
Classification

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

- Theophrastus
- Herbalists
- Carolus Linnaeus

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

- George Bentham
- Engler/Prantl
- Charles Bessey
- Arthur Cronquist
- Robert Thorne
- Rolf Dalghren
- APG
- "Rankless"

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

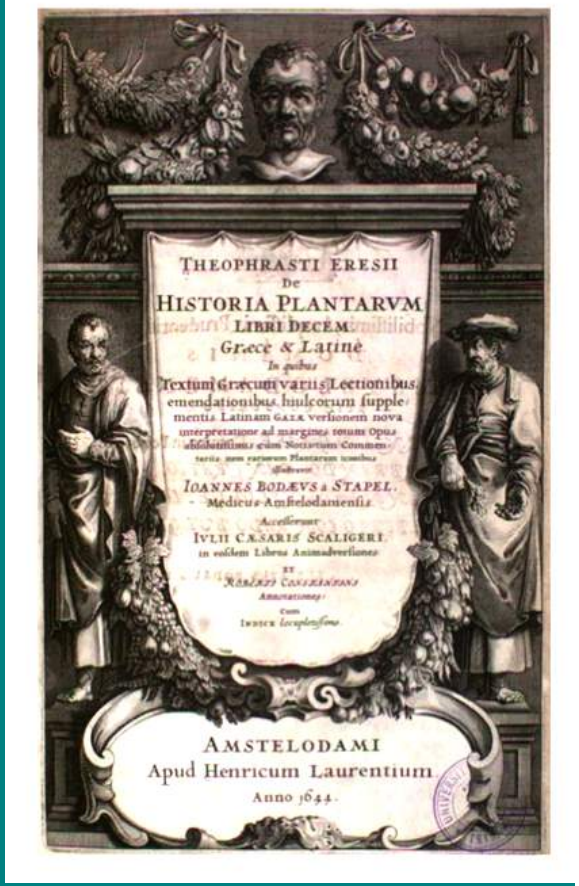
shrub

tree

Artificial Classifications

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

De Historia Plantarum



'essentialism'

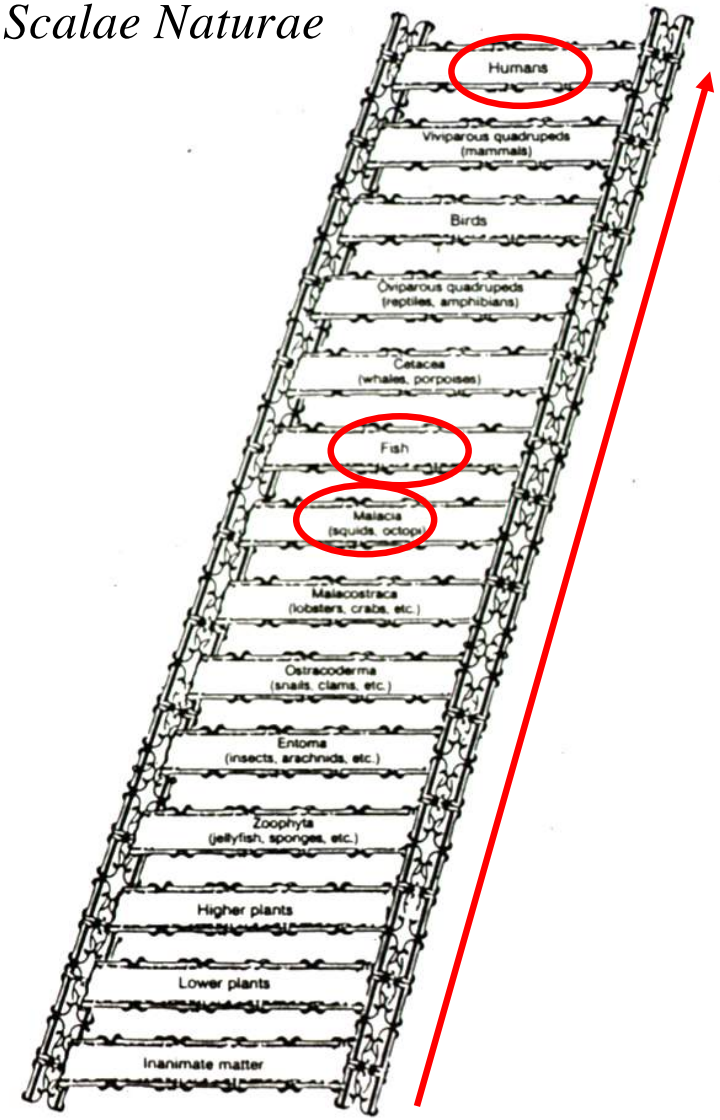
Habit as an "essence" or essential character

herb → subshrub → shrub → tree

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

Artificial Classifications

Scalae Naturae

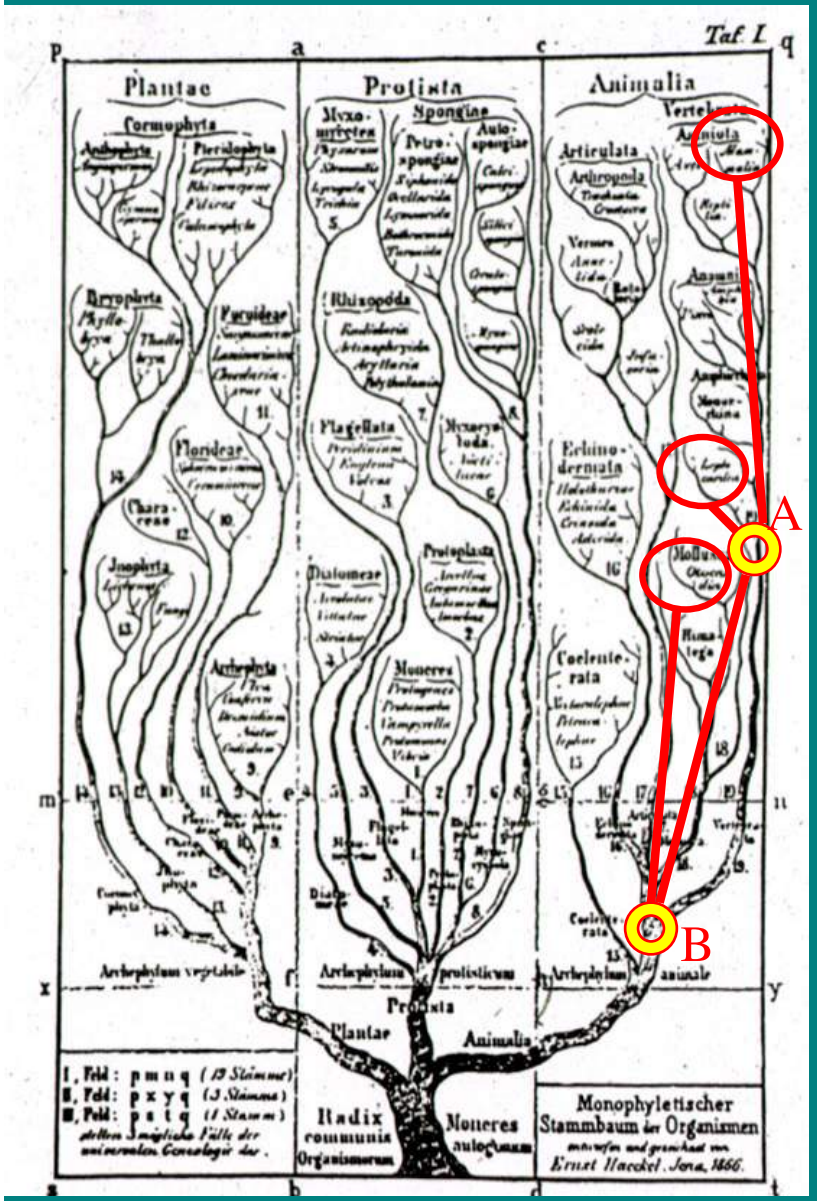


This linear gradation concept is the Aristotlean *Scalae Naturae* or Great Chain of Being or Ladder of Life

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



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

. . . 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

Artificial Classifications

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

- herbals often lavishly illustrated
- herbalists referred to as the 'German Fathers of Botany'

Leonhart Fuchs

Fuchsia

De Historium Stirpium - 1542

1580 - 1800: Pivotal Period

Artificial or Natural Systems?

— Theophrastus
— Herbalists
— Carolus Linnaeus

— Andre Caesalpino
— John Ray
— Pierre Magnol
— Antoine-Lauren de Jussieu

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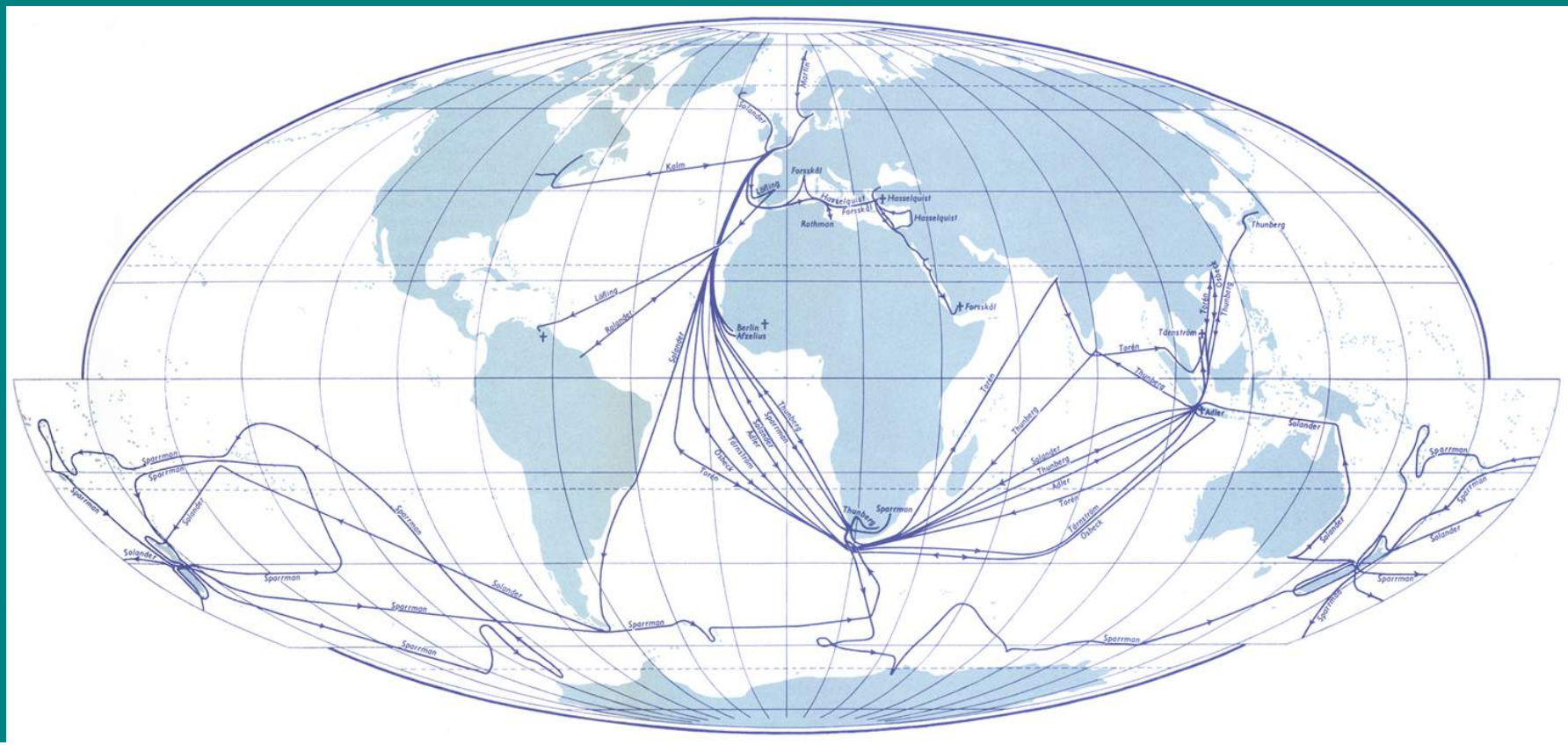
— APG
— "Rankless"

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



1580 - 1800: Pivotal Period

Artificial or Natural Systems?

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

1580 - 1800: Pivotal Period

Artificial or Natural Systems?

Andrea Caesalpino (1519-1603) - Italian doctor

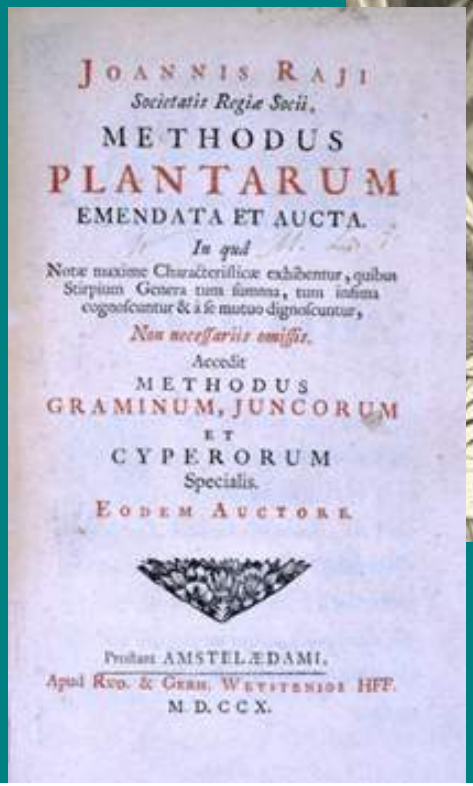
- first natural system, first herbarium, first botanical garden arranged by classification

1580 - 1800: Pivotal Period

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

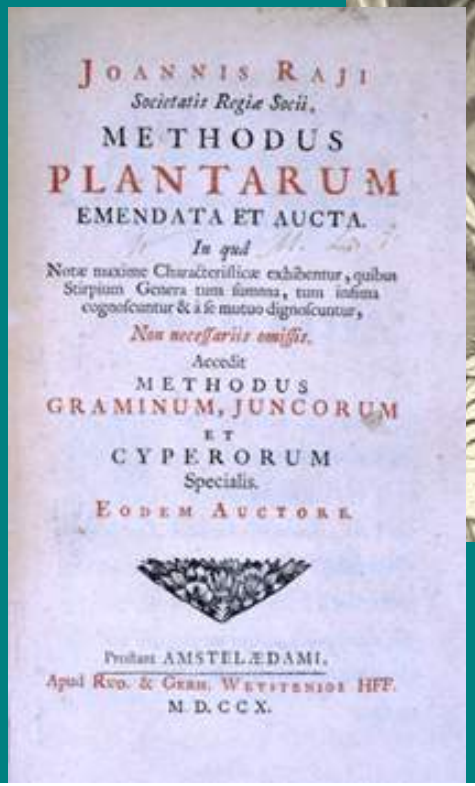

JOANNIS RAJI
Societatis Regiæ Socii,
METHODUS
PLANTARUM
EMENDATA ET AUCTA.
In qua
Notæ maxime Characteristicæ exhibentur, quibus
Stirpium Genera tum summa, tum infima
cognoscuntur & à se mutuo dignoscuntur,
Non necessariis omissis.
Accedit
METHODUS
GRAMINUM, JUNCORUM
ET
CYPERORUM
Specialis.
EODEM AUCTORE.
Prostant AMSTELÆDAMI,
Apud Rvp. & Gerh. Wetstenios HFF.
M. D. C C X.

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
  - many = orders today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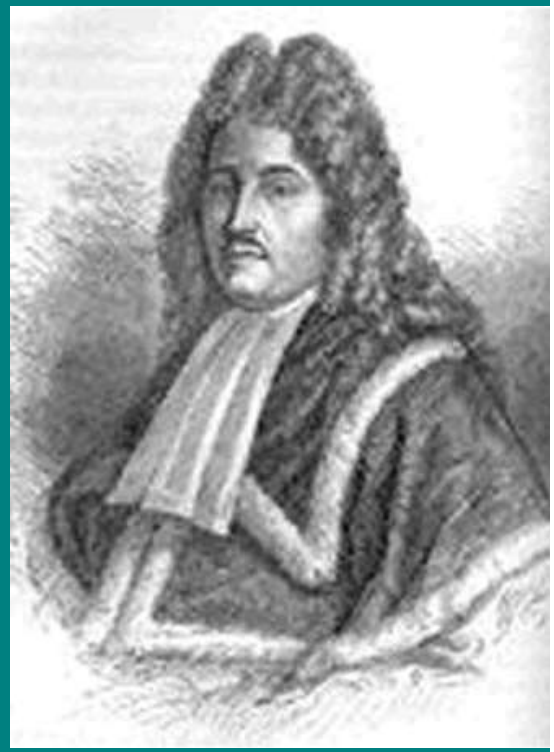
1580 - 1800: Pivotal Period

Artificial or Natural Systems?

Pierre Magnol (1638-1715) - French botanist



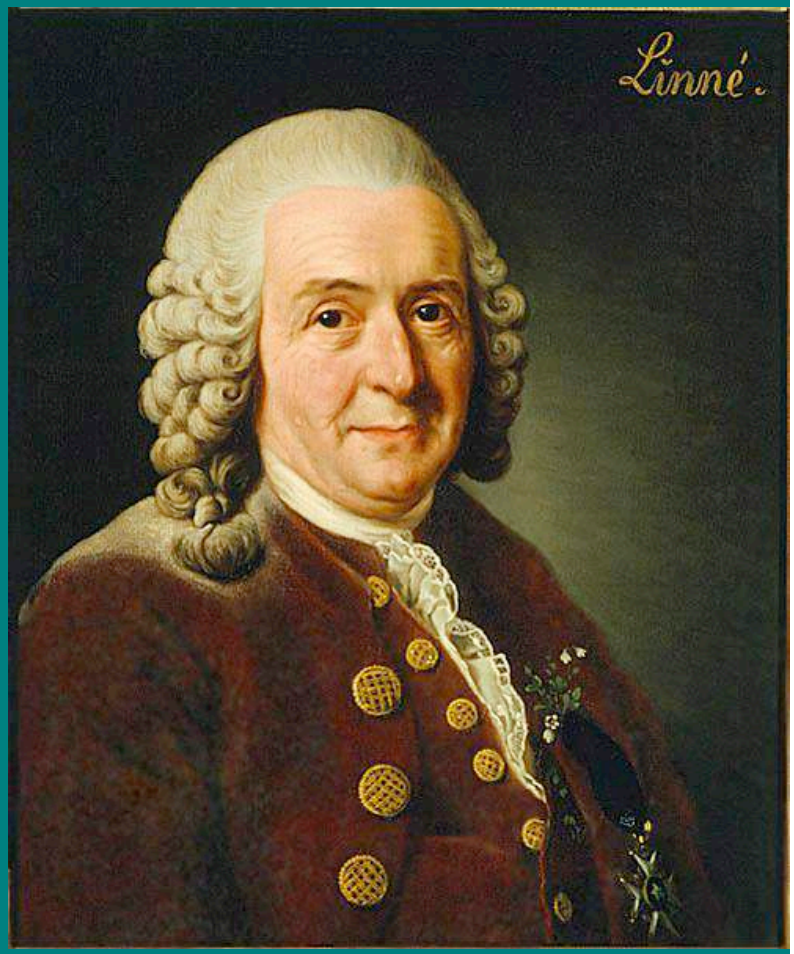
- considered Ray's system of 29 'classes' too cumbersome
- classified 76 'families' — first to recognize family level (Magnoliaceae honored after him)

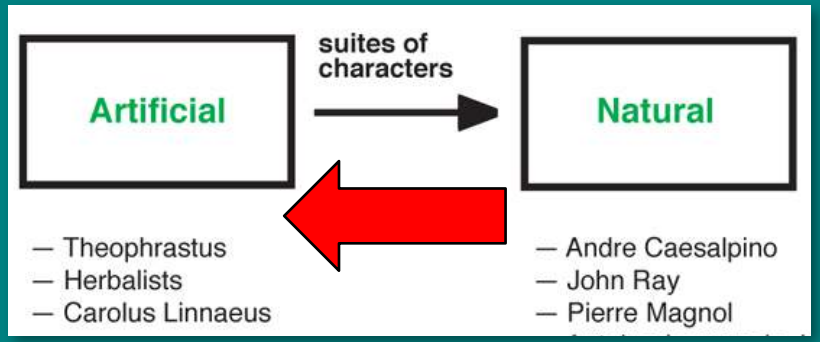
1580 - 1800: Pivotal Period

Artificial or Natural Systems?

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!



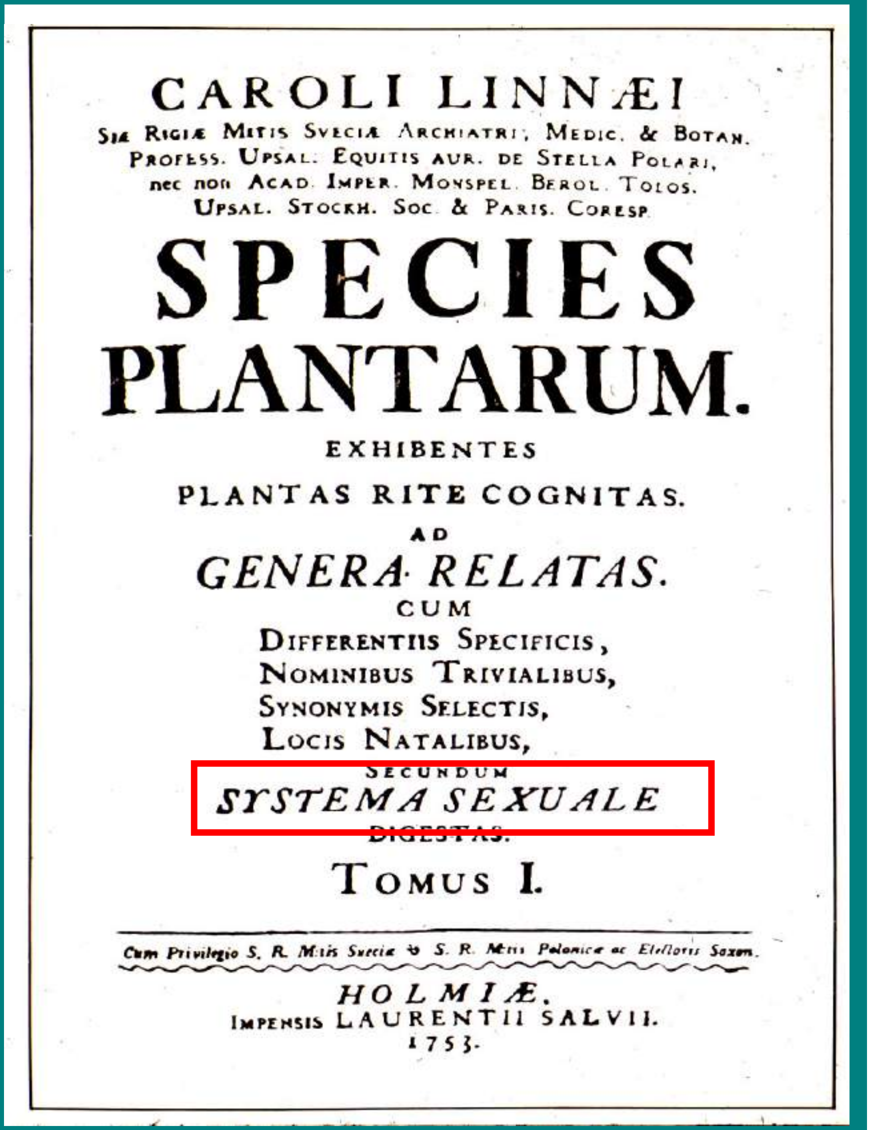


Linnaeus - Sexual System

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



CAROLI LINNÆI
SIÆ RIGIÆ MITIS SVECIÆ ARCHIATRI, MEDIC. & BOTAN.
PROFESS. UPSAL. EQUITIS AUR. DE STELLA POLARI,
nec non ACAD. IMPER. MONSPEL. BEROL. TOLOS.
UPSAL. STOCKH. SOC. & PARIS. CORESP.

SPECIES
PLANTARUM.

EXHIBENTES
PLANTAS RITE COGNITAS,
AD
GENERA RELATAS,
CUM
DIFFERENTIIS SPECIFICIS,
NOMINIBUS TRIVIALIBUS,
SYNONYMIS SELECTIS,
LOCIS NATALIBUS,
SECUNDUM
SYSTEMA SEXUALE
DIGESTAS.

TOMUS I.

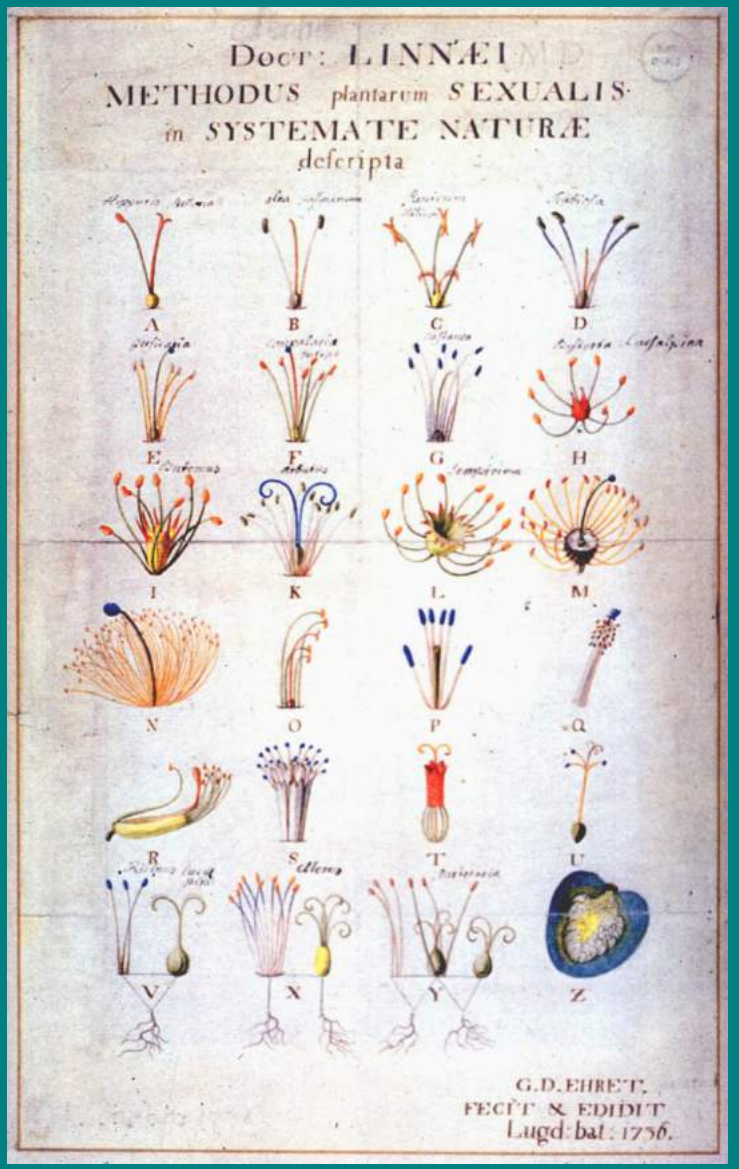
Cum Privilegio S. R. M:tis Sueciæ & S. R. M:tis Poloniæ ac Electoris Saxon.

HOLMIÆ,
IMPENSIS LAURENTII SALVII.
1753.

Linnaeus - Sexual System

Take a closer look inside *Species Plantarum*

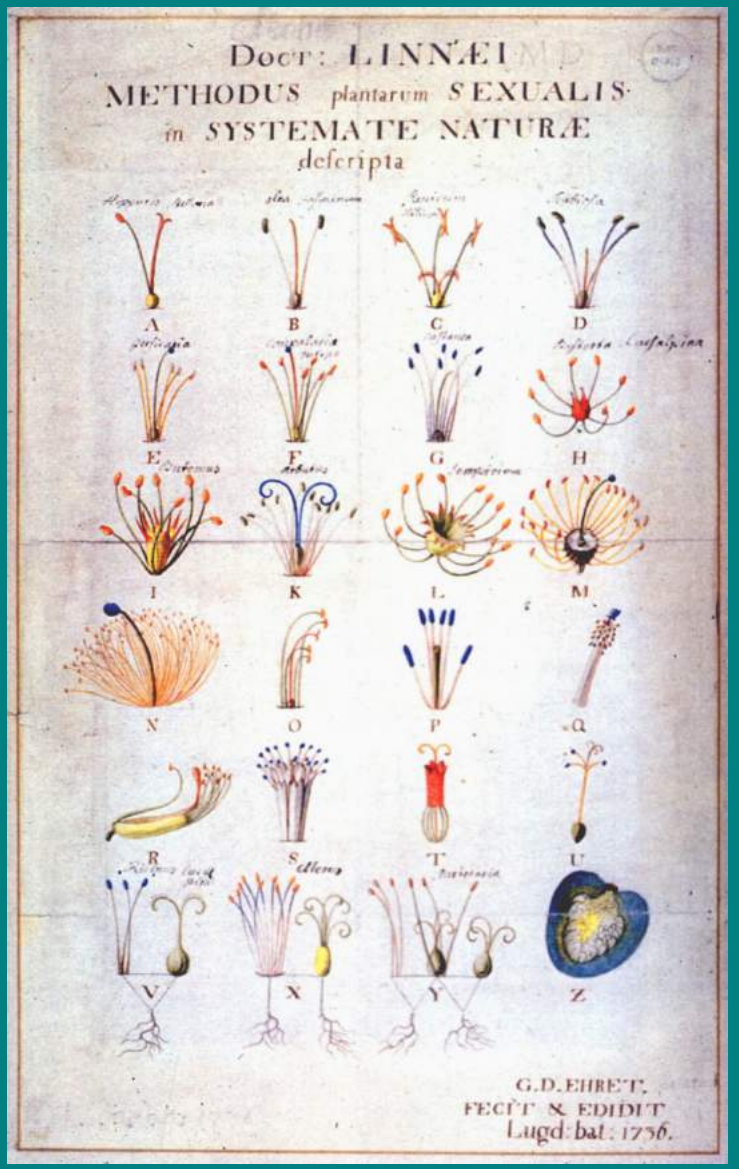
- 1st level based on number of stamens
- 2nd level based on number of pistils



Linnaeus - Sexual System

Take a closer look inside *Species Plantarum*

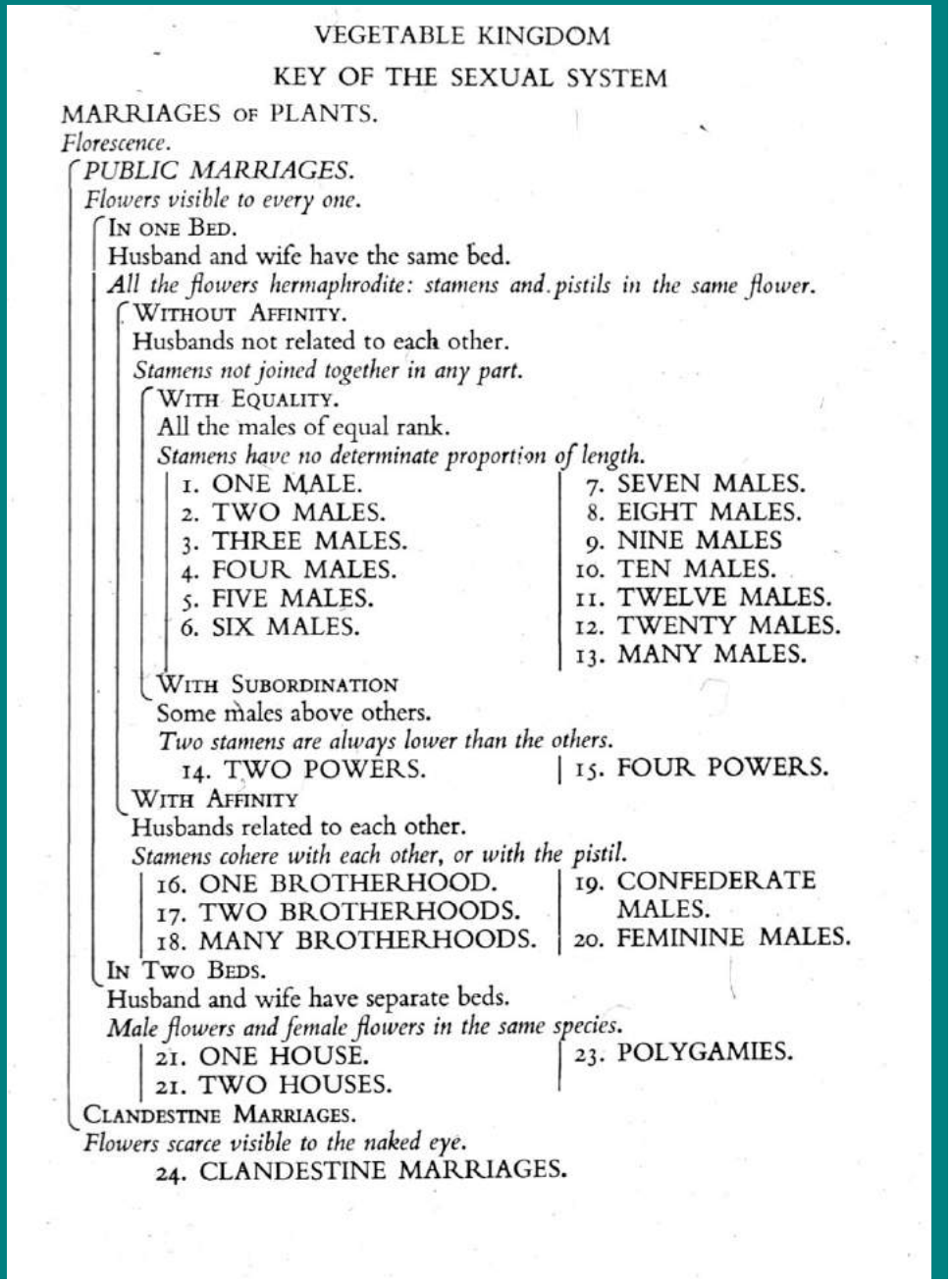
- Linnaeus got some intense criticism – especially from Johan Siegesbeck
- "loathsome harlotry . . . who would have thought that bluebells, lilies, and onions could be up to such immorality?"



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]?"



VEGETABLE KINGDOM

KEY OF THE SEXUAL SYSTEM

MARRIAGES OF PLANTS.

Florescence.

PUBLIC MARRIAGES.

Flowers visible to every one.

IN ONE BED.

Husband and wife have the same bed.

All the flowers hermaphrodite: stamens and pistils in the same flower.

WITHOUT AFFINITY.

Husbands not related to each other.

Stamens not joined together in any part.

WITH EQUALITY.

All the males of equal rank.

Stamens have no determinate proportion of length.

1. ONE MALE.
2. TWO MALES.
3. THREE MALES.
4. FOUR MALES.
5. FIVE MALES.
6. SIX MALES.
7. SEVEN MALES.
8. EIGHT MALES.
9. NINE MALES
10. TEN MALES.
11. TWELVE MALES.
12. TWENTY MALES.
13. MANY MALES.

WITH SUBORDINATION

Some males above others.

Two stamens are always lower than the others.

14. TWO POWERS.
15. FOUR POWERS.

WITH AFFINITY

Husbands related to each other.

Stamens cohere with each other, or with the pistil.

16. ONE BROTHERHOOD.
17. TWO BROTHERHOODS.
18. MANY BROTHERHOODS.
19. CONFEDERATE MALES.
20. FEMININE MALES.

IN TWO BEDS.

Husband and wife have separate beds.

Male flowers and female flowers in the same species.

21. ONE HOUSE.
21. TWO HOUSES.
23. POLYGAMIES.

CLANDESTINE MARRIAGES.

Flowers scarce visible to the naked eye.

24. CLANDESTINE MARRIAGES.

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 had the last laugh

Sigesbeckia orientalis L. – St. Paul's wort

Linnaeus - Sexual System

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

346 OCTANDRIA MONOGYNIA.

goans. Folia *anguſto-lanceolata, trinervia, oppoſita, ſcabra, ſubſeſſilia.* Flores *terminales aliquot, ſeſſiles, cincti foliis 4 flore longioribus patentibus.*

RHEXIA.

virginica. 1. RHEXIA calycibus glabris. *Gron. virg.* 41.
Alirianus vegetabilis carolinianus. *Pluk. amalt.* 8.
Lyſimachia non pappoſa virginiana, tuberariæ foliis hirſutis, flore tetrapetalo rubello. *Pluk. alm.* 235. *t.*202. *f.* 8.
Habitat in Virginia.
Caulis *tetragonus angulis membranaceis.* Folia *oppoſita, ſublanceolata, internodiis longiora, ſeſſilia, trinervia, pilis vagis hiſpidiuſcula, ſubſerrata ſerraturis ſetaceis.* Pedunculus *terminalis, dichotomus.* Flores *ſolitarii ex dichotomia, ſubſeſſiles, petalis rubris; Antheris falcatis, luteis.*

mariana. 2. RHEXIA foliis ciliatis.
Lyſimachia non pappoſa, terræ marianæ, leptoneuros, flore tetrapetalo rubello, folio & caule hirſutie ferruginea hiſpidis. *Pluk. mant.* 123. *t.* 428. *f.* 1.
Habitat in Marilandia.

OENOTHERA.

biennis. 1. OENOTHERA foliis ovato-lanceolatis planis. *Vir. cliff.* 33. *Hort. upſ.* 94. *Gron. virg.* 254. *Roy. lugdb.* 251. *Gort. gelr.* 78
Oenothera foliis ovato-lanceolatis denticulatis, floribus lateralibus in ſummo caulis. *Hort. cliff.* 144.
Lyſimachia lutea corniculata. *Bauh. pin.* 245. 516. * *Moriſ. hiſt.* 2. *p.*271. *ſ.* 3. *t.* 11. *f.* 7.
Habitat in Virginia anno 1614, unde vulgaris Europæ. ♂

multiſiliqua. 2. OENOTHERA foliis lanceolatis undulatis. *Vir. cliff.* 33. *Gron. virg.* 42. *Roy. lugdb.* 251.
Oenothera foliis lineari-lanceolatis dentatis, floribus e medio caule. *Hort. upſ.* 144.
Onagra bonarienſis villoſa, flore mutabili. *Dill. elth.* 297. *t.* 219. *f.* 286.
Habitat in agro Bonarienſi. ⊙

fruticoſa. 3. OENOTHERA foliis lanceolatis, capſulis acutangulis.
Oenothera florum calyce monophyllo, hinc tantum aperto. *Gron. virg.* 42.

Ona-

- *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

goans. Folia *anguſto-lanceolata, trinervia, oppoſita, ſcabra, ſubſeſſilia.* Flores *terminales aliquot, ſeſſiles, cincti foliis 4 flore longioribus patentibus.*

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Habitat in Marilandia.

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Habitat in Virginia *unde* 1614, *nunc vulgaris Europæ.* ♂

molliſſima. 2. OENOTHERA foliis lanceolatis undulatis. *Vir. cliff.* 33. *Gron. virg.* 42. *Roy. lugdb.* 251.
Oenothera foliis lineari-lanceolatis dentatis, floribus e medio caule. *Hort. upſ.* 144.
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Oenothera florum calyce monophyllo, hinc tantum aperto. *Gron. virg.* 42.

Ona-

Onagra anguſtifolia, caule rubro, flore minore. *Tournef. inſt.* 302.
Habitat in Virginia. ♃
Calyx *purpuraſcens, tetraphyllus, ſed rumpitur altero ſæpius & unico latere.* Tubus *filiformis, anguſtiſſimus.* Capſula *angulis 4 acutis compreſſis.* Folia *rarius denticulata.*

GAURA.

1. GAURA. *Gen. [illegible]* *biennis.*
Lyſimachia lutea anguſtifolia virginiana, flore minore. *Pluk. alm.* 235. *t.* 202. *f.* 7. *mala.*
Habitat in Virginia, Penſylvania. ♂

EPILOBIUM.

* *Staminibus declinatis.*

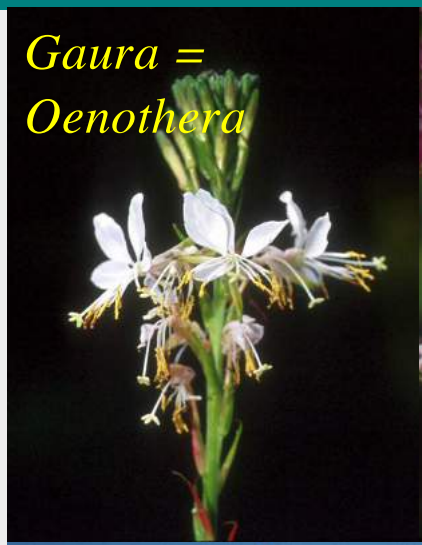
1. EPILOBIUM foliis ſparſis lineari-lanceolatis. *anguſtifolia.*
Epilobium floribus difformibus, piſtillo declinato. *Fl. ſuec.* 304.
Epilobium foliis lanceolatis integerrimis. *Fl. lapp.* 146. *Hort. cliff.* 154. *Roy. lugdb.* 250.
Lyſimachia Chamænerion dicta anguſtifolia. *Bauh. pin.* 245.
β. Lyſimachia Chamænerion dicta latifolia. *Bauh. pin.* 245.
γ. Lyſimachia Chamænerion dicta alpina. *Bauh. pin.* 245. *prodr.* 116.
Habitat in Europa *boreali.* ♃

2. EPILOBIUM foliis alternis lanceolato-ovatis. *latifolia.*
Habitat in Sibiria. ♃
Differt a præcedenti floribus duplo majoribus, foliis lanceolato-ovatis, alternis nec ſparſis, utrinque lævi ſimo tomento molliſſimis. Hæc & antecedens differunt a ſequentibus in non paucis, his enim Flores *inæquales petalis integris;* Piſtillum *declinatum;* Folia *alterna;* Folia *erumpentia revoluta contra ac in reliquis.*

* *Staminibus erectis regularibus, petalis bifidis.*

3. EPILOBIUM foliis oppoſitis lanceolatis ſerratis. *hirſutum.*
Hort. cliff. 145. *Fl. ſuec.* 305. *Gron. virg.* 154. *Roy. lugdb.* 251.
Lyſimachia ſiliquoſa hirſuta, magno flore. *Bauh. pin.* 245.
Lyſimachia purpurea. *Fuchſ. hiſt.* 491.

β. Lyſi-

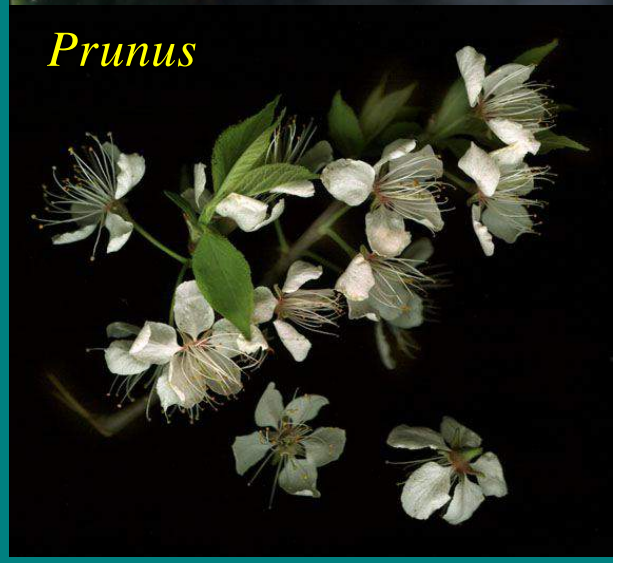


Linnaeus - Sexual System

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 away from ‘natural” classifications


Opuntia

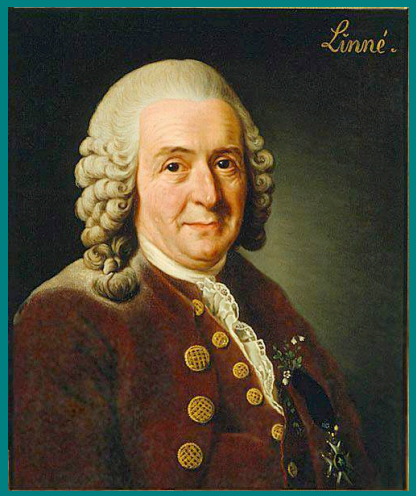

Prunus

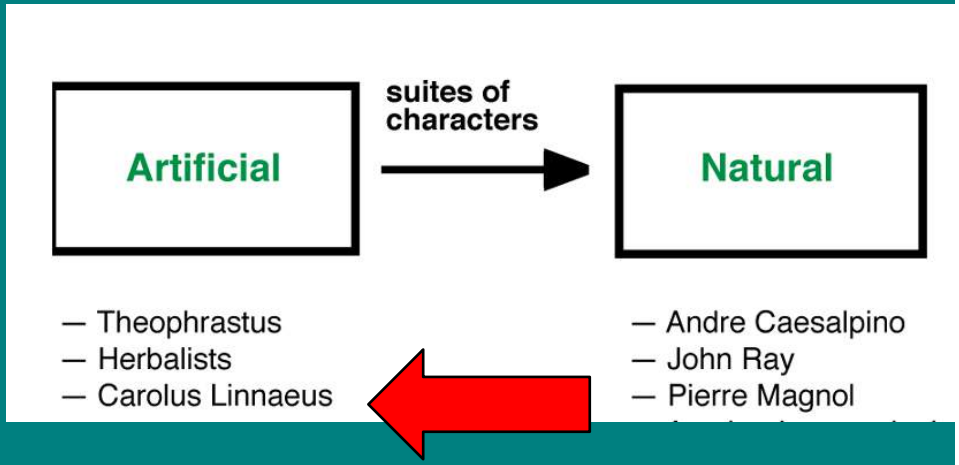
Natural Classifications

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



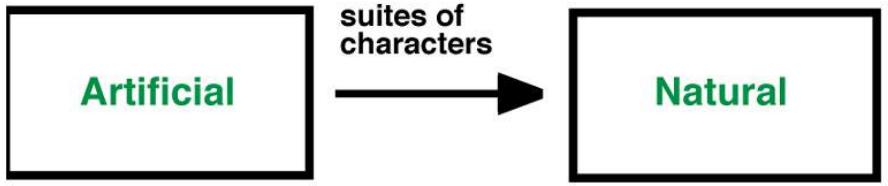


- taxonomists reconsidered purposes of classification; revisited older 'natural' ideas

Natural Classifications

Period of Natural Systems: 1760 - 1880

- 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

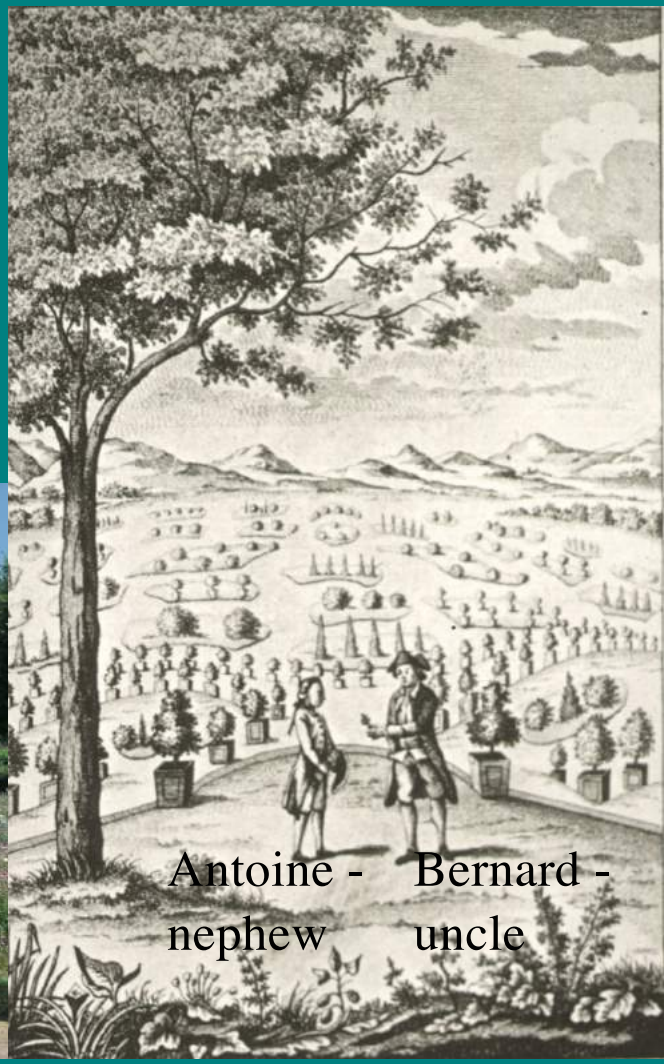
- private and public gardens were then arranged according to the Linnaean *Sexual System* of classification

Linnaean Gardens in Uppsala, Sweden

Natural Classifications

Period of Natural Systems: 1760 - 1880

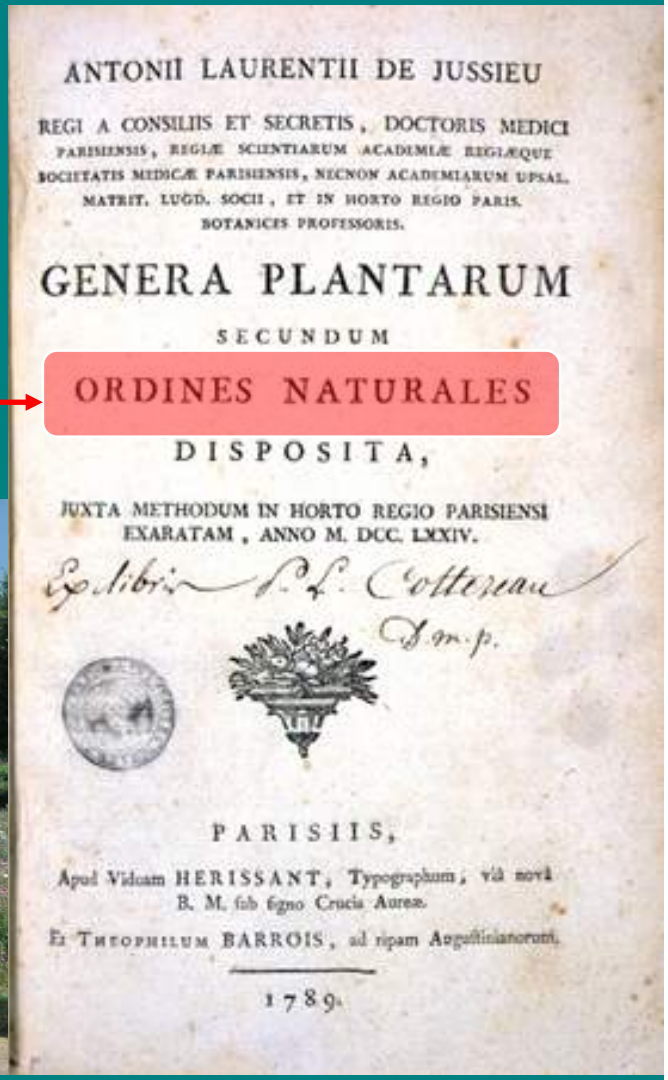
- Bernard de Jussieu experimented by replanting in the Trianon Garden on Versailles Palace grounds so that those most "similar" looking on the basis of many features would be in proximity



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



ANTONII LAURENTII DE JUSSIEU

REGI A CONSILIIS ET SECRETIS, DOCTORIS MEDICI PARISIENSIS, REGIÆ SCIENTIARUM ACADEMIÆ REGIÆQUE SOCIETATIS MEDICÆ PARISIENSIS, NECNON ACADEMIARUM UPSAL. MATRIT. LUGD. SOCII, ET IN HORTO REGIO PARIS. BOTANICES PROFESSORIS.

GENERA PLANTARUM

SECUNDUM

ORDINES NATURALES

DISPOSITA,

JUXTA METHODUM IN HORTO REGIO PARISIENSI EXARATAM, ANNO M. DCC. LXXIV.

Ex libris P. L. Cotteau

Dm.p.

PARISIIS,

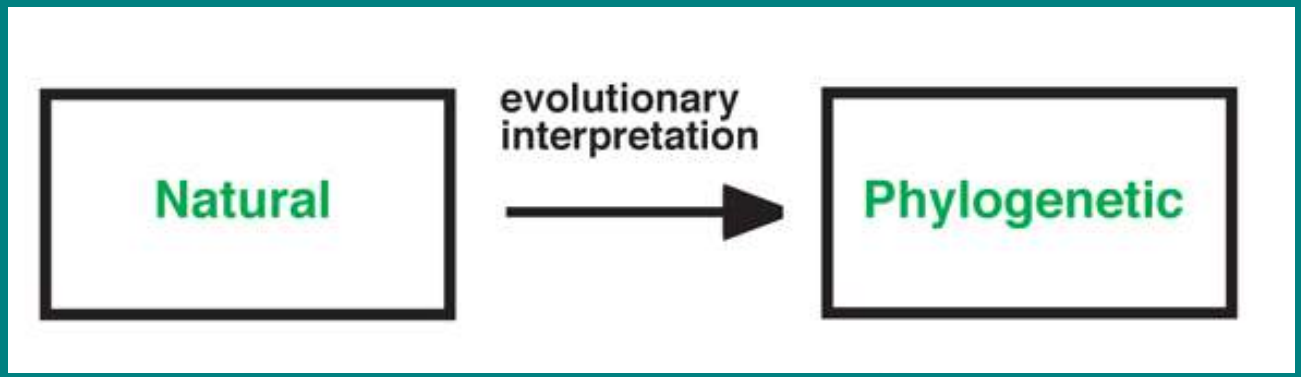
Apud Viduam HERISSANT, Typographum, viâ novâ B. M. sub signo Crucis Aureæ.

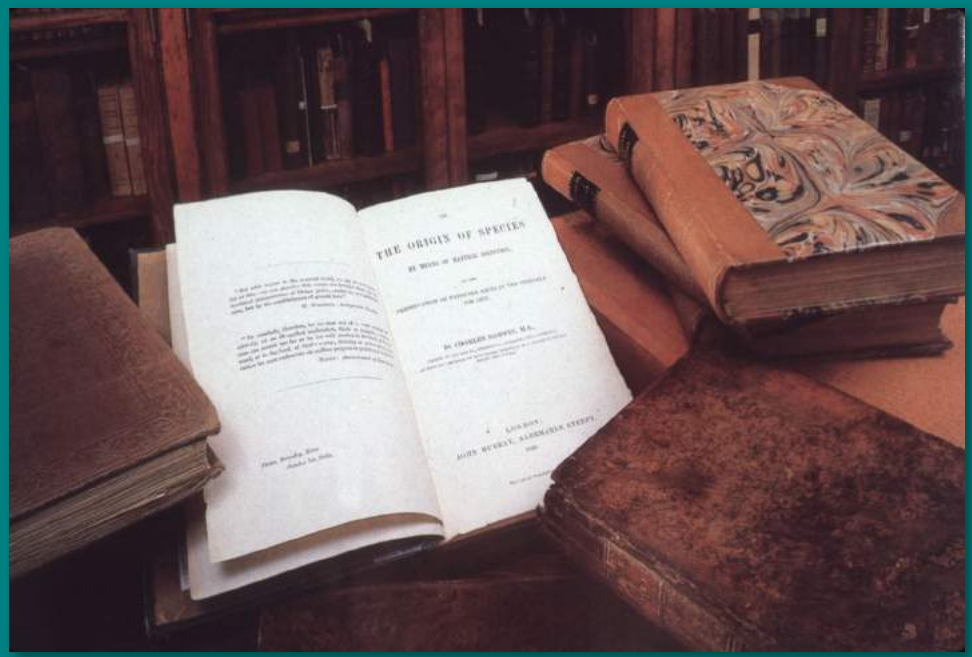
Et THEOPHILUM BARROIS, ad ripam Augustinianorum.

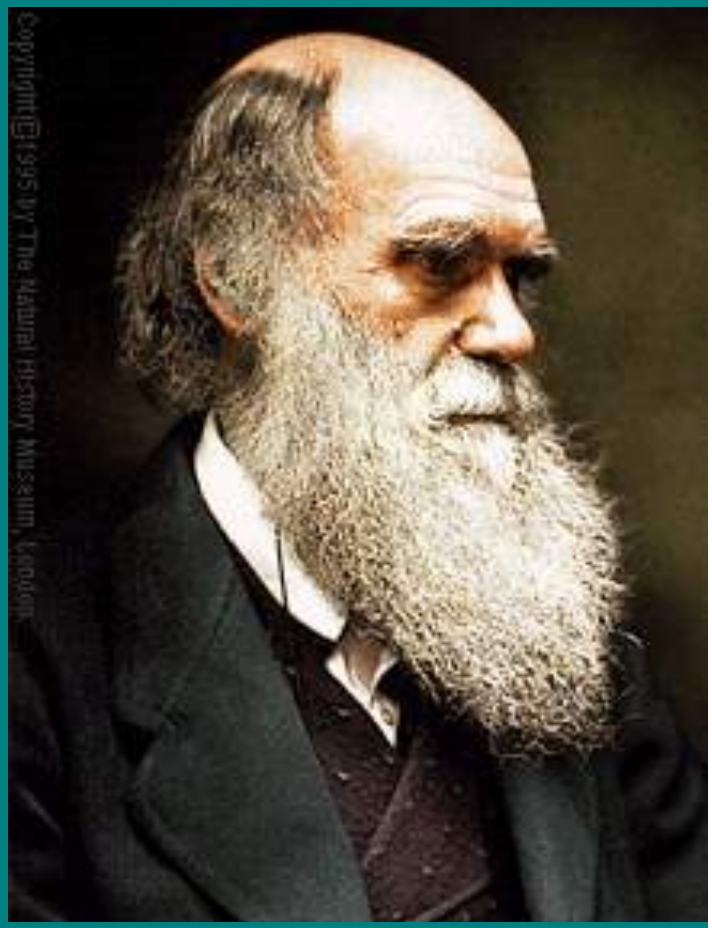
1789.

Phylogenetic Classifications

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







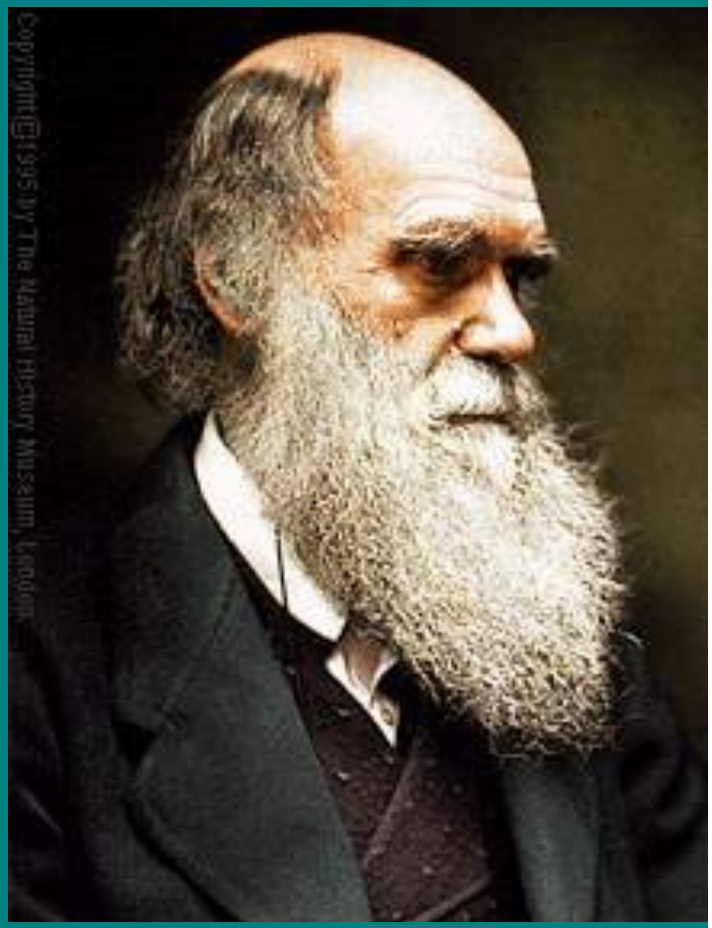
Phylogenetic Classifications

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

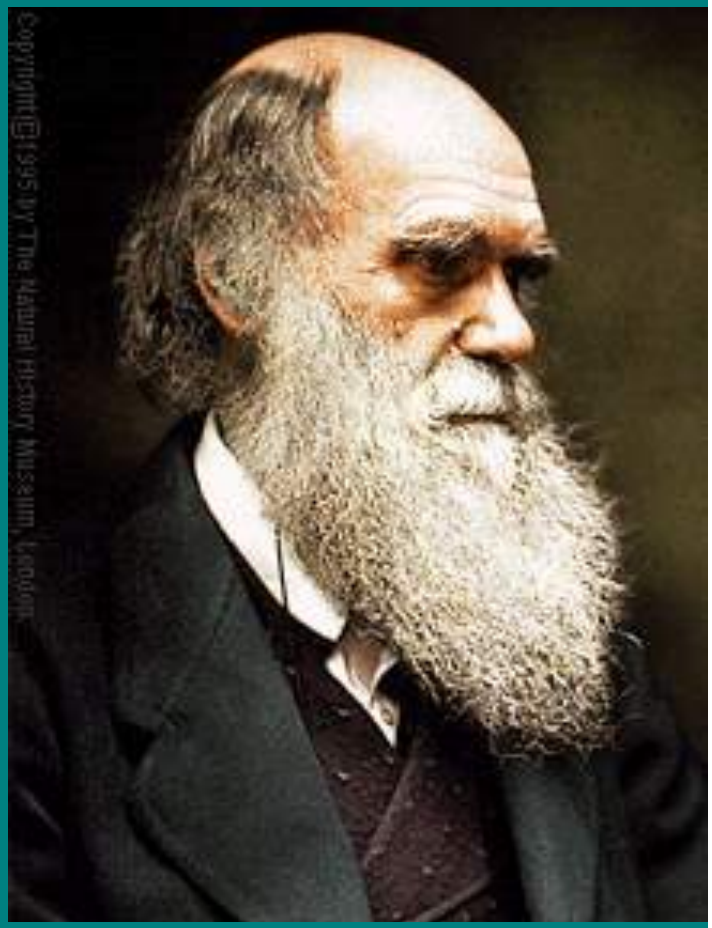


Phylogenetic Classifications

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

- 'Natural' had meant different things to different people

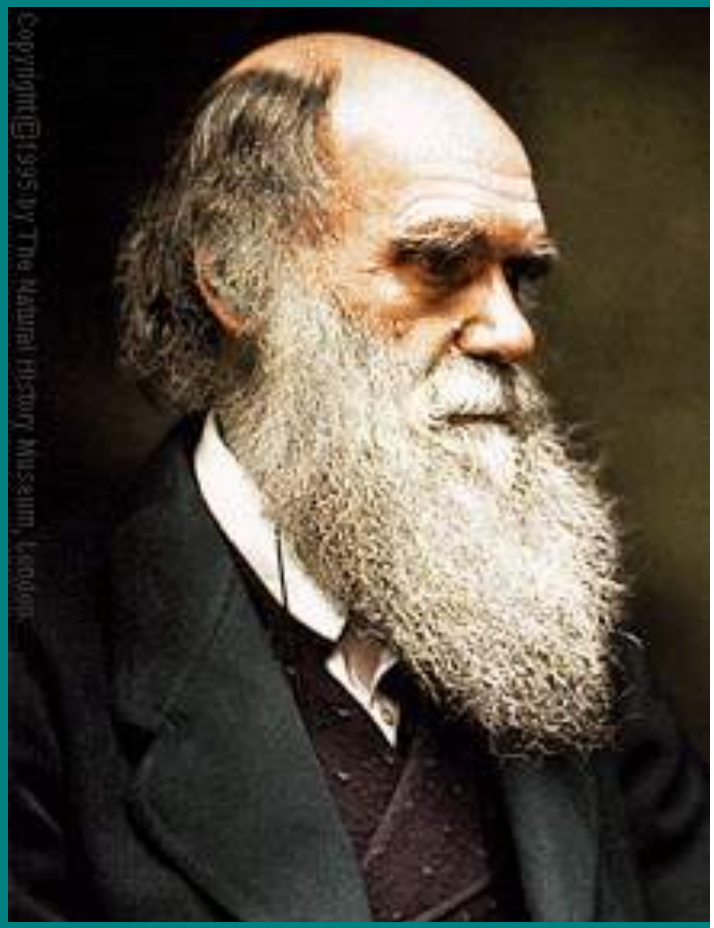
- to Darwin, 'natural' implied that two species looked similar because they shared features from a common ancestor in their genealogy



Phylogenetic Classifications

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

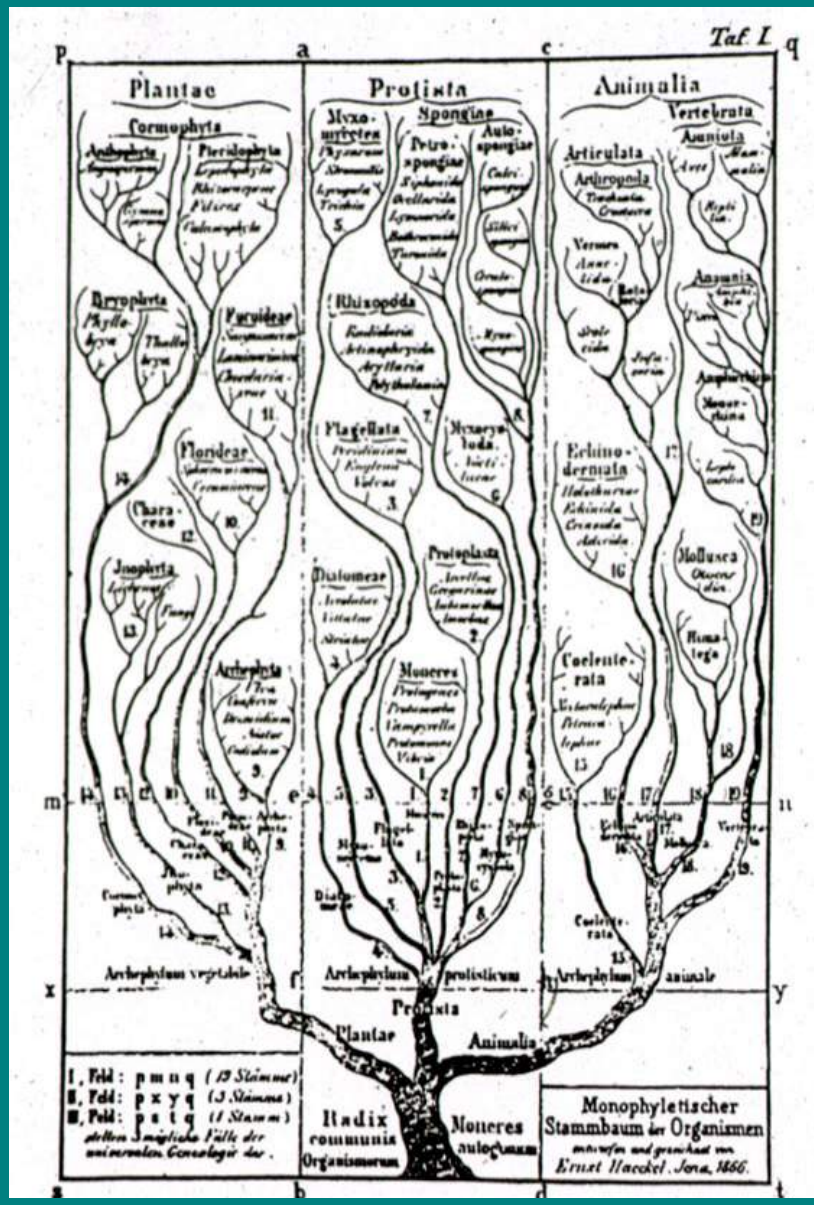
- "classification must be genealogical"
- "genealogy alone does not give classification"
- "descent with modification" : or genealogy plus change = evolution



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

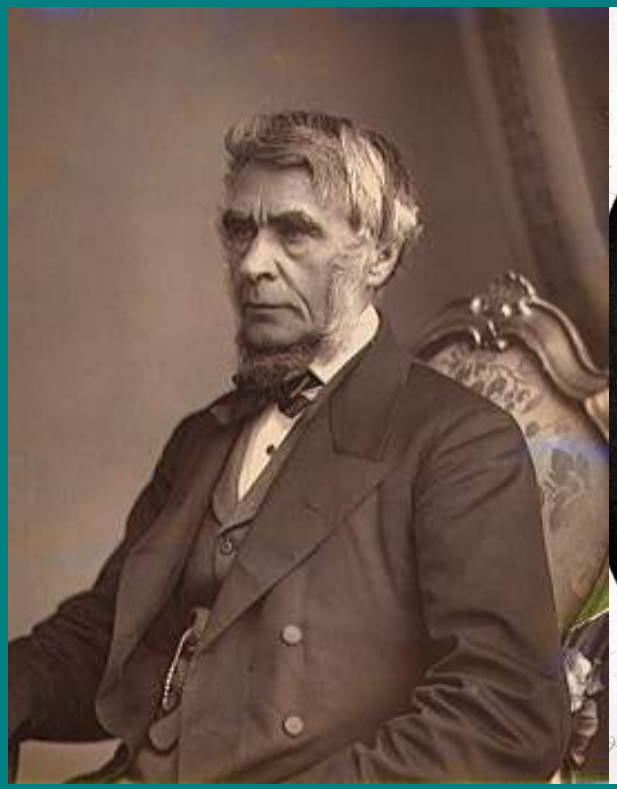


Phylogenetic Classifications

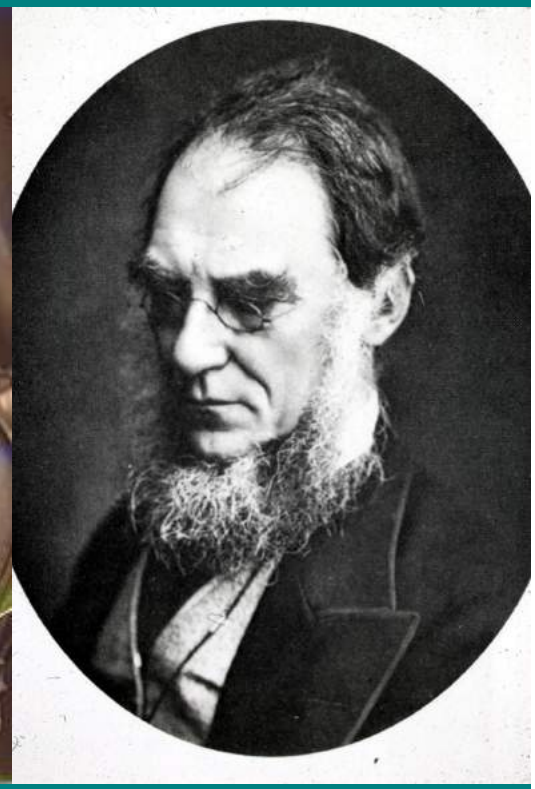
Bentham & Hooker at Kew Royal Botanic Gardens first systematists to wrestle with phylogenetic classifications

- 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

Adolph Engler
1844-1930

Karl Prantl
1849-1893

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 - 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

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

Salix - willow

University of Wisconsin Student Herbarium – *five 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

Charles Bessey (1848-1915)
at University of Nebraska

Phylogenetic Classifications

What were Bessey's main dicta or rules?

Character	Primitive State	Advanced State
1. Floral parts	all present, many in number	loss of parts, few in number
2. Floral fusion	parts separate	parts fused
3. Floral symmetry	actinomorphy	zygomorphy
4. Ovary position	hypogynous	epigynous

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

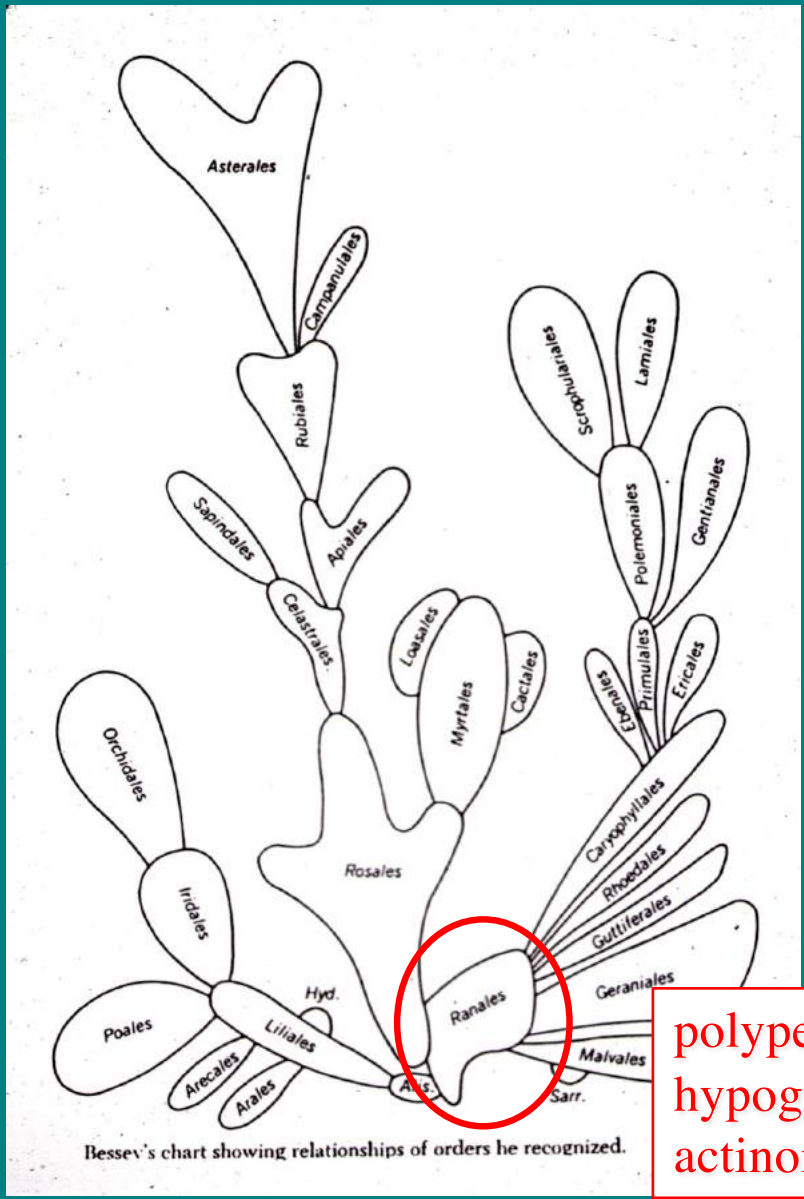
Phylogenetic Classifications

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

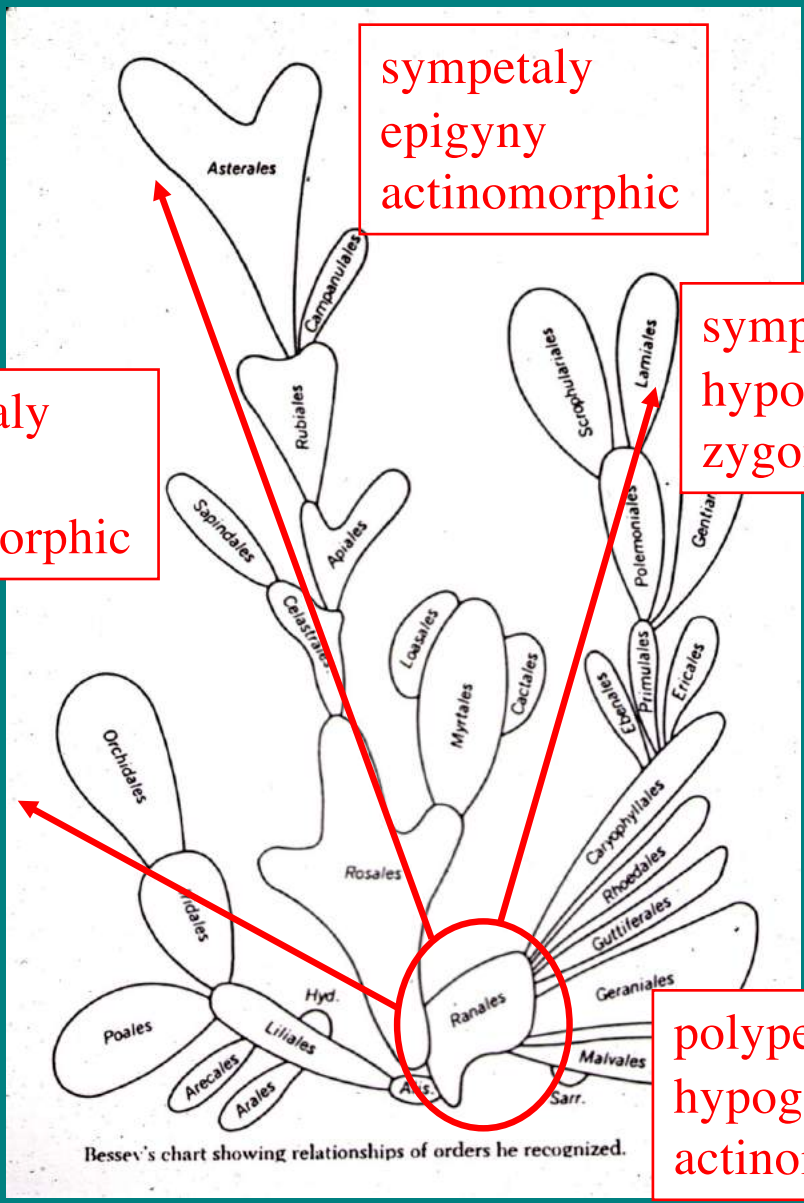
- order Ranales (*Magnolia*) considered most primitive



polypetaly
hypogyny
actinomorphic

Phylogenetic Classifications

Bessey's classification ('cactus')



Bessey's chart showing relationships of orders he recognized.

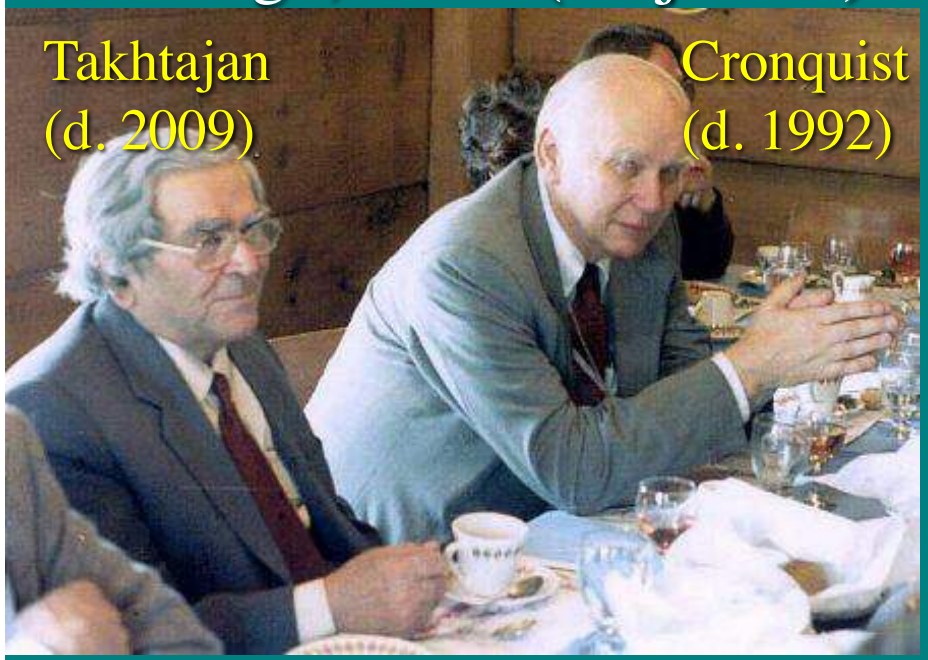
- zygomorphy, fused petals, and inferior ovary are found further up the chart

- order Ranales (*Magnolia*) considered most primitive

Phylogenetic Classifications

Contemporary classifications

- most based on Bessey's principles
- which characters stressed, though, varies (subjective)



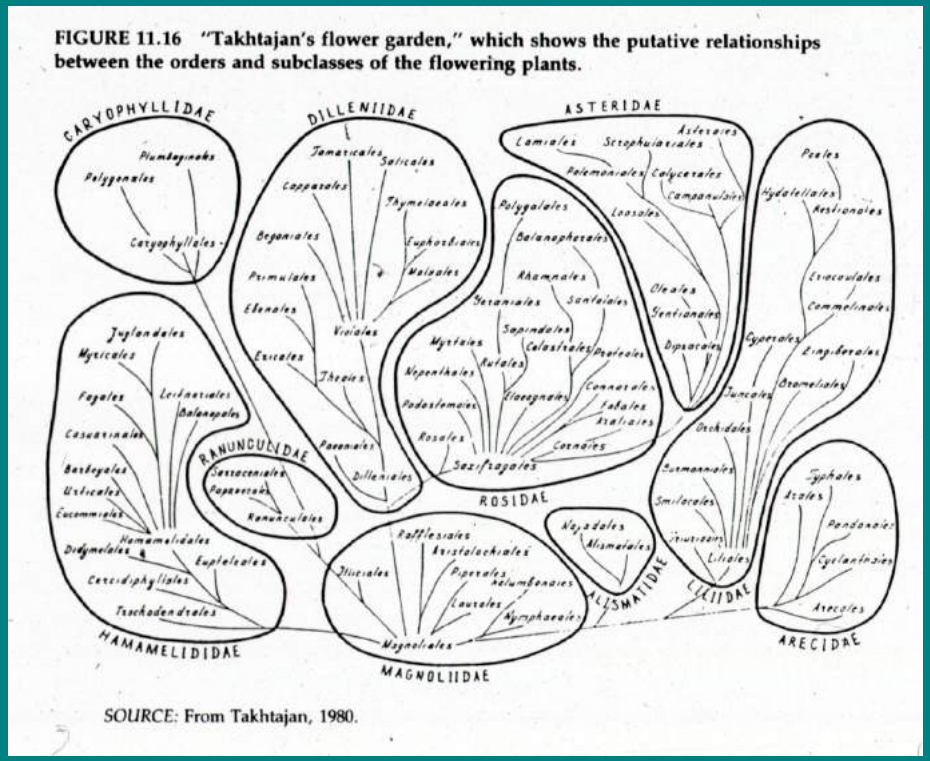


FIGURE 11.16 "Takhtajan's flower garden," which shows the putative relationships between the orders and subclasses of the flowering plants.

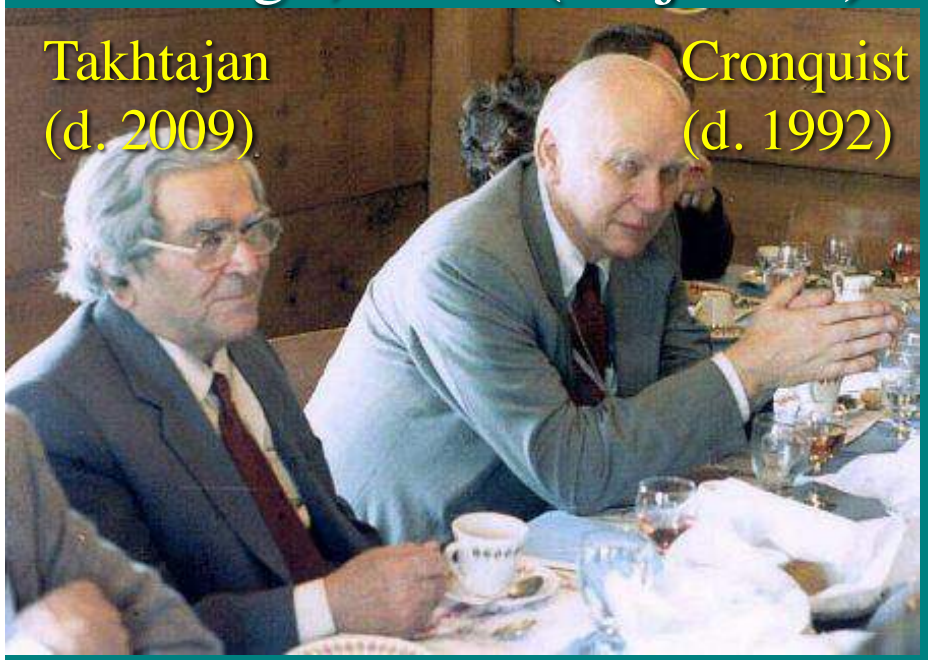
SOURCE: From Takhtajan, 1980.

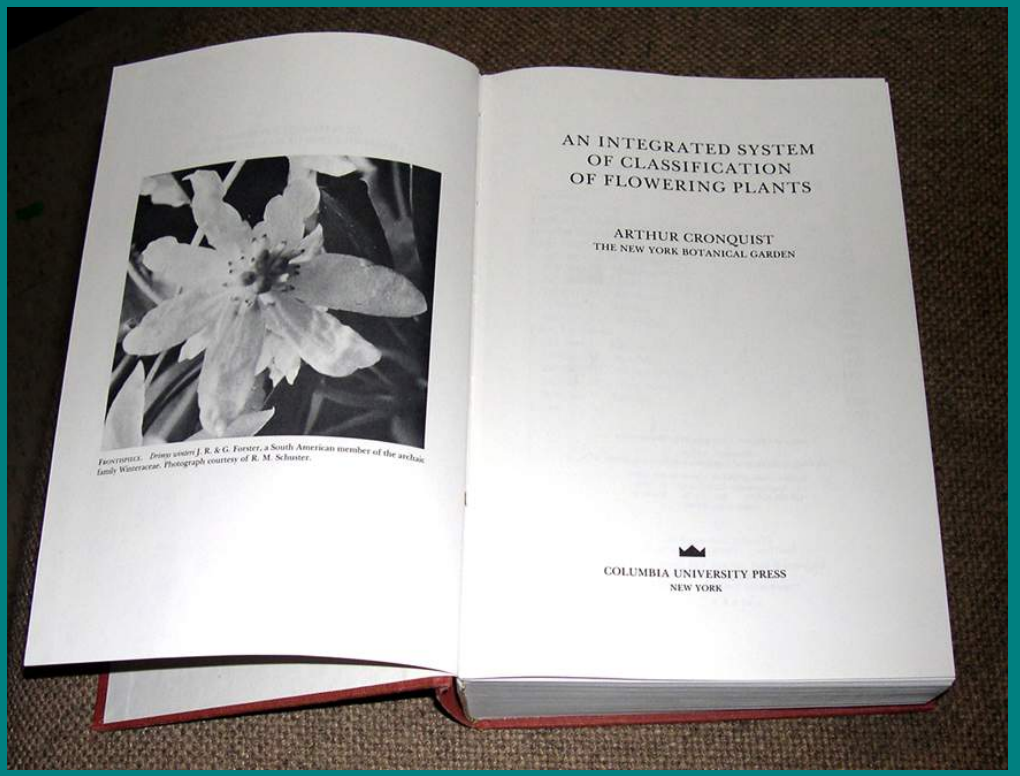
Armen Takhtajan's and Arthur Cronquist's are similar with subclasses (-idae) as the major groupings

Phylogenetic Classifications

Contemporary classifications

- most based on Bessey's principles
- which characters stressed, though, varies (subjective)





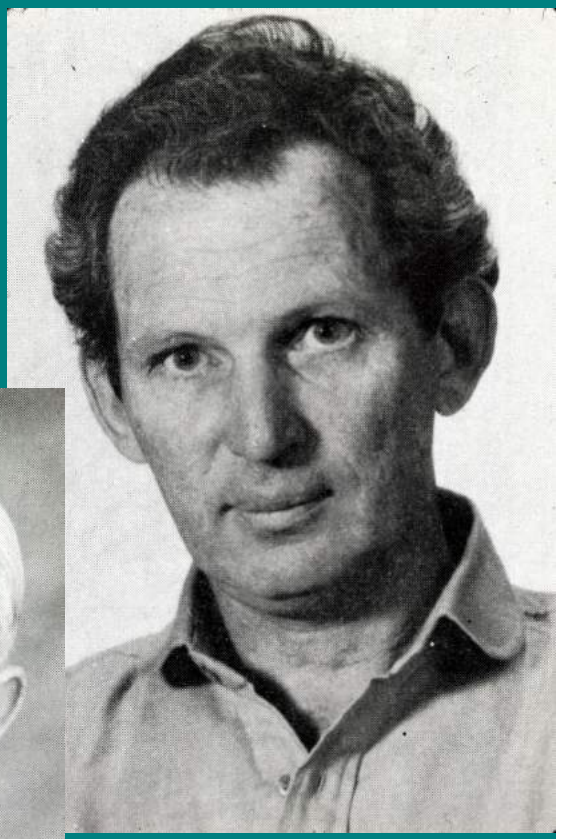
Cronquist's best developed of the contemporary classifications based on morphology

Phylogenetic Classifications

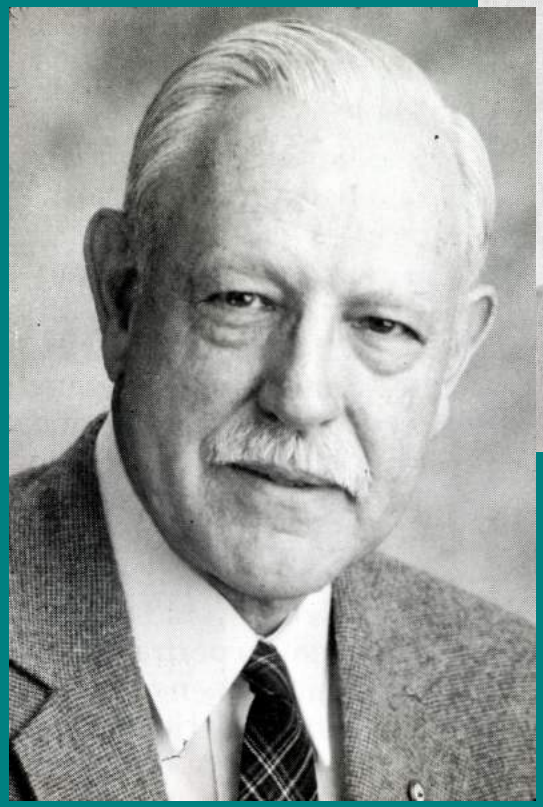
Contemporary classifications

- 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



Dalhgren



Thorne

Phylogenetic Classifications

Molecular classifications

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

PHYLOGENETICS OF SEED PLANTS: AN ANALYSIS OF NUCLEOTIDE SEQUENCES FROM THE PLASTID GENE *rbc*L[1]

Mark W. Chase,[2] Douglas E. Soltis,[3] Richard G. Olmstead,[4] David Morgan,[3] Donald H. Les,[5] Brent D. Mishler,[6] Melvin R. Duvall,[7] Robert A. Price,[8] Harold G. Hills,[2] Yin-Long Qiu,[2] Kathleen A. Kron,[2] Jeffrey H. Rettig,[9] Elena Conti,[10] Jeffrey D. Palmer,[8] James R. Manhart,[9] Kenneth J. Sytsma,[10] Helen J. Michaels,[11] W. John Kress,[12] Kenneth G. Karol,[10] W. Dennis Clark,[13] Mikael Hedrén,[14] Brandon S. Gaut,[7] Robert K. Jansen,[15] Ki-Joong Kim,[15] Charles F. Wimpee,[5] James F. Smith,[12] Glenn R. Furnier,[16] Steven H. Strauss,[17] Qiu-Yun Xiang,[3] Gregory M. Plunkett,[3] Pamela S. Soltis,[3] Susan M. Swensen,[18] Stephen E. Williams,[19] Paul A. Gadek,[20] Christopher J. Quinn,[20] Luis E. Eguiarte,[7] Edward Golenberg,[21] Gerald H. Learn, Jr.,[7] Sean W. Graham,[22] Spencer C. H. Barrett,[22] Selvadurai Dayanandan,[23] and Victor A. Albert[2]

ABSTRACT

We present the results of two exploratory parsimony analyses of DNA sequences from 475 and 499 species of seed plants, respectively, representing all major taxonomic groups. The data are exclusively from the chloroplast gene *rbc*L, which codes for the large subunit of ribulose-1,5-bisphosphate carboxylase/oxygenase (RuBisCO or RuBPCase). We used two different state-transformation assumptions resulting in two sets of cladograms: (i) equal-weighting for the 499-taxon analysis; and (ii) a procedure that differentially weights transversions over transitions within characters and codon positions among characters for the 475-taxon analysis. The degree of congruence between these results and other molecular, as well as morphological, cladistic studies indicates that *rbc*L sequence variation contains historical evidence appropriate for phylogenetic analysis at this taxonomic level of sampling. Because the topologies presented are necessarily approximate and cannot be evaluated adequately for internal support, these results should be assessed from the perspective of their predictive value and used to direct future studies, both molecular and morphological. In both analyses, the three genera of Gnetales are placed together as the sister group of the flowering plants, and the anomalous aquatic *Ceratophyllum* (Ceratophyllaceae) is sister to all other flowering plants. Several major lineages identified correspond well with at least some recent taxonomic schemes for angiosperms, particularly those of Dahlgren and Thorne. The basalmost clades within the angiosperms are orders of the apparently polyphyletic subclass Magnoliidae sensu Cronquist. The most conspicuous feature of the topology is that the major division is not monocot versus dicot, but rather one correlated with general pollen type: uniaperturate versus triaperturate. The Dilleniidae and Hamamelidae are the only subclasses that are grossly polyphyletic; an examination of the latter is presented as an example of the use of these broad analyses to focus more restricted studies. A broadly circumscribed Rosidae is paraphyletic to Asteridae and Dilleniidae. Subclass Caryophyllidae is monophyletic and derived from within Rosidae in the 475-taxon analysis but is sister to a group composed of broadly delineated Asteridae and Rosidae in the 499-taxon study.

[1] The authors acknowledge the following support: U.S. National Science Foundation (NSF) grant BSR-8906496 to MWC; BSR-9007614 to DES; BSR-9002321 to MRD; BSR-9107827 to RGO; BSR-8817992 to DHL and CFW; BSR-9107484 to BDM; BSR-9007293 and BSR-9020055 to KJS; BSR-8821264 to KAK; BSR-8717600 and BSR-8996262 to JDP; BSR-9020171 to RKJ; BSR-8817953 to SHS and RAP and BSR-8957023 to SHS; BSR-880193 to W. Alverson; a Sloan Postdoctoral Fellowship to KJK; BSR-8914635 to VAA; a grant from the American Philosophical Society to SEW; Australian Research Council grant AD9031851 to PAG and CJQ; an operating grant to SCHB and a graduate scholarship to SWG from the Natural Sciences & Engineering Research Council of Canada; a grant to MWC and doctoral fellowship to VAA from the American Orchid Society; and a postdoctoral scholarship

ANN. MISSOURI BOT. GARD. 80: 528–580. 1993.

Phylogenetic Classifications

Molecular classifications

- Angiosperm Phylogeny Group classification — APGI (1998), APGII (2003)
- APGIII (2009) – used in course and *Plant Systematics, 2nd ed.* text [APGIV (2016) "tweaked"]

Botanical Journal of the Linnean Society, 2009, **161**, 105–121. With 1 figure

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

THE ANGIOSPERM PHYLOGENY GROUP*[1]

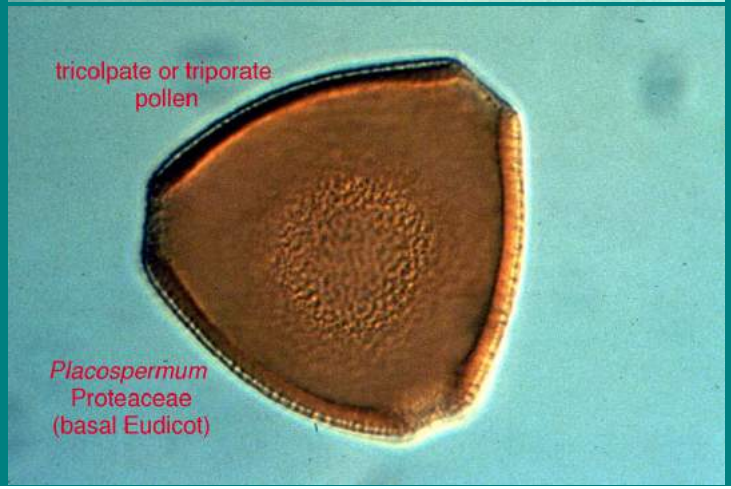
[1]*Recommended citation: APG III (2009). This paper was compiled by Birgitta Bremer, Kåre Bremer, Mark W. Chase, Michael F. Fay, James L. Reveal, Douglas E. Soltis, Pamela S. Soltis and Peter F. Stevens, who were equally responsible and listed here in alphabetical order only, with contributions from Arne A. Anderberg, Michael J. Moore, Richard G. Olmstead, Paula J. Rudall, Kenneth J. Sytsma, David C. Tank, Kenneth Wurdack, Jenny Q.-Y. Xiang and Sue Zmarzty (in alphabetical order). Addresses: B. Bremer, The Bergius Foundation at the Royal Swedish Academy of Sciences, PO Box 50017, SE-104 05 Stockholm, Sweden; K. Bremer, Vice Chancellor, Stockholm University, SE-106 91 Stockholm, Sweden; M. W. Chase, M. F. Fay, Jodrell Laboratory, Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3DS, UK; J. L. Reveal, L.H. Bailey Hortorium, Department of Plant Biology, 412 Mann Building, Cornell University, Ithaca, NY 14853-4301, USA; D. E. Soltis, Department of Biology, University of Florida, Gainesville, Florida 32611–8525, USA; P. S. Soltis, Florida Museum of Natural History, University of Florida, Gainesville, Florida, 32611–7800, USA; and P. F. Stevens, Department of Biology, University of Missouri-St. Louis and Missouri Botanical Garden, PO Box 299, St. Louis, Missouri 63166–0299, USA*

Received 12 August 2009; accepted for publication 18 August 2009

Phylogenetic Classifications

Molecular classifications

- Angiosperm Phylogeny Group classification — APGI (1998), APGII (2003)
- APGIII (2009) – used in course and *Plant Systematics, 2nd ed.* text
- APG uses DNA and a lot of morphology
  - e.g., use of pollen features to delimit "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!

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Phylogenetic Classifications

UW Botany Department Student Herbarium

Dr. John Zaborsky – 2018 Bot400 TA

Arranging these named organisms in 1 dimensional linear space?

Botanical Journal of the Linnean Society, 2009, **161**, 105–121. With 1 figure

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Issues in Grouping

1. Convergence a problem with any system

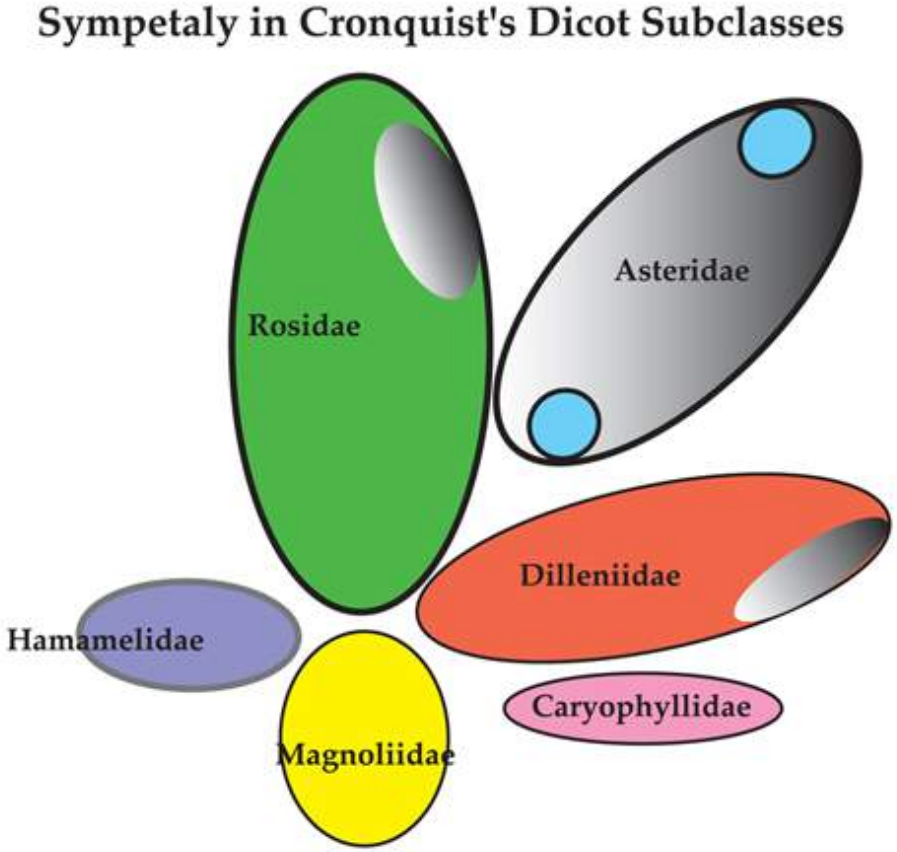
Reduced flowers

Inferior ovary

Corolla tube

Issues in Grouping

1. Convergence a problem with any system

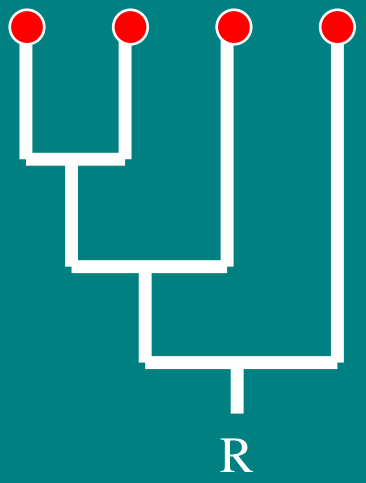


Corolla tube

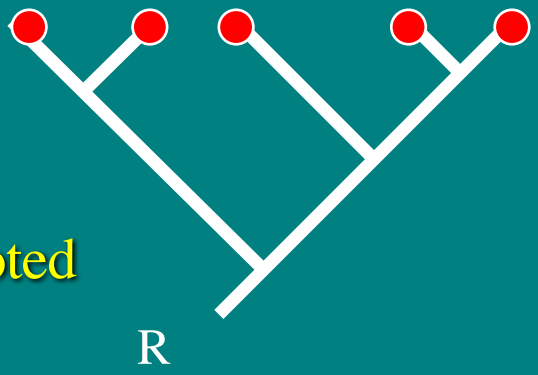
Issues in Grouping

2. "Tree Thinking" - what a phylogenetic tree is . . .

- various trees that you will see in this course



rooted



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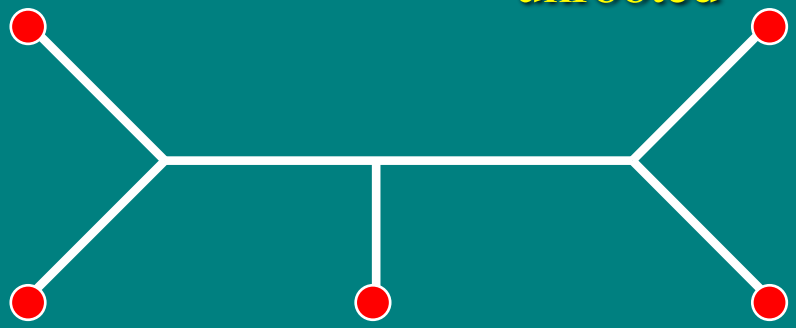
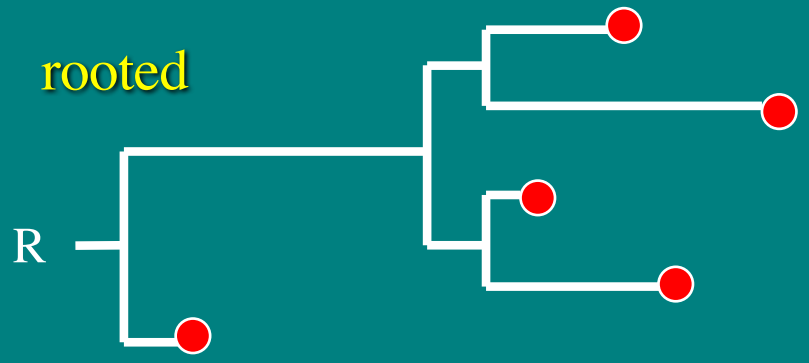


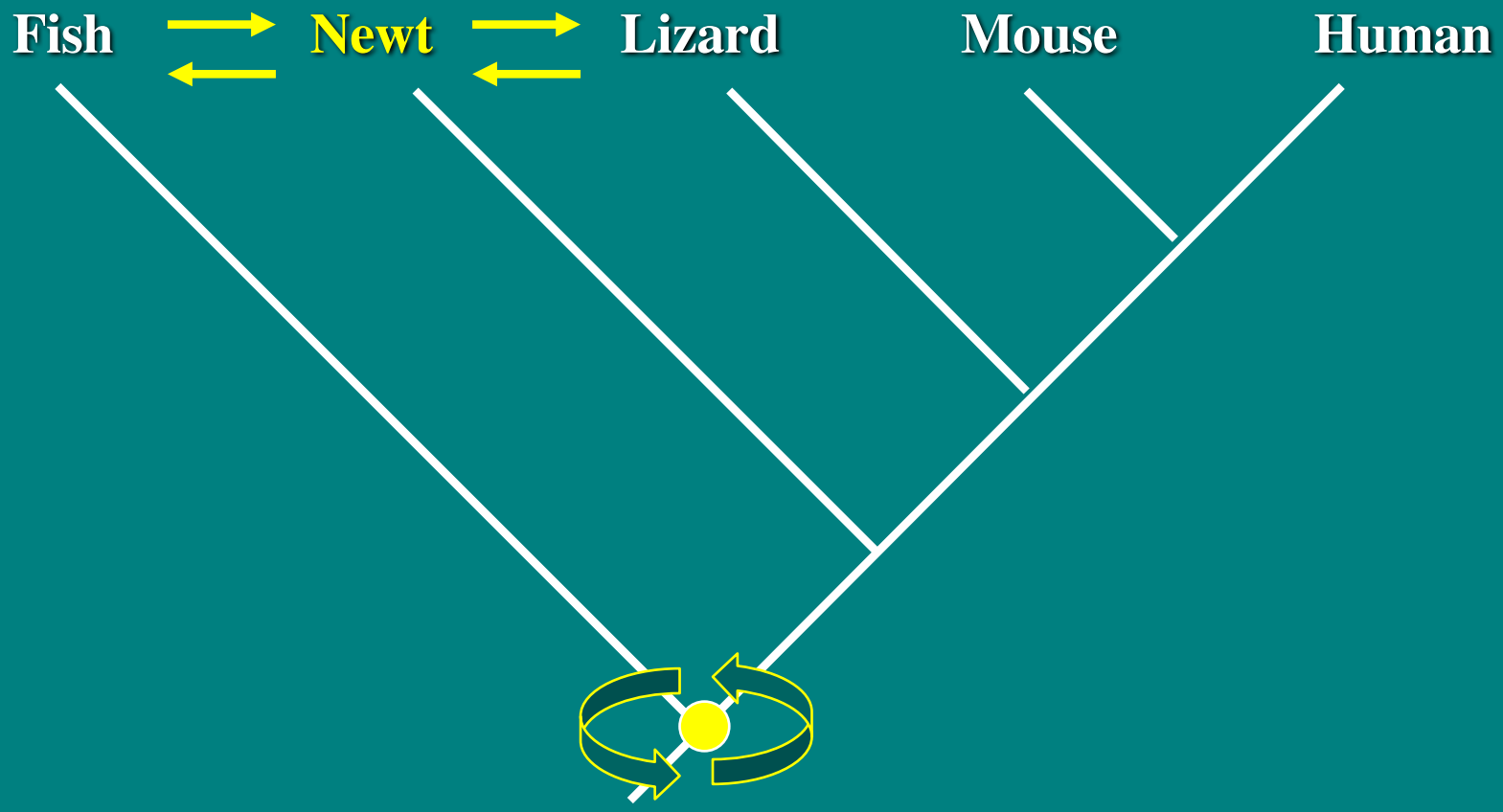
unrooted



rooted

Issues in Grouping

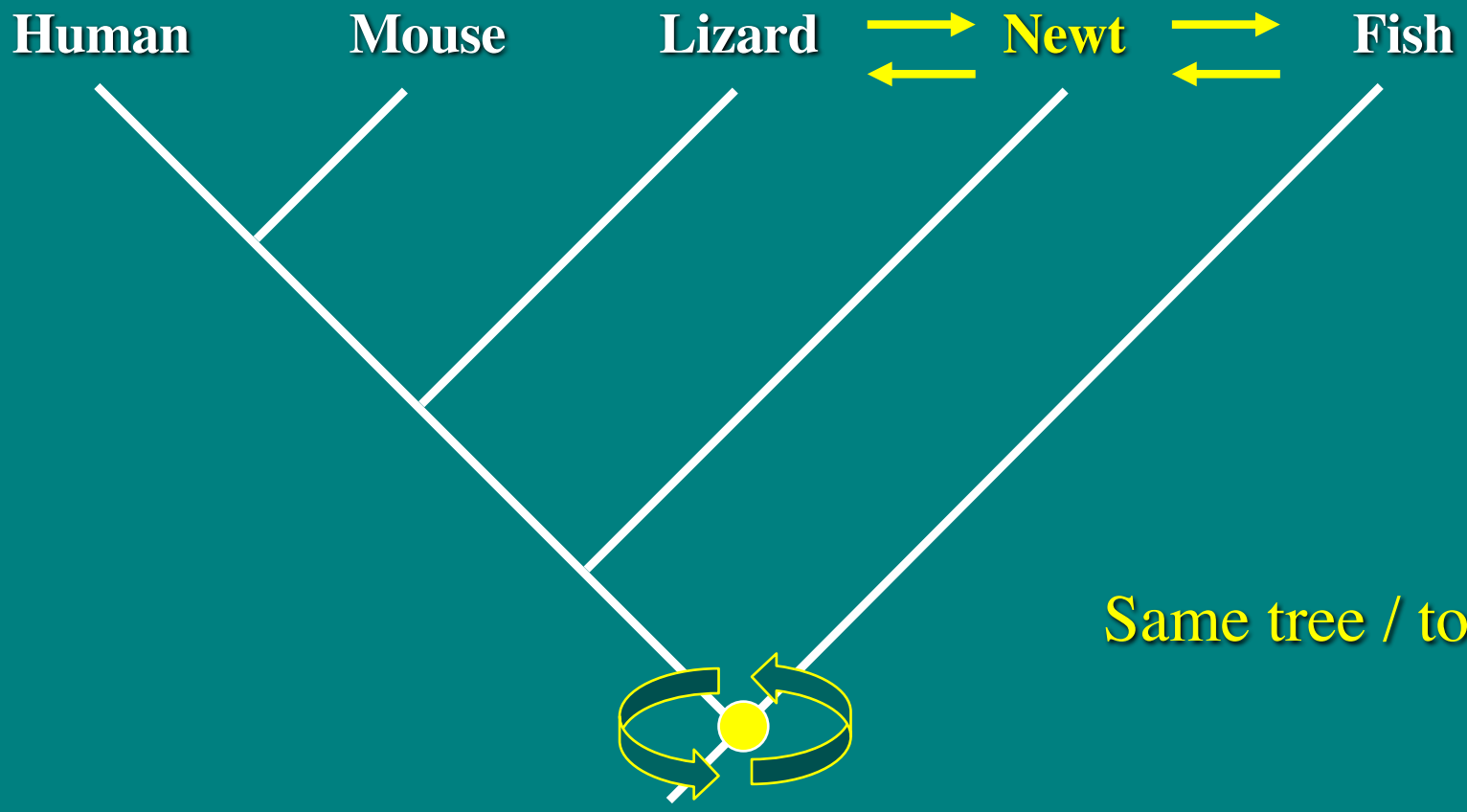
2. "Tree Thinking" - what a phylogenetic tree is not . . .



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

Issues in Grouping

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



Same tree / topology!

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

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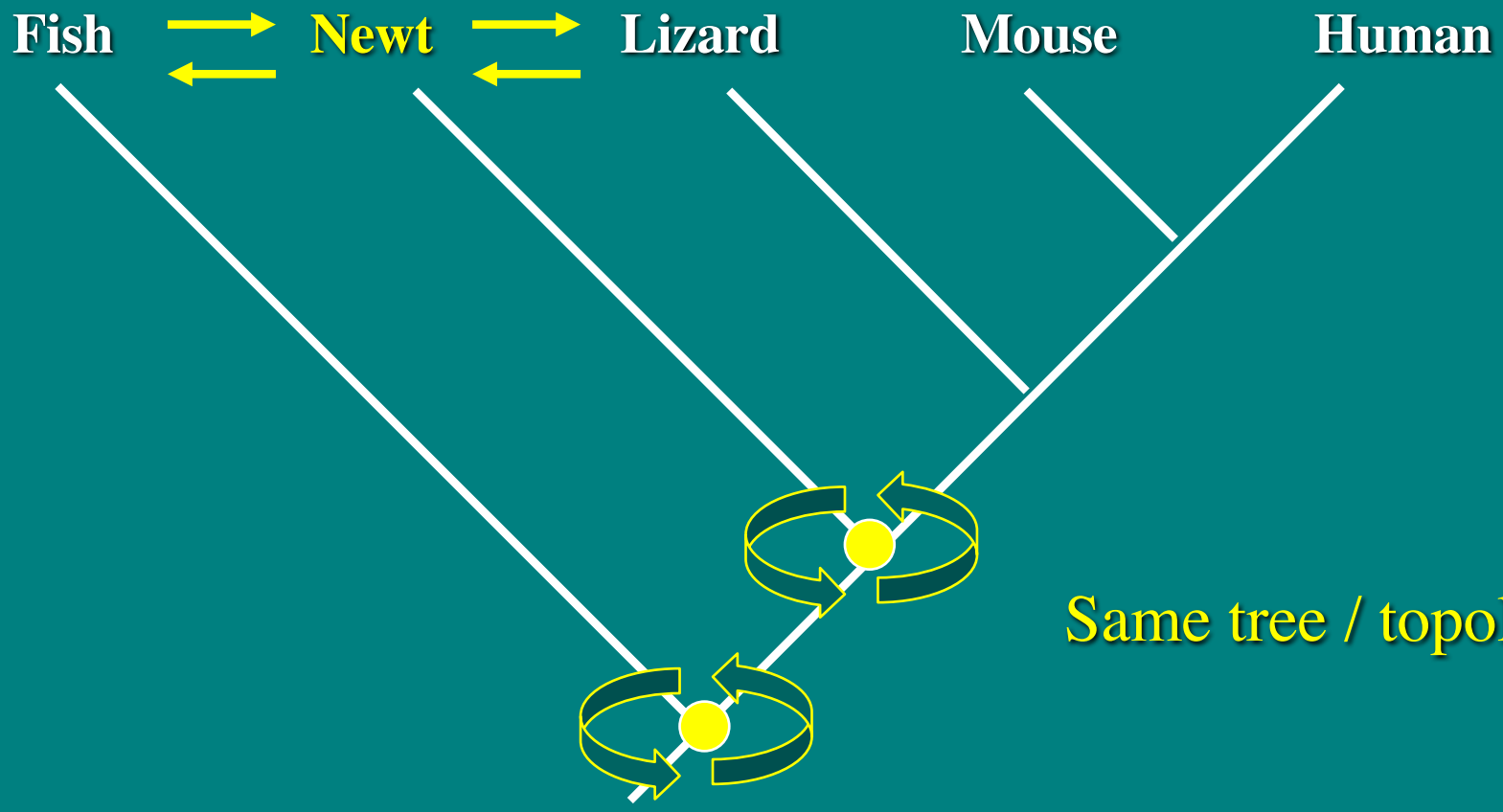

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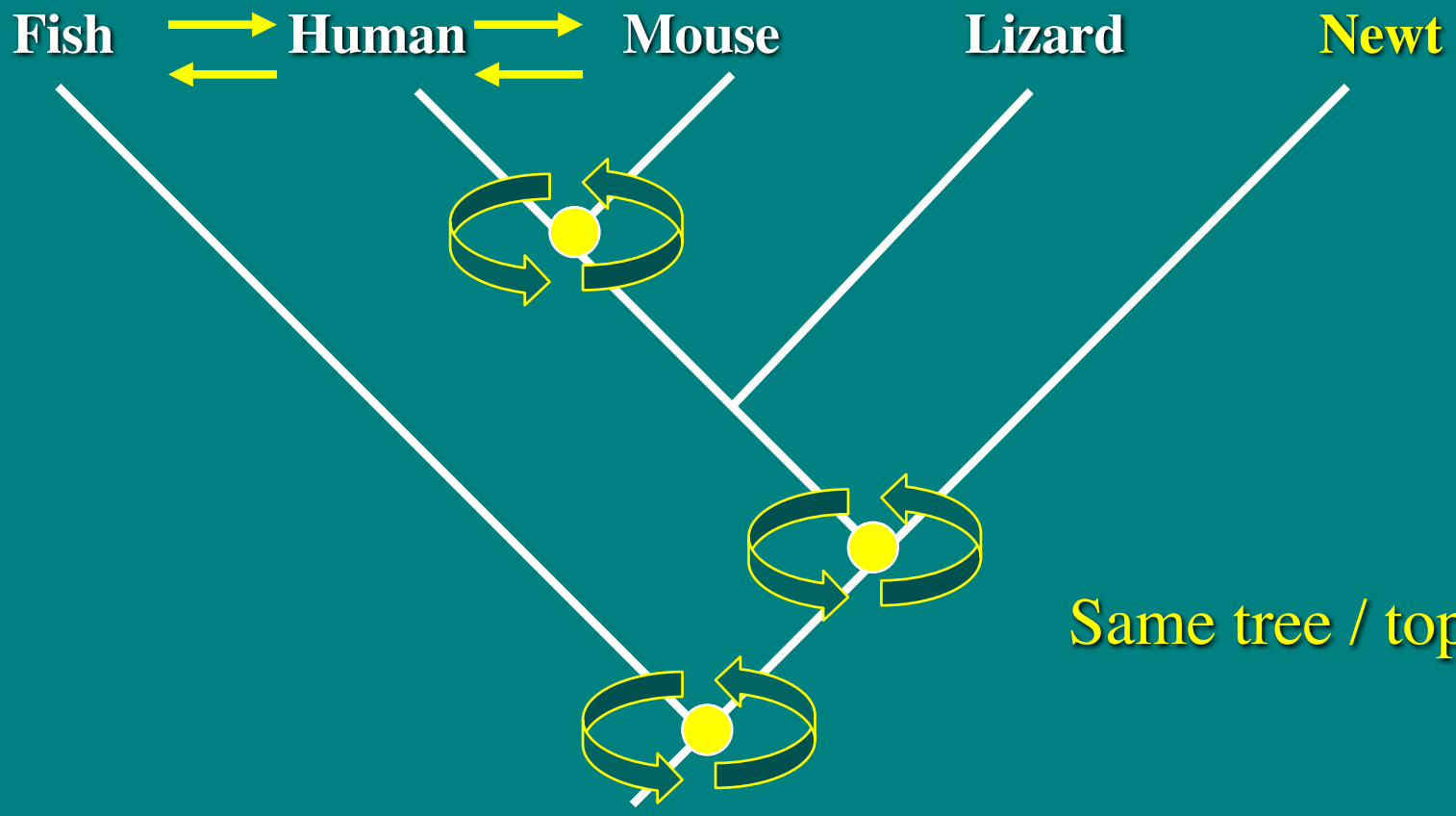

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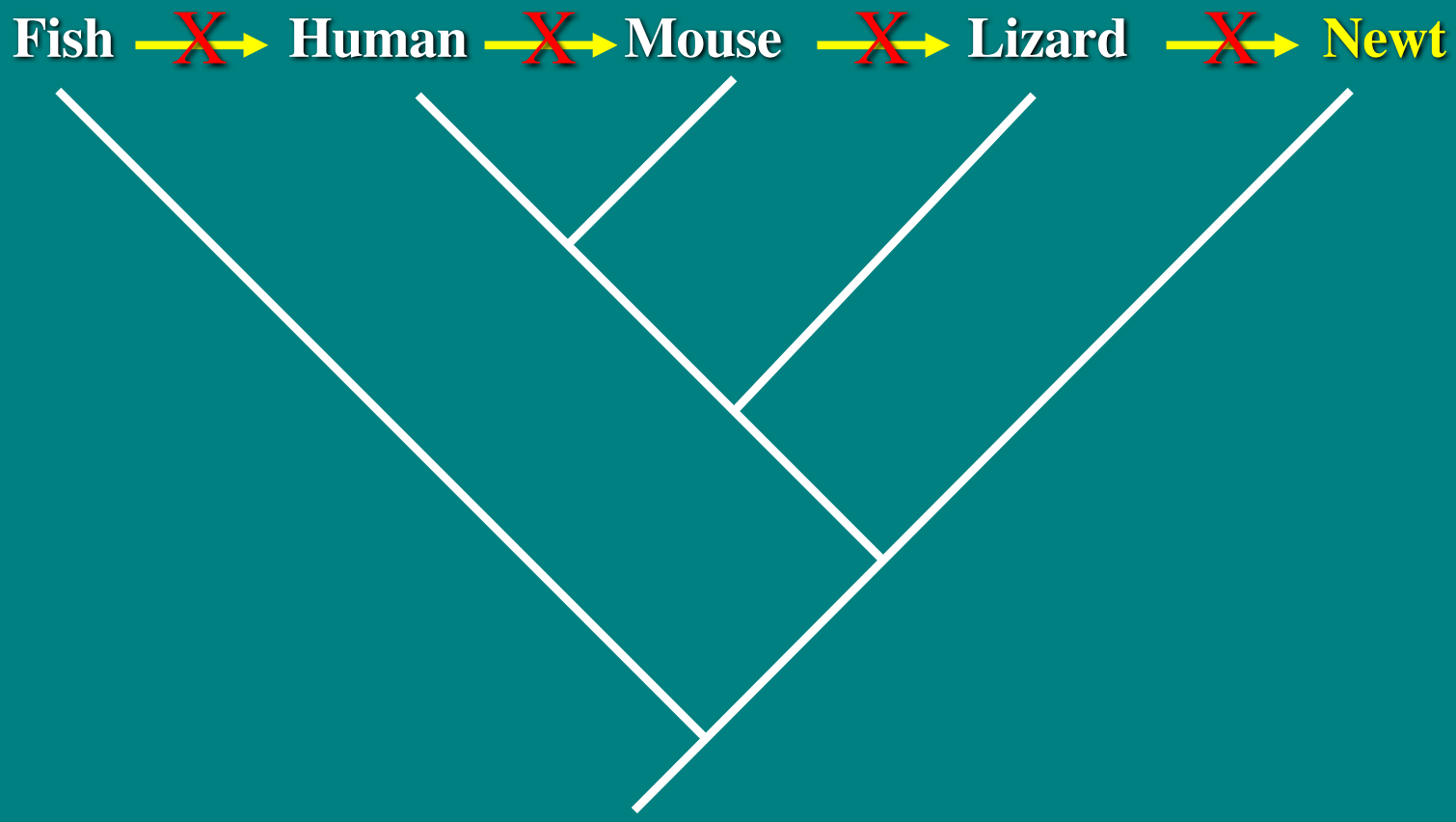

Tip reading is ladder reading, incorrect!

Issues in Grouping

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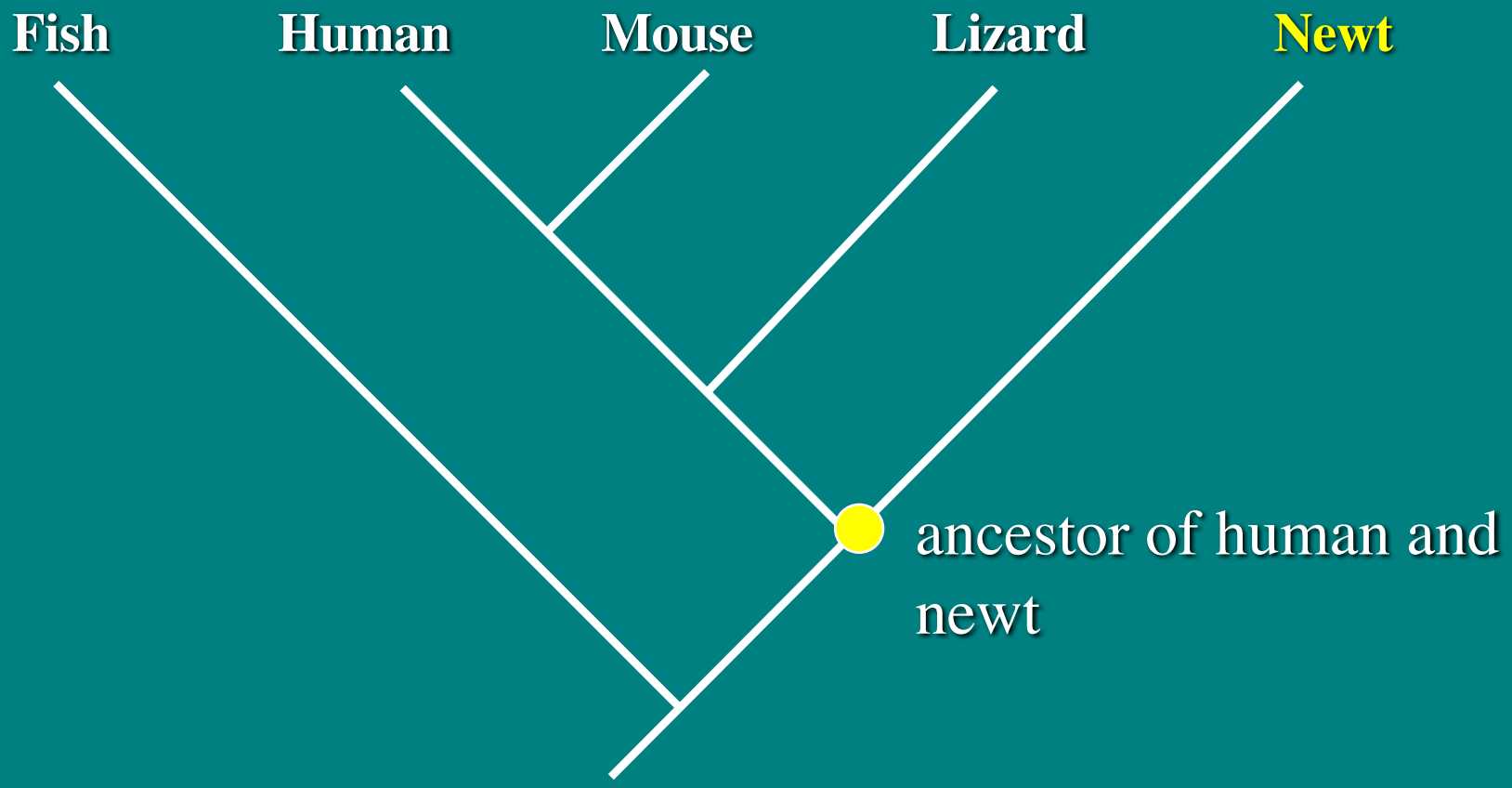
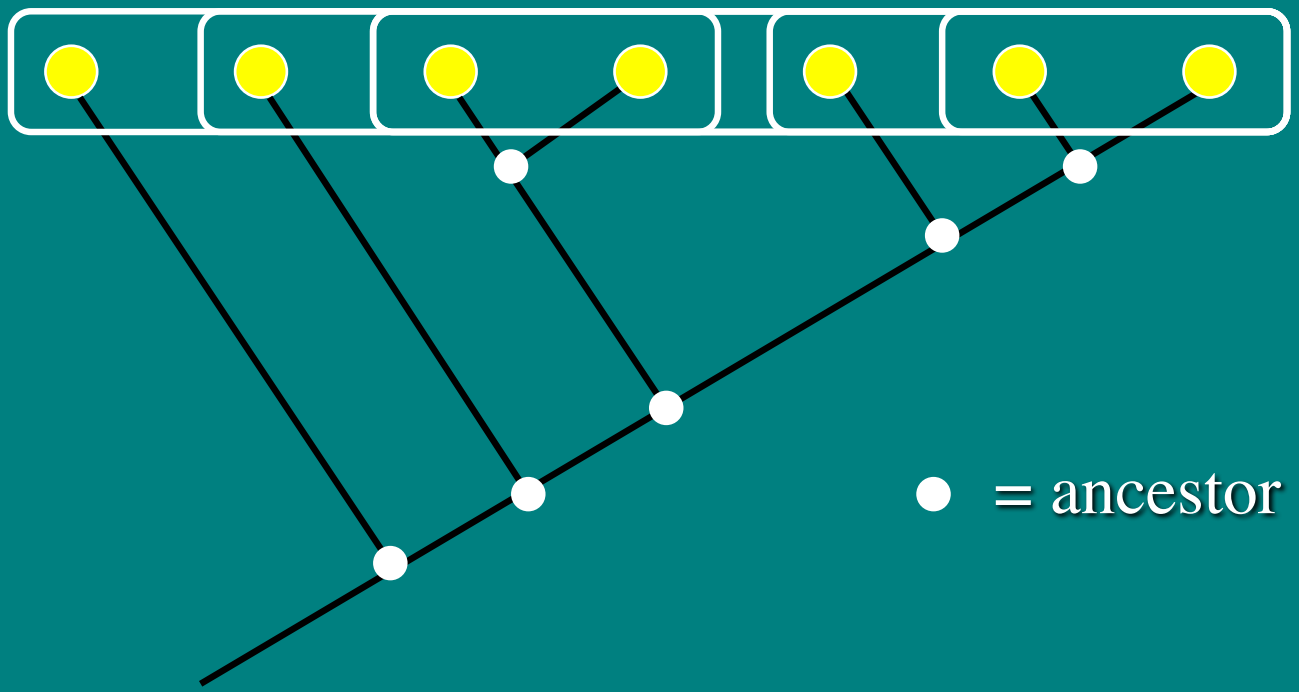


Newt is more related to Humans than Fish! They share a more recent common ancestor than either does with Fish.

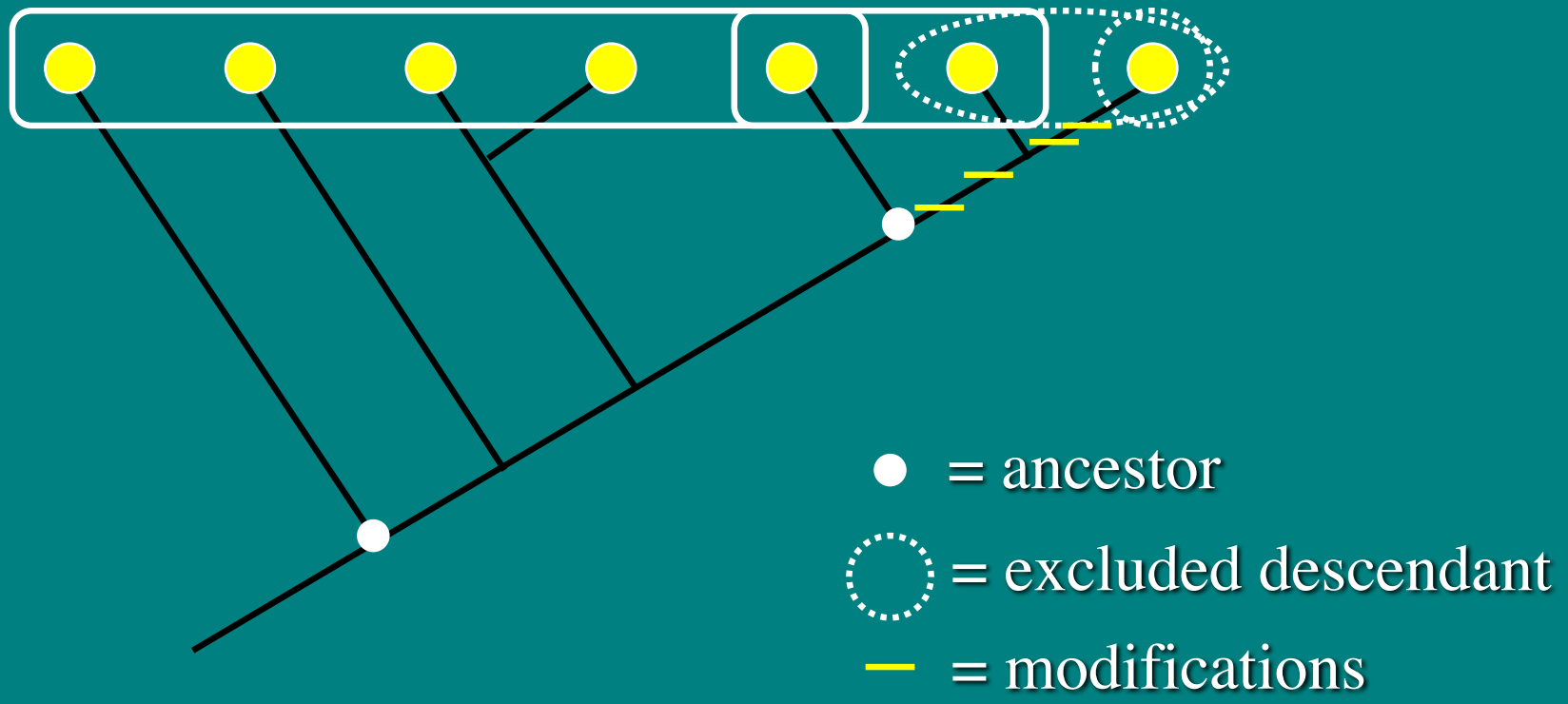
Issues in Grouping

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



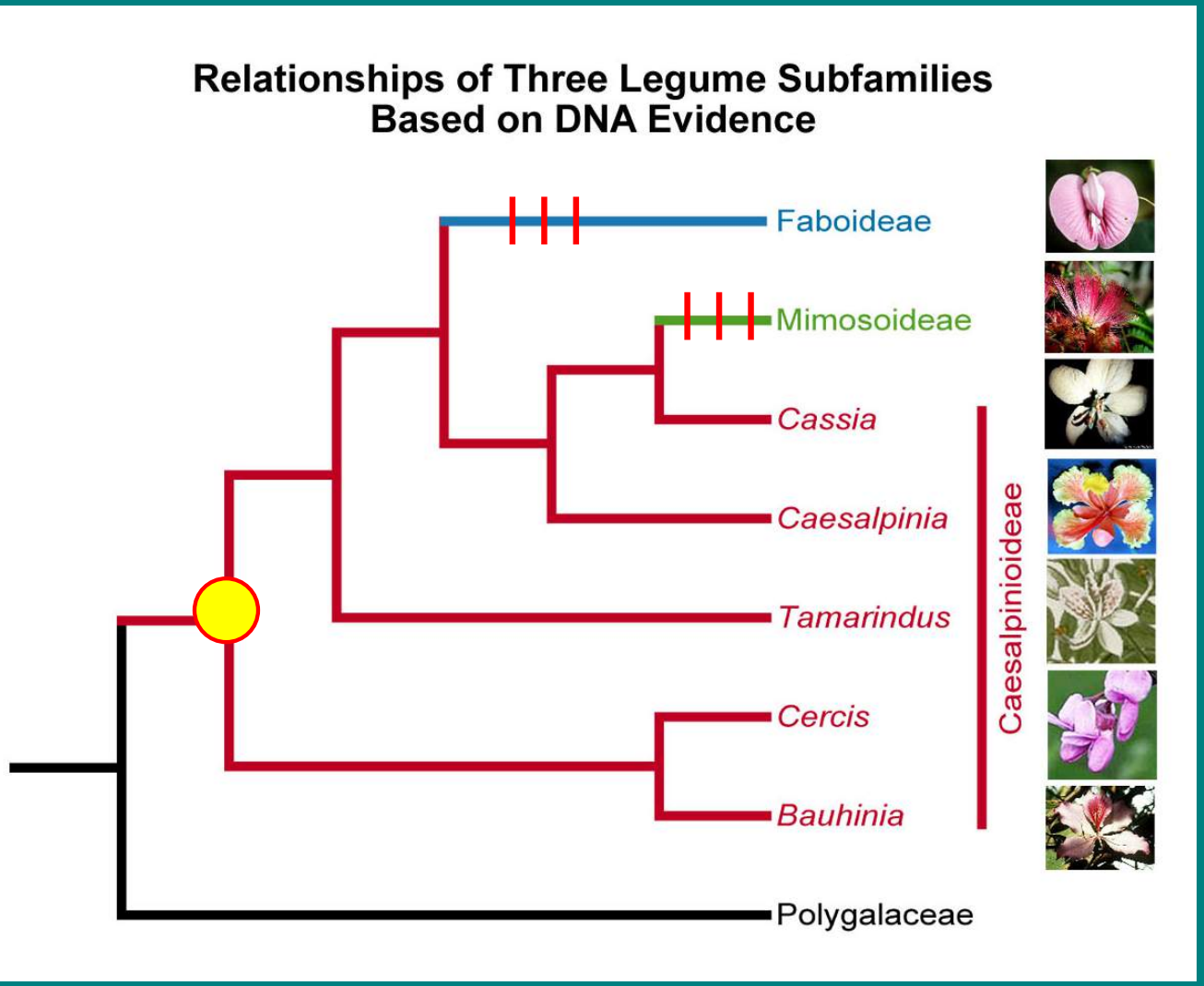
Issues in Grouping

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



Issues in Grouping

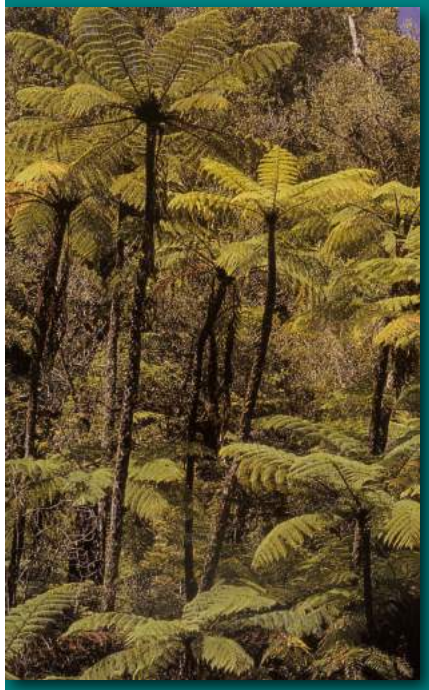
3. e.g. Caesalpinoid legumes are paraphyletic



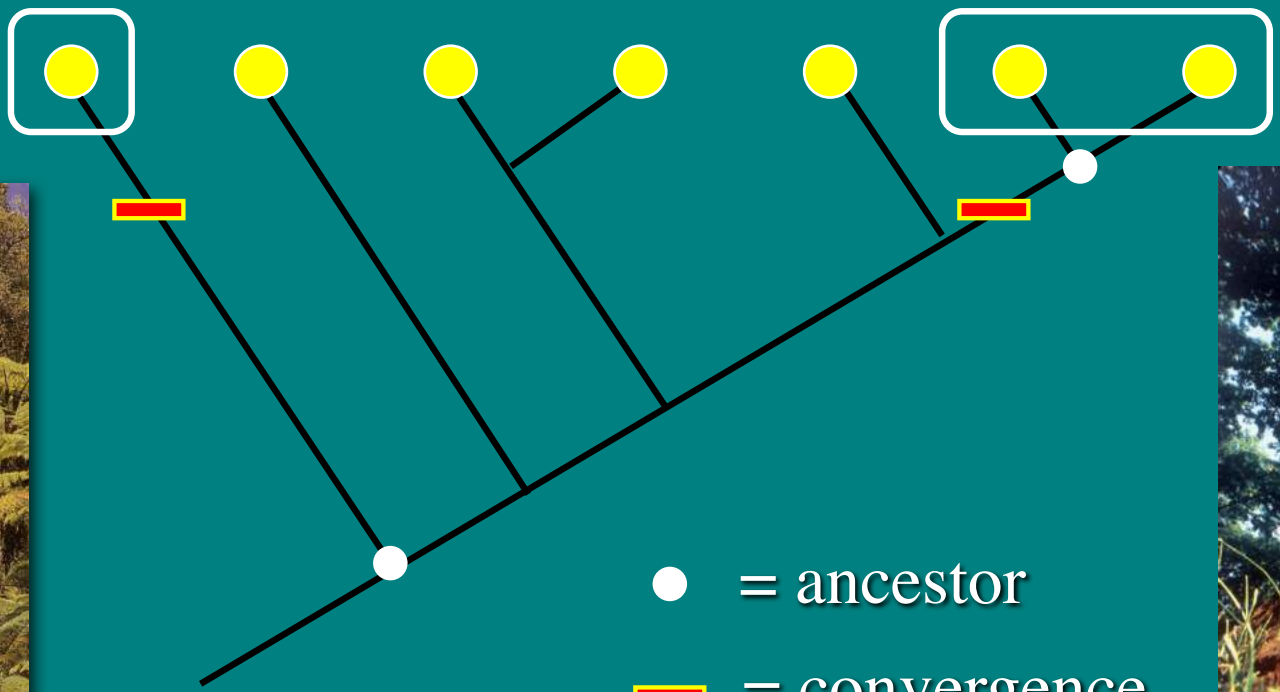
- faboid (beans, peas) and mimisoid (acacia, mimosa) legumes are highly modified
- but descended from the common ancestor of caesalpinoids

Issues in Grouping

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



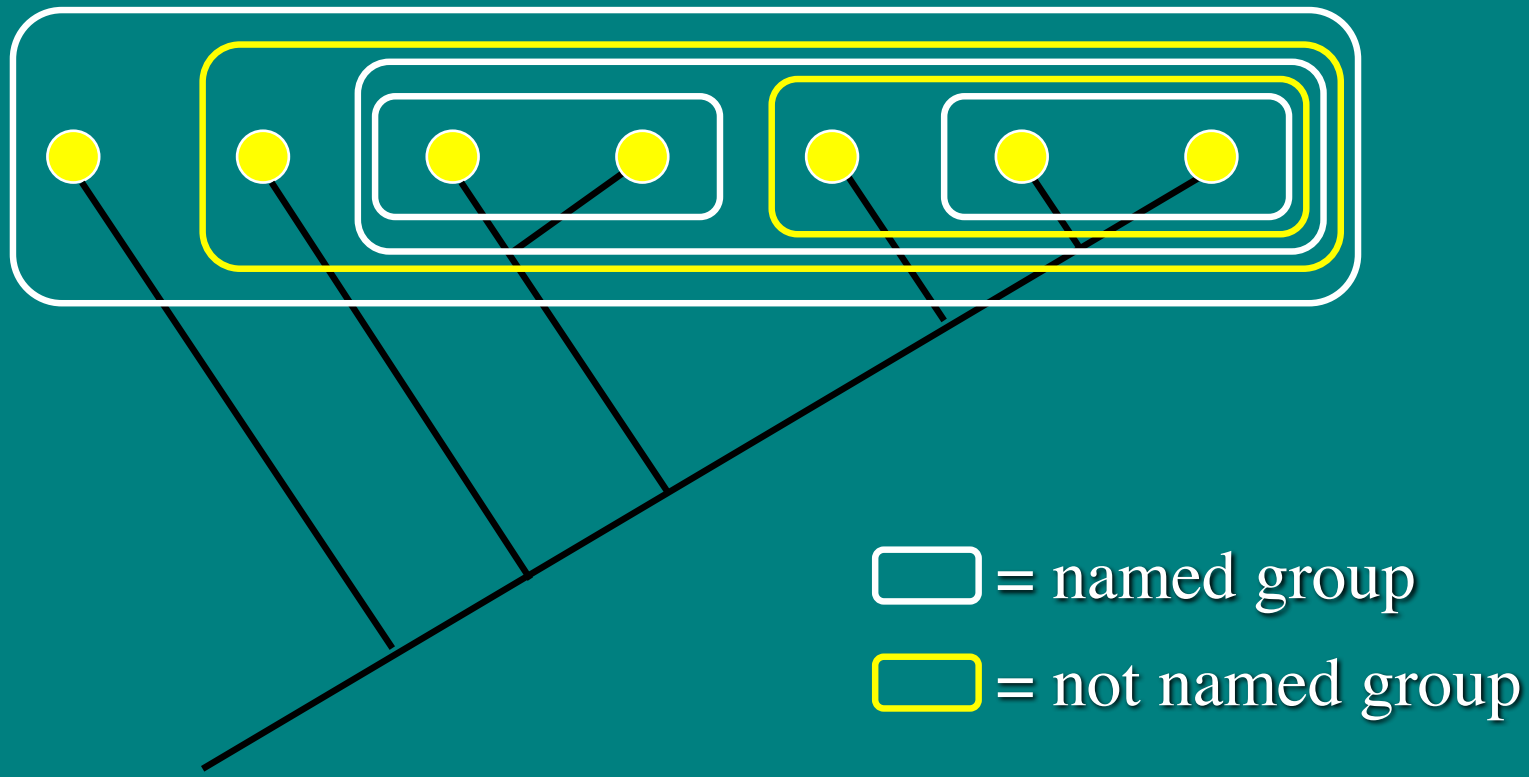
tree fern



red oak

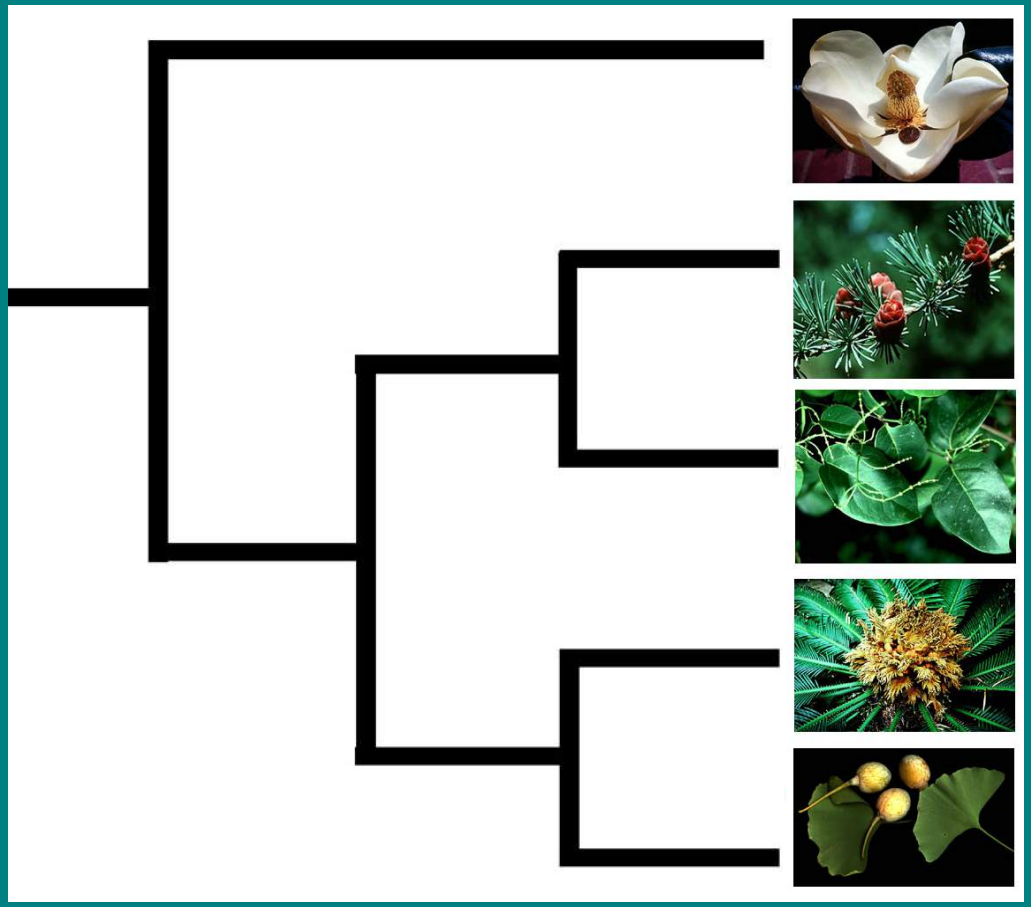
Issues in Grouping

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



Issues in Grouping

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



Gymnosperms
= 4 phyla

Issues in Grouping

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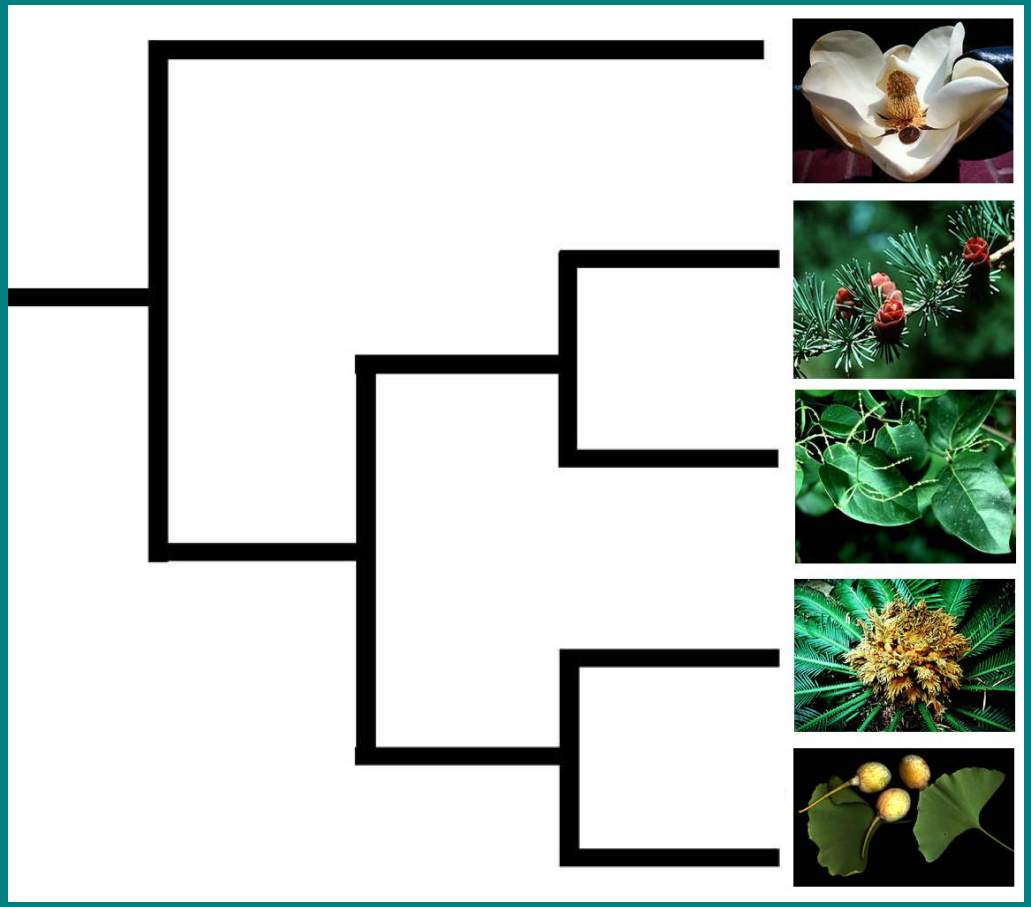

or . . .

Gymnosperms = 4 classes in 1 phylum

Issues in Grouping

6. International Code of Phylogenetic Nomenclature or PhyloCode (established 2004)
http://www.ohiou.edu/phylocode/

vs.

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

- 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!

- 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
- APGIII uses ranks for families and orders; informal rankless names for larger groups