LINNEAN CLASSIFICATION

e1 The classification of organisms < homology; not analogy >

> ... data for the inverse problems, that is, the shadows, lack essential information necessary to uniquely reconstruct the object ... this is a common feature of many inverse problems. —Charles W. Groetsch.[1]

Classification is a process whereby objects are recognized and differentiated. Organisms can be classified in any way that one chooses. For example animals which live in the water can be considered to constitute a group that can be compared to animals which live on the land. This is fine until, perhaps, one considers a hippopotamus.

The purpose of scientific classification is to reveal the origin of things. As such cannot be known *a priori*, scientific classification schemes evolve from hypotheses to explain perceived order to the development of a theory that ultimately includes a mechanism.

Plato (***Figure e1.1***) taught that this world is the imperfect reflection of an "idea." Thus, the many shapes of a triangle or a horse are distorted images of the true perfect Triangle and Horse in the transcendent world of ideas where Forms exist. These in his *Allegory of the Cave* represent the "true reality." This, couched as a conversation between Socrates and Glaucon in the *Republic*, Book VII, written 360 BCE,[2] is to show

> how use of reason can free us from the shackles that keep us in the dark cave of the world of appearance, a cave in which we can only watch shadows pass along a screen, and can lead us out into the true world, where objects are seen as they really are, irradiated by the light that streams from what Plato called the Good. This story of movement upward toward the light, culminating in a gloriously unified vision of the whole, was elaborated upon by Augustine, Spinoza and Hegel. It has become the central metaphor—the central fantasy—of Western philosophy. —*Richard Rorty*.[3]

Ignoring Antisthenes contemporary grumble: "I can see a horse, but I cannot see horseness," [4] Aristotle (***Figure e1.2***) employed empiricism to find the "essential" properties of forms to know Forms. Thus triangles in the sum of their angles, regardless of their shapes, add to the same as that of a perfect equilateral one in the mind and in the physical world.[5] The Aristotelian philosophy of essentialism trivializes variation: only essences matter.

What fossils were was long not self-evident to most. Yet, a teleology that Nature does nothing in vain (though false) allowed Fabio Colonna to "demonstrate" in 1616 the organic nature of certain fossils from comparatives studies of their residues, of say *glossopetrae* (*tongue stones*) and known sharks teeth, after burning, and of their exquisitely detailed forms that evidenced function.[6] Nicolaus Steno in *Canis Carchariae Dissectum Caput* found similarly in 1667. However, that *glossopetrae* are fossil shark teeth had to compete with the belief that the same were serpents' tongues turned to stone by St. Paul. Also, in the *Pharmacopocia* of ancient times, which (falsely) found linkages between form and function in macrocosm and microcosm, "tongue stones," analogous in appearance to a human tongue that can lick, could be rubbed on animal bites as antidotes to poisons.[7]

Aristotle defined large categories which could be subdivided along logical lines: Animals (conspicuously different from plants) are dividable into those with red blood and all others. The "blooded animals" are subdividable by mode of reproduction (live-bearing or egg-laying) and by habitat, and the others by general structure (weak-shelled, hard shelled, insects, etc.). This taxonomic method was continued by others through to the English naturalist John Ray (1627-1705).

In 1623, Swiss botanist Casper Bauhin (1560-1634) published *The Nomenclature of Plants*, a catalogue of six thousand plant species that in the place of alphabetical and other arbitrary naming systems of earlier authors, but utilizing their writings and his own observations, discerns genera and within these gives each species a descriptive name.[8]

In 1693, John Ray (1627-1705), regarded as the founder of natural history in England, formulated the idea of a species as sexually self-generating and as groups fixed as to type in that members of each can interbreed successfully only among themselves: “Forms which are different in species always retain their specific natures, and one species does not grow from that of another species.” He published this in *Methodus Plantarium* (1682) and applied it in his systematic description of all known plants of Europe in *Historia Plantarum* (3 vols., 1686-1704) and in the posthumous publication, which he arranged for, of his young friend and collaborator Francis Willughby’s (1635-1672) systematic description of birds and fishes (1713) and in his own work *Synopsis methodica animalium quadrupedum et serpentini generis*, 1719.[9]

In 1737, the Swedish botanist Carolus Linnaeus,[10] or Carl (or Charles) de (von—after his ennoblement) Linné (1707-1778) (***Figure e1.3***), published the taxonomic system, continued today. This works in the opposite direction to Aristotelian schemes, by beginning empirically with individual “species” (L. verb *specere*, to look) each distinct to the eye and grouping them by ever broader similarities in an ascending hierarchy. In this, he was not hampered by the (false) notion he expressed in *De Telluris habitabilis Incremento*, 1743, that animals were created in their variety at one time and place (Paradise). From there (taking a cue from Andrea Celsius’ contemporary writings) land animals variously dispersed to all other parts of Earth as these in succession became dry (habitable). Linnaeus’ (false) principle: The species are fixed and all can be found somewhere.[11]

Linnaeus provided a theoretical justification for Bauhin’s system of nomenclature, and explicitly introduced the modern binomial (two-parts) or, more correctly, binominal (two-words) system of naming plants by genus from the Greek *genos*, or family, and species from *eidos*, or form (*after* the less precise use of the same by Aristotle *after* Plato). By designating *Homo sapiens,* Linnaeus put humans in, not outside, the chain of being: there being not a single “generic character” to elevate them. As he “could not discover the difference between man and the orangutan [a general term for an ape in his time],” his twelfth edition of *Systema Naturae* concludes with the pointed bromide: “It is remarkable that the stupidest ape differs so little from the wisest man that the surveyor of nature has yet to be found who can draw the line between them.” Linnaeus identified twenty-four classes of plants, categorizing each by the number of pistils and stamens: this classification based on reproductive organs soon became the standard system.[12]

In 1758, Linnaeus drew up rules which furthered Ray’s use of Aristotle’s idea of *essential features* of living things that group them (as genera) and *differentia* that characterize them (as species). For example, *Bird* might be the genus and *feeding in water* the species or *Animal* might be the genus and *bird* the species. In this way he identified six classes of animals: quadrupeds, birds, amphibians, fishes, insects, and worms. Descriptions of genera included lengthy descriptions of the varieties recognized for it. As a shorthand for each long qualifying description Linnaeus placed one word in the page margin against it. These became the easily remembered designators of the species of the genus. So was born the convention of following a genus name by a single word as a species referent. Linnaeus’s “truth to nature” stylized and simplified organic forms by leaving out what an expert (as himself) would see as irrelevant detail and he disparaged reporting that would find “93 [species] of tulips (where there is only one).”[13] Mechanical observation that came to be an operational feature of the Industrial Revolution, is at best an additional method, as the “expert” is not eliminated. Nature can only be described, and understood, adequately, never perfectly.

Linnaeus is honored as the founder of modern taxonomy because he used binominal nomenclature consistently and introduced the standard hierarchy of: class, order, genus, and species. His lumper’s stance allowed for simple keys that enabled others to readily identify plants and animals from his books. This classification method is called taxonomy (Gk. *taxis*, order or arrangement; *nomos*, law). Taxonomy is the theory and practice of classifying organisms formally to achieve a stable and internationally acceptable uniform nomenclature to facilitate cross-referencing and information retrieval. No one theory lies behind modern taxonomic methods.[14] The purpose can be a simple as to provide a type of classification called a *key*. Very often the key is dichotomous and lists opposing pairs of most obvious characteristics (like in the game of *Twenty Questions*)[15] that succinctly describe and reliably place an object in a group, or which indicate for it the creation of a new group. Some keys, as for corals, are more elaborate. A biological group so defined is called a *taxon* (plural: *taxa*).

Taxa were originally thought of as natural kinds but Darwin's theory of evolution made that not so for in Darwinism, species cannot be treated as natural kinds but must be construed as historical entities. To quote David L. Hull: "One thing that natural kinds cannot do is evolve. Each has its own essence. For example, the natural kind 'triangle' is a closed geometric figure with precisely three sides. Rectangles have precisely four sides. On this account, the whole notion of triangularity evolving into rectangularity makes no sense."[16] However, in neo-Darwinism (*see* Topic *f14*) species are again natural kinds in that by a mutation a descendant of a triangle can be a rectangle.

Although "overall resemblance" classification can obscure actual relationships, experience has established that classification of organisms based on the function and shape of their parts (comparisons based on analogies) is *not* useful but classification based on the configuration and material of their parts (comparisons based on homologies) and their embryonic development *are* useful. This canonical result of taxonomy is consistent with what could have been predicted from the Darwinian theory of evolution which acclaims phylogenetic relationships.

Taxonomy, based on homologies, enjoys success as living organisms are composed of relatively few building blocks. One inference is that these building blocks sample an initial created variety and another is that from relatively few the variety has evolved. The fossil record provides a test for which. We deduce that if life has evolved, then, according to neo-Darwinism, the variety of building blocks will have changed. The fossil record shows that building blocks have episodically appeared and disappeared in the course of geologic time. The only ones evidently unchanged are the atoms of the Periodic Table. Groups of these can evolve by mutations (atomic rearrangements in the genetic code): Carbon-based entities have.

The Darwinian theory of evolution by natural selection can account for 1) structures alike in function (i.e. *analogous*) but unalike in form in unrelated organisms and 2) structures unalike in function but like in form in related organisms. For the study of the latter—features of identical anatomical origin, whatever their functional divergence—the term *homologous* was employed by Richard Owen (***Figure e1.4***)—first Hunterian Professor of Comparative Anatomy and Physiology, Royal College of Surgeons, London 1836-56 and early contributor (1859)[17] to the study of parthenogenesis (unisexual reproduction, which is the development of a new individual from an unfertilized gamete) first noted in 1849 by Charles Bonnet (1720-1793) for aphids in whose bodies at their time of birth the next generation of offspring are already forming.[18]

Components that are homologous can differ in shape and size as, for example, the humerus, ulna, radius, and fingers, in the forelimb of cats, humans, bats, and whales (***Figure e1.5***). A homology allows for the same name. A functional divergence can require different names. Thus we can talk of a bat's arm as it homologous to our arm but (short of being "winged by a bullet") we cannot refer to our arm as a wing. Most mammals have the same number of neck vertebrae, seven, even though functional specialization can be great (giraffe) or not (elephant). Homology does not imply exact similarity. In *Anatomy of a Porpess* (1680), Edward Tyson (1651-1708) noted that "there is nothing more than a Fish" without. But "within, there is nothing less. ... The structure of the viscera and inward parts have so great an Analogy [*sic*] and resemblance to those of Quadrupeds, that we find them here almost the same. The greatest difference from them seems to be in the external shape, and wanting feet. But here too we observed that when the skin and flesh was taken off, the forefins did very well represent an Arm, there being the *Scapula*, an os *Humeri*, the *Ulna*, and *Radius*, and bone of the *Carpus*, the *Metacarp*, and 5 *digiti* curiously joynted." [19]

The structure of the eyes of scallops and squid (related as mollusks) are homologous and these are very different from the analogous structures of the eyes of seals and starlings (related as vertebrates).

Forms that have parts with the same function, such as: eyes in scallops, seals and starlings; or wings of birds, bats and butterflies, should *not* engender groups of related organisms.

Biological classification has progressed somewhat, by trial and error, from artificial or key classification to a natural classification. The goal would be to replace taxonomy with systematics that interprets comparative physiology and behavior in terms of ecology, genetics and evolution. Systematics is the science of the diversity of organisms. For example, blue-green algae fit no hard and fast classification scheme and their evolutionary position is reasoned to be on the evolutionary line diverging from true bacteria to eukaryotic plants.

As no system for classification of organisms can, for the foreseeable future, be anything but utilitarian, the Encyclopedia Britannica (15th Edition) gives the following useful insight: "Major classificatory systems [of organisms] should perhaps be thought of as indexes to chapters in systematic treatises." [20] ❑

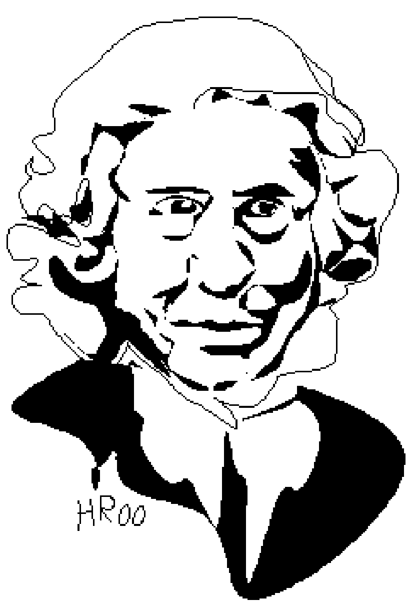
Figure e1.1 (right) **Aristocles, ca. 427-347 BCE.** His nickname ***Plato***, meaning broad, "could have referred to the width of his forehead, or body, or the breadth of his ideas."
—Judy Jones & William Wilson, *An incomplete education*.[21]

Figure e1.2 (left) **Aristotle, 384-322 BCE** (also known as *Stagirite* for his birthplace, the Greek village Stagira on the Chalcidic).

His science was foggy but none can fault the clarity of his three rules for good rhetoric: Ethos (conveying the true character of the speaker), Logos (appealing to rational thought), and Pathos (appealing to audiences' emotions).

Figure e1.3 **Carl von Linné (1707-1778)** and the title page of his foundation work in zoological nomenclature. Caroli Linnaei or Carolus Linnaeus are Latinized forms of his Swedish name. For his work is the cognomen: "God created, Linnaeus arranged." [22]

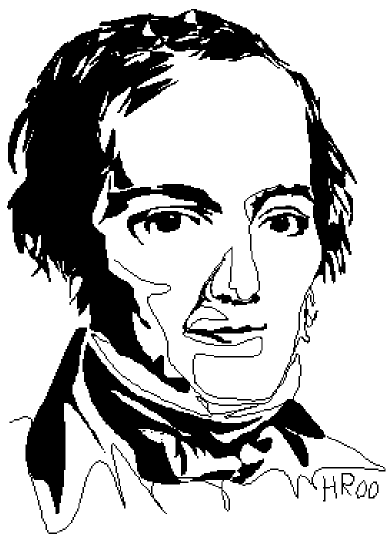
Accolades from philosopher Jean-Jacques Rousseau that Linné's sexual system of plant classification (*see* Topic *h2*) was as a source of "great pleasure," Linné accepted graciously, and criticisms from botanist Johann Georg Siegesbeck that the same made "innocent flower gardens into beds of harlotry," Linné suffered poorly, responding by giving the name *Siegesbeckia* to a small, foul-smelling weed.[23]



CAROLI LINNAEI
EQVITIS DE STELLA POLARI,
ARCHIATRI REGII, MED. ET BOTAN. PROFESS. VPSAL. ACAD. VPSAL. HOLMENS. PETROPOL. BEROL. IMPER. LOND. MONSPEL. TOLOS. FLORENT. SOC.
SYSTEMA NATVRAE
PER
REGNA TRIA NATVRAE,
SECVNDVM
CLASSES, ORDINES, GENERA, SPECIES,
CVM
CHARACTERIBVS, DIFFERENTIIS, SYNONYMIS, LOCIS.
TOMVS I.

1758

Figure e1.4 **Richard Owen** (1810-1890) [24]



His famous definitions of *analogue* and *homologue* appear only in the Glossary in the published version of his 1843 lectures on invertebrates delivered at the Royal College of Surgeons:[25]

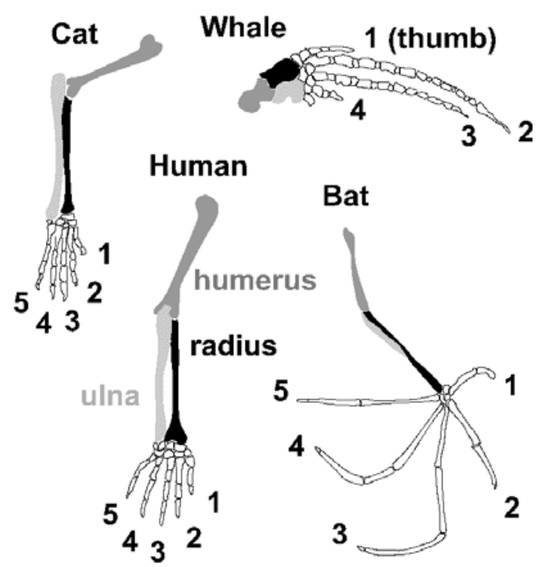
ANALOGUE *A part or organ in one animal, that has the same function as another part or organ in a different animal*.

HOMOLOGUE *The same organ in different animals under every variety of form and function*. This glossary entry, in particular, as Alec L. Panchen points out, "gives the impression strongly that in 1843 Owen did not see himself as recording new concepts or even coining new definitions, but simply as recording current usage. For 'homologue' and 'homology,' this was certainly the case. If one turns to the recently published transcriptions of the surviving lectures from Owen's first series of Hunterian lectures, delivered in 1837, one finds him using 'homologies' as though it were a familiar term." The surprise is only there if one forgets that Owen's concept of homology did not have a phylogenetic (evolutionary) perspective which it later acquired. He identified and grouped similarities in nature according to the (false) concept of *scale naturae*. Certainly, at the Academy of Sciences, Paris, February, 1830, the term "homologie" (homology) had been prominently aired when Geoffroy argued that fish and cephalopods possessed sufficient such to indicate that "higher" vertebrates could have evolved from "lower" mollusks. (Shocking then was the implication of evolution between two of Cuvier's four "separately created" branches of the animal kingdom. "Cuvier was so appalled," Deborah Cadbury reminds, "that he used his political weight to block the examination of Geoffroy's ideas.")[26]

The word "homology" or "equivalent parts" has been coopted for the principle that similarity of organic structures, or the molecular code of genes, or both, of two or more organisms indicate their common evolutionary origin. Historically, its application has had enormous value. So today, Charles Bonnet's 1764 similarity series:[27] fish–flying fish–aquatic birds–birds–bats–flying squirrels–tetrapods–monkey–man, reads like a joke.[28]

Ironically, as ever more becomes known of the molecular nature of evolution, proof of homology becomes increasingly difficult. John Maynard Smith (1920-2004) wondered in 1998 if homology is a principle too idealized to apply in modern research and has become a word ripe for burning.[29]

Figure e1.5 [30] **Homologous bones in vertebrate forelimbs** ("The arm of Man is the fore-leg of the Beast, the wing of the Bird, and pectoral fin of the Fish.")[31] that are in turn homologous in the comparable way they connect to other parts of the of the skeleton. So the "ideal or Archetype" of vertebrates could be discoverable, Owen believed: "The Archetype is progressively departed from as the organization is more and more modified in adaptation to higher and more varied powers and actions."[32]



Thirty years before Darwin's *Origin*, homologies allowed Samuel Latham Mitchell (1764-1831) to declare winningly in a New York court case that "a whale is no more a fish than [is] a man."[33]