



# **Lecture 5:** **Virus Taxonomy**

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## Learning Objectives

Describe how viruses are classified

# Lesson Outcomes

- Understands the reasons on naming viruses
- Briefly discuss the classification of viruses
- Explain the Baltimore classification
- Explain the characteristics of RNA and DNA viruses that cause human disease.

## **Basis of virus classification**

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**International Union of Microbiological Societies (1927).**

**The International Classification of Viruses (1966).**

**International committee on the taxonomy of viruses (ICTV) (1975).**

**The first report released in 1971 and (10 reports)**



## ICTV objectives

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- The objectives of the ICTV are:
- To develop an internationally agreed taxonomy for viruses
- To establish internationally agreed names for virus taxa.
- To communicate the decisions reached concerning the classification and nomenclature of viruses to virologists by holding meetings and publishing reports.
- To maintain an Official Index of agreed names of virus taxa.
- To study the virus effects in modern society and their behaviour.





At 2018:  
143 families  
4959 virus

2018

At 1971:  
2 families  
290 virus

Year	Release Info	Orders	Families	Subfam.	Genera	Species
<a href="#">2015</a>	EC 47, London, UK, July 2015; Email ratification 2016 (MSL #30)	7	111	27	609	3704
<a href="#">2014</a>	EC 46. Kingston and Montreal, Canada. July 2014. Email ratification 2015 (MSL #29)	7	104	23	505	3185
<a href="#">2013</a>	EC 45, Edinburgh, July 2013; Email ratification 2014 (MSL #28)	7	103	22	455	2827
<a href="#">2012</a>	EC 44, Leuven, July 2012; Email ratification 2013 (MSL #27)	7	96	22	420	2617
<a href="#">2011</a>	EC 42: Paris, June, 2010; EC43: Sapporo, September 2011; Email ratification 2012 (MSL #26)	6	94	22	395	2480
<a href="#">2009</a>	ICTV 9th Report; EC41: Leiden, June 2009; Email ratification 2009 (MSL #25)	6	87	19	349	2285
<a href="#">2008</a>	EC 39: Kingston, June, 2007; EC 40: Istanbul, August 2008; Email ratification 2008 (MSL #24)	5	82	11	307	2079
<a href="#">2005</a>	ICTV 8th Report (MSL #23)	3	73	11	289	1899
<a href="#">2004</a>	Postal vote 2004 (MSL #22)	3	73	11	290	1832
<a href="#">2002</a>	Plenary session vote 30 July 2002 in Paris (MSL #21)	3	70	11	251	1619
<a href="#">2002</a>	Postal vote spring 2002 (MSL #20)	3	70	9	247	1602
<a href="#">1999</a>	Plenary session vote August 1999 in Sydney (MSL #19)	3	64	9	239	1550
<a href="#">1999</a>	ICTV 7th Report (MSL #18)	3	64	9	234	1551
<a href="#">1998</a>	Postal vote autumn 1998 (MSL #17)	3	63	9	233	2370
<a href="#">1997</a>	Postal vote autumn 1997 (MSL #16)	2	56	9	197	2267
<a href="#">1996</a>	Plenary session vote August 1996 in Jerusalem (MSL #15)	2	53	9	182	2253
<a href="#">1995</a>	ICTV 6th Report (MSL #14)	1	50	9	166	2220
<a href="#">1993</a>	Plenary session vote 10 August 1993 in Glasgow (MSL #13)	1	49	9	160	1700
<a href="#">1991</a>	ICTV 5th Report (MSL #12)	1	40	9	142	1674
<a href="#">1990</a>	Plenary session vote 29 August 1990 in Berlin (MSL #11)	1	40	9	137	1290
<a href="#">1987</a>	Plenary session vote 12 August 1987 in Edmonton (MSL #10)	0	37	8	116	1275
<a href="#">1984</a>	Plenary session vote 5 September 1984 in Sendai (MSL #09)	0	35	8	103	1222
<a href="#">1982</a>	ICTV 4th Report (MSL #08)	0	29	8	97	1209
<a href="#">1981</a>	Plenary session vote 4 August 1981 in Strasbourg (MSL #07)	0	29	8	93	1091
<a href="#">1979</a>	ICTV 3rd Report (MSL #06)	0	24	8	84	1008
<a href="#">1978</a>	Plenary session vote 30 August 1978 in The Hague (MSL #05)	0	24	7	76	760
<a href="#">1976</a>	ICTV 2nd Report (MSL #04)	0	17	3	67	754
<a href="#">1975</a>	Plenary session vote 12/16 September 1975 in Madrid (MSL #03)	0	17	1	63	309
<a href="#">1974</a>	Postal vote April-May 1974 (MSL #02)	0	5	0	49	298
<a href="#">1971</a>	ICTV 1st Report (MSL #01)	0	2	0	43	290

# Classification Methods

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## First classification trials:

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*“Based on clinical and ecological properties”*

1. Common clinical and pathogenic properties  
(e.g. respiratory, nervous, digestive viruses)

2. Common organ tropism  
(e.g. liver, lung, brain, intestine)

3. Common transmission patterns  
(e.g. Arthropod-born, Air-born, vertical, venereal)

Ex. Viruses causing hepatitis (A, B, C, D,E; now belong to different families: Picorna, Hepadna, Flavi, Delta and Calici).



# Classification Methods

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## First classification trials:

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*“Based on physicochemical and antigenic properties of viruses”*

1. Virion size

(ultrafiltration - ultracentrifugation - electron microscopy)

2. Virion morphology

(Electron microscopy)

3. Virion stability

(pH – temperature – lipid solvents – detergents – radiation)

4- Virus antigenicity (Serological tests)



# Classification Methods

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## Current classification trials:

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*“Based on virus structure and replication”*

### 1. Hierarchical Classification System

(Structure of virion and characteristics of virus genome)

### 2. Baltimore Classification System

(Strategy of viral replication and mRNA synthesis)

### 3. Phylogenetic analysis/Genotyping

(Complete or partial sequencing of viral genome)





# Classification Methods

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## (A) Hierarchical classification system

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*“Based on structure of virion and characteristics of virus genome”*

1. Virus genome:

DNA or RNA, ds or ss, + or - sense, single molecule or segmented, linear or circular, haploid or diploid.

2. Capsid:

Size and symmetry (helical, icosahedral or complex).

3. Envelope:

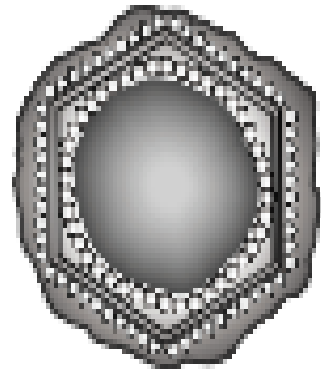
Enveloped or naked.



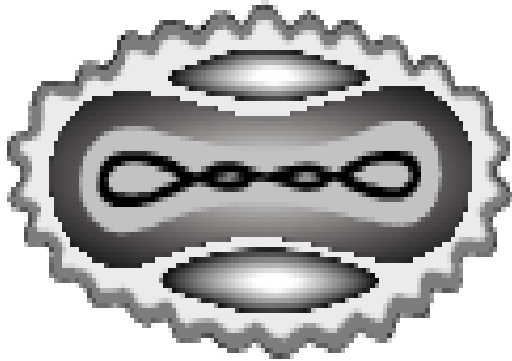
**(A) Hierarchical classification system**

**DNA**

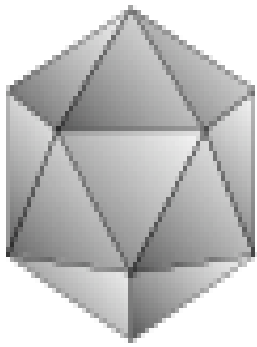
**dsDNA**



*Asfarviridae*




*Poxviridae*  
*Chordopoxvirinae*

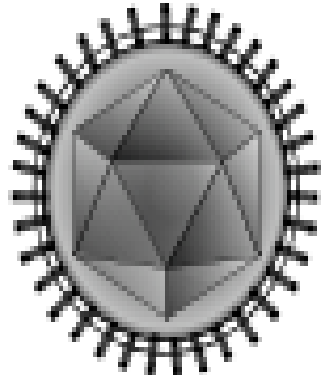


*Iridoviridae*  
*Ranavirus*  
*Lymphocystivirus*


**dsDNA (RT)**



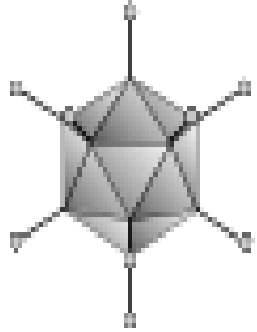
*Hepadnaviridae*



*Herpesviridae*




*Papillomaviridae*




*Adenoviridae*

**ssDNA**



*Circoviridae*



*Parvoviridae*  
*Parvovirinae*

# (A) Hierarchical classification system



**RNA**

**dsRNA**




**Reoviridae**  
*Orthoreovirus*  
*Orbivirus*  
*Coltivirus*  
*Rotavirus*  
*Aquareovirus*



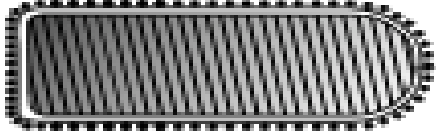
**Birnaviridae**  
*Aquabirnavirus*  
*Avibirnavirus*

**100 nm**

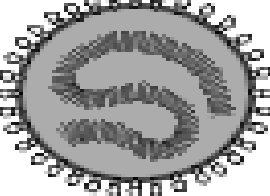
**ssRNA (-)**




**Orthomyxoviridae**




**Rhabdoviridae**  
*Lyssavirus*  
*Vesiculovirus*  
*Ephemerovirus*  
*Novirhabdovirus*



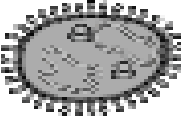
**Paramyxoviridae**




**Bornaviridae**



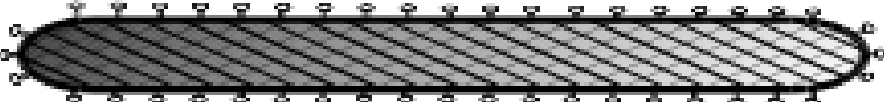
**Deltavirus**



**Arenaviridae**




**Bunyaviridae**  
*Orthobunyavirus*  
*Hantavirus*  
*Nairovirus*  
*Phlebovirus*




**Filoviridae**


**ssRNA (+)**




**Caliciviridae**




HEV-like




**Nodaviridae**  
*Betanodavirus*



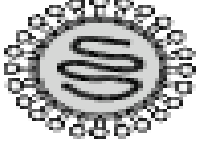
**Togaviridae**




**Picornaviridae**



**Flaviviridae**



**Coronaviridae**



**Arteriviridae**

# Basis of virus classification

## Universal system for virus taxonomy (USVT)

Established by **international committee on the taxonomy of viruses (ICTV)**:

- Virus size, shape and stability (morphology).
- Capsid symmetry (helical – icosahedral – complex).
- Presence or absence of virus envelope (**naked – enveloped**).
- Type and characteristics of the viral genome (ssRNA (+ or -), dsRNA, ssDNA, dsDNA, segmented or non-segmented).
- Strategy of virus replication (**Baltimore classification**).
- Phylogenetic classification (**partial or complete genome**)



# Baltimore classification

Adenoviruses  
Herpesviruses  
Poxviruses)

Parvoviruses

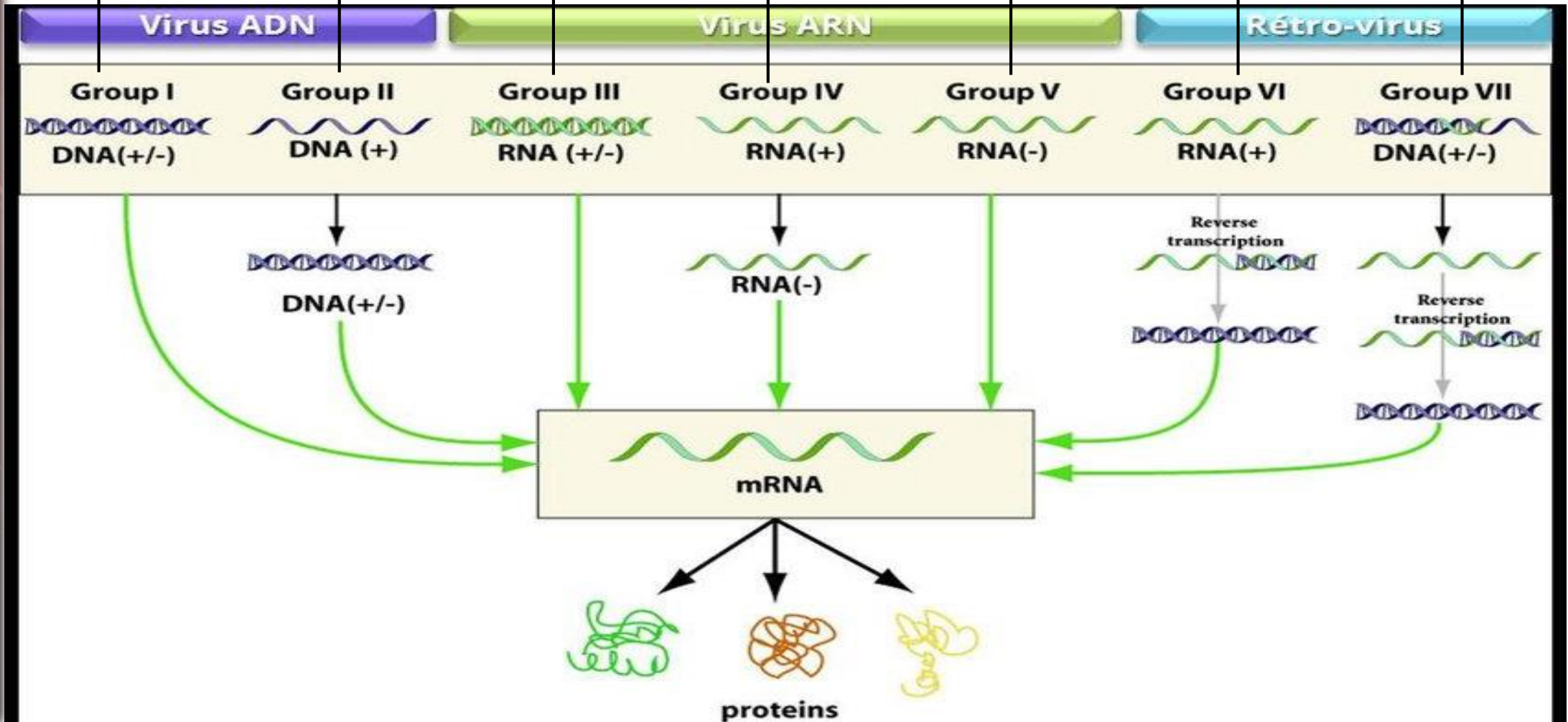
Reoviruses

Picornaviruses  
Togaviruses)

Orthomyxoviruses  
Rhabdoviruses)

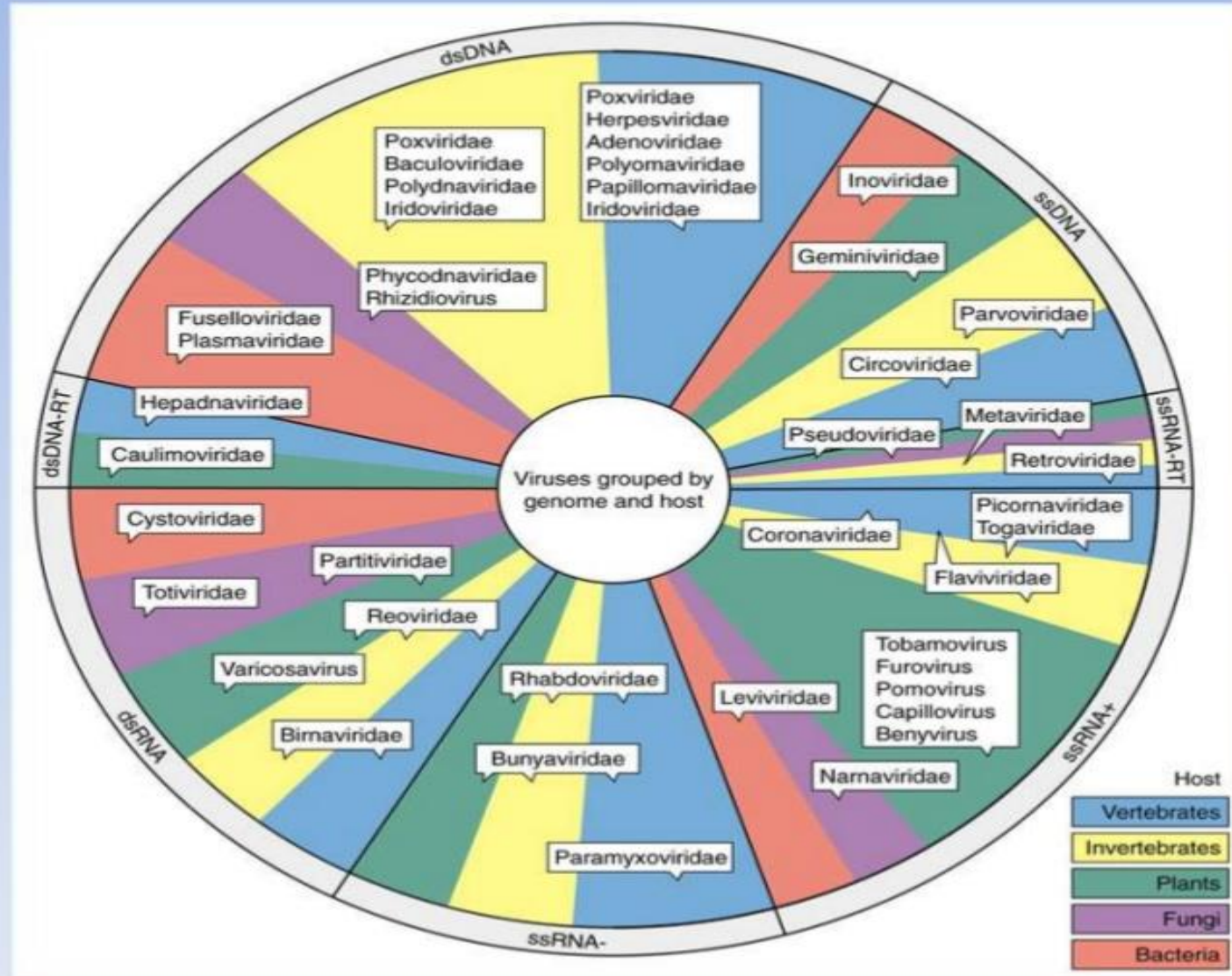
Retroviruses

Hepadnaviruses



# Baltimore classification

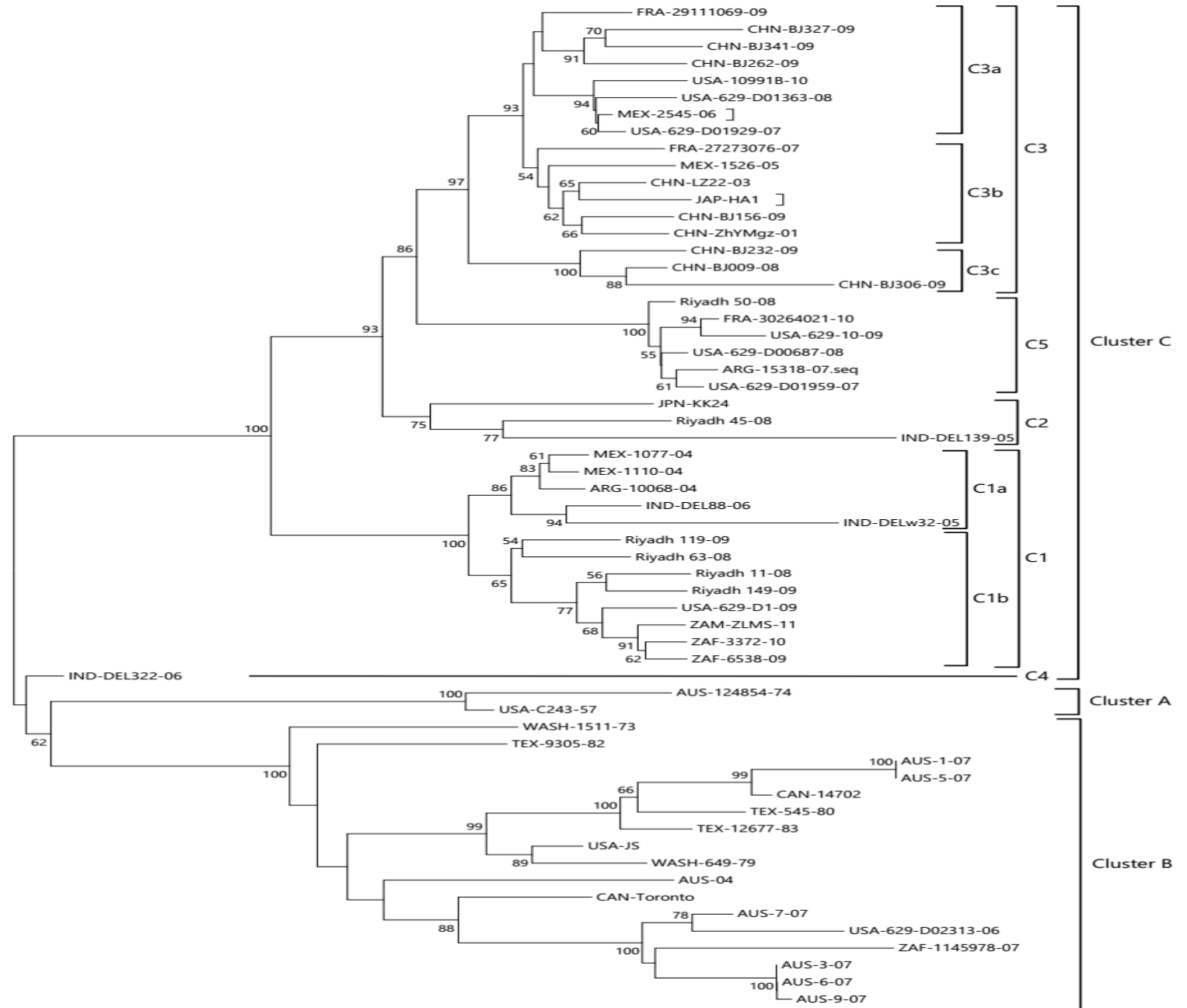
## BALTIMORE CLASSIFICATION



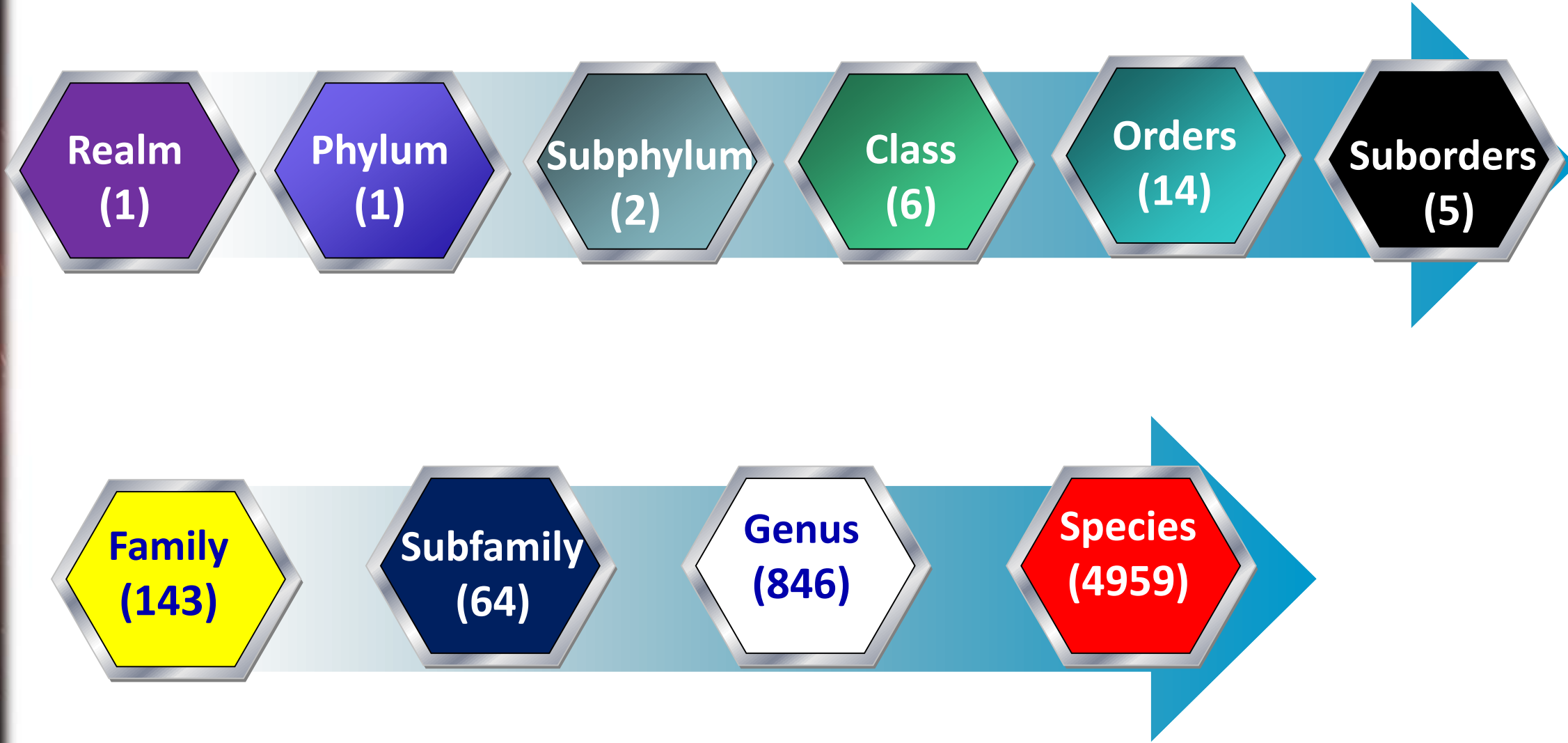
# Phylogenetic Classification



## Phylogenetic Tree of Human Parainfluenza type 3 virus



# ICTV, 2019





# ICTV, 2019

Realm (-viria)

Riboviria

Phylum (-viricota)

Negarnaviricota

Subphylum (-viricotina)

Haploviricotina

Polyploviricotina

Order (-virales)

Nidovirales

Suborder (-virineae)

Cornidovirineae

Family (-viridae)

Cornidovirineae

Subfamily (-virinae)

Orthocoronavirinae

Genus (-virus)

Specific level of classification

Species



# USVT

- Order: ends with suffix (Virales)  
Order: Mononegavirales
- Suborder (-virineae)
- Family: ends with suffix (Viridae)  
Family Poxviridae - Picornaviridae
- Subfamily: ends with suffix (Virinae)  
Subfamily: Chordopoxvirinae
- Genus: ends with suffix (Virus)





## ❖ **Key Points**

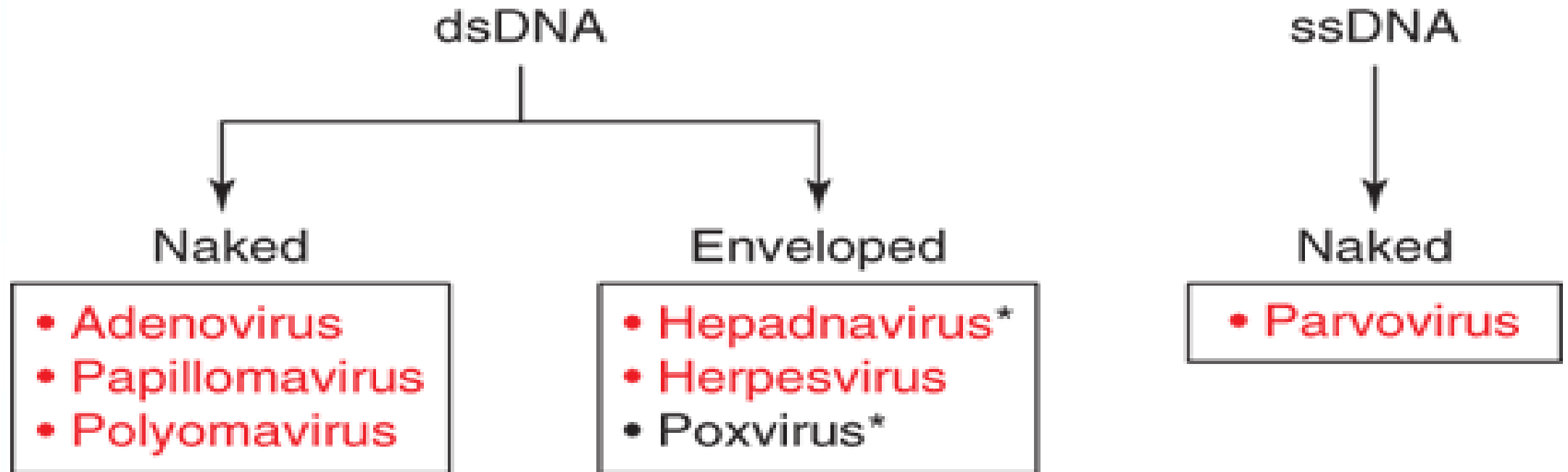
- ❖ The type of genetic material, either DNA or RNA, and whether its structure is single- or double-stranded, linear or circular, and segmented or non-segmented are factors for classification.
- ❖ Virus capsids can be classified as naked icosahedral, enveloped icosahedral, enveloped helical, naked helical, and complex.
- ❖ Virus can either have an envelope or not.
- ❖ A more recent system, the Baltimore classification scheme, groups viruses into seven classes according to how the mRNA is produced during the replicative cycle of the virus.

## ❖ **Key Terms**

- ❖ **Baltimore classification:** a classification scheme that groups viruses into seven classes according to how the mRNA is produced during the replicative cycle of the virus
- ❖ **messenger RNA:** Messenger RNA (mRNA) is a molecule of RNA that encodes for a protein product.



# DNA VIRUSES



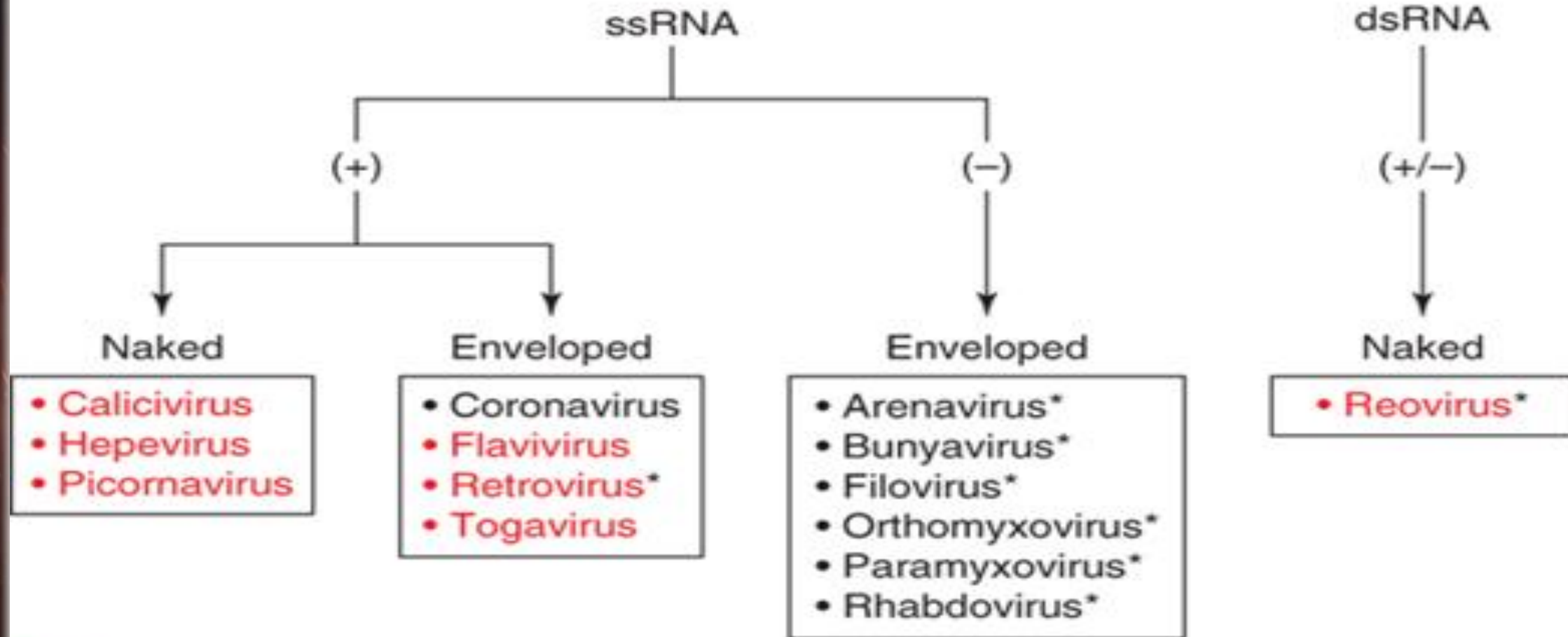
**Red** = icosahedral symmetry  
(Poxvirus has complex symmetry)

\*Viruses labeled with asterisk  
have a polymerase in the virion

Source: Warren Levinson: Review of Medical Microbiology  
and Immunology, 14th Edition, [www.accessmedicine.com](http://www.accessmedicine.com)  
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# RNA VIRUSES



Red = icosahedral symmetry  
(All others have helical symmetry)

\* Viruses labeled with asterisk  
have a polymerase in the virion

Source: Warren Levinson: Review of Medical Microbiology  
and Immunology, 14th Edition, [www.accessmedicine.com](http://www.accessmedicine.com)  
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## Classification of DAN Viruses

Virus Family	Envelope Present	Capsid Symmetry	DNA Structure <sup>1</sup>	Medically Important Viruses
Parvovirus	No	Icosahedral	SS, linear	B19 virus
Polyomavirus	No	Icosahedral	dS, circular, supercoiled	JC virus, BK virus
Papillomavirus	No	Icosahedral	dS, circular, supercoiled	Human papillomavirus
Adenovirus	No	Icosahedral	dS, linear	Adenovirus
Hepadnavirus	Yes	Icosahedral	dS, incomplete circular	Hepatitis B virus
Herpesvirus	Yes	Icosahedral	dS, linear	Herpes simplex virus, varicella-zoster virus, cytomegalovirus, Epstein-Barr virus
Poxvirus	Yes	Complex	dS, linear	Smallpox virus, molluscum contagiosum virus



## Classification of DAN Viruses

### DNA Viruses

- Sometimes referred to as the HHAPPPy viruses:
- Herpes
- Hepadna
- Adeno
- Papova
- Parvo
- **Pox**
- **Most DNA viruses are double-stranded, show icosahedral symmetry, and replicate in the nucleus.**

### DNA Viruses

- **Two DNA viruses break these rules:**
  - 1) **Parvoviridae: This virus is so simple that it only** has a single strand of DNA
  - 2) **Poxviridae: This virus is at the opposite end of the spectrum and is extremely complex.** Although it does have double-stranded DNA, the DNA is complex in nature, coding for hundreds of proteins. This virus does not have icosahedral symmetry. The DNA is surrounded by complex structural proteins looking much like a box (**POX IN A BOX**). **This virus replicates in the cytoplasm**

## DNA Viruses

**Three of the DNA viruses have envelopes:**

- Herpes Hepadna Pox

**Three are naked: A woman must be naked for the PAP smear exam.**

- PApova Adeno PArvo





## Classification of RNA Viruses

Virus Family	Envelope Present	Capsid Symmetry	RNA Structure <sup>1</sup>	Medically Important Viruses
Picornavirus	No	Icosahedral	SS linear, nonsegmented, positive polarity	Poliovirus, rhinovirus, hepatitis A virus
Hepevirus	No	Icosahedral	SS, linear, nonsegmented, positive polarity	Hepatitis E virus
Calicivirus	No	Icosahedral	SS linear, nonsegmented, positive polarity	Norovirus
Reovirus	No	Icosahedral	DS linear, 10 or 11 segments	Rotavirus
Flavivirus	Yes	Icosahedral	SS linear, nonsegmented, positive polarity	Yellow fever virus, dengue virus, West Nile virus, hepatitis C virus
Togavirus	Yes	Icosahedral	SS linear, nonsegmented, positive polarity	Rubella virus
Retrovirus	Yes	Icosahedral	SS linear, 2 identical strands (diploid), positive polarity	HIV, human T-cell leukemia virus
Orthomyxovirus	Yes	Helical	SS linear, 8 segments, negative polarity	Influenza virus
Paramyxovirus	Yes	Helical	SS linear, nonsegmented, negative polarity	Measles virus, mumps virus, respiratory syncytial virus
Rhabdovirus	Yes	Helical	SS linear, nonsegmented, negative polarity	Rabies virus
Filovirus	Yes	Helical	SS linear, nonsegmented, negative polarity	Ebola virus, Marburg virus
Coronavirus	Yes	Helical	SS linear, nonsegmented, positive polarity	Coronavirus
Arenavirus	Yes	Helical	SS circular, 2 segments with cohesive ends, negative polarity	Lassa fever virus, lymphocytic choriomeningitis virus
Bunyavirus	Yes	Helical	SS circular, 3 segments with cohesive ends, negative polarity	California encephalitis virus, hantavirus
Deltavirus	Yes	Uncertain	SS circular, closed circle, negative polarity	Hepatitis delta virus



# RNA Viruses

There are certain generalities about RNA viruses, most of which are the opposite of DNA viruses. **Most RNA viruses are single-stranded (half are positive [+1 stranded, half negative [-1]), enveloped, show helical capsid symmetry, and replicate in the cytoplasm:**

- Toga
- Corona
- Retro
- Picorna
- Calici
- Reo

RRPTCC

- Orthomyxo
- Paramyxo
- Rhabdo
- Bunya
- Arena
- Fibo

OPRFAB



## RNA Viruses

- **Exceptions:**

- 1) Reoviridae are double-stranded
- 2) Three are nonenveloped: Picorna, Calici, and Reoviridae
- 3) Five have icosahedral symmetry: Reo, Picorn, Toga, Flavi, Calici (Rhabdo has helical symmetry but shaped like a bullet).
- 4) Two undergo replication in the nucleus: Retro, Orthomyxo.

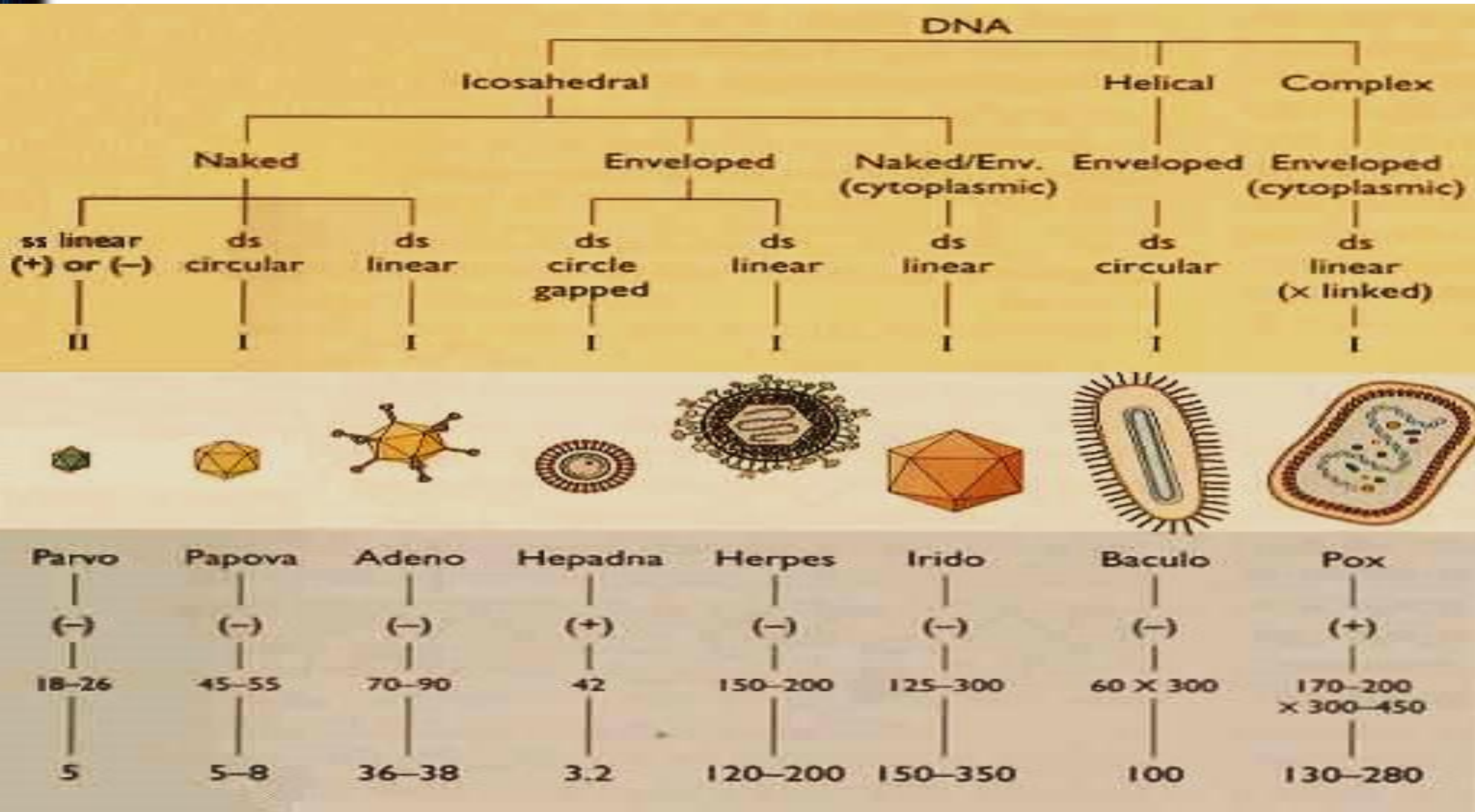


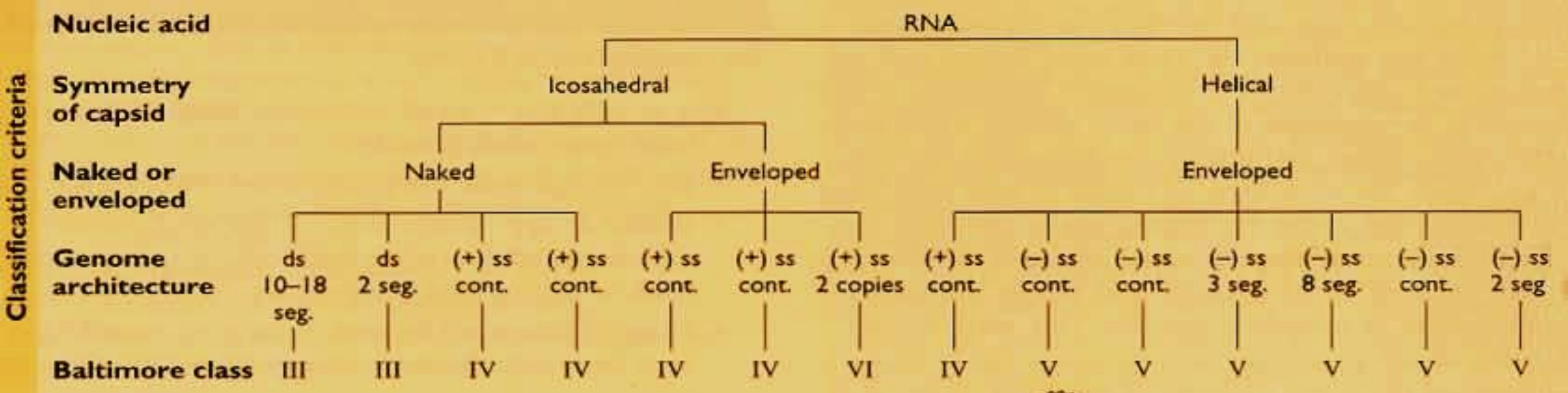
# RNA viruses (+ve sense) RNA viruses (-ve sense)

- Picornaviridae
- Togaviridae
- Flaviviridae
- Retroviridae

- Paramyxoviridae
- Rhabdoviridae
- Orthomyxoviridae
- Filoviridae
- Bunyaviridae
- Reoviridae (double-stranded)







**Properties**

<b>Family name</b>	Reo	Birna	Calici	Picorn	Flavi	Toga	Retro	Corona	Filo	Rhabdo	Bunya	Orthomyxo	Paramyxo	Arena
<b>Virion polymerase</b>	(+)	(+)	(-)	(-)	(-)	(-)	(+)	(-)	(+)	(+)	(+)	(+)	(+)	(+)
<b>Virion diameter (nm)</b>	60-80	60	35-40	28-30	40-50	60-70	80-130	80-160	80 x 790-14,000	70- 85 x 130-380	90-120	90-120	150-300	50-300
<b>Genome size (total in kb)</b>	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



The classification of viruses is based primarily on the nature of the genome and whether the virus has an envelope.

- ❖ Poxviruses, herpesviruses, and hepadnaviruses are DNA viruses with **an envelope**, whereas adenoviruses, polyomaviruses, papillomaviruses, and parvoviruses are DNA viruses non-envelope (i.e., they are naked nucleocapsid viruses). **Parvoviruses have single-stranded DNA**, whereas all the other families of DNA viruses have **double-stranded DNA**. The DNA of hepadnaviruses (hepatitis B virus) is mostly double-stranded but has a single-stranded region.
- ❖ Picornaviruses, hepeviruses, caliciviruses, and reoviruses are non- enveloped RNA viruses, whereas all the other families of RNA viruses **are an envelope**.
- ❖ Reoviruses have double-stranded **dsRNA**; all the other families of RNA viruses have single-stranded ssRNA.
- ❖ Reoviruses and influenza viruses have **segmented RNA**; all the other families of RNA viruses have non-segmented RNA.
- ❖ Picornaviruses, hepeviruses, caliciviruses, flaviviruses, togaviruses, retroviruses, and coronaviruses have **positive-polarity RNA**, whereas all the other families have **negative-polarity RNA**

1. What is the most specific level of classification
2. This is the science of classifying
3. What comes after Order in the classification system?
4. The Hierarchical Classification System scheme groups viruses according to---
5. The Baltimore classification scheme groups viruses according to -----?
6. Size and symmetry of the virus capsid are considered basic features for virus classification by:
7. Class III of the Baltimore classification system contains dsRNA viruses. Which of the following statements about this class is TRUE?
8. Which of the lists below has all of the levels of virus classification in the correct order?
9. Double-stranded DNA is found in which viruses?
10. Double-stranded RNA is found in which viruses?
11. Single-stranded positive sense RNA(+) RNA is found in which viruses?
12. Single-stranded negative sense (-) RNA is found in which viruses?
13. State the basis of Baltimore classification of viruses?
14. Viruses are often classified based on the type of genetic material and its structure. In the Baltimore classification scheme, the \_\_\_\_\_ virus has a single-stranded RNA (-) genome.
15. What is the ONLY DNA virus family that contain reverse transcriptase?
16. All RNA virus families have single stranded RNA (SS RNA) genome EXCEPT?
17. What is the ONLY DNA virus family that has single stranded DNA (SS DAN) genome ?
18. Which classification category is indicated by suffix 'Virinae'
19. All RNA virus families are an envelope EXCEPT?





## Questions

Match the Baltimore Classification group to the viral genome

Genome	Group (Roman Numerals)
Double stranded RNA	
Single stranded, positive sense RNA (ss+RNA)	
Double stranded DNA	
Single stranded, negative sense RNA (ss-RNA)	
Single stranded DNA	
Double stranded DNA with reverse transcriptase (RT)	
Single stranded, positive sense RNA (ss+RNA) with reverse transcriptase (RT)	





# TAKE HOME MESSAGES

**Stop being afraid of what could go wrong, and think of what could go right**



Thank  
You