I. INTRODUCTION

Some years ago Professor Barnett Cohen, then editor of Bacteriological Reviews, suggested the preparation of a summary of recent progress in the field of bacterial taxonomy. The decision reached, after some discussion, was that the cataloguings and listings included in such a treatise might well have reference value, but would be less useful than a more detailed analysis of a small segment of this broad subject. Such analysis could well limit itself to a frank discussion, a sampling of a few only of the nomenclatural pitfalls of microbiology. There should be included also some analyses of the errors common to the literature of bacteriology and of auxiliary fields such as biochemistry, pharmacology, and zymotechnology. Such a review may prove stimulating, even useful, to the student (perhaps likewise to journal contributors and journal editors) in his continued groping for microbiological literacy. This paper is an attempt at such a sampling.

Complete literacy in any field is not readily attained; in microbiology it would require the acquisition of a comprehensive knowledge of the status of this science and its relationships in very many fields, including taxonomy, physiology, biochemistry, genetics, cytology, modern languages, classical languages (particularly Latin and Greek), history of microbiological societies and organizations, industrial utilization of microbiology, ecology, pathology, botany, zoology, and many more. But the acquiring of a reasonable degree of literacy in a particular field or subdivision of microbiology is quite practicable. Evidence of attainment is the ability accurately and correctly to use the vernacular, coupled with skill in constructing and using correctly the scientific names and technical terms appropriate to one's field of specialization.

Aptitude and skill in use of scientific names and of technical terms is much facilitated by knowledge of origins (etymologies). The names and terms are for the most part derived from Latin or from latinized Greek. There are three categories of uses for such knowledge by the microbiologist. He should in all cases be familiar with the first two. He should understand the implications of the third if he is working with certain groups of plants such as the fungi, the algae, or the slime molds. These three categories may be defined and illustrated as follows:

a. The microbiologist should know much about the derivation of vernacular names used as scientific terms. These are words usually derived from Latin or Greek. He should be aware that for some of these vernacular scientific terms there are two spellings to be found in the dictionaries; some are "American English" and some are "British English." In many cases, where there is a difference, the English spelling is the better because it shows derivation more clearly and avoids certain confusions. One finds both "hematology" and "haematology." The English spell-
ing retains the diphthong, the American spelling uses a single vowel. What difference does it make? Perhaps not much, except that one may be surprised to find that the literal meaning of hematology is not “science of the blood” but “science of spears or darts.” If pediatrics is the science of the soil, should not pediatrics also relate in some way to soil? The Greek stems are different, but the love of simplified spelling on the part of some of our medical colleagues may lead to overemphasis. The microbiologist, when coining a new technical term, should attempt to make one in which the etymology is not obscured.

b. The microbiologist should have a working knowledge of construction of words that are to be used as names of taxa in microbiology. All names of species, genera, families, orders, etc., in all of biology must be either Latin, or latinized and treated as Latin. Most of these names are derived from the Greek. The rules of biological nomenclature assume that the Greek is first transliterated into the Latin and the appropriate Latin endings added. A sign of microbiological literacy on the part of an author is his ability to coin correctly formed names. Understandably a microbiologist may conclude that the making of correct names is shrouded in mystery and that his time will be more profitably spent in finding and describing new species that he can’t name. As a matter of fact, a few hours of study (not more than three or four) should enable any competent researcher to form satisfactory and euphonious names for the new taxa that he describes.

c. The microbiologist must have some facility in Latin composition if he names fungi, algae, or slime molds and must follow the Botanical Code of Nomenclature. Inasmuch as the three groups listed are plants, he must publish for each new species named a description written in Latin. Bacteria alone are excepted from this requirement. Some special problems are involved in formulating such descriptions, as many of the words required are not to be found in classical Latin and many neo-Latin words must be introduced to care for physiology, chemistry, and even morphology. As noted later, the grammatical construction of Latin descriptions is not particularly difficult. Nevertheless, some Latin descriptions have appeared, particularly in descriptions of new species of yeasts and molds, which lack something of accuracy.

II. THE SCIENTIFIC VERNACULAR AND LITERACY

One universal attribute of literacy is grammatical correctness in the use of the scientific vernacular in one’s writing and conversation. Phrases of dubious ancestry and correctness are avoided. The literate student never intentionally approves the use of “the data” or “the agenda is,” even though some of our American dictionaries state that such incorrect use has become so common that it may be tolerated, even accepted. Provincialisms, slang, and laboratory jargon may be recognized by inclusion in these published vocabularies but such inclusion is no adequate warrant for their use in dignified speech and in serious scientific writing.

Authors dislike to have manuscripts, which they have submitted for publication, commented upon by a reviewer who apparently questions the authors’ literacy. Most of us have had such experiences. May I cite a personal instance. Years ago, in a book dealing with bacteria that cause animal diseases, in a discussion of a passive carrier of a contagium the assumed singular of the word “fomites” was given as “fomite,” the text read “fomite (plural fomites).” An English reviewer noted the low estate of American bacterial literacy in his comment that the singular of fomites is fomes. The Latin dictionary apparently upheld the validity of his criticism. However, the sense of humiliation with reference to personal nomenclatural illiteracy disappeared when a little study and analysis revealed that author and critic were both right. The formation of the English singular fomite from the plural fomites has ample precedent, e.g., we recognize both actinomyces and actinomyces as the singular of actinomyces. Not only do some Latin (and Greek) words taken over into English have two plurals, but some Latin plurals have two English singulars. Even reviewers have been known to be in error when criticizing spellings and grammar and etymologies.

III. NAMES OF TAXA: THEIR FORMATION AND USE

The most common manifestations of lack of microbiological literacy infiltrating all microbiology are in the field of nomenclature. To be literate, one must know the idiom of nomenclature, he must be able correctly to make and to use the scientific names of the organisms with which he works. Such literacy should be an
attribute of every microbiologist. A prime requisite is the ability properly to recognize, identify, and name the living organisms with which he works, whether he is intent upon probing their characteristics as living things, or whether he uses them as tools in chemistry, genetics, biophysics, bacteriology, pathology, or elsewhere.

Many microbiologists look upon Codes of Nomenclature as necessary evils, with but little emphasis on the “necessary.” Unfortunately there has been a degree of dichotomization in the thinking and actions of biologists that have led to the creation of three independent Codes of Nomenclature, one for plants, one for animals, and one for the bacteria. The microbiologist must have some knowledge of each, for in his laboratory and classroom he deals with fungi, whose nomenclature is governed by the Botanical Code, with protosoa, which come under the Zoological Code, and with bacteria and viruses, which come under the Bacteriological Code. Misunderstandings of the interrelationships of these codes and their differences may lead to real difficulty. For example, the genus Streptomyces was included by Waksman and Henrici, the authors of the name, with the bacteria. In a paper published in one of our bacteriological journals not long ago, tabulating and classifying much information on this genus, the authors concluded that the affinities of the genus lie with the fungi and not with the bacteria, and that the rules of the Botanical Code, not those of the Bacteriological Code, should be followed. However, the authors failed to note that the Botanical Code contained some provisions that if followed in the nomenclature of this genus would lead to nomenclatural chaos. No fungus name can be recognized botanically, if published since January 1, 1935, unless a description in the Latin language is given. Names given without such Latin descriptions are not validly published and have no standing, must not be recognized even as synonyms. Probably unwittingly the authors recommended that practically all species names given in the genus Streptomyces as well as the generic name itself be discarded, which means that the genus and all its species must be renamed. Probably most microbiologists would be tempted to insist that the Streptomyces belong with the bacteria. Morals: Microbiologists, know your codes (if you appeal to them).

This review must necessarily be limited to a discussion of a few only of the many problems faced by the student in his attempt to know and use the criteria of literacy as guides. The following will be discussed: (1) construction and use of singulars and plurals, (2) the specific epithet, (3) influence of modern language spelling on spelling of scientific names, and (4) confusion of nomenclature and classification.

A. Construction and Use of Singulars and Plurals

Teachers of microbiology are constantly be-deviled by the tendency of the student to ignore the fact that most words of our scientific and technical vocabularies are taken directly from the Latin or, after latinization or romanization, from the Greek and that they retain the Latin plural. There is even some evidence that the results of this student ignorance persist into the publications of mature years. Errors in the use of singular and plural of nouns are among the most common that those made by teachers in the classroom and by authors in their journal publications. This problem proves troublesome because of misunderstandings of the techniques encountered in the transformation of scientific names of taxa into vernacular names, and because of certain complexities relating to the formation of singulars and plurals (particularly confusion as to the correct singulars and plurals of names ending in -a).

Before considering specifically the problems of literate use of singulars and plurals of scientific names in microbiology, it should be noted that in theory, at least, every plant or animal or microbial taxon has an internationally recognized scientific name as well as one or more vernacular names, the latter frequently differing in different language. Vernacular names are common for genera of higher plants. In English, oak = Quercus; violet = Viola; hawthorn = Crataegus. Similarly, species have vernacular names: white oak = Quercus alba; birdsfoot violet = Viola pedata. In microbiology we have yeast = Saccharomyces; vinegar bacterium = Acetobacter. Among species one finds gonococcus = Neisseria gonorrhoeae; brewer’s yeast = Saccharomyces cerevisiae. When no vernacular name has been applied to a plant or a microorganism, the rule is to coin one, when needed, by using the scientific name or a name readily derived from it, but not capitalized. Many of these are familiar; rose = Rosa; rhododendron = Rhododendron; aster = Aster. A few microorganisms have generally recognized vernacular names such as
A tubercle bacillus = *Mycobacterium tuberculosis.* However, any generic name in bacteriology may be converted under the rules to a vernacular name, either with the same spelling or with a minor modification. For example:

streptomyces, streptomycete = *Streptomyces*
corynebacterium = *Corynebacterium*
leptospira, leptospire = *Leptospira*
rickettsia = *Rickettsia*
treponema, treponeme = *Treponema*
pseudomonas, pseudomonad = *Pseudomonas.*

Scientific names taken from the Latin (or Latinized Greek) may have quite appropriately one or two singular forms (sometimes even more) and one or two plural forms when made into vernacular names. The Latin-English word index has one singular form, but two plurals, one, *indices,* using Latin precedent, and *indexes* the English. The name of the bacterial genus *Leptospira* when used in English vernacular has two singulars, leptospira and leptospire, and three possible plurals, leptospiiras, leptospires, and leptospire. The generic name *Streptomyces* has two singulars and one plural, in the singular streptomyces and streptomycete, in the plural streptomycetes. In the last example it should be noted that the complete stem of the name is not included in the nominative singular of the generic name, but may properly be included in the English.

One problem of singular-plural relationship has puzzled many students. May one correctly employ the name of a genus in the plural? It has been argued that the rules of all biological codes state that two genera cannot have the same correct name. Actually the rules do not make this exact statement, but emphasize that a later homonym of a generic name is illegitimate, and conversely that a name can legitimately be applied to one genus only. It is argued that the use of a generic name in the plural must indicate the existence of two genera of the same name, and that such identical generic names cannot both be correct or permissible; *ergo,* if there can be only one its name must always be singular. This is not necessarily an exact statement. A genus of animals and one of plants may have the same name. The plural of a generic name has another and very different connotation, *i.e.*, it is not used to designate two or more genera with the same name. To illustrate, the word oak is the English name for a genus of trees characterized, among other things, by bearing acorns. But a genus is a group of species, there is more than one kind of oak within the genus, there is a white oak, a burr oak, a red oak, etc. We say correctly that all oaks, meaning all kinds of oaks, produce acorns. The Latins used the name *quercus* for oak, and said *quercus omnes glandes generat,* all oaks produce acorns. A genus always includes a group of individuals, usually a group of kinds of individuals. Botanists and zoologists from the time of Linnaeus have usually not hesitated to use the generic name appropriately in the plural. One may correctly say "the *Salmonellae* are" meaning the "species of *Salmonella* are." Precedent rules this is permissible both when the word is used as a scientific name (a generic name) or when converted into a vernacular form. When put in the vernacular, an English plural is sometimes used when the result is euphonious. One may say "*shigellae are*" or "*shigellas are.*" Obviously one would not say "*bacilluses are*" for "*bacilli are*.

Many Latin and Greek singular nouns end in -a, there are also many Latin and Greek plurals which end in -a. The distinctive English ending for the plural is -s, not -a. Relatively few English words not derived from Latin or Greek have a singular ending in -a. There is ample opportunity for confusion. In our microbiological writings there is need for much microbiological literacy to avoid using singular nouns ending in -a with a plural meaning. The criteria for determining correct usage are few and relatively simple.

1. Latin nouns, ending in -a in the nominative, form the Latin plural by adding -e, as *sarcina, sarcinae; forma, formae; radicicola, radicicolae.*

2. Latinized Greek nouns ending in the nominative in -a (excepting those which end in -ma) form the latinized plural by adding -e, as *leptospira, leptospirae.*

3. Latinized Greek nouns in the nominative ending in -ma always form the latinized plural by adding -a, as *plasma, plasmata; nema, nemata; soma, somata.* There are about seventeen hundred Greek words with this ending. Note that in these words both singular and plural have -a as a terminal vowel.

4. Latin and latinized Greek nouns which in the nominative end in -um (neuter nouns) form the plural by dropping the terminal -um and
adding -a. There are thousands of such words. Examples: *spirillum, spirilla; flagellum, flagella; corynebacterium, corynebacteria.*

5. Neuter Latin nouns which in the nominative have endings other than -um also have the plural ending in -a; as in *nomen, nomina; genus, generae; mare, maria; animal, animalia; cornu, cornua.*

Perhaps the major test of microbiological literacy is the correct use of nouns which in the singular end in -a and of those which in the plural end in -a. The teacher of bacteriology must induce his students to write “the flagellum is, the flagella are; the sacrina is, the sacrinae are.” One finds in bacteriological literature the correct “washed leptospirae,” “Gram-negative bacteria, including the brucellea.” It is perhaps too much to be hoped that “this datum is, these data are” and “the agenda is, the agenda are” may again prove popular. If not, we presently will collect datas, and propel bacterias by means of flagellae or flagellas and sterilize medias. A recent journal article includes the surprising statement, “frequent septae are produced.”

Several ancillary problems arise from the grammatical confusion caused by -a endings. One can find many examples in our standard American microbiological and biochemical journals of the use of the name of a genus in the singular with a plural verb. One sees not infrequently such incorrect expressions as “the salmonella occurring in sewer rats are sometimes transmitted to man,” “The shigella have many serotypes,” or “we have shown that certain cytophaga.” Some authors apparently have rationalized a justification for this use by the claim that since a genus such as *Salmonella* includes many species, the generic name, at least in its vernacular form, may therefore be used in the sense of a collective noun. Such nouns, in English usage, may be employed either with a singular or with a plural verb. The reasoning is fallacious, there is no good precedent except that of a faulty grammar, perhaps provincialism. The explanation is much more likely that this is unwitting confusion based upon the fact that in bacteriology there are many words of Latin origin having -a in the plural, and many others that end in -a in the singular; the sound of a singular generic name when spoken followed by a plural verb is not offensive to the ear. It is interesting to observe that one does not find the expressions “the *Bacillus are*” or “the *Bacterium are,*” although such use would be equally logical.

However, incorrect use of the generic name in singular form as a plural is not confined wholly to names that end in -a. In a recently published paper one reads “fluorescent *Pseudomonas* were not encountered” and “all the *Pseudomonas* were denitrifiers,” and in the title of a dissertation “the mesophilic *Achromobacter*.” Why are these irregularities rather common? In part, certainly, because our editors have not insisted that their reviewers in turn insist on use of good grammar. They have been routed by the professors and engineers and statisticians who use “data is.”

**B. The Specific Epithet**

A second test of aptitude in microbiological literacy is proof of the possession of some real understanding of what is meant by “the scientific name of a species.” This is evidenced by ability properly to use and to construct names of species. All nomenclatural codes agree that the scientific name of a species is made up of two parts: it is a binary combination. All agree that the first component is a proper noun, in the singular number, which is the name of the genus in which the species is included. Botanists and bacteriologists agree that the second component is to be termed a *specific epithet*, but the zoologists have somewhat confused other biologists by their recent decision to call the second component the *specific name*. Why are other biologists confused? Because in bacteriology and botany the designations “species name” and “specific name” are synonymous. In zoology they are not, the *specific epithet* of the bacteriologist is the *specific name* of the zoologist. It should be clear that the specific epithet is not the name of a species, it is an explanatory word or phrase limiting the application of the generic name to a single species. The formation and correct use of the specific epithet deserve some comment.

But first, what is the meaning of epithet? It may be a single word which in some way defines or limits or modifies the meaning of the generic name or it may be a single phrase consisting of two or more words which together convey a single idea, but which do not sepa-
rately modify the generic name. The codes of nomenclature specify clearly that a specific epithet may be one of three types:

1. An adjective (simple or compound) which directly modifies the generic name, and agrees with it in gender, number, and case. As *Sarcina lutea*, the yellow *Sarcina*.

2. A noun in the genitive modifying the generic name. It need not agree with the generic name in gender or number. As *Escherichia coli*, the *Escherichia* of the colon.

3. A noun in apposition with the generic name. It agrees in case with the generic name, but need not agree in gender. As *Xanthomonas prunicola*, *Xanthomonas* the plum dweller.

These statements appear simple; it would seem that conformity to rules and recommendations should not be too difficult. But examination of the literature of bacteriology shows many lapses. Perhaps one may establish three grades of literacy in the coinage of specific epithets. In some cases a specific epithet proposed contravenes a rule, it cannot in the long run be accepted, it is illegitimate and is eventually expunged from the literature as incorrect. Such cases may be termed grade 3 literacy. In other cases the epithet does not violate any rule, but does not conform to some recommendation. For example, we are advised that a well-chosen specific epithet should in some way describe the organism named. In other words, nonsense words are frowned upon, but are tolerated. They constitute evidence of some degree of literacy. But the highest and recommended degree of literacy is evidenced by the person who follows not only the rules but the recommendations as well; he sets an example for the nomenclators who succeed him, his precedents are good.

Some examples of problems in our present literature relating to the making of specific epithets should be cited. What should be done with the name of the yeast species, *Pichia quercibus*? It is apparent that the specific epithet is derived from *Quercus*, the generic name of the oaks. It is not an adjective, but a noun which is neither in the nominative in apposition to *Pichia* nor a noun in the genitive. Apparently it is in the dative or ablative plural with the meaning "to or with oaks." What should be done with such a name? If *quercibus* was proposed as a nonsense word, a word without meaning, it may be accepted. Or, one may conclude, the name *Pichia quercibus* is illegitimate and should be discarded and a new specific epithet proposed. Again, it may be regarded as a slip of the pen, a *lapsus calami*, which may be corrected to *Pichia quercorum*, the *Pichia* of oaks.

In formation of specific epithets one is often posed with the problem of fixing upon the correct forms of the genitive of nouns to be used as specific epithets. For example, one may wish to propose a specific epithet based on the name of the disease with which the organism is associated. The answer is simple if the name of the disease ends in -osis or -asis. The genitive is the same as the nominative, one writes with confidence *Mycobacterium tuberculosis*, the *Mycobacterium* of tuberculosis. But the problem is often complicated by the fact that names of many diseases are derived from the Greek and when latinized end in -itis. In this case the genitive ending is -itis. One should not propose *Neisseria meningitidis*; if proposed, it should be corrected to *N. meningitidis*. *Clostridium endocarditis* should become *C. endocarditis*. Many names of neoplasms have the ending -oma, they belong with thousands of other Greek names with the ending -ma which have as their latinized genitive, -matis. If one does not recognize the Greek stem he may easily, but incorrectly, place the word in the first Latin declension (forma, formae). An author inadvertently named an organism associated with trachoma *Rickettsia trachomatis*. Such a *lapsus calami* should be and was corrected to *Rickettsia trachomatis*. When such a correction is made it is not customary to cite the name of the corrector, but only the name of the original proponent. The latter does not entirely escape unscathed, for in any listing of synonyms his original spelling will be cited, frequently followed by "sic" to indicate that the spelling given is truly that of the original. In *Bergey's Manual* one may find hundreds of such "sics."

What should be done with a name such as *Streptococcus equisimilis*? The specific epithet ordinarily would pass muster, it conforms to the legal requirements for a specific epithet. But what does it mean? Quite certainly the author did not intend to convey the literal meaning of "resembling a horse." He had in mind that the name *Streptococcus equis* had been applied to a related organism and wished to
express a relationship between the two species. He intended to suggest, not that the new species resembled a horse, but that it resembled *Streptococcus equi*. However, a nonsense adjective was coined. Under the rules it stands. This type of nomenclatural difficulty arises from the tendency in our laboratories and in the vernacular to speak as though the specific epithet were the name of the species. We use the specific epithet as a nickname. This tendency has resulted in the formation of many poor derivative specific epithets. For example, we often speak of the coliform bacteria or of the paracolon bacteria, meaning those organisms that seem to be rather closely related to *Escherichia coli*. Then an organism is named *Bacterium paracoli*. Literally this would seem to be a noun in the genitive meaning “of the paracolon.” But there is no anatomical structure called a paracolon. However, in giving the literal meaning of the epithet we have misinterpreted the meaning intended by the author. The intended meaning is “resembling *Escherichia coli*” (para resembling, and *coli* a specific epithet). Names thus formed as specific epithets meet the first requirement of microbiological literacy. They may be regarded as nonsense words and accepted, for the intended meaning can often be conjectured.

Another difficulty is encountered when one lifts the specific epithet from the name of one species to be used in the name of another species with some resultant nomenclatural confusion. A bacterial parasite of the garden stock (*Matthiola incana*) was named *Xanthomonas incanae*. The Latin adjective *incana* has the meaning of “gray.” The parasite’s specific epithet has been placed in the genitive *incanae* and means “of gray.” An adjective used as a specific epithet must agree grammatically with the name of the genus. This would indicate that the name should be changed to *Xanthomonas incana* even though the author had no wish to tell an untruth, to say the parasite was itself hoary. When corrected to “incana” we have a usable and legitimate name, one showing a degree of microbiological literacy, even though a meaningless species name has been coined. The relationship to the host could have been much better expressed by using either the genitive of the generic name as in *X. matthiolae* or, if this was not sufficiently specific, the entire species name of the host could be used, as in *X. matthiolae-incanae*. The use of the specific epithet of one species in coining a specific epithet for another may be hazardous.

Sometimes specific epithets are made up of two or more words. A correctly formed, compound specific epithet should have its components related as a principal and one or more modifying words. Together they should express a single idea. A generic name, together with such a compound specific epithet, is a binary combination, and is from this point of view in proper form. However, if two or more unrelated words follow the generic name, each is a distinct epithet and the proposed species name is a trinomial or polynomial, hence illegitimate. Legitimate species names must be binary in form.

A specific epithet composed of two or more words should be joined or united by a hyphen. There have been instances in which proposed specific epithets have reached gargantuan proportions. As a hypothetical example: an author proposes basing the specific epithet of a new species of *Clostridium* on the name of the disease which it produces. The disease is described as a gaseous edema of the udder of the cow. He puts the name into proper Latin form, and writes *Clostridium emphysematosis oedematis mastitidis bovis*. He is urged by a recommendation of the Code to put hyphens between these separate words to indicate that the whole constitutes a single epithet, and proposes *Clostridium emphysematosis* - *oedematis* - *mastiatis-bovis*. He has followed the letter of the law and has created a legitimate specific epithet and a legitimate species name. He has passed the first test of nomenclatural literacy. But you will agree that he has failed to pass the second test, for he has not followed the recommendation of the Code which advises that a specific epithet should be relatively short and easily pronounced. An author who proposes such a compound throws a wholly unnecessary burden upon all those who thereafter use the name. After valid publication, can such an awkward name be simplified? Yes, but it requires international agreement. Has such action ever been taken? Yes, upon request of a group of workers concerned, the problem of the species name *Streptococcus agalactiae-contagiosae* was considered by the Judicial Commission and agreement reached that the name should be shortened to *Streptococcus agalactiae*. The Code further
states that the several words of a compound specific epithet may be combined into a single word and the hyphens omitted. This has been done in some instances with rather unfortunate results. One would be somewhat surprised to see the name developed above appear as *Clostridium emphysematosaeoena.* Even Bergey’s *Manual* has fallen into the unfortunate habit of coalescing words that are separately declined. The wisdom of such a practice is debatable, they would better be separated by hyphens, for in a case of this kind a true compound word is not formed.

An author may propose two different words which separately modify the generic name and are not related one to the other. For example, he wishes to name a pseudomonad which is found in the sea and which in the laboratory under appropriate environment is able to bring about denitrification, i.e., the reduction of nitrates. He names the organism *Pseudomonas marina denitrificans,* “the marine pseudomonad that denitrifies.” But this is an illegitimate trinomial, *marina* and *denitrificans* separately modify *Pseudomonas.* The author has constructed a trinomial by proposing two specific epithets. Then he seeks to remedy the matter by combining the two words into a single specific epithet and coins the word (specific epithet) *marinodenitrificans.* There is no question but that he has shown the first level of microbiological literacy by conforming to the rule that names of species must be binary. But in this coining of a specific epithet he has produced a nonsense word, a word without an internally consistent meaning. He still intended it to mean (as a species name) “the marine, denitrifying pseudomonad.” It can scarcely mean “the marinely-denitrifying *Pseudomonas.*” It is difficult to see how “denitrifying” can modify “marine.” The author has not conformed to the Code recommendation relative to the formation of specific epithets. He did not pass the second test of microbiological literacy. Possibly he could have formed a much better species name by calling it *Pseudomonas* “the marine denitrifier,” i.e., *P. marinodenitrificator.*

Are there many such nonsense words in the literature of bacteriology, words recognized as legitimate specific epithets? There are. Here are a few examples. *Flavobacterium marinovirosum,* does the specific epithet mean slimily marine or marinely slimy? It was intended probably to mean the “marine, slimy *Flavobacterium.*” As it stands it is a nonsense word. *Streptomycyes thermofuscus*; the “hottish” brown *Streptomycyes* was probably intended to mean the “thermophilic brown *Streptomycyes,*” but does not. Bergey’s *Manual* includes a number of nonsense specific epithets that have thermo- as a first component. Among them are *Bacillus thermodiastaticus* (hot diastatic) probably intended to mean the thermophilic *Bacillus* producing diastase; *Bacillus thermoliquefaciens* (heat liquefying) intended to mean the “thermophilic liquefying *Bacillus;*” *Bacillus thermodiastaticus* (heat translucents) intended to mean the “thermophilic translucents *Bacillus.*” Of course not all words used as specific epithets beginning with thermo- are nonsense words. For example, *Bacillus thermocellulolyticus* seems to mean “digesting hot cellulose,” and *Bacillus thermophilic* the “hot-food loving *Bacillus.*”

A foreign worker proposed the name *Actinomyces longisporus ruber.* This is, of course, an illegitimate trinomial, “the longspored red *Actinomyces.*” This has been converted in America into *Streptomyces longisporeoruber,* a good example of an unnecessary nonsense epithet. It could well have been recognized initially as illegitimate, and a sensible legitimate epithet substituted. A recent patent issued in the United States includes the name of a new species of bacterium associated with a patented process, *Clostridium amylosacharobutyropyllicum.* This meets the requirements of the rule that there shall only be a single specific epithet. But what is the meaning? Literally, perhaps the starch-saccharose-butyl-propyl-polylic organism. Possibly the epithet was intended to mean the *Clostridium* that from starch and saccharose can produce butyl and propyl alcohols. Whether proposal of a name in a patent is a valid publication of the name is a question apparently not decided, but the proposal of such a name as this shows little true microbiological literacy on the part of the advising microbiologists and of the patent attorneys. Sometimes a nonsense word eventuates when the components of the specific epithet are not properly chosen. For example: *Clostridium sartagoformum.* The meaning intended seems reasonably clear: *sartago* frying pan, and *forma* shape. But there are two errors. The stem of
sartago is sartagin- and the suffix formum does not mean shape, but warm. The Latin suffix meaning shape or form is -formis, -is, -e. The meaning would have been clearer if the name chosen had been Clostridium sartaginiforme.

C. Influence of Modern Languages on Spelling of Modern Latin Scientific Names

The pronunciation of scientific names in their modern Latin form is considerably influenced by the modern language (vernacular) spoken by the pronouncer. There is also a concomitant tendency to modify spellings from those prescribed by the Codes, the better to adapt their pronunciation to the language of the nomenclator. For example, Ehrenberg in his Berlin Museum sanctum almost exactly a hundred years ago named a diatom found in the state of Iowa, U.S.A., Suriraya eioeana. He knew the dislike of the German for pronouncing i as a long vowel before an o. An Iowan in Germany quickly recognizes that his native state is not Iowa but Yo-vah. Ehrenberg incurred a nearer approach to correct pronunciation by use of the German diphthong ei. But he presented a puzzling situation to the unwary etymologist trying to determine the meaning of the adjective eioeana. However, one can scarcely term an intentional deviation of this kind illiteracy. But the tendency for the Italians to insist on spelling Greek-derived names of taxa with an f where in classic Latin phi was used is mildly irritating to those of many other tongues, just as is the American tendency to replace the Latin diphthong ae by e, as in writing Hemophilus rather than Haemophilus, forgetting that this may completely obscure the etymology. Haemophilus means "blood lover," Hemophilus means "lance or javelin lover." The American urge for "simplified spelling" manifestly should not be carried into the coining of scientific names of taxa; dangers of confusion are too great.

Some of our nomenclatural problems in bacteriology might be credited to the etymological anarchism of the chemist, particularly the biochemist, in the coining of names of chemical compounds from fragments, not stems or roots, of the names of the plants or animals with which he works. He isolates a dozen alkaloids or essential oils from a single species of plant, and attempts to include some fragment of the plant's name in the name of each new derivative. The nomenclatural problems of the chemist in chemistry are not at all those of the biologist in biology. It would prove helpful if the biochemist would consistently recognize that, in the coining of names for new species of organisms with which he works, he should follow the conventions of biology. His deviations are sometimes imitated by bacteriologists. Even the rightly renowned Winogradsky named one bacterial genus Celleibrio, another Cellfalcicula on the assumption that cell could appropriately be used as an abbreviation for the modern Latin celluloseum.

D. Confusion of Nomenclature and Classification

Bacteriologists and systematists sometimes wish to avoid the accurate and correct use of words by resorting to less definite, frequently foggy, expressions. One such is the use of the word "group" in an apparent conscious effort to avoid employing the conventional terminology of nomenclature. The word "group" apparently has a desirable aura of indefiniteness. Instead of saying the "genus Shigella" there is an urge to say the "Shigella group." Why? Apparently because there seems to be less of definiteness as to the boundaries and circumscription of a "Shigella group" than of a "genus Shigella." A genus is by definition a species or a group of species, but the use of the word genus is avoided because of a quite erroneous concept that a named genus must have a clear circumscription; the author feels that when the accepted terminology of taxonomy is used he is in some way hemmed in by boundaries he does not wish to recognize. So he uses "group" instead of "genus" and feels freer. The word "group" does have its place in nomenclature, but it should not be used (as it sometimes is) in an attempt to cover muddled thinking or a desire to avoid frank facing of facts. One evidence of nomenclatural literacy is the correct use of the accepted vocabulary of nomenclature with the understanding that departures therefrom are to be clearly understood and defined.

How did this muddying of the nomenclatural waters come about? Primarily because certain microbiologists have confused two distinct contributions to biology made by Linnaeus. This biologist proposed and inaugurated a system of
naming of plants and animals that was a marked advance over the systems prevailing previously, so advantageous in fact, that almost immediately all of biology quite consistently followed the pattern which he laid down. But he, in conformity with the thinking of his time, had what we now regard as a wholly erroneous concept of the origin of species, that of separate creation, and of the existence of distinct and permanent barriers between them. Our modern concept of species certainly is not that of Linnaeus. Hence, some microbiologists have concluded that Linnaeus’ rules of nomenclature are not appropriate for a biological world in which his concept of species does not hold. Also prevalent in some microbiological circles is the assumption that the complexities of classification in the bacteria are not of the same kind, indeed are much greater, than those to be found in the higher plants and animals. This concept, one may say quite categorically, is fallacious. Subcommittees of the International Committee on Bacteriological Nomenclature such as that on the Enterobacteriaceae have done an immense amount of valuable work; they have greatly enlarged our knowledge of several of the genera; they have proposed many sound ideas as to classification. However, their failure to accept the terminologies quite universally recognized in biology has not infrequently led to misunderstandings. Much needed work on the nomenclature of genera of the enterobacteria is still to be done. This is a task for the future. The substitution of the word “group” for “genus” or for “subgenus” may possibly have led to more confusion than it has obviated.

IV. FORMULATION OF LATIN DESCRIPTIONS AND DiAGNOSES

The microbiologist has frequently to deal with and to describe minute fungi or algae, particularly those which are economically significant. The nomenclature of the fungi, including the yeasts and molds and the algae, is governed by rules set up in the Botanical Code of Nomenclature, which rules differ in some respects from those in the Bacteriological Code. To be regarded as legitimate (acceptable) in botany the names of all new species (as well as other taxa) must be accompanied by a description written in Latin. Many microbiologists (perhaps unfortunately) are not adept at writing such Latin descriptions. Even one versed in classic Latin composition may well have difficulty, for the Latin dictionary lacks many words needed in formulating such descriptions. To complicate matters, the species of yeasts, for example, are not distinguished exclusively by morphological criteria but also by the criteria developed first in bacteriological laboratories. They are grown in media whose components have no classic Latin names, and their relationships to many chemical compounds unknown to the Latin must be indicated. Even many terms used to describe morphology and physiology cannot be put into classic Latin. Occasionally necessary is the use of words from medieval Latin, more often, the coining of new words to be regarded as modern Latin, frequently formed following the pattern of the Latin of pharmacology. Perhaps unfortunately, no criteria have been established as to the adequacy of the Latin descriptions published, either as to grammar or content. Perhaps the experts on yeast and mold taxonomy and nomenclature will not object if we glance at some of the results of this requirement for latinization. We may examine a few phrases and sentences from the yeast species descriptions of the zymologists, and illustrate some of the types of problems by scrambling portions of descriptions of several species named by the zymotechnologists.

The taxonomist has not always used or coined the most suitable modern Latin words and phrases. For example, in many cases the first phrase in the English description of a yeast is “growth in malt extract” which our authors render in modern Latin as “in musto maltato.” The literal translation of this is “in maltated must.” The classic Latin word mustum means freshly pressed grape juice. The brewer’s English for this malt extract is “beer wort.” In Smith’s English-Latin dictionary an attempt is made to give the Latin equivalent of wort, “perhaps mustum ex hordeo,” (must from barley). One wonders why there is not used the good modern Latin pharmaceutical phrase for malt extract, “extractum multi,” and why the authors have not written the more readily understood version “in extracto multi.”

Singular verbs with plural subjects cause difficulty as “sedimentum et annulus formatur” (correctly formantur),” (sediment and a ring
are formed); "Nitrax kalicus" apparently means "potassic nitrate;" why not "nitrax kali" (nitrate of potassium)? In general there is little apparent difficulty with the formation of modern Latin names of the various carbohydrates, as glucosum, saccharum, cellobiosum. But the commonly recognized rule that names of alcohols (ending in -ol) are already in acceptable modern Latin form is ignored and they appear as mannitolum and sorbitolum. The endings appropriate to the oblique cases are sometimes used for the nominative, as in "alcohol ethylicum est" for "alcohol ethylicum est." There may be lack of recognition that some modern Latin words are best regarded as indeclinable, such as "agar" rather than "agarum" (which is the generic name of a marine seaweed). "With little warts" might be rendered as "cum verrucis parvis." "Hat-shaped ascospores" is better as "ascosporae pileiformae" rather than "pleioforme acum sporae." Generic names in Latin sentences should be declined; "ex Quercus kelloggi" and not "ex Quercus kelloggi." This discussion on difficulties in correct use of Latin in mycology is not primarily to emphasize Latin literacy standards, but to point out the essential absurdity of the botanical rule which requires original diagnoses of certain groups of microorganisms in Latin. An adequate description of a yeast requires the formulation of many new words constructed on Latin precedents and from Latin or Greek or modern stems. The Botanical Code explicitly exempts the bacteria from the operation of the rule and could well be revised to except certain other groups of microorganisms. However, it must be recognized that such proposals have been voted down in recent International Botanical Congresses. If the rule is maintained (it shows signs of longevity), it should be the duty of someone competent to prepare a brief brochure listing the words of a modern Latin microbiological vocabulary with pertinent hints as to modern Latin microbiological sentence construction useful in mycology.

V. WHY LITERARY LAPSES IN MICROBIOLOGICAL LITERATURE?

Why are literary lapses common in our current publications? Here are some (not all) of the reasons.

1. There occurs a welling up in the serious writings of later life of the more or less justifiable but incorrect jargon of the laboratory. The child from the home where incorrect grammar is standard may have a language handicap in later life.

2. Many inaccuracies and lapses are to be found in textbooks. Some of the "lapses" quoted are taken from standard texts.

3. There is frequently a lack of any effective training in Latin and Greek on the part of both teacher and pupil. This is by no means the insuperable obstacle that it is often assumed to be. Some of our greatest and most literate systematists have had no formal training in the classical languages. Some facility in the use of Latin word formation in a modern language is not difficult to acquire.

4. The lack of effective scrutiny (not censorship) on the part of editors of textbooks and particularly of scientific journals. The marked improvement in recent years is due in part to such carefully worded editorial directives as are found in the Journal of Bacteriology. Part of the problem of correcting deficiencies is lack of recognition of their existence on the part of individuals and committees that review manuscripts submitted for publication.

5. Increased literacy would be evidenced by many authors through improvement in the descriptions of the species and other taxa of microorganisms that they name. As stated by Smith (Department of Zoology, University of Illinois), one should give both a description and diagnosis of the taxon. We agree with his summary: "the taxonomist needs to recognize his obligation so to construct his diagnosis as both to characterize the given entity (as an indication of what it is) and to differentiate it (as an indication of what it is not)." The problem of better nomenclature and of understanding of classifications of the bacteria would be largely solved if authors would follow this injunction.

6. The lack of an authoritative general statement as to what is "good form" or "literacy." This lack may be met in part in the near future by several publications. The newly published Seventh Edition of Bergey's Manual of Determinative Bacteriology should be helpful. Dr. Breed and his coeditors have performed a herculean service over the years and particularly in this volume in bringing a remarkable degree of order out of much disorder. But there was
insufficient time and opportunity to complete all checking of references, synonymies, and etymologies. In most cases the Seventh Edition will be a trustworthy, but not infallible, guide as to names. The revised and annotated *International Code of Nomenclature of the Bacteria and Viruses* from the International Committee on Bacteriological Nomenclature just from the press is authoritative. The annotations and examples of this Code should prove helpful. But even with these props there is still need for an authoritative brochure which would directly answer many of the questions as to what constitutes good form; what are the essential elements of microbiological literacy.

**A. Postscriptum**

The above discussion fails to enumerate all the problems encountered by the author or teacher who seeks to be microbiologically literate. He may have difficulties in the appropriate latinization of the Greek stems which he wishes to use and may employ incorrectly one of many types of transliterations which romanize but do not latinize. The correct combining forms to be used in the construction of generic names may be elusive. He discovers evidence that the name of a taxon given in some standard text (as *Bergey's Manual*) does not conform to the Rules of Nomenclature; what should he do to formulate the correct name? A complete, authoritative, and specific treatise has not been written, but should someday be compiled.

**VI. REFERENCES**

None is cited. Each reader is referred to his own lectures and publications for examples.