Part 1: <u>TITLE, AUTHORS, APPROVALS, etc.</u>

Code assigned:	**2018.001G**

Short title: Modify the International Code of Virus Classification and Nomenclature (ICVCN) to prospectively mandate a uniform genus-species type virus species naming format

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List the ICTV Study Group(s) that have seen this proposal

N/A – Direct submission to ICTV Executive Committee

ICTV study group comments and response of proposer

N/A

Submission dates

Date first submitted to SC Chair	June 6, 2018; 1st revision July 8, 2019 and July 31, 2020
Date of this revision (if different to above)	December 6, 2020

ICTV-EC comments and response of the proposer

In 2019, this proposal was voluntarily deferred by the proposers for one year to give the community additional time to discuss the subject and provide the feedback to the ICTV Executive Committee (EC). The EC voted unanimously to publish a Consultation paper in *Archives of Virology* Virology Division News to outline all species-naming options that the EC finds viable, coupled with a non-binding community survey. The EC also voted unanimously to require community feedback through the ICTV website and to promote the ongoing consultation at various venues.

This EC *Archives of Virology* Virology Division News article was published online on December 5, 2019 [1]. Community input was requested, with a deadline of June 30, 2020, at a public forum site established at the ICTV website (https://talk.ictvonline.org/ictv1/f/taxonomic-opinions/3952/binomial-species-names). Also, it was encouraged that comments be sent to the ICTV President directly, including those that were not intended to be made public, by the same deadline.

The ICTV EC considered the following viable options for species naming:
1. Genus + Latin *or* Latinized epithet
2. Genus + alphanumeric epithet
3. Genus + freeform epithet

The EC requested that the proposers modify the proposal:
1. to include viroids and satellites;
2. to include clear instructions on how to create Latinized names for people not familiar with Latinization;
3. to review any community-derived comments and concerns received by the deadline of June 30, 2020, and to address those not already addressed in the previous proposal draft;
4. to divide the proposal into sections that could be voted on individually; and
5. to add comments on "authority" and whether the proposed species naming format is truly Linnaean, or should be considered Linnaean-like, or neither.

In addition, a second TaxoProp addressing the species naming issue, TaxoProp 2020.003G, was submitted to the EC, arguing for a "free-form" species epithet in genus-species epithet binomial species names [2], and three articles were published on the issue of binomial species naming in *Archives of Virology* [3, 17, 18]. The content of these documents was reviewed by the EC to evaluate whether the current proposal should be modified further.

We therefore revised this proposal as follows:
a. In light of TaxoProp 2020.003G and the complications envisioned regarding Latinization of the names of prokaryotic virus species, this proposal was modified to make Latinization of binomial virus species names optional but encouraged. This step brings this proposal more in line with TaxoProp 2020.003G (now withdrawn), which maintains Latinization as one option in a "free-form" binomial species naming.
b. Viroids and satellites are now included in the proposal by (a) pointing out at the beginning that the word "virus" is meant to be understood to include both viroids and satellites throughout the proposal and (b) pointing out in the Latinization guide appendix that the suffixes -*viroid* and -*satellite* are to be treated as the suffix -*virus*, i.e., as being of the neuter gender.
c. A detailed guide on how to Latinize species names is now included as an appendix.
d. All community input on the ICTV webpage, internal emails sent to the ICTV President, TaxoProp 2020.003G, and articles [3, 17, 18] were reviewed and any new arguments (for or against Latinized binomial species names) were added to the proposal.
e. The proposal was divided into sections A and B, which can be voted on individually.
f. The "authority" issue was addressed by (a) explaining what is meant by authority, (b) stating that no authority has to be used in conjunction with the proposed virus species name format, and (c) changing all occurrences of "Linnaean" to "Linnaean-style" in relation to virus species names. We emphasize that we only propose changing the style of virus species naming and that the resulting

Linnaean-*looking* names would not be associated with any rules or practices connected with "true" Linnaean species names in other biological taxonomies.

In October of 2020 (EC52 meeting), the ICTV EC voted on three components of this revised proposal:
1. Section A/B: establishment of a uniform species naming format in the form of genus name-species epithet (yes or no);
2. amendment of ICVCN Rule 3.20 including the comment "Latinized format is encouraged"; and
3. a two-year time window to implement the renaming of all species names that would have to be renamed if 1) was approved.

The uniform species name proposal component was accepted by majority vote. The proposed amendment of ICVCN Rule 3.20 was accepted by majority vote pending the replacement of the word "encouraged" by "permitted" and the addition of a link to this proposal for guidance on forming Latinized names. The implementation text was requested to be changed to a sentence similar in content to "The process should start immediately and be completed in time to be considered by EC55".

These requested changes are now implemented in this new revision.

The ICVCN rule 3.20 is thus proposed to be changed to:
"A species name shall consist of only two distinct word components separated by a space. The first word component shall begin with a capital letter and be identical in spelling to the name of the genus to which the species belongs. The second word component shall not contain any suffixes specific for taxa of higher ranks. The entire species name (both word components) shall be italicized."

Part 2: NON-TAXONOMIC PROPOSAL

Text of proposal

INTRODUCTION
Virus, viroid, satellite, and other mobile genetic element (from here on "virus" [a.k.a. *sensu lato*] for simplicity) taxon names above the rank of species, just as the names of similarly ranked taxa in other biological taxonomies consist of highly standardized single words. In virus taxonomy, these names end in rank-specific suffixes and follow certain requirements (i.e., all of these names are mandated by the International Code of Virus Classification and Nomenclature [ICVCN; "Code"] to begin with a capitalized first letter, be italicized in their entirety, and end in suffixes, such as, *-virus*/*-viroid*/*-satellite* [genera], *-viridae*/*-viroidae*/*-satellitidae* [families], *-virales* [orders], *-viricetes* [classes], etc.). Examples are *Morbillivirus*/*Avsunviroid*/*Colecusatellite*, *Tombusviridae*/*Pospiviroidae*/*Tolecusatellitidae*, *Picornavirales*, and *Ellioviricetes*, respectively. As in other biological taxonomies, the addition of these rank-specific suffixes Latinizes all taxon names above the rank of species even if the word stem itself is not Latin (e.g., the virus family name *Rhabdoviridae* is a Latinized name via the suffix *-viridae* using a Greek word stem, ῥάβδος (rhábdos), meaning "rod, wand").

In botanical/mycological/prokaryotic/zoological/protistological taxonomies (that is, in *all* non-virologic cellular organismal taxonomies), species names are also highly standardized. In these taxonomies, species names, with rare exceptions, follow a binomial format spearheaded by Carl Linnaeus in 1753 [4]. This format consists of two (→"binomial") italicized and Latinized words, separated by a space, with the first

(capitalized) word being the name of the genus to which the species belongs ("genus name") and the second (lower-case) word denoting the species ("species epithet"). Depending on the biological taxonomy, these binomials are followed by a so-called "authority", i.e., typically the name of the first describer of the species and/or the year in which the description occurred. The style of "authority" depiction differs from taxonomy to taxonomy [5-7]:

- botany: ***Arabidopsis thaliana*** (L.) Heynh. [the species for thale cress, genus *Arabidopsis*];
- mycology: ***Pleurotus ostreatus*** (Jacq. ex Fr.) P. Kumm. (1871) [the species for pearl oyster mushrooms, genus *Pleurotus*]; ***Verticillium albo-atrum*** Reinke & Berthold, (1879) [the species for an ascomycete, and an example for the rare case of the Linnaean species name being a pseudobinomial due to use of a hyphen in the species epithet];
- bacteriology: ***Escherichia coli*** (Migula 1895) [genus *Escherichia*]; and
- zoology: ***Pan troglodytes*** (Blumenbach, 1775) [the species for common chimpanzees, genus *Pan*].

In virus taxonomy, species names are not yet standardized and hence follow a plethora of different formats, among others:

- non-Latinized species-genus binomials, e.g., *Lassa mammarenavirus* (included in genus *Mammarenavirus*);
- non-Latinized species-genus trinomials and multinomials using words, e.g., *Tai Forest ebolavirus*, *Calla lily chlorotic spot orthotospovirus* (included in genera *Ebolavirus* and *Orthotospovirus*, respectively);
- non-Latinized species-genus trinomials containing numbers or letters at different positions, e.g., *Mammalian 1 orthobornavirus*, *Avian orthoavulavirus 1* (included in genus *Orthobornavirus* and *Orthoavulavirus*, respectively);
- non-Latinized ("free-form") genus-species binomials (e.g., *Alphaarterivirus equid*) or multinomials containing numbers (e.g., *Etaarterivirus ugarco 1*);
- non-Latinized genus-species binomials with species epithets being numbers or letters (e.g., *Aalivirus A*, *Sanfarnavirus 1*);
- non-Latinized genus-species binomials with identical suffixes in both word components (e.g., *Senegalvirus marseillevirus*);
- Latinized Linnaean-style genus-species binomials (e.g., *Coguvirus eburi*);
- single-word species names that on first glance appear to be genus names, e.g., *Lausannevirus*;
- species names that are identical in spelling to the names of their member viruses and are only differentiated from them via italics and, sometimes, capitalization, e.g., *Cafeteria roenbergensis virus* as the taxonomic home of Cafeteria roenbergensis virus or *West Nile virus* as the species for West Nile virus; and
- species names that mimic virus names but are more or less distinct from the names of their member viruses, e.g., the species *Seneca virus A* for Seneca Valley virus; *Severe acute respiratory syndrome-related coronavirus* for severe acute respiratory syndrome coronavirus; *Pseudomonas virus D3112* for Pseudomonas phage D3112; *Salmonella virus P22* for Salmonella phage P22.

This inconsistency in species name formats and styles makes it difficult for virologists, let alone non-virologists, such as educators, policy-makers, data analysts, students, or copy editors, to identify a given name as a virus species name or to differentiate it from a virus

name. In addition, parsers and search engines, in particular those embedded in commonly used electronic scientific databases, cannot easily be programmed to recognize species names because of the lack of a species name-defining format.

PROPOSAL

SECTION A/Vote 1: The ICTV should mandate a uniform virus species naming format.

The potential need for a uniform, standardized virus species naming format to decrease confusion in literature, in databases, and during oral proceedings has been discussed at the level of the ICTV Executive Committee (EC) many times over the years, using several venues, including the annual EC meetings. During the EC48 meeting in 2016, after emphasizing that "*most EC members indicated that they were in favour of moving to a binomial system in which the genus name was followed by a single word as the specific epithet*" [8], the EC tasked a working group to describe the current variety of species name formats and to describe the advantages and potential pitfalls of a move to a uniform standard, which, regardless of what it is, ultimately would require the renaming of most currently established species. This EC-wide document [8] focused on various species naming formats, including the pros and cons of a Linnaean-style binomial format reminiscent of that used in all other biological taxonomies. Around the same time, a larger group of virologists that included several ICTV EC members authored a manuscript evaluating the feasibility and ease of switching existing virus species names to the Linnaean-style format using, as an example, all 175 then-official names of species in the order *Mononegavirales* and the family *Arenaviridae* [9].

Based on both documents, the EC discussed the issue of a standardized virus species naming format again during the EC50 and EC51 meetings in 2018 and 2019, respectively. A poll among all EC members present at these meetings resulted in unanimous support of establishing a uniform species naming format due to the advantages such a format would bring. This TaxoProp formalizes the outcome of the EC polls by officially proposing to change the Code to mandate a uniform species naming format (Vote 1).

Importantly, because virus species names are currently not formalized and because numerous formats are in use, any standardized naming format would require changing the majority of virus species names independently of the chosen uniform format.

SECTION B/Vote 2: In case of approval of Vote 1, the ICTV should mandate a uniform binomial (genus-species epithet style) virus species naming format. This format should be <*Genus_name species_epithet*> (i.e., the species names should consist of two [and only two] italicized components, separated by a space, with the first component being capitalized and identical in spelling to the name of the genus that includes the species).

There is a need to differentiate properly between the names of viruses and the names of virus species; the genuine difficulties in doing so correctly are evident in the published literature and have been pointed out by numerous experts [10-12]. At the same time, there is a long-standing history of genus-species epithet-style binomial species names in all non-virologic subspecialties of biology, which, among other things, immediately conveys genus affiliation of every species in a traditional biological (Linnaean) species name. These and other considerations resulted in EC members voting unanimously in an EC50/EC51 poll, urging a modelling of a novel uniform virus species format accordingly, i.e., to mandate a binomial virus species naming format that is characterized by:

- two single-"word" components only, separated by a space (could be true binomials akin to the names of species of cellular organisms, including *Escherichia coli* or *Homo sapiens*);
- the first word component being the genus name (identifiable by the already-mandated genus name suffixes -*virus*, -*viroid*, and -*satellite*) and the second name being the species epithet as in other biological taxonomies;
- the first word component having its first letter capitalized, (again akin to other biological taxonomies); and the second word not ending in any of the suffixes that have been reserved for higher order ranks, including -*viria*, -*vira*, -*virae*, -*virites*, -*viricota*, -*viricotina*, -*viricetes*, -*viricetidae*, -*virales*, -*virineae*, -*viridae*, -*virinae*, and -*virus* (or the equivalent suffixes for viroid, satellite, and other mobile genetic element taxa);
- both words being italicized; and
- both words consisting only of letters of the standard Latin-script English alphabet containing 26 letters and/or Arabic numbers.

This TaxoProp formalizes the outcome of the EC poll by officially proposing to change the Code to mandate a uniform binomial "genus-species epithet" virus species naming format with the stipulations outlined above (Vote 2).

Importantly, currently only a handful among the 6,590 established virus species names comply with the proposed format (namely those of the nidoviral family* Arteriviridae *and* Coguvirus eburi*). Consequently, acceptance of this TaxoProp would require almost all current virus species names to be changed independently of whether the chosen uniform format requires Latinization of species epithets or not.

The EC also discussed community suggestions to do away with taxon names and/or virus names, replacing them altogether with (alpha-)numerical codes or serial numbers. Although assigning numerical codes to taxon names was considered potentially useful for database applications and other bioinformatic purposes, replacing taxon names with numerical codes was unanimously seen as unhelpful. Scientists need to be able to communicate in written and oral form about their viruses and affiliated taxa, and numerical codes are notoriously difficult to remember for audiences even for extremely short periods of time (e.g., for an oral presentation). Furthermore, a single-digit error in a numerical code (e.g., *0765.07.978* instead of *0765.07.878*) may have far-reaching consequences in a numerical system whereas a single typographical error in an otherwise recognizable taxon name may be readily identified and corrected, making confusions much less likely (e.g., *Escherikhia coli* instead of *Escherichia coli*). Notably, the ICTV tries to minimize similar or similar-sounding taxon names already, according to current ICVCN Rule 3.13 ("New names shall not duplicate approved names. New names shall be chosen such that they are not closely similar to names that are in use currently or have been in use in the recent past.").

SECTION C (no vote): Permit, but not mandate, a uniform Linnaean-style virus species naming format.
The EC50 discussion resulted in the suggestion that additional community-wide input, and debate is necessary before mandating any genus-species epithet virus species naming format. In early 2019, an informal poll was performed by one of us (Kuhn) among all ICTV Study Groups dealing with negative-sense RNA viruses to inform the debate on this question. Within 2 weeks, one of us (Postler) was able to devise Linnaean-style names for all then-recognized (≈800) negative-sense RNA virus species. The poll was sent out to the

Study Groups to evaluate (a) whether these names were objectionable in principle and (b) whether the Study Groups saw any disadvantage to Latinization if genus-species binomial virus species names were required by the ICTV. The Study Groups did not object to the majority of the proposed names, though some of the Linnaean-style names were criticized on various grounds other than Latinization per se, resulting in suggestions for alternative Latinized names. Several general objections were made to the implementation of Latinized names, but the objectors typically did not provide suggestions for alternative naming schemes and objected primarily on the grounds of change (e.g., the perceived notion of having to learn many new names) or concerns about having to learn Latin to be able to devise novel names. Importantly, during the debate, several ardent objectors to Latinization changed their views and, after having considered all arguments that had been brought forward by others, supported Latinization of binomial species names.

Latinized binomial virus species names would bring the additional advantage that these names are internationally recognizable, as they do not change in typography (alphabet or language), even in texts using non-Latin alphabets or other scripts (Appendix A). A Latinized binomial species name, precisely because it looks foreign due to the unfamiliar Latin suffixes, typically remains unmodified by copy editors or journalists. In contrast, non-Latinized ("free-form") virus species names might be easily confused with virus names, bringing the temptation for translation or other modification based on "style" manuals followed by publishers. For instance, the current species name *Tai Forest ebolavirus* appears to be written in English and hence could easily be, but should not be, translated into Ukrainian ("еболавірус лісу Таї") when only the name of the species-associated virus (Taï Forest virus) should undergo translation ("вірус лісу Таї"). Such inappropriate transliteration/translation of species names is much less likely to occur when the species name has a distinct non-English/non-"living" language appearance (e.g., *Ebolavirus silvataiense*). Finally, untranslated and untransliterated species names also bring the advantage of serving as a connection point for species members (the viruses), which are written and translated in any language of relevance (Appendix A).

Several concerns in context of Latinization of virus species names need to be carefully considered:

Concern #1: "Latinization would require the new memorization of several thousand species names by virologists." [10, 13]
- As pointed out above, if a uniform nomenclature is adopted, most current species names would have to be changed no matter how virus species names are standardized. If memorization of species names is indeed a goal, new names will have to be memorized whether species names are Latinized or not.
- However, why individuals would have to memorize many new species names is unclear. Most virologists work with specific viruses and, thus, possibly have the need to remember certain virus names and their abbreviations—but in most cases, only a handful of the species names. Whereas virus names are supposed to be as stable as possible over time, species names will likely change on a periodic basis as virus taxonomy is being revised. Hence, new species names would have to be memorized periodically no matter their naming format. This situation is not different from other biological taxonomies, which, despite being much more developed/advanced than virus taxonomy, are still in flux, with taxon names being changed continuously and the communities coping with the changes as a matter of course.

- Memorization of the entire corpus of virus species names is probably not a real concern for virologists. As a parallel example, an entomologist is unlikely to be able to list even a fraction of the 400,000 currently established beetle species names (or even the actual beetles); a scientist who has only a rough overview of animal species would almost certainly not be able to nor need to list species names at length. Recent studies estimate that virus diversity exceeds those of prokaryotes [14-16]. Thereby it is not expected that any virologist will memorize the species composition of even smaller taxa, no matter what their naming format.

Concern #2: "English is the language of science and hence virus species names ought to be written in English."

- English is *a*, but demonstrably not *the* language of science and also not *the* language of virology. Large numbers of manuscripts are continuously being published in languages other than English, and the proportion of English to non-English languages is highly dependent on research subspecialty and virus. For instance, if such an assignment can even be considered valid, *the* language of Omsk hemorrhagic fever virus (*Flaviviridae*: *Flavivirus*) research is Russian, with 1,133 of 1,283 publications having been written in Cyrillic Russian (Kuhn, unpublished). Likewise, articles on Crimean-Congo hemorrhagic fever virus (*Nairoviridae*: *Orthonairovirus*) research were written in Farsi, French, Russian, Serbian/Croatian/Bosnian/Montenegrin, or Turkish. These proportions become even more dramatic in particular virologic subspecialties, such as epidemiology, clinic, or policy, most of which are dominated by articles in languages spoken in the regions where particular viruses are a massive problem for a local population (explaining, for instance, the Russian-language article numbers regarding Omsk hemorrhagic fever virus, which is endemic only in one region of Russia). It is not justified or wise for the ICTV to judge whether "English-language science" is the only "*good*" or "acceptable" science.
- Virus taxonomy is already largely based on non-English languages and, in fact, has been using Latin and Greek for decades. Common taxon names, such as *Rhabdoviridae*, are non-English mixtures of Greek (ῥάβδος [rhábdos], meaning "rod, wand") and Latin (*-viridae*). In essence, the names of all virus taxon ranks, with the exception of species, are already Latinized, and there has been no call to change these names to English equivalents because the use of Latin suffixes is too challenging, these names are too difficult to remember, or because "English is the language of science".

Concern #3: "Using Latin for species names is Euro-centric."

- The use of any language is "centric" to a particular area. The use of English could be considered "Euro-centric" or certainly "Anglo-centric." However, Latin is a "dead" (more appropriately, historic) language and, in our view, will be less associated with cultural imperialism than any contemporary language, specifically because the use of Latinized species names is globally accepted for species nomenclature in all non-virologic disciplines, seemingly without major concerns about cultural imperialism.
- It is also important to remember that **this proposal does not advocate translation of current species names into Latin**, but rather only to create species names that are permitted to be Latin<u>ized</u> (a crucial difference that is elaborated below).

Concern #4: "Latinizing species names is hard to do and requires experts."

- As exercises have demonstrated, devising Latinized binomial species names for virus species is not as complicated or time-consuming as is often assumed. One person took only 2 weeks to devise novel, Latinized binomials species names for almost 800 established species—most of which were deemed overall acceptable by polled Study Groups [9]. At the moment, the ICTV recognizes only 6,590 species; based on demonstrations, all current species could likely be renamed to Latinized binomials within a few months.

- All virus genus names end with the Code-mandated Latinized suffix -*virus*. Hence, genus names within Latinized binomial species names can be derived from any language and be coined without any knowledge of Latin and yet be correctly Latinized. This mandated genus name suffix ascribes a single gender to all virus genus names (the Latin word "virus," meaning slime or poison, is a noun of the neuter gender), thereby massively simplifying the declension of species epithets. The rules for species epithet declension can be followed with relative ease using a set of instructions in the absence of personal knowledge of Latin (Appendix B). Moreover, numerous current species names are coined based on geographical locations. Such species names can very easily be transformed into Latinized binomial species names by following simple rules (e.g., "use geographic name and add Latin suffix -*ense*: *Zaire ebolavirus → Ebolavirus zairense*). We devised an example rule set via Latin-knowledgeable members of the ICTV EC to support the establishment of Latinized binomial virus species names by ICTV Study Groups (Appendix B).

- Most importantly, **Latinization does not mean Latin translation**, therefore true knowledge of Latin is not required for coining Latinized binomial species names. For instance, the Latin name for the English "apple" is "malum". Apple→malum is a Latin *translation*. Both apple and malum are two distinct names for the same *thing* that one can eat, which is a member of the species *Malus pumila*. *Malus pumila* is therefore *not* the Latin name for apple (because that is malum). Instead *Malus pumila* is a category for things, in this case for a specific subset of apple plants. In English, one will always eat apples even if a scientist decided to change the species name *Malus pumila* to *Isaacus newtoni*. The Latin name for apple fruit would still be malum even if the associated species name had changed, just like any current virus name would be untouched by changing any associated species name. Furthermore, numerous species names in non-virologic taxonomies contain word stems from non-Latin/Greek languages, i.e., they have nothing to with Latin except for their Latin suffixes. Examples are:

  - prokaryotes: *Afipia clevelandensis*, named after the US Armed Forces Institute of Pathology and the US city of Cleveland. The only Latin in this species name is -*a* in the genus name and -*ensis* in the species epithet; and

  - zoology: *Wunderpus photogenicus*, named using German Wunder (miracle), Greek πούς [poús] (foot) and English "photogenic". The only Latin in this species name is -*us* in the species epithet.

There is also no need to model any new Linnaean-style virus species name after an existing one. For instance, the current species names *Adelaide River ephemerovirus* (for Adelaide River virus) and *Merino Walk mammarenavirus* (for Merino Walk virus) would not, as recently suggested [10], have to be translated into completely Latin species names, such as *Ephemerovirus flumenadelaidense* and *Mammarenavirus viamerinense*, respectively. Instead, the Latinized binomial species name for the first example could be *Ephemerovirus adelaidense* (referring

only to Adelaide) and the second could be *Mammarenavirus lipkini* (after the name of one of the discoverers of Merino Walk virus, Ian Lipkin). In fact, creating species names that are not reminiscent of the names of affiliated viruses may aid greatly in decreasing the confusion of species and virus names in general.

Summary
The Latinized binomial species naming system is used almost universally in biology. Latinized binomial species names would therefore be fairly obvious to virologists and non-virologists alike and would extend the consistency of an already-existing system for naming biological species that will be understood and appreciated by students, scientists, governmental and international policy makers, editors, authors, data curators, and readers. In such a system, existing virus names would be clearly identifiable as ("vernacular") names and could continue to exist in any language, whereas the scientific species names could serve as internationally agreed-upon points of reference spelled exactly the same way worldwide. Latinization of species names may be preferable to the use of other languages because Latin is a "dead" language with a minimal character set that does not require diacritics and that will not change in its syntax [8].

Non-Latinized ("free-form") binomial species names would share the same overall format with Latinized binomial species names: <*Genus_name species_epithet*>.

However, "free-form" binomial species names would differ from Latinized binomial species names in that the species epithet could take any form. For instance, in Latinized binomial species names, the species epithet is required to be a Latinized word written in lower case, but free-form species epithets could be single numbers, single letters of mixed cases, number-letter combinations, any word in any style, words containing letters with diacritics, and theoretically even letters or symbols of different alphabets. It is unlikely that such a mix of styles would be acceptable to the community for some of the same reasons the status quo is not optimal (see above). This calls for the establishment of certain rules for free-form species epithets.

In addition, a "free-form" format is more likely to bring about confusion with virus names. For instance, the free-form Linnaean-style binomial species name *Senecavirus A* could be easily seen as a virus name, whereas the virus member of this species is actually called Seneca Valley virus.

Finally, if "free-form" binomial virus species names are allowed to contain species epithets that consist only of individual letters or numbers, species name abbreviations as used in other biological taxonomies (*Escherichia coli* → *E. coli*; *Pan trodglodytes* → *P. troglodytes*) would become esthetically unpleasing if not downright confusing (*Senecavirus A* → *S. A* ?).

That stated, we understand and sympathize with the concerns brought about by Latinization. In particular, Latinization of prokaryotic virus species names may cause initial concern based on the prokaryotic virus community having been accustomed to number/letter combinations both in virus and virus species names. We therefore do not propose mandating Latinized virus species names but rather suggest providing the conditions for their voluntary use, being confident that the advantages of Latinized virus species names will become apparent over time.

This proposal therefore only proposes changing the Code to mandate a uniform binomial "genus-species epithet" virus species naming format, albeit without the "authority" portion of the name.

We propose that the new species format be formalized in an ICVCN change such as:
"3.20 A species name shall consist of as few words as practicable but be distinct from names of other taxa. Species names shall not consist only of a host name and the word "virus.""
to
"3.20 A species name shall consist of only two distinct word components separated by a space. The first word component shall begin with a capital letter and be identical in spelling to the name of the genus to which the species belongs. The second word component shall not contain any suffixes specific for taxa of higher ranks. The entire species name (both word components) shall be italicized.

Comment: Latinized binomial species names following the style of Linnaean species names used in other biological taxonomies are permitted ([URL to this proposal; later to be replaced with a URL to a published article providing guidance on how to create Linnaean species names])."

IMPLEMENTATION OF SECTIONS A, B, and/or C

We propose that new species names be created to follow the new naming format immediately following the EC acceptance and International Union of Microbiological Societies' ratification of this TaxoProp. We further propose that all already recognized virus species names be renamed to follow the new ICVCN Rule immediately after EC acceptance and International Union of Microbiological Societies' ratification of this TaxoProp and that this process completed in time to be considered by EC55 in 2024. This process shall be accomplished by taxonomic proposals prepared and submitted by the ICTV Study Groups and/or the ICTV Subcommittee Chairs.

We encourage the ICTV to establish and maintain a community-accessible and searchable repository or database, which clarifies the history and relationship of old/outdated and new/Linnaean-style species names, including the names of the viruses assigned to them. We also recommend that the ICTV discourage the creation of virus names that appear to be Linnaean-style species names to decrease confusion.

APPENDIX A: Examples of (Non-viral) Linnaean Species Names in Non-English Literature
Because Linnaean species names are clearly identifiable due to their "foreign-looking" Latinization, they remain unchanged in alphabet or language independently of the language of a given article.

Example 1: Turkish (extended Latin alphabet), taken from Türk tabipleri birliği. 2010. Kirim kongo kanamli atesi bilimsel degerlendirme raporu. Ankara, Turkey.

ORIGINAL (with Linnaean tick species names bolded for emphasis and virus names in green)
Bölgemizde Kırım-Kongo kanamalı ateşi virüsünün ana taşıyıcısı olan *Hyalomma marginatum* (Şekil 4) yaban hayatı ile çok yakından ilişkili olup, bozkır ikliminin diğer iklim kuşakları ile kesiştiği bölgelerde, özellikle de

kuru taban örtüsüne sahip bodur ormanlık (meşelikler, çalılıklar) alanlarda yayılış gösterir. ***Hyalomma marginatum*** iki konutlu bir yaşam döngüsüne sahiptir.

Note that this text contains a virus name, properly translated from the English "Crimean-Congo hemorrhagic fever virus" into the Turkish "Kırım-Kongo kanamalı ateşi virüsünün". Introduction of Linnaean-style virus species names would not change the text above except for a single insertion, leaving the virus name untouched:

MODIFIED ORIGINAL
Bölgemizde Kırım-Kongo kanamalı ateşi (***Orthonairovirus haemorrhagiae***) virüsünün ana taşıyıcısı olan ***Hyalomma marginatum*** (Şekil 4) yaban hayatı ile çok yakından ilişkili olup, bozkır ikliminin diğer iklim kuşakları ile kesiştiği bölgelerde, özellikle de kuru taban örtüsüne sahip bodur ormanlık (meşelikler, çalılıklar) alanlarda yayılış gösterir. ***Hyalomma marginatum*** iki konutlu bir yaşam döngüsüne sahiptir.

Example 2: Russian (Cyrillic alphabet), taken from Г. Г. Онищенко *et al*. 2014. Анализ эпидемиологической ситуации по геморрагической лихорадке с почечным синдромом в Хабаровском крае и Еврейской Автономной Области, прогноз ее развития на послепаводковый период 2013–2014 гг. Пробл особо опасн инфекц (1): 56-59.

ORIGINAL (with Linnaean rodent species names bolded for emphasis, vernacular rodent names in blue, and virus names in green)
К настоящему времени здесь идентифицированы 5 серологически и/или генотипически различающихся хантавирусов: Хантаан (дальневосточный вариант FE), Амур, Хабаровск, Владивосток и Пуумала (дальневосточный вариант), каждый из которых взаимосвязан в своей эволюции с определенным грызуном-носителем. Однако только 2 из них – вирусы Амур и Хантаан (FE) доказаны в качестве этиологического агента при ГЛПС. Резервуарным хозяином генотипа Амур является восточноазиатская лесная мышь (***Apodemus peninsulae***) и генотипа Хантаан FE – полевая мышь (***Apodemus agrarius***).

Note that this text contains several virus names, properly translated from the English "Hantaan virus", "Amur virus", "Khabarovsk virus", "Vladivostok virus", and "Puumala virus" into the Russian "[вирус] Хантаан", "[вирус] Амур", "[вирус] Хабаровск", "[вирус] Владивосток", and "[вирус] Пуумала", respectively. The text also contains two Russian rodent names, "восточноазиатская лесная мышь" and "полевая мышь", which in English would be called "Korean field mouse" and "striped field mouse", respectively, whereas their associated species names would be identical in spelling and Latin alphabet in both Russian and English texts.

Example 3: Chinese (Chinese non-alphabetic script), taken from 高海女, 李兰娟. 2014. 埃博拉病毒病研究的现状和思考. 中华临床感染病杂志 7(6): 481-485.

ORIGINAL (with Linnaean bat species names bolded for emphasis and virus names in green)
1976 年发现埃博拉病毒后，科学家认定这是一种人兽共患传染病，在自然界中存在不发病的贮存宿主。然而，研究人员多次在流行区的各种动物中均未能检测到该病毒，直至 2005 年才第一次在锤头果蝠(***Hypsignathus monstrosus***)、无尾肩章果蝠(***Epomops franqueti***)、小领果蝠(***Myonycteris torquata***)中同时发现埃博拉病毒的 RNA 及抗体。

Note that this text contains a virus name, properly translated from the English "Ebola virus" into the Chinese "埃博拉病毒". Introduction of Linnaean-style virus species names would not change the text above except for a single insertion, leaving the virus name untouched:

MODIFIED ORIGINAL
1976 年发现埃博拉病毒(***Ebolavirus johnsoni***)后，科学家认定这是一种人兽共患传染病，在自然界中存在不发病的贮存宿主。然而，研究人员多次在流行区的各种动物中均未能检测到该病毒，直至 2005 年才第一次在锤头果蝠(***Hypsignathus monstrosus***)、无尾肩章果蝠(***Epomops franqueti***)、小领果蝠(***Myonycteris torquata***)中同时发现埃博拉病毒的 RNA 及抗体。

APPENDIX B: A Practical Guide for the Conversion of Virus Species Names to Latinized Binomials
Creating a standardized nomenclature for virus species based on Latinized binomials has several advantages, including (i) compatibility with all other biological taxonomies, which is especially useful for bioinformatics, as the parsers for virus species names would be the same as for all other species names, and (ii) creating a truly international frame of reference, as Latinized binomials would be clearly distinct from virus common names, whether in English or another language. Unlike species names, virus names indeed can and do differ between languages for many common human veterinary and plant viruses. Despite these considerable benefits, the idea of converting a large number of species names to Latinized binomials may appear to be a daunting task. The Latin language is less familiar to the scientific community than it used to be, as its teaching at school and its use in academic communications has declined or disappeared. However, we contend that the grammatical rules and syntax required for such a change are surprisingly simple and can be implemented in a formulaic manner, i.e., in the form of guide that can be followed rather than a language that has to be learned. Here, we describe a series of practical steps to create Latinized binomials for scientists with or without any prior knowledge of Latin. Importantly, a transition to Latinized binomial species names would not and should not affect current practices for assigning virus common names.

1) The Grammatical Basis of Latinization
Linnaean binomials consist of two words, a genus name (*e.g., homo:* a human) followed by a species epithet (*e.g., sapiens:* wise, judicial, or rational). Together, these two words identify the species. While the genus name is always a noun, the species epithet is typically either an adjective that modifies the genus (*e.g.*, *homo sapiens* is the wise human) or a noun in the singular genitive form that identifies the associated disease, host, discoverer, or other eponym. For example, *Borrelia burgdorferi* is the bacterial species in the genus *Borrelia*, named after its discoverer Willy Burgdorfer, whereas *Nelloptodes gretae* is the insect species recently named in honor of environmental activist Greta Thunberg.

It is quite easy to use a *noun* in the so-called *genitive case*, which typically indicates a possessive or original relationship, as species epithet, because each Latin noun has exactly one singular genitive form. By default, this form is listed in every entry of standard Latin dictionaries and can be applied immediately without any additional knowledge. Latin dictionaries are freely available online, for example, the aptly named "Latin Dictionary" (https://www.online-latin-dictionary.com) and "William Whitaker's Words" (http://archives.nd.edu/words.html). The more involved creation of Latinized words based on personal names is discussed below.

If an *adjective* is used as the species epithet, it automatically assumes the same gender as the associated genus name. The current virus genera, which are already Latinized, uniformly end in the suffix -*virus*. The Latin word *virus*, meaning slime or poison, is of the

neutral gender, consequently all virus genus names and any associated adjective epithets are automatically neuter as well [likewise, we propose here to treat the suffixes -*viroid* and -*satellite* and those of other mobile genetic elements as of being of neutral gender as well and hence to apply all recommendations listed here equally to virus, viroid, satellite, and other mobile genetic element species names]. This is a considerable convenience compared to other biological taxonomies, in which all three genders are amply represented. However, Latin adjectives come in a variety of different classes with different endings, known as declensions, and it is not always immediately obvious which one is the correct one to be used[1].

Latinization often involves non-Latin words, such as proper names or geographic locations. In this context, it is worth mentioning that, although the Classical Latin alphabet does not include the letters "j", "u", or "w", the alphabet of Medieval Latin is identical to the current alphabet of the English language and includes these letters, and this is the alphabet we recommend be used. As per current ICTV guidelines, diacritical marks and numerals should continue to be omitted.

2) Names Based on Geographical Origin

The Latin suffix -*ensis* denotes an adjective that describes a location of origin. This is commonly used in other biological taxonomies (*e.g.*, *Homo neanderthalensis* is the species of humans originally found in the Neandert(h)al[2] valley of Germany). As viruses are often named after the geographical location at which they were first isolated, this offers a convenient method of creating grammatically simple, neuter adjectives to serve as species epithets, without the difficulties of identifying the proper declension. The neuter form of -*ensis* is -*ense*, which can be directly attached to the name of a location. For instance, *Examplovirus neanderthalense* would be a species in the genus *Examplovirus* whose first member was in some way associated with Neandert(h)al valley. Analogously, the first member of the related species *Examplovirus bostonense* would have been associated in some way with Boston. When the suffix -*ense* is added to a word ending on a vowel, that vowel is occasionally omitted for aesthetic reasons. For consistency and simplicity, we recommend retaining such vowels (*e.g.*, *Examplovirus atlantaense*, not *Examplovirus atlantense*).

Procedure for creating a Latinized binomial based on geographical origin:
(i) Identify the geographical location.
(ii) Add -*ense*.
(iii) Combine with established genus name ending in -*virus*:
<genus name ending in -*virus*> <name of location+*ense*>.
Example: *Examplovirus neanderthalense*

3) Names Based on Persons, Things, or Entities

Although not yet very common, some viruses are named after persons (or objects or institutions). To create a corresponding species epithet, the name is Latinized and converted to the genitive form. Latinization of personal names is typically achieved by directly appending the appropriate Latin suffix. The ending differs between the three genders, with the base form being -*a* for females, -*us* for males, and -*um* for neuters (*e.g.*, an object, institution, or organization). For each of these, the cognate genitive form can be created directly, as detailed in Table 1. For example, a virus species in the genus *Examplovirus* to be

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1   For those interested, there is an excellent Latin grammar available online for free, Bennett's New Latin Grammar (https://www.thelatinlibrary.com/bennett.html). This work is approximately a century old, but since the Latin language has been static for centuries, its contents remain current.

2   The spelling of Neanderthal in German was changed to Neandertal as part of the German spelling reform of 1901. Of note, there has not been a spelling reform of Latin for centuries.

named after Jane Goodall (Goodall*a*) might be named *Examplovirus goodallae*, whereas a related species dedicated to Max Delbrück (Delbruck*us*) could be designated *Examplovirus delbrucki*.

Procedure for creating a Latinized binomial based on a personal name:
(i) Identify the gender of the eponym.
(ii) Append the corresponding Latinizing suffix in the genitive, as listed in Table 1.
(iii) Combine with established genus name ending in -*virus*:
<genus name ending in -*virus*> <Latinized eponym in the genitive form>.
Example: *Examplovirus goodallae*

Table 1. Genitive Forms of Suffixes for the Latinization of Personal Names

Gender of Eponym	Suffix in Genitive Form
Feminine	-*ae*
Masculine	-*i*
Neuter	-*i*

4) Names Based on a Disease

Some viruses and/or their species are named after the disease they cause. Transforming such names into Latinized binomials is comparatively convenient, as medical nomenclature typically employs Latin or Latinized suffixes in the naming of conditions. To form the genitive of such a medical term, only the suffix has to be altered. Table 2 provides a list of suffixes commonly used in medical terminology and the corresponding genitive form. For instance, if a member of a species in the fictitious genus *Examplovirus* causes an inflammation of the tonsils (tonsillitis), the species name might be *Examplovirus tonsillitidis*.

Procedure for creating a Latinized binomial based on a disease:
(i) Identify the suffix of the medical term for the disease.
(ii) Change the suffix to the genitive form, *e.g.*, using the information provided in Table 2.
(iii) Combine with established genus name ending in -*virus*:
<genus name ending in -*virus*> <medical term for disease with genitive form of suffix>.
Example: *Examplovirus tonsillitidis*

Table 2. Suffixes Commonly Used in Medical Terminology and their Genitive Form[3]

Suffix	Suffix in Genitive Form
-*e*	-*is*
-*ia*	-*iae*
-*is* (except -*itis*)	-*is*
-*itis*	-*itidis*
-*ium*	-*ii*
-*lysis*	-*lysis*
-*o*	-*onis*

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3   Medical terminology is frequently an amalgam of Latin and Greek etymology, which occasionally affects suffixes as well. To circumvent this problem, we are using a Latin-based declension (even those of Greek suffixes) wherever possible.

-oma	*-omatis*
-or	*-oris*

5) Names Based on the Host

Viruses are frequently named after a host they infect coupled with the disease symptoms they induce (more the case in plant virology). Conveniently, all established non-viral species, and therefore all known viral hosts, are either already classified or will be classified in Latinized taxonomies, and consequently host-based Latinization simply requires finding the genitive form of the Latinized host name. In our experience, it is typically better to choose the genus name of the host, rather than its species epithet, as the epithet by itself is typically less informative and many viruses infect hosts of several species within the same genus. Following this logic, an *Examplovirus* species whose members infect fish of the species *Perca flavescens* (yellow perch) could be named *Examplovirus percae*.

Table 3 lists Latin endings commonly used in the naming of non-viral genera. This list is by necessity incomplete, as some suffixes are used by multiple different declensions. In those cases, different words with the same ending may have different endings in the genitive form. We therefore advise the investigators to use a Latin dictionary or other credible resource (such as those mentioned above) to determine the Latin translation, as well as the cognate genitive form, of the common name of the host. For instance, for a species in the genus *Examplovirus* whose members infect Darwin's foxes (*Lycalopex fulvipes*), a quick search would reveal that the Latin word for fox is *vulpes*, with the genitive *vulpis*. Consequently, this virus species might be named *Examplovirus vulpis*.

If a virus species is to be named after a host taxon higher than genus, other rules apply, as taxa on the level of family and higher are by convention always denoted in the plural form. This is grammatically more complex, as the only unambiguous suffix is *-ae* (*e.g.,* Hominidae, the family that includes humans). In such cases, the singular genitive form is also *-ae*. An examplovirus species whose members infect members of Hominidae might thus be named *Examplovirus hominidae.* Alternatively, an examplovirus isolated from bats, which comprise the entire taxonomic order Chiroptera, might simply be named *Examplovirus vespertilionis*, as the Latin word for bat is *vespertilio*.

Procedure for creating a Latinized binomial based on a host genus:

(i) Identify the genus name of the host species.

(ii) If the suffix …

    a. is listed in Table 3, change the host's genus name to the genitive form.

    b. is not listed in Table 3, consult a dictionary to determine whether the host's genus name is a Latin word (*e.g.*, *canis*, *mus*, or *homo*) and use the genitive form listed in the dictionary.

(iii) If (ii) a. and (ii) b. fail (as in, the suffix of the host's genus is <u>not</u> listed in Table 3 and the host's genus name is <u>not</u> a Latin word), consult a dictionary to identify the Latin translation of a suitable animal name and use the cognate genitive listed in the dictionary (*e.g., catus* for cat or *araneae* for spider).

(iv) Combine with established virus genus name ending in *-virus*:

    <virus genus name ending in *-virus*> <host genus name in the genitive form>.

Example: *Examplovirus percae*

Table 3. Unambiguous Suffixes Commonly Used in Naming of Non-viral Genera and their Genitive Form

Suffix	Suffix in Genitive Form
-a	*-ae*
-as	*-atis*
-e	*-is*
-or	*-oris*
-u	*-us*
-um	*-i*
-ys	*-ysis*

6) Contractions and Omissions

The current, non-Latinized virus species names often consist of more than two words, precluding a direct conversion to Latinized binomials. Virologic taxonomy has a long history of elegantly circumventing this problem by use of contractions, as exemplified by the family names *Tobamoviridae* (after <u>to</u>bacco <u>mo</u>saic virus) or *Hepeviridae* (after <u>hep</u>atitis <u>E</u> virus). We recommend continuing this tradition when creating Latinized species epithets. For instance, the virus species currently named *Drosophila affinis sigmavirus* could be converted to the Latinized binomial *Sigmavirus draffinis*. Occasionally, parts of the non-Latinized name can simply be omitted. For example, the species currently named *Iranian wheat stripe tenuivirus* might be renamed to *Tenuivirus tritici*, as the wheat species belongs to the genus *Triticum*.

7) When all else fails, be creative!

The guidelines provided here will allow the direct conversion of most current viral species names to Latinized binomials. However, there are inevitably instances for which these guidelines fall short and additional knowledge of Latin would be required to enable direct Latinization. In such cases, we encourage scientists to use their imagination to create their own grammatically simple alternatives. For instance, the species currently designated as *Severe acute respiratory syndrome-related coronavirus* could be converted to the arguably much simpler *Betacoronavirus sarsi*, using the acronym SARS and Latinizing it as a neutral eponym (see Chapter 4 and Table 3). Analogously, if the recently emerged SARS-CoV-2 were to be assigned a separate species name, a quick consultation of a Latin dictionary would reveal promptly that the Latin word for "second" is *secundus*, which may be used in a contraction with *sarsi* to create the Latinized binomial *Betacoronavirus secusarsi* (see Chapter 6).

Other situations may require more creative approaches. For instance, there is no Latin word for lacewing, making the direct Latinization of *Lacewing mivirus* difficult. However, the Latin word for lace is *denticulatum*. Following the guidelines provided in Chapter 3 and Table 2, this could be used to create the Latinized binomial *Mivirus denticulati*.

Problems can also arise when the direct conversion of different species in the same genus would yield identical results. For example, the species *Lepeophtheirus caligrhavirus* and *Salmonlouse caligrhavirus* are both named after the host salmon louse (*Lepeophtheirus salmonis* (Krøyer, 1837)). Accordingly, their direct conversion would yield the same Latinized binomial for both virus species, i.e., *Caligrhavirus lepeophtheiri*. Therefore, one of them could be named after the host, whereas the other could be named after the location

where the members of both species were first isolated (Norway): *Caligrhavirus lepeophtheiri* and *Caligrhavirus norwayense* (see Chapter 5).

8) Summary
Much of the resistance to the introduction of Latinized binomials into the taxonomy of viruses is based on the argument that converting thousands of species names from English to a Latinized form is impractical and too challenging to implement for the majority of scientists that do not possess pre-existing knowledge of the Latin language. Although this concern is quite understandable, we hope this guide has demonstrated that such a conversion would in fact be far simpler and less arduous than one might suppose. Latinization is much more accessible than strict Latin translation, and thus provides enough flexibility to be implemented by any virologist, regardless of any pre-existing knowledge of Latin, yet can ensure a standardized and stable viral taxonomy that is compatible with all other branches of biology.

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