The expansion of virosphere in the age of metagenomics and consequences in the virus taxonomy and nomenclature

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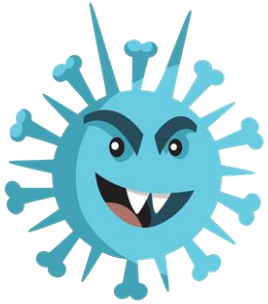
In this talk we will:

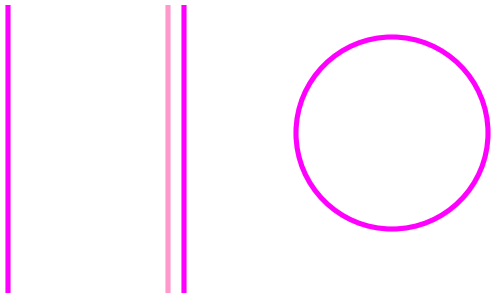
- Review the definitions of viral particle, virion and virus
- See how viruses were named before
- Learn about the impact of metagenomics in virus taxonomy
- Learn about new criteria and ways of naming viruses

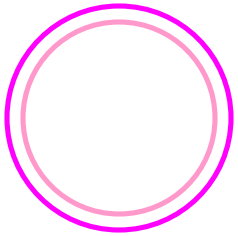


- **What are viruses made of?**

  - **virus genome**

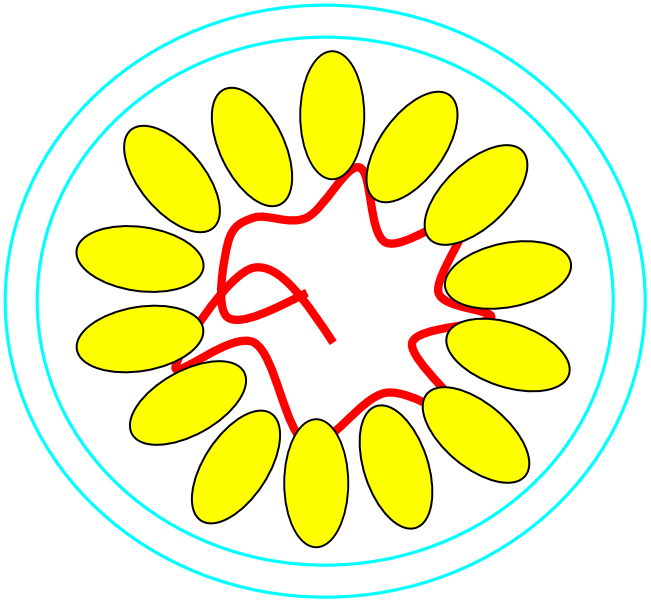
DNA **or** **RNA**

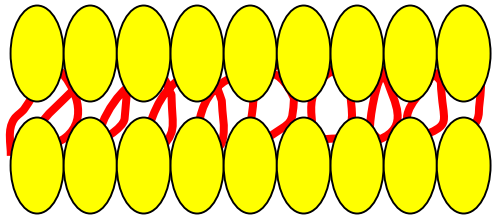




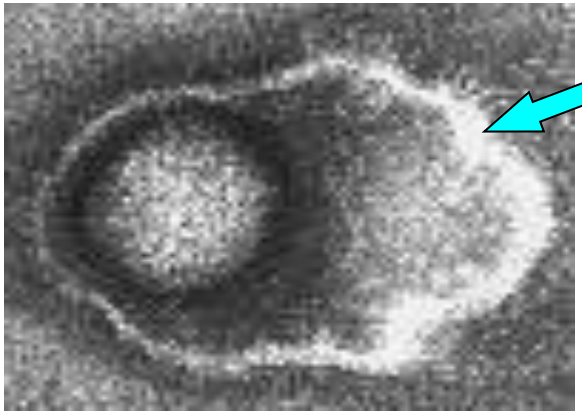
- single stranded, ss (+ or – in RNA)
- double stranded, ds
- linear, l
- circular, c

- **What are viruses made of?**
  - **genome**
  - **capsid (a shell made of protein subunits)**



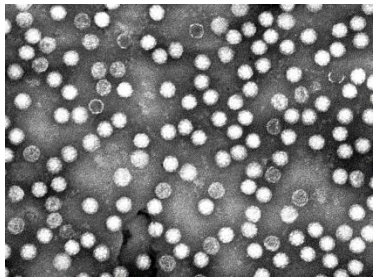


- **viral envelope (toga, peplos) rare in phytoviruses and bacteriophages, cellular origin, a hallmark of complex virus particles**

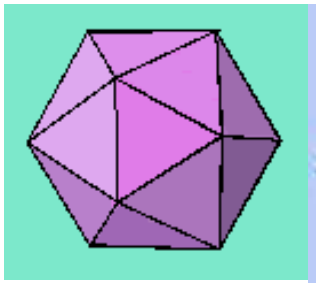


human herpesvirus 1 envelope

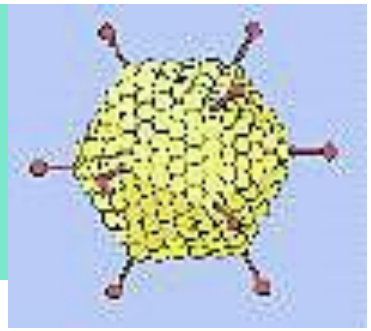
• Some examples of simple and complex viral particles



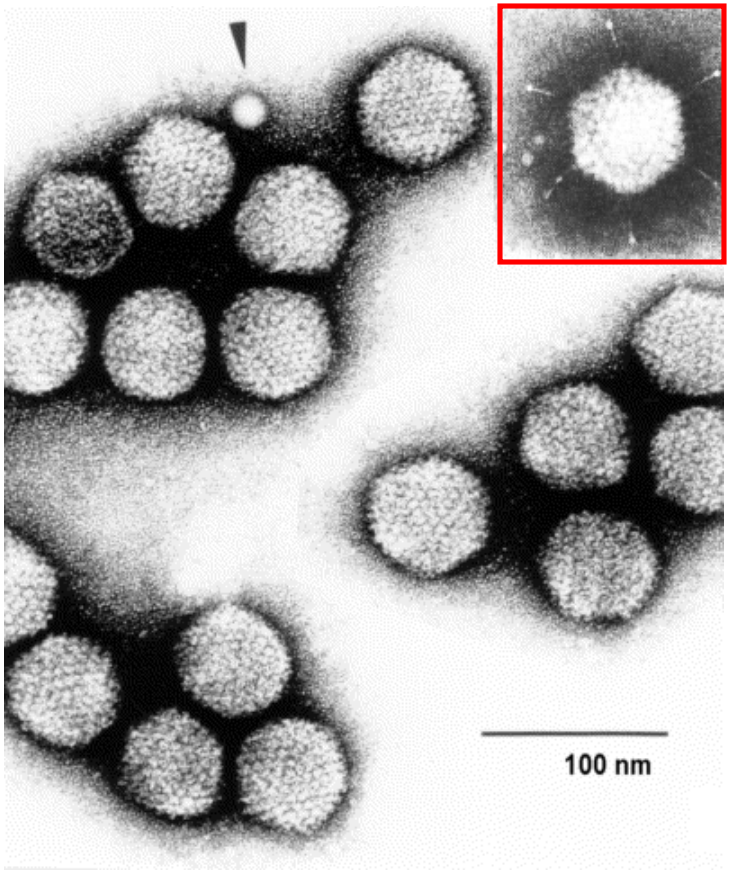
TYMV, 30nm

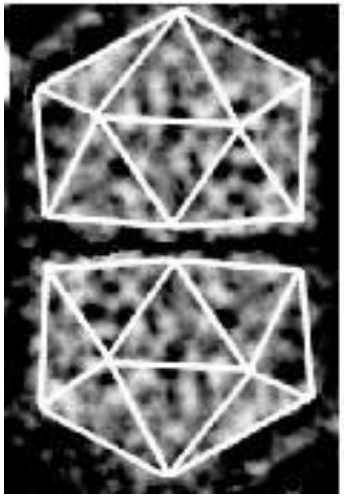


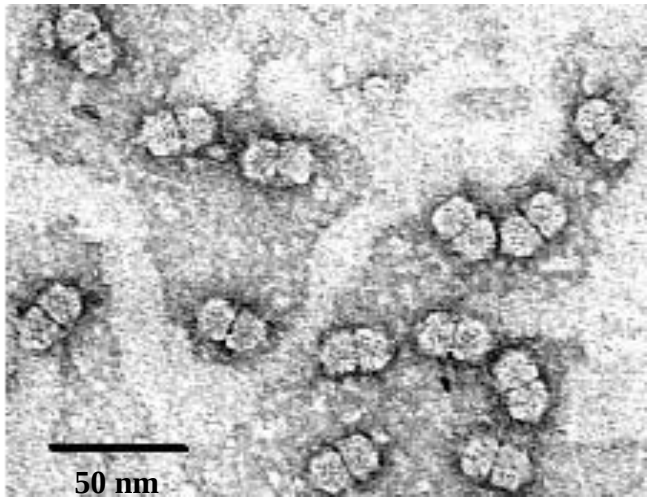
icosahedron



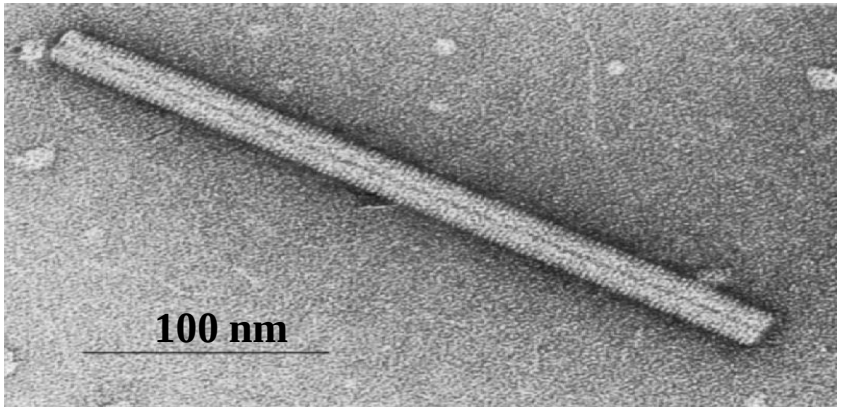
adenovirus





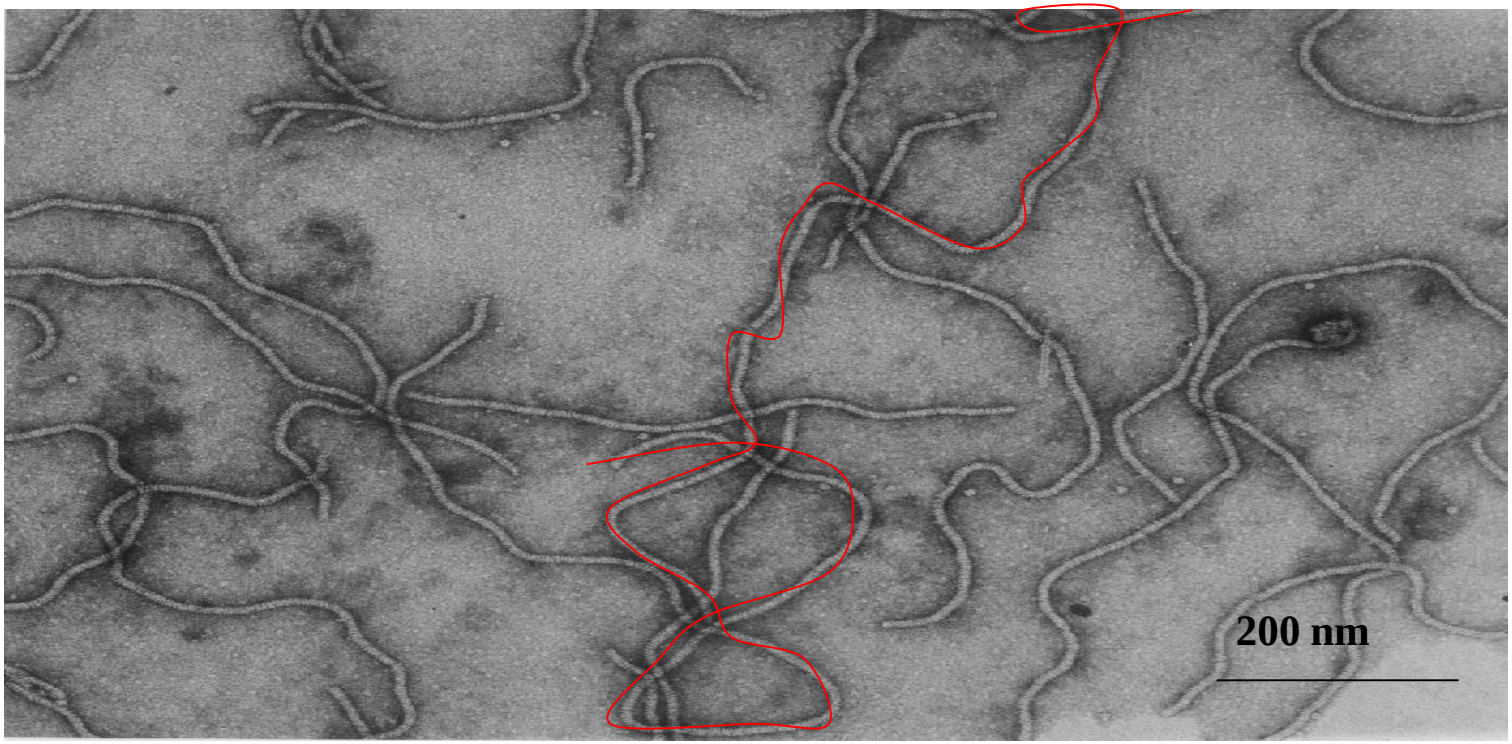


maize streak virus, 18x30 nm



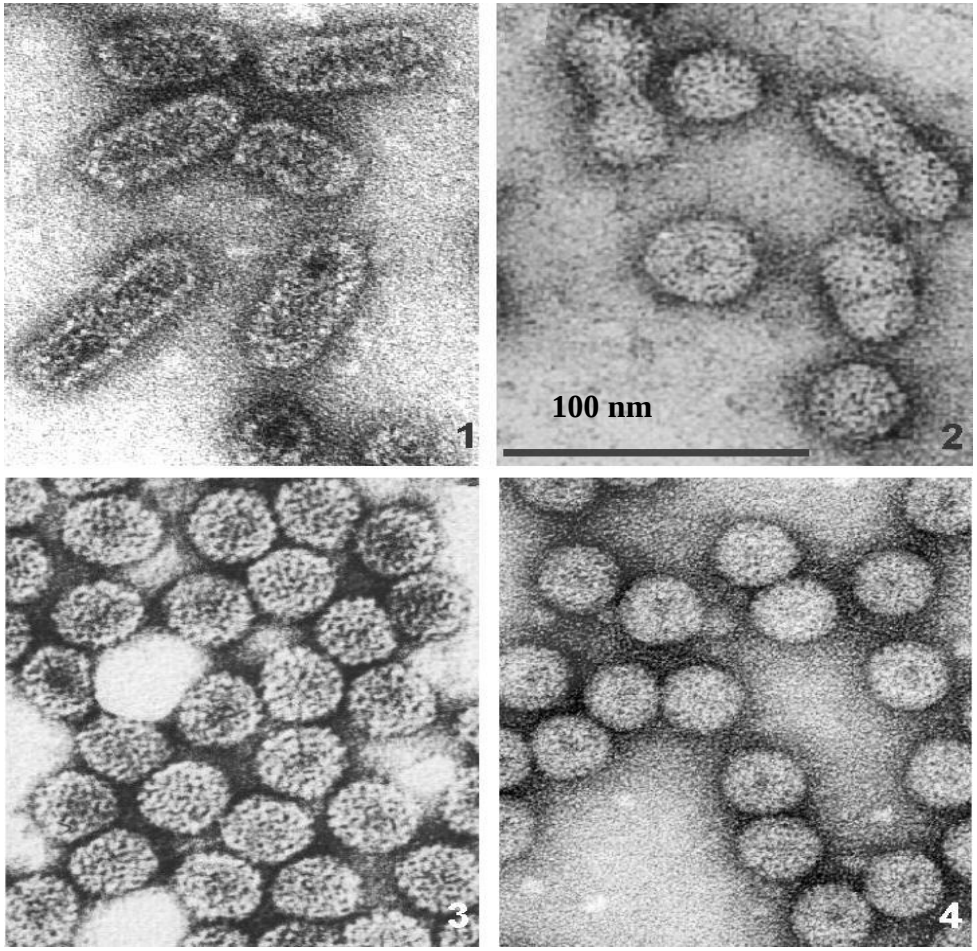
TMV

300x18 nm, rod like (rigid anisometric virion)



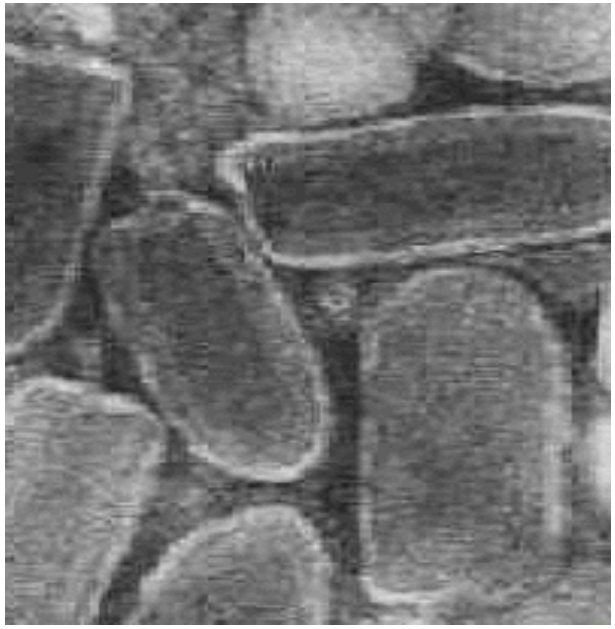
citrus tristeza virus (CTV), *Closteroviridae*

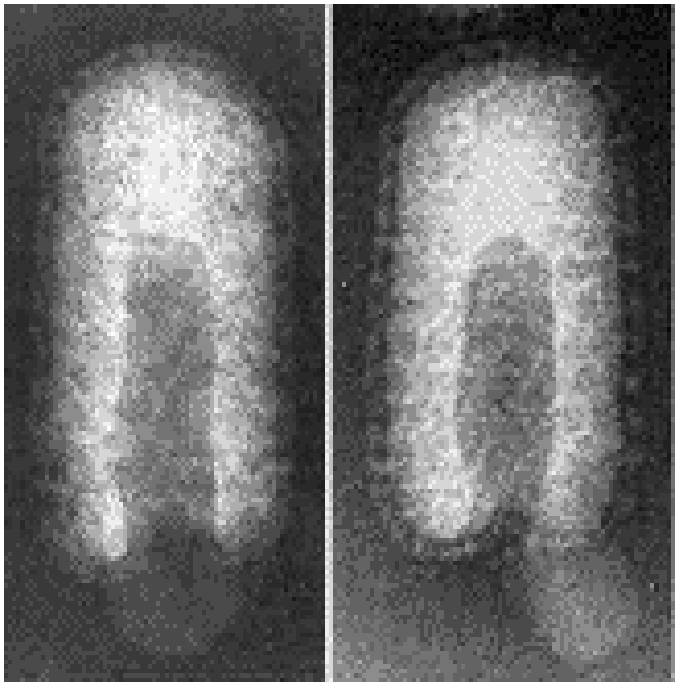
3000x11 nm, threadlike (flexible anisometric virion)



Bromoviridae

pleomorphic simple viral particles





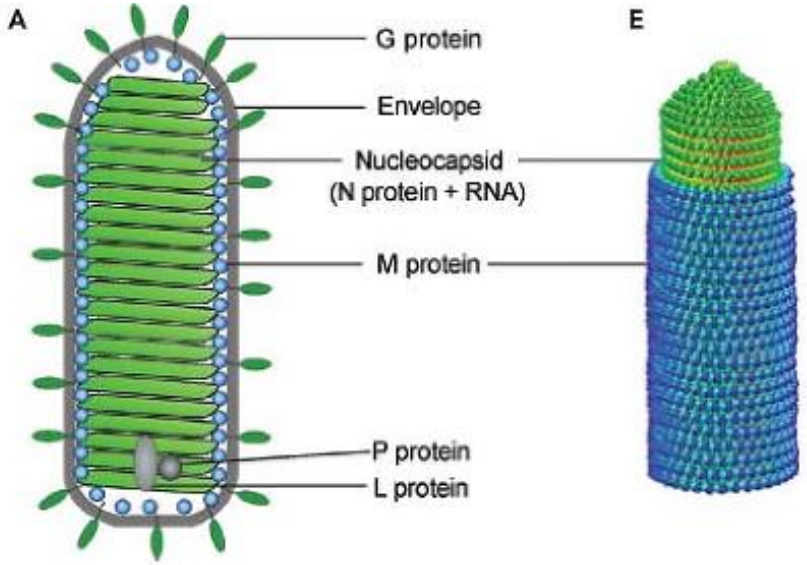
Rhabdoviridae **(rabies and related mammals, fish, insect and plant viruses)**

Complex virions:

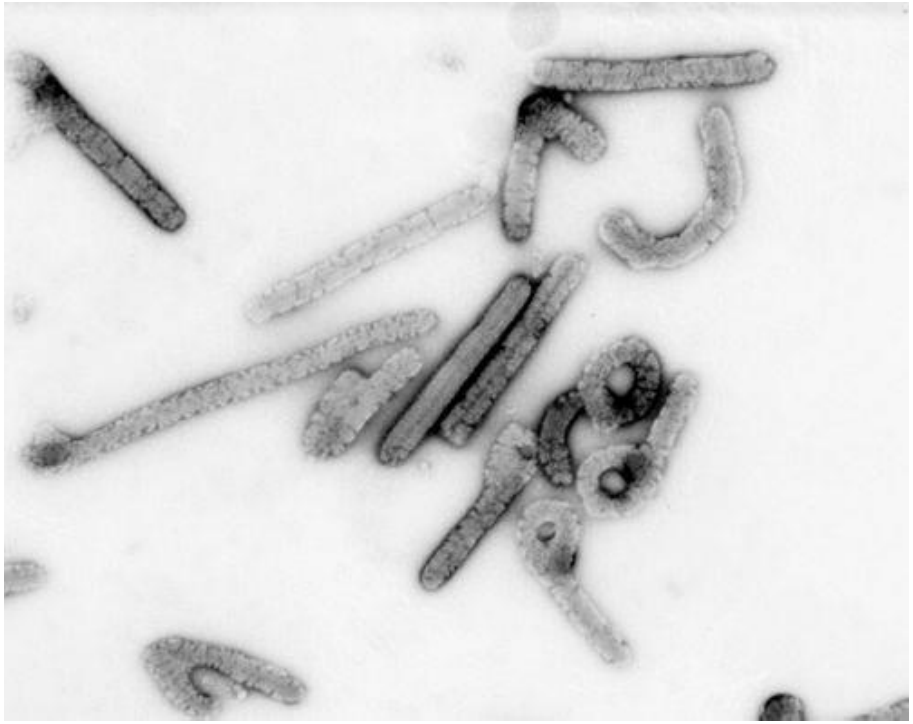
envelope (toga, peplos) with spikes (projections, peplomeres)

nucleocapsid (core of genome+proteins)

additional elements (matrix, tegument)



EBOV



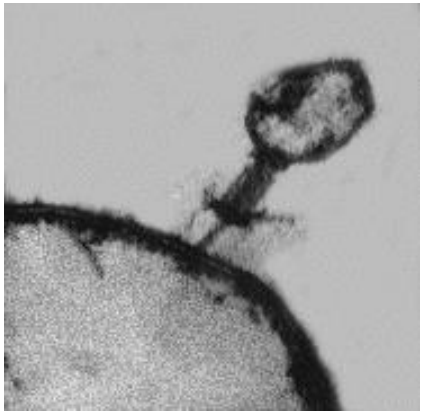
MARV

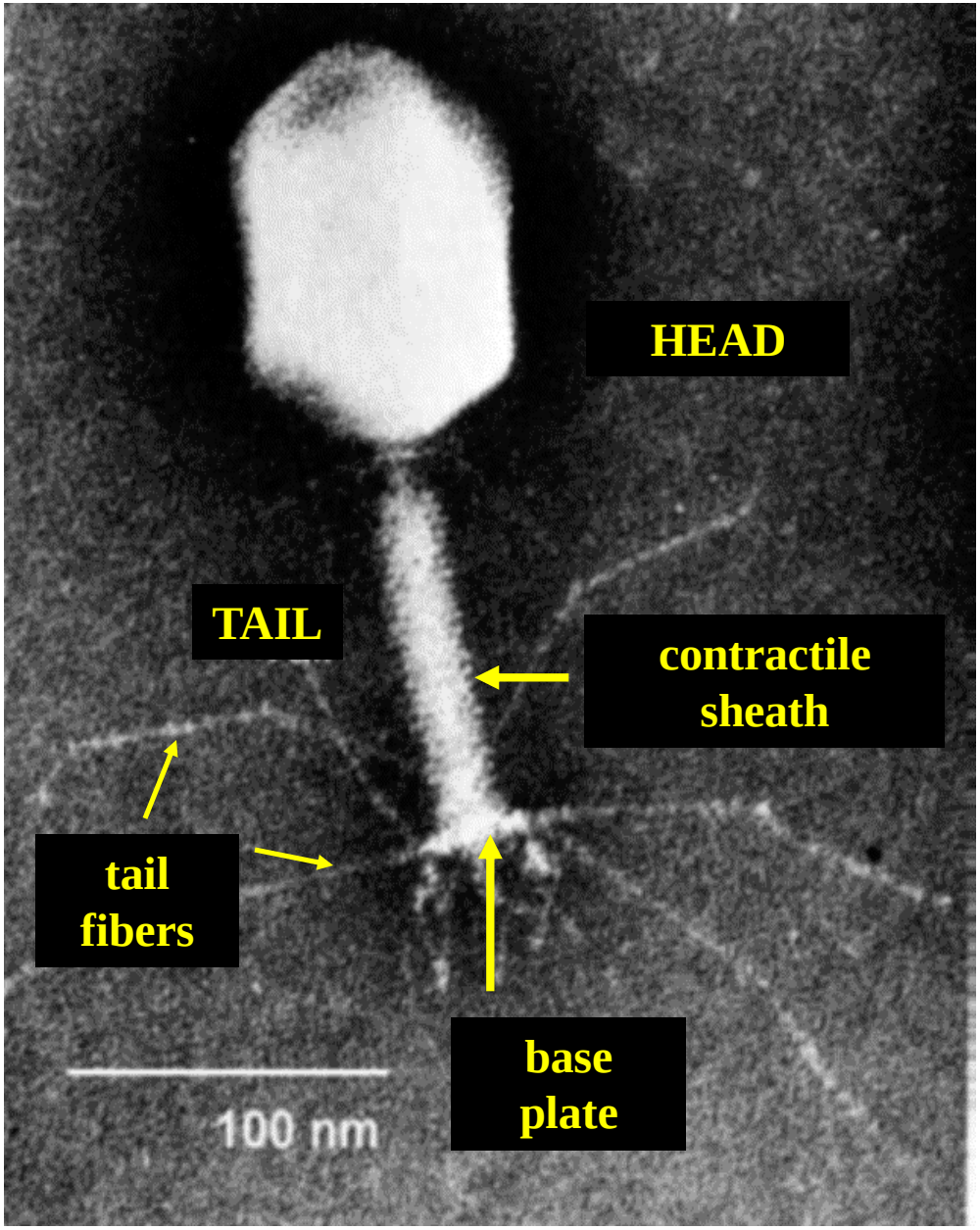
- **both have enveloped and pleomorphic virions (6, U, circle), up to 1400x80 nm**

100 000x (R. Regner, NCIP, CDC)

Bacterio(phage) particles:

phage T4 (*Escherichia coli*)





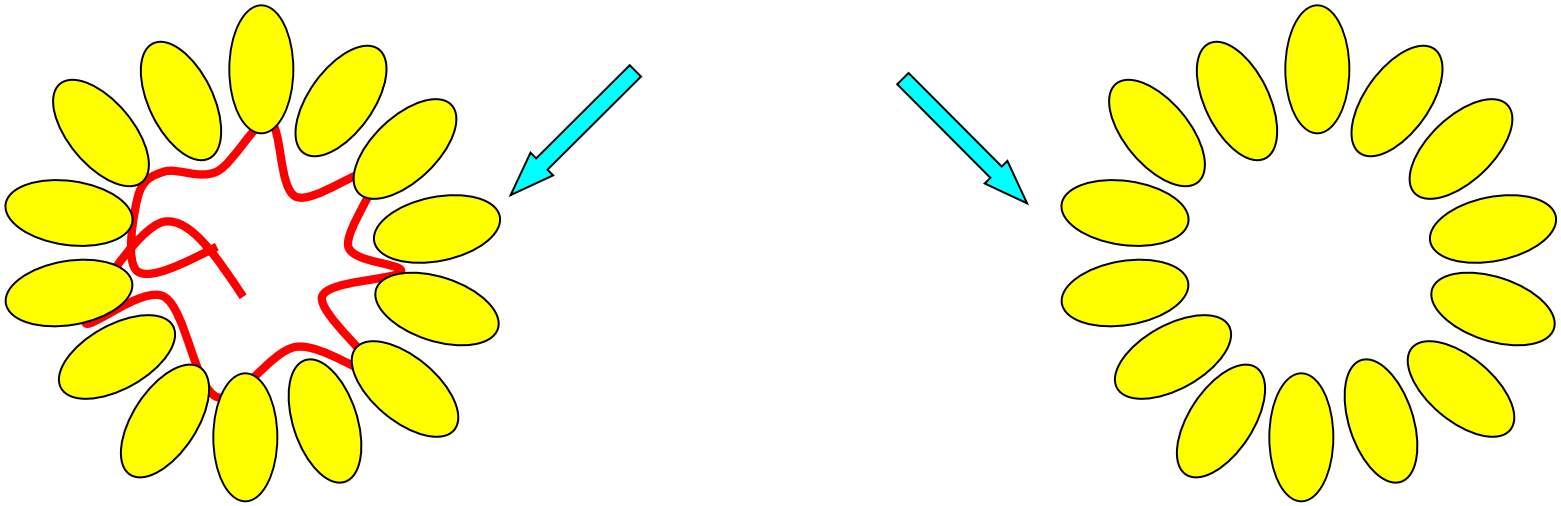
filamentous: M13, fd, f1

spherical: ϕX174

Exceptions – very complex virions, unusally structured (e.g. giant viruses)

- **What is a virion?**

virus particle = “body” of a virus



“full”, normal/functional, infectious

“empty”, defective, noninfectious

Virion = free (extracellular) and intact viral particle able to infect a host cell (fit for replication in a host and transmission in nature).

- **Definitions of a virus:**

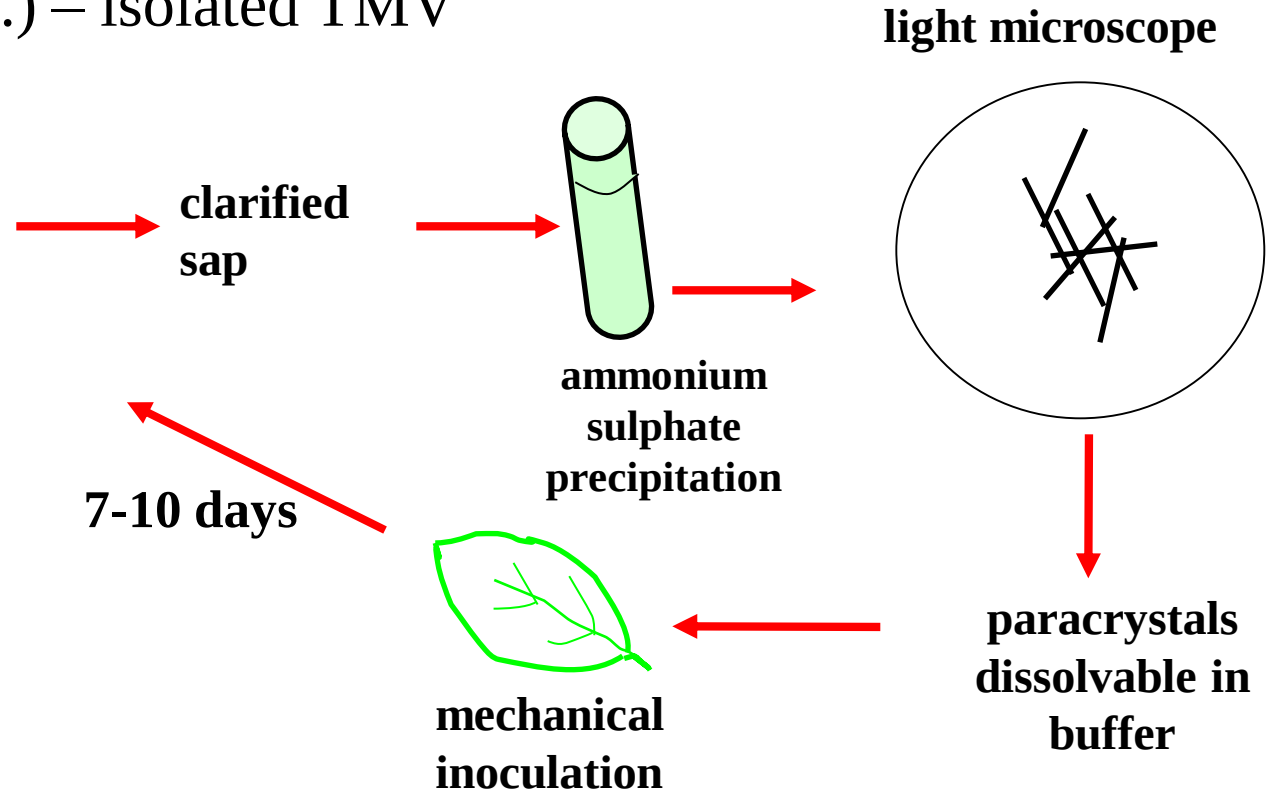
1. VIRUSES are infectious agents generally containing only one type of nucleic acid in a protein shell consisting of one or a few types of proteins and sometimes of lipoprotein envelope that can contain carbohydrates.

Viruses are capable of transmitting its own genetic blueprint, subvert host cell machinery for its replication. Some of them can integrate into the host genome and become latent or persistent. Some can transform cells, perturb cellular growth control mechanisms and cause tumors.

2. In short…the smallest independently replicating biological entities made of nucleic acids and proteins parasitizing translational machinery of the host cell.

- **Are viruses alive?**

W. Stanley (1935.) – isolated TMV



- pure agent isolated, forms crystals, infectious soluble crystals (replication)

⇒ **Viruses are on the borderline of living and nonliving worlds (old paradigm).**

•Living in „classical biology”:

A cell is the simplest form of life, all characteristics of life (reproduction, growth, metabolism, energy exchange with environment).

Viruses have no cellular structure!

• Living in modern biology:

Nucleic acids store genetic information (basis of inheritance) in living world, reproduction (through cells), dissemination, evolution and adaptation to various biological and abiotic conditions (habitats, ecological niches).

Viruses do all that!

What is then the definition of a virus?

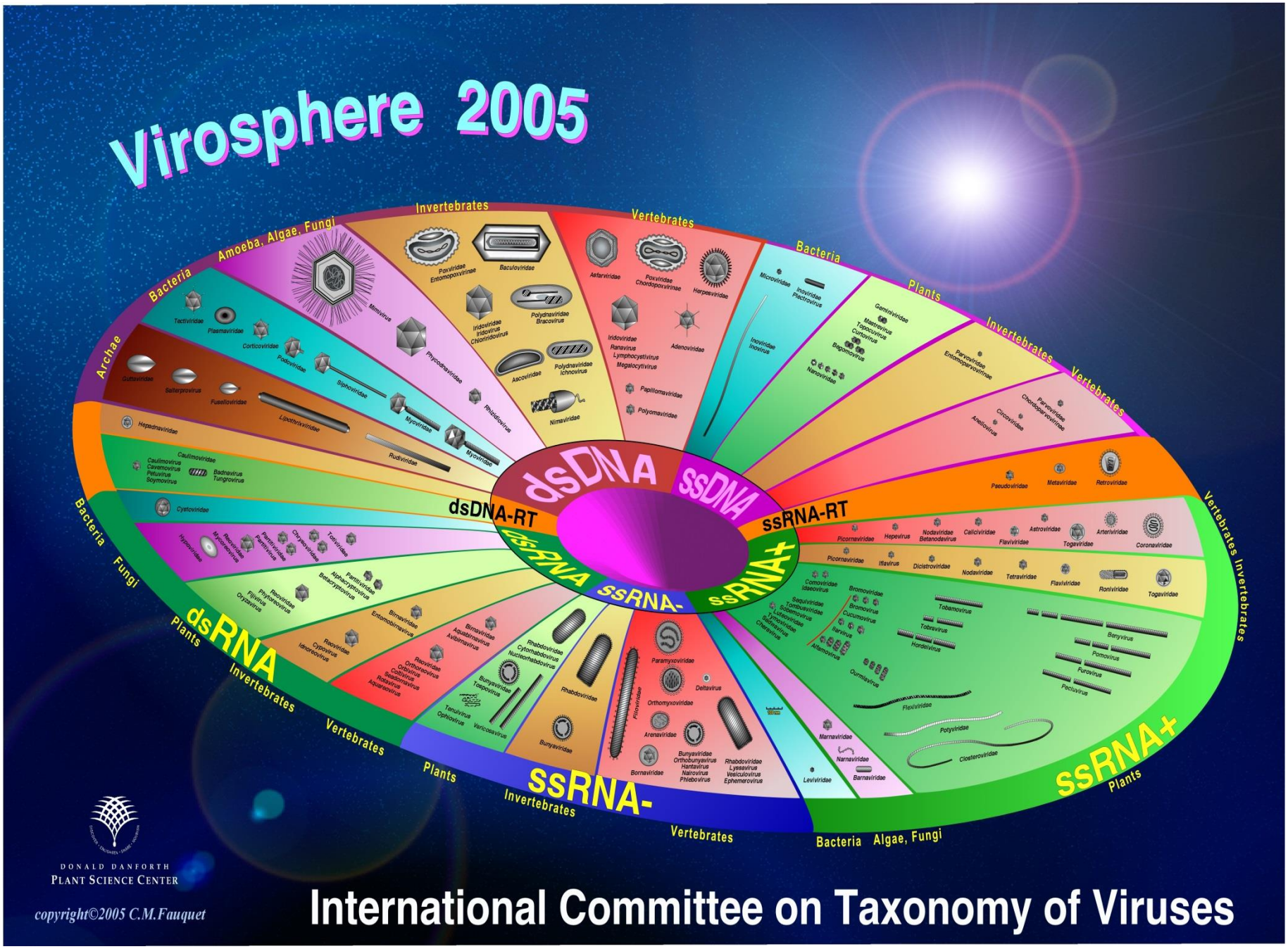
Virus particle – alone (without a host cell) cannot replicate.

Virus in a permissive cell – normal replication.

Virus is a „two-phase microbe” (Vincent Racaniello).

Dr. McCoy speaking to captain Kirk of the Starship Enterprise:

It’s life, Jim, but not as we know it!


Virosphere 2005
dsDNA
ssDNA
dsDNA-RT
ssRNA-RT
dsRNA
ssRNA-
ssRNA+
Archae
Bacteria
Amoeba, Algae, Fungi
Invertebrates
Vertebrates
Bacteria
Plants
Invertebrates
Vertebrates
Vertebrates Invertebrates
Bacteria Fungi
Plants
Invertebrates
Vertebrates
Plants
Invertebrates
Vertebrates
Bacteria Algae, Fungi
Plants
Poxviridae Entomopoxvirinae
Baculoviridae
Iridoviridae Iridovirus Chloriridovirus
Polydnaviridae Bracovirus
Ascoviridae
Polydnaviridae Ichnovirus
Nimaviridae
Asfarviridae
Poxviridae Chordopoxvirinae
Herpesviridae
Iridoviridae Ranavirus Lymphocystivirus Megalocytivirus
Adenoviridae
Papillomaviridae
Polyomaviridae
Microviridae
Inoviridae Plectrovirus
Inoviridae Inovirus
Geminiviridae Mastrevirus Topocuvirus Curtovirus Begomovirus
Nanoviridae
Parvoviridae Entomoparvovirinae
Parvoviridae Chordoparvovirinae
Circoviridae Anellovirus
Pseudoviridae
Metaviridae
Retroviridae
Picornaviridae
Hepevirus
Nodaviridae Betanodavirus
Caliciviridae
Astroviridae
Flaviviridae
Togaviridae
Arteriviridae
Coronaviridae
Picornaviridae
Iflavirus
Dicistroviridae
Nodaviridae
Tetraviridae
Flaviviridae
Ronivirus
Togaviridae
Comoviridae Idaeovirus
Sequiviridae Sadwavirus Sequivirus Ullavirus
Tymoviridae Maculavirus Tymovirus
Bromoviridae
Bromovirus
Cucumovirus
Ilarvirus
Alfamovirus
Oumivirus
Tobamovirus
Tobravirus
Hordeivirus
Benyvirus
Pomovirus
Furovirus
Pecluvirus
Flexiviridae
Potyviridae
Closteroviridae
Marnaviridae
Narnaviridae
Barnaviridae
Levivirus
Hypoviridae
Reoviridae Mycoreovirus
Partitiviridae Partitivirus
Chrysoviridae
Totiviridae
Partitiviridae Alphacryptovirus Betacryptovirus
Reoviridae Phytoreovirus Fijivirus Oryzavirus
Birnaviridae Entomobirnavirus
Reoviridae Cypovirus Idnoreovirus
Birnaviridae Aquabirnavirus Avibirnavirus
Reoviridae Orthoreovirus Coltivirus Seadornavirus Rotavirus Aquareovirus
Rhabdoviridae Cytorhabdovirus Nucleorhabdovirus
Bunyaviridae Tospovirus
Tenuivirus Ophiovirus
Varicosavirus
Rhabdoviridae
Bunyaviridae
Paramyxoviridae
Deltavirus
Filoviridae
Orthomyxoviridae
Arenaviridae
Bornaviridae
Bunyaviridae Orthobunyavirus Hantavirus Nairovirus Phlebovirus
Rhabdoviridae Lyssavirus Vesiculovirus Ephemerovirus
Mimivirus
Phycodnaviridae
Rhizidiovirus
Tectiviridae
Plasmaviridae
Corticoviridae
Podoviridae
Siphoviridae
Myoviridae
Guttaviridae
Salterprovirus
Fuselloviridae
Lipothrixviridae
Rudiviridae
Hepadnaviridae
Caulimoviridae Caulimovirus Cavemovirus Petuvirus Soymovirus
Badnavirus Tungrovirus
Cyctoviridae
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International Committee on Taxonomy of Viruses

- **Virus nomenclature of the past and present**

BEFORE

- no binominal nomenclature mostly…
- nomenclature somewhat reflected classification according to hosts

animal viruses (human and animal hosts)

plant (phytoviruses)

fungal viruses (mycoviruses)

bacterial viruses ((bacterio)phages)

viruses of archaea

• Old nomenclature (still in vernacular names of viruses):

descriptive names according to the symptoms in hosts from which a virus was isolated for the first time,

according to a location of infection in an organism or disease type,

geographical area (toponym),

researcher name,

there were some Latinized ones…not consistent!

• English was the official naming language but not even that was consistently used!

smallpox virus, variola virus (VARV-IND)
Why not great pox virus?

• virus **acronyms** also part of the nomenclature…however…

CMV cucumber mosaic virus *(Cucumovirus)*
citomegalovirus (CMV, hCMV, mCMV), now human betaherpesvirus 5; human cytomegalovirus (HuBHV5; HCMV)

PPV precarious point virus, *Phlebovirus*, *Bunyaviridae*
Pyrus pyrifolia virus, *Partitiviridae*
porcine parvovirus, *Parvovirus*, *Parvovirinae*, *Parvoviridae*
plum pox virus, *Potyvirus*, *Potyviridae* (sharka disease)

Inconsistencies were/are a problem.

- Phage nomenclature:

Combinations of characters (letters, numbers)
usually mean something (T1, T7, Qβ, fd, Mu, λ)

What does Mu mean in a Mu phage name?

ICTV -International Committee on Taxonomy of Viruses

https://talk.ictvonline.org

Until 2017. – five rank system, genera according to the type species (Latinized suffixes):

*Mononega**virales*** - order

*Paramyxo**viridae*** - family

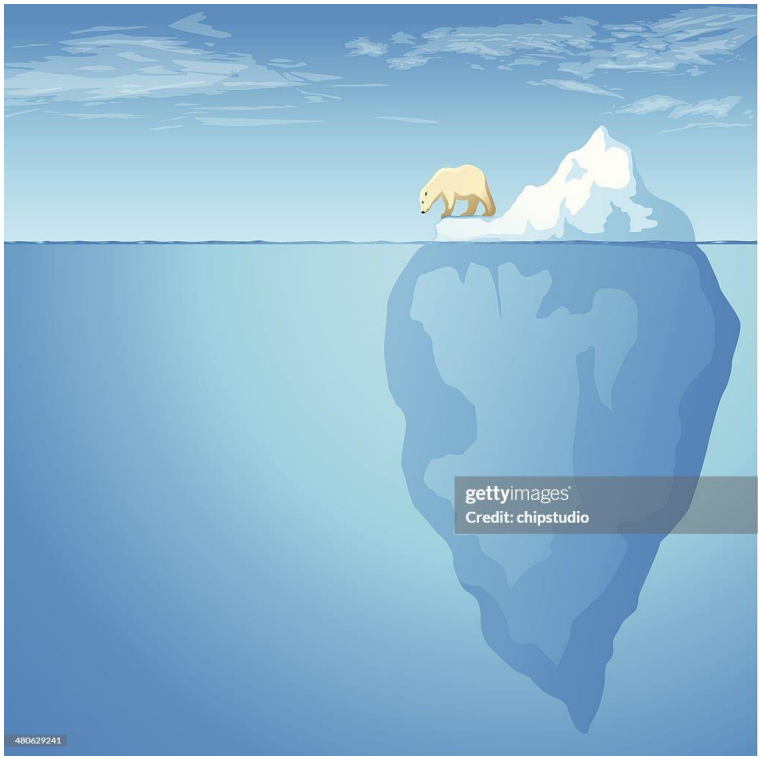
*Paramyxo**virinae*** - subfamily

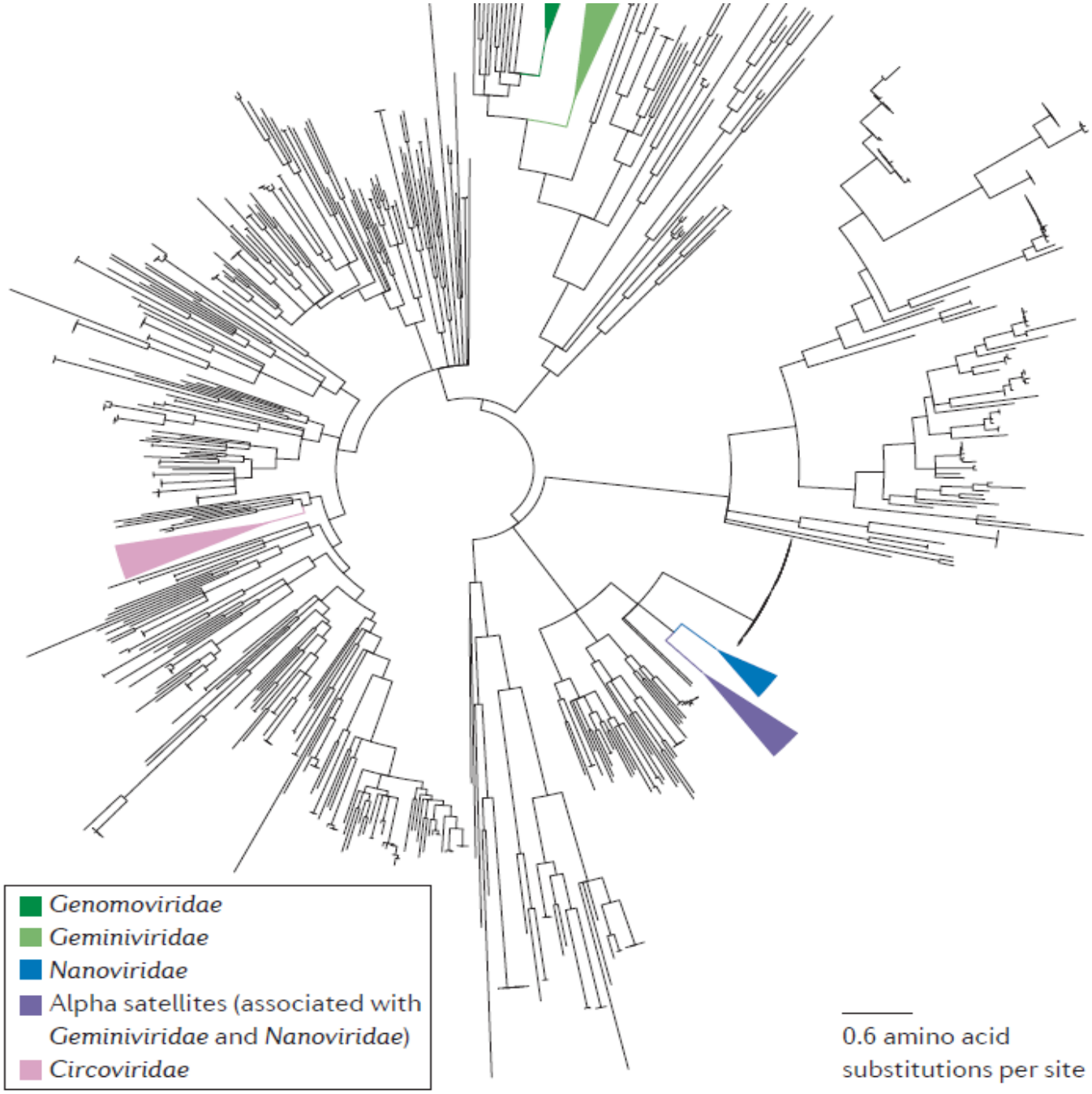
*Morbilli**virus*** – genus

measles virus (MeV) - virus name (vernacular, everyday)

What about the number of viruses and taxonomy NOW?

Metagenomic investigations have contributed immensely to the number of known viruses but also to the way we classify them and name them.





Initial metagenomic investigations revealed about 125.000 new viral genomes and enriched gene databases minimum 16x.

SsDNA and RNA viruses in sea environments are much more abundant than expected (circular Rep-encoding ssDNA viruses, CRESS-DNA).

International Committee on Taxonomy of Viruses – virus classification

- Before - genome type (DNA/RNA)
  virion symmetry (capsid)
  envelope
  particle size and shape
  (biology, genome organization, relationships)

- Modern - genome and genetic product relatedness (phylogeny)

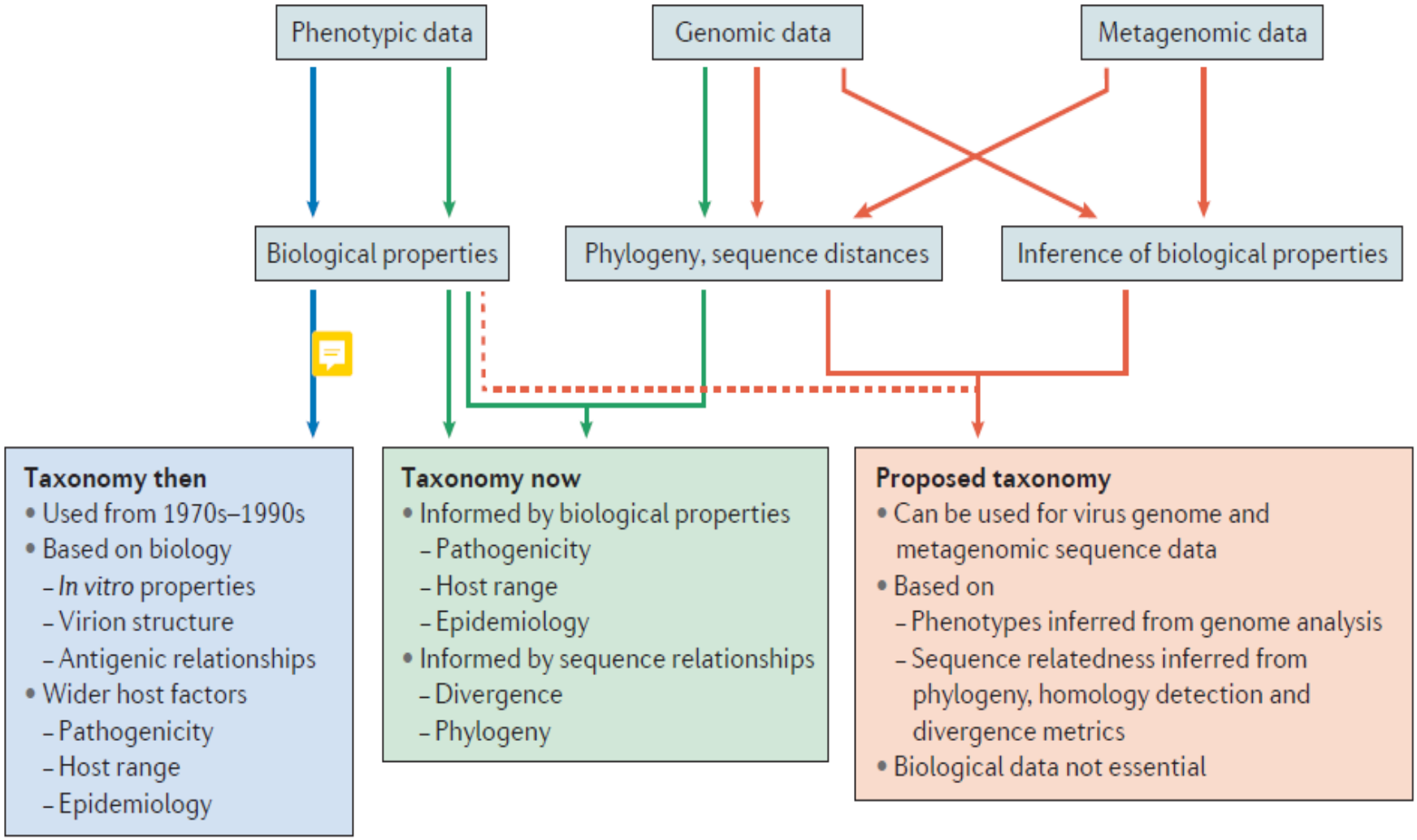
http://www.ictvonline.org/Report
Approved taxa - http://www.ictv.global/msl.htm

Simmonds *et al*. 2017, Virus taxonomy in the age of metagenomics (doi:10.1038/nrmicro.2016.177)

Some major proposals that may be of interest include (1) a restructuring of the bunyaviruses including 'promotion' of the family Bunyaviridae to an order Bunyavirales and the incorporation of some previously unassigned genera of plant viruses within the order; (2) classification of the betasatellites associated with many begomoviruses; (3) creation of various genera and species in the family Genomoviridae - the first family to be populated exclusively by viruses known only from metagenomic studies; (4) further major expansion of the phage order Caudovirales.
Mike Adams, ICTV Business Secretary

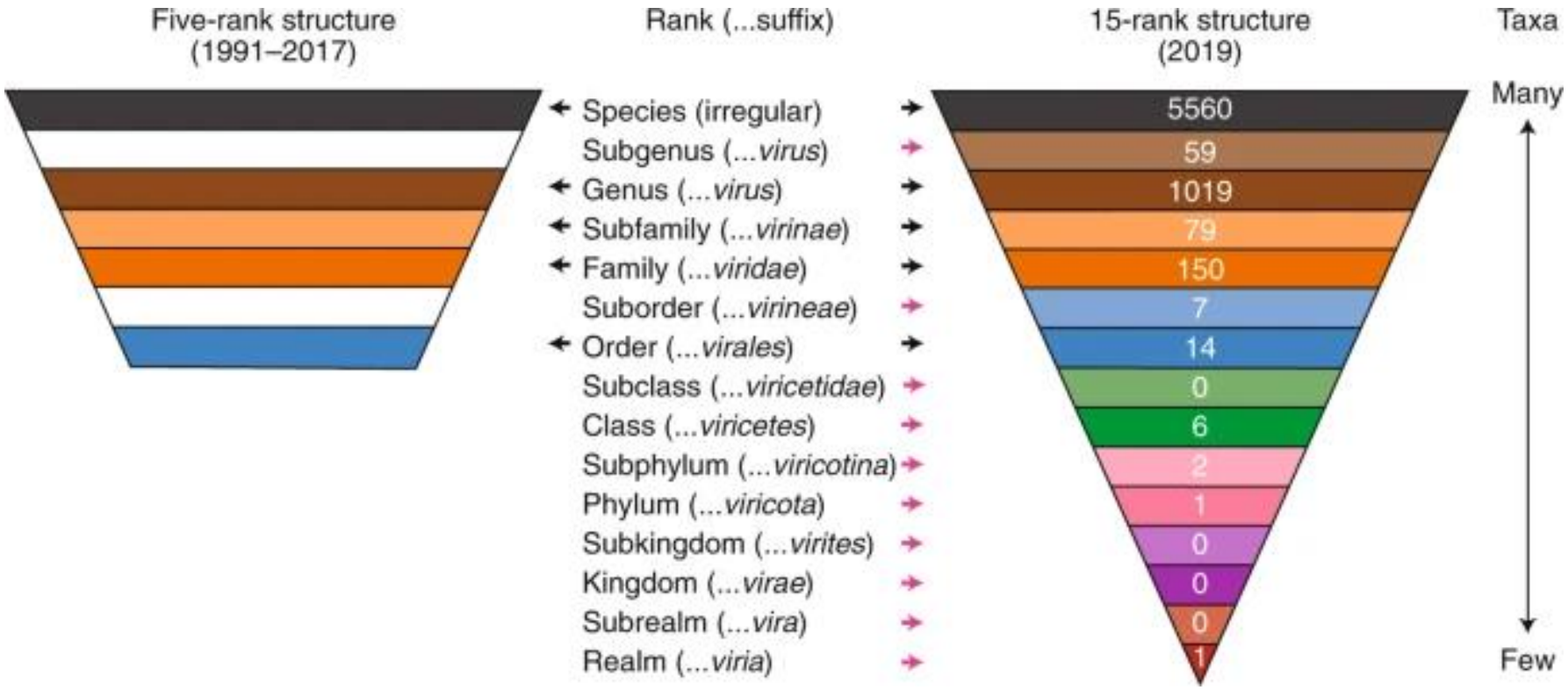
Virus taxonomy in the age of metagenomics

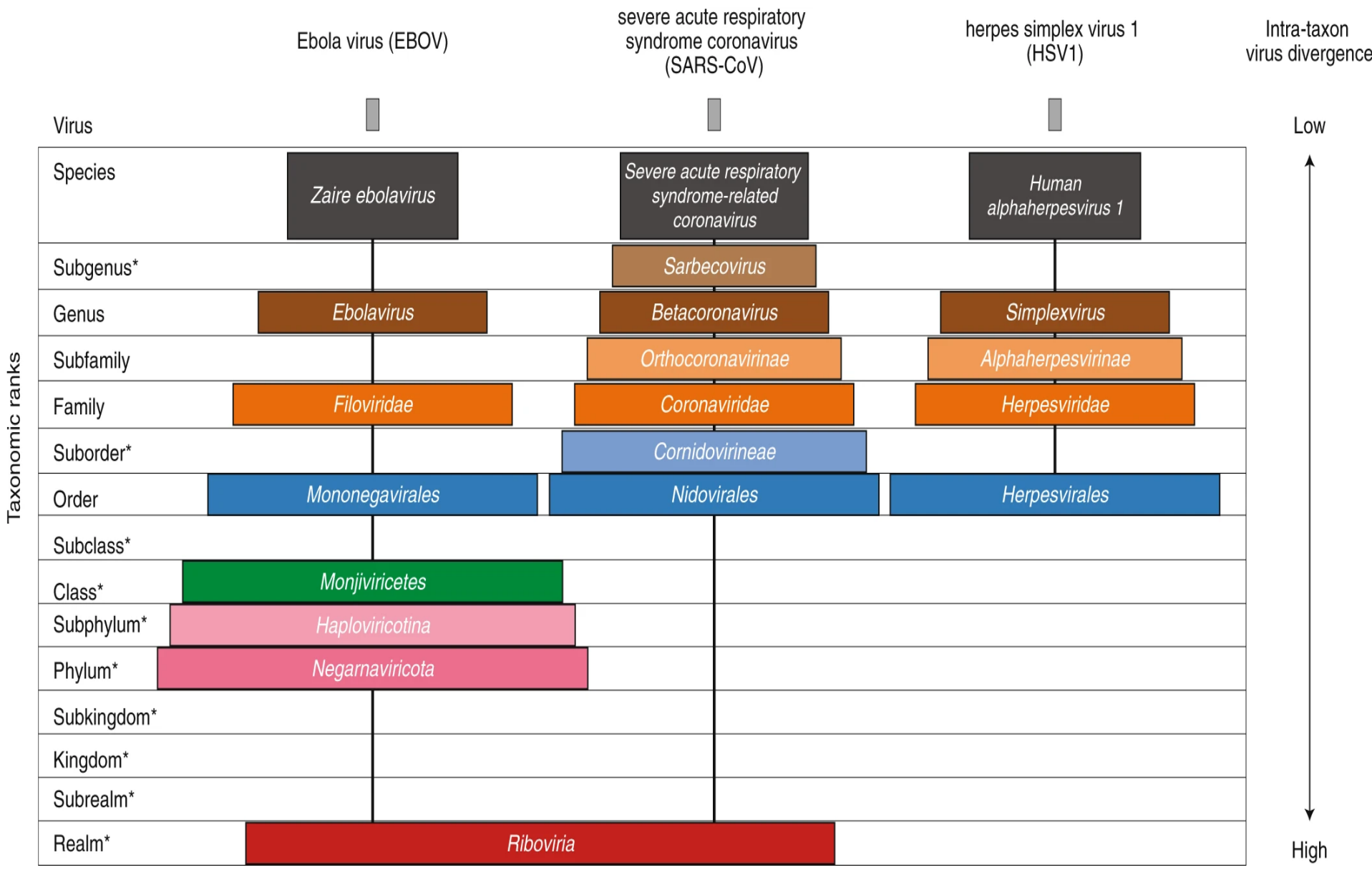
Simmonds et al. 2017, Nature Reviews Microbiology
doi:10.1038/nrmicro.2016.177



In the 2019, only 4958 virus species…constant changes and big leaps! Fifteen rank taxonomy, new viruses, virus name changes, no italic in naming viruses as physical entities.

ICTV, The new scope of virus taxonomy: partitioning the virosphere into 15 hierarchical ranks. Nature Microbiology 5: 668-674 (2020). https://doi.org/10.1038/s41564-020-0709-x





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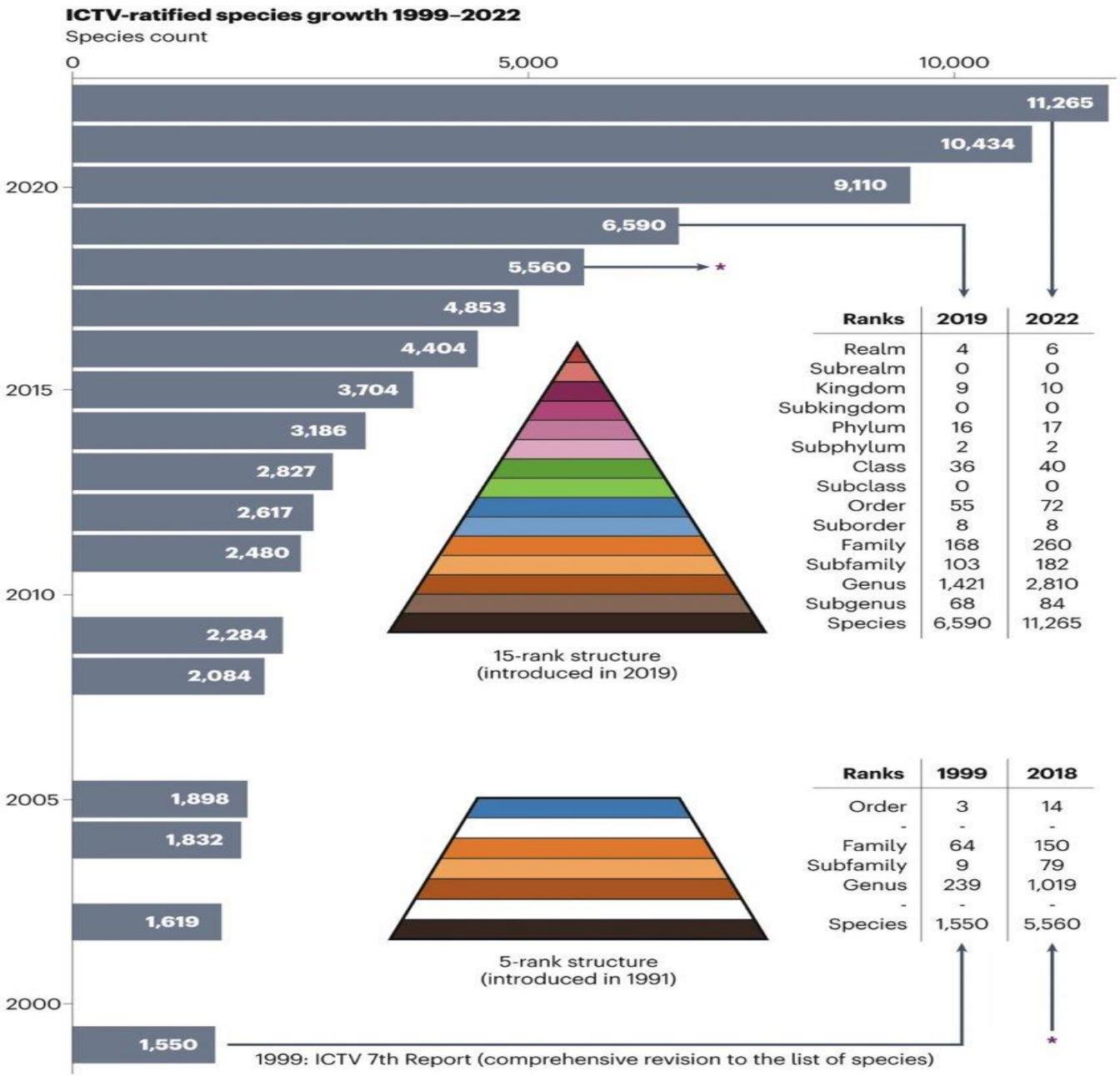


Adrieannsens et al. Nature Biotechnology 2023, https://doi.org/10.1038/s41587-023-01844-2

How do we write virus names and species than?

Since 2021 binominal ***virus species*** naming, as other biological species! Species is a man made category.

Virus (physical entity) name is not in italic, same or similar as before:

tobacco mosaic virus (in English)

Other languages may have different names for this biological entity.

Acronym : TMV

Family *Virgaviridae*, genus *Tobamovirus*

Species name:

Tobamovirus tabaci

Species names are being updated follow the ICVG info.

https://ictv.global/help/vmr/find_species_name

Table 2 Nomenclature for a virus infecting maize and for the virus species

Language	Virus name	Virus species name
English	maize mosaic virus	*Alphanucleorhabdovirus maydis* (in any language)
Arabic	الذرة موزاييك فيروس	
Chinese	玉米花叶病毒	
French	virus de la mosaïque du maïs	
Japanese	トウモロコシモザイクウイルス	
Russian	вирус мозаики кукурузы	
Spanish	virus del mosaico del maíz	
Swahili	virusi vya Batobato ya mahindi	

ICTV -International Committee on Taxonomy of Viruses

https://talk.ictvonline.org

*Mononega**virales*** - order

*Paramyxo**viridae*** - family

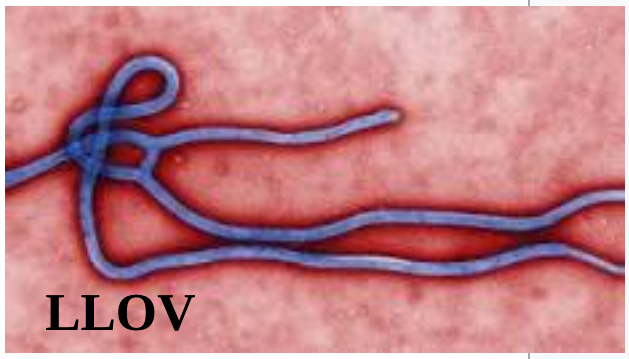
*Paramyxo**virinae*** - subfamily

*Morbilli**virus*** – genus

Morbilivirus hominis – virus species (***italic!***)

Not italic for virus vernacular (everyday) name (measles virus, MeV), or a virus isolate!

https://www.youtube.com/watch?v=6YxNYnHTxAg



Entry of a virus to the USA Army research facility in Reston (VA) in 1989 with monkeys from Philippines. It was similar to Ebola virus, but not pathogenic to humans. Nowadays known as Reston virus.

Family *Filoviridae*: four genera, eight species and more viruses.

Genus name	*Species name*	Virus name (acronym)
Cuevavirus	*Lloviu cuevavirus*	Lloviu virus (LLOV)
Dianlovirus		Měnglà virus (MLAV)
Ebolavirus	*Bombali ebolavirus*	Bombali virus
	Bundibugyo ebolavirus	Bundibugyo virus (BDBV; before BEBOV)
	Reston ebolavirus	Reston virus (RESTV; before REBOV)
	Sudan ebolavirus	Sudan virus (SUDV; before SEBOV)
	Taï Forest ebolavirus	Taï Forest virus (TAFV; before CIEBOV)
	Zaire ebolavirus	Ebola virus (EBOV; before ZEBOV)
Marburgvirus	*Marburg marburgvirus*	Marburg virus (MARV)
		Ravn virus (RAVV)

Why cataloging and naming of viruses is so important?

Virus diversity is not well known and viral potential is untapped:

- phage therapy,
- algal bloom control,
- understanding evolution of life on Earth,
- epidemic prediction,
- new drugs,
- new enzymes,
- biotechnology tools…

To give a name is to know.
To classify is to now.

When in doubt, READ up.

Archives of Virology
https://doi.org/10.1007/s00705-021-05323-4

VIROLOGY DIVISION NEWS

Differentiating between viruses and virus species by writing their names correctly

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JOURNAL OF GENERAL VIROLOGY

RESEARCH ARTICLE
Postler *et al.*, *Journal of General Virology* 2022;103:001800
DOI 10.1099/jgv.0.001800

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Guidance for creating individual and batch latinized binomial virus species names

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May 2025, 10 (5)

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| Virology | Perspective

Virus species names have been standardized; virus names remain unchanged

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doi: 10.1128/msphere.00020-25 1

JOURNAL OF GENERAL VIROLOGY

REVIEW
Siddell *et al.*, *Journal of General Virology* 2023;104:001840
DOI 10.1099/jgv.0.001840

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Virus taxonomy and the role of the International Committee on Taxonomy of Viruses (ICTV)

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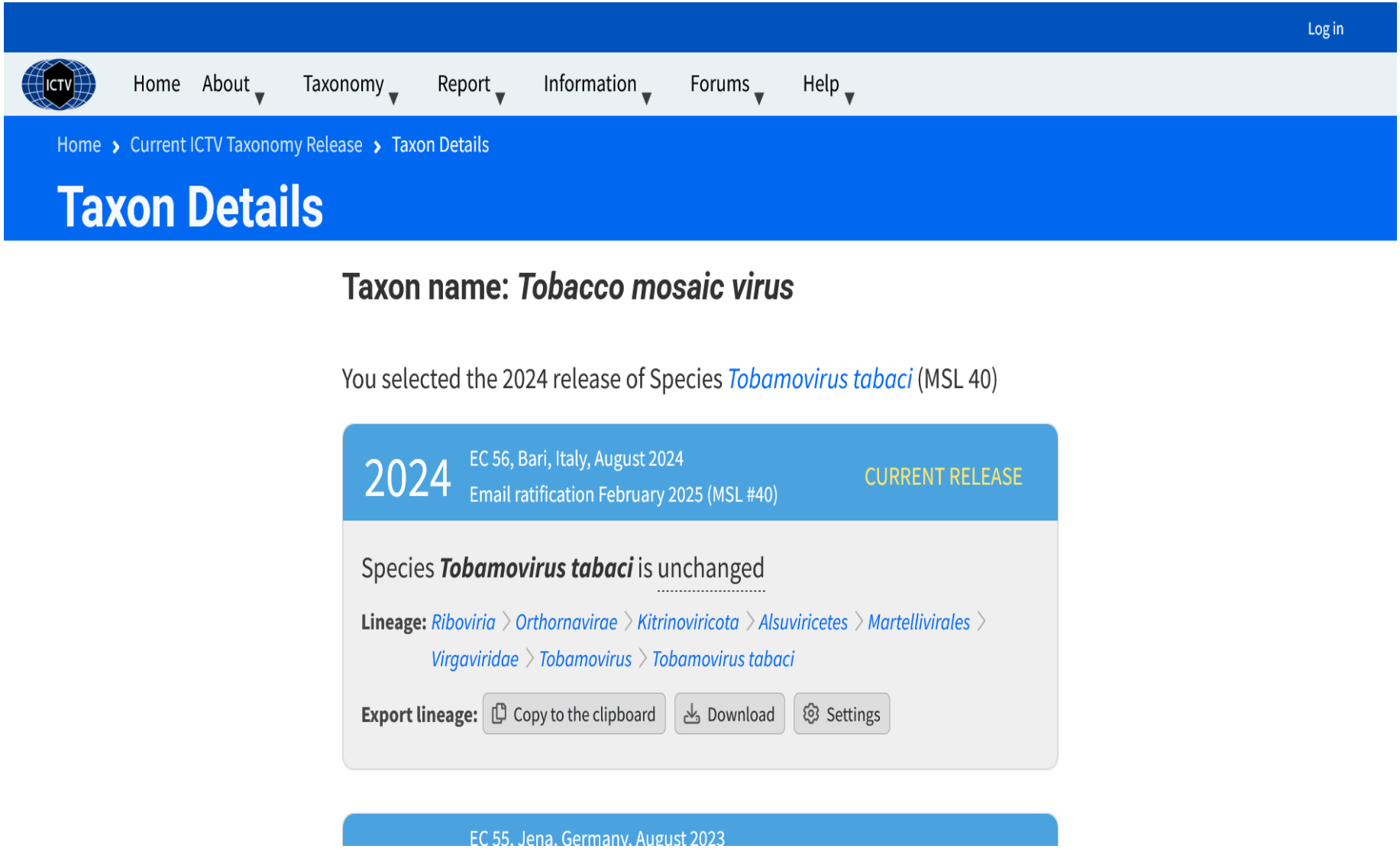

Currently, one of the numerous taxa at the species level …but not all newly discovered have been reported!

Archives of Virology (2026) 171:23
https://doi.org/10.1007/s00705-025-06485-1

VIROLOGY DIVISION NEWS

Changes to virus taxonomy, the international code of virus classification and nomenclature, and the ICTV statutes ratified by the International Committee on Taxonomy of Viruses (2025)

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Table 1 Summary of ratified taxonomic changes in 2025

Rank	MSL39 Total[a]	New	Abolished	Moved	Renamed	Other	MSL40 v2 Total[b]	Net change
Realm	6	1	0	0	0	0	7	+1
Subrealm	0	0	0	0	0	0	0	0
Kingdom	10	1	0	1	0	0	11	+1
Subkingdom	0	0	0	0	0	0	0	0
Phylum	18	4	0	0	0	0	22	+4
Subphylum	2	2	0	0	0	0	4	+2
Class	41	8	0	4	1	0	49	+8
Subclass	0	0	0	0	0	0	0	0
Order	81	11	0	5	2	1	93	+12
Suborder	11	1	0	0	0	0	12	+1
Family	314	55	0	10	2	−1	368	+54
Subfamily	200	15	−2	15	1	0	213	+13
Genus	3,522	243	−2	100	4	6	3,768	+246
Subgenus	84	2	0	0	0	0	86	+2
Species	14,690	1,563	−38	105	273	0	16,213	+1,523

[a]Total number of taxa in the ICTV Master Species List (MSL) #39 prior to the 2025 ratification vote

[b]Total number of taxa after the 2025 ratification vote (listed in the ICTV MSL #40).

Learning outcomes

You should be able to:

- **Differentiate viral taxa (basic ranks) and viruses in writing and generally**

- **Understand viral diversity and the reasons for its growth.**