Rules of Nomenclature for Fungi and Bacteria

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SUMMARY: Attention is drawn to certain requirements of the current International Botanical and Bacteriological Codes of Nomenclature, with special reference to the denoting of categories, the proposal of new species, and the changing of names; three procedures commonly encountered by authors and editors. The requirements for the proposal of new specific names of fungi and bacteria are:

General requirements. The name chosen must be in Latin binomial form and should be coined according to the practices set out in the Codes (Bact. Code, Rules, 6, 27, 28, Appendix A; Bot. Code, Art. 33, 82, Rec. 83A).

The name must be effectively published. (It is desirable that scientific journals in which new taxa are proposed should indicate the exact date of publication of the parts.)

The name must be validated by a concise description (the diagnosis) of the diagnostic features of the new taxon. (The diagnostic features should not have to be deduced from an exhaustive account of the organism possibly spread over several pages.)

The description should, whenever possible, be accompanied by illustrations of which the scale and the specimen(s) on which they are based should be stated.

All measurements should be in the metric system.

The date of collection or isolation of the type material should be given together with the precise locality and the substrate or host (the last being designated by its scientific name).

The location of the type should be stated.

The etymology of the name should be explained.

Special requirements for fungi. The diagnosis must be in Latin (Bot. Code, Art. 44).

The type specimen should be deposited, if possible, in a national herbarium, and if the type is a collection and portions are deposited in several herbaria then one of these isotypes should be designated as the holotype.

Special requirements for bacteria. No Latin diagnosis is required but 'in works written in a language unfamiliar to the majority of workers in bacteriology, it is recommended that the authors publish simultaneously the diagnosis in a more familiar language' (Bact. Code, Rec. 12a).

Subcultures of the type strains should be deposited at one or more of the national culture collections.

Micro-organisms belong to several kingdoms, and workers in microbiology have to be familiar with the codes for international nomenclature agreed upon by zoologists, botanists and bacteriologists. There is now general agreement among biologists on the fundamental bases for scientific nomenclature, and the three codes, though independent, show many features in common and differ from one another only in minor and often rather trivial technical details. In a previous article (Ainsworth, 1948) some of the similarities and differences between the zoological and botanical codes were indicated, and though the

general principles are still unchanged a number of the statements made in that review need modification because a new Botanical Code was adopted by the 1950 International Botanical Congress and the Bacteriological Code, approved by the fourth International Congress for Microbiology (1947), has been modified by decisions of the fifth and sixth International Congresses for Microbiology held in Rio de Janeiro (1950) and in Rome (1953), respectively. The purpose of the present article is, therefore, to draw attention to certain requirements of the current Botanical and Bacteriological Codes with special reference to fungi and bacteria and, while not absolving the systematist from a close and critical study of the original texts, to attempt to increase the awareness of microbiologists about some general aspects of nomenclature and perhaps to increase respect for internationally acceptable names.

The international rules of nomenclature

The *International Rules of Zoological Nomenclature* were instituted in 1901 and have remained substantially unchanged apart from the series of more than 200 'Opinions' on matters of their interpretation given by the International Commission on Zoological Nomenclature. The 1953 International Zoological Congress did, however, sanction the issue of a revised version of the Code (see Hemming, 1953). The *International Rules of Botanical Nomenclature* first appeared in 1906, were re-issued in 1935, and the current version adopted by the Stockholm Congress in 1950, appeared in 1952 under the new title of *International Code of Botanical Nomenclature*. The bacteriologists' Code, which concerns 'bacteria, related organisms, and the viruses', is the most recent. The tentative *International Bacteriological Code of Nomenclature*, as adopted by the 1947 International Microbiological Congress, was published in 1948 and reprinted in this *Journal* in the following year (*J. gen. Microbiol.* 1949, 3, 444-62). At the 1953 Rome Congress it was agreed that there should be prompt publication of a revised code as the *International Code of Nomenclature of Bacteria and Viruses*, with a short title of *Bacteriological Code*. Unlike botanists, bacteriologists have a permanent Judicial Commission responsible for their Code and for issuing, on request, formal Opinions on the interpretation of the rules and on the status of names. Such Opinions and other proposals for changes or interpretations of the Code are published in the *International Bulletin of Bacteriological Nomenclature and Taxonomy*. Decisions made and published by the International Committee on Bacteriological Nomenclature and by the Judicial Commission are automatically confirmed at the next International Microbiological Congress if they have not been challenged in the meantime. Although botanists have no Judicial Commission there is a series of standing Congress committees which make various recommendations in connexion with the Code; before submission to an International Botanical Congress such recommendations are now normally published in *Taxon*, the official news bulletin of the International Association for Plant Taxonomy.

The Botanical Code is divided into principles, rules, and recommendations which are set out in a series of eighty-three numbered Articles. The Bacteriological Code, which is set out as a series of numbered Principles and Rules,

closely resembles the Botanical Code, and unless stated to the contrary, or clearly inapplicable, any rule or recommendation mentioned without comment may be taken to apply to both codes.

The scope of nomenclature

Before considering the requirements of the Codes it is necessary to stress the subservience of nomenclature to taxonomy. Rules of nomenclature are of little help in devising systems of classification, in determining what shall or shall not be included in a particular taxonomic group, or in answering such questions as what constitutes a 'good' species. These are all matters of taxonomy and are therefore questions for individual judgement. This reflexion of taxonomy by nomenclature explains why the frequent appeals by applied biologists for stability in the nomenclature of the relatively few organisms in which they are interested cannot be met when there are still taxonomic uncertainties. Rules of nomenclature ensure uniformity in the form and precision in the application of scientific names after the taxonomic decisions have been taken. Judgement is more rarely involved in their application. The codes are arbitrary sets of rules devised because zoology and bacteriology like botany 'cannot make satisfactory progress without a precise system of nomenclature which is used by the great majority... in all countries' (Bot. Code, Art. 1). A code of nomenclature is not a penal code and there is no compulsion, and so 'should be simple and founded on considerations sufficiently clear and forcible for everyone to comprehend and be disposed to accept' (Bot. Code, Art. 3).

The objectives of nomenclature are '(1) to aim at fixity of names' and '(2) to avoid or to reject the use of forms and names which may cause error or ambiguity or throw science into confusion' (Bot. Code, Art. 4). These aims are in general achieved by the 'law of priority' and by the use of nomenclatural types. The law of priority does not over-ride all other considerations; for example a name published without a description of the organism or a reference to a previously published description, has no standing in nomenclature.

Nomenclature thus deals with the *terms* which denote the categories of taxonomic groups and the relative ranks of these categories and the *names* which are applied to the individual taxonomic groups or *taxa* (sing. *taxon*), a term introduced in the latest Botanical and Bacteriological Codes.

The new Codes also distinguish clearly for the first time between *legitimate* and *illegitimate* names or epithets,* which are names or epithets chosen in accordance with or contrary to the rules, respectively, and the *correct* name of a taxon with a particular circumscription, position, and rank, which is the name that must be adopted under the rules. This last ensures that an organism can have as many *correct* names as there are different views on its taxonomy, but only one correct name for each taxon with a given circumscription.

The Botanical and Bacteriological Codes are intended to give guidance in every eventuality and they are therefore rather complex. In the following

* A specific epithet (the 'trivial name' of zoologists) is the second component of a Latin binomial name of which the generic name is the first.

sections attempts are made to indicate the principal requirements of the codes for denoting categories, proposing new species, and changing names (or avoiding the changing of names), the procedures most commonly encountered by authors and editors.

Terms and categories

‘Every individual is treated as belonging to a number of categories of consecutive rank and consecutively subordinate of which species is the basic one.’

This quotation from Principle 7 of the new Bacteriological Code expresses a familiar and current view. Equally familiar are the supra-specific categories (genus, family, order, class, division) and the sub-specific categories (sub-species, variety, form); categories which may be further subdivided to meet the demands of any particular situation.

The supra-generic categories may be distinguished at a glance by characteristic suffixes: family names end in- *aceae* (subfamilies in *-oideae*, tribes in *-eae*), names of orders in *-ales* (suborders in *-ineae*). For plants the suffix for classes is *-opsida* and for divisions *-phyta* except for fungi for which the suffix *-mycota* is recommended for divisions and *-mycetes* for classes, classes of Algae being distinguished by the suffix *-phyceae*.

In general the stem of a family name is a generic name, which, for bacteria, should be that of the type genus (e.g. Spirochaetaceae from *Spirochaeta*), that for an order a family name (e.g. Spirochaetales from Spirochaetaceae), etc.

Under the Botanical Code the relative order of the categories must not be changed and names given to misplaced terms are treated as not validly published (Art. 15). A special exception is, however, made for the names of subdivisions of genera in Fries's *Systema Mycologicum* which are treated as validly published although termed ‘tribes’, a term correctly denoting subdivisions of a family.

New species

The proposal of a new species implies that the new species is distinct from the often large number of related species already proposed; for fungi, for example, that it is a distinct taxon from the hundred thousand species proposed; the fact that more than half of these have already been relegated to synonymy or rejected suggests a need for great caution and for sound taxonomic work. The Codes are not however concerned with the soundness of the taxonomy but only with the regulation of the new name.

A specific name must be in Latin binomial form and the Codes offer detailed advice on what is good taste in the coining of names. (There is nothing in the Bacteriological Code, however, to prevent the use of common names, and these should be encouraged.) Publication must be both *effective*, that is by the distribution of printed matter (but after 1 January 1953 not as tradesmen's catalogues or newspapers, Bot. Code, Art. 39), and *valid* (effective publication conforming to the special requirements of the Codes). Among the requirements of the Botanical Code for the valid publication is the necessity, on and from 1 January 1935, for names of new taxa of recent plants, the bacteria excepted,

to be accompanied by a Latin diagnosis (Art. 44). Many authors follow, or attempt to follow, this ruling but other competent workers ignore this requirement and publish the diagnosis in one or more modern languages. Such names are therefore technically invalid but they would rarely if ever be rejected on the score of merely lacking a Latin diagnosis, and it is possible that a Botanical Congress will eventually decide to allow some relief in this connexion (see the argument advanced by Lund (1953) for the use of modern languages in place of Latin for algal taxa).

The application of the names of taxa is given precision by the use of nomenclatural types but under the new Botanical Code the rules of typification (and priority) do not apply to the names of taxa above the rank of order (Art. 26). The nomenclatural type of an order is a family, that of a family a genus, that of a genus a species, that of a species or sub-specific taxon a type specimen, which may be a herbarium specimen or culture; in certain cases it may be merely a published description with or without illustrations. The nomenclatural type indicates the essential features of any taxon, but its scope is left to the judgement of taxonomists. A taxon may be treated so narrowly as to include only the type, it may be treated so broadly as to cover one or more related taxa; in such instances the name of the taxon must be changed as soon as its circumscription covers a taxon bearing an earlier name which then takes precedence (see below).

For higher plants and animals the nomenclatural type is a single specimen, for fungi it is more frequently a single collection which may comprise more than one individual. Such material should be most carefully preserved and its whereabouts stated after the diagnosis, together with details of the place and date of collection or isolation and, if a parasite, by the scientific name of the host.

'Nomenclatural types of bacterial species obviously cannot be the (air) dried or preserved specimens used for higher plants or animals. A type (specimen) may be either a living culture [*culture* is to be interpreted as including every method of maintaining organisms in a living state (in a medium, in a host by passage, in cells or exudates, or desiccated)] maintained in a bacteriological laboratory, more particularly in one of the national type culture collections, or it may be a description' (Bact. Code, Rec. 9). A *type culture* is defined as 'a living culture of an organism which is a descendant of the original culture or isolation from which the author who first described the organism made his original description, which culture has been maintained pure, and which agrees in its characters with the original description' (Bact. Code, Rec. 9).

Authors of new species of bacteria are urged to deposit cultures in one of the major culture collections. When a type culture no longer exists the Judicial Commission may designate a substitute type culture (neotype) as the type; this was done in designating the Marburg strain as the type culture of *Bacillus subtilis* Cohn, the type species of the genus *Bacillus*.

Name changes

Changes of name may be necessitated for technical reasons connected with the Codes.

The name may not be the earliest one. The official starting-point for bacterial nomenclature is Linnaeus, *Species Plantarum*, Ed. 1, 1 May 1753,* and this is also the starting-point for the nomenclature of higher plants, Lichens, Myxomycetes, and, with certain exceptions, Algae. For Fungi, however, the nomenclature starts from Persoon, *Synopsis Methodica Fungorum*, 31 December 1801 (for Uredinales, Ustilaginales, and Gasteromycetes) and Fries, *Systema Mycologicum*, Vol. 1, 1 January 1821 (for other groups). Under the Codes the legitimate name is the first to be validly published after the official starting-point for the nomenclature of the group in question. Names in use before the appropriate starting-point are invalid and take their priority status from the date at which they were taken up by a later author. For example, the maize smut must be known as *Ustilago maydis* (DC.) Corda and not as *Ustilago zeae* (Beckm. ex Schw.) Unger because although the epithet *zeae* was first published in 1768 it was not validated until 1822, seven years after the introduction of the epithet *maydis* by De Candolle for the same fungus.

There may be an earlier *homonym*, that is the identical name may have been used before for another taxon. The generic name *Gnomoniopsis* Stoneman, 1898, was changed to *Glomerella* because of the earlier *Gnomoniopsis* Berlese, 1892. Botanists and zoologists do not consider the same names when applied to taxa in the plant and animal kingdoms to be homonyms—*Drosophila* as applied to a genus of toadstools and *Drosophila* as applied to a genus of fruit flies are both legitimate names. 'Bacteriological nomenclature and botanical nomenclature are interdependent in the sense that a name of a bacterial group is to be rejected if it is a later homonym of the name of any plant group' (Bact. Code, Prin. 3) but bacteriological nomenclature is independent of zoological nomenclature with the exception of protozoology. *Listerella* Pirie, *Pfeifferella* Buchanan, *Phytomonas* Bergey *et al.*, and *Rhizomonas* Orla-Jensen are among the bacterial names that must be rejected because they are later homonyms of protozoan genera (see *Int. Bull. bact. Nom. Tax.* 3, 109, 1953). To provide a new name for *Listerella* is not quite straightforward as the other name used for this genus, *Listeria* Pirie, 1940, is a later homonym of a plant, *Listeria* Necker, 1790. The plant name is not in use and the Botanical Committee on Bacteria is to be asked to recommend the rejection of *Listeria* Necker, and so release *Listeria* for use by bacteriologists.

Another reason for changes of name under the Botanical and Bacteriological Codes is because the binomial is a *tautonym*, the specific epithet exactly repeats the generic name, e.g. the specific epithet of *Sphaeria nummularia* Fr. when transferred to *Nummularia* was changed to *bulliardii* by Tulasne because *Nummularia nummularia* would have been a tautonym. Zoologists find no

* Many bacteriologists think that the starting date for bacterial nomenclature should be much later, and certainly in the era of pure cultures. In 1950 the subcommittee on viruses recommended that the starting date of virus nomenclature should be some time in the future.

difficulty in accepting tautonyms, and their use in botany would often, as in the example given, indicate the type species of the genus.

For pleomorphic fungi, that is to say for those exhibiting two or more states in the life cycle, the Phycomycetes excepted, the first valid name or epithet applied to the perfect state (the state bearing basidiospores, ascospores, or other sexually produced spores) takes precedence, and so the discovery of the perfect state of a fungus necessitates a change of name, but the reworded Art. 69 (the old Art. 57) makes it clear that the usual practice of keeping in use the names of imperfect states in works referring to such states is acceptable. For example, the discovery that *Diplocarpon rosae* Wolf was the perfect state of the imperfect fungus *Actinonema rosae* (Lib.) Fr. necessitated a change in name of the pathogen, a change that need not be accepted in Britain where the perfect state is unknown.

The most important name-changes result from taxonomic work. One species may be considered to comprise more than one element and so a new specific or subspecific taxon is proposed. When a species or other taxon is divided into two or more taxa the original name must be retained for one of them, i.e. for that element which is based on the type of the original taxon. Also, according to the new Botanical Code (Art. 34), the proposal of a new variety of a species automatically creates a second subordinated taxon of the same rank which has as its nomenclatural type the type of the original taxon. Further, this second taxon, the one based on the nomenclatural type of the next higher taxon, is designated by repeating the epithet of the higher taxon unaltered but without the citation of an author's name, e.g. the proposal of *Scopulariopsis brevicaulis* Bain. var. *alba* Thom automatically created a variety *Scopulariopsis brevicaulis* Bain. var. *brevicaulis* based on the type of the species and the name *Scopulariopsis brevicaulis* would now cover both varieties.

The same requirement exists in bacteriology (Rule 7); if an author subdivided *Staphylococcus pyogenes* into two varieties, *aureus* and *albus*, he would automatically create a third variety *Staphylococcus pyogenes* var. *pyogenes*.

More frequently, taxonomic work may suggest that a species would be better classified in another genus, to which it is then transferred, the name of the author of the original species being inserted in parenthesis before that of the author making the transfer, e.g. *Xanthomonas hyacinthi* (Wakker) Dowson (syn. *Bacterium hyacinthi* Wakker). Under the Botanical Code such transfers are from 1 January 1953, only valid 'when the *basonym* (the name-bringing or epithet-bringing synonym) is clearly indicated with its author and the place and date of publication' (Art. 42).

Finally a name may be changed because taxonomic studies are considered to show that two taxa are the same; when the name of the earlier is applied to the new grouping the later name is cited as a synonym, e.g. *Erwinia carotovora* (Jones) Holland (syn. *Bacillus phytophthorus* Appel).

Attention must be drawn to the two very different types of synonyms illustrated by the last two examples. In the first the synonymy is 'obligate',

it is one of definition, in the second it is 'facultative', for it is a matter of the taxonomist's opinion. In citing synonymies it is useful to differentiate these two types of synonyms by three- and two-bar identity signs, e.g. *Bacterium hyacinthi* $\equiv$ *Xanthomonas hyacinthi*; *Bacillus phytophthorus* = *Erwinia carotovora*.

In passing it may be noted that misidentifications should not be included in the synonymy but added after it. A misapplied name should be indicated by the words 'auct. non' followed by the name of the original author and the bibliographical reference (Bot. Code, Rec. 60F). For example, the misidentification of the rust fungus *Uredo gladioli* Requien as the gladiolus smut fungus by Oudemans could be recorded under *Urocystis gladiolicola*, after any synonyms, as *Uredo gladioli* auct. non Requien, Oudemans, *Enumer. Syst. Fung.* 1, 1215, 1216, 1919.

Conservation

In order to prevent the undesirable consequences which sometimes follow the rigid application of the rules both the Botanical and Bacteriological Codes provide procedures by which a name can be retained in use as an exception. Such names are said to be 'conserved', a fact that should be indicated on formal occasions by the addition of *nomen conservandum* (nom. conserv.) after the name; a rejected name is indicated by *nomen rejiciendum* (nom. rej.). The most usual reason for the need to invoke Congress to conserve a name is to prevent inconvenience resulting from the re-introduction of a neglected earlier name, e.g. of *Syringospora* Quinq., 1868 for *Candida* Berkhout, 1923; also *Chlorobacterium* Guillebeau, 1890, a generic name never used, was rejected to allow the conservation of *Chlorobacterium* Lauterborn, 1915 (type *Chlorobacterium symbioticum* Lauterborn). Another reason is involved when it is desirable to retain a name in use for a taxon which excludes the original nomenclatural type. The current Botanical Code lists genera of fungi, algae, and other groups which have been conserved.

Generic names of certain bacteria have already been conserved under the Bacteriological Code, e.g. *Bacillus* Cohn (see St John-Brooks & Breed, 1937). The generic name *Bacterium* and the family name *Bacteriaceae* have been rejected by the Nomenclature Committee and will be the subject of Opinion No. 4 (revised). (For Opinion No. 4 as originally promulgated, see Cowan, 1953). Authors must thus now allocate to other genera those species that they would have included in *Bacterium*. For example, *Bacterium coli* would be correctly named *Escherichia coli*. The taxonomic position of *Bacterium aerogenes* is more difficult, and an author must answer the question 'Can I distinguish between *Klebsiella* and *Aerobacter*?' If he can answer 'Yes' then he can use *Aerobacter*, but if the answer is 'No' *Klebsiella* is the generic name to be used. When a binomial is needed for the water bacteriologist's 'intermediate coliforms', the combination *Escherichia freundii* is correct. Paracolon can often be allocated to the genera *Escherichia* or *Klebsiella* (or *Aerobacter*) and, when necessary, can be called *Escherichia dispar*, *E. alkalescens*, etc. Also, the Gram-positive rods classified in the genus *Bacterium* in the 6th edition of the *Bergey Manual* must be allocated among other genera

such as *Kurthia* and the new genus *Brevibacterium*, specially proposed by Breed for the Gram-positive rods that cannot be assigned to a genus.

The family name *Bacteriaceae* having been rejected, a request has been made to the Nomenclature Committee that the incorrect *Enterobacteriaceae* might be allowed as an exception to replace the rejected name because other correctly coined names (i.e. formed by adding the suffix *-aceae* to the stem of a generic name) such as *Escherichiaceae*, *Proteaceae*, *Klebsiaceae*, *Salmonaceae*, *Shigaceae*, though possible are all unpleasant and difficult to pronounce.

Other bacterial generic names approved for conservation at Rome included *Gallionella* Ehrenberg (type *G. ferruginae*), *Beggiatoa*, *Klebsiella*, *Kurthia*, *Neisseria*, *Nocardia*, *Pasteurella* and *Leptothricia*, and among those rejected were *Chlorobacterium* Guillebeau, *Babesia*, *Bacteriopsis*, *Pseudospira*, *Pseudospirillum* and some other names that have not appeared in recent literature.

So far all International Botanical and Zoological Congresses have refused to accept the principle of the conservation of specific names but it appears not unlikely that botanists may adopt the principle of the rejection of specific names which would achieve the same objective as conservation of specific names without many of the disadvantages (see *Taxon*, 1, 78, 1952). Bacteriologists are more daring, and at Rome the names *Shigella dysenteriae*, *Shigella flexneri*, *Shigella boydii* and *Shigella sonnei*, were all declared legitimate and the specific epithets of the last three were conserved against any earlier synonyms. Type strains are to be designated by the *Enterobacteriaceae* Subcommittee.

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