



SYSTEMATICS
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SYSTEMATICS

The ultimate objective of BIOLOGY is to understand the world. SYSTEMATICS is the study of the natural world in terms of its biodiversity, the variety of life on Earth and the interdependence among all living things.

When the STUDY OF THE *DIVERSITY* OF LIFE is viewed through the lens of the theory of EVOLUTION, it becomes equivalent to the STUDY OF THE *HISTORY* OF LIFE.

ASKING QUESTIONS IN SYSTEMATICS:

Questions in systematics are asked in the framework of the variables

FORM - TIME - SPACE:

1 - FORM. To consider FORM we ask questions to determine the DIFFERENTIATION of organisms based on similarities and differences. For example, when we study a new fish we observe its characteristics, we describe it in detail, and we compare it with other fishes so we can differentiate it from others.

2 - TIME. We look at TIME to study the phylogenetic (evolutionary) history of organisms. In other words, we look at the relationships between organisms to try to define how closely the taxa are related.

3- SPACE. To look at SPACE variables in our systematics study, we incorporate data on geographic distribution. This kind of study is called BIOGEOGRAPHY, or the geography of life.

SOURCE OF DATA

The basic data for our study in systematics is provided by the morphological attributes (CHARACTERS) and the geographic distribution of living and fossil fishes. However, the mere compilation of data, no matter how highly ordered, is not enough to help us understand the world. We need to develop a terminology that will allow us to communicate and record what we find. TAXONOMY is the area of SYSTEMATICS that comprises the theory and practice of describing the diversity of organisms and expressing this diversity in the precise language of DESCRIPTION and CLASSIFICATION.

TAXON

A note before we continue: When we refer to a TAXON (plural: TAXA), we are referring to any named group of two or more organisms, i.e., it can be at any level within the classification system.

For example: The carp and the minnow are both members of Cyprinidae, a taxon at the level of family. The carp belongs to the genus *Cyprinus*, and the minnow to the genus *Notropis*, therefore the two fishes are different taxa at the level of genus.

These are initial definitions of these concepts. As you read, these will be defined and explained further.

HOW SHOULD WE NAME AND RANK GROUPS IN A CLASSIFICATION SYSTEM?

NOMENCLATURE (nomen = name)

We said previously that, according to cladistics, CLASSIFICATION is demonstrated by the relationship between the groups in the taxa shown in the cladogram. Next we will translate these groups into a system of names. The system we use was proposed in the 18th century by Carl Linné. Linné latinized his own name to Carolus Linnaeus. He conceived the biological system as a hierarchy with specified CATEGORIES or RANKS to accommodate groups of organisms. When Linnaeus developed this system of classification, the theory of evolution had not yet been proposed. However, the idea of a hierarchy is consistent with an observable fact: It's possible to arrange organisms in groups of increasing inclusiveness, a fact that had already been noted by the ancient

Greeks. In this system, each group, or taxon, has a unique name and a specified rank. The traditional categories used in Linnaean classification are:

Kingdom - Phylum - Class - Order - Family- Genus - Species

Each categorical rank includes the preceding rank. For instance, kingdom includes many phyla while family is subordinate to order, order to class, and so on. The hierarchy could be also interpreted as an inclusion relationship using a Venn diagram (see the example below).

If we consider the example of the shark, the salmon, and the lizard, we can classify them in the following way according to the Linnaean classification system:

Superclass Gnathostomata (jawed fishes, which surprisingly, include ourselves and all other tetrapods [see below])

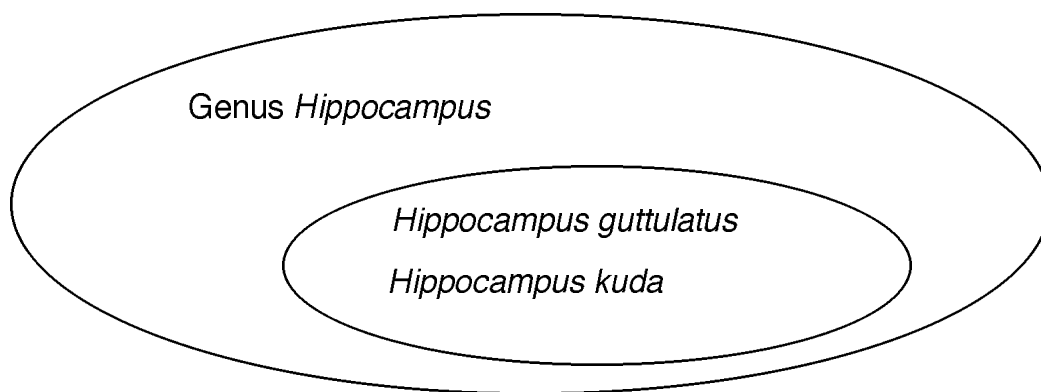
Class Chondrichthyes (including cartilaginous fishes like the shark)

Grade Teleostomi

Class Sarcopterygii (including Tetrapoda like the lizard)

Class Actinopterygii (including fishes like the salmon)

Let's take another example: the genus of the seahorse is *Hippocampus*. Among the seahorses commonly kept by enthusiasts we find two species: *Hippocampus guttulatus* (common seahorse) and *Hippocampus kuda* (golden seahorse).



Note: According to convention, the names of genus and species are always either written in italics or underlined.

Now let's stop for a while to talk about three concepts we have just introduced: CHARACTERS - DIFFERENTIATION - CLASSIFICATION.

CHARACTERS

- If SYSTEMATICS is the DOOR to the world's biodiversity, CHARACTERS are the KEY we use to unlock that door.
- CHARACTERS are the ATTRIBUTES or FEATURES we find in species.
- Systematists use different types of characters. Here are some examples relevant to fishes:
 - 1- **Morphological characters**
 - 2- **Molecular data**: DNA sequences
 - 3- **Biochemical data**: allozymes, enzymes
 - 4- **Ecology**: modes of life
 - 5- **Behavior**: reproductive patterns
- **Morphological characters** include the structural attributes of individuals. These often give us the first clue to the similarities and differences between taxa. In ichthyology we specifically use four kinds of morphological characters:
 - **Meristic characters**: These are characters that can be counted, e.g., number of teeth, number of scales or plates, number of fin rays.
 - **Morphometric characters**: Characters that can be measured, e.g., standard length, eye diameter, fin length, body depth, head width, etc.
 - **Anatomical characters**: These include characters of the skeleton (osteology), muscles (myology), nerves, etc.
 - **Color pattern**.
- During this course, we will focus on **morphological** characters. Here's an example of how to use morphological characters to define organisms: You want to differentiate a dog from a cat. You know of course, how to recognize one from the other, but let's do it using words. Make a list of characters useful for comparison, such as body shape, color, leg length, tail, hair, teeth, toes, etc. These characters show differences, for instance, the color gray versus the color brown.

FORM - DIFFERENTIATION

The basic SKILLS we use in science to study organisms and to find useful characters in the classification process are OBSERVATION and DESCRIPTION.

Sometimes, this is the main objective of a project. Let's say we want to publish an identification key, or dichotomous key, to the fishes of a pond near New York that will allow fishermen and naturalists to identify fishes on their own. We sample the pond and catch three different species: A, B, and C. We've seen them before and recognize them. We are able to DIFFERENTIATE between these three species using external characters. This allows us to construct a table of characters.

	COLOR	SHAPE	EYE SIZE	SCALES
Species A	Gray	Elongate	Small	Absent
Species B	Green	Elongate	Large	Present
Species C	Gray	Flattened	Small	Present

This table becomes the basis for what we call an IDENTIFICATION KEY. The reader chooses between a series of two oppositional statements. Each statement directs the reader to the next step. The reader follows the key until the eventual identification of the specimen at hand. Using this example, let's construct a key:

1. Body color gray _____ Go to number 2.
 Body color green _____ Your fish is Species B.
2. Body shape elongate and without scales _____ Your fish is Species A.
 Body shape flattened, scales present _____ Your fish is Species C.

Now, along comes our fisherman, after a day's fishing, with both fish and identification guide. He consults the key and finds that the first couplet is about body color. His fish is gray, so he is directed to couplet 2. He reads the two statements, matching his specimen against them. His fish is flattened with scales, so he knows the fish is Species C.

Differentiation helps us learn about characters, how and what to observe. It trains us to compare individuals, and to detect the similarities and differences between them.

ASSIGNMENT

Construct an alternative key to these species using the information in the table above. Post your key in the Forum.

TO CLASSIFY means to group similar things.

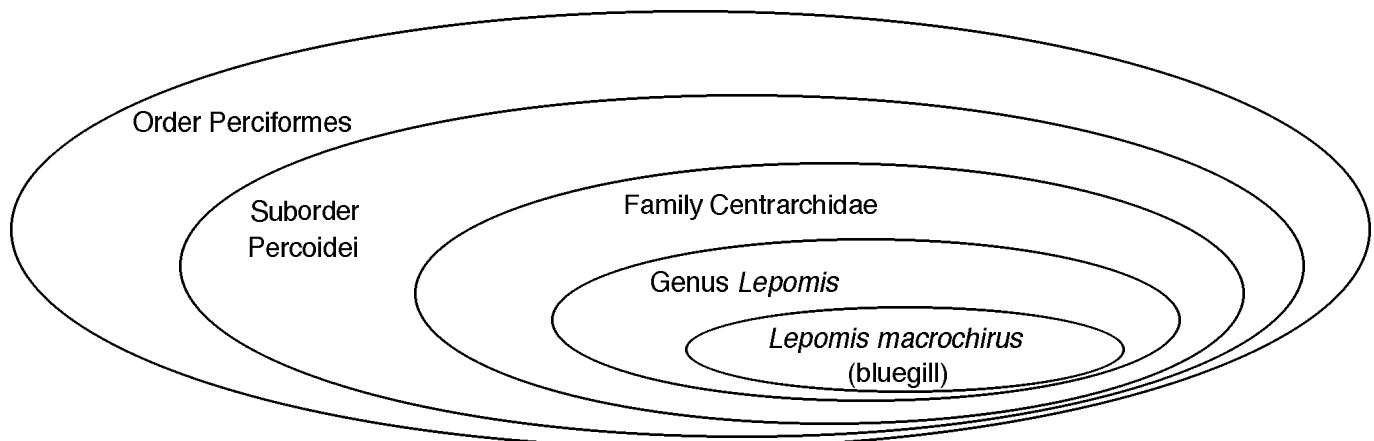
We do this all the time with such things as foods, clothes, dogs, and people.

Now, let's figure out a new "virtual" project. This time let's look at some fish species of the family Centrarchidae. Our objective is to classify them. But what do we mean by classification?

CLASSIFICATION

Systematists classify organisms according to BIOLOGICAL CLASSIFICATION. As you're no doubt aware, this is a biological system of named groups and subgroups consisting of various kinds of organisms. Biological classification allows us to identify and differentiate different kinds of organisms so that ultimately, through the classification of organisms, we can discern patterns in the natural world.

A main feature of BIOLOGICAL CLASSIFICATION is the HIERARCHICAL ranking of groups: We can think of a CLASSIFICATION as a way of organizing taxa within groups and then organizing these groups within further groups. Most classifications take the form of Linnaean hierarchies, with the relative positions of groups and subgroups being tagged with a Linnaean rank -- phylum, family, genus, etc. Such classifications can also be represented graphically, using a branching structure (a cladogram), or a Venn diagram (see the example below). Let's take as an example the bluegill, a species of sunfishes:



When we classify, the basic questions we ask are:

- 1. WHAT GROUPS SHOULD WE RECOGNIZE?**
- 2. HOW SHOULD THESE GROUPS BE SUBDIVIDED?**
- 3. WHAT NAMES AND RANKS SHOULD WE GIVE THE GROUPS AND SUBGROUPS?**

And the answers to these questions are:

WHAT GROUPS SHOULD WE RECOGNIZE IN THE CLASSIFICATION? HOW SHOULD THESE GROUPS BE SUBDIVIDED?

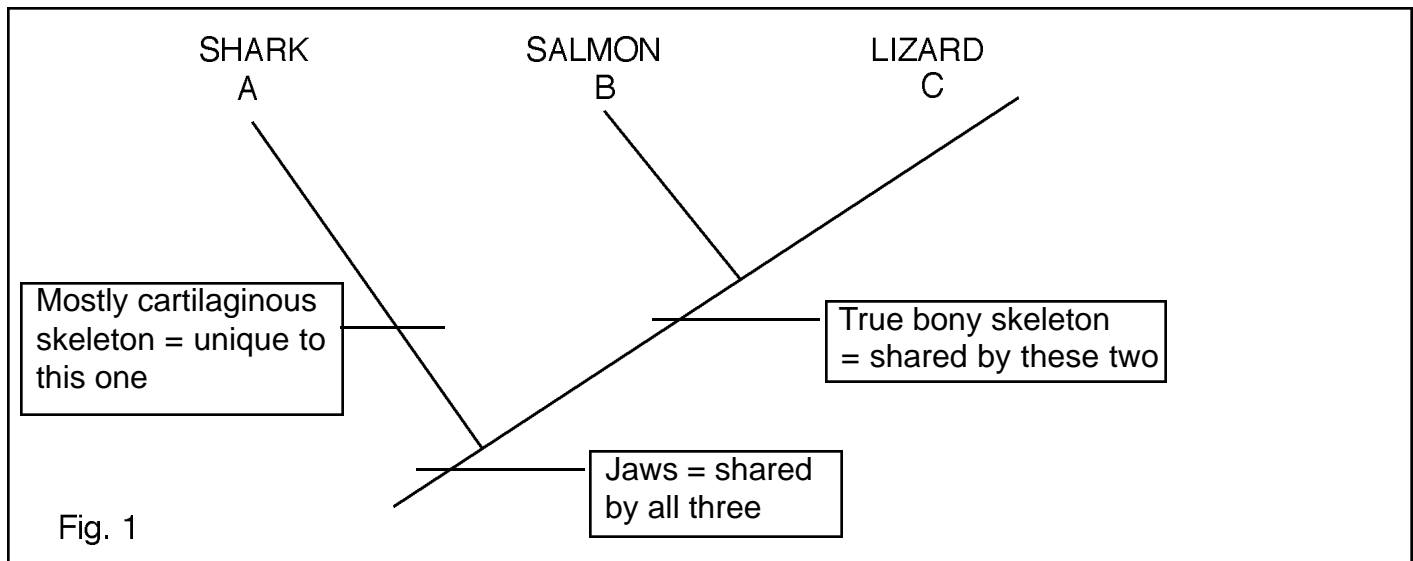
TIME - CLADISTICS

- The discipline of systematics attempts to understand the diversity of the living world.
- Biological diversity is the product of EVOLUTION and TIME; therefore it has a history.
- Systematists propose that the best way to describe such diversity is through classifications reflecting that history.
- Therefore, the GROUPS that a classification recognizes should be NATURAL GROUPS, i.e., groups of organisms that exist in nature as a result of evolution.
- The method consists of attempting to discover relationships of common ancestry indirectly through finding evidence in the form of shared characters.
- This kind of systematics is called PHYLOGENETIC SYSTEMATICS and the method itself is called CLADISTICS.

WHAT IS THE BASIS OF THE CLADISTIC METHOD?

Cladistics is one classification method. The main idea of this method is to group taxa based on shared derived characters, or synapomorphies (“syn” = same/shared, “morph” = shape), shared by organisms within the taxa. Therefore, let’s propose the hypothesis that taxa share derived characters because they have a common ancestor from whom they inherited those derived characters. The group, composed of the two taxa that share the derived character/s, plus their hypothetical common ancestor, is called a MONOPHYLETIC GROUP (from *mono*, single, *phyletic*, lineage). Monophyletic groups are the basis for classification in cladistics. We can say, therefore, that these are natural classifications that reflect the history of the taxon.

Let's look at the following example, a branching diagram, called a cladogram. It shows the phylogenetical relationships of three taxa: shark, salmon and lizard.



Following our train of thought, we can “read” the cladogram as follows:

If we look at the taxa shown in this branching diagram, the salmon and the lizard are more closely related to each other than either is to the shark, because they share the presence of the character “true bony skeleton.” We hypothesize that this character originated in their common ancestor. This character is not shared with the shark. Similarly, the shark is more closely related to the group [salmon and lizard] because the shark, salmon, and lizard all share the character “presence of jaws,” which originated in a common ancestor.

Here's where fishes fall in the Linnaean hierarchy:

Kingdom Animalia	This category includes all animals.
Phylum Chordata	This category corresponds to all those animals that are chordates, i.e., they share the advanced character “presence of notochord” (the precedent of the backbone).
Subphylum Vertebrata	This category corresponds to the subgroup of chordates that share the character “presence of skeleton” (vertebrates).
Superclass Gnathostomata	This category corresponds to the group that includes all vertebrates that share the character “presence of jaws” (jawed vertebrates).
Grade Teleostomi or Osteichthyes	This category corresponds to the subgroup among jawed fishes with the shared advanced character “presence of a true bony skeleton” (bony fishes).

The use of the Linnaean hierarchy is a convention; in fact, other methods have been proposed. However, the Linnaean system has allowed systematists to “talk” to each other across the centuries and transcend barriers created by language.

SPACE - BIOGEOGRAPHY

Organisms exhibit particular distribution patterns over the surface of the earth.

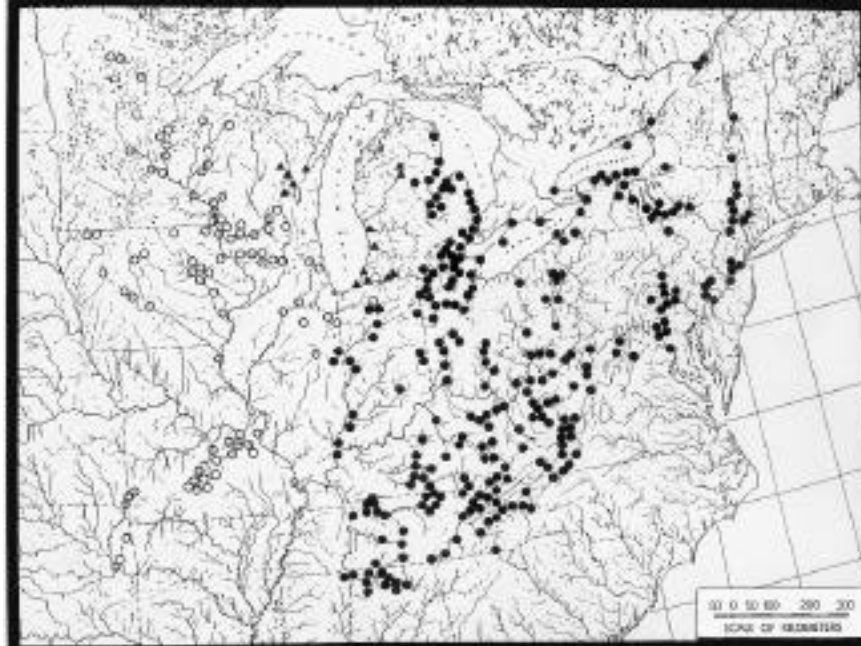
The BASIC QUESTION that biogeographers ask is:

“WHAT LIVES WHERE AND WHY?”

Again, this is a kind of detective question:

1) The “WHAT LIVES WHERE” part of the question involves sampling, i.e., taking samples in the field. It also involves careful note-taking in order to record and describe where the species were collected in order to be able to identify them. This is a part of the work of systematists that we’ve already discussed. The “WHAT LIVES WHERE” part of the job can also be accomplished by examining specimens from museum collections. In other words, we can use specimens collected by other people. Examining museum material is particularly important when the distribution of the studied species has changed over time. Museum specimens provide a record of past species distribution. They include the name of the collector, the date on which the specimen was collected, all locality details, and any other relevant information. In either case, we need to identify and check the place where the specimen was collected in a species distribution map.

Examine the following example - a distribution map that shows two subspecies of *Notropis spilopterus*, a species of minnow, from a research project in which the goal was to check the geographic variation of that species.



2) In the “WHY” part of the question, we try to determine the CAUSES and EXPLANATIONS of the present distribution. However, as with the phylogenetic history of the taxa, these causes are part of the history. We can only reconstruct them based on clues and indirect evidence, and then propose hypotheses.

The ANSWER to the “WHY” involves two main factors:

- ECOLOGICAL FACTORS. Distribution is determined by ecological variables. In the example of fishes, these variables include water temperature and salinity. Such factors usually have an influence on the movement of organisms. This results in DISPERSAL of a species. While we can't prove that dispersal occurred, we can't deny it, either. Especially when it's a contemporary phenomenon that we can observe ourselves, such as the increased distribution of an exotic species like the carp when introduced into a new environment.

- HISTORICAL FACTORS. To determine these, we need to consider the history of the Earth. Do you remember the example of the population of Species A that was subdivided into two species by the formation of a mountain chain? And then a second mountain formation again changed the distribution pattern? This is an example of a distribution caused by historical

factors. In this case, our hypothesis of phylogenetic relationships can help us propose an hypothesis of the relationships between the distribution areas, which in turn can be tested by applying the phylogenetic relationship hypothesis to other organisms (insects, plants, different groups of fishes, etc.).

Let's review some of the concepts we've learned this week:

- **SYSTEMATICS**

- ASKING QUESTIONS IN SYSTEMATICS: **FORM - TIME - SPACE**

- SOURCE OF DATA

- **CHARACTERS**

- FORM - **DIFFERENTIATION**: OBSERVATION and DESCRIPTION

- **CLASSIFICATION**: ASKING QUESTIONS.

- WHAT GROUPS SHOULD BE RECOGNIZED IN THE CLASSIFICATION? HOW SHOULD THEY BE SUBDIVIDED? TIME - **CLADISTICS**

- WHAT NAMES AND RANKS SHOULD THE GROUPS AND SUBGROUPS HAVE IN THE CLASSIFICATION? **NOMENCLATURE**

- SPACE - **BIOGEOGRAPHY**