

How to name a prokaryote? Etymological considerations, proposals and practical advice in prokaryote nomenclature¹

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Received 1 February 1999; accepted 10 February 1999

Abstract

This essay tries to bring together the most important aspects of etymology in prokaryote names, the theoretical basis and the practical application. The scientific names of prokaryotes are formed from a large thesaurus of Latin and Greek words and word elements. The rules for forming such names are explained and discussed (including pronunciation and accentuation). Elaborate advice is given for forming generic names and specific epithets in general as well as from personal and geographic names, from names of biota that host prokaryotes and from names of chemicals and pharmaceuticals. Further, names based on words of other than Latin or Greek origin as well as so-called arbitrary names are explained and their formation is exemplified. Names of the highest taxa are critically discussed. Examples of case histories of malformed names are given. Practical etymology is described for genera and species. A number of proposals are made for further developing the International Code of Nomenclature of Bacteria with respect to an easier understanding of etymology. © 1999 Federation of European Microbiological Societies. Published by Elsevier Science B.V. All rights reserved.

Keywords: Epithet; Etymology; Greek; Latin; Name; Name formation; Nomenclature

1. Introduction

*What's in a name? – That what we call a rose by
any other name would smell as sweet.*

(W. Shakespeare: *Romeo and Juliet*, Act II, sc. 2)

1.1. Introductory remark

More than 25 years of active membership in the International Committee for Systematic Bacteriology (ICSB) and in the Editorial Board of the International Journal of Systematic Bacteriology and there especially my self-adopted task of watching the correctness of new Latin names by offering advice in etymology and questions of prokaryote nomenclature have built up the urge in me to write this essay. I have always been interested in languages and names, in etymology and semantics. What I write hereafter is the outflow of the experiences I have

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¹ A modified and condensed version of this article will appear in *Bergey's Manual of Systematic Bacteriology*, 2nd edition, Vol. 1, under the title: Etymology in nomenclature of prokaryotes.

gathered in these tasks including correspondence in etymological (often intertwined with nomenclatural) matters with hundreds of colleagues. Therefore, I shall try to write this chapter from the viewpoint of the microbiologist as a user, for the user rather than writing it *ex cathedra* as a classicist might want to do. And what I write here are my own opinions on these matters and they are not meant to offend anyone who has other or better insights.

I have put this chapter under the famous Shakespearean quotation cited above, because no other quotation has such intimate bearing on etymology in biological nomenclature.

1.2. *The Latin/Greek thesaurus of words and word elements*

Scientific terminology in its terms as well as in its names has to fulfill other requirements than everyday language. These requirements have been excellently described by the late Fritz C. Werner, a German zoologist [1].

The first requirement is that every term unambiguously circumscribes a clearly conceivable idea and that every name stands for a special object or a special group of objects characterized by determined features.

The second requirement is that the total number of discernable objects and of abstract concepts must equal the large number of different words and word combinations, as long as the principle of unambiguous naming is to be kept. The number of objects, processes and concepts is growing every day and hour with the scientific development in depth and width, with the development of human society and the changes in nature due to human activities.

As more and more nations participate in these developments, it is important that scientific terms and names fulfill a third requirement, namely international understandability.

These three requirements – unambiguity, large numbers, international use – are met to a high degree by the fact that the terminology of natural sciences and medicine is to its largest extent taken from the ‘word material’ of the classical languages Greek and Latin. The fact that these ‘dead’ languages no longer undergo natural and living changes makes their word material a given thesaurus that has been used and

may be used further freely for present-day needs. Consequently one has more or less arbitrarily given these classical words and word elements certain new contents. Using a living and permanently changing language in this way would promptly lead to problems and misunderstandings.

In the first line the use of the ancient word material allows the naming of the many new and – in their numbers – permanently increasing objects and concepts for which there are no words in the respective national (living) languages; even circumscriptions and combinations of words would hardly suffice. Latin and Greek offer a wealth of word elements and ways to form words that are by far not exhausted yet and will do so for a long time in the future, although scientists have not always been careful or reasonable in their ‘creations’. By mixing Greek and Latin elements, by dropping syllables, repositioning letters, contractions and arbitrary formations the antique wealth of words has been partially widely changed. Further many other languages have contributed. Finally names of scientists and other persons have been latinized.

What Werner [1] did not emphasize is the fact that Latin remained the international language (*lingua franca*) of philosophy, religion, law, sciences and politics throughout the European Middle Ages and the Renaissance, for philosophical and scientific publications up into the 19th century. Its usage – although within these limited circles – led to an enormous increase in words, usually adopted from other European or oriental languages (e.g. Arabic). And it also needs to be mentioned here that Latin remains the spoken language in the center of the Catholic Church, the Vatican, until today (and further). This is especially documented by the fact that the *Libreria Editoria Vaticana* takes all efforts to integrate new Latin words coined for modern objects and concepts into the written and spoken Latin of the Vatican. The *Lexicon Recentis Latinitatis*, which appeared 1992 in Italian [2] and in 1998 in German [3], contains about 15 000 new – ‘from astronaut to zabaione’ – Latin words, word combinations and circumscriptions of the fields of sciences, technics, religion, medicine, politics, sports and even daily used language.

The thesaurus of words enlarged this way is thus no longer identical with that of either classical lan-

guage but represents ‘something new’ that has developed along historical lines and follows special laws of language nowadays.

All of the statements made by Werner [1] apply to general scientific and medical terminology as well as to biological nomenclature. And they apply especially to the scientific nomenclature of prokaryotes (bacteria and archaea) and viruses because these – in contrast to most animals, plants, and larger fungi – due to their usual invisibility do not have popular or vernacular names in any living language.

Nomenclature (‘the system of names used in a branch of learning or activity’) is an indispensable tool for correct information in our fast growing scientific world with its rapidly developing information networks.

The binomial nomenclature used in biosystematics goes back to 1735 when the Swedish botanist Carolus Linnaeus (Karl von Linné, 1707–1778, ennobled 1757) published his famous ‘Systema Naturae’ – according to the scholarly habits of his times in Latin.

By introducing the species concept and the use of Latin and Greek for the names of living beings Linnaeus laid the principles of modern biological systematics as well as nomenclature.

In our ‘age of informatics’ one could certainly think of other ways to name the vast number of plants, fungi, animals, protists and prokaryotes, perhaps by a number and/or letter code. For the human brain, however, names are still by far the easiest memorizable and workable form within a system – as long as they are readable and pronounceable.

Unfortunately the knowledge of classical Latin and Greek is permanently decreasing, even in Europe – and even in countries with modern languages derived from classical Latin or Greek. It appears that (besides in academia) only in a few Central European countries Latin and, less frequently, Greek are regularly offered in the curricula of secondary school systems (i.e. schools of the type High School, Gymnasium, Lycée, etc.).

Already today only a rather small number of the scientific community – in our case the microbiologists – are really familiar with the vast and valuable thesaurus of words mentioned above.

For the scientific names of prokaryotes the International Code of Nomenclature of Bacteria (ICNB,

Bacteriological Code), issue of 1992, is the compulsory compendium of governing Rules.

The purpose of this essay, however, is not to explain the Bacteriological Code (ICNB), but to deal with etymology, explain it and give advice for naming new isolates. Etymology means ‘origin and historical development of a word, as evidenced by study of its basic elements, earliest known use, and changes in form and meaning’ or ‘the semantic derivation and evolution of a word’. ‘Etymology’ is derived from Greek *etymon*, ‘the truth’ and thus aims at the true, the literal sense of a word.

Etymology is a necessary element in biological nomenclature as it explains the existing (i.e. so far given) names and helps to form new names. For the average microbiologist, ‘etymology’ is that part of a species or genus description that stands first, describes the accentuation, origin and meaning of the name, contains strange abbreviations and is often considered superfluous or nasty. I shall come to appropriate examples at the end of this chapter.

In 1993, the late professor of classical languages, Thomas Ozro MacAdoo of Blacksburg, VA, USA, wrote a marvellous chapter on ‘Nomenclatural literacy’ [4] with the intention of helping bacteriologists in giving correct names. MacAdoo has carefully described and exemplified the five Latin declensions, the Greek alphabet and its Latin equivalents, the Greek declensions and their Latin equivalents, adjectives and participles, compounding in Latin and Greek and the latinization of modern proper names. It cannot and will not be my task to equal this excellent and scholarly piece of work, as it contains an introduction to the two classical languages and requires a basic knowledge of – at least Latin – grammar. I highly recommend reading – or better studying – MacAdoo’s paper. But I am afraid that I cannot agree with him on the way personal names should be latinized nowadays.

1.3. Pronunciation and accentuation

For many bacterial names the common pronunciation nowadays differs from the pronunciation that is correct according to Latin rules (cf. common textbooks for Latin). It is unfortunately strongly influenced by the speaker’s mother tongue, a clear indi-

cation that Latin is no longer the lingua franca of the scientific world. Whereas native speakers of languages that are written close to phonetics – such as Italian, Spanish, Portuguese, Dutch or German – usually pronounce Latin close to its spelling, native speakers of French and especially of English (languages pronounced rather differently from their spelling) often pronounce Latin according to the pronunciation rules of their languages, i.e. further away from the written form. These differences in pronunciation are not generally as important as differences in spelling, because the name in question is often understood despite differences in pronunciation. Substantially helpful here, however, could be to pronounce at least the vowels as they are pronounced in Spanish and Italian, languages whose pronunciations have stayed close to their Latin origin. International science will have to live with this problem until – in a far future – all languages will perhaps be written according to phonetic rules.

In many Central European High Schools Latin pronunciation has gone back to the times of Caesar and Augustus when the Romans always pronounced the letter c as the sound k. As a consequence students pronounce, e.g., Caesar ‘Kaesar’ (origin of the German word Kaiser = Emperor) or Cicero ‘Kikero’. In bacteriology this leads to alternative pronunciations of *Acinetobacter*, *Acetobacter* etc. (as akinetobakter, aketobakter, etc.) by some younger European microbiologists.

I consider it a pity that on the one hand in scientific terms, mainly in chemistry and physics, the writing of Greek k remained (*keratin*, *kinetics*) whereas in biological nomenclature it has usually – but not always – been latinized to c (*Triceratops*, *Acinetobacter*). Fortunately, classical Latin had already introduced the Greek z for transliterated Greek words, and Medieval Latin introduced the letter j for the consonantic i. Meanwhile several names of bacteria starting with J have been proposed (e.g., *Janthinobacter*). It makes sense to use the j in Latin names as the first letter of a word or word element when it is followed by a vowel.

A pronunciation problem is that of some personal or geographical names used in generic names or specific epithets, e.g. the bacterial generic name *Buttiauxella*, named after the French microbiologist Buttiaux (pronounced: ‘buttio’). This generic name

and specific epithets such as ‘*bordeauxensis*’, ‘*leicesterensis*’ or ‘*worcesterensis*’ may be pronounced fully (as Latin would require) or pronounced as though they were spelled ‘buttioella’, ‘bordoensis’, ‘lesterensis’, ‘woosterensis’. I am afraid that we will have to leave the decision of pronunciation in such cases to the single scientist, as a rule for such ‘problems’ seems rather difficult to be conceived.

Frequently accentuation of Latin names appears to pose problems, especially when Greek word elements are involved. In such cases, however, Greek accentuation has to be replaced by Latin accentuation, because the Bacteriological Code [5] stipulates Latin as the language of prokaryote names. In classical times Latin words with two syllables were accentuated on the first syllable. Words with three or more syllables followed the ‘paenultima’ rule, i.e. the penultimate syllable received the accent, as long as that syllable contained a long (spoken) vowel (e.g. *dissipa’ tus*) or a vowel followed by two (or more) consonants (e.g. *frumen’ tum*). If neither was the case, usually the third last (antepaenultima) syllable received the accent (e.g., *agra’ rius*) [6].

2. Formation of generic names and specific epithets

Since Linnaeus, biological species carry ‘double’, i.e. binomial names, consisting of a *genus* (kind) and a *species* (appearance) name. The latter – if taken by itself – is called ‘specific epithet’. A complete species name thus consists of the genus name and the specific epithet. In principle the language of biological nomenclatural names is Latin. In nomenclature, words of Greek origin as well as such of any other origin are treated as Latin, i.e. they have to be ‘latinized’.

Only those bacterial names that appeared in the Approved Lists of Names [7] and the Validation Lists that have regularly appeared since 1980 in the International Journal of Systematic Bacteriology have standing in nomenclature. Regularly updated non-official lists of legitimate bacterial names are published by the German Culture Collection DSMZ, Braunschweig, Germany, twice a year. Dr. J.P. Euzéby, Toulouse, France, provides an even more detailed non-official list electronically on the Web site <http://www-sv.cict.fr/bacterio/>.

For microbiologists in need of Latin and Greek words and word elements for prokaryote names I have added a number of references on dictionaries and other helpful literature to the reference list of this article. These citations are marked with an asterisk after the reference number.

2.1. Compound names

Compound names are formed by combining two or more words or word elements of Latin and/or Greek origin into one generic name or specific epithet. In most cases two word elements are used (e.g. *Thiobacillus*, *thiolparus*), but up to four elements may be found (e.g. *Ectothiolorhodospira*).

In principle the formation of such combined or compound names is not at all difficult. There are four basic rules to be followed:

1. Except for the last word element only the stems are to be used.
2. The connecting vowel is -o- when the preceding element is of Greek origin, it is -i- when the preceding element is of Latin origin.
3. A connecting vowel is dropped when the following element starts with a vowel.
4. Hyphens are not allowed.

In order to avoid later changes, these recommendations, given in the Bacteriological Code, Appendix 9 [5] (cf. also [8]) should be strictly followed, i.e. they should be considered rules without exceptions.

The reader may protest here and mention, e.g., *Lactobacillus* as being against this ruling. *Lactibacillus* would indeed be the correct name, however, the name *Lactobacillus* is much older than the Bacteriological Code and has become a well established name. The ending -phile (or -philic) in English is often added to words of Latin origin connected by -o- (e.g., acidophile, francophile, anglophile, nucleophile, lactophile, etc.). This is due to the meaning of -phile, 'friendly to', which commands the dative case. In the most common Latin declension, the 2nd, the dative is formed by adding an -o to the stem (acidophile, friendly to whom/what?, friendly to acid). Therefore in bacteriology we have a number of older compound names of Latin origin with the connecting vowel -o-. By unknowingly taking over such origi-

nally dative-derived word elements ending in -o, names such as *Lactobacillus* came into existence. Such cases prove that Appendix 9 of the Bacteriological Code [5] does not have the power of a Rule yet. In the future new name formations of that kind should be avoided.

There are numerous mistakes with respect to compound names. Sometimes authors want to express that their new organism was isolated from a certain part of an animal's body, e.g., from the throat of a lion; throat is *pharynx* (Greek word stem: *pharyng-*), lion is *leo* (Latin word stem *leon-*). These stems may be correctly combined in two ways: '*pharyngoleonis*' or '*leonipharyngis*'. Unfortunately the authors chose *leopharyngis*, which may be corrected to the latter. This example demonstrates the different connecting vowels as well. Two more examples may emphasize the importance of word stems: *Obesumbacterium* should be corrected to *Obesibacterium*, as the Latin stem of the first component is *obes-*, and the connecting vowel must be -i-. The generic name *Carbophilus* was formed the wrong way, because the stem of the first component is *carbon-*; the correct name would be *Carboniphilus*. As good Latin dictionaries indicate the genitive of a noun, and the genitive usually shows the stem (e.g. *carbo*, *carbonis*, the coal) also scientists without training in Latin should be able to identify the stem of a Latin noun. MacAdoo [4] gives a very useful overview of word stems and declensions for non-classicists. An excellent pocket book on word elements (stems) of Latin and Greek origin for usage in scientific terms and names is the one by Werner [1], which so far has appeared only in German. An English translation would be of great value for biologists worldwide.

Other typical, by now well established misnomers whose connecting vowels have not been dropped are *Acetoanaerobium*, *Cupriavidus*, *Haloanaerobacter*, *Haloanaerobium*, *Haloarcula*, *Pseudoalteromonas*, *Streptoalloteichus*, *Thermoactinomyces*, *Thermoanaerobacter*, *Thermoanaerobacterium*, not to mention numerous specific epithets with that stigma.

2.2. Generic names

The name of a genus (or subgenus) is a Latin noun (substantive) in the nominative case. If adjectives or participles are chosen to form generic names they

have to be transformed into substantives (nouns) and handled as such.

Both Latin and Greek know three genders, i.e. contain nouns of masculine, feminine and neuter gender. Adjectives associated with nouns follow these in gender. For the correct formation of specific epithets (as adjectives) it is therefore necessary to know the gender of the genus name or of its last component.

The more frequent last components in compound generic names of masculine gender are: *-arcus*, *-baccillus*, *-bacter*, *-coccus*, *-ferax*, *-fex*, *-ger*, *-globus*, *-myces*, *-nostoc*, *-oides*, *-philus*, *-planes*, *-sinus*, *-sipho*, *-vibrio* and *-vorax*; of feminine gender: *-arcula*, *-baccica*, *-cystis*, *-ella*, *-ia*, *-illa*, *-ina*, *-musa*, *-monas*, *-opsis*, *-phaga*, *-pila*, *-rhabdus* (!), *-sarcina*, *-sphaera*, *-spira*, *-spina*, *-spora*, *-thrix* and *-toga*; of neuter gender: *-bacterium*, *-bactrum*, *-baculum*, *-bium*, *-filamentum*, *-filum*, *-genium*, *-microbium*, *-nema*, *-plasma*, *-spirillum*, *-sporangium* and *-tomaculum*.

2.3. Specific epithets

As demanded by Rule 12c of the Bacteriological Code [5], the specific (or subspecific) epithet must be treated in one of the three following ways:

1. as an adjective that must agree in gender with the generic name;
2. as a substantive (noun) in apposition in the nominative case;
3. as a substantive (noun) in the genitive case.

Correct examples of these three ways are *Staphylococcus aureus* (adjective: 'golden'), *Desulfovibrio gigas* (nominative noun: 'the giant'), and *Escherichia coli* (genitive noun: 'of the *colum* = colon'), respectively.

2.3.1. Adjectives and participles as specific epithets

Latin adjectives belong to the first, second or third declension. Those of the first and second declensions have different endings in the three genders, whereas in the third declension the situation is much more complicated, as there are adjectives that do not change with gender, others that do and adjectives that are identical in the masculine and feminine gender and different in the neuter. Table 1 gives some

examples of these respective cases. Note that also comparative adjectives are listed. I recommend always looking up an adjective in the dictionary before using it for the formation of a name.

Participles are treated as if they were adjectives, i.e. they fall under Rule 12c, (2), of the Bacteriological Code [5]. Infinitive (also named 'present') participles in the singular do not change with gender. According to the four conjugations of Latin they end in *-ans* (e.g. *vorans*, devouring, from *vorare*, to devour), *-ens* (e.g. *delens*, destroying, from *delere*, to destroy, *deleo*, I destroy), *-ens* (e.g. *legens* reading, from *legere* to read, *lego*, I read), *-iens* (e.g. *capiens*, from *capere*, to seize, *capio*, I seize), *-iens* (e.g. *audiens*, from *audire*, to listen, *audio*, I listen). Note that the ending of the first person singular in the present is decisive!

Perfect participles change their endings with gender and are treated like adjectives of the first and second declensions, e.g., *voratus*, *vorata*, *voratum*, devoured, *deletus*, *deleta*, *deletum*, destroyed, *lectus*, *lecta*, *lectum*, (irregular) read, *captus*, *capta*, *captum*, (irregular) seized, *auditus*, *audita*, *auditum*, listened/heard.

2.3.2. Nominative nouns in apposition as specific epithets

While the above mentioned first and third ways to form specific epithets are generally well understood

Table 1
Examples of Latin adjectives

Masculine	Feminine	Neuter	English translation
First and second declensions			
bonus ^a	bona	bonum	good
aureus ^a	aurea	aureum	golden
miser	misera	miserum	wretched
piger	pigra	pigrum	fat, lazy
ruber	rubra	rubrum	red
pulcher	pulchra	pulchrum	beautiful
Third declension			
puter	putris	putre	rotten
celer	celeris	celere	rapid
facilis ^a	facilis	facile	easy
facilior	facilior	facilius	easier
maior	maior	maius	more
minor	minor	minus	less
simplex	simplex	simplex	simple
egens	egens	egens	needy

^aMost common types.

and usually do not pose problems, the formation of epithets as substantives in apposition has obviously been misunderstood in several cases. So, for instance, when the name *Mycoplasma leocaptivus* was proposed for an isolate from a lion held in captivity, the authors – probably accidentally – called their bacterium ‘the captive lion’, whereas they rather wanted to explain the origin of their isolate ‘from a captive lion’; thus ‘*captivileonis*’ would have been the correct epithet.

A nominative noun in apposition does not just mean that any nominative noun may be added to the generic name to automatically become its acceptable epithet. In grammar, apposition means ‘the placing of a word or expression beside another so that the second explains and has the same grammatical construction as the first’; i.e. the added nominative noun has an explanatory specifying function for the generic name, such as in general English usage ‘the Conqueror’ has for ‘William’ in ‘William, (called) the Conqueror’. Thus *Desulfovibrio gigas* may be understood as *Desulfovibrio dictus gigas* and translated as ‘*Desulfovibrio*, called the giant’, which – with reference to the unusual cell size of this species – makes sense.

Because all specific epithets ending with the Latin suffixes *-cola* (derived from *incola*, ‘the inhabitant, dweller’) and *-cida* (‘the killer’) fulfill the above mentioned requirement, they are to be considered correct.

Most legitimate specific epithets formed in bacteriology as nominative nouns in apposition so far have been mentioned and – where necessary – corrected recently [9,10].

Although they are not explicitly ruled out by the Bacteriological Code [5], I have so far not encountered tautonyms, i.e. specific epithets identical with and repeating the genus name, in bacterial nomenclature (such as in zoology *Canis canis*, the dog). In order to avoid confusion, it would be wise to abstain from proposing such names.

2.3.3. Genitive nouns as specific epithets

The formation of specific epithets as genitive nouns rarely poses problems, as the singular genitive of substantives (nouns) is usually given in the dictionaries. If the plural genitive is preferred, as, e.g. in *Rhizobium leguminosarum* (‘of legumes’), one has to

find out the declension of the noun, as plural genitives are different in different declensions. This question will be addressed below.

2.4. Formation of bacterial names from personal names

Persons may be honored by using their name in forming a generic name or a specific epithet. This is an old custom in the whole area of biology. The Bacteriological Code [5], however, strongly recommends refraining from naming genera (including subgenera) after persons quite unconnected with bacteriology or at least with natural science (Recommendation 10a) and in the case of specific epithets to ensure that, if taken from the name of a person, it recalls the name of one who discovered or described it, or was in some way connected with it (Recommendation 12c). It is good style to ask the person to be honored by a scientific name for permission (as long as she/he is alive). Authors should refrain from naming bacteria after themselves or coauthors after each other in the same publication, as this is considered immodest by the majority of the scientific community.

The Bacteriological Code provides only two ways to form a generic name from a personal name, either directly or as a diminutive; both are always in the feminine gender.

Appendix 9 of the Bacteriological Code [5] recommends how such names should be formed. Appendix 9 has, however, not the power of the Rules.

The application of the classical Roman rules of name giving, as MacAdoo [4] did it, does not make sense as modern names worldwide follow different and various rules and regulations. A differentiation in *prenomina*, *nomina*, and *cognomina* is therefore no longer applicable and should not be used as a basis for latinization of names nowadays. Principally modern family names are either *nomina* or *cognomina* in the classical sense. Continuing latinization of names as practised in ancient Rome would have the advantage that the practice will not change but rather stay frozen in time. Therefore MacAdoo [4] would have liked to set up a uniform rule for latinization of names. But attention has to be paid to the fact that since classical times throughout the Middle Ages up into the 19th century (usually learned) peo-

ple of other nations than the Roman have latinized their names, and thus several varieties of such latinizations have developed and must be considered as historically grown. Therefore – as they are not incorrect – they cannot be denied or refused under the Bacteriological Code (Appendix 9) [5]. I have therefore tried to give the recommended rulings of Appendix 9 a simpler and clearer wording and have given examples according to those latinizations that have historically occurred before [8]. The results were revised and are compiled in Table 2.

Some personal names in Europe were already latinized before 1800 and have been kept since. If they end in -us, replace the ending by -a or -ella (diminutive) respectively (e.g. the name Bucerius would result in '*Buceria*' or '*Buceriella*'). Beware, however, of Lithuanian names such as Didlaukus, Zeikus etc.! These are not latinized but genuine forms and would receive the ending -ia according to Table 2.

Not more than one person can be honored in one generic name or epithet. In the case of the Brazilian microbiologist Henrique da Rocha Lima, the generic name *Rochalimaea* was formed by dropping the particle 'da' and combining his two family names. Combinations of the names of two or more persons cannot be constructed under this aspect. Here the only possibility would be the provision of the Bacteriolog-

ical Code [5] for forming 'arbitrary names'. These are treated below.

If an organism is named after a person, the name cannot be shortened, e.g. '*Wigglesia*' after Wigglesworth, '*Stackia*' after Stackebrandt or '*Goodfelli*' after Goodfellow etc., but must appear in full. Certainly titles (Sir, Lord, Duke, Baron, Graf, Conte, etc.) and particles (de, da, af, van, von, etc.) indicating nobility or local origin of the family should as far as possible not be included in bacterial names, although they may belong to the name according to the laws of the respective country.

Rarely, generic names or specific epithets have been formed from forenames (first names, given names, Christian names), i.e. not from the family name, so the genus *Erwinia* was named after the American microbiologist Erwin F. Smith. The first name Elizabeth appears in *Bartonella* (formerly *Rochalimaea*) *elizabethae*. One could imagine that in avoiding the usually rather long Thai family names first names should be chosen in those cases. Also unusually long double (hyphenated) names such as the (hypothetical) Basingstoke-Thistlethwaite or Sap-orochnikov-Shindlefrink hopefully do not occur too often among microbiologists to be honored by a bacterial name (hyphens are not allowed, anyhow!).

One could think of a simplified standard proce-

Table 2

Ways to form generic names from personal names (names in quotation marks are so far hypothetical names)

Personal name ending in	Add ending	Person	Example (direct formation)	Diminutive ending	Example (diminutive formation)
-a	-ea	da Rocha Lima	<i>Rochalimaea</i>	drop a, add -ella	' <i>Rochalimella</i> '
-e	-a	Benecke	<i>Benecke</i>	-lla	' <i>Beneckella</i> '
	-ia	Burke	<i>Burke</i>	-lla	' <i>Burkella</i> '
-i	-a	Nevski	<i>Nevskia</i>	-ella	' <i>Nevskiella</i> '
-o	-a	Beggiato	<i>Beggiatoa</i>	-nella	' <i>Beggiatonella</i> '
	-nia	Cato	' <i>Catonia</i> '	-nella	<i>Catonella</i>
-u	-ia	Manescu	' <i>Manescuia</i> '	-ella	' <i>Manescuella</i> '
-y	-a	Deley	<i>Deleya</i>	-ella	' <i>Deleyella</i> '
-er	-a	Buchner	<i>Buchnera</i>	-ella	' <i>Buchnerella</i> '
	-ia	Lister	<i>Listeria</i>	-iella	' <i>Listeriella</i> '
Any consonant ^a	-ia	Cabot	' <i>Cabotia</i> '	-(i)ella	' <i>Cabot(i)ella</i> '
		Wang	' <i>Wangia</i> '	-(i)ella	' <i>Wang(i)ella</i> '
		Salmon	' <i>Salmonia</i> '	-ella	' <i>Salmonella</i> '
		Escherich	<i>Escherichia</i>	-(i)ella	' <i>Escherich(i)ella</i> '
		Zeikus ^a	' <i>Zeikusia</i> '	-(i)ella	' <i>Zeikus(i)ella</i> '

^aThis name of Lithuanian origin is not a genuine latinized name. If it were so, the genus names '*Zeikia*' or '*Zeik(i)ella*' might have been possible.

ture to ease formation of generic names from personal names. (1) All names ending in consonants or -a receive the ending -ia, all others the ending -a. (2) Diminutive formation: all names ending in consonants receive the ending -ella, all names ending in vowels receive the ending -nella. This simplified scheme should perhaps be recommended by the Bacteriological Code [5] as an optional alternative to its Appendix 9. Such a ruling should, however, not be introduced with retroactive power as Principle 1 of the Bacteriological Code [5] aims at constancy of names.

To form specific epithets from personal names there are principally two possibilities: the adjective form and the genitive noun form. The adjective form has no means to recognize the sex of the honored person, which – in principle – is not necessary for nomenclatural purposes. The personal names receive appropriate endings according to the gender of the generic name as indicated in Table 3. Thus an adjective epithet is formed that has the meaning ‘pertaining/belonging to (the person)’.

When the genitive of a latinized personal name is formed for a specific epithet, the sex of the person to be honored may be taken into consideration as indicated in Table 4.

On the basis of classical, medieval and modern usage any of the forms of latinization listed in Table 4 may be chosen. As evident from Table 4 the formation of specific epithets from personal names as genitive nouns poses certain problems only with names ending in -a and -o.

Classical Roman names of male persons such as Agrippa, Caligula, Caracalla, Galba, Seneca, etc. were used in the first declension like the masculine nouns *poeta* (the poet), *nauta* (the sailor) or *agricola*

(the land dweller, farmer), irrespective of the fact that most of the nouns in this declension are of the feminine gender. If bacteria had been named after these gentlemen, their specific epithets would have been *agrippae*, *caligulae*, *caracallae*, *galbae* and *senecae*, respectively. I think that Volta, Migula and Komagata are dignified successors in this row.

If authors consider it necessary to indicate the sex of the person to be honored, there are several choices, in the following exemplified by the Japanese name Nakamura: (a) Mr. Nakamura is latinized to Nakamuraus, resulting in a specific epithet ‘*nakamurai*’; (b) Mr. Nakamura is latinized to Nakamuraeus (like Linnaeus or my ancestors Nissaeus and Molinaeus), resulting in a specific epithet ‘*nakamuraei*’; (c) Ms. Nakamura may be latinized to Nakamuraea, resulting in a specific epithet ‘*nakamuraeae*’; (d) Mr. Nakamura is latinized to Nakamuraius, as in MacAdoo’s opinion it should be normative [4], resulting in a specific epithet ‘*nakamuraii*’; (e) Ms. Nakamura is latinized to Nakamuraia, resulting in a specific epithet ‘*nakamuraiae*’.

By now the reader will understand that the latter possibilities (b–e), although permissible or even recommended by MacAdoo [4], look and sound rather awkward and are likely to produce many misspellings. Therefore I strongly suggest using the classical version and version a only.

Roman names ending in -o usually followed the third declension, i.e. the genitive is formed by adding the ending -*nis*, which also reveals that such words have stems ending in n, e.g. Nero/Neronis, Cicero/Ciceronis or the noun *leolleonis* (the lion). Medieval Latin followed this custom, so for the medieval German emperors named Otto the genitive Ottonis was used in writing, which was done only in Latin then.

Table 3

Formation of specific epithets from personal names in the adjective form (all examples given are hypothetical so far)

Ending of name	Example: family name	Add the ending for gender		
		masculine	feminine	neuter
Consonant	Grant	-ianus	-iana	-ianum
-a	Kondratieva	-nus	-na	-num
-e	Lee	-anus	-ana	-anum
-i	Bianchi	-anus	-ana	-anum
-o	Guerrero	-anus	-ana	-anum
-u	Manescu	-anus	-ana	-anum
-y	Bergey	-anus	-ana	-anum

Therefore it makes sense to treat Spanish, Italian, Portuguese, Japanese, Chinese, Ukrainian, Indonesian as well as all other names that end in -o the same way.

Several European names are derived from classical Greek and end in -as, such as Thomas, Andreas, Aeneas, Cosmas, etc. In their genitive form they receive the ending -ae: Thomae, Andreae, Aeneae, Cosmae, etc. Although one could argue for a Latinization to Thomasius, Andreasius, etc., to form the specific epithets *thomasi*, *andreasii*, etc., I tend to recommend using the classical ending -ae.

2.5. Formation of bacterial names from geographical names

Authors often consider it appropriate to indicate the geographical origin, provenance or occurrence of their isolates in the respective specific epithets.

Such epithets are simply constructed by adding the ending -ensis (masculine or feminine gender) or -ense (neuter gender) to the geographical name in agreement with the latter's gender. Only if the name of the locality ends in -a, -e or -en these letters are dropped before adding -ensis/-ense (e.g. *jenensis* from Jena, *hallensis* from Halle, *bremensis* from Bremen). Sometimes authors make the mistake of adding -iensis/-iense. This is only correct if the locality's name ends in -ia (e.g. California leads to *californiensis*). The advice given above guarantees that such mistakes will not happen.

Epithets on the basis of geographical names cannot be formed at all as substantives in the genitive

case, as if they were derived from personal names. (e.g. the city of Austin, Texas, cannot lead to 'austini' but must lead to 'austiniensis').

Quite a number of localities in the Old World (Europe, Asia, Africa) have classical Greek, Latin and medieval Latin names and adjectives derived from these: *europaeus*, *africanus*, *asiaticus*, *ibericus*, *italicus*, *romanus* (Rome), *germanicus*, *britannicus*, *hibernicus* (Ireland), *indicus* (India), *arabicus* (Arabia), *gallicus* (France), *polonicus*, *hungaricus*, *graecus* (Greece), *hellenicus* (Hellas, classical Greece), *hispanicus* (Spain), *rhenanus* (Rhineland), *frisius* (Friesland), *saxonicus* (Saxony), *bavaricus* (Bavaria), *bretonicus* (Brittany), *balticus* (Baltic Sea), *mediterraneus* (Mediterranean Sea), etc.

After the 'discovery' of the other parts of the world by European sailors and travellers European geographers continued at first to give Latin names to 'new' continents and countries, so adjectives like *americanus*, *cubanus*, *mexicanus* etc. were introduced.

Wherever such older adjectives exist they may be used as specific epithets to indicate geographical origins.

European and mediterranean cities and places of classical times may have had quite different names than nowadays: e.g. *Lucentum* (Alicante, Spain), *Argentoratum* (Strasbourg, France), *Lutetium* (Paris, France), *Traiectum* (Utrecht, Netherlands), *Ratisbona* (Regensburg, Germany), *Eboracum* (York, UK), *Londinium* (London, UK), *Hafnia* (Copenhagen, Denmark). Microbiologists are free to demonstrate their knowledge of these ancient names but may, of course, as well use epithets derived from the present

Table 4

Formation of specific epithets from personal names as genitive nouns (hypothetical epithets in quotation marks)

Ending of name	Add for female	Example, female person	Add for male	Example, male person
-a	-e (first declension)	Catarina, ' <i>catarinae</i> '	-e (classic)	Komagata, <i>komagatae</i> , Volta, <i>voltae</i>
	–	–	-i	Thomalla, ' <i>thomallai</i> '
	-ea	Julia, ' <i>juliae</i> '	-ei	Poralla, ' <i>porallae</i> '
-e	-iae	Mateka, ' <i>matekaiae</i> '	-ii	Ventosa, ' <i>ventosaii</i> '
	-ae	Hesse, ' <i>hesseae</i> '	-i	Stille, ' <i>stillei</i> '
-i	-ae	Kinski, ' <i>kinskiae</i> '	-i	Suzuki, ' <i>suzukii</i> '
-o	-niae	Cleo, ' <i>cleoniae</i> '	-nii	Guerrero, ' <i>guerreronii</i> '
	–	–	-nis	Otto, ' <i>ottonis</i> '
-u	-iae	Feresu, ' <i>feresuiiae</i> '	-ii	Manescu, ' <i>manescui</i> '
-y	-ae	Macy, ' <i>macyae</i> '	-i	Deley, <i>deleyi</i>
-er	-ae	Miller, ' <i>millerae</i> '	-i	Stutzer, <i>stutzeri</i> , Stanier, <i>stanieri</i>
Any other letter	-iae	Gordon, ' <i>gordoniae</i> '	-ii	Pfennig, <i>pfennigii</i> , Zeikus, ' <i>zeikusii</i> '

names of such places, e.g. *alicantensis*, *strasburgensis*, *parisensis*, *utrechtensis*, *yorkensis*, *regensburgensis* [4].

Many localities (mostly lakes, rivers, seas, valleys, islands, capes, rocks or mountains, but also some towns or cities) have names that consist of two words, usually an adjective and a substantive (noun), e.g. Deep Lake, Black Sea, Dead Sea, Red River, Rio Grande, Rio Tinto, Long Island, Blue Mountain, Baton Rouge, etc., or of two substantives, e.g. Death Valley, Lake Windermere, Loch Ness, Martha's Vineyard, Ayers Rock, Woods Hole, Cape Cod, etc. Forming specific epithets from the names of such localities may pose a problem, because the use of the adjectival suffixes *-ensis* and *-ense* may lead to rather strange looking or awkward constructions, such as '*blackseaensis*' or '*redriverense*', although such epithets would be correct in the sense of the Bacteriological Code [5]. If the name of a locality lends itself to translation into Latin, specific epithets may alternatively well be formed as genitive substantives by forming the genitives of the two components and concatenating them without a hyphen, like the existing ones *lacusprofundi* (of Deep Lake), *marisnigri* (of the Black Sea), *marismortui* (of the Dead Sea), or (of two nouns) *vallismortis* (of Death Valley). Note that in Latin the basic noun comes first, the determining word (adjective or noun) second. If possible one should avoid the inclusion of articles such as *the*, *el*, *il*, *le*, *la*, *de*, *den*, *het*, *der*, *die*, *das* or their plurals *los*, *les*, *ils*, *gli*, *le*, *de*, *die*, etc., as they are used for locations in several languages, e.g. La Jolla, La Paz, El Ferrol, El Alamein, Le Havre, The Netherlands, Die Schweiz, Den Haag, Los Angeles, etc. Articles would unnecessarily elongate names without adding substantial information.

2.6. Formation of names for bacteria living in association or symbiosis with other biota

An enormous reservoir of bacteria for future research – I dare to predict at least two million new species [11] – is the microflora more or less tightly associated with other biota. All animals with digestive tracts have a gut flora and special feeders have special gut floras.

Also the plant microfloras have so far been mainly investigated with respect to nitrogen fixation and dis-

eases of economically important plants. Who has cared about the diseases of economically unimportant plants or weeds so far?

It is to be expected that microbiologists working in these fields will want to give new isolates names that relate to their hosts or associates. That is, Latin nomenclatural names of animals, fungi, plants and protists have been and too a much larger extent will be used.

This area of bacterial name giving is unfortunately full of traps. Clearly, naming a bacterium after a host animal bearing a tautonym (such as *Picus picus*, the woodpecker) is easier than having to choose between the generic name and a different specific epithet of the host. It is therefore important to know what these mean and how they were formed (adjective, substantive in genitive, etc.), in order to avoid nasty, ridiculous or embarrassing mistakes.

The following example may demonstrate this situation. Certainly a bacterium isolated from the common house fly *Musca domestica* should not receive the epithet *domesticus*, *-a*, *-um* ('pertaining to the house'); its epithet should rather be *muscae* (of the fly) or *muscicola* (dwelling in/on the fly), the latter being a nominative noun in apposition.

The *domestica* associated with *Musca* is an adjective. If we theoretically considered it an independent noun meaning 'the one pertaining to the house' one could, of course, form the genitive from it and thus produce a bacterial epithet *domesticae*. In this example, however, that would not make much sense as too many things 'pertain to a house'. But formally it would not violate the Rules of the Bacteriological Code[5].

The easiest way of forming such specific epithets is the use of the genitive case of the generic name of the eukaryote in question, e.g. *suis*, *equi*, *bovis*, *muscae*, *muris*, *aquilae*, *falconis*, *gypis*, *elephantis* (of the pig, horse, cow, fly, mouse, eagle, falcon, vulture, elephant), or *fagi*, *quercus* (fourth declension genitive, spoken with long u), *castaneae*, *aesculi*, *rosae*, *liliae* (of the beech, the oak, chestnut, horse chestnut, rose, lily).

Alternatively the genitive of the plural is recommendable, especially if several species of the eukaryotic genus house the bacterial species in question. The formation of the plural genitive needs knowledge of the stem and declension of the word. The

following examples may be of some principal assistance:

- first declension: -arum (*muscarum*, of flies, *rosarum*, of roses);
- second declension: -orum (*equorum*, of horses, *pinorum*, of pines);
- third declension: -um (*leonum*, of lions, *canum*, of dogs);
- third declension: -ium (*felium*, of cats, *ruminantium*, of ruminants);
- fourth declension: -um (*quercum*, of oaks);
- fifth declension: -rum (*abierum*, of the species belonging to *abies*, a genus of pine).

Be aware of irregular forms such as *bos* (the cow), genitive *bovis*, plural genitive *bovum*! Use dictionaries and look up the declension in MacAdoo [4]!

2.7. Names taken from languages other than Latin or Greek

Besides names of persons or localities many words from languages other than Latin or Greek have been and certainly will be used in bacterial names. Here a few examples may suffice to demonstrate the width and variety of such cases.

During late medieval and renaissance times alchemy became rather fashionable with European scientists and many Arabic words entered the future terminology of chemistry. One of these – often used in bacterial names – is ‘alkali’ (Arabic *al-qaliy*, the ashes of saltwort) from which the element kalium (K, English: potassium) received its name. As the -i at the end of the word belongs to the stem it is wrong to speak and write of alkalophilic instead of alkaliophilic microbes. Latinized names of bacteria containing this stem should therefore be corrected to, e.g. *Alkaligenes*, *alkaliphilus* etc., and new ones should be formed correctly!

A rather common mistake occurs with the English suffix -philic (e.g. hydrophilic: friendly to water, water-loving). This is clearly an English transformation of the Latin -philus, -a, -um (originating from Greek *philos*, friendly). All names formed so far and ending in -philicus, -a, -um are wrong and should – in my opinion – be changed to -philus, -a, -um as soon

as possible. Here, however, Rule 57a (accordance with the rules of Latin) would have to be weighed against Rule 61 (retaining the original spelling) of the Bacteriological Code [5].

A marvellous and rather curious example of a name taken from two non-classical languages in an arbitrary combination is *Nostoc*, the pre-Linnean generic name of a well known cyanobacterium. As Malcolm Potts found out, it was coined by the German scientist, philosopher, alchemist and pharmacist Paracelsus (Aureolus Philippus Theophrastus Bombastus von Hohenheim, 1493–1541) who named certain greenish slimy spots on meadows by merging the old English *Nosthryl* (nostril) with its German equivalent *Nasenloch* to *Nostoch* [12]. The organisms later found in said slimy spots were consequently called *Nostoc*.

The bacterial genus name *Asticcacaulis* is a peculiar chimera between English and Latin. The isolate – apparently related to *Caulobacter*, an organism with stalked cells – did not form stalks itself. The bud (daughter cell) was formed right on the mother cell. The describing author latinized the English word ‘stick to a presumed Latin word ‘*sticca* and, as the stick (stalk) was absent, ‘*ab sticca*’ – contracted to *asticca* – and then added the Latin *caulis* (bud) thus obtaining the nicely sounding *Asticcacaulis*.

National foods or fermentation products often do not have equivalent Latin names and if typical microorganisms found in them or causing their fermentations are described, they have been (and may be) named after them, e.g. sake, tofu, miso, yogurt, kvas, kefir, pombe, pulque, aiva etc. However, these names cannot be used unaltered as specific epithets in the form of nominative substantives in apposition [8]. It is desirable that they be properly latinized. The best way to do so is to form a neuter substantive from them by adding -um (e.g. *sakeum*, *tofum*, *kefirum*, *pombeum*, etc.) and use the genitive of that (ending: -i) in the specific epithet (e.g. *sakei*, *tofui*, *kefiri*, *pombe*, etc.)

The formation of the epithet *simbae* from the East African Swahili word *simba*, lion, for a *Mycoplasma* species was not necessary because in this genus the corresponding Latin epithet *leonis* (of the lion) had not been used before.

2.8. Formation of bacterial names from names of elements and compounds used in chemistry and pharmacy

The almost unlimited biochemical capacities of bacteria are another rather inexhaustible source for new names. Many generic names as well as specific epithets have been formed from names of chemical elements, compounds and even pharmaceutical and chemical products or their registered or unregistered trade names.

The late Robert E. Buchanan [13] listed numerous examples of such generic names and specific epithets. Based on the classical Latin/Greek thesaurus, enriched with numerous Arabic words the pharmaceutical sciences have – since the Middle Ages – developed a Neo-Latin terminology for chemicals of all categories.

The vast majority of names of chemicals are latinized as neuter nouns of the second declension with nominatives ending in -um, genitives in -i. The following groups belong in this category.

Most of the chemical elements, with the exception of carbon (L. *carbo*, *carbonis*), phosphorus (L. *phosphorus*, *phosphori*), and sulfur (L. *sulfur*, *sulfuris*), have the ending -(i)um; nitrogen may also be called *azotum* besides *nitrogenium*, calcium may also be called *calx* (genitive *calcis*).

Chemical and biochemical compounds ending in -ide (anions), -in, -ane, -ene, -one, -ol (only non-alcoholic compounds), -ose (sugars), -an (polysaccharides), -ase (enzymes) (-um is added, or the -e at the end is replaced by -um).

Acids are named *acidum* (L. neuter noun, acid), followed by a descriptive neuter adjective, e.g. sulphurous acid *acidum sulfurosum*, sulphuric acid *acidum sulfuricum*, acetic acid *acidum aceticum*.

The second largest category of chemicals are treated as neuter nouns of the third declension. These are the ones ending in -ol (the alcohols), -al (aldehydes), -er (ethers, esters), and -yl (organic radicals); latinization does not change their names at the end, whereas the genitive is formed by adding -is.

Anions ending in -ite and -ate are treated as masculine nouns of the third declension. The English ending -ite is latinized to -is, with the genitive -itis, e.g. nitrite becomes *nitris*, *nitritis*. The English ending

-ate is latinized to -as, with the genitive -atis, e.g. nitrate becomes *nitras*, *nitritis*.

Only few chemicals have names that are latinized in the first declension as feminine nouns, ending in -a with a genitive -ae. Besides chemicals that always had names ending in -a (such as urea), these are drugs found in classical and medieval Latin, such as gentian (*gentiana*) and camphor (*camphora*), further modern drugs, whose Latin names were formed by adding -a, such as the French *ergot* becoming *ergota* in Latin.

The most important group of this category are alkaloids and other organic bases, such as nucleic acid bases and amino acids with English names ending in -ine. In Neo-Latin this ending is -ina, with the genitive -inae, e.g. *betaina*, -ae, *atropina*, -ae; *adenina*, -ae; *alanina*, -ae, etc.

For their use in bacterial generic names and specific epithets word stems and genitives of latinized chemical names are the basis. In principle they are then treated like any other word elements.

2.9. Arbitrary names

Either genus names or specific epithets “may be taken from any source and may even be composed in an arbitrary manner” (Bacteriological Code, Rule 10a and Rule 12c [5]). They must, however, be treated as Latin. These ‘rubber’ paragraphs open up a box of unlimited possibilities for people whose Latin is at the end. But in view of the million names that will have to be formed in the future they are a simple necessity – whether Latin formalists like them or not.

Examples of arbitrary generic names are *Cedecea*, *Afipia*, and in the near future ‘*Vipia*’ and ‘*Desemzia*’, which were derived from the abbreviations CDC (Center for Disease Control), AFIP, VPI (Virginia Polytechnical Institute), and DSMZ (Deutsche Sammlung von Mikroorganismen und Zellkulturen), respectively. Examples of arbitrary specific epithets are, e.g. (*Salmonella*) *etousae*, derived from the abbreviation ETOUSA (European Theater of Operations of the US Army), and (*Bacteroides*) *thetaitaomicron*, formed from the three Greek letter names theta, iota and omicron.

Soon the new genus *Simkania* will be described. The name is a latinized contraction of the first and

family names of the microbiologist Simona Kahane. Certainly an arbitrary name, short, elegant and easy to pronounce, that points at future possibilities of bacterial name giving. Authors should aim at such easily spelled and pronounced short names, when they take advantage of arbitrary name giving.

3. Names of highest taxa

Whereas the formation of names of higher prokaryotic taxa up to order follows the Rules of the Bacteriological Code [5], also with respect to priority, the highest taxa have for a long time remained unregulated. Often one has the impression that they are hung up high above the clouds, the latter representing an area where the connections to orders and families remain obscure. Only recently the ICSB has moved to take the highest taxa under the Bacteriological Code as well.

Returning to etymology, however, certain peculiarities in the names of highest taxa cannot be overlooked here. And this does not only pertain to nomenclature but to concept names as well.

The undoubtedly great leap forward in phylogeny-based systematics due to 16S rRNA (and/or 16S rDNA) sequencing as introduced by Carl Woese has presented us with some awkward names.

The completely new realm of life' of the 'Archaea' (plural of *archaeum*, latinized from Greek *archaeon*, 'the old one') was first named Archaeobacteria in contrast to the 'real' bacteria 'Eubacteria' [14]. Besides the missing connecting vowel required in archaeobacteria, (correctly Archaeobacteria) this dualism within the prokaryotes could have been kept this way, nomenclature-wise.

Nevertheless, Woese et al. [15] – not content with the idea that the 'new realm's' name still contained the unwanted word 'bacteria', i.e. in order to demonstrate the difference between the two prokaryote groups – then replaced 'Archaeobacteria' by 'Archaea', perhaps not realizing that it is not the archaeologists who work on these organisms, but still the bacteriologists. Also neither the bacteriological techniques used for this work nor the ecological importance or peculiarities of the organisms merit a separation and 'a change into archaeology'.

There is indeed evidence suggesting that the 'Arch-

aea' present surviving lines of the oldest cellular life forms, but under the name Archaeobacteria they would do that as well. A new name often seems to be considered more modern by many (usually younger) scientists and becomes fashionable, especially, when things are brought forward in an aggressive or polemic manner [16]. This behavior is fatally reminiscent of the way of politicians selling the public a new name for an old concept as a 'real change' or 'reform'. From a glance at most recent textbooks on microbiology I am afraid that Archaea may finally prevail.

The new category for 'realm of life', as introduced by Woese and coworkers [15], namely 'domain', needs to be mentioned in this concept. One should rather have used the word empire (or Latin *imperium*) in that concept [17,18]. 'Domain' had been used before in biochemistry/molecular biology as a topological term for special areas of or on large molecules (such as proteins, nucleic acids, peptidoglycans or ribosomes) and thus was in principle an occupied term. In German the word ('Domäne') even means certain territories (agricultural or forest land, large farms, etc.) owned by the state (government, king, etc.). So, I strongly oppose 'domains' in Woese's sense. Otto Kandler, in a publication on 'cell wall biochemistry and the three-domain concept of life', has even used 'domain' in the biochemical sense (parts of the cell wall structure of *Halococcus morrhuae*) and in Woese's sense at the same time [19].

The argument that 'empire' would sound 'feudalistic' is ridiculous, as the word 'kingdom' (used in English for Latin *regnum*) is equally 'feudalistic' and has been used in biology unprotected for centuries.

It would lead too far also to discuss here the fascinating etymology of the word chimaeras Urkingdom, Urcaryote and Progenote [14,20] as their existence as terms may be of limited duration. A discussion of the terminological misuse of Progenote has been published by Karl Popper and Günther Wächtershäuser [21].

Fortunately this 'new wave' in the science of prokaryotes has not led to the demand to ban typical 'bacteriological' word elements such as *-bacter*, *-bacterium*, *-coccus*, etc. from the 'domain of archaea'. The names of the taxa of all prokaryotes including archaeobacteria, Archaeobacteria or Archaea fall

under the regulations and jurisdiction of the Bacteriological Code [5], which includes the responsibility of the ICSB and its Judicial Commission.

4. Some case histories of malformed names

From the viewpoint of classical Latin many of the bacterial names created up to now are – plainly said – lousy in their grammar and etymology. However, under the Rules of the Bacteriological Code [5] they are acceptable.

A few case histories of wrong bacterial names are worth mentioning in a chapter on etymology because of their scurrility.

Acetobacter xylinus. This specific epithet goes back to Brown 1886, who described a *Bacterium xylinum*. Several subsequent changes of the genus (Trevisan 1889: *Bacillus xylinus*, Ludwig 1898: *Acetobacterium xylinum*, Pribram 1933: *Ulvina xyлина*) prove by the change in gender that the epithet is an adjective. Because before 1951 (Bacteriological Code [5], Opinion 3), the gender of names ending in *-bacter* was not fixed as masculine, *Acetobacter xylinum* Holland 1920 and Bergey et al. 1925 (all names and dates before 1950 cited were taken from Index Bergeyana [22]) were not wrong either. As a consequence of Opinion 3 the species should be named *Acetobacter xylinus*. The Approved Lists of Names [7], however, listed the organism as *Acetobacter aceti* subspecies *xylinum*! In 1983 Yamada [23] revived the species status and correctly called it *A. xylinus*. The compiler of Validation List 14 (Int. J. Syst. Bacteriol. 1984) incorrectly put a *sic* after *xylinus* and changed it to the neuter form *xylinum*! (The Latin expression *sic* is used to point out a mistake or other peculiarity.) Unexpectedly the previous authors obeyed this falsifying change and even tried to give the neuter epithet justification by explaining it as a nominative noun in apposition (*xylinum*, M.L. neut. n. cotton). ‘*Acetobacter* called the cotton’ makes little sense and certainly does not meet the requirements of a nominative noun in apposition (cf. [9]). Finally, Euzéby [24] corrected the name to *A. xylinus*.

Methanobrevibacter arboriphilus. In 1975 the new species *Methanobacterium arbophilicum* was described. The organism was isolated from rotting trees and the authors wanted to express ‘friendly to trees’

by the epithet. In Latin, tree is *arbor*, genitive *arboris*, i.e. the stem is clearly *arbor-*, not *arbo-*. The second error was that the English ending *-philic* was latinized to *-philicum* instead of correctly to *-philum*. Although this was already pointed out to the authors in 1976, they did not correct the epithet themselves. Then, in a review paper, Balch et al. [25] rearranged the methanogenic prokaryotes and transferred the species to the genus *Methanobrevibacter* as – upon my advice – *M. arboriphilus* (the correct form of the epithet). It was again the compiler of the Validation List No. 6 (Int. J. Syst. Bacteriol. 1981), who created a new wrong form of the epithet, *arboriphilicus*! Although I immediately informed him about his error, he did not correct it. And so this wrong epithet still occurred in 1989 in Bergey’s Manual of Systematic Bacteriology, Vol. 3 [26]. To my knowledge it has still not been corrected!

Some time ago an author wanted to create the specific epithet ‘*nakupumuans*’ and explained this word as derived from the Maori word *nakupumua*, breaking protein down to fragments. Being informed that there was neither need to use another language than Latin, nor any specific connection between the Maori and protein degradation, the author decided to call the isolate *proteoclasticum*. Accepting such name formations in prokaryote nomenclature simply would mean giving up Latin as the basic language of biological nomenclature. As long as names can be formed from the Latin/Greek thesaurus at our disposal, names from other languages must be avoided.

An author wanted to propose a specific epithet in honor of a colleague and formed an epithet ending in *-icus*. As this is not within the Rules, I advised him to choose an epithet ending either in *-ii* (genitive noun) or in *-ianus* (adjective). His answer was that he did not like the former and felt that the latter sounded like an insult to the colleague to be honored!

Another colleague correctly formed the generic name *Acidianus* (accentuation: a.cid.ia’ nus) from the Latin neuter noun *acidum*, acid and the Latin masculine noun *Ianus*, the Roman god with the two faces, by which he wanted to point at the ability of the organism to both oxidize and reduce elemental sulfur. With this spelling the epithet promptly became mispronounced (a.ci.di.a’ nus) suggesting a different meaning and causing suggestive jokes. Here

the use of the consonantic *i*, i.e. *j* would have sufficed to suppress the misinterpretation: *acidijanus* would be the choice.

Could the fear of suggestive jokes have been the reason why the editors of Index Bergeyana [22] avoided the correct name Index Bergeyanus for their valuable compendium of bacterial names existing until then?

These examples (especially the last one) also show that nobody is free from making mistakes. During my work in this field I have made several and have sometimes even given wrong advice – quite to my embarrassment afterwards.

5. Practical etymology in descriptions of genera and species

As mentioned before, for the average microbiologist ‘etymology’ is a kind of nasty linguistic exercise necessary for the description of a new genus or species. In reality he/she has to ‘create’ a new name; the organism has been isolated and determined by the author, not ‘created’! The better and more modest wording would be to ‘propose’ a new name.

On the basis of six examples of such etymologies I shall try to explain how these are composed.

Escherichia coli: Esch.er.i' chi.a (better: E.sche.ri' chi.a)

M.L. fem. n. *Escherichia*, named after Theodor Escherich, who isolated the type species of the genus. co' li. Gr. n. *colon* large intestine, colon; M.L. gen. n. *coli*, of the colon

Rhodospirillum rubrum: Rho.do.spi.ril' lum.

Gr. n. *rhodum* the rose; M.L. dim neut. n. *Spirillum*, a bacterial genus; M.L. neut n.

Rhodospirillum a red *Spirillum*. (Etymology of the latter: Gr. n. *spira* spiral, M.L. dim. neut n. *Spirillum* a small spiral)

ru' brum. L. neut. adj. *rubrum* red.

Azotobacter paspali: A.zo.to.bac' ter.

French n. *azote* nitrogen; M.L. masc. N. *bacter* the equivalent of Gr. neut. n. *bactrum* a rod or staff. M.L. masc n. *Azotobacter* nitrogen rod

pas.pa' li. M.L. gen n. *paspali*, named for *Paspalum*, generic name of a grass.

Pseudomonas fluorescens: Pseu.do.mo' nas.

Gr. adj. *pseudos* false, Gr. n. *monas* a unit, M.L.

fem. n. *Pseudomonas* false monad flu.o.res' cens. M.L. v. *fluorescere* (*fluoresco*) fluoresce, M.L. part adj. *fluorescens* fluorescing.

Desulfovibrio gigas: De.sul.fo.vi' brio (or: De.sul.fo.vib' rio). L. pref. *de* from, L. n. *sulfur* sulfur, L. v. *vibrare* vibrate. M.L. masc. n. *Vibrio* that which vibrates, a bacterial generic name. M. L. masc. n. *Desulfovibrio* a vibrio that reduces sulfur compounds.

(Note: if we were meticulous, the name should be either ‘*Desulfatibrio*’ referring to sulfate, or ‘*Desulfurivibrio*’ referring to sulfur. As *Desulfo-* may cover both, in this case it is certainly the best name for the genus!)

gi' gas. L. nom. n. *gigas* the giant.

Thermoanaerobium aotearoense: Ther.mo.an.ae.ro' bi.um.

Gr. adj. *thermos* hot, Gr. pref. *an-* without, Gr. n. *aer* air, Gr. n. *bios* life. M.L. neut. n. *Thermoanaerobium* life in heat without air

a.o.te.a.ro.en' se. Maori n. *Aotearoa* New Zealand, L. neut. suffix *-ense* indicating provenance, M.L. neut. adj. *aotearoense* from or pertaining to Aotearoa (New Zealand).

From these examples several regularities can be deduced.

After the name or epithet the ‘etymology’ starts with an indication of accentuation. The word is broken into a row of syllables interrupted by full stops. The accent-bearing syllable is indicated by an accent sign behind it (note: never before it!) instead of a full stop. The classical Latin language did not develop explicit rules about breaking up words into syllables, the Romans broke written words the way they were spoken, and – logically – split compound words between compounds. Grammarians came up with a Greek influenced theory and – in addition – medieval manuscript writing developed certain simple rules [6]. These were: (a) Single consonants including *x* and *z* as well as *ch*, *ph*, *th* belong to the subsequent syllable (e.g. *pa.ter*, *lu.xus*, *Epichar.mus*). (b) If two (or more) consonants follow each other, the last one belongs to the following syllable (e.g. *om.nis*, *sump.tus*). However, when *b*, *p*, *d*, *t*, *g* or *c* are followed by *l* or *r* (sometimes by *m* or *n*) these sequences remain unseparated (e.g.: *ca.pra*, *tene.brae*, *cas.tra*, *ma.gnus*). (3) Irrespective of the rules above, combined words are broken between their composing elements (e.g. *ab.ire*, *post.ea*, *sic.ut*). As the rules for breaking

words into syllables are different for different modern languages, one should not follow any of them, but continue the Roman custom.

The accentuation is followed by the etymology proper of the name. The abbreviations commonly in use indicate the language of origin (Gr. classical Greek, L. classical Latin, M.L. modern Latin), the type of word or word element (adj. adjective, n. noun/substantive, v. verb, part. adj. participle used as adjective, dim. diminutive, pref. prefix, suff. suffix), the case (gen. genitive, nom. nominative, the latter being seldom indicated) and the gender of nouns or adjectives (fem. feminine, masc. masculine, neut. neuter).

The word elements are explained in the sequence in which they occur in the name. Then, as a summary the language, the gender and the word type of the complete name or epithet are given, followed by the Latin name and its translation.

The abbreviation M.L. is very often misunderstood as medieval Latin. I personally would therefore prefer a ruling that M.L. should really mean medieval Latin and that modern Latin, better Neo-Latin, would be abbreviated N.L.

6. Recommendations (from the viewpoint of language) for future emendations of the Bacteriological Code

We should not aim for pure classical Latin in biological nomenclature but rather develop the Latin/Greek thesaurus at our disposal further by following the Rules of the Bacteriological Code [5] or – in other fields of biology – the respective codes of nomenclature. This is in reality what has happened since Linnaeus' times in any case. In my opinion the Bacteriological Code has excellent provisions to do so. This is already documented by the low number of Opinions that had to be issued by the Judicial Commission of the ICSB in the last 10 years.

For several years the development for a uniform code of nomenclature for all biological taxa has been on the way, with participation of well known taxonomists from bacteriology, botany, mycology, phycozoology, protozoology, virology and zoology with the support of the International Unions of Biological and Microbiological societies, IUBS and IUMS [27]. These activities were initiated by the general

scientific demand to assess the total extent of biodiversity on earth, in order to increase conservation and – perhaps – stop extinction of the diverse biota. For this purpose a unified system of biological names is considered indispensable. Drafts of the future universal 'BioCode' have been published, the latest (fourth) draft by Greuter et al. [28]. As soon as the BioCode is accepted by the taxonomic committees of the different biological disciplines involved, the Bacteriological Code [5] will have to be aligned with it. This means that changes in etymological rulings may also be expected. Unfortunately the recommendations for latinization in the BioCode (Articles 37–39) are not yet ready and therefore cannot be commented upon here.

Besides the cases mentioned in the text above, where I recommended certain changes or simplifications, there are only a few points where – in my opinion – the Rules need further development with respect to etymology.

Stronger emphasis should be put on short and easily pronounceable names.

Words from languages other than Latin or Greek should be banned as long as an equivalent exists in Greek or Latin or can be constructed by combining word elements from these two languages, and as far as they are not derived from names of geographical localities or local foods or drinks (e.g. sake, kefir, kvas, pombe, tofu, miso, yogurt, etc.), for which no Latin/Greek names exist.

Formation of bacterial names on the basis of latinized names of chemical compounds should be regulated under the Code. Here the recommendations of Buchanan [13], as explained above should be the basis.

The principal ban of ordinal numbers (adjectives) for the formation of bacterial names by Rule 52 (2), Bacteriological Code [5] only makes sense for those above 10 because of their length. Therefore, this part of Rule 52 should be abandoned.

In the transliteration of the Greek letter *k* to the Latin letter *c* the sound *k* gets lost when the vowels *e*, *i*, or *y* follow, and instead the *c* is (in English) pronounced as a sharp *s* in these cases. Therefore, to preserve the sound *k* before *e*, *i*, and *y*, the letter *K* should be kept even in the Latin transliteration (example: *Akinetobacter* as in *k*inetics instead of *Acinetobacter*).

Authors should refrain from naming bacteria after themselves or coauthors after each other in the same publication, as this is considered unethical by the majority of the scientific community.

Generic names and specific epithets formed from personal names can only contain the name of one person, not a combination or contraction of the names of two or more persons.

In the future, bacteriologists (including those that work on archaeobacteria and cyanobacteria) should avoid names that end in *-myces* or *-phyces* in order to avoid confusion with mycology and phycology, i.e. with eukaryote nomenclature. Articles 25–28 of the future BioCode [28] will even forbid prokaryote names ending in *-myces*, *-phyta*, *-phyces* etc. or in *-virus*.

In the etymology given with the description of a taxon, there should be an indication whether a Latin name is from classical Latin ('L.') or Greek ('G.'). from a medieval Latin ('M.L.') source or formed as Neo-Latin ('N.L.'). This will save time for those who want to look up such names and words in dictionaries, and it will end ambiguous interpretation of M.L. as either 'modern' Latin or 'medieval' Latin. Already Buchanan [13] preferred 'Neo-Latin' over 'modern' Latin.

Acknowledgements

I wish to thank J.P. Euzéby, Toulouse, France, and Lanfranco de' Clari, Lugano, Switzerland, for their extremely helpful correspondence on etymology of bacterial names, and the Fonds der Chemischen Industrie for financial support.

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