Principles of Systematics

Systematics: *The Science of Biodiversity*

G.G. Simpson (1961): The scientific study of the kinds and diversity of organisms, and of the relationships among them

Stace (1989): The science & description of the variation or organisms, the investigation of the causes & consequences of this variation, and the manipulation of data obtained to produce a system of classification

Mayr & Ashlock (1991): The science of dealing with the diversity of organisms

Judd et al. (2002): The science of organismal diversity, particularly to:

- discover all the branches of the evolutionary tree of life
- document all the changes that have occurred during the evolution of these branches
- describe all species (the "tips" of these branches)

Goals of Systematics

1. **Classification:** grouping organisms
2. **Nomenclature:** naming organisms & their groups
3. **Identification:** determining the identity of a classified, named organism
4. **Inventory:** checklists, floras, faunas
5. **Phylogeny & Evolution:** evolutionary history, biogeography, etc.

For many, "Taxonomy" = Systematics (1-5).
For others, "Taxonomy" = 1-4, but does not include Phylogeny and Evolution

Note: Many people confuse Classification, Nomenclature, & Identification.
They are related, but not the same.

I. Classification

Organization of organisms into a logical system of categories

Involves: 1. Recognizing groups of organisms

2. Organizing smaller groups into larger groups (=ranking & hierarchy)

E.g.: grouping individuals or populations into a species

grouping related/similar species into a genus

grouping related/similar genera into a family

Aside: "Rank-free" classifications have been proposed (e.g., the Phylocode) -- recognizing only "clades" (lineages), but the rationale for these often confuses classification & nomenclature

A. Approaches to Classification

1. Early Approaches: Artificial Classifications

Tend to be “top-down” (classify by dividing)

Andrea Cesalpino (1583), *De Plantis*
--divided all plants into Trees vs. Herbs

This approach...

united plants we now consider unrelated:		while separating them from obvious relatives:
conifers		
legumes (woody)	→	legumes (herbaceous)
capers	→	mustards
euphorbs (woody)	→	euphorbs (herbaceous)

Carolus Linnaeus (1735), Sexual System in *Systema Naturae*

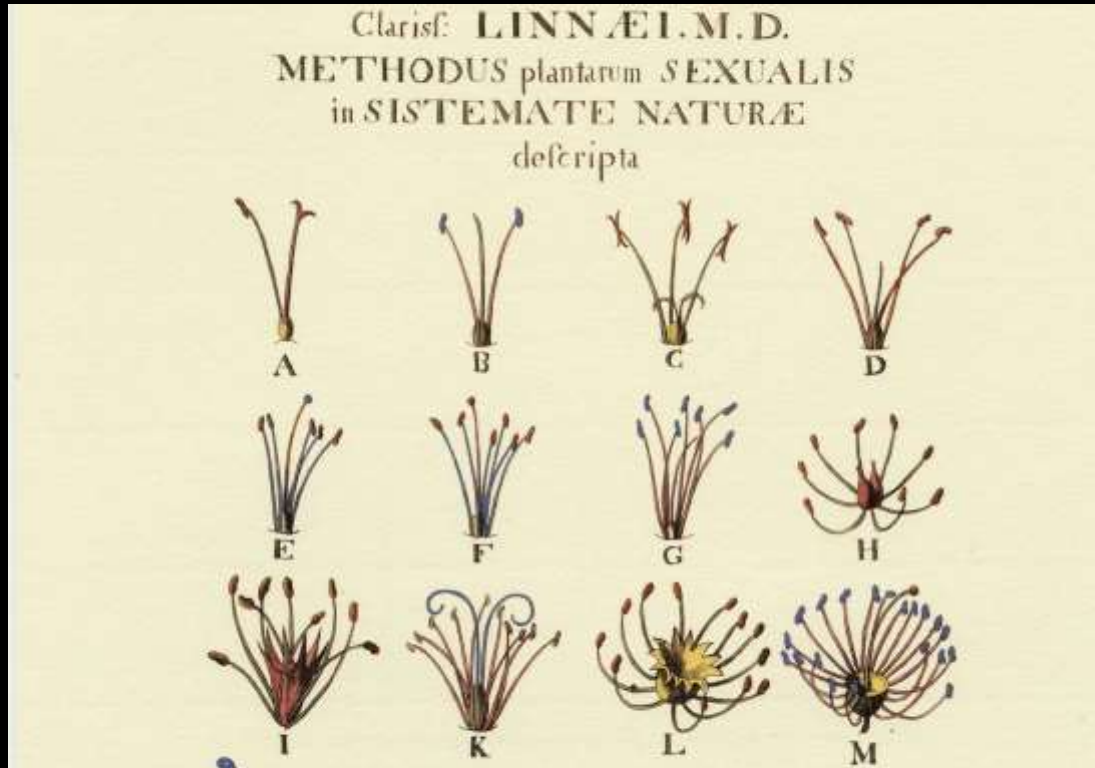
Divided all plants first by the number of stamens:

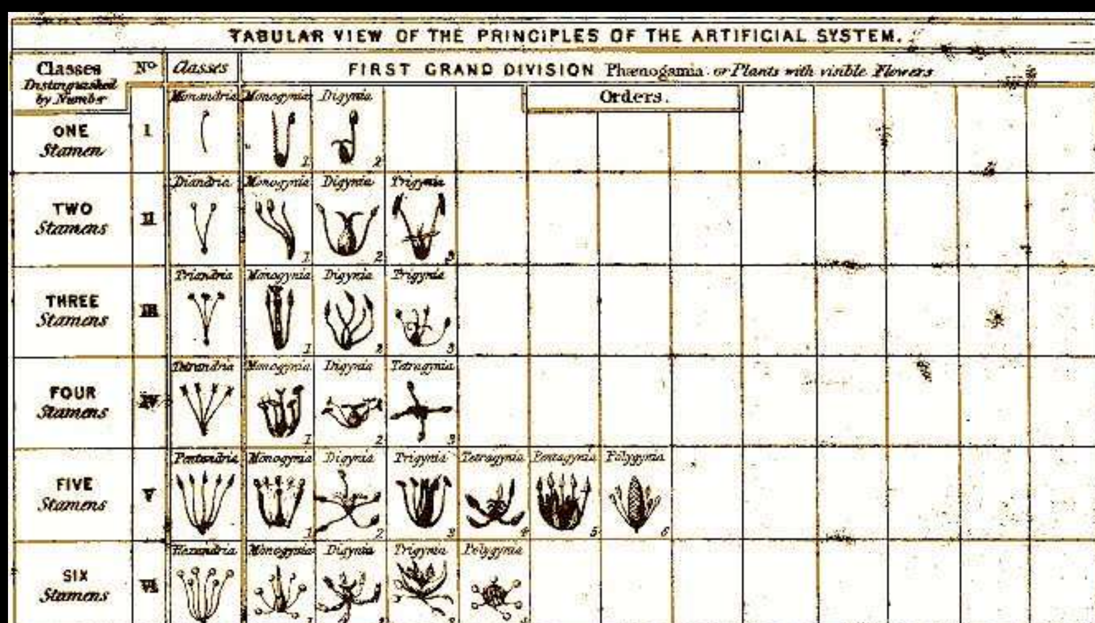
- **Monadria**
  - **Monogynia**
  - **Digynia**
  - **Trigynia**
  - ***etc.***
- **Diandria**
- **Triandria**
- **...**
- **Dodecandria**
- ***etc.***

Then, within each group, by the number of pistils

Again, unrelated groups were united, and closely related groups were separated.

Artificial systems are appealing because they are easy to use, but are better as <u>identification</u> tools than for classification.





TABULAR VIEW OF THE PRINCIPLES OF THE ARTIFICIAL SYSTEM.

Classes Distinguished by Number	No	Classes	FIRST GRAND DIVISION Phænogamia or Plants with visible Flowers					
			Orders.					
ONE Stamen	I	Monandria	Monogynia	Digynia				
TWO Stamens	II	Diandria	Monogynia	Digynia	Trigynia			
THREE Stamens	III	Triandria	Monogynia	Digynia	Trigynia			
FOUR Stamens	IV	Tetrandria	Monogynia	Digynia	Tetragynia			
FIVE Stamens	V	Pentandria	Monogynia	Digynia	Trigynia	Tetragynia	Pentagynia	Polygynia
SIX Stamens	VI	Hexandria	Monogynia	Digynia	Trigynia	Polygynia		

2. Later Approaches: Natural Classifications

"natural" can have different meanings:

--rational
--predictive
--evolutionary ← the way we use it today (nature reflects evolution)
--*etc.*

Tend to be "bottom-up" (classify by grouping, not dividing)

typically use several to many characters (not just 1) to identify groups

smaller groups then organized into larger (more inclusive) groups by same method

John Ray (1690),
Synopsis Methodica Stirpium Britannicum
= an early example

Predictive value of Natural Systems:

- when a classification system reflects "natural" relationships (esp. evolutionary relationships), you may **predict** that characters found in one species may also be found in a closely related species.

  E.g., --developmental characters
  --anatomical characters (fibers, etc.)
  --morphological characters
  --biochemical characters (e.g., medicines)

Ranks & Hierarchical Classification

- By organizing millions & millions of species into ever more inclusive groups, we provide fewer categories to learn, making it easier to communicate

  Entomologists discuss "orders" { Diptera (flies), Coleoptera (beetles), Lepidoptera (moths) }

  Vertebrate zoologists & botanists discuss "families" { Corvidae (crows), Fabaceae (legumes) }

The "Linnaean Hierarchy"

Linnaeus also devised the system used to group & "rank" organisms

The 7 principle ranks:

- **Kingdom**
- **Phylum** or **Division**
- **Class**
- **Order**
- **Family**
- **Genus** [Genera]
- **Species** [Species]

Same rank, but "phylum" used for animals . . .

. . . and "division" is used for plants

Are ranks "real"?

Debate as to whether ranks are "natural (=real) entities", or merely "human abstractions"

Most taxonomists admit that higher ranks are ± arbitrary

e.g., say you have 20 species:

= ± arbitrary decisions, as long as they reflect evolutionary relationships

- **system 1:** 2 genera (5 spp. + 15 spp.)
- **system 2:** 4 genera (5 spp. + 10 + 2 + 3 spp.)
- **system 3:** 20 genera (each with 1 species)

Whether "species" are "real" (and how to define them) is hotly debated among biologist, but most taxonomists argue they are real

<u>Species concepts</u>: Defining a "species" is highly controversial, despite the central role this concept plays in biology (more later)

B. Methods of Classification

1. The "Traditional" School

Often described as:

eclectic: use a variety of methods, characters, definitions

intuitive: reliance on the taxonomist's...

...perception of the "*gestalt*" of the organisms

...brain power to perceive complex patterns
to determine relationships

...use of selective weighting of characters
(different characters are "important", or not,
at different ranks & among different organisms)

Not especially objective (or repeatable by other researchers)

Yet rather successful: when results are compared to
modern methods, many groups confirmed

2. The Evolutionary School

Originated in the early-20th C. "New Synthesis"

combining *Darwin's evolution* by natural selection with *Mendel's genetics*, along with *Paleantology* (which helped to interpret character homology)

Two steps:

a. Establish "classes" (species, genera, etc.) according to similarity

b. Test these classes for "monophyly" (=relationship through common descent) and remove any members that do not conform to monophyly

Example:

a. Group all reptiles lacking legs into one "class"

--but this includes snakes *plus legless lizards*

b. Remove legless lizards because they share a common ancestor with 4-legged lizards, not snakes

3. Phenetics & Numerical Taxonomy

a. Phenetics: Any approach that emphasizes similarities in the phenotype

Thus, overall similarities are the basis of classification

No attempt to reconstruct evolutionary history

"Taxa" are defined not as "evolutionary lineages", but instead the distribution of as many features as possible among organisms

Rationale:

The "true" evolutionary history (=phylogeny) is unknowable (& untestable)

Thus, it's better to build a classification system based in overall similarity, which is knowable (& testable)

b. Numerical Taxonomy: A phentic approach developed by Sokal & Sneath (1973), *Principles of Numerical Taxonomy*


Robert Sokal


Peter Sneath

Abandons concepts of:

b/c these are "subjective" notions

- --homology
- --character weighting
- --species definitions/concepts
- --phylogeny

Replaces these with "objective" notions:

1. Avoid controversial definitions (e.g., "species"); simply code terminal unit as "OTU" (operational taxonomic unit)

2. Characters are recorded (scored) at "face value", with no interpretation as to homology with other characters or the evolution of the character

reliance on <u>many</u> characters led to development of sophisticated algorithms (early proponents of computers)

3. Use as many characters as possible (avoid 1-character taxonomies) -- the many "good" characters will swamp out the few misinterpreted characters

4. Construct "phenograms" or "cluster diagrams" depicting groups of OTUs that are most similar (avoid "subjective" interpretations such as "phylogeny" and "lineage")

4. Cladistics (Phylogenetic Systematics)

Willi Hennig (1950), *Phylogenetic Systematics*

Classification should reflect evolutionary relationships

To accomplish this, the taxonomist should try to reconstruct the actual branching patterns of evolution (*clados* = branch)

To build "cladograms" (phylogenetic trees):

a. Define characters and establish homologies among terminals (taxa)

b. Arrange branches of the tree in such as way as to minimize the number of changes (=parsimony)

c. Taxa are defined on the basis of "synapomorphies" (=shared, derived characters); only derived characters (not ancestral characters) are useful for defining groups

d. Only "monophyletic" groups should be accepted (and monophyly is defined more strictly here)

much more about this later

C. Stages of Classification

- classification is a gradual, continual process (often = many years)
- usually focused on a single group at a time

alpha taxonomy	1. Exploratory stage	initial field collections preliminary classification
	2. Systematic Stage	carry out extensive field & museum studies
omega taxonomy	3. Biosystematic Stage	detailed studies of genetics, cytology, morphology, anatomy, breeding, etc.
	4. Encyclopedic Stage	data from a wide range of disciplines assembled to form a good, predictive, natural classification

alpha taxonomy: based solely on obvious, external morphology, etc.

omega taxonomy: ultimate, perfected system based on all available sources of characters (often not attainable)

D. Types of Classification Publications

1. Broad "Systems" of Classification

Deals with very large groups (angiosperms, bivalves, birds)

- Linneaus (1753), *Systema Natura*
- Cronquist (1981), *Integrated System...*
- APG (Angiosperm phylogeny group) System (1998–2016)

2. Monographs

A comprehensive study of all taxonomic data in some group (usu. smaller groups, such as a family or genus)

Integrates all former research on a group with original research by the author:

- history of classification
- complete list of synonyms
- geographic variation
- geographic distribution
- maps
- keys
- morphology
- anatomy
- ecology
- cytology
- phylogeny
- *etc.*

Difficult to achieve this level of comprehensive depth (not too many "true" monographs)

3. Revisions

Similar in scope to a Monograph, but not as comprehensive

Usually less historical background

Often focuses on taxonomy (with less depth in ecology, geography, *etc.*)

Often includes:

- Some background
- Keys for Identification
- Complete or abbreviated synonomies
- Morphological descriptions
- Phenology
- Maps & Illustrations

II. Nomenclature: *The study and system of naming organisms*

nomen = name
calare = to call

Latin for "to call by name"

- Involves the system of RULES by which names are applied, and from which you can interpret the correct (or incorrect) application of names
- The rules for different organisms are covered by different "codes":

  ICN: International Code of Nomeclature for algae, fungi and plants — *We'll stress this*

  ICNCP: International Code of Nomeclature for Cultivated Plants

  ICZN: International Code of Zoological Nomeclature

  ICNB: International Code of Nomeclature for Bacteria

- Nomenclature is distinct from classification*!*

  Application/rejection of a NAME does not imply the acceptance/rejection of any particular taxon concept

A. Guiding Principles of the Codes

1. Uniqueness

a. Each taxon should have only 1 name

If a taxon should get 2 names (b/c different authors gave it a name twice, or by lumping 2 spp. into 1), the codes provide a mechanism to determine which is correct

b. Each name should be applied to only 1 taxon

If the same name should be applied to different organisms, the codes provide a mechanism to determine which needs to be renamed

2. Universality

The same name is used, regardless of culture, country, language

LATIN is used as the universal language

ROMAN characters are used (even if the rest of the publication is in Greek, Cyrillic, Chinese, *etc.*)

сѣянными волосками. Вѣтви супротивныя, кончающіяся колючкою. Почки съ чешуйками. Цв. (желтовато-) зеленоватые, однополые, двудомные (рѣже многобрачные); чшл., лп. и тч. по 4; лп. безъ ноготковъ; столбикъ 4 (2)-раздѣльный. Пл. черный на нѣсколько выпукломъ днѣ чш., о 4, рѣже 5 косточкахъ. Кустарникъ или деревце. ♄. 150—300.

R. cathártica L., К. слабительная (Жестеръ).

Май—іюнь. Во всѣхъ черноз. и степн. мѣстн. оч. обыкн. по куст., склон. и опушк., къ с. отъ границы черноз. рѣже, по сух. склон., б. ч. на навестн.; въ самыхъ с. губ. видно, кажется, не встрѣч. Не указ. для Яр., Ко. Лѣкарств. Пл. ядов. (сильно слабит.).

о. Л. очередные, эллиптическіе, острые, почти или совершенно цѣльно-крайніе, съ обѣихъ сторонъ срединнаго нерва съ 6—8 косыми, параллельными жилками, снизу вдоль жилокъ съ волосками. Вѣтви кверху (какъ чрш. и цвтн.) волосистыя, безъ колючекъ. Почки безъ чешуекъ. Цв. обоеполые. Чшл., лп. и тч. по 5; лп. съ ноготкомъ, съ внутренней стороны бѣлые, снаружи зеленоватые; столбикъ цѣльный съ головчатымъ рыльцемъ. Пл. на плоскомъ днѣ чш., сначала красные, зрѣлые—черные, о 2—3 косточкахъ. ♄. 150—300.

R. Frángula L. (Frangula Alnus Mill.), К. ломкая.

Май—іюнь. По лѣс. и куст., всюду оч. обыкн. Б. ч. кустарникъ, рѣже деревце. Лѣкарств. (кора).

Сем. XXIV. Papilionáceae L., Мотыльковыя.

1. Л. цѣльные. Цв. золотисто-желтые, довольно крупные; чш. двугубая, верхняя губа до основанія 2-раздѣльная, нижняя о 3 зубчикахъ; лодочка тупая; тч. однобратственныя; столбикъ шиловидный, восходящій (согнутый къ оси цв.); рыльце конечное, косвенно сидящее, обращенное къ оси цв. Пл. 1-гнѣздный, продолговатый или линейно-продолговатый. Невысокіе кустарнички — Дрокъ, **Genista L.**—97.

о. Л. сложные (иногда нижніе л. простые, но при этомъ желтые цв. собраны въ головку съ обверткою изъ пальчато-раздѣльныхъ л.) — 2

2. Л. тройные (какъ у клевера) или о 5 листочкахъ, пальчато-расположенныхъ — 3

о. Л. перистые, объ 1 парѣ листочковъ или о нѣсколькихъ (многихъ) парахъ, съ усиками или безъ усиковъ — 9

3. Р. б. ч. вьющіяся, съ довольно крупными цв., собранными въ пазушныя кисти и расположенными въ нихъ попарно. Чш. 2-губая, верхняя губа о 2, нижняя о 3 зубчикахъ; флагъ съ 2 придатками; столбикъ въ верхней части бородатый, завитой вмѣстѣ

36. 白花菜科 CAPPARIDACEAE

分属检索表

1. 草本，很少亚灌木或攀援植物 ······························ 2. 白花菜属 Cleome
1. 灌木或乔木。
   2. 叶为单叶 ······························ 1. 山柑属 Capparis
   2. 叶为掌状复叶，有小叶 3 片 ······························ 3. 鱼木属 Crateva

1. 山柑属 Capparis L.

曲枝槌果藤（青皮刺、公须花）

Capparis sepiaria L., Syst. Nat. ed. 10, 2: 1071. 1759.

多枝灌木，有时攀援，高 0.6~1 m。小枝密被灰黄色柔毛，枝粗壮，"之"形弯曲，幼时被毛，后变无毛；刺粗壮，长 2~5 mm，尖利，外弯。叶坚草质或薄革质，长圆状椭圆形或长圆状卵形，长 2~5（7）cm，宽（0.8~）1~2（3.2）cm，顶端钝形或圆形，但常微缺，基部急尖至圆形，有时微心形，干后表面常呈浅灰绿色，表面无毛或早期变无毛，稍有光泽，背面至少在中脉上有宿存被毛，中脉表面平坦或近基部稍下沉，背面凸起，侧脉 4~6（9）对，纤细，网状脉不明显；叶柄长 3~6 mm，密被短柔毛。花小，白色，芳香，排成无总花梗的亚伞形或短总状花序，常着生在侧枝顶端，很少顶生，每花序上有花 (6) 10~22（25）朵；花梗纤细，长 8~20 mm，无毛；萼片卵形，长 3~5 mm，宽 3~4 mm，外轮草质，内凹，无毛；花瓣膜质，长圆状倒卵形，长 4~6 mm，宽 1.5~3 mm，或多或少被柔毛；雄蕊 25~45；雌蕊柄纤细，长 7~10（12）mm，常在近基部有短柔毛；子房卵球形，长约 1.5 mm；果球形，直径约 1 cm，干后呈暗褐色，表面平滑，果柄纤细。种子 1~4 粒。花期 4~6 月；果期 8~12 月。

产于北岭、南岭。生于近沟谷或灌丛中。分布于华南地区。自印度、斯里兰卡经热带东南亚直达澳大利亚都有。

用于海岸附近、旷野道旁、干燥缓坡及砂土地带绿化。

3. Stability

Strict adherence to the rules can sometimes cause changes to well established & widely used names

- **--can cause confusion**
- **--can hinder communication & info retrieval**

Thus, the codes provide mechanisms for *exceptions* to the rules when such exceptions promote stability

Typically in the form of "conserved" names that would otherwise be rejected by the rules (or a "rejected" name that would be accepted)

Ex. 1: Conserved Family Names

The ICN dictates certain endings for names at certain ranks, including *–aceae* for names at the rank of family

But these 8 families have older names that have been used since antiquity.

The code provides for an exception to used the non-standard names

Arecaceae →	Palmae
Brassicaceae →	Cruciferae
Clusiaceae →	Guttiferae
Fabaceae →	Leguminosae
Asteraceae →	Compositae
Lamiaceae →	Labiatae
Apiaceae →	Umbelliferae
Poaceae →	Gramineae

Ex. 2: Conserved Genus Names

a. *Pittosporum* Banks ex Gaertn. (1788)

The correct name for this genus should be *Tobira* Adans. (1763), acc. to the rules.

But many species were described originally as *Pittosporum*, and that genus formed the basis of the family name, “Pittosporaceae”

Therefore, an exception was approved to “conserve” *Pittosporum* against *Tobira*

b. Schefflera J.R. Forst. & G. Forst. (1775)

The correct name for this genus, as currently circumscribed, should be *Sciodaphyllum* P. Browne (1756), acc. to the rules

Because of the widespread use of *Schefflera,* an exception was approved to “conserve” it against *Sciodaphyllum*

For plants, these exceptions must be approved by an International Botanical Congress

4. Independence from Classification

The code provides the mechanisms for correctly applying names, but this has no bearing on taxon concepts

The codes do NOT tell a scientist which classification system to use (simply which name to use for a given system)

Ex.: the Order Apiales

Traditionally, this order is classified as having 2 families:

- Apiaceae Lindl. (1836)
- Araliaceae Juss. (1789)

But some taxonomists "lump" these 2 families.

In this case, the code dictates that Araliaceae must be used for this lumped family

The taxonomist is ***free*** to use ***either*** classification (1 family or 2), but ***if*** the 1-family system is used, it ***must*** be called Araliaceae.

B. Working Principles of the Codes

1. Ranks and the Formation of Names
2. The Type Method
3. The Principle of Priority

1. Ranks, Hierarchy, & Formation of Names

a. The 7 principle ranks *(to which others may be added)* with standard endings

Taxonomic Hierarchy

The seven principle ranks of the Linnaean hierarchy (**bold**), and other common intermediate ranks.

Taxonomic Rank	Standard Ending (ICN)	Standard Ending (ICZN)	Example: carrot
Kingdom	-----	-----	Plantae
Subkingdom	-bionta	-----	
Division/Phylum	**-ophyta** -mycota (fungi)	-----	Magnoliophyta
Subdivision/-phylum	-phytina	-----	
— / Superclass	(n/a)	-----	
Class	**-opsida** -phyceae/-mycetes	-----	Magnoliopsida
Subclass	-idea -phycidae/-mycetidae	-----	Rosidae
Superorder	-anae	-----	Cornanae
Order	**-ales**	-----	Araliales
Suborder	-ineae	-----	
— / Superfamily	(n/a)	-oidea	
Family	**-aceae**	**-idae**	Apiaceae
Subfamily	-oideae	-inae	Apioideae
Tribe	-eae	-ini	Dauceae
Subtribe	-inae	-----	Daucinae
Genus	-----	-----	*Daucus*
Subgenus	-----	-----	
Section (§) / —	-----	(n/a)	§ *Daucus*
Subsection / —	-----	(n/a)	
Species (sp.)	-----	-----	*Daucus carota*
Subspecies (ssp.)	-----	-----	*D. carota* ssp. *sativus*
Variety (var.) / —	-----	(n/a)	
Forma / —	-----	(n/a)	

b. Formation of Names

Above the rank of Genus: Latin *uninomials* (one name), technically plural adjectives, treated as nouns

Standardized endings denote rank

Araliaceae

Genus: Latin *uninomials* in the singular

Aralia

Below the rank of Genus: "Combinations" (2 or more names that must occur together)

Subgeneric ranks: must include the name of the genus, the rank name, and the "subgeneric epithet"

Costus subgenus *Metacostus*

Euphorbia section *Africanae*

Species names: Always a *BINOMIAL* combination formed by combining the name of the genus and the "specific epithet"

Homo sapiens
Apis mellifera
Apium graveolens

Infraspecific taxa: a *TRINOMIAL* combination formed by adding the "infraspecific epithet" to the species name

- ICZN: allows only subspecies

  Puma concolor coryi

- ICN allows for different ranks (subspecies, variety, form), so the rank must be indicated:

  Lobelia spicata var. *scaposa*

Tautonyms vs. Autonyms

ICZN allows the genus name and specific epithet (& even the subspecific epithet) to be identical:

=Tautonyms {
Bison bison
Apis apis apis

ICN does not allow tautonyms.

But, when a genus is subdivided into 2+ subgeneric groups, *or* a species is subdivided into 2+ infrageneric groups...

...then one of the subgeneric or infraspecific names is automatically established:

Costus subgenus *Metacostus*
Costus subgenus *Costus*

=Autonyms

Viola tricolor var. *hirta*
Viola tricolor var. *tricolor*

Autonyms are created automatically acc. to both INC and ICZN

Authors/Authorities

The name of the author who first published the name

ICZN: authorities are optional, and not part of the name

INC: authorities are required for all ranks from the Family and below, and form part of the name

Ex. 1: Simple cases

Family:	Rosaceae Juss. (=A.L. de Jussieu)
Genus:	*Rosa* L. (=Linnaeus)
Species:	*Rosa gallica* L.
Variety:	*Rosa gallica* L. var. *damascena* Voss
Variety: (autonym)	*Rosa gallica* L. var. *gallica*

Full authorities also include the Year and Place of publication:

Rosa gallica L., Sp. Pl. 1: 492. 1753.

In publications, after the full name is used the first time, the authority is usually omitted, & the genus name may be abbreviated (e.g., *R. gallica, E. coli, C. elegans*).

Ex. 2: More complex cases

actual author

a. ***Gossypium tomentosum* Nutt. ex Seem.**

“ex” means “from”, and indicates that the name originated in an informal way to Nuttall, but that he failed to validly publish it

Seemann was the first to vaildly publish it

…and thus the name may be simplified to *Gossypium tomentosum* Seem.

actual author

b. ***Viburnum ternatum* Rehder in Sargent**

Rehder was the actual author of the name, but it appeared in a publication from another author.

In this case, Sargent edited a series of books called “*Trees and Shrubs*”, but solicited additional authors to work on selected taxa.

May be simplified to *Viburnum ternatum* Rehder

Ex. 2: New Combinations ("combinatio nova")

Occur when a combination (such as a species name) is transferred from one taxon to another.

***Festuca bromoides* L.** = **a species named by Linnaeus**

But Samuel Gray transferred this species to the genus *Vulpia.*

Thus, the "new combination" (comb. nov.) is written:

***Vulpia bromoides* (L.) Gray**

author of basionym (→ (L.)) *author of comb. nov.* (→ Gray)

In creating the comb. nov., Gray <u>must</u> use the available specific epithet ("*bromoides*").

Here, *Festuca bromoides* L. serves as the BASIONYM, and Linnaeus' role in naming the basionym is recorded as (L.)

...while Gray's role in naming the new combination is recorded after the parentheses.

ICZN allows use of the basionym author, but does not require it; ICN requires it.

2. Establishing Names: The Type Method

All names, from rank of family & below, must have a nomenclatural type ("typus").

The type is an element to which the name is attached.

This name-bearing element is either:

- **a specimen — for the ranks of genus and below**

or

- **a taxon — for the ranks above genus**

a. The Type Specimen (for species and below)

= a single specimen; for plants, defined as:

- **a single herbarium sheet *(may incl. >1 plant, if small)***

If curated together:

- **several sheets, if they indicate parts of a whole *(e.g., sheet 1 of 3, 2 of 3, 3 of 3)***
- **a specimen with material preserved separately *(boxes of large cones/fruits, pickled materials),* if so labeled**

BUT not duplicate collections (*see later*)

For older types, other elements were allowed
(e.g., illustrations, seeds, wood)

For animals, materials such as skins, skeletons, pickled samples, etc., can serve as the type specimens

b. Holotypes and other kinds of types

There can be only 1 type specimen for any 1 name

Holotype: The single type specimen, designated by the author in the original publication

Isotypes: Duplicate collections of the holotype (must bear the same collection number, from the same date and locality)

Syntypes: Used for older names (before changes to ICN):

- If 2 or more specimens were listed as the "type"
- If 2 or more specimens were cited, but none were designated as the "type"

Paratypes: Other material (in addition to the type) listed by the author
(e.g., "other specimens examined" or "representative specimens")

Description of a new species showing types:

binomial combination (sp. nov.) with author

Latin description or diagnosis (no longer required)

Vernacular (English) description

Type specimen (holo- and iso-designated): Veillon 4031 A

Additiona material (=paratypes)

1. **Schefflera cabalionii** Lowry, *sp. nov.* — Fig. 1.

Arbores andromonoicae, foliis compositis digitatis, 35-75 cm longis; foliolis (5-)7-11 ellipticis ovatis, 12-28 × 6-11 cm, petiolo 20-42 cm longo, a lenticellis pustulosis ad basin instructo; stipula ligulata circa 2 cm longa. Inflorescentia, in umbella composita, ut videtur lateralis sed vero terminalis secundum gemmae axillaris excrescentiam; axibus secundariis circa 3-5 in longitudinem ad 10-12 cm aequans, umbellulis circa 12-16-floris, pedicellis 1.5-2 cm longis. Petala 5, elliptica ovata, 1.5-2 mm crassa, 7-9 mm longa. Stamina circa 250, in orbes circa 5. Ovarium, carpellis 10-12, a disco nectarifero profonde concavo-infundibuliforme superato; stylis nullis, stigmatibus bilabiatis in disco sessilibus. Fructus ellipsoido-urniformis, 3-3.5 × 1.8-2 cm, in sicco valde costato, a toro conspicuo dilatato, instructo.

Andromonoecious (?) trees. Leaves 35-75 cm long, leaflets (5-)7-11, subcoriaceous, elliptic-ovate, 12-28 × 6-11 cm, the primary vein slightly raised above, prominent beneath, the secondary veins ca. 20-40 per side, prominent above and beneath, curving slightly from the midvein and strongly arcuated towards the margin, those toward the apex sometimes curving back around to the adjacent vein, tertiary veins prominent, forming a dense network, the apex broadly acute to nearly obtuse and often somewhat acuminate, the margin entire, thickened and minutely revolute, the base attenuate; petiolules stout, 1.5-5 cm long; petiole stout, 20-42 cm long, the base clasping and enlarged, densely pustular lenticellate, the ligulate stipule ca. 2 cm long. Inflorescence a compound umbel, morphologically terminal, but probably appearing lateral (at least in fruit) due to retarded development and concurrent rapid extension growth of an adjacent axillary bud, erect to spreading, the primary axis very short (absent?), the secondary axes (peduncles) ca. 3-5, about 10-12 cm long at anthesis and in fruit, corticate lenticellate towards the base, pustular lenticellate at the top, umbellules with ca. 12-16 flowers, some of which may be functionally staminate, the rest hermaphroditic and presumably protandrous, the pedicels stout, short in bud, expanding to 1.5-1.8 cm long at anthesis, and to 2 cm in fruit, subtended by an involucel of ca. 7-9 stiff, early caducous, deltoid-lanceolate bractlets each ca. 3-5 mm long. Calyx very broadly cupuliform to nearly flat, the rim entire, thick, undulate. Corolla hemispheric to depressed ovoid in bud, with a slightly pointed apex, the petals 5, 1.5-2 mm thick, elliptic-ovate, 7-9 mm long. Stamens ca. 250 in hermaphroditic flower (mature staminate flowers unknown), in about 5 series, the filaments slender, ca. 3.5-4 mm long, the anthers narrowly oblong-elliptic, ca. 2.5 mm long, with 4 thecae. Ovary 10-12-carpellate, ca. 1.5 mm high and narrowly obconical at anthesis, surmounted by a deeply concave-funnelform nectar disk concealed by the stamens, styles wanting, the 10-12 narrowly elliptic, bilabiate stigmas sessile on the disk. Mature fruit ellipsoid-urniform, 3-3.5 cm high, 1.8-2 cm wide, strongly ribbed when dry, with the persistent calyx and scars of the petals and stamens forming an evident, flared collar around the enlarged disk.

TYPE: *Veillon 4031 "A"*, Vanuatu, Santo, crête direction Voutmele, 1200 m (holo-, P!; iso-, NOU!).

ADDITIONAL MATERIAL. — SANTO: Crête direction du Voutmele, 1350 m, *Veillon 4031 "B"* (NOU). Cumberland, entre rivière Piamégou et Piamaèto, 900-1200 m, *Cabalion 889* (PVNH); *901* (NOU, PVNH). Pialupup, 900 m, *Bourdy 317* (BISH, K, NOU, NSW, P, PVNH).

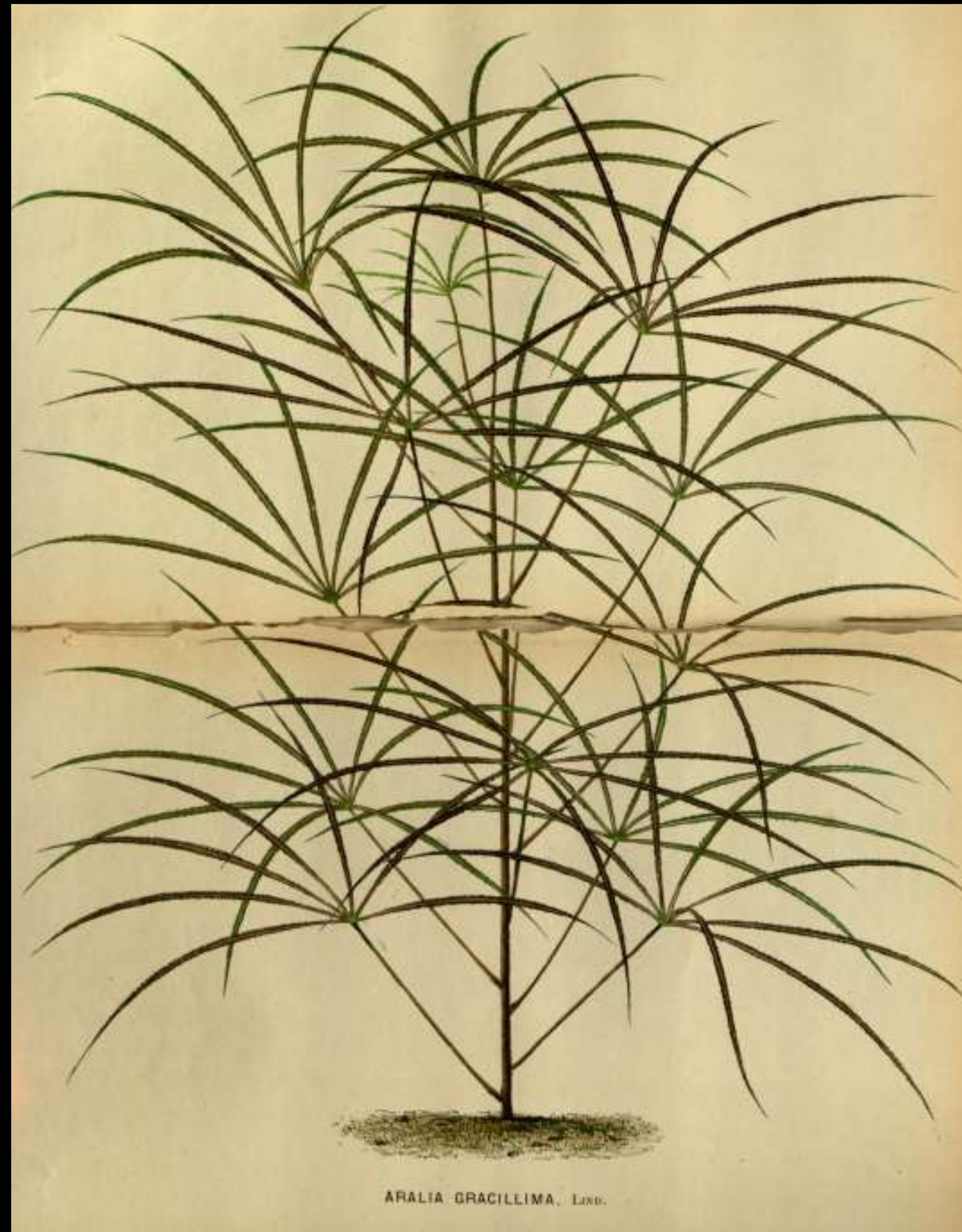
As noted above, *Schefflera cabalionii* is the first species belonging to the closely related group of taxa often treated under the segregate genus *Plerandra* to be collected in Vanuatu. It is easily distinguished from its Fijian relatives by its complete lack of styles and its deeply concave disk. The presence of approximately 250 stamens in the hermaphroditic flowers of *S. cabalionii* further separates it from most Fijian species; only *P. grayi* Seem. and *P. pickeringii* A. Gray (combinations in *Schefflera* to be made elsewhere) have as highly polymerous an androecium, but the former has much smaller fruits, while the latter has a highly evident, protracted stylopodium (SMITH & STONE, 1968; SMITH, 1985).

Digital image of the Holotype of the same species:

Type of

Aralia veitchii **Hort. ex Carrière var.** ***gracillima*** **Linden ex E. Fourn.**

(*L'Illustration Horticole.* 1876)



Illustrations are no longer generally allowed as types

c. What if there is no holotype?

...b/c author failed to designate one (older names)

...b/c holotype is missing/destroyed

In such cases, a new type can be designated

Lectotype: if material from original author is available, the new type can be chosen, in this order:

- Isotypes, if any (1st choice)
- Syntypes, if any (2nd choice)
- Paratypes, if any (last choice)

Neotype: if (and only if) a lectotype cannot be designated, material not noted by the original author can be designated

If the **holotype** is rediscovered, it supersedes the lectotype/neotype

If **original material** (iso-/syn-para-types) is rediscovered, a new lectotype can supersede a neotype

d. Types for Infraspecific Taxa (e.g., Subspecies)

(1) For the "nominal" or "typical" subspecies (or other infraspecifc ranks) whose names are autonyms, the type specimen is automatically the type of the species

(2) For all other subspecies (or other infraspecifc ranks), the type must be designated as above, for species

e. Types for Genera

= a type species (which, indirectly, refers back to the type specimen of that species)

e.g., the type (or type species) of...

...the genus *Apium* L. = *Apium graveolens* L.

...the genus *Aralia* L. = *Aralia racemosa* L.

f. Types for Ranks above Genus

= a type genus

e.g., the type of...

...the family Apiaceae Lindl. = *Apium* L.

...the order Poales Small = *Poa* L.

g. Names are attached to Types

If the type is removed from one taxon and transferred to a second taxon, the remaining members of the first taxon must be re-named.

e.g., *Schefflera*

Currently, the genus is defined broadly, to include ~900 species.

We have evidence that the type (*S. digitata*) belongs to a small group (8 spp.) not closely related to the others

In this case, the name "*Schefflera*" stays with the 8 spp., and the other ~893 spp. must be re-named.

Note: The "type" is not necessarily "typical"

Note distinction b/w the NAME (nomenclature) and the TAXON CONCEPT (classification)

It is not necessarily "representative" or "average", and it does not represent all variation in the entire taxon

It does not serve as the only material from which to describe the taxon

Rather, it is simply the element to which the name is attached

h. Types not required for ranks above Family

3. The Principle of Priority

Recall: Uniqueness:
- each taxon may have only 1 correct name
- each name must be applied to only 1 taxon

A. Violations to Uniqueness

1. Homonyms: same taxon name, but different authors

2 different authors independently applied the same name to different taxa (usu. based on different types):

Later homonyms are considered "ILLEGITIMATE"

2 authors applied the same name within the same family:

Azorella caespitosa Vahl (1794) {Apiaceae}
Azorella caespitosa Cav. (1799) {Apiaceae}

3 authors applied the same genus name to taxa in 3 families:

Horsfeildia Willd. (1806) {Myristicaceae}
Horsfeildia Blume ex DC. (1830) {Araliaceae}
Horsfeildia Chifflot (1909) {Gesnariaceae}

In the ICN, even names that are almost (but not exactly) identical can be judged homonyms:

Asterostemma Decne. (1838)
Astrostemma Benth. (1880)

2. Synonyms: different names applied to the same taxon

a. Homotypic (or Nomenclatural) Synonyms

2 names that are based on the exact same type:

Chrysophyllum cainito L. (1753)
Chrysophyllum sericeum Salisb. (1796)

b. Heterotypic (or Taxonomic) Synonyms

2 names erected for what appeared to be 2 different taxa, based on 2 different types, but were later united into 1 taxon:

Schefflera J.R. Forst. & G. Forst. (1775)
Didymopanax Decne. & Planch. (1854)

Azorella spinosa (Ruiz & Pav.) Pers. (1802)
Azorella pectinata Phil. (1894)

But, if these taxa should be divided again, the heterotypic synonyms may be reinstated.

B. How to resolve Homonyms & Synonyms

1. **Priority:** the earliest legitimate name (at the same rank) is the correct name

- To be "legitimate", the name must be...

Names not published both effectively & validly are considered "ILLEGITIMATE"

...effectively published

refers to an allowable publication

...validly published

refers to correct application of the rules for forming names, designating the type, *etc.*

2. **Exceptions to Priority**

a. Starting dates

Names published earlier than these starting dates do not have priority over Linnaeus' names (with some exceptions).

ICN: Linnaeus' *Species Plantarum*, 1 May 1753

ICZN: Linnaeus' *Systema Naturae*, 1 Jan 1758

b. Conservation/Rejection

- Decisions to accept later names, which are "conserved" against earlier "rejected" names, to serve the goal of stability.
- Must be approved by International Botanical Congress

4. Terms (& abbreviations) frequently used

species nova	(sp. nov.)	newly described species
genus novum	(gen. nov.)	newly described genus
combinatio nova	(comb. nov.)	new combination (based on basionym)
nomen conservandum	(nom. cons.)	a name conserved by sanction (despite its lack of priority)
nomen rejiciendum	(nom. rejic.)	the name rejected when another names is conserved
nomen nudum	(nom. nud.)	a name effectively published, but not validly published (always illegitimate)
nomen ambiguum	(nom. ambig.)	a name used erroneously & persistently (& thus a source of errors)

nomen novum nom. nov. a "replacement" name
(a new name to replace a name otherwise prohibited by the code)

E.g.: In a recent study that lumped the genera *Huanaca* and *Laretia* into the genus *Azorella* , these genera included:

- *Huanaca acaulis* Cav. (1800)
- *Laretia acaulis* (Cav.) Gillies & Hook. (1830)

Following the regular rules for making new combinations, (based on the basionyms), both species would be "*Azorella acaulis*"

But this violates the principle of "uniqueness", since only 1 of these can be called "*Azorella acaulis*" (which one?)

Huanaca acaulis Cav. (1800) has priority,
so it becomes *Azorella acaulis* (Cav.) Plunkett & Nicolas

The taxon with the later name must be given a "replacement name" (nom. nov.)

Laretia acaulis (Cav.) Gillies & Hook. (1830) is later, so it is given a new name
(in this case, *Azorella ruizii* Plunkett & Nicolas)

III. Identification

The activity of determining the identity of a individual organism

Requires an already existing:

- classification system
- nomenclature

May involve three activities (alone or in combination):

- Sight recognition *(requires knowledge of the flora)*
- Matching against already identified specimens
  (requires representative collection of possible species)
- Using an identification tool ("keys", guide books, *etc*.)

Identification is an important activity for many people:

- systematists: identifying field-collected material for museums, herbaria, scientific studies
- ecologists:
- environmental scientists:
  e.g., studies of vegetation, wetlands delimitations, *etc.*
- other scientists (natural products chemists, etc.)
- amateur natural historians (bird-watchers, butterfly collectors, wildflower collectors, *etc*.)

producing ID tools is one of the most practical "products" of the taxonomist

IV. Inventory

Surveys of all the organisms of a given type
(all plants, or just angiosperms, or animals, or just birds, etc.)

& usually limited to some specific geographic regions
(North America, New York state, Monmouth County, Shark River Park)

Flora: **All the plants of a certain region**
(e.g., flora of NE USA, fern flora of New Jersey, vascular flora of China)

Fauna: **All the animals of a certain region,**
(e.g., fauna of Fiji, avefauna of Europe, herpetofauna of New Guinea)

Flora vs. Vegetation:

flora = all species present, without regard to abundance
(whether it is present once, or thousands of times)

vegetation = a measure (& interpretation) of which plants are most abundant (and "important")

"Faunation": **The animal equivalent of "vegetation", but in general, these are not done so often**

Note: "Flora" (like "fauna") represents the <u>actual</u> biodiversty of the defined region (or a <u>list</u> of this biodiversity)

We often speak of books as "floras", such as:

- *Flora of North America*
- *Flora of China*
- *Flora Vitiensis Nova*

...but technically, these are "<u>manuals</u>" of the flora.

Floristics: the activity of recording/studying the flora

Much of the temperate Northern Hemisphere has been well documented (esp. N.Am., Eur., parts of Asia), *but still more to do!*

Much of the tropics & temperate Southern Hemisphere have been poorly documented (e.g., S.Am., SE Asia, Africa), *in many places, race-against-time to discover species before they are lost to extinction*

Presentations of Floristic Info

Checklists: simple lists of the taxa occuring in a given area

Annotated Checklists: provide some additional info.

may include:
- *brief indication of habitat, geography*
- *status as rare/threatened*
- *status as native/introduced*
- *placement in the classification*
- *representative herbarium specimens*

Atlases: books (or on-line resources) with distribution maps for each species

Manuals: books that combine listing of species with...

- *treatments (written descriptions)*
- *taxonomic info (e.g., classifications, synonymies)*
- *illustrations &/or photos*
- *maps & keys*
- *etc.*

V. Evolution & Phylogeny

Evolution: mechanism whereby populations or organisms change over time

more later !

Includes:

- **anagenesis:** changes in a single lineage over time
- **cladogenesis:** splitting of 1 lineage into 2
- **reticulation:** merging of 2 lineages (e.g., by hybridization)
- **extinction:** loss of a lineage

...and the mechanisms for how these processes occur

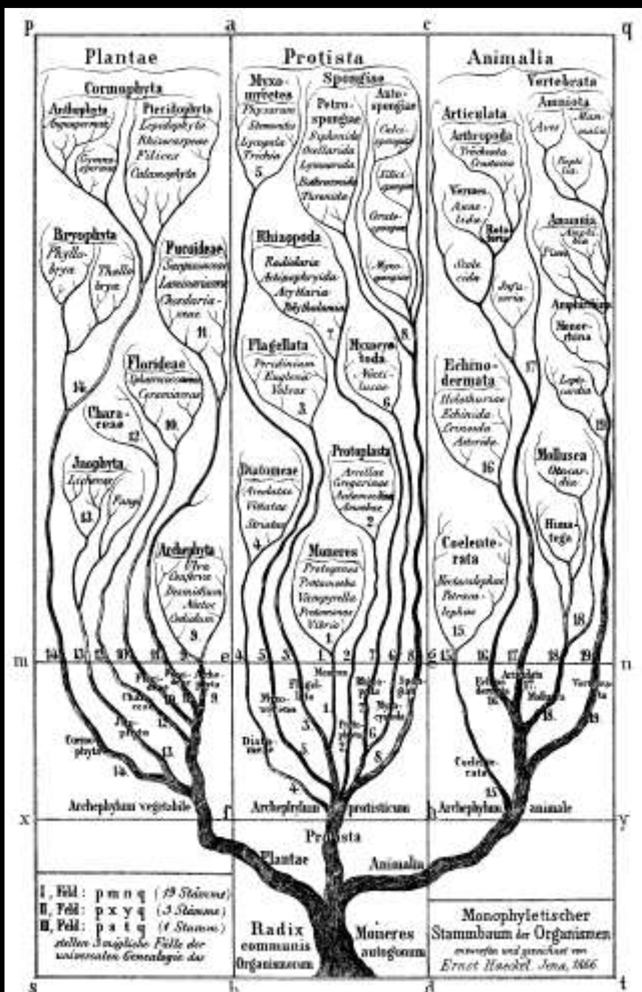
Evolution is the source for all the organismal diversity we seek to understand in Systematics

Phylogeny: = the evolutionary history of organisms

more later !

= a "tree of life", or graphical representation of evolutionary relationships

Phylogeny reconstruction is the attempt to discover or estimate the branching patterns of evolutionary history



Intuitive phylogeny by Ernst Haeckel (1866) showing hypothesis of evolutionary relationships among all life

Modern phylogeny based on DNA data showing phylogeny of six genera