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NOMENCLATURE AND TAXONOMY

Nomenclature (Scientific • Common)

When casually discussing nature, whether verbally or in print, we typically use pretty informal language. Simple, everyday terms for plants and animals are more than adequate for expressing ourselves. We do not talk about *Malus* and *Citrus sinensis* (taxonomic terms) when referring to apples and oranges because it is simply not effective communication. However, we do use such terms when we want to make specific scientific distinctions—say, between the prairie crab apple, which botanists identify as *Malus ioensis,* and the sweet crab apple, which they have designated *Malus coronaria.*

Because this book deals with differences, many of them technical and somewhat detailed, the reader will encounter quite a few such scientific names, some of which may appear not only needlessly elaborate but also virtually unpronounceable—although nothing as tongue twisting as *Paracoccidioides brasilensis,* a lung-infecting fungus, or *Brachyta interrogationis interrogationis* var. *nigrohumeralisscutellohumeroconjuncta,* a longhorn beetle. As for pronunciation, unless one really feels that the word will be used in conversation, there is no need to be concerned with "getting it right."

But why does science eschew common names and instead encumber itself with such a seemingly inexplicable vocabulary? Because, in part, "common" does not necessarily mean "universal." What may be an organism's common name in one part of the country may be quite different in another, making any initial exchange of information suspect. For example, in the Midwest the thirteen-lined ground squirrel *(Spermophilus tridecemlineatus)* is commonly, but mistakenly, called a gopher, which is really the rightful name of a much larger rodent *(Geomys bursarius)*. Furthermore, some organisms seem to have acquired a different name every time they were spotted in a new locale, such as the mullein, a plant of the figwort family that is saddled with almost 150 aliases.

Unfortunately, this is just the sort of predicament that faced the entire biological science community up until the mid-eighteenth century: scientists from different countries and even individual scientists within the same country sometimes used different names for the same plants and animals. Early attempts to rectify the predicament by using descriptive Latin words to identify each species only led to new problems. Species often ended up bearing unwieldy labels, such as the red-winged blackbird's *Sturnus niger alis superne rubentibus* and the catnip plant's *Nepeta floribus interrupte spicatus pedunculatis*. Ultimately, it was the Swedish botanist Carolus Linnaeus[1] who remedied the problem by establishing a specific methodology for naming all organisms. He devised a binomial nomenclature that gave each species its own, and purposely unique, two-part name.

In accordance with this system, scientific names of species (viruses excepted) always consist of at least two terms—for example *Homo sapiens*. The first term *(Homo)* is the genus (plural, genera) it belongs to, and the second term *(sapiens),* called the specific epithet, its species group. An organism is never referred to by its specific term alone: both terms must be used or indicated. In print, genus names always begin with a capital letter and the species name with a lowercase letter, and both are always italicized. If all the species of a genus are included in a statement, scientists will often indicate only its genus, followed by "spp." If the genus is in doubt, a question mark will follow the term. This most often occurs in classifying fossils or when a family is undergoing reorganization.

Whenever a scientific name is first mentioned in a piece of literature, both terms are used. Any subsequent use of the name in that work may be abbreviated by using the initial letter of the genus plus the full species name—for example, *H. sapiens*. Other species of the same genus that follow may be likewise abbreviated, but in all cases the references must be unambiguous. For subspecies, after the genus and species names have been established, these may be indicated by their initial letters, with the subspecies name written in full.

While these rules probably appear quite reasonable, the question may have occurred: why not use more familiar words? Instead of *Geomys bursarius,* why didn't scientists just label the animal "*plains gopher*" or some other common name, using simple everyday terms? In answer: the foreign ring to these names is a result of using Latin or Latinized words and word roots, the language of science that was favored by European scholars at the time binomial nomenclature was introduced (in some cases, Greek is also used but in a Latin form).

As a dead language, Latin is ideal because it is free of any nationalistic conceit and bias—averting any potential squabbling over which language has the best common name for an organism. It is also functional, in that suffixes are easily appended, forming terms that carry noteworthy information.[2] For instance, the scientific name for the Eastern Hog-Nosed skunk is *Conepatus leuconotus,* which comes from four descriptive terms: *konis,* "dust"; *pateo,* "I walk"; *leukes,* "white"; and *notos,* "the back." Linked together, they tell us that the animal is a "white back that roams the open or desert-like country." Unfortunately, scientific names do not always accurately describe an organism, which, for those who are familiar with Latin, may be a bit misleading. The pronghorn's genus name, for example, is *Antilocapra,* a name derived from *anthlops* (for antelope) and *capra* (for she goat); the pronghorn is neither. But scientific names are not always so formal or rooted in the precepts of academia. Naming is a privilege usually reserved by the first scientist to describe an organism and, as such, may reflect a personal interest, rather than some particular character of the organism. One scientist named two new species of wasps *Polemistus chewbacca* and *P. yoda* after characters in the movie *Star Wars.* And Godzilla, the famous Japanese movie monster, was the source of the crustacean genus name *Godzillius.*

As for common names, Robert Bakker, one of the world's foremost authorities on dinosaurs, summed up the latitude scientists enjoy in naming their discoveries. Bakker observed, "[There are] no rule books to name dinosaurs. It can be Urdu. It can be Hindu. It can be an anagram [although if it is also to be a taxonomic name it must be pronounceable]. It could be nonsense syllables—as long as they are not overtly insulting to some colleagues."[3] And as if to underscore the point, Bakker named one of his recent dinosaur finds Big Ed. However, under the codes governing the spelling of zoological organisms, if "Big Ed" were to be a taxonomic name, it would at least have to be Latinized with a Latin termination.

Yet as clever as these names may be, most scientific names are not concocted willy-nilly. The creation of almost all such names is guided by various international codes, each code determined by the discipline it serves. Formal terms involving animals are governed by the rules of the *International Code of Zoological Nomenclature,* those of wild plants by the *International Code of Botanical Nomenclature,* cultivated plants by the *International Code of Nomenclature for Cultivated Plants,* and bacteria by the *International Code of Nomenclature of Bacteria.* And viruses, although not regarded as living organisms, are nonetheless also named and classified (in an order with families, subfamilies, etc.) according to the *International Code of Virus Classification and Nomenclature.* These international codes do not regulate all ranks, just the more specific, lower ones. The zoological code, for instance, concerns itself only with those names of taxa in the ranks of superfamily down through subspecies.

While all codes follow taxonomic and Latin grammar rules, they are independent as to the terms they allow to be used. Therefore, the same term may be used in different fields of science. *Corydalis,* for example, is used in botany for a genus of herbs and in entomology for a genus of predatory insects called Dobsonflies. Likewise, *Ricinus* is the genus name for both the castor bean and the blood-sucking bird louse. Such duplication may also occur among the unregulated ranks within a discipline. In zoology "Decapoda" is used to designate not only one of its crustacean orders but one of its mollusk suborders as well. Organisms also have had different designations in separate disciplines. Until just recently, the troublesome plant/animal-like euglena could be found listed in the algal family Euglenaceae by botanists and in the protozoan family Euglenidae by microbiologists.

This illustrates the fact that scientific names, as well thought out as they may be, are not engraved in stone. While a change in name is not at all uncommon, it is never done casually but rather because of some compelling rationale. The name may already be in use or an older name may be found to take precedence, but most commonly, it is because the organism is reclassified. The echidna, or spiny anteater, is a perfect example.

When first discovered and described in 1792, the echidna was thought to be a relative of the anteater of South America and was therefore classified in the anteater genus under the name *Myrmecophaga aculeta* (prickled anteater). However, on closer examination in 1802, the echidna was found to be not a placental animal like the anteater but a monotreme like the platypus and was therefore reassigned to the platypus genus *Ornithorhynchus* (birdlike snout), with the species label of *hystrix* (porcupine-like). But shortly thereafter, scientists decided that this strange animal deserved its own genus, so they renamed it *Echidna hystrix* after the Greek goddess Ekhidna, who was half reptile and half mammal. Then in 1876 a new form of echidna was discovered in New Guinea, one with a much longer snout and shorter spines. These and other features made it so different from *E. hystrix* that it clearly required its own genus. Faced with creating a new genus name, zoologists decided that some shared feature should unite the names of both echidna genera. This feature would be their tongues. So *E. hystrix* was renamed *Tachyglossus* (rapid tongue) *aculeatus* (with prickles) and the New Guinea long-snouted echidna received the name *Zaglossus* (great tongue) *bruijni* (from the name of a noted naturalist).

Although such reclassifications will continue, they will probably never reach the extent they did during the trend away from the "splitting" approach to classification to a "lumping" approach. The splitters, who held sway into the early twentieth century, often regarded an organism's unique characteristics as compelling reasons to separate it, taxonomically, from similar organisms. This typically resulted in genera with a seeming overabundance of species (see "Brown Bear," chapter 7). But as biologists reevaluated their approach to taxonomy, they began to see the wisdom in lumping together those species with close similarities, which effectively reduced the number of genera and species. The net result was that many organisms lost their old designations, sometimes receiving not only a new species label but a new genus label as well.

One of the basic tools in classifying an organism is the type of words used. When one forms a binomial name, the genus term is always a singular noun (e.g., "tongue"), whereas the species name may be a noun, an adjective, or a Latin rendering of a proper name. Except for the kingdoms, which need only be a plural noun, the taxa (taxa [singular, taxon] are specific groups within a rank) of other ranks are formed from plural adjectives used as nouns and are often appended with specific endings. These endings often serve as an immediate indicator of the rank of the taxon. For example, within the ranking of the koala bear are the taxa Phalangeria and Phalangeridae. The "ia" ending indicates that this is its order name, and the "idae" indicates its family name. Listed as follows are taxa endings for the plant and animal kingdoms. The parenthetical endings after "varies" are only typical; often they are found in only one taxon of a higher rank, and may not be the only such ending in that rank.

	Taxa Endings	
Rank	**Plants**	**Animals**
Phylum/Division	-phyta	varies (-a)
Subphylum/Division	varies (-phytina)[4]	varies (-data)
Class	varies (-opsida)[4]	varies (-lia)
Subclass	varies (-idae)[4]	varies (-ia)
Superorder[5]	varies (-anae)	-orpha
Order	-ales	varies (-formes)
Suborder	-ineae	varies (-morpha)
Superfamily[5]	N/A	-oidea

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	Taxa Endings	
Rank	**Plants**	**Animals**
Family	-aceae	-idae
Subfamily	-oideae	-inae
Tribe	-eae	-ini

Kingdom • Phylum • Class • Order • Family • Genus • Species

These seven terms represent one of mankind's most ambitious undertakings: the continuing effort to uncover and describe the relationships that unite Earth's incredible variety of life. In addressing this task, two scientific disciplines are particularly crucial, systematics and its subdivision, taxonomy. Systematics deals with the kinds, diversity, and evolutionary history of organisms, which enables taxonomy to identify, name, and classify them into related groups. Together, the two work to assign every living thing—past and present—a position on the tree of life. (Often both disciplines are collectively indicated by either term.) No simple task, this immense undertaking assesses a variety of factors that ranges from ancestry to physical characteristics to gene sequencing.

The working assumption behind this endeavor is that billions of years ago, all life was born of a common ancestry and that every subsequent form of life, no matter how unique, is related to all others. Under this principle, the more temporally close an organism is linked to another in certain shared characteristics, the more closely related they are apt to be. We, as *Homo sapiens,* are more closely related to the gorilla than to the sea squirt, but not as closely as we are to our 500,000-year-old relative *Homo erectus*. An incalculable number of evolutionary links, many unknown and undiscoverable, connects these four organisms, but the clues pointing to their evolutionary kinship are unequivocal. This does not mean that certain lower forms of life such as sea squirts were necessarily our ancestors (sea squirts, in fact, appear to be an evolutionary dead end), but only that their appearance on Earth arose from a different branch of the same primeval stock.

In their work, taxonomists classify life onto a hierarchical framework consisting of increasingly restrictive categories, much in the same way one could rank a deck of playing cards. To illustrate: if we take an entire deck of cards as the broadest division, all cards would be members. Each also belongs to a smaller group of either red or black cards. By themselves, the red cards easily fall into one of two other groups: hearts or diamonds. Considering just one suit, we can make a distinction between the court cards and the numbered cards, giving us two yet smaller groupings. Taking the 10 numbered cards, we can further divide them into two groups of odd- and even-numbered members. From this point, we have the individual cards themselves.

Using such a hierarchical system of classification, we can pick any card from the deck and assign it a place on the tree of playing cards. If our lone card happens to be the three of diamonds, we know that it is a member of an odd card group, which is a member of the noncourt group, which in this case is a member of the diamond group, which is a member of the red group, which is a member of the group of all cards. This is a tree of five ranks, from the rank of deck to the rank of individual card. An important point to keep in mind in this analogy is that there is no inherent connection between the various cards. A card manufacturer could make all the clubs red and all the hearts black and not change the fundamental nature of the deck.

The beauty of this system is that at a glance, one can determine how closely individual cards are "related" to one another (in this particular scheme). The three of clubs may seem very much akin to our three of diamonds—being of equal value and rank (the fifth)—yet it is apparent that they show no common connection until we move all the way up to the first rank. That they are both "threes" is trivial, in this case. Had we ranked the cards by their numerical value before separating them into suits, their shared status as "threes" would more closely link the two.

This is the same type of disclosure we see in our classification of life. Bottle-nosed dolphins and pompano dolphins appear very similar in several ways: they both swim in the sea, employ the same means of locomotion, eat the same type of food, and have comparable body shapes, tail fins, dorsal fins, and pectoral fins. Yet the bottle-nosed is a mammal and the pompano, a fish. And if one tracks their classification back to a common rank, it would be at the intermediate rank of subphylum, five ranks away, where the reptiles, amphibians, and birds also come together. So, in spite of their similarities, taxonomy shows us that the bottle-nosed and the pompano are only distantly related.

When we ranked the deck of cards, we did so according to a principle called *phenetic* classification, which relies on similarities. We first considered similar color, then suit, status as a court card or not, and whether it was evenly divisible by two or not. Phenetically, we could just as well have first divided the deck into court and noncourt cards instead of red and black. Yet in the majority of cases (those not involving most microorganisms), biologists are able to employ a much more precise and informative technique.

When ranking the higher organisms, scientists most often use *phylogenetic* analysis,[6] a technique that while relying on the similarity of shared structures and functions, also considers whether they are primitive or subsequently derived. Therefore, apparent close similarity does not automatically equal close relatedness. In practice, this prevents us from indiscriminately taking a trait—such as possession of a tail, for example—and classifying animals into tailed and nontailed groups. Such an exercise would put monkeys with alligators and humans with oysters. While this classification is logically valid, it tells us nothing about the real relationships among the four.

Along with shared traits, assessment may also involve patterns of evolutionary descent based on the elapsed time between common ancestors. Taken together, these factors and other considerations form the basis of all taxonomic groups, which are called taxa. These are the groupings that fill out the system of ranks extending from domain down to species, a reflection of evolutionary progress (or at least kinships), as best we understand it (domain, a new rank, is discussed later on).

Conceived in the eighteenth century by Carolus Linnaeus (1707–1778), the system originally classified life forms into three ranks: kingdom, genus, and species. Later on, Linnaeus would add the ranks of class and order, to which the German evolutionist Ernst Haeckel[7] inserted the ranks of phylum and family (botanists and bacteriologists often use "division" as an equivalent label to "phylum" in their classification of plants and bacteria).[8] Today, every form of life, from dinosaur to newly discovered microbe, is assigned a position within each of the eight ranks. For humans, lions, and alligators, these rankings are as follows:

	Human	**Lion**	**Alligator**
Rank	**Taxon**	**Taxon**	**Taxon**
Domain	Eucarya	Eucarya	Eucarya
Kingdom	Animalia	Animalia	Animalia
Phylum	Chordata	Chordata	Chordata
Class	Mammalia	Mammalia	Reptilia
Order	Primates	Carnivora	Crocodilia
Family	Hominidae	Felidae	Alligatoridae
Genus	*Homo*	*Panthera*	*Alligator*
Species	*sapiens*	*leo*	*mississippiensis*

As a hierarchy, this system of ranks is very simple. A genus is a group of closely related species whose members have more in common with each other than with members of species of other genera. A family is a group of closely related genera. An order is a group of closely related families, and so on, up to the rank of kingdom.

Notice that there is no rank called subphylum listed, which was mentioned as the first common rank of mammals, fish, amphibians, reptiles, and birds. This rank, along with others, is an optional fine-tuning of the hierarchical system that is used when a more precise grading of a lineage is required. If a particular trait within a taxon exhibits a significant split in evolutionary development, the rank may be subdivided into smaller units or may be subordinated under an optional higher rank.

In the ranking of *Homo sapiens,* both types of fine-tuning have been proposed: between the ranks of phylum (taxon, Chordata) and class (taxon, Mammalia), the ranks of subphylum and superclass can be established. The subphylum rank indicates that Chordata was subdivided, with the mammals, fish, amphibians, reptiles, and birds assigned to the subphylum taxon Vertebrata. (The other subphylum taxa are Urochordata, the sea squirts; Hemichordata, the acorn worms; and Cephalochordata, the lancelets.) The superclass rank indicates that Mammalia, along with other Vertebrata classes (Amphibia, Reptilia, etc.), were grouped into at least two higher taxa. There are two: Agnatha, for those without jaws (e.g., the lampreys); and Gnathostomata, for those with jaws. A more precise ranking of humans then is Animalia—Chordata—Vertebrata—Gnathostomata—Mammalia—Primates—Hominidae—*Homo—sapiens.* Other proposed human hierarchies have different or additional intermediate ranks.

In a few cases an intermediate rank is established simply as a convenience, rather than to express a substantiated relationship among organisms. The intermediate taxon Glires, a cohort rank, has been used by some to group the rodent order Rodentia with the rabbit order Lagomorpha. Lacking any concrete evidence of close kinship, Glires is based merely on the likelihood that in the distant past rodents and rabbits were closely related.

As with the eight main ranks, intermediate ranks follow an established order, with each scientific discipline determining its own groupings. For the animal and plant kingdoms, these groupings fill in the mandatory eight-rank hierarchy as follows.

Domain: Eucarya

Animals	**Plants**
Kingdom	Kingdom
Subkingdom	
Phylum	Division/Phylum
Subphylum	Subdivision
Infraphylum	Infradivision or Branch
Superclass	
Class	Class
Subclass	Subclass
Infraclass	
Supercohort	
Cohort	
Superorder	Superorder
Grandorder	
Mirorder	
Order	Order
Suborder	Suborder
Infraorder	
Superfamily	
Family	Family
Subfamily	Subfamily
Tribe	Tribe
	Subtribe
Genus	Genus
Subgenus	Subgenus
	Section
	Subsection
	Series
	Subseries
Species	Species
Subspecies; or Race, Breed	Subspecies
Form	Variety
Infrasubspecies; or Race	Subvariety
Breed, Form	Form
	Subform
	Cultivar

Any organism classified in an intermediate rank must be included in all higher, but not necessarily lower, intermediate ranks within the major rank. Therefore, if an animal's classification includes infraclass, it must also include class and subclass but not necessarily cohort. Those intermediate ranks designated as "super . . . " are not considered an extension of the preceding rank but of the next major rank. Superfamily, for instance, is a member of the "family group" of ranks, although it precedes the rank of family.

No organism has a lineage traceable through all of these intermediate ranks, but some plants do require quite a few. And whereas intermediate ranks do serve an important function, some have been of only minimal use, such as supercohort, grandorder, and mirorder. Certain intermediate ranks, such as series, are used only in botany, while others, like race, are used primarily in zoology. And not all ranks are officially recognized by taxonomic codes. In zoology, only the eight primary ranks and those prefixed by "super" or "sub" are officially recognized. In botany, the eight primary ranks and only those prefixed by "sub" are acknowledged. Moreover, no taxonomic code officially sanctions the ranks of breed or cultivar[9] ranks used for artificially created variants. Also, bacteriology uses the unofficial rank of strain to classify bacteria populations having a particular character, such as the biovars, the morphovars, the serovars, and the phagovars.

Biological classification is a rigorous undertaking, involving great care in the collection and interpretation of data. Unfortunately, the shortage, quality, and inconsistency of such data may not allow for anything more than theorizing. The result is that hierarchical trees are not immutable facts but assumptions, and the placement of an organism or its extended lineage often rests on supposition. This is why one will find instances throughout this book where authorities are in disagreement. Entomologists, for example, often assign the cockroaches to the suborder Blattaria and the mantids to the suborder Mantodea, both of which fall under the order Dictyoptera; however, other authorities eliminate Dictyoptera as rank and treat Blatteria and Mantodea as independent orders, with no change in name.[10]

But an even greater challenge confronts the bacteriologist. Until recently, this relatively new field was unable to identify any phylogenic relationships among bacteria; consequently, species were ranked only by phenetic criteria, which means that many will now be in need of substantial reclassification. Fortunately, other fields of study have eluded such a broad reorganization, yet because their taxonomy is far from complete, they are not without their own classification problems and challenges.

The root of such disputes is not that one scientist is less informed than another—although this certainly could be the case—but that the whole task of classification is hindered by inadequate and conflicting data. To deal with these obstacles, scientists constantly wrestle with an assortment of questions: What traits are significant? What weight should they carry? Are these primitive traits or are they later modifications? Are they shared by all members of a group? Such questions typically result in answers that not only shape the process of classification but also determine the foundation of each taxon. This is particularly true of those ranks extending from phylum/division to genus. Unlike the rank of species, they are not governed so much by definition as they are molded by the traits and evolution of their subjects, which often creates the need for intermediate ranks.

Because the foundation of each taxon is determined by the characteristics of its members, the magnitude and the extent of the defining traits among various taxa within a rank can vary widely. Within the bat order, Chiroptera, the family Phyllostomidae is distinguished from the family Vespertillionidae only by an additional bone in the third finger and often the presence of a leaflike projection on the nose; whereas in the Artiodactyla, even-toed ungulates, a considerable number of differences distinguish the pig family Suidae from the giraffe family Giraffidae. Furthermore, within a taxon not all relevant identifying characteristics may be applicable to all members. In a particular order, the traits involved in separating one family from another may not be the same as those that distinguish it from a third family.

This illustrates an important point: individual taxa of a rank seldom share a common foundation. For example, within the rank of class the principles that define the clam taxon, Bivalvia, are nothing like those that define the millipede taxon, Diplopoda. But, then, what defines a rank such as class? What is the common denominator that makes a class a class or a family a family? Well, there really isn't any. Each rank is only a position or a level, not a biological construct. Scientists are constrained by the characteristics and the evolution of their subjects, while at the same time are bound by taxonomic rules. In practice, no matter how strange or unique a new organism may be, characteristics are almost invariably established (usually phylogenetically, as much as possible) to suit each of the mandatory eight ranks. One current exception is the amoeba-like animal trichoplax, for which no class or order has been established. Taxa of higher ranks are generally defined by the more general or gross features of an organism. Lower-ranked taxa like genus and species depend on more particular features. When a ranking is completed, there will be eight specific levels, each defined by increasingly distinctive features as the species rank is approached.

Yet sometimes, as with a unique organism, formulating the specifics for each rank is not only irrelevant, but the resulting taxa are essentially meaningless. As an example, the ginkgo tree is commonly listed as belonging to the class Gymnosperma, order Ginkgoales, family Ginkoaceae, genus *Ginkgo,* and species *biloba.* It is the only species in the entire order, which means there is essentially no useful difference between the characteristics that define its order taxon and those defining its species taxon (the same is true of the aardvark, the singular representative of the mammalian order Tubulidentata). In such cases the formation of a taxon may be no more than a formality as required by the rules of taxonomy. And, as with the ginkgo order, in such instances intermediate taxa often go unmentioned in literature.

Of the eight ranks, kingdom and species are decidedly unique and deserve elaboration. When Linnaeus devised his system incorporating genus and species, three great kingdoms were recognized: animal, plant, and mineral. Biologists, ignoring the mineral kingdom for obvious reasons, decided that if an organism could move about and digest food, it belonged in the animal kingdom, and if it stayed put and did not digest food, it went into the plant kingdom. However, with the advent of more powerful microscopes and exacting biological techniques, it was soon discovered that some organisms, mainly microorganisms such as bacteria and amoebas, were neither plants nor animals. This led scientists to seriously question the two-kingdom classification as it was then defined. More important, it became obvious that life required more than two kingdoms to properly classify its diversity. But the ensuing task of deciding what kingdom an organism belongs to was not an easy one. Consequently, classification systems with between 4 and 20 kingdoms were suggested, each with varying advantages and disadvantages.

This dilemma was tentatively resolved in 1959 when R. H. Whittaker proposed a concept employing five kingdoms, a system that soon became widely accepted. Like others, Whittaker based his kingdoms more on cellular structure and nutritional mode than on the evolutionary principles that underpin the other ranks. His five kingdoms, with examples, are:

Monera	Bacteria and cyanobacteria
Protoctista	Amoebas, algae, ciliates
Fungi	Mushrooms, mildews, yeasts
Plantae	Trees, flowers, dandelions
Animalia	Clams, bees, humans

As suitable as this system was, some organisms resisted rigid classification. Slime molds, for instance, possessing both animal and plant characteristics, were, until quite recently, claimed in both Protoctista and Fungi. In a more recent scheme (1978), the five kingdoms were grouped into two superkingdoms: Eukaryotae, organisms with nuclear membranes, for example, plants and animals; and Prokaryotae, organisms without nuclear membranes, the bacteria. (A nuclear membrane is a covering that surrounds the nucleus of a cell.) In effect, this reordering gave us two major branches of life.

However, this distinction lasted only until 1996, when the existence of a third branch of life was said to be proven—the branch from which all other forms of life are thought to have arisen. Named Archaea, its microbial members were once known as archaebacteria and were classified as a distinct group within Monera.[11] The Archaea, a very peculiar group of organisms, are distinguished not only by their genetic makeup but by where they live and how they function. Often found living on sewage and in sediments and swamps, they exist without sunlight, feeding on carbon dioxide, nitrogen, and hydrogen and producing methane gas as a waste by-product. They also live in places hostile to all other forms of life: 8,600 feet under the ocean at pressures 200 times greater than on Earth's surface, in 185° F water (close to boiling), and in extreme cold. But more important, their distinction rests in the fact that two-thirds of their genes do not resemble those found in any other form of life.

The upshot of all this reassessment and reworking is that taxonomy has now been expanded to eight ranks. At the top is the rank of domain, which consists of three taxons: Bacteria, Archaea, and Eucarya (although the rank of domain has been in use for several years, it has still not been universally accepted). In one revision the rank of superkingdom has been dropped, Eukaryotae was renamed Eucarya, and Prokaryotae has been eliminated. Also, the kingdom Protoctista is no longer a formal designation, although it is sometimes used to indicate all members of Eucarya, other than those belonging to the Fungi, Plantae, and Animalia kingdoms. Those organisms that once made up Protoctista have now been divided among as many as eighteen new kingdoms (some have also been reassigned to the Fungi, Plantae, and Animalia kingdoms), each on equal footing with Fungi, Plantae and Animalia. All of this reordering is quite new and much of it is tentative, and, of course, not all scientists are satisfied with it, so there are certain to be many changes before taxonomy really settles down.

The following is an example of one newly proposed reordering. Because the Bacteria domain is quite unsettled, the validity of its kingdoms, listed in the table, is very tenuous. The Archaea domain is also shaky, with additional kingdoms likely to surface in the future. So, too, with Eucarya; with continued molecular studies, it will certainly undergo further revisions.

Domain: Eucarya

Kingdoms			
Animalia	Plantae	Fungi	Diatoms
Phaeophyta	Chrysophyta	Xanthophyta	Oomycota
Labyrinthulids	Apicomplexa	Dinoflagellata	Ciliates
Rhodophyta	Acrasiomycota	Entamoeba	Naegleria
Euglenozoa	Myxomycota	Parabasalids	Microsporida
Diplomonads			

Domain: Archaea

Kingdoms		
Euryarchaeota	Crenarchaeota	Koryarchaeota

Domain: Bacteria

Kingdoms			
Proteobacteria	Planctomyces	Chlamydia	Spirochaetes
Bacteroids	Firmicutes	Thermotogales	Hydrogenbacter
Cyanobacteria and Chloroplasts		Green sulphur bacteria	

Thirty-four kingdoms![12] This is an incredibly explosive increase in just a single reordering, and with more likely on the way—not a comforting thought for the interested layperson or the beginning biology student. And aside from the future revisions that taxonomy is bound to undergo, most of the kingdoms, besides being saddled with tongue-twisting names, will seldom be remembered or understood by anyone other than biologists. Perhaps, if the layperson is lucky, most of these kingdoms will eventually be reduced to subkingdom status or combined with one another. But this is a very big "perhaps."

At the species level, the critical differences separating one species from another often range from the obvious to the obscure. Among the lizards of Florida, it is easy to spot the external features that distinguish the bright green–colored green anole *(Anolis carolinensis)* from the somber-hued brown anole *(A. sagrei),* but for the gray wolf *(Canis lupus)* and the red wolf *(C. rufus)* there is little apparent difference except a slight variation in size and coloring (some authorities have suggested that the red wolf be regarded as a subspecies of *C. lupus*). And when one looks at dogs (domestic canines, *C. familiaris*),[13] such traits are totally ignored, allowing a range of shapes, sizes, and colorings that is immense. This illustrates why outward appearances can be deceiving. The Alaskan malamute, for instance, appears to have more in common with the gray wolf than with the chihuahua, but when their DNA profiles are considered, and from an exacting anatomical standpoint (mainly, skull features), this is decidedly not the case. What does separate one species from another usually rests with reproductive factors—the crux of the species rank and much of the controversy that surrounds its definition.

Unfortunately, the biological sciences have yet to come up with a universal definition of "species." The various species concepts now in use have arisen out of the need to address classification issues that are often particular to only one branch or sphere of biology and therefore are seldom widely applicable. These concepts include biological, biosystematic, evolutionary, genetic, morphological, paleontological, and phylogenetic definitions.

The most widely used of these definitions, based on the biological concept of species, usually takes a form akin to that formulated by biologist Ernst Mayr. Mayr contends that a species is a "reproductively isolated aggregate of populations which can interbreed with one another because they share the same isolating mechanisms."[14] The heart of this definition lies in the criterion of reproductive isolation.

Reproductive isolation embraces any element of nature that prevents the reproduction of fully viable offspring. Some of these elements keep organisms apart before they can mate. These include ecological barriers, which physically keep populations from meeting; temporal barriers, wherein species breed at different times of the day or the year; behavioral barriers, where organisms consciously reject, for whatever reason, other organisms; and mechanical barriers, such as incompatible physical or physiological differences in the two organisms. Other prohibitive elements occur after mating has taken place. These include cases where the sperm and the egg do not reach each other or fail to fuse; where a hybrid dies before it sexually matures; and where the hybrid is sterile. The essence of this definition of species is the ability of two organisms to successfully reproduce by mating.

However, not all organisms reproduce by mating. Some asexual organisms reproduce by fission, where an organism simply splits into two equal organisms (euglenids); binary fission, in which a parent organism splits into two offspring (certain green algae); and parthenogenesis, in which there are no males—the egg always develops into a female (bdelloid rotifers).

Although most flowering plants reproduce sexually, there are those that self-pollinate, so the use of the biological definition of species to sort out these particular plants is questionable. Also, the biological definition cannot be applied to fossils. Obviously, in such cases other criteria must be used to determine species. Typically, these will involve external morphology (physical characteristics), chemical and physiological properties, or genetic makeup. A species that reproduces by mating is also usually considered to be a naturally occurring group of interbreeding, or potentially interbreeding, organisms that shares a unique gene pool and produces fertile offspring. Within this somewhat qualified statement are several key ideas.

"Naturally occurring" excludes offspring resulting from species deliberately brought together. In the wild, Bactrian camels *(Camelus bactrianus)* and Arabian camels *(C. dromedarius)* do not mate because their dispositions, habits, and territories differ; consequently, their gene pools go unmixed. Yet in Turkey, where they are deliberately interbred, they produce fertile offspring (some males are born sterile).

Not many crossbreedings between closely related species are this successful. If offspring do result, they are most often either deformed or infertile. (One glaring exception to this stipulation is *Canis,* the genus of wolves, coyotes, and dogs—see "Wolf," chapter 7). Mules are such sterile animals, the product of the mating of a mare and an ass—there are no mother or father mules. Yet not everyone feels that the fertility/infertility criterion of species definition is a practical one. Keith Rushford, in his book *Conifers,* observes, "The traditional criterion of a species being interfertile between members of the species and, under natural circumstances, at least partially intersterile with members of another species is subject to too many qualifications to be useful in practice."[15]

But "interbreeding" does keep intact those features that distinguish one species from another. Although some cross-species mating may take place, usually it is not enough to break down the species' identity. The major factors in preserving a species' identity are the isolating mechanisms mentioned in the biological definition of species.

"Potentially" is used to include within a species those populations that while not normally interbreeding, could successfully do so. The

Inuits of the North and the Pygmies of Africa do not mate with each other, yet they are not considered separate species because, among other reasons, unlike the two camel species, there are no instinctual barriers inhibiting mating. Humans readily disregard "race" and often find those of different ethnicities quite desirable. Bactrian and Arabian camels, given the choice of mating within their species or with each other, prefer to mate with their own—they are not considered to be potential interbreeders. Within a species, those unique populations of potentially successful interbreeders are often designated as subspecies or, as was the case with humans, races.

A subspecies is almost always a geographically isolated group, which, given enough time (usually, thousands of years), may evolve into a bona fide new species. Crucial to such changes are shifts in the environment and the accompanying genetic mutations that offer the necessary variations needed for adaptation.

Although "subspecies" sits at the bottom of the hierarchical ladder, its importance should not be underestimated. "Kingdom" may have greater status and "species" more recognition, but it is "subspecies" that is often the laboratory of incipient species, the rank of innovation, and the genesis of diversity.

Various mnemonic sentences have been devised to help you remember the order of the eight ranks. Here are three that may come in handy.

Domain	**Kingdom**	**Phylum**	**Class**	**Order**	**Family**	**Genus**	**Species**
Daffy	King	Philip	Came	Over	For	Ginger	Snaps
Daddy	Keeps	Putting	Cashews	Out	For	Gray	Squirrels
Danish	Kings	Play	Chess	On	Furry	Green	Squares