CHAPTER 5

ARISTOTLE'S AND LINNAEUS' CLASSIFICATIONS OF LIVING CREATURES

The human mind seeks to categorize and classify. Thus Aristotle recognized animals as "blooded" (vertebrates) and "without blood" (invertebrates) and described in great detail the characteristics of each (Fig. 5.1). No society has trouble distinguishing in most instances among fish, amphibia, reptiles, birds, and mammals. Some animals do cause trouble: it was widely argued, until decided by the anatomists (Chapter 2, page 28) whether whales, seals, and porpoises were mammals or fish, and there were even some rather amusing accommodations: in Catholic ritual, during Lent and on Fridays, the eating of flesh (meat of mammals) was forbidden. In the American South and in South America, respectively porpoises and capybaras (a pig-size guinea pig-like animal that spends much of its time in rivers) were redefined as "honorary fish" and thus permissible for consumption. However, beyond this crude classification we generally push further into detail as long as our curiosity and economic interest push us. Among the mammals, we distinguish cats and dogs, and among the dogs, hunters, lap dogs, guard dogs, and racing dogs. Whalers knew which whales were either too difficult or too worthless to hunt, and those that were valuable and easy to hunt (the "right whale"). Sailors landing on a foreign shore and needing to recaulk their ships could identify trees that could supply the appropriate sap ("pitch pines"). However, most of this classification remained sporadic, inconsistent (would a penguin be a bird or a fish?), and local. By the 18th C, enough was being learned about the world that such a haphazard structure was clearly unsatisfactory. Carolus Linnaeus changed that by attempting to classify the entire range of known living things. This classification, accomplished in the mid 18th C, accomplished three major feats: binomial nomenclature, non-linear relationships, and stratification. The fourth and most important accomplishment, however, was that the third was so clear and structured that it led to the eventual recognition of its own inadequacy, becoming the basis for the questioning that was an important element for the understanding of evolution.

The first accomplishment attributed to Linnaeus, binomial nomenclature, was, strictly speaking, not his. Many societies have had general and specific means of naming individuals, whether they were by lineage (the Biblical "Isaac the son of Joseph"), by occupation ("William [the black]Smith"), characteristic ("John Short") or origin ("William [of] England"). By the same token, the Latin-versed scholars often referred to animals and plants by two names, but more often by verbose descriptions. The Bauhin brothers in the 16th C had tried to simplify the annotations, much as scientists today do in their writing. A scientist today might abbreviate an unwieldy complete description ("the membrane-bound phospholipid phosphatidyl serine (PS)") and thereafter refer in the text only to "PS". The Bauhin brothers similarly used a general and specific pair of terms to refer to specific organisms. However, Linnaeus was the first to use this shorthand consistently and widely, assigning the equivalent of a family name and given name, as is described in Chapter 1, page 10. Since his classification was widely published and read, he considerably popularized the custom.

Linnaeus' second accomplishment was to show the relationships not as a linear order, in which each organism was necessarily higher or lower in perfection than any other organism (See Table 5.1) but rather alongside each others: rodents were not necessarily higher or lower than horses or dogs. This was the beginning of the branched tree picture that Darwin finally drew (Fig. 5.4) Third, he built the classification into a hierarchy, stratifying it beyond the simplest levels of similarity. Beyond the specific and generic or first name-last name classification ("Dog, the common one" = Canis familaris or "Panther, the spotted one" = Panthera pardus) he grouped organisms into broader and broader categories, each one superseding the previous (dog–>carnivorous mammal–>mammal–>vertebrate–> animal–>eukaryotic organism) in a hierarchical tree, as is illustrated in Fig. 5.2 and Table 5.1. Over the years, by this heroic effort, he put into systematic order 4,400 species of animals and 7,700 species of plants. This accomplishment was several-fold. First, although lineage was not understood as a biological phenomenon, it indicated connections, as we might expect levels of increasing similarity in appearance as we move along the familial tree humans–>Caucasian humans–>European Caucasians–>Mediterranean

Table 5.1. Classifications according to Aristotle

God
Humans
Mammalian animals
Flying squirrels
Bats (and birds?)
Fish
Reptiles
Shelled animals
Insects
Sensitive plants
Plants
Short mosses
Mushrooms
Stones
Crystalline salts
Metals
Earth

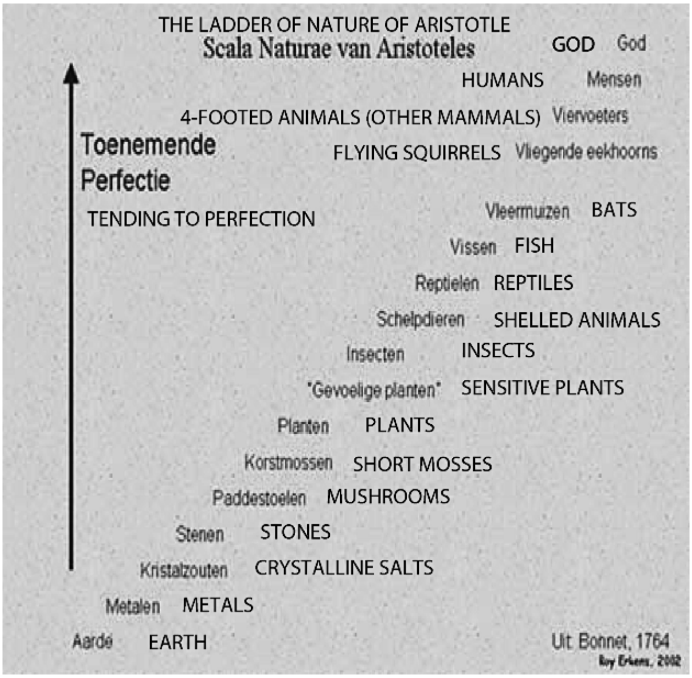

Figure 5.1. Aristotle's Scala Naturae, or Scale of Life, as described in an 18th C Dutch document. The translation of the terms is in CAPITAL LETTERS. Though Aristotle's classifications improved on others' ideas in that he recognized the difference between the live-bearing seagoing mammals and egg-laying fish, he lumped many types of shelled animals together, and did not clearly recognize that bats and flying squirrels, like humans, were mammals. Credits: http://www.kennislink.nll/upload/78469_962_1020862987092-systhematiek2.jpg

peoples–>Italians–>people from around Naples (as in the last name "Napolitano")–>a individual (Maria Napolitano). The existence of this sequence of groupings could not fail to provoke questions about the significance of the groupings—why do they exist, and why do these groups of animals and plants have the same basic structures?—as well as the inferred limitations of the groupings—why are there only these groupings? Why are there not animals with both four legs and wings (or do such animals exist? See page 45.) Such questions would begin to haunt the 19th C.

Linnaeus' fourth accomplishment was that his third accomplishment, the ordering and classification of all organisms, was so thorough that it sealed its own fate. Linnaeus, in good Protestant style, felt that he was doing God's work and helping to understand God's creation in classifying all organisms, though he understood that he angered local clergy by daring to classify humans in the same general grouping as chimpanzees. In a similar fashion, Jewish scholars were producing tracts on the secular (and therefore forbidden, or at least discouraged) subjects of zoology and anatomy, under the ruse of depicting the animals of the Old Testament. The problem was that, while his project had begun because the exploration of the world had demonstrated that there were too

Figure 5.2. Classification according to Linnaeus, Although he recognized structural similarities among related organisms and vastly improved the systematization of types of animals and plants, he was unable to account for several organisms, which he listed as "paradoxical animals" and many of his classifications by today's interpretation were wrong (see Table 5.2). Nevertheless, by grouping organisms as he did, he created the basis for others to recognize that the similarities meant common origin. Credits: Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus differentiis, synonymis, locis or translated: System of nature through the three kingdoms of nature, according to classes, orders, genera and species, with differences of character, synonyms, places). 1735 (Wikipedia)

many creatures in the world to understand and study unless they were systematized in some fashion, this systemization quickly proved to be a never-ending task, as more and more species were discovered and added to the list. More importantly, by the 19th C, approximately forty years after Linnaeus had published his compendium, arguments were arising as to how to classify new discoveries. It is easy enough to sort coins into pennies, nickels, dimes, quarters, half-dollars, and dollars, but is the steel penny of the Second World War a penny, as its shape indicates, or a nickel, as its color indicates?

In biological terms that are relatively easy to understand, ladybird beetles (ladybugs) are small red beetles with black spots, but they may range from almost entirely red beetles with a tiny black spot to almost entirely black beetles with a trace of red, and the red may vary from crimson through orange to yellow. By today's terms, now that we have worked much of this out, they are the same species if they can successfully breed with each other (see below), but to the scientists doing these classifications, what was the true character of the species, and are all these beetles one species, two species, or several species? This question continues today. One can see in any museum a collection of varieties of butterflies, snails, or other small, easily preserved organisms, demonstrating the variability of animal and plant life; and many passionate collectors collect, photograph, or otherwise document the variation among a single species. In the 19th C, this situation was not a given but a conundrum: What were species? Was there an ideal type for a species, with all variants being imperfect attempts to reach it, as Aristotle argued? Were there boundaries? If so, what were the boundaries? If there was no continuum, what defined and decided the boundaries? If there was no clear boundary—for instance, if the largest green frog (known as *Rana clamitans*) was the same size as the smallest bullfrog (known as *Rana catesbeiana*—did this mean that there was no clear distinction between one species and another? And what did the Bible say about this? Thus the very system that Linnaeus had put in place to structure and classify all of Creation was ultimately to undercut the conviction of unique and specific creation.

Although we now think that some of Linnaeus' classifications were incorrect, the general pattern is essentially unchanged. What he described was a hierarchy of similarities (Table 5.2; a modern version of the table, incorporating current views, is given in Table 5.3). The question is, what is truly biological and what is an artificial construct of human imagination? In other words, does a species really exist? Do genera (the plural of "genus') really exist? The question is more complex than one might imagine. The problem is best illustrated in the phenomena of ring species, discussed further on page 167. If one catches a leopard frog in, say, upstate New York, there is no problem whatsoever in identifying it. Nor, for that matter, do leopard frogs have any trouble identifying each other. Leopard frogs exist from Northern Quebec to Louisiana. Leopard frogs from Quebec look like and easily breed with leopard frogs from Maine; those from Maine with those in Massachusetts; those in Massachusetts with those in New York, etc. The problem arises when one compares a frog from Quebec with one from Louisiana. They look a bit different. The one from Louisiana is a bit fatter, and its nose is pointier than the frog from the north. It has fewer and rounder spots. Its call sounds noticeably different (Fig. 5.3) More troubling, if one tries to get a Quebec frog to breed with a Louisiana frog, the mating does not go well at all, and even if they do mate the eggs rarely if at all hatch successfully. If we define a species as a population that can successfully interbreed, then the Louisiana and Quebec frogs are two species; but if we go province and state by state across its range, frogs in the same region can interbreed, and at no point do we find a point at which *Rana pipiens* from the north is clearly separate from *Rana pipiens* from the south. So by this criterion they are the same species.

Table 5.2. Classification according to Linnaeus (Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus differentiis, synonymis, locis or translated: "System of nature through the three kingdoms of nature, according to classes, orders, genera and species, with differences of character, synonyms, places")

Kingdom		Class	Order	Genera	Species
Animals	I. Quadruped	Anthropomorph	Humans	Homo	Europeans (Homo europaeus albesc.(=white))
	Body: hirsute	Independent hands			Americans (Homo americanus rubesc. (=red))
	Feet: 4				
					Asians (Homo asiaticus fulcus (=yellow))
	Female: viviparous, milk-producing				
					Africans (Homo africanus niger (=black))
			Apes		
			Monkeys & others		
		Wild animals	Bears		
			Cats		
			Porpoises		
			Otters		
			Seals		
			Hyenas		
			Dogs		Dog
					Fox
					Wolf
			Bats		
		Rodents	Squirrels		
			Mice	Rats	
				Mice	

			(Mus)	Domestic mouse (Mus domesticus)
		Shorttailed mouse (Mus brachiurus)		
		Longtailed mouse (Mus macrourus)		
			Lemurs	
			Marmots	
		Beavers		
		Rabbits		
	Horses	Horses		
		Elephants		
		Hippopotamuses		
		Pigs		
	Split-hooved animals	Camels		
		Bovines (cows)		
		Gazelles		
		Deer		
		Sheep	Ovis	Common sheep (Ovis vulgaris)
				Arabic sheep (Ovis arabicus)
				African sheep (Ovis africanus)
				English sheep (Ovis angolenfis)
II. Birds	Hawks			
	Crows			
	Geese			
	Swans			
	Ducks			
	Chickens			

(*Continued*)

Table 5.2. *(Continued)*

Kingdom		Class	Order	Genera	Species
		Passerines			
	III. Amphibia	Serpents	Turtles Frogs Alligators Snakes		
		Paradoxical animals			
	IV. Fish No legs; fins; true dorsal fins	Whales* (horizontal tail)			
		Sharks (cartilage instead of bone) Short-gilled fish Spiny-finned fish Divided-finned fish			
	V. Insects	Hard shelled (beetles)			
		Veined wings	Butterflies Wasps*		
			Flies* (mouth under head)	Houseflies (Musca)	Musca domesticus
					Musca species 1 Musca species 2
				Horseflies (Tabanus)	

				Mosquitoes (Culex)
				Crane flies (Tipula)
		Dragonflies*		
		Half-winged	Crickets*	
			Fireflies*	
			Ants*	
			Sucking bugs	
		Wingless	Lice	
			Fleas	
			Crabs	
			Spiders	
	VI. Worms	Crawling worms	Earthworms	
			Tapeworms	
			Leeches	
		Shelled	Cockles	
			Nautilus	
			Oysters	
			Clams	
		Plantlike	Sea cucumbers	
			Starfish	
			Sea urchins	
			Jellyfish*	
			Squid	
			Microshelled	
Plants				

Table 5.3. Modern hierarchical classification system derived from Linnaeus

Rank	Example	Translation and description	Others at this rank
Domain	Eukaryotes	All organisms with true nuclei (essentially all plants and animals except bacteria and viruses)	Bacteria; viruses
Kingdom	Animals	All organisms that feed rather than live by photosynthesis, not including parasitic plants and fungi	Plants; fungi
Phylum	Chordates	All animals with a notochord (a rigid structure that preceded a true bony backbone: lampreys and some small marine organisms have a notochord but no backbone, and sharks do not have a true skeleton)	Mollusks; arthropods
Class	Mammals	Warm blooded, fur-bearing animals that suckle their young	Amphibians; reptiles; birds
Order	Carnivores	Flesh-eating mammals with teeth that can tear	Rodents; bats; whales and porpoises
Family	Cats	Lions, tigers, panthers, and cats	Dogs; skunks; otters
Genus	Panthers	Large, spotted, or uniformly-colored cats	Lynx; domestic cat; cheetah
Species	Leopard	A specific type of large spotted carnivorous cat ("leopard" literally translates as "spotted lion") that does not voluntarily cross-breed with other large cats.	Lion; tiger; jaguar

There are many similar situations. For instance, the common herring gull of the northern latitudes varies slightly along a geographical pattern, from Greenland westward across North America, continuing into Siberia, and onward to Europe. At no point is there a clear demarcation between one type and another. However, the gulls of Greenland look noticeably different from the ones in England and Ireland, and they do not interbreed. One could argue that the Greenland gulls and the English gulls were different species but, following the variations westward from Greenland, they appear to be one species. It remains theoretically possible for a mutation arising in a gull in Nova Scotia to reach the population in Ireland, as it remains theoretically possible for a mutation arising in a Louisiana leopard frog to reach the population in Quebec.

Situations such as the existence of ring species can teach us much about how new species arise, and was a major argument in Darwin's *Origin of the Species*, and

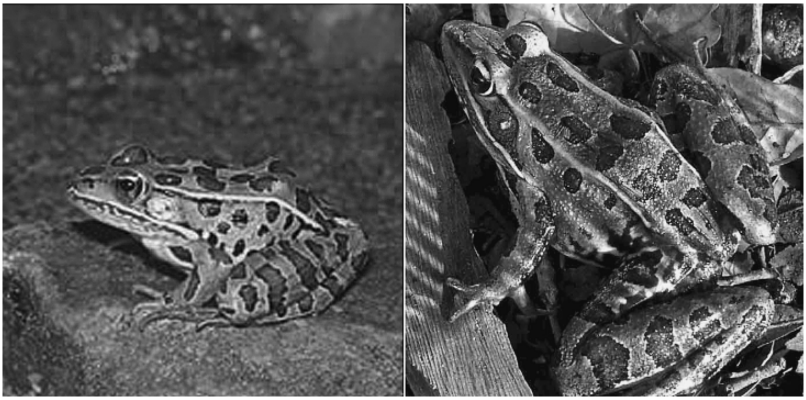

Figure 5.3. Northern (left) and Southern (right) leopard frogs. To a trained eye, these frogs can be distinguished by the pointier nose of the Southern frog, and the blotchier spotting and more complete leg stripes of the Northern frog. Their calls are very different, as may be heard by listening to http://allaboutfrogs.org/files/sounds/nleaprd.wav and http://allaboutfrogs.org/files/sounds/sleaprd.wav. They do not interbreed, though intermediates do. Credits: Northern leopard frog - http://www.umesc.usgs.gov/terrestrial/amphibians/mknutson_5003869_overview. html (public domain) (Wikipedia), Southern leopard frog - http://cars.er.usgs.gov/Education/sldshw/herpeto -logy /slides.html

will be addressed in other chapters. For our purposes here, it is sufficient to understand that the ability to interbreed is a true biological distinction and is used by biologists to define species. A species is a population that successfully interbreeds, with the progeny (young) being of equal health and fertility as the parents. This rule separates, for instance, the horse and donkey. In captivity, they will interbreed and produce healthy, vigorous mules. However, the mules are sterile, and there will be no grandchild generation. Also, organisms that do not reproduce sexually but simply divide, such as some bacteria, create a problem for this definition but, for most readily visible organisms that people encounter, the definition works.

Beyond species, the definitions become more arbitrary. The branching tree structure, which Linnaeus saw but from which he did not draw any conclusions, became central to Darwin's hypothesis concerning the origin of species (Fig. 5.4) but does not ultimately resolve the definitions of genera, , families, orders, classes, and phyla, in the same sense that it is often difficult to decide, at the outer reaches of a family, who is truly a cousin. To take the Napolitano example above, one can easily identify the Napolitano clan and the Siciliano clan but when a third cousin twice-removed from the Napolitanos marries a grandchild of the Sicilianos, to which clan do they belong? In many countries people vehemently argue that a child born in that country but of foreign parents is not truly a member of that country, and in the US, an individual who represents the third generation born in the US but who bears a surname or appearance that is not from northwest Europe may be considered as not truly American. There is a creature that looks and feels basically like an earthworm, but it has fleshy legs and fleshy antennae like a millipede. If it had a hard shell and hard legs and antennae, it would look like a millipede (Fig. 5.5).

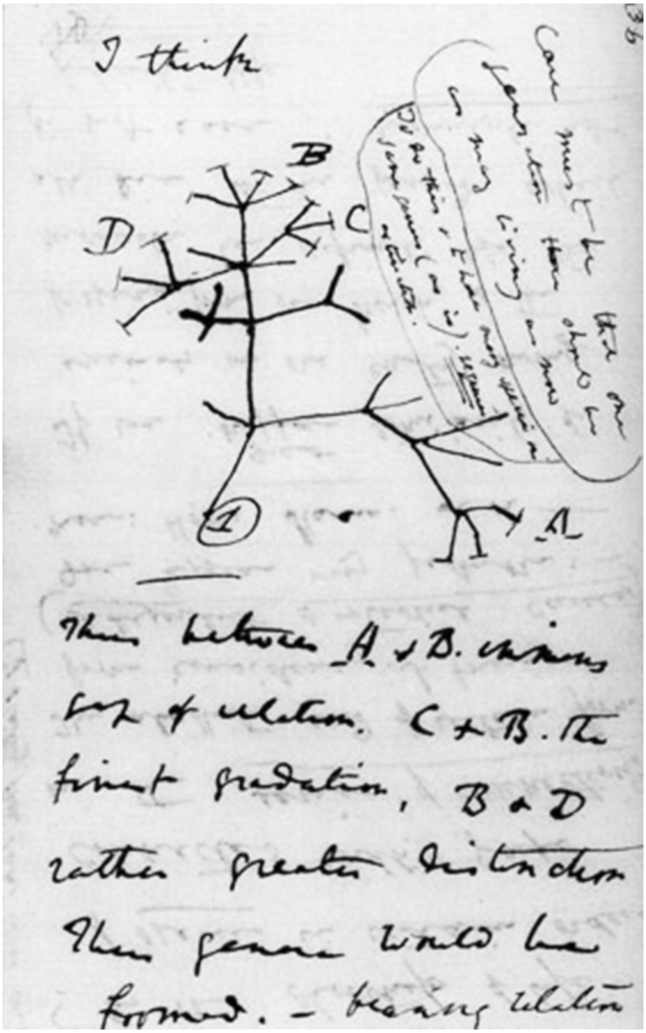

Figure 5.4. Darwin's branched tree. Darwin's original sketch of a potential evolutionary tree (theoretical) found in his notebooks. Note that all organisms start at an original point (1) and that they evolve in ever-increasing diversity, with surviving (extant) families marked by the letters A–D, with others having become extinct. Credits: Tree of Life: the first-known sketch by Charles Darwin of an evolutionary tree describing the relationships among groups of organisms. © Syndics of Cambridge University Library

Does it belong to the phylum of the worms (Annelida) or the phylum of the jointed animals (Arthropoda)? The juvenile forms of sea squirts, marine organisms that basically look like bags with two holes through which they pump water, have a notochord with a brain above the notochord and nerves that run along the back of it, and they have tail muscles in the chevron pattern typical of fish. Do these structures

Figure 5.5. An evolutionary intermediate. Top: the common Annelid (ringed) earthworm. Its body is divided into segments, and the head end is slightly swollen, but there are no limbs, antennae, or obvious other external specializations. Middle, a velvet worm from Australia. It has a soft body like an earthworm, but soft, fleshy feet-like appendages and soft, fleshy antennae. Bottom: a centipede. It has a hard shell and hard, jointed legs, both characteristic of arthropods (lobsters, crabs, insects, and spiders; the name "arthropod" means "jointed-footed animal"). It also has a clearly-defined head, which allows it to centralize information coming in from the senses. Credits: Velvet worm - http://www.ars.usda.gov/is/kids/insects/story5/velvetadventures2.htm

make them card-carrying members of the chordate phylum (which includes the vertebrates) or not? There are egg-laying warm-blooded furry creatures, such as platypuses (Fig. 11.1) and echidnas. Frogs have smooth moist skin and lay their eggs in clumps, while toads have dry warty skins and lay their eggs in strings, but there are amphibia whose skins are intermediate and whose eggs are in what might describe as elongated clumps. The fossil record includes many such intermediates such as feather-bearing dinosaurs that, unlike birds, had teeth and bony tails. Today we can trace by the evidence of DNA when lineages separated from each other, and how far apart they are (Chapters 14 and 15), but ultimately designations above the level of species are human constructs. Most species are easily classifiable, but there are always examples for which the borders are fuzzy. To summarize: The concept of species is as close as we come to a truly biological distinction. The branching tree by which we describe life on earth reflects the manner in which the variety of life appeared on earth, as we will explore in the following chapters but, while many of the classifications appear to be obvious—birds versus reptiles, cats versus dogs, peaches versus apples—we know of many intermediates, and at the borders the distinctions are human decisions.

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STUDY QUESTIONS

1. Compare and contrast the classification schemes of Aristotle, Linnaeus, and Darwin. What are the strong points and weak points of each? What evidence is there to defend each?
2. Taking an example cited in the text, if you found an animal that you could not obviously classify as a frog or a toad, by what criteria would you classify it? Is there a reason to classify it?
3. There are some creatures normally considered to be fish (lungfish) that have scaleless, slimy skins through which they can get oxygen and primitive lungs so that they can breathe air. Their fins are rather fleshy, allowing them to crawl across the land, and they can spend considerable time out of water. Are they amphibia or fish? How can you tell? (This question is discussed further on page 153. Speculating on the topic at this point will help you to understand the issues in this chapter.)
4. You notice that, in a local pond, some frogs sing their mating calls in the early evening, while others, that look the same, sing only in the early morning. Similarly, some of the female frogs seem to listen to songs only in the evening, and others only in the morning. Are they different species? Defend your argument.
5. Argue against the proposition that all classifications above the species level are arbitrary.
6. By what criteria do we classify bats and porpoises among the mammals, and penguins among the birds? Do you agree or disagree with these classifications? Explain.
7. What criteria would you use to distinguish among different groupings of plants? Why?