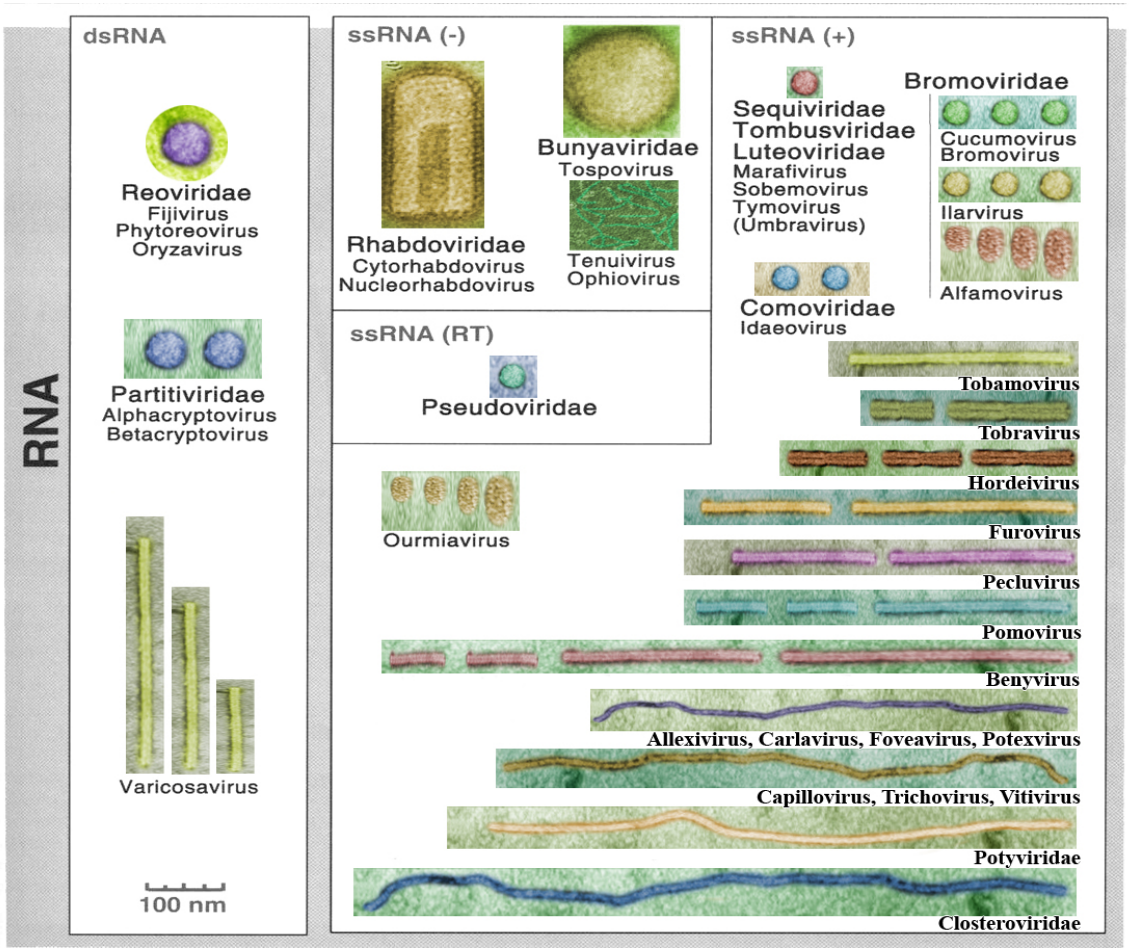
Classification, Nomenclature, and Orthography of Plant Viruses



OUTLINE

A. Classification of all viruses

1. Purpose of classification
2. Classification system
3. Orthography of virus taxons

B. Concept of a Virus Species

1. Definition of a virus species
2. How are species determined?
3. Orthography of a species
4. Nomenclature of a species

C. Taxons below species

1. Types
2. Nomenclature

D. Taxons higher than species

1. Genus
2. Family

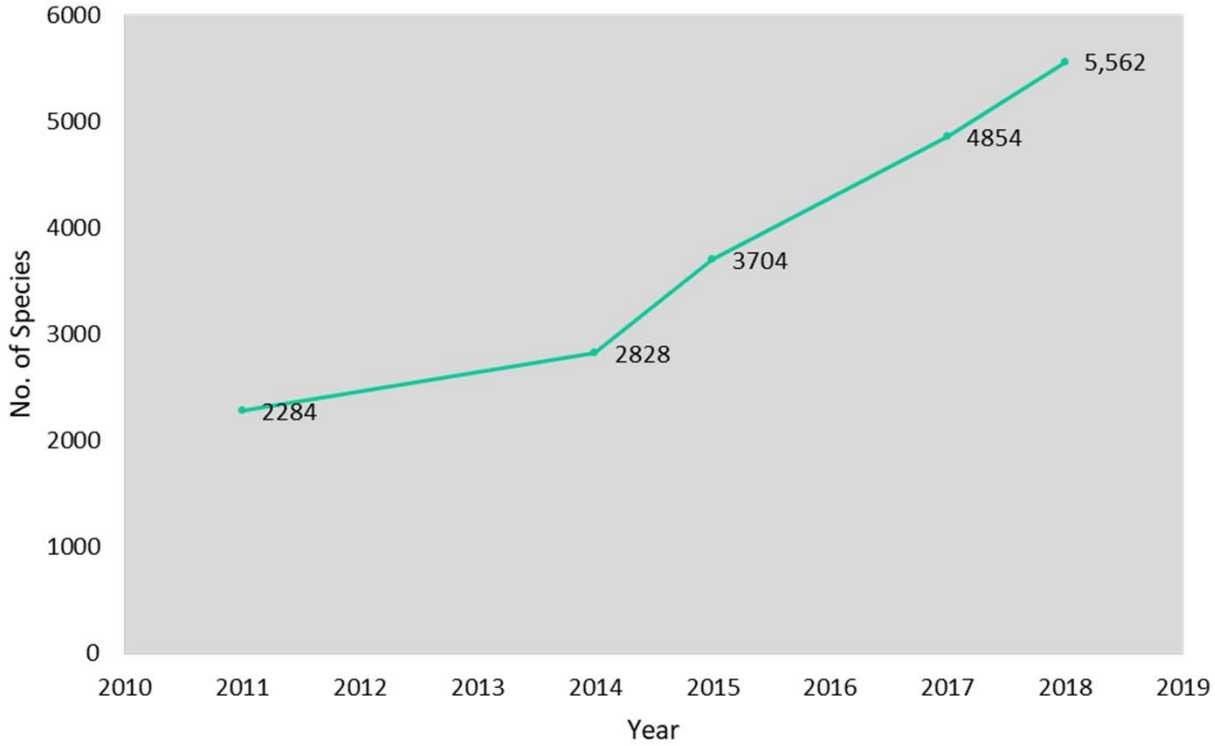
E. Examples show relatedness of viruses within families and genera

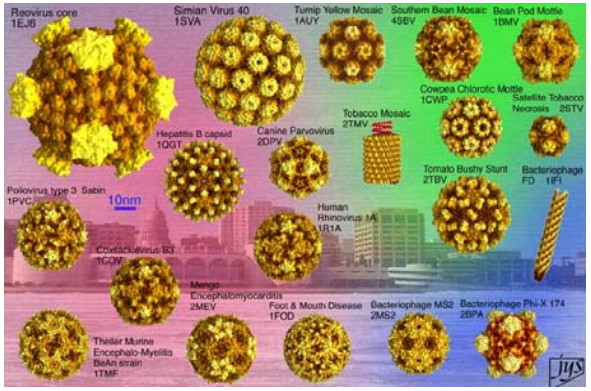
1. *Potyviridae*
2. *Geminiviridae*
3. *Closteroviridae*

Objectives

1. Understand how viruses are taxonomically organized
2. Understand how and why virus species are grouped into genera, and families
3. Become familiar with different families and genera of plant viruses
4. Be able to use viral taxonomic terms correctly
5. Understand the concept of a virus species
6. Know how to correctly write the name of a virus species and its acronym

A. Classification of all viruses





Species = complete sequence obtained

No. of approved species expected to increase 10 x within next 5 years

A. Classification of Viruses

- 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

A. Classification of Viruses

In addition:

- Viral taxonomy is useful tool
- Provides some insight into possible origins of the viruses and their genes.
- Presents a system to keep track of the large numbers of different viruses being isolated and studied throughout the world.
- A universal language in the scientific literature.

Until 1980s viruses were distinguished using information host range and symptom expression
(= The Dark Ages)
(but surprisingly accurate)

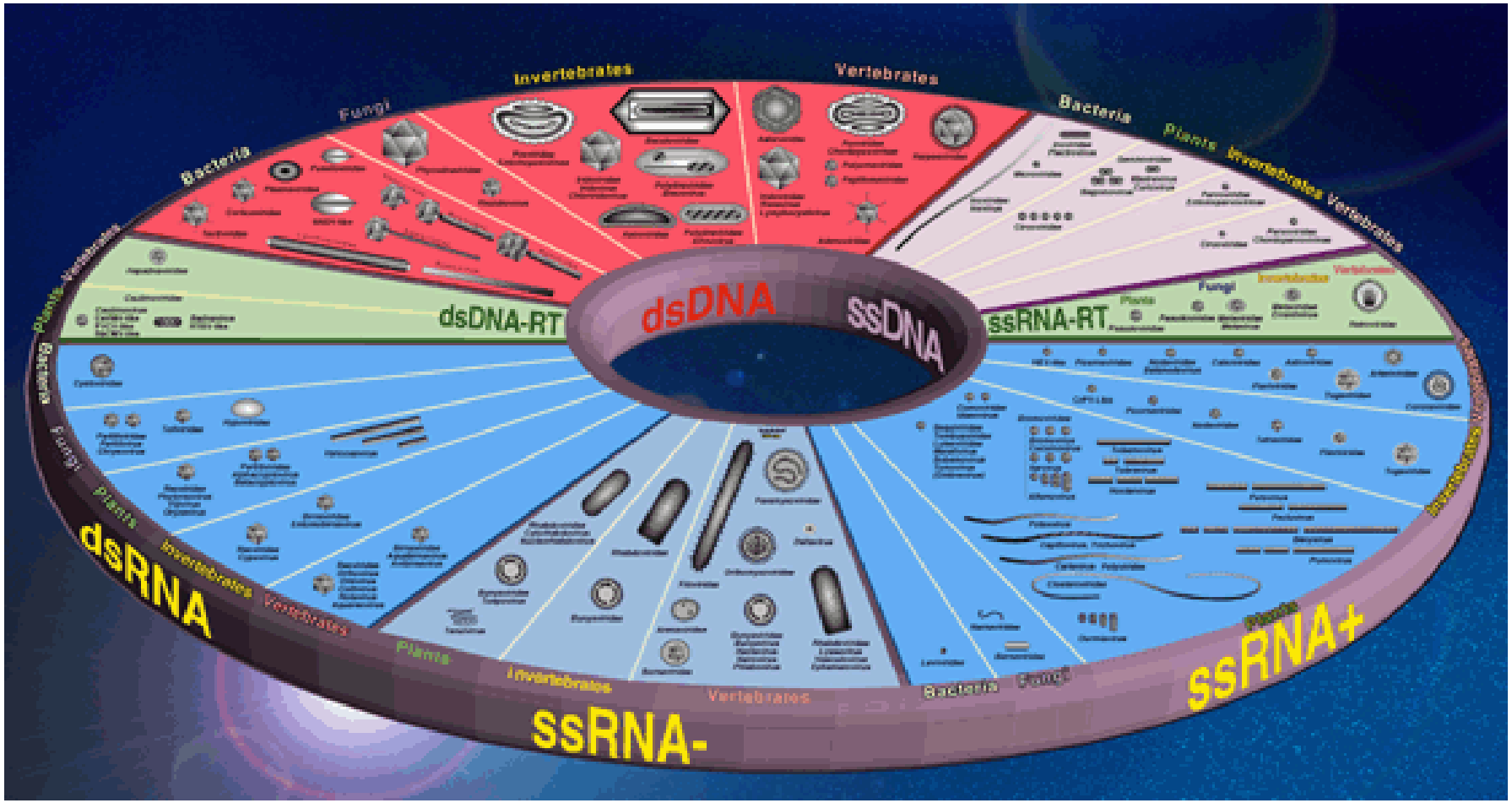
Current Criteria for Classification of Viruses

The most important criteria for classification are:

- **Genome Type: RNA; DNA;** ss- or ds-; circular; linear
- **Host Organism(s):** eukaryote; prokaryote; vertebrate, etc.
- **Particle Morphology:** filamentous; isometric; naked; enveloped

- In many cases, just **morphology** is sufficient to allow identification of a virus down to **family** if not **genus**

Viruses Organized by Genome Type, Host, Particle Morphology



https://viralzone.expasy.org/6896

Current Status of Plant Viruses:

Baltimore Classification System

122 genera in 24 families, [10 genera unassigned to family]

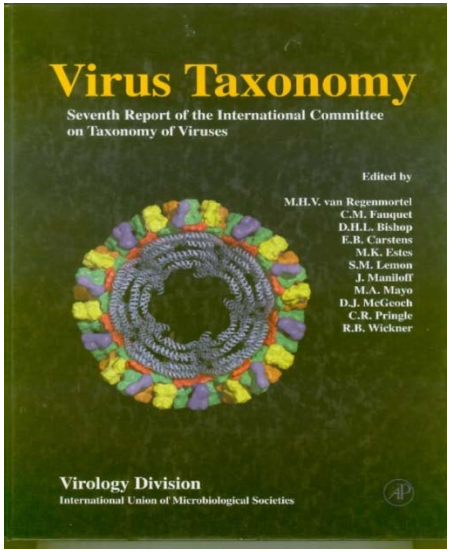
Distribution of virus families and genera that include plant virus species:

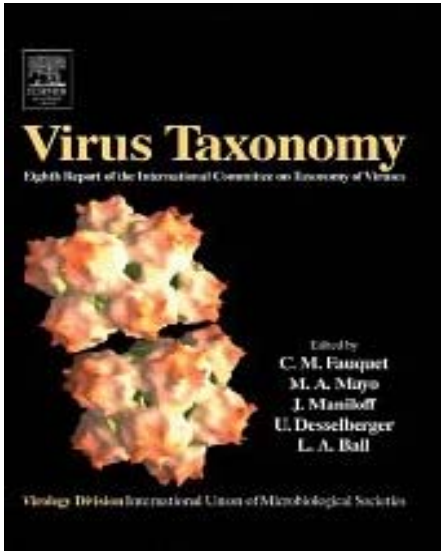
		DNA		RT	RNA			
	No.	**dsDNA**	**ssDNA**	**RT**	**dsRNA**	**ssRNA (+)**	**ssRNA (-)**	**Circ. ss RNA**
Virus	Families		2	1	4	12	5	2
	Genera		11	8	8	87 (10)	8	8
Satellite	Families		2					
	Genera		13					
Transposon	Families			2				
	Genera			3				

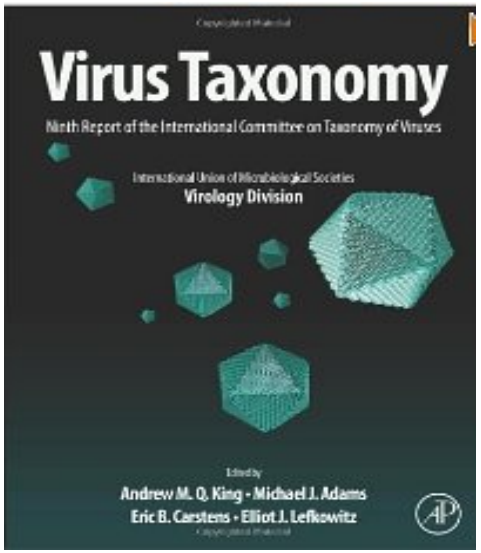
RT = Reverse transcribing

International Committee on Taxonomy of Viruses

VIROLOGY DIVISION - IUMS







2000 2005 2011

http://www.ictvonline.org/virusTaxonomy.asp

Hierarchical Levels (Taxa) used to Classify Viruses:

Virus Order
Family
Subfamily
Genus
Species
Strains/Variants

Orthography:
Recommendations of the ICTV for writing virus families and genera

- Formal terms used for virus families, genera, and species should be those approved by the International Committee on Taxonomy of Viruses (ICTV).

- The accepted names of virus orders (*e.g.*, *Tymovirales*), families (*e.g.*, *Betaflexiviridae*), subfamilies (*e.g.*, *Quinvirinae*), and genera (*e.g.*, *Carlavirus*) are printed in italics and the first letters of the names are capitalized.

Characteristics

Sequence Homologies

Genome Rearrangement

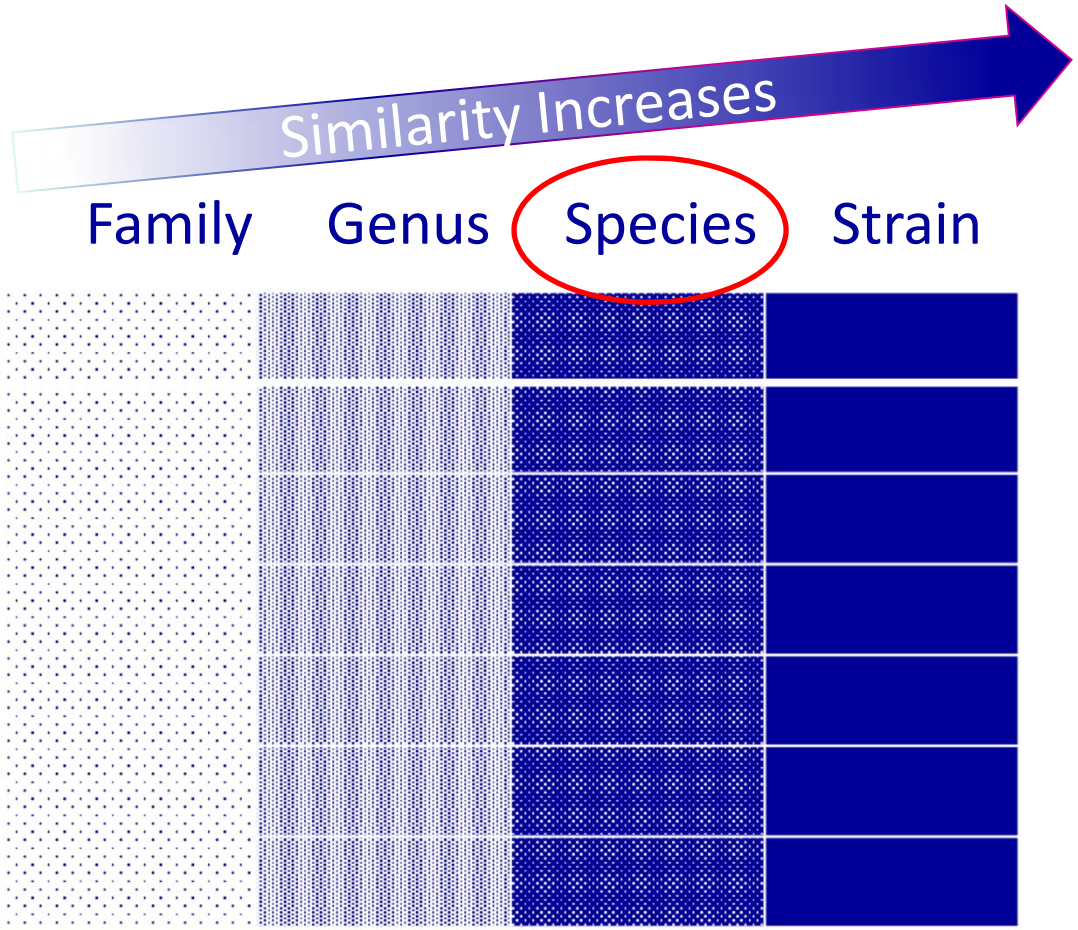
Serological Relationships

Vector Transmission

Host Range

Cell And Tissue Tropism

Geographical Distribution



Viruses are grouped in such a way that species characteristics become more similar as you approach the species taxon

B. Concept of a Virus Species

WHAT IS A VIRUS SPECIES?

ICTV: “A virus species is a polythetic class of viruses that constitutes a replicating lineage and occupies a particular ecological niche"

A virus species represents a cluster of virus strains (isolates/variants /sequences) that may come from a number of sources.

A virus species is not a sequence, it is a collection or cloud of sequences with slight variations in biological, chemical characteristics

What is required to be a unique virus species?

Genome sequence has become the main focus of taxonomists to classify a virus species

- **compare the sequence of a new virus against all known viruses**

- **determine how similar the genome is to known viruses using mathematical algorithims**

- **cutoffs of sequence identity are established by ICTV committees for each genus and family**

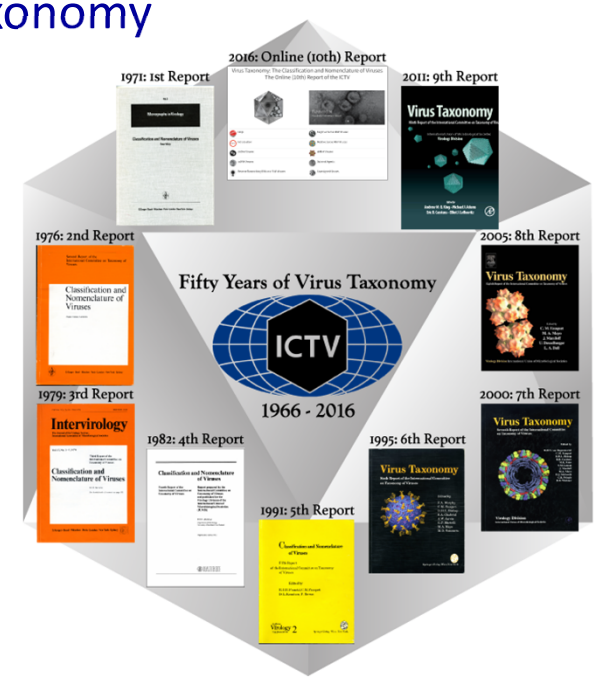
Species Classification:

Criteria for species demarcation vary among different families

- Committees of virologists were formed for each virus family,
- Committee members make the decisions regarding taxonomy status, name, acronym, etc…
- Decisions are published periodically in: journal articles, ICTV Virus Taxonomy site and on Viral Zone:

http://www.ictvonline.org/virustaxonomy.asp

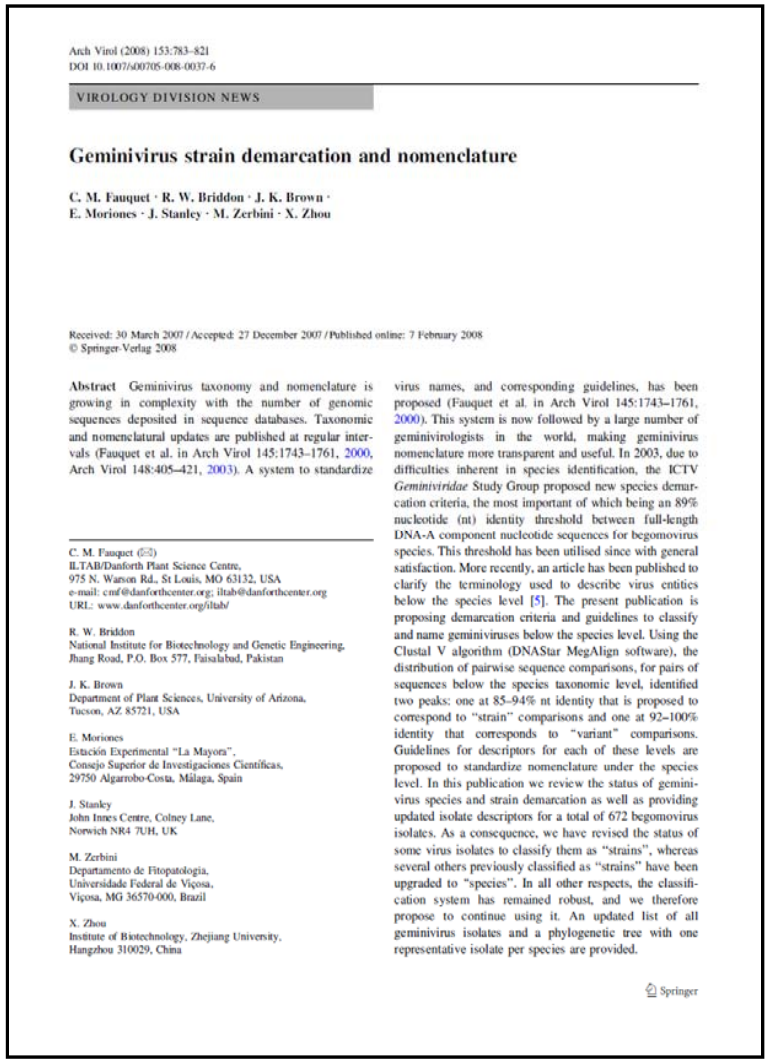
http://viralzone.expasy.org



Taxonomy of the family *Geminivirus*:

Details presented in this paper

Written by the ICTV Committee on *Geminiviridae*



Arch Virol (2008) 153:783–821
DOI 10.1007/s00705-008-0037-6

VIROLOGY DIVISION NEWS

Geminivirus strain demarcation and nomenclature

C. M. Fauquet · R. W. Briddon · J. K. Brown · E. Moriones · J. Stanley · M. Zerbini · X. Zhou

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Abstract Geminivirus taxonomy and nomenclature is growing in complexity with the number of genomic sequences deposited in sequence databases. Taxonomic and nomenclatural updates are published at regular intervals (Fauquet et al. in Arch Virol 145:1743–1761, 2000, Arch Virol 148:405–421, 2003). A system to standardize virus names, and corresponding guidelines, has been proposed (Fauquet et al. in Arch Virol 145:1743–1761, 2000). This system is now followed by a large number of geminivirologists in the world, making geminivirus nomenclature more transparent and useful. In 2003, due to difficulties inherent in species identification, the ICTV *Geminiviridae* Study Group proposed new species demarcation criteria, the most important of which being an 89% nucleotide (nt) identity threshold between full-length DNA-A component nucleotide sequences for begomovirus species. This threshold has been utilised since with general satisfaction. More recently, an article has been published to clarify the terminology used to describe virus entities below the species level [5]. The present publication is proposing demarcation criteria and guidelines to classify and name geminiviruses below the species level. Using the Clustal V algorithm (DNAStar MegAlign software), the distribution of pairwise sequence comparisons, for pairs of sequences below the species taxonomic level, identified two peaks: one at 85–94% nt identity that is proposed to correspond to "strain" comparisons and one at 92–100% identity that corresponds to "variant" comparisons. Guidelines for descriptors for each of these levels are proposed to standardize nomenclature under the species level. In this publication we review the status of geminivirus species and strain demarcation as well as providing updated isolate descriptors for a total of 672 begomovirus isolates. As a consequence, we have revised the status of some virus isolates to classify them as "strains", whereas several others previously classified as "strains" have been upgraded to "species". In all other respects, the classification system has remained robust, and we therefore propose to continue using it. An updated list of all geminivirus isolates and a phylogenetic tree with one representative isolate per species are provided.

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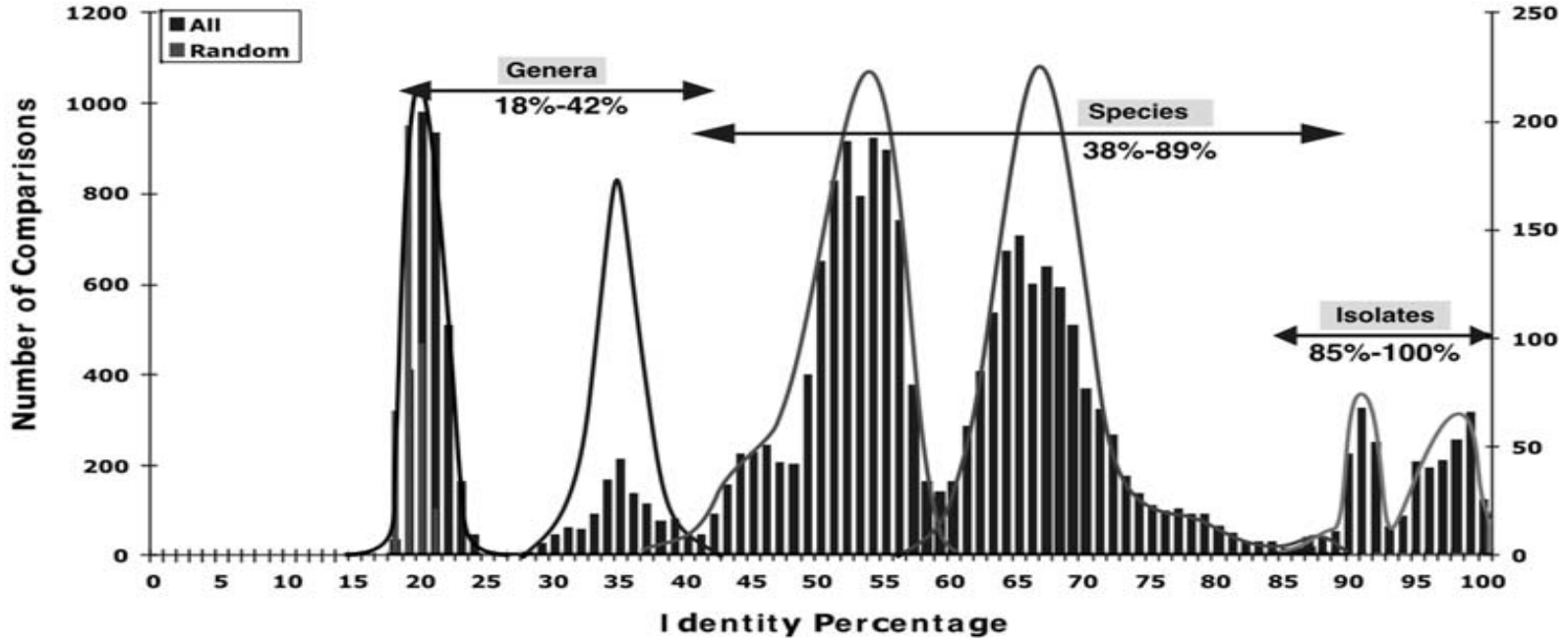
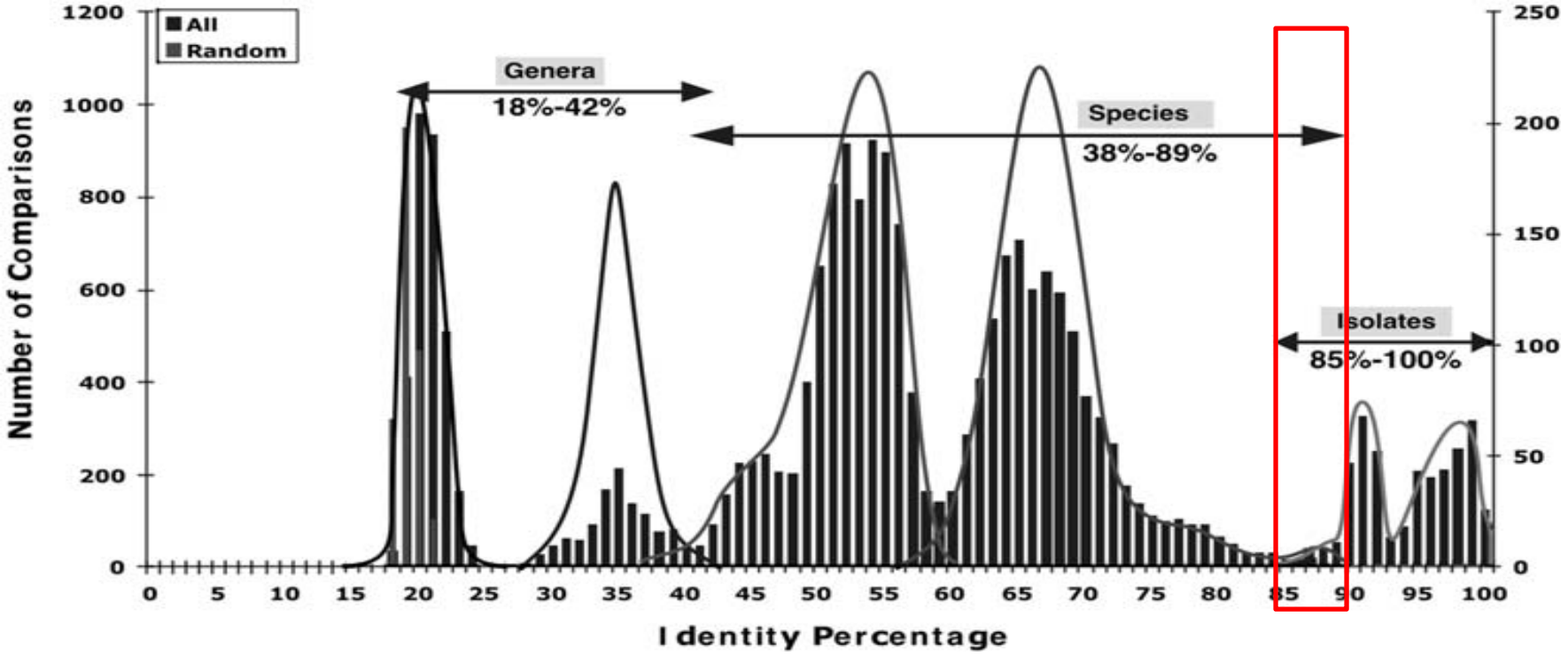
Ex. 1) Genus Species, and Strain Demarcation in the *Geminiviridae*



Based on the sequence of the A component

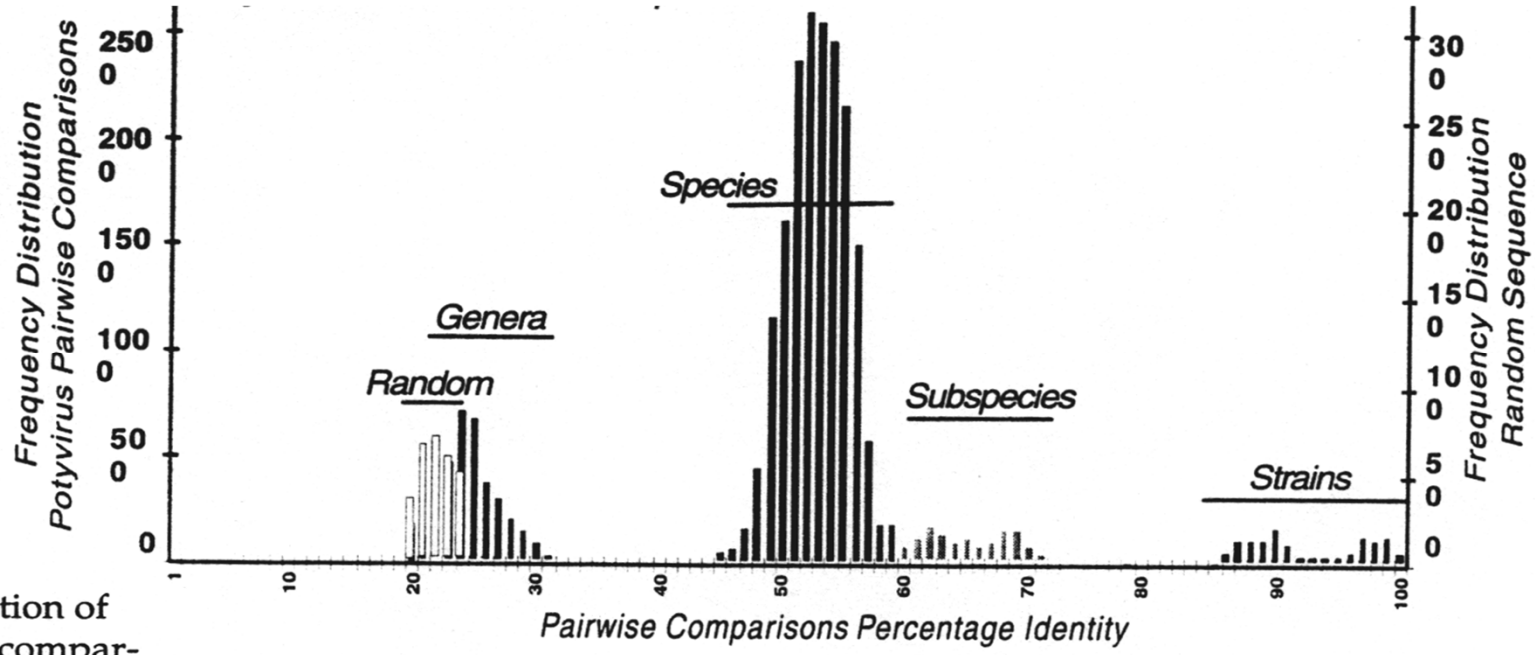
This study used 672 geminivirus isolates and calculated identity percentages using the algorithm: Pairwise sequence comparison (PASC)

- Viruses in different genera share 18-42% percent identity
- Viruses that are different species share 38%-89% percent identity
- Viruses that share 89% or more percent identity were variants of a single virus species



Ex. 2) *Potyviridae*

Species are defined by the differences in the nucleic acid sequence of the coat protein



Frequency distribution of pairwise sequence comparisons of 219 nucleic acid sequences of coat proteins of members of the family *Potyviridae*.

Orthography:
Recommendations of the ICTV regarding the use of species names

- Species names are printed in italics and have the first letter of the first word capitalized (*e.g., Cowpea mild mottle virus*). Other words are not capitalized unless they are proper nouns (*e.g., Sida golden mosaic Florida virus*), or alphabetical identifiers (*e.g., Potato virus Y)*.

- Since it is virus names that are used repeatedly in a text, they are the names that need to be abbreviated. Species names should never be abbreviated.

- ✓ **Summary of Recommendations:** when the entire species is discussed as a taxonomic entity, the species name is italic and has the first letter and any proper nouns capitalized (e.g., *Tobacco mosaic virus, Potato virus Y*).

- ✓ **HOWEVER,** When the behavior or manipulation of individual viruses is discussed, the vernacular (e.g., tobacco mosaic virus, potato virus Y) should be used.

Virus Species - Orthography

- **But** ……when referring to the virus in a publication there is currently not a universally accepted method

- For example, any of the following are possible depending upon the journal and the year (rules change)

Tomato yellow leaf curl virus

Tomato yellow leaf curl begomovirus

tomato yellow leaf curl virus

Virus Species - Nomenclature

How are the names of virus species created?

- The names of individual plant viruses have been derived from the common name of the host species in which they are first discovered together with a description of the characteristic symptoms of infection.

Ex. - Tobacco mild green mosaic virus
Tomato mottle virus
Bean common mosaic virus

Archives of Virology 133:496-498

Virus Species – Nomenclature Con't

- What do you do if the symptoms of a new virus are the same as those of another virus?

  Problem: Host, symptom, "virus": *Tomato yellow leaf curl virus*
  Answer: Host, symptom, location, "virus"
  e.g. Tomato yellow leaf curl Sardinia virus
  Tomato yellow leaf curl China virus

- Cannot use personal names, non-english terms are discouraged
  e.g. Pepper golden mosaic virus (was Texas pepper virus),
  Pepper hausteco yellow vein virus (was accepted but is unusual)
- Some old names have been grandfathered-in:
  e.g. Potato virus Y, Cactus X virus

Virus Species - Nomenclature

How are acronyms of virus species created?

Plant Virus Name Acronyms: The Principles

1. Abbreviations should be as simple as possible.
2. An abbreviation must not duplicate any other acronym previously coined and still in current usage
3. Abbreviations use the first letters of each word with approved letters for symptoms ie mosaic = m; mottle = mo, y = yellow
4. The word “virus” in a name is abbreviated as “v”.

Fauquet, M. C. and Mayo, M. A. 1999. Abbreviations for plant virus names - 1999. Arch. Virol. 144 (6)

Characteristics

Sequence Homologies

Genome Rearrangement

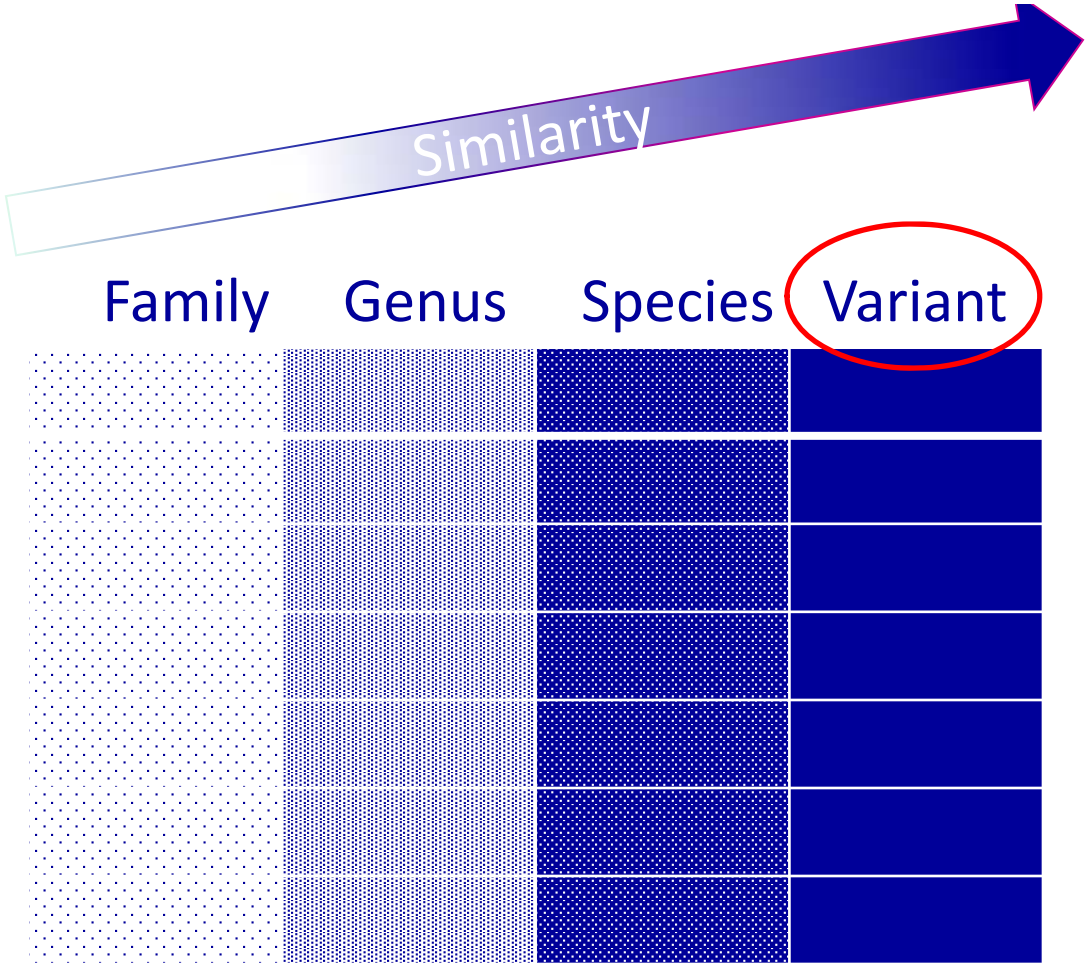
Serological Relationships

Vector Transmission

Host Range

Cell And Tissue Tropism

Geographical Distribution



C. Taxons below species

ICTV does not address virus taxonomy and classification issues below the species level

Levels below species: variants, isolates, strains, serotypes, types, sub-types, etc.)

- Names of virus strains are not italicized. The first letter of the first word is not capitalized (*e.g.,* herpes simplex virus) unless it is a proper noun, typically based on the binomial name of the species it infects; *e.g.*:
  - Virus species name: *Tomato yellow leaf curl virus*
  - Virus strain name: Tomato yellow leaf curl virus-Mld

  Species names are in italic script; strain names are in Roman script.

D. Taxons higher than species

1. Genus
2. Family
(3. Order)

Characteristics

Sequence Homologies

Genome Rearrangement

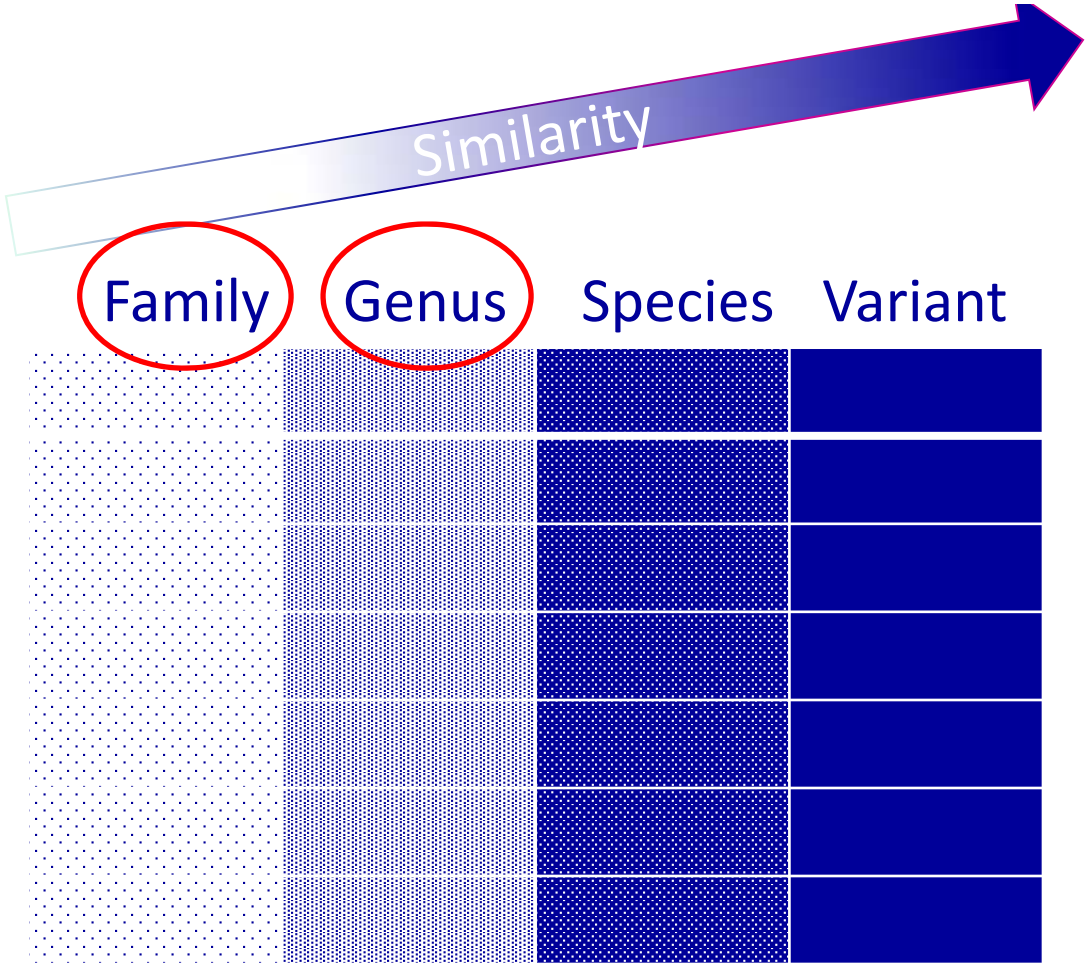
Serological Relationships

Vector Transmission

Host Range

Cell And Tissue Tropism

Geographical Distribution



Virus Genera:

Nomenclature:

- Written in italics and first letter is capitalized
  Ex. *Begomovirus, Potyvirus, Potexvirus*

- Name of the genera is derived from the type species (usually)
  Ex. *Cucumovirus* comes from the type species, *Cucumber mosaic virus*
  Ex. *Begomovirus* comes from the type species, *Bean golden mosaic virus*

Criteria Used to Place Virus Species in Family or Genera

I. All virus species in a family (genus) will have similar properties of the virion

1. Similar shape of the particle (icosahedral, helix, etc..)
2. All will have a membrane or won't have a membrane
2. Type of nucleic acid (DNA or RNA) will be identical
3. Identical strandedness (single or double stranded)
4. All genomes will be either linear or circular nucleic acid
5. All genomes will have the same sense (positive, negative, or ambisense)
6. All will have similar terminal modifications (protein caps, polypeptides, poly A tails, etc..)
7. All will share some nucleotide sequence homology

Criteria Used to Place Virus Species in Family or Genera

II. All virus species in a genus will have similar genome organization con't

1. Similar number and size of genome segments
2. Similar number and size of proteins
3. Proteins will have similar functions
4. Proteins (which have the same functions) will have regions of high amino acid sequence homology
5. All viruses will have some similar antigenic properties
    1. Similar abilities to elicit an immune response
    2. Serological relationships among members
    3. Will share some epitopes

III. All virus species in a genus will have similar biological properties

1. Similar pathogenicity, association with disease

2. Similar tissue tropisms, pathology, histopathology
   (ie phloem-limited or epidermal/mesophyll)

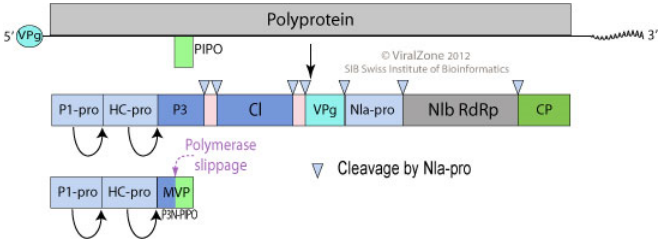
3. Similar vector relationships (type of vector)
   vector species within the same family

4. Mode of transmission in nature
   (persistent, semi-persistent, non-persistent)

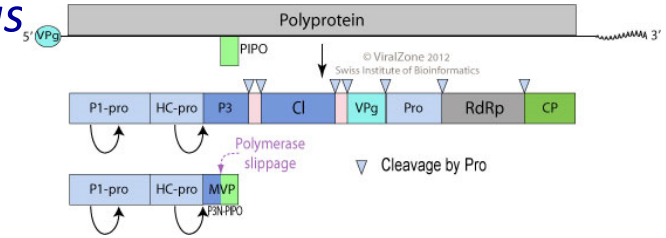
Example 1 *Potyviridae* – 8 genera

Brambyvirus

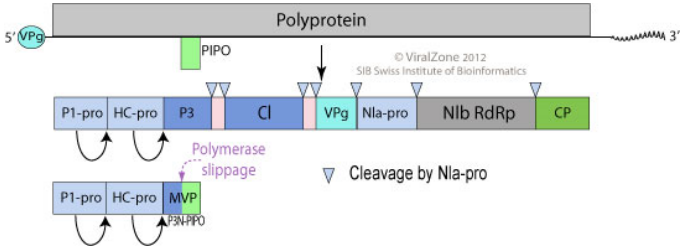
Bymovirus



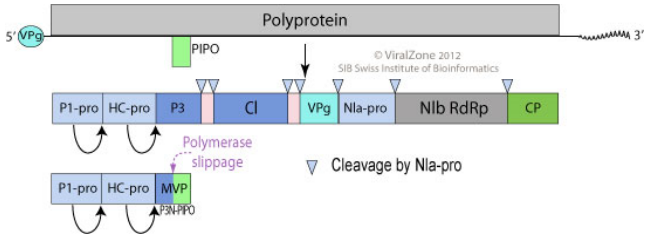
Ipomovirus



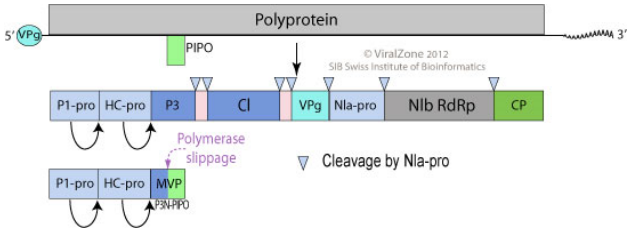
Macluravirus



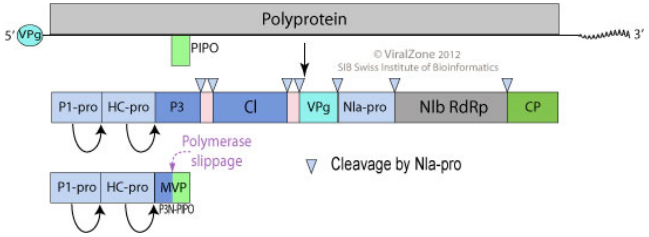
Poacevirus



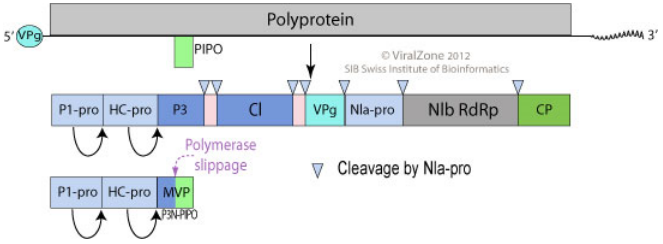
Potyvirus



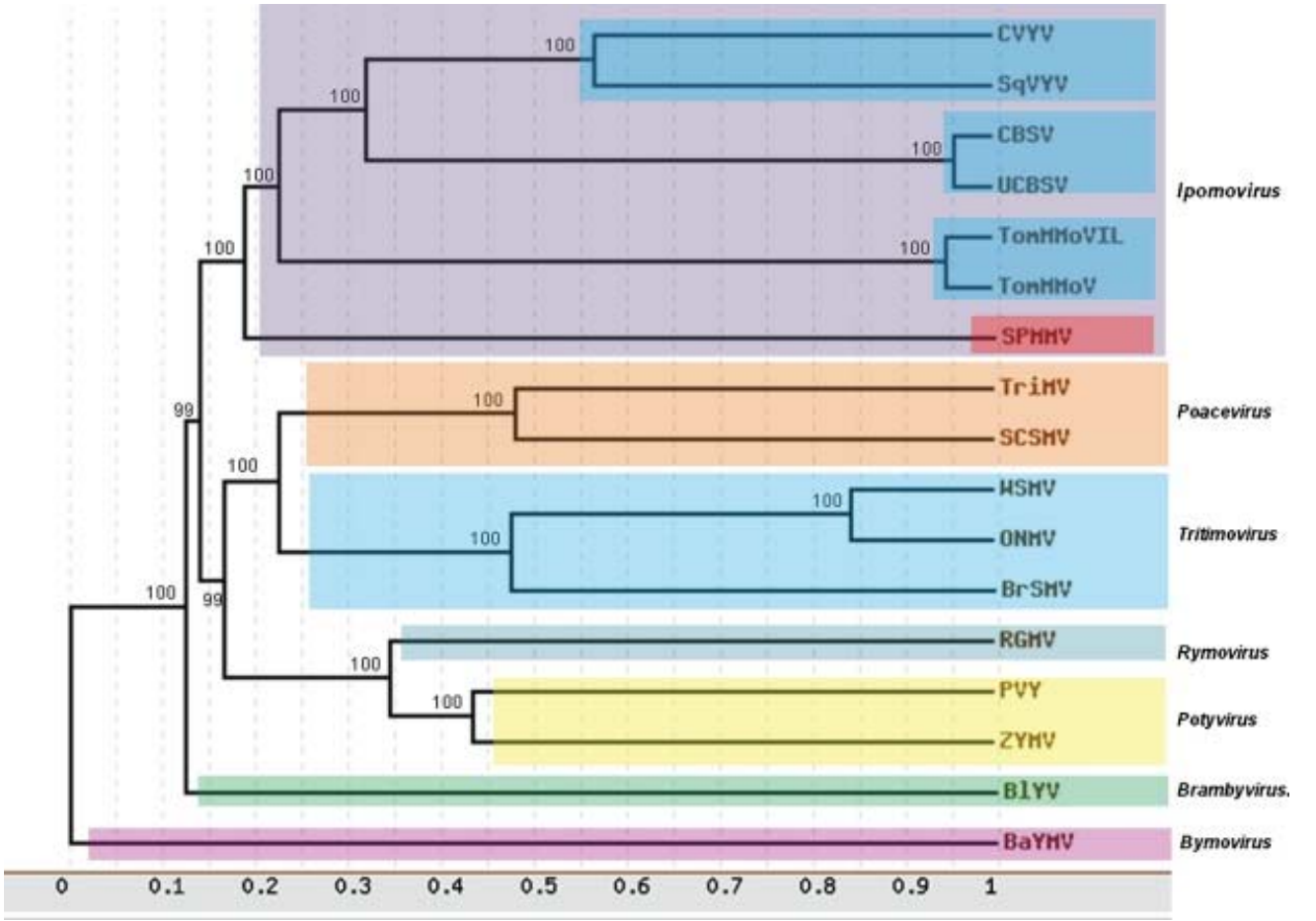
Rymovirus



Tritimovirus



Example 1. *Genera of the Potyviridae*



Vector, Mode of Transmission

Whitefly, Semi-persistent

Mite, Persistent (?)

Mite, Semi-persistent

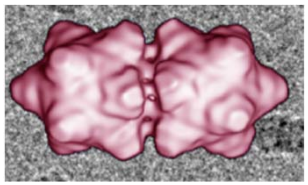
Mite, Persistent(?)

Aphid, Non-persistent

Unknown

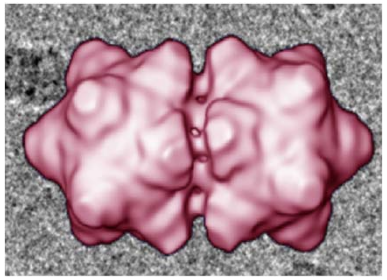
Fungus

Example 2. *Geminiviridae*



9 Genera:	Type Species:	No. Species:
Becurtovirus	*Beet curly top Iran virus*	2
Begomovirus	*Bean golden mosaic virus*	388
Capulavirus	*Euphorbia caput-medusae latent virus*	4
Curtovirus	*Beet curly top virus*	3
Eragrovirus	*Eragrostis curvula streak virus*	1
Grablovirus	*Grapevine red blotch virus*	1
Mastrevirus	*Maize streak virus*	37
Topocuvirus	*Tomato pseudo curly top virus*	1
Turncurtovirus	*Turnip curly top virus*	2

Geminiviridae



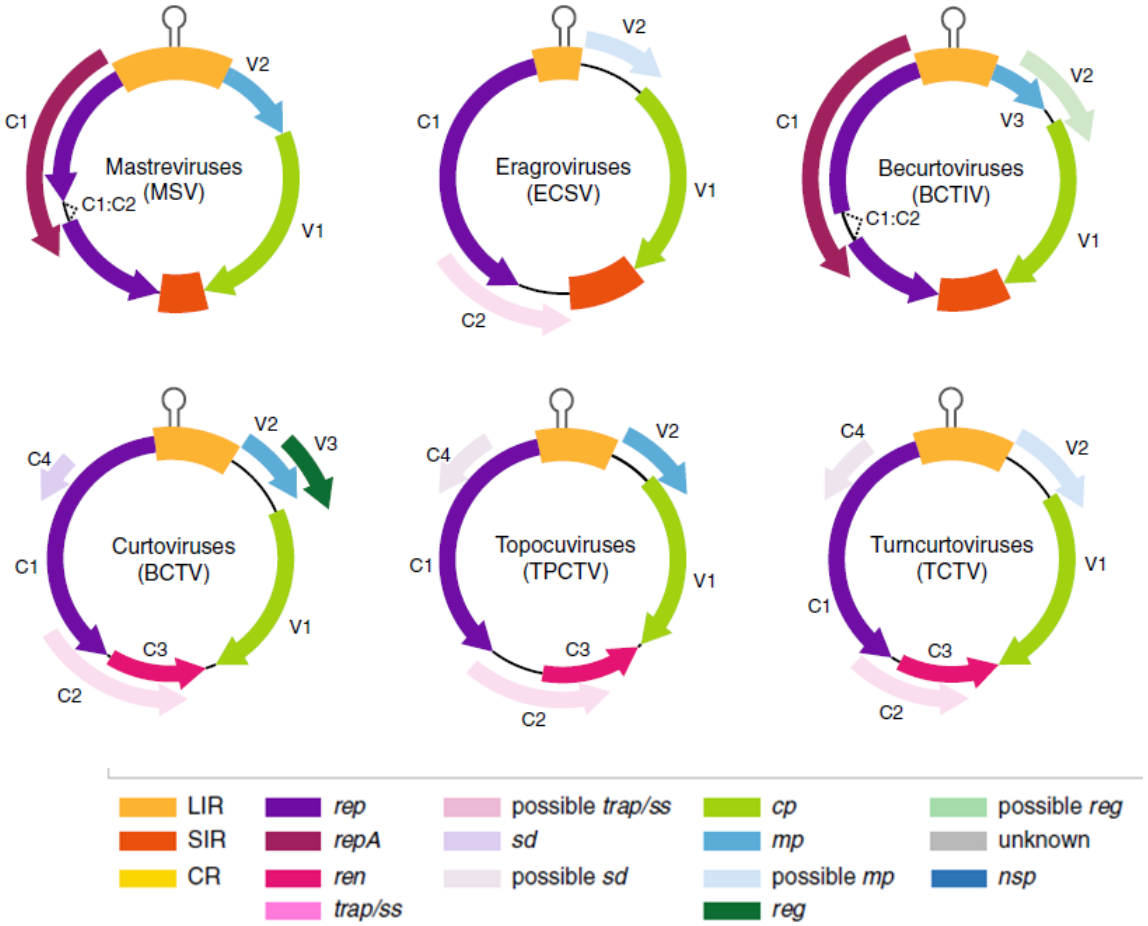
I. Similar properties of the virion

All species in all genera of the family have a particle morphology consisting of the fusion of two incomplete icosahedra (18x30 nm) into a geminate particle, which contains a circular, single-stranded DNA genome

II. Similar genome organization

***Geminiviridae*:**

Becurtovirus
Begomovirus
Curtovirus
Eragrovirus
Mastrevirus
Topocuvirus
Turncurtovirus

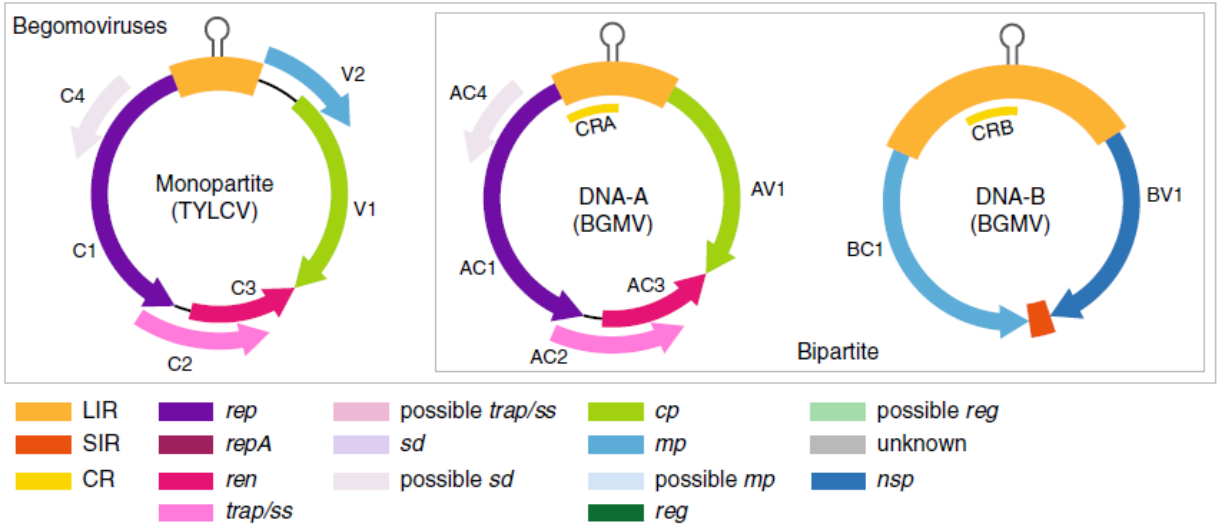


- Similar arrangement of genes
- Most have monopartite genomes

II. Similar genome organization

***Geminiviridae*:**

Becurtovirus
Begomovirus
Curtovirus
Eragrovirus
Mastrevirus
Topocuvirus
Turncurtovirus



- Species in the Genus *Begomovirus* have either monopartite or bipartite genomes

- Arrangement of genes is a little different in the bipartite genomes

III. Similar biological properties

Example: *Geminiviridae* Con't:

1. All known vectors are in the Order *Hemiptera*

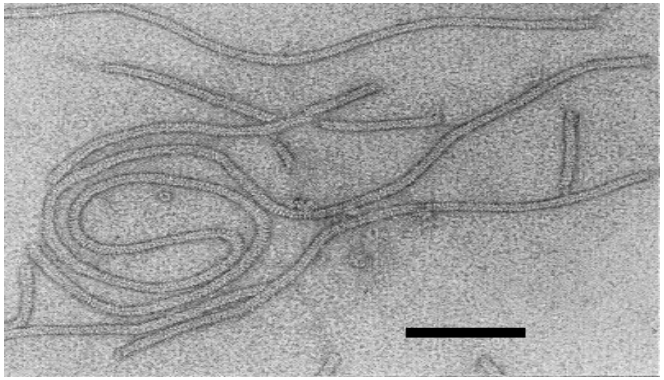
- *Mastrevirus* leafhoppers
- *Becurtovirus*, *Curtovirus* leafhoppers
- *Grablovirus, Topocuvirus* treehopper
- *Begomovirus* whiteflies
- *Capulavirus* aphid
- Genus *Eragrovirus, Turncurtovirus* Unknown

?

2. Transmitted in the same manner (persistent)
3. All replicate in phloem-associated parenchyma
4. Virus particles at low concentration in plant hosts

Example No. 3. *Closteroviridae* – 3 Genera

Closterovirus
Crinivirus
Ampelovirus

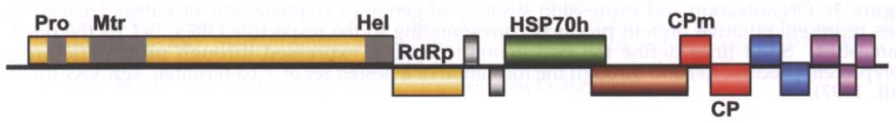


I. Similar properties of the virion

- Same particle shape but size may vary among species
  - Monopartite viruses are longer (1250-2000 nm)
  - Bipartite particle lengths are shorter 650-800 and 700-900 nm
- Genomes are single stranded positive sense RNA
- All viruses are moderately antigenic

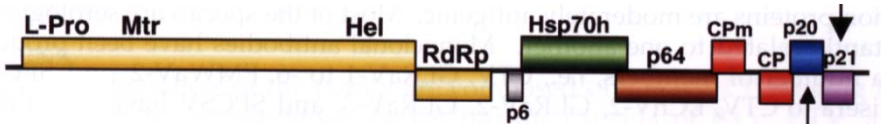
II. Similar genome organization:

Ampelovirus (monopartite)



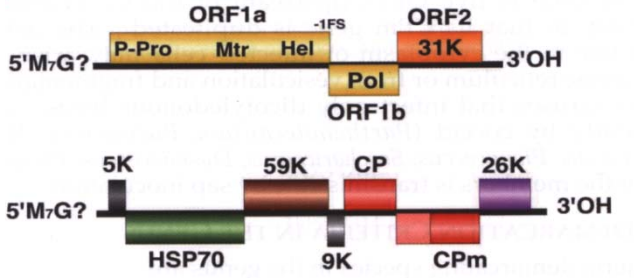
12 ORFs

Closterovirus (monopartite)



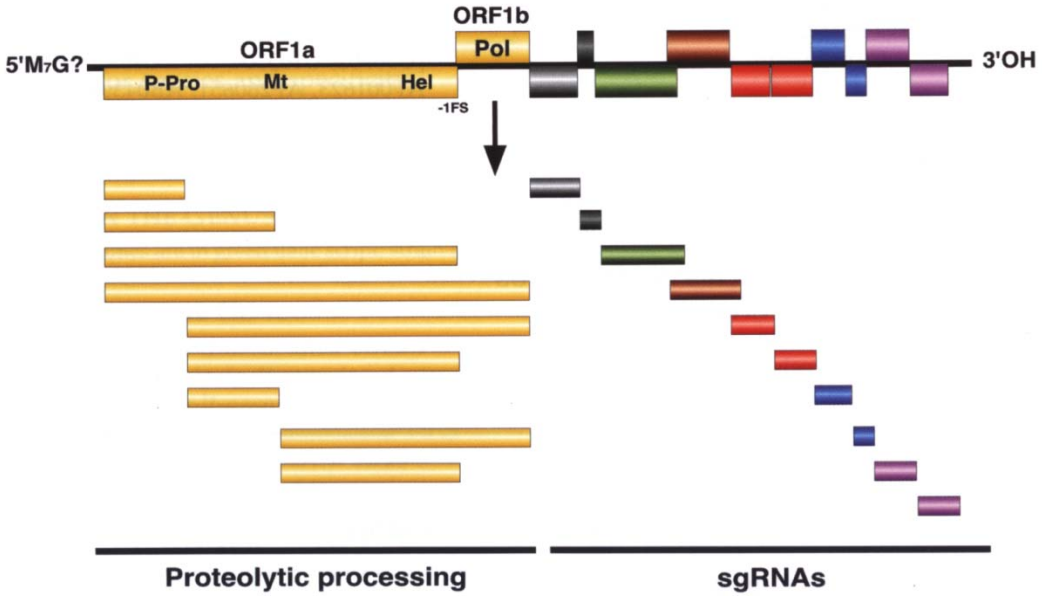
9 ORFs

Crinivirus (bipartite)



11 ORFs

All use a similar replication strategy –
proteolytic processing, subgenomic RNAs



V. Similar biological properties

Viruses in all 3 genera share similar biological characteristics:

- Yellowing symptoms
- Occur in very low concentrations in the host
- Are more easily found in older leaves
- Phloem-limited

CTV (Closterovirus)

CYSDV (Crinivirus)

V. Similar biological properties

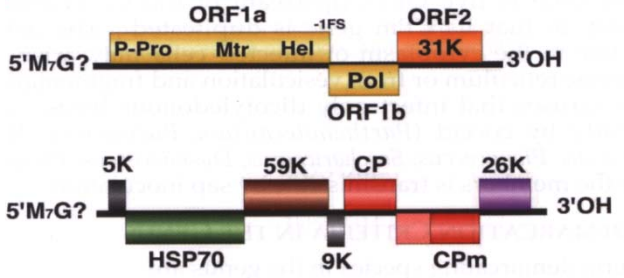
Ampelovirus — **Mealybugs (semi-pers.)**

12 ORFs

Closterovirus — **Aphids (semi-pers.)**

9 ORFs

Crinivirus — **Whiteflies (semi-pers.)**



11 ORFs