Classification

- classification is the 3rd goal of systematics
- ancient search for “natural” system of classification
- important non-Western systems
  - Parashara (India) 2000 BC
  - Chinese
  - Aztecs
  - Egyptians
  - Mayan (Tzeltal) = ethnotaxonomy

Systems of Classifications

Examine three main systems of classifications and how they “evolved” in the context of western civilization

Artificial Classifications

Theophrastus (372-287 BC) took the philosophical ideas of Plato and Aristotle and applied them to taxonomy

'essentialism'

Habit as an “essence” or essential character

- herb
- subshrub
- shrub
- tree
Artificial Classifications

Theophrastus (372-287 BC) took the philosophical ideas of Plato and Aristotle and applied them to taxonomy

‘essentialism’

Habit as an “essence” or essential character

herb → subshrub → shrub → tree

Theophrastus saw a linear gradation when essences are used to arrange organisms

Artificial Classifications

Evolution does not advocate this “ladder” of life, but rather advocates a “branching tree”

Evolution asserts (testable!) that fish are more closely related to humans because they have a more recent common ancestor A than the common ancestor B with molluscs

Artificial Classifications

This linear gradation concept is the Aristotelian Scalae Naturae or Great Chain of Being or Ladder of Life

Unidirectional progression and rank on ladder leads to (false) ideas of relationships = “fish more closely related to molluscs than fish are to humans”

Concept of ladder of life still around today and causes much of the controversy and mis-understanding surrounding evolution

Artificial Classifications

. . . back to Theophrastus and his classification of plants

• clearly artificial as conifers are placed with some (woody) angiosperms and some (woody) ferns

herb → subshrub → shrub → tree

• logical, efficient, easy, but rigid system of classification — a priori choice of characters
Artificial Classifications

Herbalists - physicians: a second group using artificial systems of classification - 15-16th centuries

- little emphasis placed on system of classification of the plants — alphabetical or medicinal property

- less than 1000 species of plants were known; no need for intricate classification system in the herbals

Herbalists often lavishly illustrated

Herbalists referred to as the 'German Fathers of Botany'

De Historium Stirpium - 1542

1580 - 1800: Pivotal Period

Artificial or Natural Systems?

- Theophrastus
- Herbalists
- Carolus Linnaeus

- Andre Caesalpino
- John Ray
- Pierre Magnol
- Antoine-Laurent de Jussieu

- George Bentham
- Engler/Prantl
- Charles Breyer
- Arthur Cronquist
- Robert Thorne
- Rolf Dalström
- APG
- "Rankdoss"

1580 - 1800: Pivotal Period

Artificial or Natural Systems?

- world-wide trade and exploration = many new plant species were seen by European taxonomists

Linnaeus & students' travels
Andrea Caesalpino (1519-1603) - Italian doctor
• struggled with question how to form a more 'natural' classification *De plantis libri XVI* (1583)
• private collection of 768 plants arranged in 266 sheets in 3 volumes
• arranged by reproductive features of the plants - flowers and fruits
• first natural system, first herbarium

John Ray (1628-1705) - English blacksmith
• argued that all parts of the plant should be used in classification
• classified 18,000 species in *Methodus Plantarum* (1703) first by fruit types and subdivided by flower and leaf features

Artificial or Natural Systems?
1580 - 1800: Pivotal Period
Pisa, Italy
• first natural system, first herbarium, first botanical garden
• arranged by classification

• first recognized distinction between dicots and monocots
25 'classes' of dicots
4 'classes' of monocots
many = orders today
1580 - 1800: Pivotal Period

Artificial or Natural Systems?

Pierre Magnol (1638-1715) - French botanist

- considered Ray’s system of 29 ‘classes’ too cumbersome
- classified 76 ‘families’ — first to recognize family level (Magnoliaceae honored after him)

Carolus Linnaeus (1707-1778) - Swedish taxonomist

- work of Caesalpino, Ray, and Magnol in producing a workable classification system culminated in Linnaeus’ Sexual System
- however, this classification system was a backward step to artificial!

Linnaeus - Sexual System

What did he do?

- greatest achievement - *Species Plantarum* in 1753 arranged as *Systema Sexuale*
- classification based on reproductive features like Caesalpino, but selective and features chosen a priori simply on workability

Linnaeus - Sexual System

Take a closer look inside *Species Plantarum*

- 1st level based on number of stamens
- 2nd level based on number of pistils
Linnaeus - Sexual System

Take a closer look inside *Species Plantarum*

• Linnaeus got some intense criticism – especially from Johan Siegesbeck

• “loathsome harlotry . . . who would have thought that bluebells, lilies, and onions could be up to such immorality?”

Linnaeus - Sexual System

Take a closer look inside *Species Plantarum*

• Linnaeus got some intense criticism – especially from Johan Siegesbeck

• “would God allow 20 men or more [the stamens] to have one wife in common [the pistil]?”

Linnaeus - Sexual System

Take a closer look inside *Species Plantarum*

• Linnaeus had the last laugh

*Sigesbeckia orientalis* L. – St. Paul’s wort

Linnaeus - Sexual System

How does it work? *Oenothera biennis* or evening primrose

• *Oenothera* has 8 stamens - placed in *Octandria* (1st level)

• *Oenothera* has 1 pistil (but 4 fused carpels) - placed in *Monogynia* (2nd level)
### Linnaeus - Sexual System

Note that *Oenothera* is placed with other genera of the family Onagraceae.

Linnaeus and followers DID realize that the system would have issues:

- cacti and cherries have little overall similarity to each other
- but both have many stamens and a single pistil — placed in Polyandria / Monogynia
- Linnaeus more concerned with mechanics: usable, predictable, expandable, immutable
- Sexual System artificial, and thus backward step away from "natural" classifications

### Natural Classifications

**Period of Natural Systems: 1760 - 1880**

- late 18th century saw accumulation of botanical collections
- Linnaeus had provided popular and efficient cataloguing scheme but unrelated plants were often grouped
- taxonomists reconsidered purposes of classification; revisited older "natural" ideas

**de Jussieu family of Paris produced the most complete "natural" classification**

- their natural system came from the practice of "taxonomic gardens"

Antoine-Laurent de Jussieu
Natural Classifications

Period of Natural Systems: 1760 - 1880

- private and public gardens were then arranged according to the Linnaean Sexual System of classification

Linnaean Gardens in Uppsala, Sweden

Natural Classifications

Period of Natural Systems: 1760 - 1880

- Bernard de Jussieu experimented by replanting in the Trianon Garden on Versailles Palace grounds so that those most "similar" looking on the basis of many features would be in proximity

Phylogenetic Classifications

Phylogenetic systems date to 1859 and publication of Origin of Species by Charles Darwin

Antoine - Bernard - uncle

Antoine Laurent de Jussieu published Genera Plantarum in 1789 based on the de Jussieu family’s new, more natural classification system - and today reflected in the plantings at the Trianon Gardens.
Phylogenetic Classifications

Phylogenetic systems date to 1859 and publication of *Origin of Species* by Charles Darwin

- 'Natural' had meant different things to different people
- to Linnaeus and others 'natural' referred to the ordered structure of the universe and biota as ordained by God - specific or special creation
- to others "natural" groupings of taxa into larger groups implied relationships based on genealogy - with or without a God

Phylogenetic Classifications

Phylogenetic systems to Darwin must include genealogy + amount of change (or similarity)

- "classification must be genealogical"
- "genealogy alone does not give classification"
- "descent with modification": or genealogy plus change = evolution

Phylogenetic Classifications

Phylogenetic systems represented by the "tree" metaphor

- Darwin argued that "common ancestry" is a fact — and outcome is a phylogenetic 'tree'
- less than a decade later Ernst Haeckel published the first tree of life
- all classification systems since have been phylogenetic
Phylogenetic Classifications

Bentham & Hooker at Kew Royal Botanic Gardens first systematists to wrestle with phylogenetic classifications

• provided Darwin with much of his botanical evidence for evolution

• rudimentary phylogenetic system quickly over-shadowed by two younger Germans

George Bentham 1800-1884
Joseph Hooker 1817-1911

Phylogenetic Classifications

Engler and Prantl produced the monumental Die Naturlichen Pflanzenfamilien between 1887-1915

• original classification was "natural" and based on many characters

• by 1915 their system had a phylogenetic flavor with simple plants listed first and progressing to more complex plants

Adolph Engler 1844-1930
Karl Prantl 1849-1893

Phylogenetic Classifications

Engler and Prantl produced the monumental Die Naturlichen Pflanzenfamilien between 1887-1915

• stressed that "simple" flowers - that is with few or no parts - were "primitive"

• e.g., "Amentiferae" - a group with reduced flowers were considered primitive

• their system can be called "simple = primitive" or "Salix = primitive"

Salix - willow
Phylogenetic Classifications

Engler - Prantl classification system became the standard to arrange herbaria and floras by early 20th century

Salix - willow
University of Wisconsin Student Herbarium - three years ago - Salicaceae listed first in dicots

Phylogenetic Classifications

Charles Bessey revolutionized the classification of angiosperms by his ideas on primitive vs. advanced characters

- hypothesized the primitive vs. advanced state of many characters of plants - see handout
- Bessey’s ‘dicta’ or rules were the basis of his phylogenetic classification scheme
- formed the basis for all subsequent modern systems

Phylogenetic Classifications

What were Bessey’s main dicta or rules?

<table>
<thead>
<tr>
<th>Character</th>
<th>Primitive State</th>
<th>Advanced State</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Floral parts</td>
<td></td>
<td>loss of parts, few in number</td>
</tr>
<tr>
<td>2. Floral fusion</td>
<td></td>
<td>parts fused</td>
</tr>
<tr>
<td>3. Floral symmetry</td>
<td></td>
<td>zygomorphy</td>
</tr>
<tr>
<td>4. Ovary position</td>
<td></td>
<td>epigynous</td>
</tr>
</tbody>
</table>

Phylogenetic Classifications

Bessey’s dicta or rules

- similar to foliar theory of the flower
- “Magnolia = primitive” idea
- general trend in angiosperms has been reduction, loss, and fusion
Phylogenetic Classifications

Bessey’s classification (‘cactus’)

- Bessey produced a classification system based on his rules
- Orders (‘ales’) of flowering plants attached showing relationships and degree of primitive vs. advanced features
- Order Ranales (Magnolia) considered most primitive

Contemporary classifications

- Most based on Bessey’s principles
- Which characters stressed, though, varies (subjective)

Takhtajan (d. 2009)

Cronquist (d. 1992)

Armen Takhtajan’s and Arthur Cronquist’s are similar with subclasses (-idae) as the major groupings

Cronquist’s best developed of the contemporary classifications based on morphology
Phylogenetic Classifications

Contemporary classifications

- Rolf Dalhgren (d. 1987): Danish taxonomist who emphasized chemical features
- Robert Thorne (d. 2014; Rancho Santa Ana Botanical Garden): was still modifying his morphology based system using DNA evidence

Molecular classifications

- The 1993 paper examining DNA of 500 genera of seed plants revolutionized phylogenetic classification

Molecular classifications

- APG uses DNA and a lot of morphology
  - e.g., use of pollen features to define: "eudicot" = the 3-pored pollen bearing flowering plants
Phylogenetic Classifications

Molecular classifications

- Angiosperm Phylogeny Group classification — UW Botany Gardens first garden based on the APG system!

An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG III

THE ANGIOSPERM PHYLOGENY GROUP**

*Henningsen, A. (2001). The paper was compiled by Stephen Henningsen, John Zaborsky, and Andrew J. Schill. The paper is available from the American Museum of Natural History, New York, NY, USA.

UW Botany Department Student Herbarium

John Zaborsky – Ph.D. grad

Arranging these named organisms in 1-dimensional linear space?

Issues in Grouping

1. Convergence a problem with any system

Reduced flowers

Inferior ovary

Corolla tube

Issues in Grouping

1. Convergence a problem with any system

Sympetalous in Cronquist's Dicot Subclasses

<table>
<thead>
<tr>
<th>Asteraceae</th>
<th>Rosidinae</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antirrhinum</td>
<td>Dipsacaceae</td>
</tr>
<tr>
<td>Helianthus</td>
<td>Onagraceae</td>
</tr>
<tr>
<td>Brassica</td>
<td>Plantaginaceae</td>
</tr>
</tbody>
</table>

Corolla tube
Issues in Grouping
2. "Tree Thinking" - what a phylogenetic tree is . . .

- various trees that you will see in this course

Issues in Grouping
2. "Tree Thinking" - what a phylogenetic tree is not . . .

Fish ⇔ Newt ⇔ Lizard ⇔ Mouse ⇔ Human

Is a Newt more closely related to a Fish than to a Human?

Issues in Grouping
2. "Tree Thinking" - what a phylogenetic tree is not . . .

Human ⇔ Mouse ⇔ Lizard ⇔ Newt ⇔ Fish

Same tree / topology!

Is a Newt more closely related to a Fish than to a Human?
Issues in Grouping

2. “Tree Thinking” - what a phylogenetic tree is not ...

Is a Newt more closely related to a Fish than to a Human?

Tip reading is ladder reading, incorrect!

Issues in Grouping

2. “Tree Thinking” - what a phylogenetic tree is not ...

Newt is more related to Humans than Fish! They share a more recent common ancestor than either does with Fish.

Issues in Grouping

3. Named groups are monophyletic (ancestors and all descendants)

○ = ancestor
Issues in Grouping

3. . . . vs. paraphyletic (not all descendants included - usually because these are highly modified) - should these be allowed?

- ancestor
- excluded descendant
- modifications

3. e.g., Caesalpinoid legumes are paraphyletic

• faboid (beans, peas) and mimisoid (acacia, mimosa) legumes are highly modified
• but descended from the common ancestor of caesalpinoids

Issues in Grouping

3. . . . vs. polyphyletic (more than one ancestor - defined by convergent feature) - these are avoided

- ancestor
- convergence

Issues in Grouping

4. Not all monophyletic groups are named - limited categories available in ranked (Linnean) systems

- named group
- not named group
Issues in Grouping

5. Ranks are arbitrary - but follow Linnean categories: kingdom, phylum, class, order, family, genus, species

- Magnoliophyta
- Pinophyta
- Gnetophyta
- Cycadophyta
- Ginkgophyta
- Gymnosperms = 4 phyla

Issues in Grouping


- Taxon based on phylogeny (a "clade") - rankless
- Content of taxon specified by the phylogeny or tree
- Any clade can be named
- What clade a species is in will not change!

International Code of Nomenclature or "ranked" / "Linnean" system

- Ranked taxon defined based on types
- Content of defined taxon not specified except for type
- Limited number of groups or ranks can be named
- What taxa a species is in can change!

Issues in Grouping

- In practice and informally, recent phylogenetic classifications have been using a hybrid of ranked and rankless groupings
- APG III uses ranks for families and orders; informal rankless names for larger groups