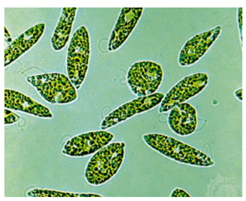
HOW TO CLASSIFY IT ALL?

Linnaeus, Whittaker

Classifying nature

For centuries, humans have classified nature in various ways: things that we eat, things we don't; this tree is useful for building things, this tree is too soft; this is good for medicine, this is useful for dyes, this is good for making baskets, and this is good for nothing. Many cultures only named plants and animals that they used, and saw no reason to name things that were not useful.

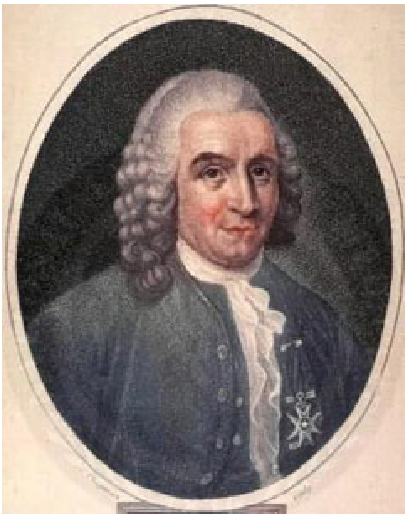





During the middle ages, Europe rediscovered the writings of the Greek and Roman philosophers, who had explored all aspects of nature. Europeans developed curiosity about the natural world as well, and began collecting what they knew into large books. Information about plants was assembled into books called flora. These were often based on the writings of the Greeks and Romans, which the philosophers of the Middle Ages considered as absolutely authoritative. As a result, philosophers and early naturalists in northern Europe used the names and descriptions of plants of the Mediterranean from the ancient writings, and tried to apply those names and descriptions to plants that grew locally. A few bold naturalists added their own descriptions as well.

However, the wild plants that they described often had many different names, or the same common name might be applied to many different wild plants. Two naturalists who thought they were describing different plants sometimes discovered they were writing about the same thing — likewise, two naturalists who thought they were talking about the same plant might discover they were describing two very different things.

While the flora of the Middle Ages were interesting and often scholarly, they were difficult to use. Latin names were long and clumsy. Identification of plants was often careless. Descriptions and illustrations were sometimes vague. Folk information about plants that had never been tested was passed on as fact simply because it appeared in another book somewhere. The plants might be arranged by their use, or by alphabetical order, or some other system that made sense to the writer but might not make sense to the reader.



Linnaeus

Carl von Linnae (1707-1778), better known today as Linnaeus, wasn't the first to attempt a universal system of classification, but he was certainly the most successful. The system that Linnaeus developed was so useful that the principles of it are still employed today.

Linnaeus studied medicine in Sweden, but the state of medical education was so pathetic at the time that he was largely self-taught. At the age of twenty-eight, Linnaeus graduated and moved to the Netherlands in search of a career. He took with him a handful of original papers in natural history that he had written, including an hypothesis that malaria was caused by living on clay soils. His work impressed the Dutch physicians and naturalists who read it. Linnaeus was soon accepted into their influential society, and received help in publishing his papers.

Linnaeus' primary interest was naming and classifying organisms. The Netherlands formed the hub of the shipping trade at a time when Europeans were actively exploring the world, bringing back animals, plants, and mineral specimens from faraway and exotic places. While strolling through private gardens, Linnaeus might encounter plants from distant Asia or Africa. Many wealthy people kept entire rooms filled with specimens of crystals, rare minerals, stuffed animals, shells, and preserved plants. None of these new exotics could be found in the medieval flora, and no classification system that had been invented yet could encompass all of them.

Linnaeus himself had experience in exploring and making fresh discoveries. As a young man, he traveled to Lapland where he spent five months studying its natural history as well as the customs of the nomadic Lapps. In 1737, he published an account of his trip, titled *Flora Lapponica*. Soon after his trip he was offered an opportunity to travel to South Africa to collect plants for wealthy Dutch collectors, but chose instead to finish his medical degree and take a position as the house physician superintendent of the garden of a wealthy Dutch financier. The two parts of his job weren't so far apart as we might assume today, since gardens were used not just as pleasure grounds, but as source of household food and medicine.

One thing that Linnaeus discovered as he tried to classify the plants of Lapland and from other more faraway places was that they did not fit into any of the known classification schemes, which were built largely around Mediterranean and European plants. He recognized a pressing need for a more general — and easier to use — classification system. His first publication toward such as system was a modest seven page monograph titled *Systema naturae*, published in 1735.

The *Systema natura* described a new system for plants, animals, and minerals. Among Linnaeus' novel contributions was a classification of flowering plants based on their sexual parts. The ancient Greeks and Romans had no idea that plants reproduced sexually, so reproduction formed no part of their ideas of order and classification. Sexual reproduction of plants was well understood by the end of the seventeenth century and Linnaeus exploited the new knowledge in his system.

His organization scheme was a nested hierarchy of categories called taxa. The largest of these taxa was the level of kingdom. In the modern version of Linnaeus' system, each kingdom containes many phyla. Each phylum containes many orders, and so on through the taxa: kingdom, phylum, class, order, family, genus, species.

Linnaeus divided the flowering plants into twenty-four orders based on the number and position of the stamens (the male parts of the flower). The classes broke apart into sixty-five orders, based on the number and position of the pistils (the female parts of the flower). Other characteristics divided the classes into families and genera, and finally to species. This was far simpler than the system proposed by the seventeenth-century French botanist, Joseph Pitton de Tournefort, who defined 698 genera and felt that any serious naturalist should put forth the effort to memorize them all.

More important than the classification scheme was Linnaeus' method for naming plants and animals: his binomial nomenclature system. Before Linnaeus, scientific names were long and complex. They consisted of two parts: a set of words that defined a group that the plant belonged to, and a long string of descriptive characteristics to define that particular species. Because there was no fixed system that all naturalists used, confusion reigned. In referring to the scientific name of a plant, a naturalist also had to refer to the source of the name, as names varied from system to system, and from flora to flora. Linnaeus' simplified naming system paved the way for a standardized system of naming all living things.

While the Linnaean system was easy to use and practical for the field naturalist, it received criticism for being an artificial system. Other naturalists sought a more natural system, looking for patterns in nature as their guide for finding natural "families" or groups of organisms that seemed to belong together. These were not necessarily the kind of evolutionary relationships that we think of today; recall that the idea that species could change in time had not been well established. While a few naturalists pursued ideas of evolutionary change, the idea of "natural families" was more about shared features seen in groups of similar organisms than about shared ancestry.

Buffon and Cuvier

Buffon, who proposed one of the first evolutionary models, viewed nature as being formed of "natural families." Dogs, foxes, and wolves, for example, looked very similar to one another, and belonged to a natural family. So did horses, donkeys, and zebras. Buffon proposed that all of these organisms had a similar internal body plan. Internal particles of some sort created the basic form, but the form could be shaped by the environment to some degree.

This formed part of Buffon's theory of organic change: when populations of organisms were moved to a different environment, that environment pushed the basic body plan into a form suitable for that environment. Buffon felt that the embryo should be most vulnerable to this process, since it was still forming into its final shape. Thus all organisms should be shaped the same way at the same time to become perfectly suited to their environment (note that while this idea made logical sense, observations of actual horses in Africa failed to support it, and the science of genetics eventually rejected the idea). Buffon, however, believed that change was limited only to natural families. Horses moved to Africa might, over several generations, look more and more like zebras, but they would not begin to look like anything that was not horse-like.

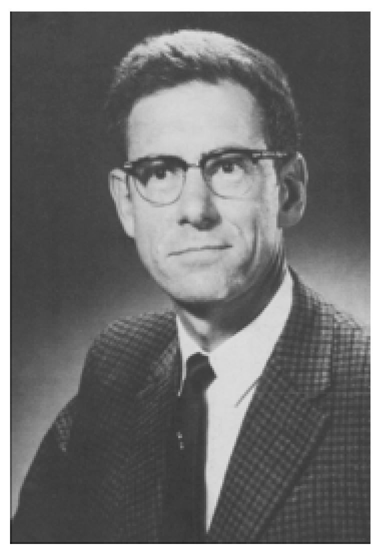
Natural families, therefore, formed the basis of Buffon's scheme of classification that he used in writing his famous 36-volume work, *Histoire naturelle*. This was intended to be a complete catalog of the entire natural world. Buffon outlined his theory of the origins of the earth, and described all that was known about humans, minerals, quadrupeds (four-legged animals), and birds (other specialists completed the remaining topics after Buffon's death). In order to catalog everything, Buffon sorted through the collections of the Royal Gardens of France, and relied heavily on the writings of Aristotle (of ancient Greece) and Pliny (of ancient Rome). While he knew that both authors had uncritically included descriptions of fanciful and mythical beasts and a good deal of folklore, Buffon believed that these errors could be corrected with enough study. Aristotle was particular influential in Buffon's system, since Aristotle had proposed that nature had a logical order based on general principles which humans could uncover and understand. While Aristotle himself did not construct a system of classification, the notion that such a natural system existed that humans could uncover was the underlying model to Buffon's approach.

Cuvier, who had studied under Buffon, also took a naturalistic approach to classification of organisms. However, Cuvier parted from other naturalists at the time in his rejection of a system that simply described likenesses between organisms or their parts. In Cuvier's opinion, it was the function of the parts that mattered. The whole organism, he stated, was a functional unit with a structure that was dictated by the surrounding environment and the organism's relationship to that environment. In Cuvier's model of the world, organisms could not vary far from their own natural form because they were all parts of a great, organic machine. Change one part, and the entire machine would cease to function. In this Cuvier differed from his mentor, Buffon.

Like Buffon, though, Cuvier thought that organisms should be classified into natural groups without any hierarchical relationships: that is, no set of organisms should be thought of as "higher" or "lower" than any other group. Cuvier divided animals, which he knew best, into four natural groups based not on their external form, but on the structure of their nervous systems: Vertebrata (today's Subphylum Vertebrata), Mollusca (today's Phylum Mollusca), Articulata (today's Class Arthropoda), and Radiata (today's Phylum Cnidaria, Phylum Ctenophora, and Phlyum Echinodermata).

Other naturalists also created systems based on naturalistic categories. None, however, could beat the Linnaean system for simple utility. While naturalistic groupings have been incorporated into today's system of classification, the basic Linnaean structure and the system of binomial nomenclature still hold the whole system together.

Whittaker



The Linnaean system worked reasonably well for all visible organisms that fell clearly into the two Kingdoms of living things: Plants and Animals. However, by the mid-19th century microbiology and cell biology were making rapid strides. Scientists were describing many different microorganisms, some of which fell neatly into the "animal" or "plant" category based on whether they moved and consumed food (animal-like) or were stationary and made their own food through photosynthesis (plant-like).

But there were some organisms that defied any neat classification into these two systems. Fungi, for example, are stationary organisms like plants. They have cell walls around their cell membranes like plants, though the cell walls are made of a different material. Unlike plants, fungi don't photosynthesize, but have to consume other organisms to get their food. Yet they aren't animal-like, since they digest food externally and absorb it instead of taking food directly into their own bodies.

Then there was *Euglena*, a one-celled pond-dwelling organism that seemed to cross all boundaries. *Euglena* has chloroplasts and can photosynthesize, so it's plant like. It also moves rapidly by beating the water with its flagella, and eats bacteria, so it's also animal-like. Where should *Euglena* be classified? Most systems put it in with the plants, but with the understanding that this wasn't a good fit.

Robert Whittaker (1920-1980) was the first to propose a widely-accepted method of dividing the two Linnaean kingdoms into taxa that better represented nature itself. Whittaker started his career a frustrated student of the plant sciences who had earned an undergraduate degree in botany, but whose application to the graduate program in the Botany Department of the University of Illinois was rejected. Whittaker applied to and was accepted by the Zoology department, where he proceeded to earn a Ph.D. with his study of the distribution of plant communities in the Smoky Mountains of Tennesee — a degree in Zoology earned with a dissertation that mentioned not one single animal.

What Whittaker found particularly interesting in his studies were organisms that didn't fit — those that seemed to be neither plant nor animal, but were stuck in one kingdom or the other for reasons that seemed entirely arbitrary. In fact, his open criticisms of current classification and ideas competing with his own intimidated may of his colleagues, and may have cost him his first teaching position when he criticized the work of one of the senior professors in his department. His intensity in his research and the breadth of his biological knowledge, however, added to his ability to absorb and master huge amounts of literature on whatever subject he was pursuing, helped Whittaker gain a reputation as an expert — as well as a maverick — in his field.

Whittaker's first attempt to reform the classification system, published in the early 1950's, was a three-kingdom system based on ecological functions: Plants, Animals, and Fungi. Plants consisted of organisms that photosynthesized, animals were those that took in food from the environment, and fungi were those that digested food externally before taking it in. Fungi were further separated from the plants by their body form: long, filamentous cells that grew into the material that the organisms was decaying. These groups reflected what was known about evolutionary relationships at the time.

While the three-kingdom system was an improvement, there were still problems. Whittaker recognized that in this system, bacteria would have to be classified with the fungi even though they are structurally very different and represent different branches on the evolutionary tree.

In 1957, Whittaker published a new system that addressed this problem. Borrowing a category proposed by H.F. Copeland, Whittaker added a fourth kingdom, Protista. Copeland had lumped many hard-to-classify algae, protozoans, and fungi into this kingdom. Whittaker included only one-celled organisms, and created a scheme where ancestral animal-like, plant-like, and fungus-like protists gave rise in the past to today's animals, plants, and fungi.

The system was better, but scientists recognized that distinct differences existed between the bacteria, which have DNA but no nucleus and no organelles, and the eukaryotic one-celled organisms which have a nucleus and organelles. This was such a fundamental difference that it required another way of grouping these two types of organisms. In 1959, Whittaker first proposed placing all bacteria into a fifth kingdom. It wasn't until 1969 that he formally published a new system that included Kingdom Monera, the kingdom of the bacteria. Within a few years, the system was universally adopted.

Today

Today, the old science of taxonomy (classifying things based on their appearance) has matured into the science of systematics, in which scientists attempt to understand how organisms are related to one another. Common features, in other words, are the result of common descent. Systematists attempt to understand lines of descent by examining fossils, analyzing DNA, comparing molecular data such as proteins or photosynthetic pigments, and other types of evidence.

Recently, a new taxa was added above Kingdom: Domain. Whittaker's Kingdom Monera is now divided into two Domains: Archaea and Bacteria, which represent two fundamentally different groups of prokaryotic organisms. The kingdoms within these Domains are still being worked out. While the remaining four kingdoms (Protista, Fungi, Plantae, and Animalia) are classed in Domain Eukarya, Kingdom Protista has become problematic. Whittaker had created the kingdom to hold all one-celled organisms, and later all one-celled eukaryotic organisms, but modern molecular evidence shows that even those organisms can be divided into groups descending from entirely different ancestral lines, suggesting that Kingdom Protistsa may contain several distinct groups that might well be raised to the level of Kingdom. Furthermore, Kingdom Protista has become a "catch-all" category for groups that still do not fit well in the other kingdoms. Algae were placed in Protista because all groups of algae have single-celled members, and there are differences between the cell walls and photosynthetic pigments of algaes and the green plants -- except for the green algaes, which are closer to plants. Taxonomists are recognizing that the algaes should not be treated as one group, but rather different organisms that have been labeled "algaes" belong to different groups based on their DNA and other molecular data. Slime molds also are problematic, since slime molds are sometimes amoeba-like, sometimes fungus-like, and sometimes almost animal-like.

Clearly the work of classifying organisms has not come to an end. There is still much to understand about the relationships between organisms. Like Buffon, Cuvier, and many other 18th century naturalists, today's scientists are working to classify organisms based on natural groups, which today are defined as evolutionary relationships between species. The Linnaean model of nested taxa remains as the overall structure of the system, and the binomial nomenclature system that Linnaeus invented still gives all organisms standardized names, so that scientists all around the world can know exactly what organisms other scientists are talking about.

Questions

1. Describe the basic differences between the approaches of Linnaeus and his systemic rivals, Buffon and Cuvier. Then describe how Whittaker's approach and the science of Systematics today uses principles founded by all three of these naturalists.

2. Today there are three Domains, and within Domain Eukarya there are four Kingdoms: Prostists, Fungi, Plants, and Animals. If you pick up a Biology textbook fifty years from now, will the chapters describing these groups look similar to what you read in your textbook today. or will there be differences? What kinds of differences, if any, do you predict? Why?

3. What features did Linnaeus base his system of classification on? What features did Cuvier use in his classification? What did Whittaker use? Was any one of these scientists more correct than the others? Why or why not?

4. On the whole, what is science? Is today's science of Systematics any more (or less) scientific than the taxonomic work performed by Linnaeus, Buffon, Cuvier, and Whittaker? Why or why not? Use examples from the reading to support your ideas.