Classification of Angiosperms

- 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
- folk systematics (ethnotaxonomy) — scientific?

Folk Classifications

- 5-6 categories
- arranged hierarchically
- unique beginner = kingdom
  - plant, animal

Unique form: cactus in Tzeltal (Mayan)
Folk Classifications

- 5-6 categories
- arranged hierarchically
  - unique beginner = kingdom
  - life forms (tree, vine, grass)

Unique form: strangler - Aguaruna (Peru)

Are these indigenous, innate classifications non-scientific?

62% of folk genera match "scientific" species!

Table 1: Correspondence of Tzeltal generic taxa with botanical species in the area (which are named in Tzeltal)

<table>
<thead>
<tr>
<th>Taxa correspondence</th>
<th>Under-differentiation, type 1</th>
<th>Under-differentiation, type 2</th>
<th>Over-differentiation</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>98</td>
<td>65</td>
<td>17</td>
</tr>
<tr>
<td>Total</td>
<td>N = 471</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Folk Classifications
Are these indigenous, innate classifications non-scientific?

Tzeltal classification recognizes one folk genus for 2+ scientific species about 20%

<table>
<thead>
<tr>
<th>Taxonomic Level</th>
<th>Tzeltal Recognition</th>
<th>Scientific Recognition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lantana</td>
<td>1</td>
<td>2+</td>
</tr>
<tr>
<td>Pinus</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Over-differentiation in 4 ethnotaxonomies involve important taxa
Folk Classifications

Further evidence that all humans perceive biodiversity and classify in similar ways

1. Level of polytypy in genera (monotypic = 1 sp. per genus, etc.) is similar worldwide

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’

“a genus is any group of species that may be logically and exhaustively distinguished on the basis of one or a very few essential properties”
Artificial Classifications

Theophrastus (372-287 BC) took the philosophical ideas of Plato and Aristotle and applied them to taxonomy. He saw a linear gradation when essences are used to arrange organisms. 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. The concept of ladder of life still around today and causes much of the controversy surrounding evolution.

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.

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Artificial Classifications

Herbalists: a second group using artificial systems of classification

• association of plant taxonomy with medicine goes back to Dioscorides (AD 60)
• here prescribing “mandrake” in the nightshade family
• family Dioscoreaceae – yam family – named after this doctor

Artificial Classifications

Herbalists: a second group using artificial systems of classification

Source of edible yam; sources of steroids, cortisones, first oral contraceptives (diosgenin, progesterone)

Artificial Classifications

Herbalists: a second group using artificial systems of classification

• published *De Materia Medica* in which medicinal plants were listed by medicinal properties

Artificial Classifications

Herbalists: a second group using artificial systems of classification

• after Dark Ages, renewed interest in medicinal value of herbs due to great plagues of 15-16th centuries
• invention of European printing press in 15th century facilitated printing of information into “herbals”
Artificial Classifications

Herbalists: a second group using artificial systems of classification

- 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

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

Artificial Classifications

Herbalists: a second group using artificial systems of classification

- herbals often lavishly illustrated
- herbalists referred to as the ‘German Fathers of Botany’
  De Historium Stirpium - Fuchs

1580 - 1800: Pivotal Period

Artificial or Natural Systems?

- world-wide trade and exploration — many new plant species were seen by European taxonomists
  Sir Joseph Banks (1768-1771)
1580 - 1800: Pivotal Period

Artificial or Natural Systems?

• world-wide trade and exploration — many new plant species were seen by European taxonomists
• more formal system of classification was necessary
• suites of intrinsic characters of plants needed to be used

Artificial or Natural Systems?

Andrea Caesalpino (1519-1603) - Italian doctor
• struggled with question how to form a more ‘natural’ classification
• 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, first botanical garden

1580 - 1800: Pivotal Period

Artificial or Natural Systems?

Andrea Caesalpino (1519-1603) - Italian doctor
• first natural system, first herbarium, first botanical garden

Artificial or Natural Systems?

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
1580 - 1800: Pivotal Period

Artificial or Natural Systems?
John Ray (1628-1705) - English blacksmith
* first recognized distinction between **dicots** and **monocots**
  - 25 ‘classes’ of dicots
  - 4 ‘classes’ of monocots
  = *orders* today

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* in the progress towards natural systems

Linnaeus - Sexual System

What did he do?
* $125 grant in 1732 funded 5 month floristic inventory of Lapland
* priceless collection was the impetus for his treatment of the world-wide flora
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*

• prime divisions based on number of stamens

• secondary divisions based on number of pistils

• was Linnaeus a sexist?

• not here! number of stamens more variable than of pistils - essential for a mechanical, workable system

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 - Sexual System

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 towards “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.

Natural Classifications

Period of Natural Systems: 1760 - 1880

- The number and diversity of tropical plants in Senegal influenced Michel Adanson.
- Grouped plants by affinities observed among multiple relationships of characteristics.
- Published his classification in Familles des Plantes in 1763.

What is one of the two main pollinators that David photographed visiting flowers of the baobabs?
**Natural Classifications**

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

- **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*

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**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*

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**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.

*Antoine - uncle, Bernard - nephew*

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**Natural Classifications**

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

- 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.

*Antoine Laurent de Jussieu*
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, this grouping 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

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

Adolph Engler 1844-1930
Karl Prantl 1849-1893

- 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

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

- 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

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>Flower parts</td>
<td>All present, same as number</td>
<td>Fewest parts, fewest number</td>
</tr>
<tr>
<td>Floral fusion</td>
<td>Parts separate</td>
<td>Parts fused</td>
</tr>
<tr>
<td>Floral symmetry</td>
<td>Actinomorphic</td>
<td>Zygomorphic</td>
</tr>
<tr>
<td>Ovary position</td>
<td>Polypetalous</td>
<td>Epipetalous</td>
</tr>
</tbody>
</table>

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
Phylogenetic Classifications

**Bessey’s classification (‘cactus’)**

- Zygomorphy, fused petals, and inferior ovary are found further up the chart
- Order Ranales (Magnoliidae) considered most primitive

**Contemporary classifications**

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

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

Rolf Dalhgren (d. 1987): Danish taxonomist who emphasized chemical features

Robert Thorne (Rancho Santa Ana Botanical Garden): still modifying his morphology based system using DNA evidence

Cronquist’s best developed of the contemporary classifications based on morphology
Phylogenetic Classifications
Molecular classifications
• the 1993 paper examining DNA of 500 genera of seed plants revolutionized phylogenetic classification

• Angiosperm Phylogeny Group classification — APG I (1998); APG II (2003) used in Plant Systematics text

• APG III (2009) — used in course

• APG uses DNA and a lot of morphology
  • e.g., use of pollen features to delimit “eudicot” — the 3-pored pollen bearing flowering plants

• Angiosperm Phylogeny Group classification — UW Botany Gardens first garden based on the APG system!
Issues in Grouping

1. Convergence a problem with any system
   • repeated shifts to wind pollination & reduced flowers

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?

No! this is the ancestor of human and newt

Tip reading is ladder reading, incorrect!

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
Issues in Grouping

3. e.g. **Caesalpinoid** legumes are paraphyletic

- **Faboid** (beans, peas) and **Mimosoid** (acacia, mimosa) legumes are highly modified
- but descended from the common ancestor of caesalpinoids

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Issues in Grouping

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

---

Issues in Grouping

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

---

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

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

- Magnoliophyta
- Pinopsida
- Gnetopsida
- Cycadopsida
- Ginkgopsida

Gymnosperms = 4 classes in 1 phylum

OR...

Issues in Grouping


- taxon based on phylogeny (a “clade”) - rankless
- content of taxon specified by the phylogeny or tree
- any clade can be named

http://www.ohiou.edu/phylocode/

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

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