Dimensions of the virion and capsid

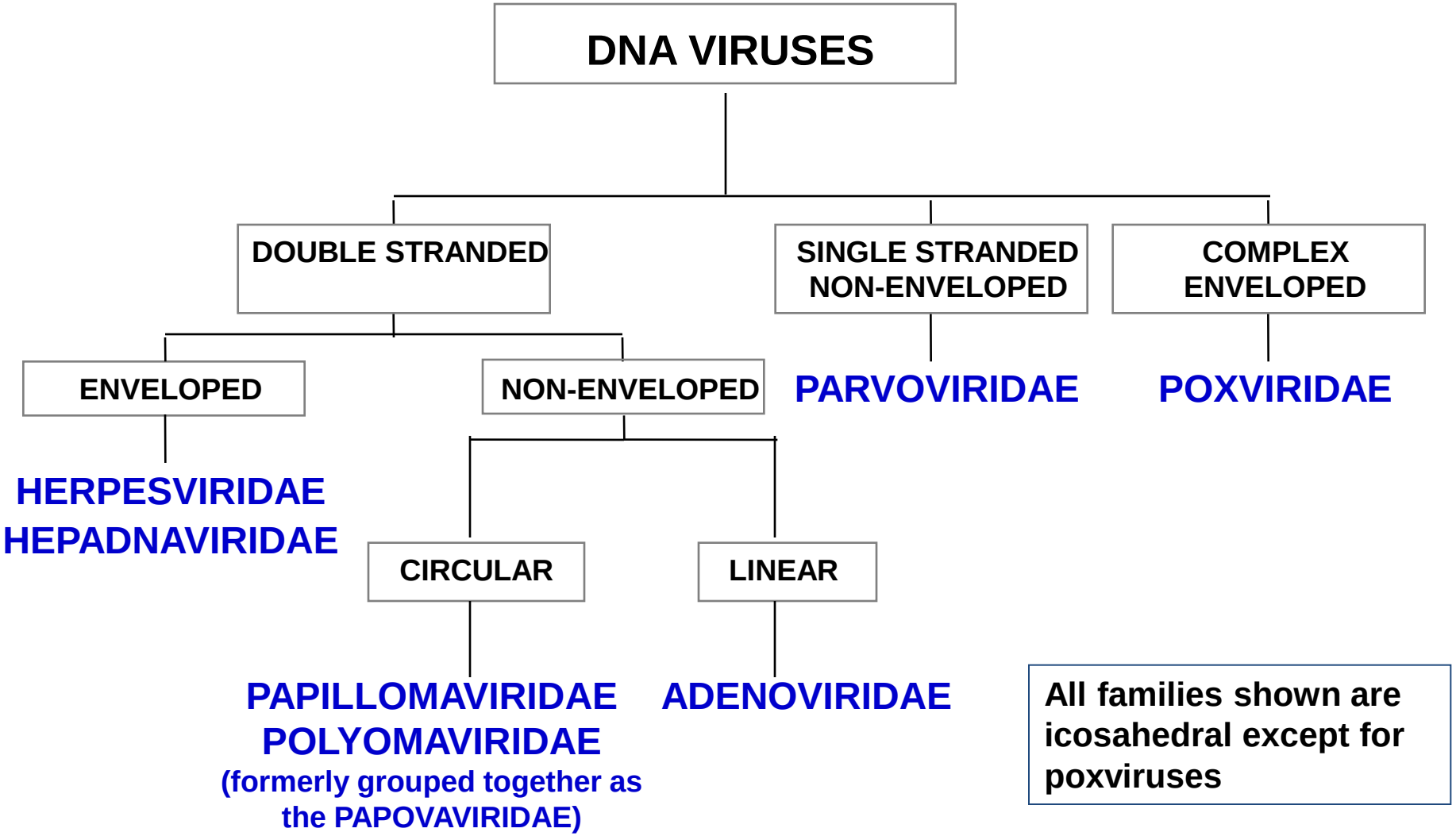
# Genome based classification

**a) DNA viruses**

**Group I:** viruses possess double-stranded DNA and include such virus families as Herpesviridae (examples like HSV1, HSV2, VZV, EBV, CMV, Poxviridae (smallpox) and many tailed bacteriophages.

The mimivirus was also placed into this group.

**Group II: viruses possess single-stranded DNA and include such virus families as** Parvoviridae and the important bacteriophage M13.



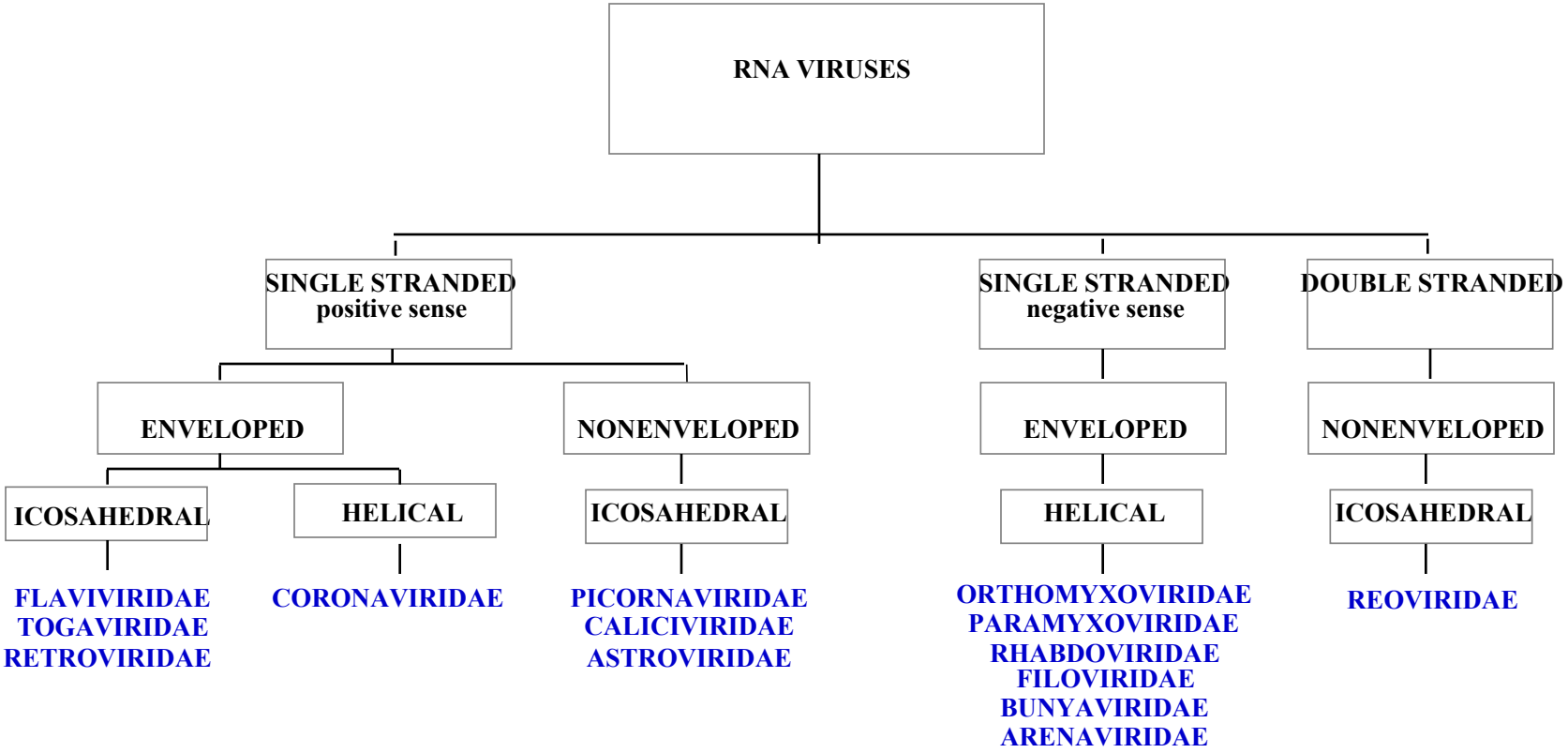

Modified from Volk et al., Essentials of Medical Microbiology, 4th Ed. 1991

## b) RNA viruses

**Group III:** viruses possess double-stranded RNA genomes, e.g. rotavirus. These genomes are always segmented.

**Group IV:** viruses possess positive-sense single-stranded RNA genomes. Many well known viruses are found in this group, including the picornaviruses (which is a family of viruses that includes well-known viruses like Hepatitis A virus, enteroviruses, rhinoviruses and foot-and-mouth virus), SARS virus, hepatitis C virus, yellow fever virus, and rubella virus.

**Group V:** viruses possess negative-sense single-stranded RNA genomes. The deadly Ebola and Marburg viruses are well known members of this group, along with influenza virus, measles, mumps and rabies.


RNA VIRUSES
SINGLE STRANDED
positive sense
SINGLE STRANDED
negative sense
DOUBLE STRANDED
ENVELOPED
NONENVELOPED
ENVELOPED
NONENVELOPED
ICOSAHEDRAL
HELICAL
ICOSAHEDRAL
HELICAL
ICOSAHEDRAL
FLAVIVIRIDAE
TOGAVIRIDAE
RETROVIRIDAE
CORONAVIRIDAE
PICORNAVIRIDAE
CALICIVIRIDAE
ASTROVIRIDAE
ORTHOMYXOVIRIDAE
PARAMYXOVIRIDAE
RHABDOVIRIDAE
FILOVIRIDAE
BUNYAVIRIDAE
ARENAVIRIDAE
REOVIRIDAE

## c) Reverse transcribing viruses

**Group VI:** viruses possess single-stranded RNA genomes and replicate using reverse transcriptase. The retroviruses are included in this group, of which HIV is a member.

**Group VII:** viruses possess double-stranded DNA genomes and replicate using reverse transcriptase. The hepatitis B virus can be found in this group.

# Host based classification

a) Animal Viruses (Vertebrates & Invertebrates)

b) Plant Viruses (Angiosperm, Gymnosperm, Pteredophyte, Bryophytes)

c) Viruses of bacteria, fungi & algae

d) Insect viruses

# VIRUS LIFE CYCLE

- ADSORPTION
- PENETRATION
- UNCOATING AND ECLIPSE
- SYNTHESIS OF VIRAL NUCLEIC ACID AND PROTEIN
- ASSEMBLY (maturation)
- RELEASE

# Host Factors

- Genetic Resistance
  - loss of receptors
  - variation in immune response genes
  - genetic defects in defenses
- age related susceptibility
  - greater susceptibility of new born animals
  - greater susceptibility of adults
- prior exposure, acquired resistance
- maternal protection
- concurrent infections, immuno-suppression, increase in susceptible cells

# The origin of viruses

Three theories were proposed about the origin of viruses

1. **Regressive evolution (parasitism)**
   Viruses degenerated from previously independent life forms
   Lost many functions
   Retain only what they needed for parasitic lifestyle

2. **Cellular origins**
   Viruses derived from subcellular functional assemblies of macromolecules that gained the capacity to move from cell to cell.

3. **Independent entities**
   Evolution on course parallel to that of cellular organisms.
   Evolved from primitive, pre-biotic self-replicating molecules.

A hypothesis controversially states that DNA viruses of green algae may be the oldest eukaryotic viruses since their genome sequences are similar to eukaryotic sequences.

- **Problem: no fossil record.**
- **Solution: Genomes as the fossil record.**
- Relationships among different viral genomes provide insight into virus origins. This is the basis of molecular taxonomy.

## Evolution of Viruses

❖ The constant change of a viral population under selective pressures is known as virus evolution.

❖ Despite of minimal set of genes, viral populations display a wide diversity.

❖ The sources of this diversity are mutation, recombination and reassortment and selection.

# Parameters of viral evolution

- Virus-infected cells produce large numbers of progeny
- Large numbers of mutants arise when viral genomes replicate – mutants inherited to progenies.
- Sequence conservation in changing genomes – *cis* acting sequences of RNA virus under less changes during mutation. Such sequences are necessary for viral activities.
- Genetic shift and Genetic drift, a change in gene and morphological structures respectively. These mechanisms are taken up for diversity production.

- Genetic bottlenecks - extreme selective pressure on small populations resulting in diversity loss, accumulation of non-selected mutations, or both.

- Genetic Information Exchange – Recombination.

- Two pathways for virus Evolution
  - Viral populations co-evolve with their hosts so that both share a common fate.
  - Viral populations infect multiple host species. When one host species is compromised, the viral population can replicate in another.

# Database

- The development of ICTVdB has been supported by the ICTV since 1991 and was initially intended to aid taxonomic research.

- The database classifies viruses based primarily on their chemical characteristics, genomic type, nucleic acid replication, diseases, vectors, and geographical distribution, among other characteristics.

- The database was developed at the Australian National University with support of the US National Science Foundation and sponsored by the American Type Culture Collection

In view of their lesser structural complexity viruses became useful instruments for the study of genetics, cell biology, structural biology and biochemistry allowing the study of many basic parameters of life and development

# CONTROL METHODS

- INVOLVE KNOWLEDGE OF:
  - RESERVOIRS
  - MODE OF TRANSMISSION
  - METHODS TO INACTIVATE VIRUS OF INTEREST
  - VACCINES
  - ANTI-VIRAL DRUGS
  - DEVELOPMENT OF DRUG RESISTANCE

# Prevention of virus infections/disease

- Vaccination
  - inactivated vaccines
  - attenuated vaccines
  - subunit
  - vectored
  - DNA vaccines
- Management

# Why vaccination sometimes fails to protect

- Improper use
- Genetic differences between animals
- Antigenic differences
- Blocking by maternal antibodies
- Administration following infection (exceptions-rabies)

# Diagnosis of viral diseases

- clinical signs
- virus detection
- detection of exposure

} Laboratory

# Detection of virus

- Isolation (isolation +immunological detection)
- Quantitation (plaque assay)
- PCR
- Haemagglutination (or HAI)
- ELISA (in clinic or lab)
- Immunological detection (IH or IF)
- Electron microscopy

# Laboratory Detection of Viruses

I. **Cytopathic effects** – cells from animals and tissue culture

II. **Plaques** = areas of cell death in tissue culture that are unique to a particular virus

   A. **Inclusions bodies** =intracellular areas resulting from virus maturation and assembly that are unique to a particular virus

   B. **Antigenic changes** = chemical changes in infected cells resulting from the viral modification of the cell membrane

   C. **changes in cell morphology**

      – Shape, size, Staining properties

# Clinical Diagnosis of Viral Diseases

- **Viral protein detection**
  - Immunofluorescence = detects viral antigen on/within cell – using specific labeled monoclonal antibody
  - Enzyme immunoassay = detects viral antigens on/within cell
  - Enzyme linked immunosorbent assay =
    - detects virus or viral antigen released from infected cells
- **Viral nucleic acid detection**
  - Gene probes or hybridization
    - northern blot, southern blot, etc
- **Host immune response**
  - Detection of Virus-specific antibody

# Laboratory Culture of Viruses

- Viral Isolation and Culture
  - Sources of living cells
    - animals
    - human fetal tissue
    - embryonated eggs
    - tumors
  - Types of Tissue Culture
    - primary cell culture fresh cells from specific human/animal organs
    - secondary cell culture dissociated subcultured primary cells
      - these cell lines often mutate and die (senese), thus are short lived
    - diploid cell lines = mostly human fetal cells(fibroblastic)
      - young developing cells which are long lived, do not mutate, and senese
    - tumor cells - malignant cells which seldom sense and can be sub-cultured for indefinite generations

# Tissue Cultures for Various Viruses

- Poliovirus — human and primate tissue culture
- Rhinovirus — human embryonic kidney and lung tissue culture
- Bunyavirus — baby mice; mosquitoes, human tissue culture
- Rubella virus — monkey cell culture
- Influenza, mump, measles viruses - chicken embryo, monkey or calf kidney, human tissue culture
- Rhabdovirus — mice; human and hamster kidney; chicken and duck embryo
- HIV — human lymphocyte cell culture; chimpanzees
- Papillovirus — human fetal brain tissue culture
- Herpesviruses — human embryonic fibroblast culture
- Hepatitis A virus — human cell culture
- Hepitatis B virus — living primates( virus cannot be grown in cell culture)

# Overview of Virus Properties

## Prokaryote

- RNA – 5-8 kb
- DNA – 10-200 kb
- Few enveloped
- Range of complexity
- Range of morphologies
- Few divided genomes

## Lower eukaryote

- RNA – 5-10 kb
- DNA – 180-1200 kb
- Internal envelope
- Range of complexity
- Range of morphologies
- No divided genomes

## Animal

- RNA – 5-30 kb
- DNA: 5-350 kb
- Many enveloped
- Range of complexity
- Range of morphologies
- Some divided genomes

## True Fungi

- RNA – 2.5-28 kb
- DNA – none
- Enveloped ones have no capsid
- Little genome complexity
- Little morphological complexity
- Some divided genomes

## Plant

- RNA – 0.3-28 kb
- DNA – 3-10 kb
- Few enveloped
- Little genome complexity
- Little morphological complexity
- Many divided genomes

# Viruses can be useful too…

- Biological control of pests
- Cancer therapy
- Gene therapy
- Vaccine development
- Nanotechnology
- Tools to investigate host cells
- Symbiotic virus-host relationships