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Taxonomy, Classification and Nomenclature of Viruses

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Glossary

Classification The categorization of organisms into defined groups on the basis of identified characteristics.
Family A category in the virus taxonomic classification of related organisms, comprising one or more genera.
Genus A category in the virus taxonomic classification of related organisms, comprising one or more species.
Nomenclature The assigning of names to organisms in a scientific classification system.
Order A category in the virus taxonomic classification of related organisms, comprising one or more families.
Species A virus species is a polythetic class of viruses that constitutes a replicating lineage and occupies a particular ecological niche.
Taxonomy The science of classifying plants, animals, and microorganisms into increasingly broader categories based on shared features. The practice or principles of classification.

Introduction

Virus taxonomy is a very important but controversial field of science. It was ranked as the first constraint for the modern development of virus databases, and the exponential increase in virus sequencing is worsening the situation. However, substantial progress has been made particularly in the last 20 years, both on the conceptual framework and practical implication of virus taxonomy. The International Committee on Taxonomy of Viruses (ICTV) is the only committee of the Virology Division, of the International Union of Microbiological Societies (IUMS), in charge of that task since 1966, for the international virology community. Virus Taxonomy Reports have been published regularly by ICTV and they became the reference in virus taxonomy and nomenclature. This article aims at providing some historical information about the establishment and changes in virus taxonomy and describes the current status of virus classification, nomenclature, and orthography.

There is no such thing as a 'natural' or a 'biological' classification; by essence any classification is an arbitrary human invention and viruses are no exception. The question really is “How can we classify viruses in such way that it makes sense and is useful to many scientists?” The need for virus classification is not only supported by the common human need for organization, but also as a scientific tool to compare viruses and extrapolate useful information from one virus to another and from one family to another. Crucial biological information can be extrapolated directly from human viruses like picornaviruses to plant comoviruses and vice versa, when the classification indicates many structural and genomic common characteristics. When a newly discovered virus is assigned to a particular taxon, this virus can immediately be granted a number of a priori properties that only need confirmation and that have an immediate impact on specific virological studies. Furthermore, although it is not clearly stated by ICTV that the current classification is thought to reflect virus evolution, it is accepted that virus taxonomy is aiming at this objective and could become a tool by itself to study and evaluate virus evolution.

Virus nomenclature cannot be dissociated from classification. There must be a coherent system for naming viruses accompanied with a system for classifying viruses. Furthermore, using correct orthography and typography of virus taxa is not simply an exercise meant to complicate the task of virologists but is based on rules that help scientists to extract useful information from what is written down. It is therefore important to establish and follow guidelines for orthography, nomenclature, and classification of viruses. For all these reasons, virus classification and nomenclature have always been very controversial and have led to passionate discussions over the past four decades.

Historical Background of Virus Taxonomy

The first evidence for the existence of viruses was shown by Beijerinck in 1898, but it was not until the 1920s that virologists began to classify viruses. The first system referred to pathogenic properties of animal and human viruses and to symptoms for plant viruses. For example, viruses sharing the pathogenic properties causing hepatitis (e.g., hepatitis A virus, hepatitis B virus, yellow fever virus, Rift Valley fever virus) were grouped together as ‘the hepatitis viruses’. In 1939, Holmes published a classification of plant viruses dependent on host reactions and differential host species using a binomial–trinomial nomenclature based on the name of the infected plant. It was only in the 1950s, with the utilization of the electron microscope, that
the first real virus classification was established. Naturally the shape and size of virus particles became major criteria for virus classification. Because of that powerful and rapid technology the number of newly discovered viruses increased rapidly and several hundreds of new viruses were listed in a short period of time.

In 1966 in Moscow, at the International Congress for Microbiology, 43 virologists created the International Committee on Nomenclature of Viruses (ICNV) with the aim of developing a worldwide recognized taxonomy and nomenclature system for all viruses. The name of the ICNV was changed in 1974 to the more appropriate ICTV. The ICTV, which is the only committee of the Virology Division of the International Union of Microbiological Societies, is now recognized as the official international body that decides on all matters related to taxonomy and nomenclature of viruses.

Since 1966, virologists have agreed that all viruses isolated from different organisms should be classified together in a unique system, separate from that of microorganisms such as fungi, bacteria, and mycoplasma. However, there has been much controversy on how to achieve this aim. Lwoff, Horne, and Tournier in 1962 proposed the adoption of a system classifying viruses into subphyla, classes, orders, suborders, and families. It was also proposed that the hierarchical classification would be based on the type of nucleic acid (DNA or RNA), the strandedness (single = ss or double = ds), the presence or absence of an envelope, the capsid symmetry, the type of replication cycle (with or without an RNA intermediate for DNA viruses), and the number of genome segments. This hierarchical classification system has never been recognized by the ICTV, but most of the criteria used to demarcate the major classes of viruses formed the basis of the universal taxonomy system now in place, and all published ICTV reports have used this scheme with only minor changes.

It is only in the last 15 years that a hierarchical classification level higher than the family was proposed and accepted. A first order, Mononegavirales, was accepted in 1990, and the orders Caudovirales and Nidovirales were adopted in 1996. In 2005, ICTV considered introducing four new orders namely Picornavirales, Herpesvirales, Reovirales, and Retrovirales, and these may become accepted in the near future.

It is important to note that the species category for viruses was only adopted in 1991. From then onwards viruses were assigned to species or tentative species. In addition, a list of species demarcation criteria has been established for each family. It is anticipated that by 2010 the ICTV will have introduced species criteria for all viruses and that some level of homogeneity will have been reached, although it is perfectly acceptable to have different sets of criteria for different families of viruses.

Since the establishment of the ICTV, a total of eight virus taxonomic reports have been published. At the first meeting of the Committee in Mexico City in 1970, two families with corresponding two genera and 24 floating genera were adopted to begin grouping the vertebrate, invertebrate, and bacterial viruses together, and in addition, 16 plant virus ‘groups’ were introduced. Although virologists working with vertebrate viruses had assigned viruses to genera and families for many years, plant virologists until 1993 used the term ‘group’ to designate viruses with similar properties. It was only in 1995 that the ICTV adopted a uniform system for all viruses, encompassing 2,644 assigned viruses. The Eighth ICTV Report on Virus Taxonomy, published in 2005 describes a Universal Virus Classification that comprises 3 orders, 73 families, 9 subfamilies, 287 genera, and 5,450 viruses belonging to 1950 species (Table 1).

Over the past four decades the number of classified viruses, as well as the number of each type of taxa, has increased exponentially and continues to grow (Figure 1). Because DNA sequencing has become a routine technique, it seems likely that the number of recognizes viruses and viral taxa will continue to grow exponentially. Furthermore, virus genome sequences provide qualitative and quantitative criteria for defining the molecular variability of viruses that are useful for classification purposes. Sequencing will also permit identification and classification of many viruses that are difficult to isolate and characterize by other methods.

**Organization and Structure of ICTV**

The ICTV is the only Committee of the Virology Division of the International Union of Microbiological Societies. It is a non-profit organization composed of volunteered virologists from many countries who make decisions on virus names and taxa through a democratic process. The ICTV operates through subcommittees and study groups consisting of more than 500 virologists with expertise in human, animal, insect, protozoa, archaea, bacteria, mycoplasma, fungi, algae, and plant viruses.

Taxonomic proposals are initiated and formulated by study groups or by single individuals. The proposals are examined, offered to public scrutiny, accepted by the relevant subcommittee and presented for approval by the Executive Committee of the ICTV. All decisions are ratified by postal vote, where all members of the ICTV and more than 50 national microbiological societies are represented. Presently, there are 75 study groups working in concert with six subcommittees: one each for the vertebrate, invertebrate, plant, bacterial, and fungal viruses and one for the virus ICTV Database (ICTVdB). The ICTV does not impose taxa but ensures that all propositions are compatible with the International Code for Virus Classification and Nomenclature for accuracy, homogeneity, and consistency. The ICTV regularly
| Order                  | Family          | Subfamily          | Genus                                      | Type species                  | Host |
|-----------------------|-----------------|--------------------|--------------------------------------------|-------------------------------|------|
| The DNA viruses       |                 |                    |                                            |                               |      |
| The dsDNA viruses     |                 |                    |                                            |                               |      |
| **Caudovirales**      |                 |                    |                                            |                               |      |
| Myoviridae            |                 |                    |                                            |                               |      |
| "T4-like viruses"     | Enterobacteria  | phage T4           | B                                          |                              |      |
| "P-like viruses"      | Enterobacteria  | phage P            | B                                          |                              |      |
| "P-like viruses"      | Enterobacteria  | phage P            | B                                          |                              |      |
| "Mu-like viruses"     | Enterobacteria  | phage Mu           | B                                          |                              |      |
| "SP1-like viruses"    | Bacillus phage  | SP1                | B                                          |                              |      |
| "φH-like viruses"     | Halobacterium   | phage φH           | Ar                                         |                              |      |
| Siphoviridae          |                 |                    |                                            |                               |      |
| "λ-like viruses"      | Enterobacteria  | phage λ            | B                                          |                              |      |
| "T1-like viruses"     | Enterobacteria  | phage T1           | B                                          |                              |      |
| "T5-like viruses"     | Enterobacteria  | phage T5           | B                                          |                              |      |
| "L5-like viruses"     | Mycobacterium   | phage L5           | B                                          |                              |      |
| "c2-like viruses"     | Lactococcus     | phage c2           | B                                          |                              |      |
| "ψM1-like viruses"    | Methanobacterium| phage ψM1          | Ar                                         |                              |      |
| "ψC31-like viruses"   | Streptomyces    | phage ψC31         | B                                          |                              |      |
| "N15-like viruses"    | Enterobacteria  | phage N15          | B                                          |                              |      |
| Podoviridae            |                 |                    |                                            |                               |      |
| "T7-like viruses"     | Enterobacteria  | phage T7           | B                                          |                              |      |
| "P2-like viruses"     | Enterobacteria  | phage P2           | B                                          |                              |      |
| "ψ29-like viruses"    | Bacillus phage  | ψ29               | B                                          |                              |      |
| "N4-like viruses"     | Enterobacteria  | phage N4           | B                                          |                              |      |
| Tectiviridae           | Tectivirus      |                    |                                            |                               |      |
| Corticoviridae         | Corticovirus    | Pseudalteromonas   | phage PM2                                  | B                              |      |
| Plasmaviridae          | Plasmavirus     | Achromobacter      | phage L2                                   | B                              |      |
| Lipothrixviridae       | Alphalipothrixvirus| Thermoproteus      | tenax virus 1                             | Ar                             |      |
| Betalipothrixvirus     | Sulfolobus      | islandicus filamentous virus| Ar |      |
| Gammalipothrixvirus    | Acidinius       | filamentous virus 1| Ar                                         |                              |      |
| Rudiviridae            | Rudivirus       | Sulfolobus         | islandicus rod-shaped virus 2              | Ar                             |      |
| Fuselloviridae         | Fusellovirus    | Sulfolobus         | spindle-shaped virus 1                     | Ar                             |      |
| Sulterprovirus         | His1 virus      |                    |                                            |                               |      |
| Gutaviridae            | Gutavirus       | Sulfolobus         | Newzealandicus droplet-shaped virus         | Ar                             |      |
| Poxviridae             | Chordopoxvirinae|                    |                                            |                               |      |
| Orthopoxivirus         | Vaccinia virus  |                    |                                            |                               |      |
| Parapoxivirus          | Orf virus       |                    |                                            |                               |      |
| Avipoxivirus           | Fowlpox virus   |                    |                                            |                               |      |
| Capripoxivirus         | Sheepox virus   |                    |                                            |                               |      |
| Leporipoxivirus        | Myxoma virus    |                    |                                            |                               |      |
| Suipoxivirus           | Swinepox virus  |                    |                                            |                               |      |
| Molluscipoxivirus      | Molluscum       | contagiosum virus  |                                            |                               |      |
| Yatapoxivirus          | Yaba monkey     | tumor virus        |                                            |                               |      |

Continued
| Order       | Family               | Subfamily | Genus                        | Type species                             | Host  |
|-------------|----------------------|-----------|------------------------------|------------------------------------------|-------|
| Alphaentomopoxvirus | Melolontha melolontha | entomopoxvirus | I                            |                                         |       |
| Betaentomopoxvirus  | Amsacta moorei | entomopoxvirus ‘L’ | I                            |                                         |       |
| Gammaentomopoxvirus | Chironomus luridus | entomopoxvirus | I                            |                                         |       |
| Asfarviridae      | Asfivirus            |           | African swine fever virus    |                                         | V, I  |
| Iridoviridae      | Iridovirus           |           | Invertebrate iridescent virus 6 |                                         | I     |
|                    | Chloriridovirus      |           | Invertebrate iridescent virus 3 |                                         | I     |
|                    | Ranavirus            |           | Frog virus 3                 |                                         | V     |
|                    | Lymphocystivirus     |           | Lymphocysts disease virus 1   |                                         | V     |
|                    | Megalocytivirus      |           | Infectious spleen and kidney necrosis virus | | V     |
| Phycodnaviridae   | Chlorovirus          |           | Paramecium bursaria Chlorella virus 1 | | Al    |
|                    | Coccolithovirus      |           | Emiliania huxleyi virus 86   |                                         | Al    |
|                    | Prasinovirus         |           | Micromonas pusilla virus SP  |                                         | Al    |
|                    | Phymnesiovirus       |           | Chrysochromulina brevifilum virus PW1 | | Al    |
|                    | Phaeovirus           |           | Ectocarpus siliculosus virus 1 |                                         | Al    |
|                    | Raphidovirus         |           | Heterosigma akashiwo virus 01 |                                         | Al    |
| Baculoviridae     | Nucleopolyhedrovirus |           | Autographa californica multiple | nuleopolyhedrovirus | I     |
|                    | Granulovirus         |           | Cylidia pomonella granulovirus |                                         | I     |
| Nimaviridae       | Whispovirus          |           | White spot syndrome virus 1   |                                         | I     |
| Herpesviridae     | Alphaherpesvirinae   |           | Simplexvirus                 | Human herpesvirus 1                      | V     |
|                    | Varicellovirus       |           | Human herpesvirus 3           |                                         | V     |
|                    | Mardivirus           |           | Gallid herpesvirus 2          |                                         | V     |
|                    | Iltovirus            |           | Gallid herpesvirus 1          |                                         | V     |
| Betaherpesvirinae | Cytomegalovirus      |           | Human herpesvirus 5           |                                         | V     |
|                    | Muromegalovirus      |           | Murid herpesvirus 1           |                                         | V     |
|                    | Roseolovirus         |           | Human herpesvirus 6           |                                         | V     |
| Gammaherpesvirinae| Lymphocryptovirus    |           | Human herpesvirus 4           |                                         | V     |
|                    | Rhadinovirus         |           | Sariminae herpesvirus 2       |                                         | V     |
| Adenoviridae      | Ictaurivirus         |           | Ictalurid herpesvirus 1       |                                         | V     |
|                    | Mastadenovirus       |           | Human adenovirus C            |                                         | V     |
|                    | Aviadenovirus        |           | Fowl adenovirus A             |                                         | V     |
|                    | Atadenovirus         |           | Ovine adenovirus D            |                                         | V     |
|                    | Sidadenovirus        |           | Frog adenovirus               |                                         | V     |
| Polyomaviridae    | Polymavirus          |           | Simian virus 40               |                                         | V     |
| Papillomaviridae  | Alphapapillomavirus  |           | Human papillomavirus 32       |                                         | V     |
|                    | Betapapillomavirus   |           | Human papillomavirus 5        |                                         | V     |
|                    | Gammapapillomavirus  |           | Human papillomavirus 4        |                                         | V     |
|                    | Deltapapillomavirus  |           | European elk papillomavirus   |                                         | V     |
| Papillomaviridae | Species | Common Name |
|------------------|---------|-------------|
| Epsilonpapillomavirus | Bovine papillomavirus 5 |
| Zetapapillomavirus | Equine papillomavirus 1 |
| Etapapillomavirus | Fringilla coelebs papillomavirus |
| Thetapapillomavirus | Psittacus erithacus timneh papillomavirus |
| Iotapapillomavirus | Mastomys natalensis papillomavirus |
| Kappapapillomavirus | Cotton tail rabbit papillomavirus |
| Lambdapapillomavirus | Canine oral papillomavirus |
| Mupapillomavirus | Human papillomavirus 1 |
| Nupapillomavirus | Human papillomavirus 41 |
| Xipapillomavirus | Bovine papillomavirus 3 |
| Omikronpapillomavirus | Phocoena spinipinnis papillomavirus |
| Pipapillomavirus | Hamster oral papillomavirus |

| Polydnaviridae | Species | Common Name |
|---------------|---------|-------------|
| Bracovirus | Cotesia melanoscela bracovirus |
| Ichnovirus | Campoletis sonorensis ichnovirus |

| Ascoviridae | Species | Common Name |
|-------------|---------|-------------|
| Ascovirus | Spodoptera frugiperda ascovirus 1a |

| Unassigned | Species | Common Name |
|------------|---------|-------------|
| Mimivirus | Acanthamoeba polyphaga mimivirus |

### The ssDNA viruses

| Inoviridae | Species | Common Name |
|------------|---------|-------------|
| Inovirus | Enterobacteria phage M13 |
| Plectrovirus | Acholeplasma phage L51 |

| Microviridae | Species | Common Name |
|--------------|---------|-------------|
| Microvirus | Enterobacteria phage ψX174 |
| Chlamydiamicrovirus | Chlamydia phage 1 |
| Bdellomicrovirus | Bdellovibrio phage MAC1 |
| Spiromicrovirus | Spiroplasma phage 4 |

| Geminiviridae | Species | Common Name |
|---------------|---------|-------------|
| Mastrevirus | Maize streak virus |
| Curtovirus | Beet curly top virus |
| Topocuvirus | Tomato pseudo-curly top virus |
| Begomovirus | Bean golden yellow mosaic virus |

| Circoviridae | Species | Common Name |
|--------------|---------|-------------|
| Circovirus | Porcine circovirus-1 |
| Gyrovirus | Chicken anemia virus |

| Unassigned | Species | Common Name |
|------------|---------|-------------|
| Anellovirus | Torque teno virus |
| Nanoviridae | Subterranean clover stunt virus |
| Babuvirus | Banana bunchy top virus |

| Paroviridae | Species | Common Name |
|-------------|---------|-------------|
| Parovirus | Minute virus of mice |
| Erythrovirus | Human parovirus B9 |
| Dependovirus | Adeno-associated virus 2 |
| Amdovirus | Aleutian mink disease virus |
| Bocavirus | Bovine parovirus |

| Densovirinae | Species | Common Name |
|-------------|---------|-------------|
| Densovirus | Junonia coenia densovirus |
| Iteravirus | Bombyx mori densovirus |
| Brevidendovirus | Aedes aegypti densovirus |
| Pefudenvirus | Periplaneta fuliginosa densovirus |
| Order | Family | Subfamily | Genus | Type species | Host |
|-------|--------|-----------|-------|--------------|------|
| The DNA and RNA reverse transcribing viruses | | | | | |
| Hepadnaviridae | Orthohepadnavirus | | Hepatitis B virus | V |
| | Avihepadnavirus | | Duck hepatitis B virus | V |
| Caulimoviridae | Caulimovirus | | Cauliflower mosaic virus | P |
| | Petuvirus | | Petunia vein clearing virus | P |
| | Soyimovirus | | Soybean chlorotic mottle virus | P |
| | Cavemovirus | | Cassava vein mosaic virus | P |
| | Badnavirus | | Commeilina yellow mottle virus | P |
| | Tungro virus | | Rice tungro bacilliform virus | P |
| Pseudoviridae | Pseudovirus | | Saccharomyces cerevisiae Ty1 virus | F, P |
| | Hemivirus | | Drosophila melanogaster copia virus | F, I |
| | Sirevirus | | Glycine max SIRE1 virus | P |
| Metaviridae | Metavirus | | Saccharomyces cerevisiae Ty3 virus | F, P, I |
| Retroviridae | Orthoretrovirinae | | | |
| | Alpharetrovirus | | Avian leukemia virus | V |
| | Betaretrovirus | | Mouse mammary tumor virus | V |
| | Gammaretrovirus | | Murine leukemia virus | V |
| | Deltaretrovirus | | Bovine leukemia virus | V |
| | Epsilonretrovirus | | Walleye dermal sarcoma virus | V |
| | Lentivirus | | Human immunodeficiency virus 1 | V |
| | Spumaretrovirinae | | | |
| | Spumavirus | | Simian foamy virus | V |
| The RNA viruses | | | | |
| The dsRNA viruses | | | | |
| Cystoviridae | Cystovirus | | Pseudomonas phage 6 | B |
| Reoviridae | Orthoreovirus | | Mammalian orthoreovirus | V |
| | Orbivirus | | Bluetongue virus | V, I |
| | Rotavirus | | Rotavirus A | V |
| | Coltivirus | | Colorado tick fever virus | V, I |
| | Seadornavirus | | Banna virus | V |
| | Aquareovirus | | Aquareovirus A | V |
| | Idnoreovirus | | Idnoreovirus 1 | I |
| | Cypovirus | | Cypovirus 1 | I |
| | Fiji virus | | Fiji disease virus | P, I |
| | Phytoreovirus | | Wound tumor virus | P, I |
| | Orzyavirus | | Rice ragged stunt virus | P, I |
| | Mycoreovirus | | Mycoreovirus 1 | F |
| Birmaviridae | Aquabirnavirus | | Infectious pancreatic necrosis virus | V |
| | Avibirnavirus | | Infectious bursal disease virus | V |
| Family               | Genus                        | Species                                                                 |
|---------------------|------------------------------|-------------------------------------------------------------------------|
| Totivirus            | Totivirus                    | Saccharomyces cerevisiae virus L-A                                      |
|                     |                             | Giardia lambia virus                                                   |
|                     |                             | Leishmania RNA virus 1–1                                                |
| Partitivirus         | Partitivirus                 | Atkinsonella hyphoxylon virus                                           |
|                     |                             | White clover cryptic virus 1                                            |
|                     |                             | White clover cryptic virus 2                                            |
| Chrysovirus          | Chrysoirus                   | Pericillium chrysogenum virus                                           |
| Hypoviridae          | Hypovirus                    | Cryptonectria hypovirus 1                                               |
|                     |                             | Vicia faba endornavirus                                                 |
| Unassigned           |                             |                                                                         |

**The negative-stranded ssRNA viruses**

**Mononegavirales**

| Family               | Genus                        | Species                                                                 |
|---------------------|------------------------------|-------------------------------------------------------------------------|
| Bornaviridae         | Bornavirus                   | Borna disease virus                                                     |
| Rhabdoviridae        | Visceral virus                | Vesicular stomatitis Indiana virus                                      |
|                     | Lyssavirus                   | Rabies virus                                                            |
|                     | Ephemeral virus              | Bovine ephemeral fever virus                                            |
|                     | Novirhabdovirus              | Infectious hematopoietic necrosis virus                                  |
|                     | Cytomervirus                 | Lettuce necrotic yellow virus                                           |
|                     | Nucleothovirus               | Potato yellow dwarf virus                                               |
| Filoviridae          | Marburgivirus                | Lake Victoria marburgivirus                                             |
|                     | Ebola virus                  | Zaire ebolavirus                                                       |
| Paramyxoviridae      | Paramyxovirinae              |                                                                         |
|                     | Rubulavirus                  | Mumps virus                                                             |
|                     | Avulavirus                   | Newcastle disease virus                                                 |
|                     | Respirovirus                 | Sendai virus                                                            |
|                     | Henipavirus                  | Hendra virus                                                            |
|                     | Morbillivirus                | Measles virus                                                           |
| Pneumovirinae        |                             |                                                                         |
|                     | Pneumovirus                  | Human respiratory syncytial virus                                       |
|                     | Metapneumovirus              | Avian metapneumovirus                                                   |
|                     | Varicosavirinae              | Lettuce big-vein associated virus                                       |
|                     | Ophiovirus                   | Citrus psorosis virus                                                   |
| Orthomyxoviridae     | Influenza virus A            | Influenza A virus                                                       |
|                     | Influenza virus B            | Influenza B virus                                                       |
|                     | Influenza virus C            | Influenza C virus                                                       |
|                     | Thogotovirus                 | Thogoto virus                                                           |
|                     | Isavirus                     | Infectious salmon anemia virus                                          |
| Bunyaviridae         | Orthobunyavirus              | Bunyamwera virus                                                        |
|                     | Hantavirus                   | Hantaan virus                                                           |
|                     | Nairobi virus                | Dugbe virus                                                             |
|                     | Phlebovirus                  | Rift Valley fever virus                                                |
|                     | Tospovirus                   | Tomato spotted wilt virus                                              |
|                     | Tenuivirus                   | Rice stripe virus                                                       |
|                     | Arenavirus                   | Lymphocytic chorionema virus                                            |

**Continued**
| Order         | Family            | Subfamily | Genus   | Type species                      | Host |
|--------------|------------------|-----------|---------|-----------------------------------|------|
|              |                  |           |         | Deltavirus                         | V    |
| The positive-stranded ssRNA viruses |                  |           | Levivirus | Enterobacteria phage MS2          | B    |
| Leviviridae  | Levivirus         |           |         |                                   |      |
|              | Allolevivirus     |           |         | Enterobacteria phage Q1           | B    |
| Namnaviridae | Namnavirus        |           |         | Saccharomyces 20S namnavirus      | F    |
|              | Mitovirus         |           |         | Cryphonectria mitovirus 1         | F    |
| Picornavirida| Enterovirus       |           |         | Poliovirus                        | V    |
|              | Rhinovirus        |           |         | Human rhinovirus A                | V    |
|              | Cardiovirus       |           |         | Encephalomyocarditis virus        | V    |
|              | Aphthovirus       |           |         | Foot-and-mouth disease virus      | V    |
|              | Hepatovirus       |           |         | Hepatitis A virus                 | V    |
|              | Parechovirus      |           |         | Equine rhinitis B virus           | V    |
|              | Erbovirus         |           |         | Aichi virus                       | V    |
|              | Kobuvirus         |           |         | Porcine teschovirus               | V    |
|              | Teschovirus       |           |         |                                   | I    |
|              | Unassigned        |           |         |                                   | I    |
|              | Inflaviridae      |           |         | Infectious flacherie virus        | I    |
|              | Cripavirus        |           |         | Cricket paralysis virus           | I    |
|              | Marnaviridae      |           | Marnavirus | Heterosigma akashiwo RNA virus | F    |
|              | Sequiviridae      |           | Sequivirus | Parsnip yellow fleck virus       | P    |
|              | Waikavirus        |           |         | Rice tungro spherical virus       | P    |
|              | Unassigned        |           |         |                                   | P    |
|              | Sadnavirus        |           |         | Satsuma dwarf virus               | P    |
|              | Chervirus         |           |         | Cherry rasp leaf virus            | P    |
|              | Comoviridae       |           | Comovirus | Cowpea mosaic virus               | P    |
|              | Fabavirus         |           |         | Broad bean wilt virus 1           | P    |
|              | Nepovirus         |           |         | Tobacco ringspot virus            | P    |
|              | Potyviridae       |           | Potyvirus | Potato virus Y                    | P    |
|              | Ipomovirus        |           |         | Sweet potato mild mottle virus    | P    |
|              | Macluravirus      |           |         | Maclura mosaic virus              | P    |
|              | Rymovirus         |           |         | Ryegrass mosaic virus             | P    |
|              | Tritimovirus      |           |         | Wheat streak mosaic virus         | P    |
|              | Bymovirus         |           |         | Barley yellow mosaic virus        | P    |
|              | Caliciviridae     |           | Lagovirus | Rabbit hemorrhagic disease virus  | V    |
|              | Norovirus         |           |         | Norwalk virus                     | V    |
|              | Saposivirus       |           |         | Sapporo virus                     | V    |
|              | Vesivirus         |           |         | Vesicular exanthema of swine virus| V    |
|              | Unassigned        |           |         |                                   | V    |
|              | Hepeviridae       |           |         | Hepatitis E virus                 | V    |
|              | Astroviridae      |           | Avastrovirus | Turkey astrovirus     | V    |
|              | Mamastrovirus     |           |         | Human astrovirus                  | V    |
|              | Nodaviridae       |           | Alphanodavirus | Nodamura virus | I |
|              | Betanodavirus     |           |         | Striped jack nervous necrosis virus | V |
|              | Tetaviridae       |           | Betatetravirus | Nudaurella capensis f virus | I |

Table 1 Continued
| Classification | Species | Common Name                                      | Type  |
|---------------|---------|--------------------------------------------------|-------|
| Unassigned    | Omegatetravirus | Nudaurelia capensis o virus                      | I     |
| Luteoviridae  | Sobemovirus  | Southern bean mosaic virus                       | P     |
|               | Luteovirus   | Barley yellow dwarf virus-PAV                    | P     |
|               | Polerovirus  | Potato leafroll virus                            | P     |
|               | Enamovirus   | Pea mottle mosaic virus-1                        | P     |
| Unassigned    | Umbra virus | Carrot mottle virus                              | P     |
| Tombusviridae | Dianthovirus | Carnation ringspot virus                         | P     |
|               | Tombusvirus  | Tomato bushy stunt virus                         | P     |
|               | Aureusvirus  | Pothos latent virus                              | P     |
|               | Avenaviruses | Oat chlorotic stunt virus                        | P     |
|               | Camovirus    | Carnation mottle virus                           | P     |
|               | Necrovirus   | Tobacco necrosis virus A                         | P     |
|               | Panicotavirus | Pancum mosaic virus                              | P     |
|               | Machlovirus  | Maize chlorotic mottle virus                     | P     |
| Nidovirales   | Coronaviridae | Coronavirus infectious bronchitis virus          | V     |
|               | Torovirus    | Equine torovirus                                 | V     |
| Arteriviridae | Arterivirus  | Equine arteritis virus                           | I     |
| Flaviviridae  | Flavivirus   | Yellow fever virus                               | V, I  |
|               | Pestivirus   | Bovine viral diarrhea 1 virus                    | V     |
|               | Hepacivirus  | Hepatitis C virus                                | V     |
| Togaviridae   | Alphavirus   | Sindbis virus                                    | V, I  |
|               | Rubivirus    | Rubella virus                                    | V     |
| Unassigned    | Tobamovirus  | Tobacco mosaic virus                             | P     |
|               | Tobaviruses  | Tobacco rattle virus                             | P     |
|               | Hordevirus   | Barley stripe mosaic virus                       | P     |
|               | Furivirus    | Soil-borne wheat mosaic virus                    | P     |
|               | Pomovirus    | Potato mop-top virus                             | P     |
|               | Peckvirus    | Peanut clump virus                               | P     |
|               | Benyvirus    | Beet necrotic yellow vein virus                  | P     |
| Bromoviridae  | Alfamovirus  | Alfalfa mosaic virus                             | P     |
|               | Bromovirus   | Brome mosaic virus                               | P     |
|               | Cucumovirus  | Cucumber mosaic virus                            | P     |
|               | Ilarvirus    | Tobacco streak virus                             | P     |
|               | Oleaviruses  | Olive latent virus 2                             | P     |
| Unassigned    | Ourmiavirus  | Ourmia melon virus                               | P     |
|               | Ideovirus    | Raspberry bushy dwarf virus                      | P     |
| Tymoviridae   | Tyomovirus   | Turnip yellow mosaic virus                       | P     |
|               | Marafivirus  | Maize rayado fino virus                          | P, I  |
|               | Maculavirus  | Grapevine fleck virus                            | P     |
| Closteroviridae | Closterovirus | Beet yellows virus                               | P     |
|               | Ampelovirus  | Grapevine leafroll-associated virus 3            | P     |
|               | Crinitivirus | Lettuce infectious yellows virus                 | P     |
| Order      | Family          | Subfamily       | Genus             | Type species                  | Host |
|------------|-----------------|-----------------|-------------------|-------------------------------|------|
| Flexiviridae | Potexvirus      |                 | Potato virus X    | P                             |      |
|            | Mandarivirus    |                 | Indian citrus ringspot virus | P                             |      |
|            | Allexivirus     |                 | Shallot virus X   | P                             |      |
|            | Carlavirus      |                 | Carnation latent virus | P                             |      |
|            | Foveavirus      |                 | Apple stem pitting virus | P                             |      |
|            | Capillovirus    |                 | Apple stem grooving virus | P                             |      |
|            | Vitivirus       |                 | Grapevine virus A | P                             |      |
|            | Trichovirus     |                 | Apple chlorotic leaf spot virus | P                             |      |
|            | Barnavirus      |                 | Mushroom bacilliform virus | F                             |      |

**Unassigned viruses**

Unassigned Vertebrate Viruses

Unassigned Invertebrate Viruses

Unassigned Prokaryote Viruses

Unassigned Fungus Viruses

Unassigned Plant Viruses

The subviral agents: Viroids, satellites and agents of spongiform encephalopathies (prions)

**Viroids**

- **Pospiviroidae**
  - Pospiviroid
  - Hop stunt viroid
- **Hostuviroid**
- **Cocadviroid**
- **Apscaviroid**
- **Coleviroid**
  - Coleus blumei viroid 1

**Avsunviroidae**

- **Avsunviroid**
- **Pelamoviroid**

**Satellites**

- **Vertebrate Prions**
- **Fungi prions**

Virus hosts: Al, Algae; Ar, Archaea; B, Bacteria; F, Fungi; I, Invertebrates; P, Plants; Pr, Protozoa; V, Vertebrates.
publishes reports describing all existing virus taxa and containing a complete list of classified viruses with their abbreviations. The ICTV published its Eighth Report in 2005. An internet website is also maintained where all new taxonomic proposals are loaded and where the most important information relative to virus taxonomy is made available and updated regularly. The increasing number of virus species and virus strains being identified, along with the explosion of data on many descriptive aspects of viruses and viral diseases, particularly sequence data, has led the ICTV to launch an international virus database project (ICTVdB) and a Taxonomic Proposal Management System specifically to handle taxonomic proposals.

Polythetic Classification and Demarcation Criteria

There are currently two systems in use for classifying organisms: the Linnean and the Adansonian systems. The Linnean system is the monothetic hierarchical classification applied by Linnaeus to plants and animals, while the Adansonian is a polythetic hierarchical system. Although convenient to use, the Linnean system has shortcomings when applied to the classification of viruses because there is no obvious reason to privilege one criterion over another. The Adansonian system considers all available criteria at once and makes several classifications, taking the criteria successively into consideration. Criteria leading to the same classifications are considered correlated and are therefore not discriminatory. Subsequently, a subset of criteria is considered, and the process is repeated until all criteria can be ranked to provide the best discrimination of the species. Furthermore, qualitative and quantitative data can be simultaneously considered when building such a classification. In the case of viruses, the method is not used on a systematic basis, although it has been shown that at least 60 characters are needed for a complete virus description (Table 2).

The increasing number of reported viral nucleic acid sequences allows the construction of phylogenetic trees based on a single gene or a group of genes. Sequence comparisons by themselves have not satisfactorily provided a clear classification of all viruses together but are widely used at the order, family, and genus levels. Recently the National Center for Biotechnology Information (NCBI) in Washington developed a system of pairwise sequence comparisons (the so-called PASC system) between viral sequences which allows a new virus to be assigned to known taxa. It seems probable that, in future, virus classification will make increasing use of sequence data.

For more than 40 years, the ICTV has been classifying viruses essentially at the family and genus levels using a nonsystematic polythetic approach. Viruses are first clustered in genera and then in families. A subset of characters including physicochemical, structural, genomic, and biological criteria is then used to compare and group viruses. This subset of characters may change from one family to another according to the availability of the data and depending on the importance of a particular character for a particular family. Obviously, there is no homogeneity in this respect in the current virus classification system, and virologists weigh the criteria in a subjective process. Nevertheless, over time, there has been a great stability of the current classification at the genus and family levels. It is also clear that hierarchical classification above the family level will encounter conflicts between phenotypic and genotypic criteria and that virologists may have to reconsider the entire classification process in order to progress at this level.

Virus Taxa Descriptions

Virus classification continues to evolve with the technologies available for describing viruses. The first wave of descriptions, those before 1940, took into account mostly the visual symptoms of viral diseases along with modes of viral transmission. A second wave, between 1940 and
1970, brought together an enormous amount of information from studies of virion morphology (electron microscopy, structural data), biology (serology and virus properties), and physicochemical properties of viruses (nature and size of the genome, number and size of viral proteins). The impact of descriptions on virus classification has been particularly influenced by electron microscopy and the negative-staining technique for virions in the 1960s and 1970s. With this technique, viruses could be identified from poorly purified preparations of all tissue types and information about size, shape, structure, and symmetry could be quickly provided. As a result, virology progressed simultaneously for all viruses infecting animals, insects, plants, and bacteria. Since 1970, the virus descriptors list has included genome and replication information (sequence of genes, sequence of proteins), as well as molecular relationships with virus hosts.

The most recent wave of information used to classify viruses is virus genome sequences. Genome sequence comparisons are becoming more and more prevalent in virus taxonomy as exemplified by the presence of a significant number of phylogenetic trees in the *Eighth ICTV Report*. Some scientists promote the concept of quantitative taxonomy, aimed at demonstrating that virus genome sequences contain all the coding information required for all the biological properties of the viruses. This is in complete agreement with the polythetic concept of virus species definition if one considers that the unique sequence of a genome contains in fact all the information of the virus to perform all the steps of its replication cycle with structural and nonstructural genes and all of its biological functions. A good example of quantitative taxonomy is the re-classification of flaviviruses from the genus *Flavivirus* in the family *Togaviridae* into the new family *Flaviviridae* based upon sequencing of the yellow fever virus genome and comparisons with the gene sequence arrangement of members of the genus *Alphavirus* in the family *Togaviridae*. Another recent example is the merging of the genera *Rhinovirus* and *Enterovirus* in the family *Picornaviridae*, based on the fact that phylogenetic trees and pairwise comparisons did not support the continued distinction between the two genera.

There is a correlative modification of the list of virus descriptors, and Table 2 lists the family and genus descriptors which are used in the current ICTV report. Table 2 lists 45 different types of properties where each property (e.g., morphology) can take on different individual states (e.g., filamentous, icosahedral, etc.). A universal lists of virus descriptors has been established which is used by the ICTVdB. It contains a common set of descriptors for all viruses and subsets for specific viruses in relation to their specific hosts (human, animal, insect, plant, and bacterial).

Table 2  Virus family descriptors used in virus taxonomy

| I. Virion properties |   |
|----------------------|---|
| A. Morphology properties of virions |   |
| 1. Virion size |   |
| 2. Virion shape |   |
| 3. Presence or absence of an envelope and peplomers |   |
| 4. Capsomeric symmetry and structure |   |
| B. Physical properties of virions |   |
| 1. Molecular mass of virions |   |
| 2. Buoyant density of virions |   |
| 3. Sedimentation coefficient |   |
| 4. pH stability |   |
| 5. Thermal stability |   |
| 6. Cation (Mg$^{2+}$, Mn$^{2+}$) stability |   |
| 7. Solvent stability |   |
| 8. Detergent stability |   |
| 9. Radiation stability |   |
| C. Properties of genome |   |
| 1. Type of nucleic acid – DNA or RNA |   |
| 2. Strandedness – single stranded or double stranded |   |
| 3. Linear or circular |   |
| 4. Sense – positive, negative, or ambisense |   |
| 5. Number of segments |   |
| 6. Size of genome or genome segments |   |
| 7. Presence or absence and type of 5’-terminal cap |   |
| 8. Presence or absence of 5’-terminal covalently linked polypeptide |   |
| 9. Presence or absence of 3’-terminal poly(A) tract (or other specific tract) |   |
| 10. Nucleotide sequence comparisons |   |
| D. Properties of proteins |   |
| 1. Number of proteins |   |
| 2. Size of proteins |   |
| 3. Functional activities of proteins (especially virion transcriptase, virion reverse transcriptase, virion hemagglutinin, virion neuraminidase, virion fusion protein) |   |
| 4. Amino-acid-sequence comparisons |   |
| E. Lipids |   |
| 1. Presence or absence of lipids |   |
| 2. Nature of lipids |   |
| F. Carbohydrates |   |
| 1. Presence or absence of carbohydrates |   |
| 2. Nature of carbohydrates |   |
| II. Genome organization and replication |   |
| 1. Genome organization |   |
| 2. Strategy of replication of nucleic acid |   |
| 3. Characteristics of transcription |   |
| 4. Characteristics of translation and post-translational processing |   |
| 5. Site of accumulation of virion proteins, site of assembly, site of maturation and release |   |
| 6. Cytopathology, inclusion body formation |   |
| III. Antigenic properties |   |
| 1. Serological relationships |   |
| 2. Mapping epitopes |   |
| IV. Biological properties |   |
| 1. Host range, natural and experimental |   |
| 2. Pathogenicity, association with disease |   |
| 3. Tissue tropisms, pathology, histopathology |   |
| 4. Mode of transmission in nature |   |
| 5. Vector relationships |   |
| 6. Geographic distribution |   |
The Order of Presentation of the Virus Classification

Currently, and for practical reasons only, virus classification is structured according to the ‘Order of Presentation of Viruses’ indicated in Table 1. The presentation of virus orders, families, and genera in this particular order reflects convenience rather than any hierarchical or phylogenetic consideration. The Order of Presentation of Viruses follows four criteria: (1) the nature of the viral nucleic acid, (2) the strandedness of the nucleic acid (single stranded (ss) or double stranded (ds)), (3) the use of a reverse transcription process (DNA or RNA), and (4) the sense of gene coding on the encapsidated genome (positive, negative, or ambisense). These four criteria give rise to six clusters comprising the 86 families and unassigned genera (genera without a designated family). Within each cluster, families and unassigned genera have been listed according to their possible affinities. For example, the families Picornaviridae, Dicistroviridae, Segnaviridae, Comoviridae, and Potyviridae are listed one after another because they share a number of similarities in their genome organization and sequence relatedness and they may form the basis for a proposed order in the future.

A New Virus Taxon: The Virus Species

For many years, virologists debated the existence of virus species which was a very controversial issue and a series of definitions surfaced at regular intervals but none was adopted. However, in 1991, the ICTV Executive Committee accepted the species concept and the adopted definition is “A virus species is a polythetic class of viruses that constitutes a replicating lineage and occupies a particular ecological niche.” This simple definition has already and will continue to have a profound effect on virus classification. In the Eighth Report of the ICTV, the ‘List of Species’ and the ‘List of Tentative Species’ are accompanied by a ‘List of Species Demarcating Criteria’ provided for each genus. Naturally, this list of criteria should follow the polythetic nature of the species definition, and more than one criterion should be used to determine a new species. It is obvious that most criteria are shared among the different genera, within and across families. These shared criteria include host range, serological relationships, vector transmission type, tissue tropism, genome rearrangement, and sequence homology (Table 3). However, while the nature of the criteria is similar, the levels of demarcation clearly differ from one family to another. This may reflect differences in appreciation from one family to another, but most likely reflects the differential ranking of a particular criterion in different families. The huge differences in sequence homologies (up to 30%) among lentivirus nucleoprotein sequences may not have the same biological significance as small differences for potyvirus capsid protein sequences (0–10%), and therefore universal levels of sequence identity for similar genes may not exist for viruses. However, it is important to note that the nature of the demarcating criteria at the genus level will probably not change since they have passed the test of years. Despite the fact that they were mostly established using biochemical and structural criteria, most of them have remained valid when correlated with genome organization and sequence data.

A Uniform Nomenclature for All Virus Taxa

Nomenclature is tightly associated with classification, in the sense that the taxonomic names indicate, to some extent, the nature of the taxa. Similarly for viruses, the ICTV has set rules for virus nomenclature and the orthography of taxonomic names that are regularly revised and improved. The international virus species names end in ‘virus’, international genus names in

| Table 3 | List of criteria demarcating different virus taxa |
|---------|-----------------------------------------------|
| I. Order | Common properties between several families including: |
|         | Biochemical composition |
|         | Virus replication strategy |
|         | Particle structure (to some extent) |
|         | General genome organization |
| II. Family | Common properties between several genera including: |
|         | Biochemical composition |
|         | Virus replication strategy |
|         | Nature of the particle structure |
|         | Genome organization |
| III. Genus | Common properties within a genus including: |
|         | Virus replication strategy |
|         | Genome size, organization, and/or number of segments |
|         | Sequence homologies (hybridization properties) |
|         | Vector transmission |
| IV. Species | Common properties within a species including: |
|           | Genome arrangement |
|           | Sequence homologies (hybridization properties) |
|           | Serological relationships |
|           | Vector transmission |
|           | Host range |
|           | Pathogenicity |
|           | Tissue tropism |
|           | Geographical distribution |
‘...virus’, international subfamily names in ‘...virinae’, international family names in ‘...viridae’, and international order names in ‘...virales’. In formal taxonomic usage, the virus order, family, subfamily, genus, and species names are printed in italics (or underlined) and the first letter is capitalized. For all taxa except species, new names are created following ICTV guidelines. Because of the difficulty in creating new official international names for virus species, it has been decided in 1998 by the ICTV to use the existing English vernacular virus names. However, to differentiate virus species names from virus names it has also been decided that their typography would be different, that is, the species names would be italicized, and the first letter of the name capitalized while the virus names would not. In addition ICTV had created an additional category called ‘Tentative Species Names’ to accommodate viruses that seemed to belong to a new species, but did not have enough data to support this decision; it was also a way to ‘reserve’ a name already used in literature. In 2005, ICTV decided to replace this category by ‘Unassigned Virus names’. In formal usage, the name of the taxon precedes the name of the virus but replacing the word ‘virus’ by the genus name: for example, Cucumber mosaic cucumovirus and Tobacco mosaic tobamovirus. This system is called ‘the non-latinized binomial system’, although the binomial order is the opposite of the typical latinized binomial system where the genus name ends with the virus name. Though this usage is favored by many scientists, and examples of such a practice can be found for human, animal, and insect viruses (e.g., Human rhinovirus, Canine calicivirus, and Acheta densovirus), it has not yet been adopted as a universal system by the ICTV; however, it has been decided that each study group would decide what is best for the viruses they deal with and the new names would have to be ratified through a formal taxonomic proposal by the ICTV.

In formal usage, the name of the taxon precedes the name of the taxonomic unit: for example, “the family Picornaviridae” or “the genus Rhinovirus”. In informal vernacular usage, virus order, family, subfamily, genus, and species names are written in lower case roman script; they are not capitalized or italicized (or underlined) – for example ‘animal reoviruses’. To avoid ambiguous identifications, it has been recommended to journal editors that published virological papers follow ICTV guidelines for proper virus identification and nomenclature and that viruses should be cited with their full taxonomic terminology when they are first mentioned in an article, for example, order Mononegavirales, family Paramyxoviridae, subfamily Pneumovirinae, genus Pneumovirus, species Human respiratory syncytial virus.

A Universal Classification System

The present universal system of virus taxonomy is set arbitrarily at the hierarchical levels of order, family, subfamily, genus, and species. Lower hierarchical levels, such as suborder, subgenera, and subspecies, may be considered in the future if need arises. Hierarchical levels under the species level such as strains, serotypes, variants, and pathotypes are established by international specialty groups and/or by culture collections, but not by the ICTV.

Species

The species taxon is always regarded as the most important taxonomic level in classification but has proved difficult to apply to viruses. In 1991, the ICTV accepted the definition of species, stated above, proposed by Marc van Regenmortel. The major advantage of this definition is that it can accommodate the inherent variability of viruses and is not dependent on the existence of a unique set of characteristics. Members of a polythetic class are defined by more than one property and no single property is absolutely indispensable. Thus, in each family, it might be possible to determine the set of properties of the class ‘species’ and thus to verify if the family members are representatives of the class ‘species’ or if they belong to a different taxonomic level.

Many practical matters are related to the definition of a virus species. These include (1) homogeneity of the different taxa across the classification, (2) diagnostic-related matters, (3) virus collections, (4) evolution studies, (5) biotechnology, (6) sequence database projects, (7) virus database projects, (8) publication matters, and also (9) intellectual property rights.

Genera

There is no formal ICTV definition for a genus, but it is commonly considered as “a population of virus species that share common characteristics and are different from other populations of species.” Although this definition is somewhat elusive, this level of classification seems stable and useful. Some genera have been moved from one
family to another (or from one family to an unassigned genus status such as the genus *Hepevirus*) over the years, but the composition and description of these genera has remained very stable. The characters defining a genus are different from one family to another. The use of subgenera has been abandoned in current virus classification.

Families

Genera are usually clustered in families, and most of the time, when a new genus, obviously not belonging to any existing family, is created, virologists also create a new family. Even after the creation of the ICTV, plant virologists have continued to classify plant viruses in ‘groups’, refusing to place them in genera and families. This position was mostly caused by a refusal to accept a binomial nomenclature. However, because of obvious similarities, plant reoviruses and rhabdoviruses had been integrated into the families *Reoviridae* and *Rhabdoviridae* (Table 1).

Plant virologists subsequently accepted in 1995 the placing of plant viruses into species, genera, and families. The number of unassigned genera is regularly decreasing with time; the most recent clustering is the creation of the family *Flexiviridae* with the genera *Potexvirus*, *Carlavirus*, *Mandarivirus*, *Foveavirus*, *Capillovirus*, *Allexivirus*, *Vitivirus*, and *Trichovirus*. However, there are still 22 unassigned genera that do not belong to any family. Their presence originates mostly from the preference of plant virologists for accumulating data on virus species and genera before clustering genera in families. The unassigned genus status is now being used by animal virologists as a convenient temporary classification status. Examples are the unassigned genera *Anellovirus*, that is close to the family *Circoviridae* but different enough to be separated, the previously unassigned genus *Cripavirus* that has been upgraded to full family status (*Dicistroviridae*), and another unassigned genus *Iflavirus* that has been created to accommodate new picorna-like viruses that are not typical picornaviruses.

Orders

As mentioned above, the higher hierarchical levels for virus classification are extremely difficult to establish. To date only three orders have been accepted: *Caudovirales*, *Mononegavirales*, and *Nidovirales*. The first order, *Mononegavirales*, was established in 1990 and comprises the nonsegmented ssRNA negative-sense viruses, namely, the families *Bornaviridae*, *Filoviridae*, *Paramyxoviridae*, and *Rhabdoviridae*. This order was formed because of the great similarity between these families over many criteria, including their replication strategies. A second order, *Caudovirales*, contains all families of dsDNA phages possessing a tail, including the families *Myoviridae*, *Podoviridae*, and *Siphoviridae*. The order *Nidovirales* comprises the families *Coronaviridae*, *Arteriviridae*, and *Retroviridae* and was created because it was clear that the viruses belonging to these families share many properties and yet are so different that they cannot be placed together in the same family. Many members of the ICTV advocate the creation of many more orders, and as a matter of fact four new orders encompassing the families *Herpeviridae*, *Picornaviridae*, *Reoviridae*, and *Retroviridae* have been proposed and provisionally named but it has been decided to proceed cautiously in this area so as to avoid creation of short-lived orders. The creation of formal taxa higher than the orders—for example kingdoms, classes, and subclasses—has not been considered by the ICTV.

See also: Nature of Viruses; Phylogeny of Viruses; Virus Classification by Pairwise Sequence Comparison (PASC); Virus Databases; Virus Species.

Further Reading

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Relevant Website

http://www.ictv.ird.fr – ICTV; Taxonomic Proposal Management System.