TwoOldGuys™ Study Guides
BI114 Biological Concepts for Teachers
Chapter 1. Introduction
1.3. the Species Concept & Phylogeny

Based on Indiana's Academic Standards, Science, as adopted by the Indiana State Board of Education, Nov 2000.
Numbers refer to the age-appropriate grade-level for the content.

REVIEW

We have developed a [tentative, but all of science is tentative] definition of life, and confirmed it by applying it to all known life-forms consistent with the cognitive development of the 8th grade mind. In the course of outlining the known living things, we have expanded the 20-Questions classification scheme to include the higher rank taxa: Kingdom, Phylum, and Class.

SPECIES CONCEPT

The formally recognized taxa include Kingdom, Phylum, Class, Order, Family, Genus, and species, of which only the lowest is actually defined. The Kingdoms are defined by enumeration. The species is the only taxon with a true definition, which it has because it is considered to be one of the fundamental units in Biology along with the population, the individual and the cell. The formal definition of the population recognizes it as the fundamental unit of genetics and of ecology. The individual does not have a formal definition, although the cell is the subject of a theory. Such issues constitute the study of classification which is called systematics or phylogeny depending on the assumptions used. This was the primary activity among Biologists [also called

Naturalists, who attempted to identify all living things (taxonomy) and determine their life histories] until about the middle of the 20th Century, when Modern Biology was developed.

Kingdom definitions

grade 8: to college:

The traditional two Kingdom System [Animals and Plants] served reasonably well during the Naturalist period of Biology. Animals basically exhibited movement and ate other organisms, while Plants had cell walls and carried on photosynthesis to manufacture their own food. But it became increasingly obvious that many one-celled creatures did not fit neatly into the Animal or Plant Kingdoms, since they exhibited movement, ate other organisms, had cell walls and manufactured their own food by photosynthesis. As a result it was suggested that the one-celled organisms be separated into a third Kingdom, yet there are two very different groups of one-celled organisms. We finally accepted a five Kingdom System (Whittaker, 1969), as follows:

Animals: multicellular, eukaryotic organisms which exhibit movement, derive their energy from eating other organisms, lack cell walls. (Study of this kingdom is called Zoology.)

Plants: multicellular, eukaryotic organisms that capture solar energy by photosynthesis, have cell walls. (Study of this kingdom is called Botany.)

Fungi: mostly multicellular, eukaryotic organisms with cell walls, derive their energy by decomposing dead organisms. (Basically no one wanted to claim these, but the study of this kingdom is now called Mycology.)

Protists: mostly single-celled, eukaryotic organisms which may exhibit characteristics of Animals or Plants or both. (The study of the Protists and of the bacteria is called Microbiology.)

Monera: [bacteria] single celled, prokaryotic organisms with a wide variety of nutritional habits. (The study of bacteria, but not Protists, is called Bacteriology.)

eukaryotic= refers to a 'true nucleus,' or a nucleus with a nuclear membrane, and DNA existing in discreet chromosomes with associated chromatin (protein).
prokaryotic= refers to 'before nucleus,' or nuclear region not separated from the cell with a membrane, and with 'naked' DNA not organized into chromosomes.

You need to know, but do not need to include in your lesson plans, that there are currently a few proposals to revise the classification system to include Viruses [may or may not be considered to be living], some primitive bacteria [proposed Kingdom Archaea] and others. In addition, based on data at the molecular or chemical level, it has been suggested that we create a new higher taxon, the Domain. Initially this proposal would create three Domains: Archaea including only the Kingdom Archaea; Bacteria including those Kingdom Monera not in the Archaea [bacteria and blue-greens]; and Eukarya including all of the Kingdoms of Eucaryotes [protists, fungi, plants and animals].

We would like to believe that the Kingdoms are real, describing the natural division of living organisms into groups. However, this suggestion does not lead to any predicted observable events, so must be taken as an assumption. It is commonly assumed among systematists that the lesser taxa; phylum, class, order, family and genus; are 'artificial' in the sense that they exist only in the minds of taxonomists and then only for the convenience of grouping organisms into logical categories. The phylogenists also agree that these taxa are artificial, but

useful for describing the evolutionary history of living organisms. Phylogenists are currently working to establish non-artificial definitions of the higher taxa below the Kingdom level.

Species definition

The species is one of only four biological units that are levels both of organization and of function, and that are considered "real" (Gould, 1977, p. 232) in the sense that these units are "complex, self-maintaining, and self-replicating systems which are subject to death." As you are supposed to remember at this point, *that* was our tentative definition of Life! The definition of the species will be developed in this section, while the definitions of the population, individual and cell will be developed in subsequent sections.

grade K: to 3:

A good starting point for a discussion of the species would be an exercise in comparing and contrasting. However, at this age, the introduction of the term "species" is optional and not recommended. The better choice of vocabulary word to describe these types of animals is "kinds of animals."

Encourage students to select two clearly dissimilar types (species) of animals

For any children, a good choice would be pets; such as cat, dog, parrot, fish...
If your school is in a rural area, at least some of the children will be equally familiar with livestock; such as cow, pig, chicken...
The students can be expected to

recognize how examples of each kind are similar:

how dogs are like other dogs, parrots are like other parrots.

recognize how kinds are different:

how parrots differ from dogs.

If you need assistance in seeing the variety of creatures in the pet kinds of animals, and if you have classroom access to the web, here are two examples of web sites [breeding organizations, not commercial sites] that may help by providing descriptions and photographs of recognized breeds. If you look at both sites you will quickly learn why you want to insist that the two types of animals be *clearly* dissimilar. To "compare and contrast between dogs and cats" is a good example of a difficult question; and you are expected to remember forever that good science asks simpler questions. Equally good examples of simpler questions are to "compare and contrast between dogs and parrots," or "...between dogs and fish."

dogs: "American Kennel Club", a listing of 150 breeds.
http://www.akc.org/breeds/index.cfm
cats: "International Progressive Cat Breeders Alliance", a partial listing of 73 breeds.
http://www.ipcba.8k.com/RecognizedBreedAssociations.html

Even when the kinds of animals being compared are less obviously different; for example: dogs and cats, squirrels and chipmunks, cows and buffalos; we generally have little difficulty assigning an individual animal to the 'correct' kind. This suggests that those kinds of animals which we call different kinds actually represent real groups of animals. We can also assume that the same statement applies to Plants (or even fungi, protists, and bacteria).

grade 3: to 6:

Recognize that litters are more like parents than like different types (species)

cats have litters of kittens, not puppies
dogs have litters of puppies, not kittens
robins have clutches of baby robins, not bluejays

There are two important additions to the species concept as we established it in the grade K to 3 version. The first should be obvious from the above: when any kind of animal has babies, the babies will be of the same kind as the parents. When a mixed breed, mutt dog has puppies, although there may be considerable variation among the puppies, the entire litter is clearly baby dogs. Perhaps less obvious (to the 4th grade mind), but just as important, is that the individuals will grow up to be the same kind of animal as the parents. Not only can we generally recognize an individual to be a member of the 'correct' kind of animals, but also we can expect the individuals and their offspring to remain members of the same kind they always were. This expectation will apply even when the young animals are raised by surrogate parents of a different type (species).

The term "species" is not particularly important to the understanding of the species concept for this age group. The decision to introduce or not to introduce the term should be made not on its scientific merits but on the language skills of your population of students, which must be reevaluated each year.

grade 6: to 8:

Different types of animals (and plants) are classified as different species

Species breed true

The technical term for "kinds" of organisms is "species," and we should now be encouraging the students to learn and use the correct technical terms for concepts and objects. The correct technical term for living things is "organism." However, merely changing the terminology does not change the concept. The key features of the species concept as we want it understood by the students have already been suggested, but can be refined for this population of students. Each individual organism is a "life-time" member of a species. The individual was born (hatched, germinated) as a member of the species, and remains a member of the same species all its life (and beyond should it become fossilized). This constancy even spans generations. When the individuals of any species reproduce, the offspring will also be members of the same species (with a few exceptions explained in the secondary to college level content). This inter-generational constancy is summarized by the statement, "species breed true."

Different species do not cross-breed

A corollary of the hypothesis that species breed true is that species should not be able to cross-breed. Logically if members of two different species, for example a horse and a donkey, were to mate, by the hypothesis of species breeding true, the offspring of the horse parent would be horses while the offspring of the donkey parent would be donkeys. When real horses are mated with real donkeys the offspring are part horse, part donkey and are called "mules." The name mule

implies a different species from the horse parent and from the donkey parent. If mule is a 'new' species, then we could expect the mating of two mules would produce more mules. No one has ever mated two mules successfully, because all mules are sterile [this may no longer be considered to be true], and incapable of reproducing. As a reminder, we just described a prediction of an observable event [the corollary stated above] based on a hypothesis ["species breed true"], then reported the results of an experimental test which confirms the prediction. In our version of how science is done, experimental confirmation of a hypothesis increases our confidence in the hypothesis.

grade secondary: to college:

The species is defined as all populations of actually or potentially interbreeding organisms sharing a common gene pool

The modern species definition (Mayr, 1969) incorporates the traditional definition (Linneaus) that the species is 'all populations of similar organisms,' and adds the concept of intergenerational continuity by restricting the definition to 'those populations which are actually or potentially interbreeding.' Because they are actually or potentially interbreeding means that they are “sharing a common gene pool” (Gould, 1977, p. 232). So, all populations of a little dark grey mouse, with a naked (hairless) tail and a light grey belly and feet, are the species House Mouse (*Mus musculus*) based on the Linneaus definition. Such populations are found in Indianapolis, Chicago, New York, London, Berlin, etc. There is experimental confirmation that the Kansas City, MO, and St Louis, MO, populations are capable of reproducing [hence potentially interbreeding]. In the wild, the Kansas City and St Louis populations do not interbreed simply because mice don't normally commute that far.

One exception to the intergenerational continuity of life is the evolutionary development of new species. This process of speciation requires that a reproducing pair of animals of one species have offspring of a different species. Among plants there are cases of two different species reproducing together and yielding individuals of a third species. This will be discussed in greater detail in a later chapter.

Population definition

grade 4: to 5:

In nature, there will be more than one individual of each type in a given area

Depending on the cognitive maturity of your students, you may need to approach this with the idea that wild animals have "friends" and neighbors, too. In much of contemporary childrens' literature, animals are portrayed with "friends" which are animals of other kinds. It may be a good literary device, but real animals associate with their own kind. Should you need to be 'politically correct' about this, remember that for humans to associate with their own kind requires that they associate with *all* humans, not just any particular ethic sub-group of humans. Likewise, wild animals do not associate only with a recognizable sub-group of their kind but with any of their kind.

grade 6: to 8:

Wild animals occur as groups (populations) of individuals within a given area

Animals tend to form into groups (called populations) of like kind, and these populations tend to occupy relatively small geographic space. Sometimes the area occupied is a result of habitat, such as a woods

surrounded by open fields, where the woodland population is restricted to the woods. Other times the habitat may occupy a relatively large area, yet the populations may still be restricted to smaller areas, based on the distance the individuals are likely to travel in a day.

These populations may tend to remain separate from other groups in different areas

When the habitat is small enough to hold only one population, and surrounded by a different habitat, the individuals of the population generally will not cross the alternate habitat to get to another population of the same species. When the habitat is large enough to hold more than one population, we think [not know, therefore an assumption] that the populations still tend to remain separate from each other.

There may be some migration between areas

That the individuals of the populations *tend* to remain with the population says only that most, but not all, individuals do so. In any population, at least a few individuals will leave the population in search of other habitats to occupy. As they leave their home population, they are said to "emmigrate;" and if they arrive at another suitable habitat, they are said to "immigrate." A mnemonic to remember these is: **E**mmigrate out the **E**xit, **I**mmigrate **I**n. "Migrate" without any prefix refers to leaving an area with the intent to return. The importance of emmigration - immigration to species cannot be overstated. All species are like the opening moments of Pinky and the Brain [TV series 1995-1998. Amblin Entertainment and Warner Brothers Television], when Pinky asks, "What are we going to do tonight, Brain?" and the Brain

replies, "Same thing we always do, Pinky. We're going to try to take over the world."

grade secondary: to college:

The population is defined as all individuals of
- similar organisms occupying a given geographic area
- interacting, and potentially interbreeding organisms, sharing same gene pool

This definition of the population differs from the species definition above only in that it is restricted to a relatively small geographic area within which the individuals actually interact. The size of this area is determined by the distance the individuals are likely to travel in search of food, or of mates.

The Individual and the Cell

grade college:

For the most part we understand what we mean by individual; it is "the smallest unit of any species (or population) which has all of the characteristics of the species." In common English, one animal or plant. But, strawberries can reproduce by sending out runners which become new plants when they touch the ground. However these new plants are still attached to the 'parent' plant, raising the question whether they are a single individual or two separate individuals. The definition above seems to avoid this dilemma, since the strawberry plants can be separated and each will exhibit the characteristics of strawberries.
The cell is "the smallest unit which has all of the characteristics of Life."

Classification

grades 6: to college:

Taxa (singular: taxon), or classification units from smallest to largest are

species (singular and plural)
Genus (plural: genera)
Family
Order
Class
Phylum (plural: phyla)
Kingdom

All of these taxa are artificial except for the species. The higher taxa are normally used to suggest the degree of relationship among the included lower taxa.

grades secondary: to college:

Classification

Systematics

- systematic collection of information on similarities/differences, and
- organization of taxa to reflect similarities/differences.

The goal of systematics is to collect complete information about all living organisms, and to organize the information into hierarchical categories based on similarities within taxa and differences between taxa. Similar species are grouped into a genus; similar genera are grouped into a family; ...; similar phyla are grouped into a Kingdom.

Phylogenetics

- intent is to describe evolutionary relationships among taxa.

Starting with the data from systematics, we attempt to deduce which characteristics are most likely to reflect the evolutionary history of any group of organisms, such as a genus. Thus, a species is more closely related to other species in the same genus than to species of another genus. The basic difference between systematics and phylogenetics is that phylogenetics adds the assumption that evolution created the diversity of life forms on this planet.

Cladistics

- attempt to quantify the degree of similarity among taxa

The assumption added for cladistics is that the percentage dissimilarity of the genetic information between any two species is an estimate of the evolutionary separation between the two species.

Works cited

Gould, S. J. *Ever Since Darwin, Reflections in Natural History*. New York: W. W. Norton & Co., 1977: 232.

Mayr, E. *Principles of Systemic Zoology*. New York: McGraw-Hill Book Co., 1969.

Whittaker, R. H. "New Concepts of Kingdoms of Organisms." Science Vol. 163 (1969): 150-160.