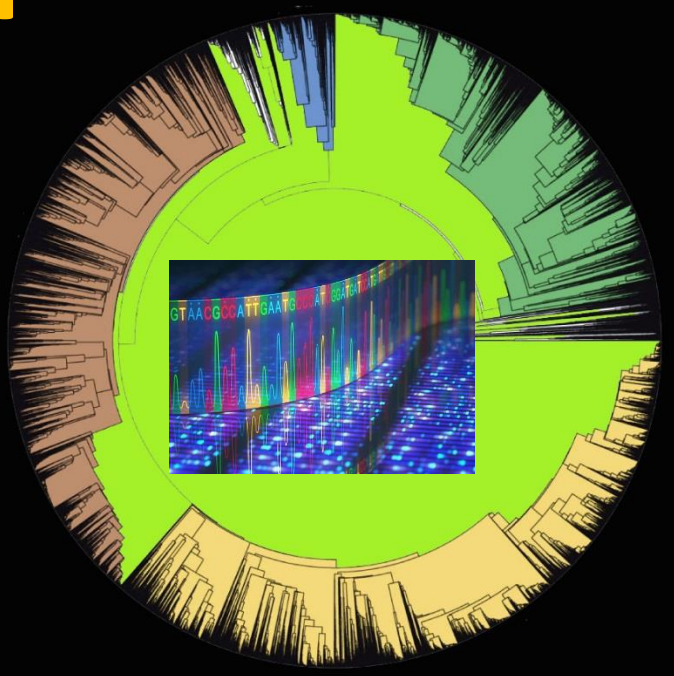
EXPERIMENTAL TAXONOMY

(BOT 322)

Updated
26 February 2026



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هيئة تقويم التعليم والتدريب
Education & Training Evaluation Commission
اعتماد NCAAA
2024
TP-153

Course Specification

(Bachelor)

Course Title:	EXPERIMENTAL TAXONOMY
Course Code:	BOT322
Program:	BOTANY
Department:	BOTANY AND MICROBIOLOGY
College:	SCIENCE
Institution:	KING SAUD UNIVERSITY
Version:	5th
Last Revision Date:	2/26/2026

Table of Contents

هيئة تقويم التعليم والتدريب
Education & Training Evaluation Commission

A. General information about the course:

1. Course Identification

1. Credit hours: 2					
2 (1+0+1)					
2. Course type					
A.	☐University	☐College	☒ Department	☐Track	☐Others
B.	☐Required		☒ Elective		
3. Level/year at which this course is offered: (5th /3)					
4. Course General Description:					
The use of comparative experimental methods in taxonomy units. Eco-geographical distribution and its taxonomic importance. Natural hybridization. Anatomical, cytological, and chemical differences and their taxonomic value. Fertility and its significance					
5. Pre-requirements for this course (if any)**:**					
None					
6. Co-requisites for this course (if any)**:**					
None					
7. Course Main Objective(s):					
1. Using empirical taxonomic evidence to identify plant species 2. Using statistical programs to find out the percentage of similarities and differences between plant species 3. The influence of environmental factors on the emergence of plant diversity					

2. Teaching mode (mark all that apply)

No	Mode of Instruction	Contact Hours	Percentage
1	Traditional classroom	45	100%
2	E-learning		
3	Hybrid • Traditional classroom • E-learning		
4	Distance learning		

3. Contact Hours (based on the academic semester)

No	Activity	Contact Hours
1.	Lectures	15
2.	Laboratory/Studio	30
3.	Field	
4.	Tutorial	
5.	Others (specify)	
Total		45

B. Course Learning Outcomes (CLOs), Teaching Strategies and Assessment Methods

Code	Course Learning Outcomes	Code of PLOs aligned with program	Teaching Strategies	Assessment Methods
1.0	Knowledge and understanding. At the end of the course, the graduate will be able to:			
1.1	Explain how anatomical, cytological, chemical, and ecological evidence are used in experimental plant taxonomy.	K2	Interactive lectures, case-based discussion, and comparative analysis of taxonomic studies	Midterm exam, final exam
1.2	Recognize contemporary taxonomic challenges related to hybridization, environmental variation, and biodiversity conservation.	K4	Research article discussion, guided seminars	Written exam questions, seminar presentation
2.0	Skills			
2.1	Analyze experimental taxonomic data using statistical tools to determine similarities and differences among plant species.	S1	Practical data analysis sessions, supervised computer lab (Excel/statistical tools)	Practical lab exam, project report

Code	Course Learning Outcomes	Code of PLOs aligned with program	Teaching Strategies	Assessment Methods
2.2	Apply laboratory techniques (microscopy, anatomical, and cytological observation) to collect taxonomic evidence responsibly.	S2	Laboratory demonstrations, hands-on practical training	Practical lab exam, lab quizzes
3.0	Values, autonomy, and responsibility			
3.1	Demonstrate ethical responsibility in handling plant materials and reporting experimental findings.	V1	Instructor-guided discussion on research ethics, lab supervision	Instructor observation, project evaluation rubric
3.2	Work effectively within a team to conduct and present experimental taxonomic investigations.	V2	Group project work, peer collaboration	Group project assessment, peer evaluation

C. Course Content

No	List of Topics	Contact Hours
1.	Introduction	1
2.	experimental methods in taxonomy	1
3.	The use of comparative experimental methods in taxonomy	2
4.	Taxonomic evidences	1
5.	Plant structure as evidence of taxonomy	1
6.	Plant anatomy as evidence taxonomy	2
7.	Phytochemistry	2
8.	Eco-geographical distribution and its taxonomic importance	2
9.	Natural hybridization	2
10.	Cytological and chemical differences and their taxonomic value.	1
11.	Fertility and its significance.	1
Total		16

D. Students Assessment Activities

No	Assessment Activities *	Assessment timing (in week no)	Percentage of Total Assessment Score
1.	First Mid-term Exam	7th	10/100
2.	Second Mid-term Exam	13th	10/100
3.	Seminar and project discussion	14th	10/100
4.	Practical Lab Exam	16th	30/100
5.	Final Exam	18th	40/100

*Assessment Activities (i.e., Written test, oral test, oral presentation, group project, essay, etc.).

E. Learning Resources and Facilities

1. References and Learning Resources

Essential References	- Farhan, A. Fahad, Al-Hemaid & Hassan, H.M. 1999 Arabic translation of C.A. Stace "Plant Taxonomy & Biosystematics" King Saud University, Riyadh. - Sharma, O.P. 1993. Plant Taxonomy, Tata Mc. Grank Hill Company Limited, New Delhi, India
Supportive References	
Electronic Materials	http://www.botnik.univie.ac.at/iapt/index_layer.php http://www.bgbm.org/iapt/nomeclature/code/saintlous/0000St.Luistitle.htm
Other Learning Materials	

2. Required Facilities and equipment

Items	Resources
facilities (Classrooms, laboratories, exhibition rooms, simulation rooms, etc.)	Classrooms, laboratories
Technology equipment (projector, smart board, software)	data show, Smart Board
Other equipment (depending on the nature of the specialty)	

F. Assessment of Course Quality

Assessment Areas/Issues	Assessor	Assessment Methods
Effectiveness of teaching	Students & Peer Reviewers	Indirect
Effectiveness of	Instructors	Direct/ Indirect

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Assessment Areas/Issues	Assessor	Assessment Methods
Students assessment		
Quality of learning resources	Students& Instructors	Indirect
The extent to which CLOs have been achieved	Instructors	Direct
Other		

Assessors (Students, Faculty, Program Leaders, Peer Reviewer, Others (specify)
Assessment Methods (Direct, Indirect)

G. Specification Approval

COUNCIL /COMMITTEE	ACADEMIC ACCREDITATION COMMITTEE FOR THE DEPARTMENT OF BOTANY AND MICROBIOLOGY
	NOVEMBER 11, 2024

BOT 322: Experimental Taxonomy
Written examination-
First Mid Term Exam- 10 Marks
Second Mid Term Exam- 10 Marks
Final Exam- 40 Marks
Total = 60 Marks
Practical – 40 Marks
Total 60+40=100 Marks

Why experimental taxonomy needed ?

1. Introduction to Taxonomy

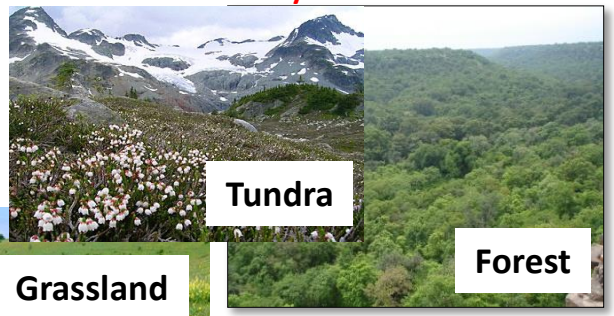
- Taxonomy is the science concerned with identification, nomenclature, and classification of organisms.
- It provides a systematic framework for organizing plant diversity.
- Taxonomy helps understand evolutionary relationships among species.
- It establishes universal scientific names for plants.
- Classification groups plants based on shared characteristics.
- Taxonomy supports biodiversity conservation efforts.
- Morphological characters traditionally formed the basis of classification.
- Modern taxonomy integrates molecular and genetic data.
- Taxonomic studies assist agriculture, forestry, and medicine.
- Taxonomy forms the foundation of all biological sciences.

Introduction about Plant Taxonomy / Systematics

Q: Why we keep the stuffs of our home at the fixed place or arrange into some kinds of system?

- **Every Human being is a Taxonomist**

Plant Biodiversity



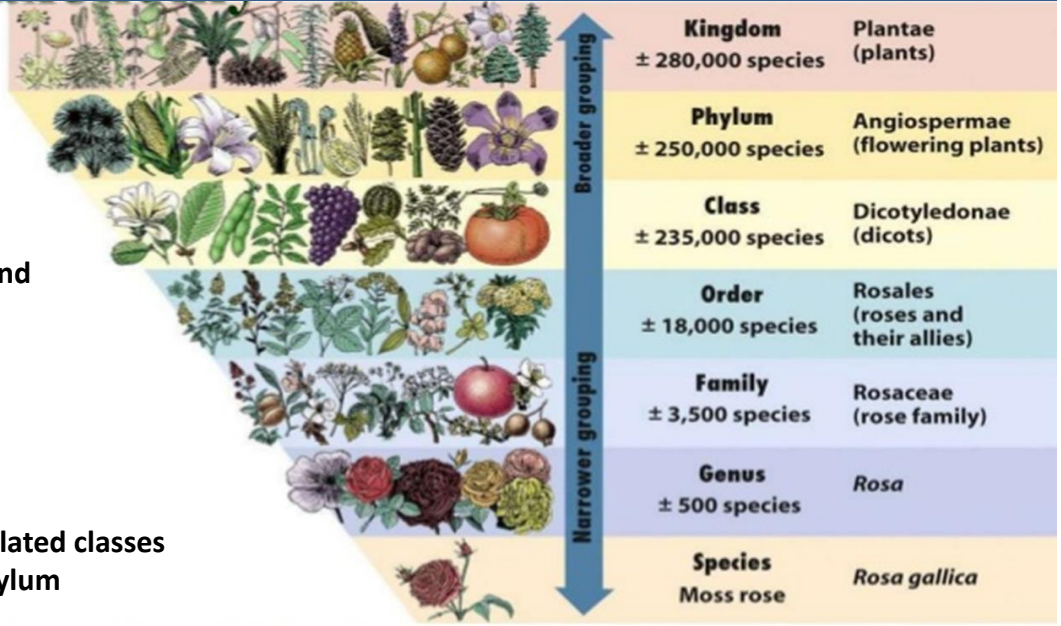
We study plants because:

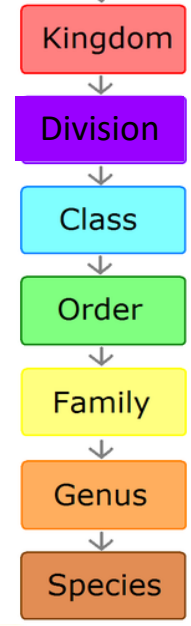
- ❑ Plants produce oxygen. We breathe oxygen. We cannot live without oxygen.
- ❑ Plants convert Carbon dioxide gas into sugars through the process of photosynthesis.
- ❑ Every things we eat comes directly or indirectly from plants.
- ❑ Plants provide fibres for paper or fabric.
- ❑ Many chemicals produced by the plants used as medicine.
- ❑ Study of plants science helps to conserve endangered plants.
- ❑ Plants can be a source of biofuels. Sugars, starches and cellulose can be fermented into ethanol. Ethanol is used as fuel.
- ❑ Study of plants science helps to learn more about the natural world

- Plant Biodiversity: diversity among and within plant and animal species in an environment
- We have millions of different kind of plants, animals and microorganism. There are about 15000 species of Mossess, 13000 species of fern plants, 900 species of Gymnosperms, 250000 species of angiosperms, 10000 species of algae, 5.1 million of fungi species. We need to scientifically identify, name and classify all the living organism.
- Taxonomy / Systematics is the branch of science deals with classification of organism.

TAXONOMIC HIERARCHY

- Carrolus Linnaeus first adopted the hierarchic system of taxonomy classification in 1753.
- The succession groups are as follow:
- **Species**: Organisms sharing a set of biological traits and reproducing only their exact kind.
- The lowest major group, representing plants and animals referred to as Species.
- **Species is the fundamental unit in taxonomy**
- **Genus**: Genus are the closely related species
- **Family** : Family is the closely related genera
- **Order** : Order is the closely related families
- **Class** : Class are the closely related order
- **Division / Phylum**: Division or Phylum is the related classes
- **Kingdom**: Kingdom is the related Division / Phylum





Objective / Goals / Aims of Plant Taxonomy

- ❑ To provide an inventory of plant taxa for local, regional or continental needs.
- ❑ To establish suitable method for identification, nomenclature and description of plant taxa.
- ❑ Classification of organism into classes, Order, Families, Genera, and species
- ❑ To provide significantly valuable information concerning wild and medicinal species, endangered species, unique plants, genetic and ecological diversity

Scope of Taxonomy

- ❖ Taxonomy is one of the oldest sciences.
- ❖ It provides thorough knowledge of living species and their various forms.
- ❖ All the branches of biology are dependent on taxonomy for proper identification the species.
- ❖ It has been proceeded further incorporating data from phytochemistry, cyto-genetics supported by proper computation.

Basic components (Principles) of Plant Taxonomy / Plant Systematics

- Plant collection, Preservation and Documentation
- Plant Structure (Taxonomic Terminology, Taxonomic description of external and internal morphology)
- Taxonomic Identification
- Scientific Nomenclature / Botanical nomenclate : Nomenclature deals with the application of a correct name to a plant or a taxonomic group. Scientific names are necessary because the same common name is used for different plants in different areas of the world.
- Taxonomic Classification (History and Systems of Plant Classification)
- Taxonomic evidences / Source of data (Morphology, Anatomy, Embryology, palynology, Micromorphology, Chemistry, DNA etc.) in plant taxonomy

Kingdom: Plantae
Class: Angiosperms
Order: Arecales
Family: Arecaceae
Genus: *Phoenix*
Species: *P. dactylifera*

Types of Taxonomy / Taxonomic Studies / Plant Taxonomic Classification

From the various stages of classification, the types of taxonomy are defined: -

❖ **Alpha (α) Taxonomy / classical taxonomy:-**

It involves description and naming of organisms. It is the parent of other types of taxonomy.

❖ **Beta (β) Taxonomy: -**

In addition to morphological description, it also involves consideration of affinities and their inter-relationship between separate group of species.

❖ **Gama (ɣ) Taxonomy: -**

It is concerned with description, inter-relationship and evolution of one species from the other.

❖ **Omega (Ω) Taxonomy: -**

It is the modern experimental taxonomy in which the taxonomic activities have been enriched with data from ecology, phyto-chemistry, phyto-geography, cyto-genetics and physiology coupled with adequate computation.

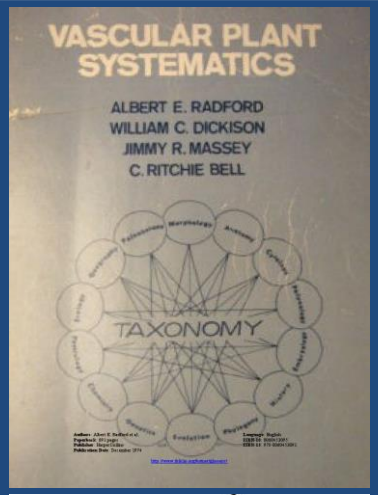
Types of Taxonomy / Taxonomic Studies / Plant Taxonomic Classification

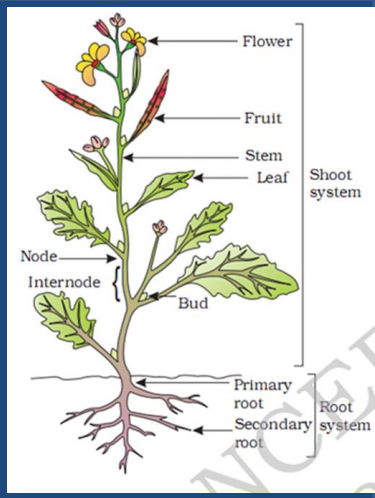
Alpha (α) Taxonomy / classical taxonomy:- It involves description and naming of organisms. It is the parent of other types of taxonomy.

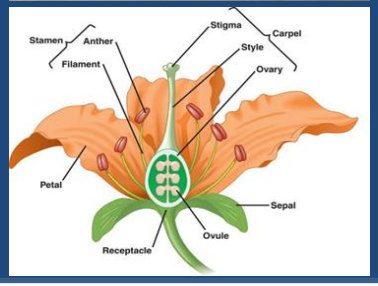
Omega (Ω) Taxonomy: - It is the modern experimental taxonomy in which the taxonomic activities have been enriched with data from ecology, phyto-chemistry, phyto-geography, cyto-genetics and physiology coupled with adequate computation.

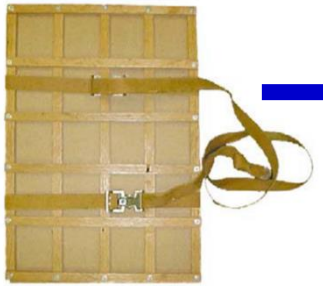
Herbarium: Plant collecting, Preservation and Documentation

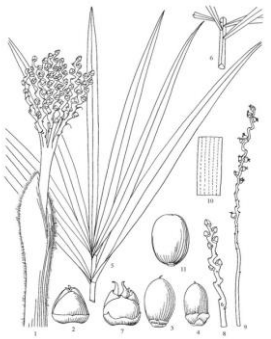
- **To make a herbarium specimen, the plant is collected, and notes are made about it. The plant is then pressed until dry between blotters that absorb moisture and mounted onto a herbarium sheet with a suitable label, and stored in steel cabinet arranged into some system of classification.**
- **Herbarium techniques involve : (i) Collection, (ii) Drying, (iii) Poisoning, (iv) Mounting, (v) Stitching, (vi) Labelling, and (vii) Deposition.**
- **Flora = it is the documentation of plants occurring in a particular region.**
- The FLORA is the main Resources of Taxonomic Information
- **A HERBARIUM is a collection of dried plants systematically named and arranged for ready reference and study.**



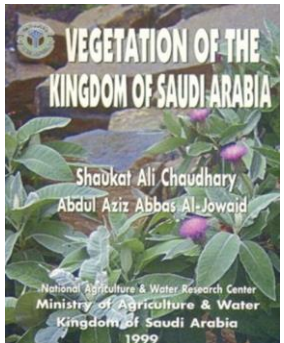


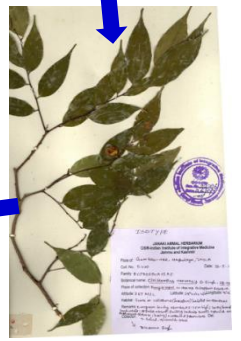






Phoenix dactylifera Linnaeus, Sp. Pl. 2: 1188. 1753.
Stems solitary or clustered and then with few shoots, to 30 m tall, to 50 cm in diam., rough with persistent, diamond-shaped leaf bases. Leaves 3-5 m; sheath and petiole to 1 m; rachis 1-2 m; acanthophylls many per side of rachis; pinnae to 200 per side of rachis, linear, irregularly arranged and spreading in different planes; middle pinnae to 40 × 2 cm. Male inflorescences erect, to 1 m, with many rachillae, these ca. 30 cm; female inflorescences erect, becoming pendulous, to 2 m, with to 150 rachillae, these to 40 cm. Fruits variable in shape, usually oblong, to 7 × 3 cm, brown or black; endosperm homogeneous.





Basic components of Plant Taxonomy

***Phoenix dactylifera* L**

Taxonomic Identification

Stems solitary or clustered and then with few shoots, to 30 m tall, to 50 cm in diam., rough with persistent, diamond-shaped leaf bases. Leaves 3–5 m; sheath and petiole to 1 m; rachis 1–2 m; acanthophylls many per side of rachis; pinnae to 200 per side of rachis, linear, irregularly arranged and spreading in different planes; middle pinnae to 40 × 2 cm. Male inflorescences erect, to 1 m, with many rachillae, these ca. 30 cm; female inflorescences erect, becoming pendulous, to 2 m, with to 150 rachillae, these to 40 cm. Fruits variable in shape, usually oblong, to 7 × 3 cm, brown or black; endosperm homogeneous.

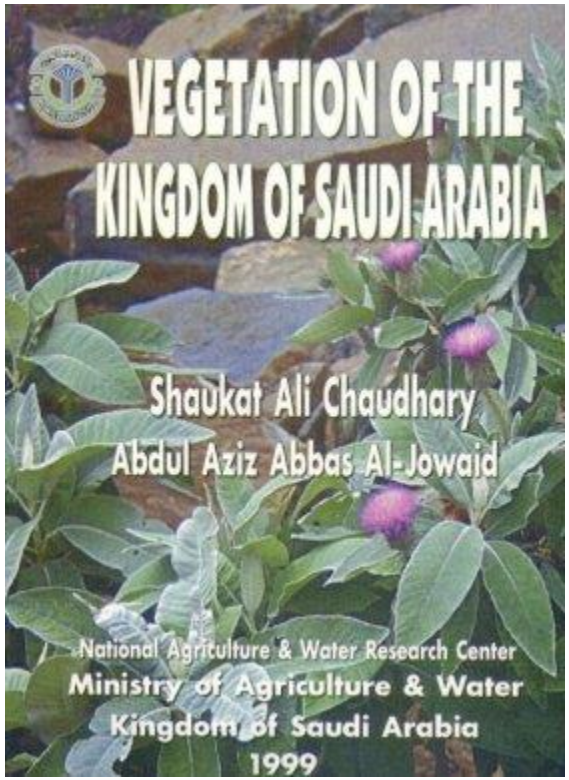
Taxonomic description (Plant Morphology)

Plant Classification

Kingdom: Plantae
Class: Angiosperms
Order: Arecales
Family: Arecaceae
Genus: *Phoenix*
Species: *Phoenix dactylifera*

Scientific name / Botanical Nomenclature

The FLORA is the main Resources of Taxonomic Information



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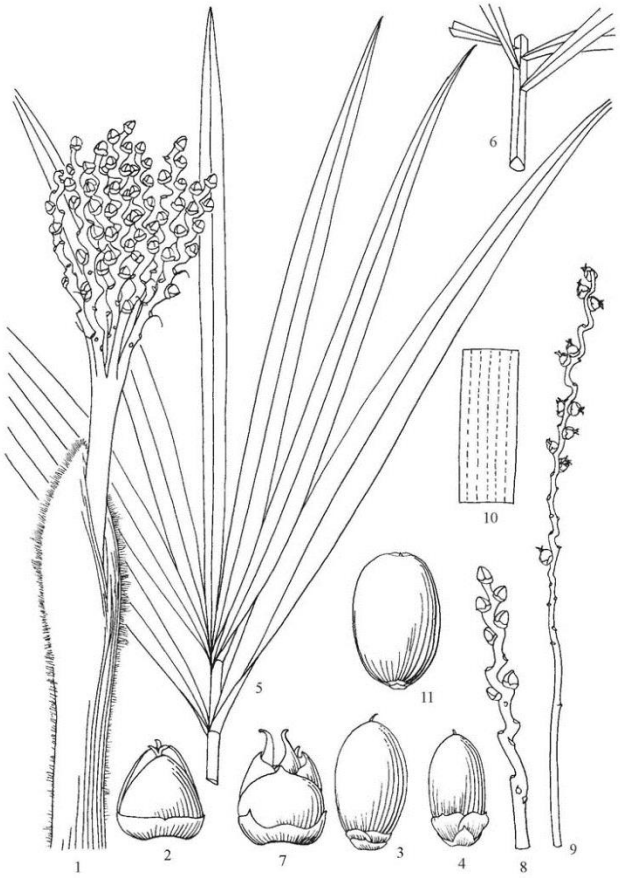


Description of plant need taxonomic terminology

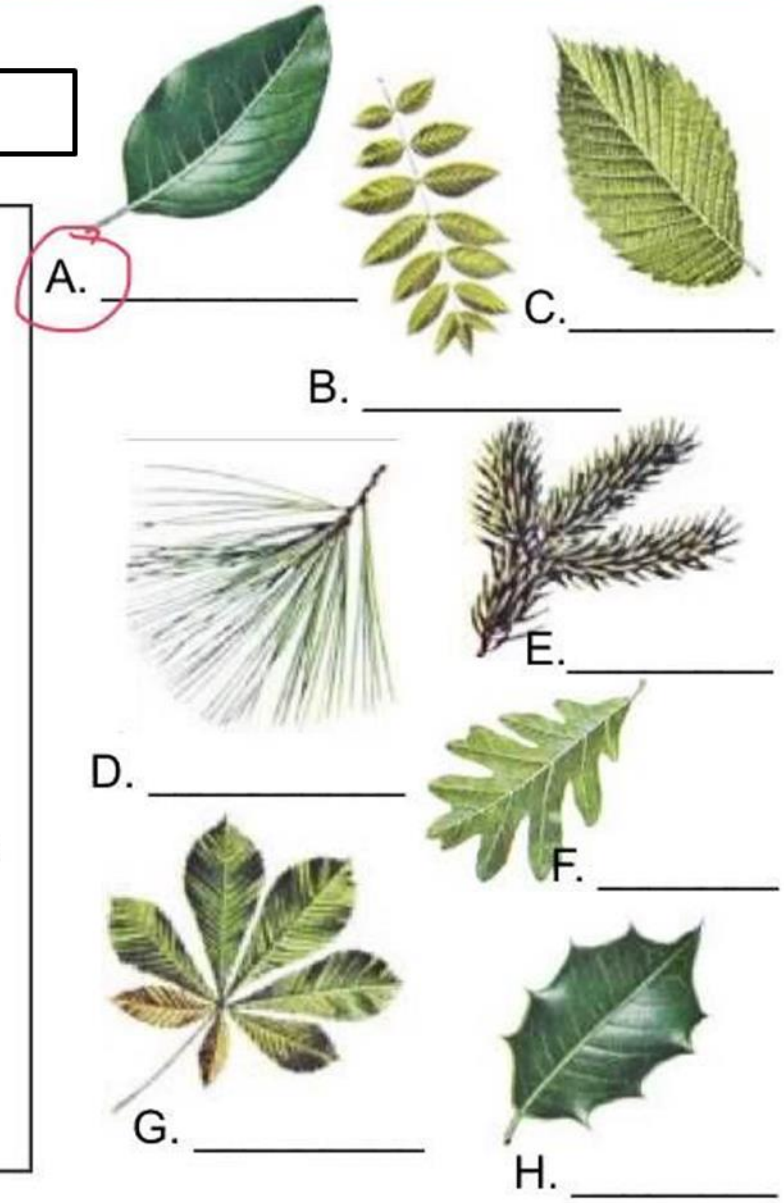
Phoenix dactylifera Linnaeus, Sp. Pl. 2: 1188. 1753.

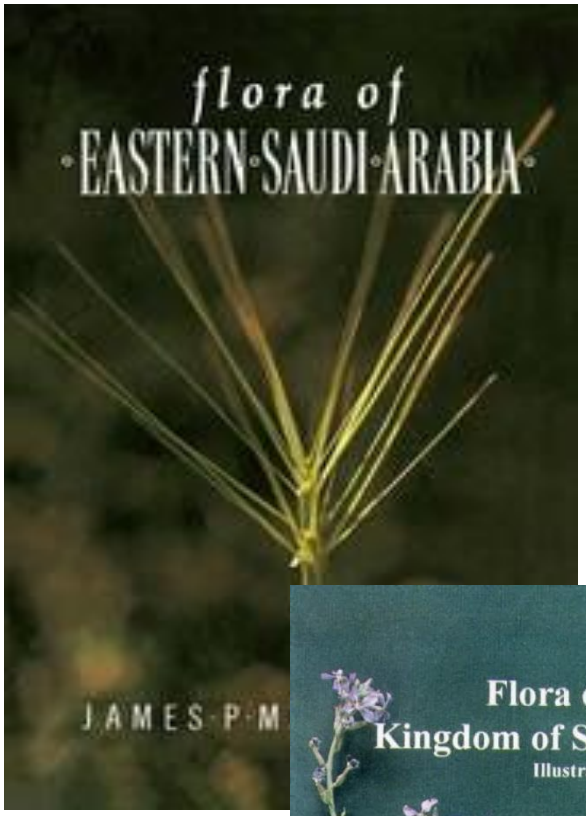
Stems solitary or clustered and then with few shoots, to 30 m tall, to 50 cm in diam., rough with persistent, diamond-shaped leaf bases. Leaves 3-5 m; sheath and petiole to 1 m; rachis 1-2 m; acanthophylls many per side of rachis; pinnae to 200 per side of rachis, linear, irregularly arranged and spreading in different planes; middle pinnae to 40 × 2 cm. Male inflorescences erect, to 1 m, with many rachillae, these ca. 30 cm; female inflorescences erect, becoming pendulous, to 2 m, with to 150 rachillae, these to 40 cm. Fruits variable in shape, usually oblong, to 7 × 3 cm, brown or black; endosperm homogeneous.

Plant Identification Methods

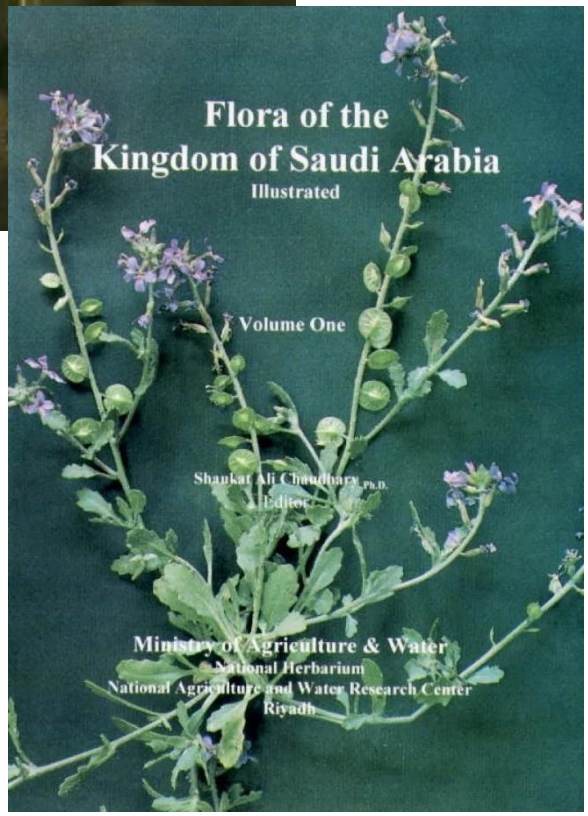
Morphological Key

1.	a. Needle leaves	go to 2
	b. Non-needle leaves	go to 3
2.	a. Needles are clustered	Pine
	b. Needles are in singlets	Spruce
3.	a. Simple leaves (single leaf)	go to 4
	b. Compound leaves (made of "leaflets")	go to 7
4.	a. Smooth edged	go to 5
	b. Jagged edge	go to 6
5.	a. Leaf edge is smooth	Magnolia
	b. Leaf edge is lobed	White Oak
6.	a. Leaf edge is small and tooth-like	Elm
	b. Leaf edge is large and thorny	Holly
7.	a. Leaflets attached at one single point	Chestnut
	b. Leaflets attached at multiple points	Walnut

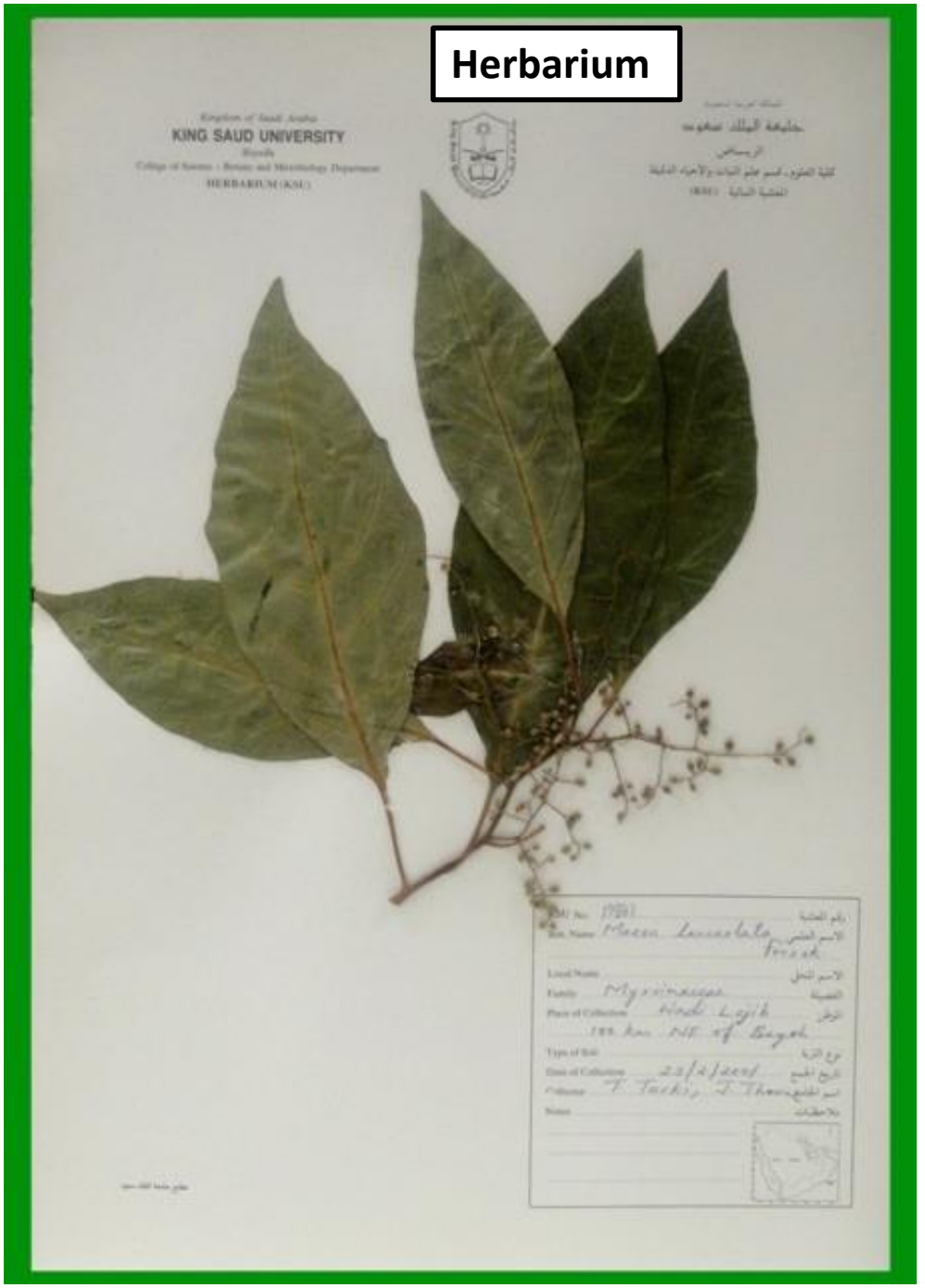




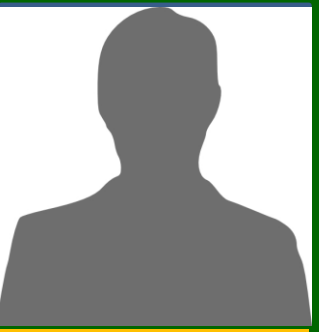
Flora



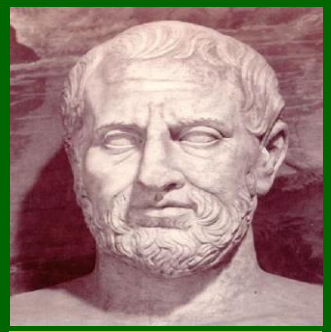
Herbarium



SYSTEM OF PLANT CLASSIFICATION

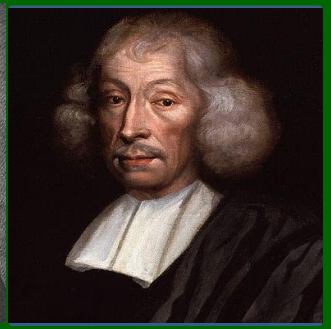


Preliterate Mankind / Folk taxonomies:



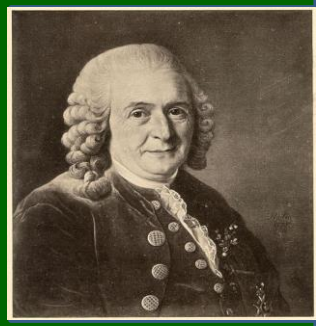
Theophrastus (372 BC to 287 BC):

Andrea Cesalpino (1519-1603)

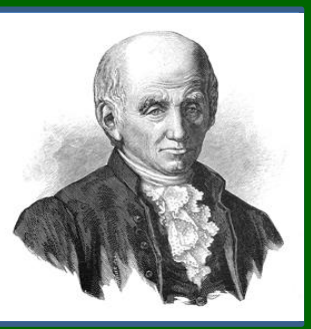


John Ray (1627-1705)

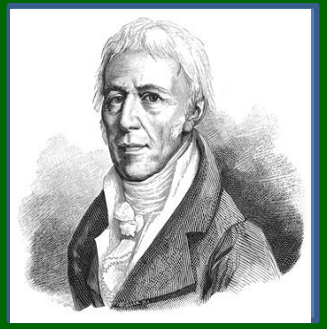
J. P. de Tournefort (1656-1708)



Carolus Linneaus (1753)



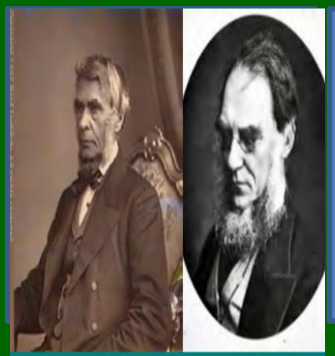
Michel Adanson (1727-1806)

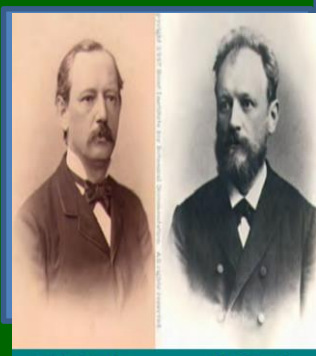


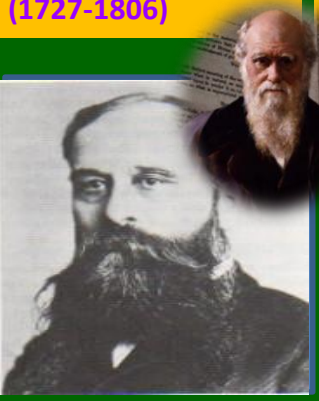
Jean B.P. Lamarck (1744-1829)

Antoine Laurent de Jussieu (1748-1836)

de Candolle (1778–1841)

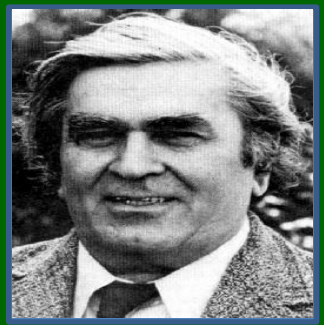






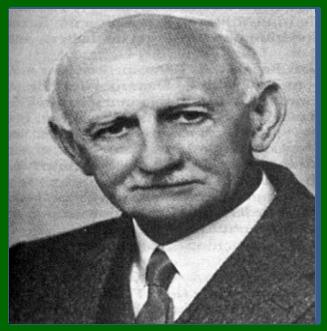
Charles E. Bessey (1845-1915)

Auther Cronquist 1968

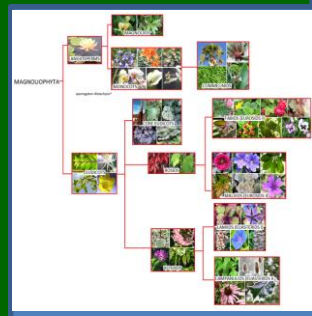


Armen Takhtajan 1969

Rolf Dahlgren (1932-87)

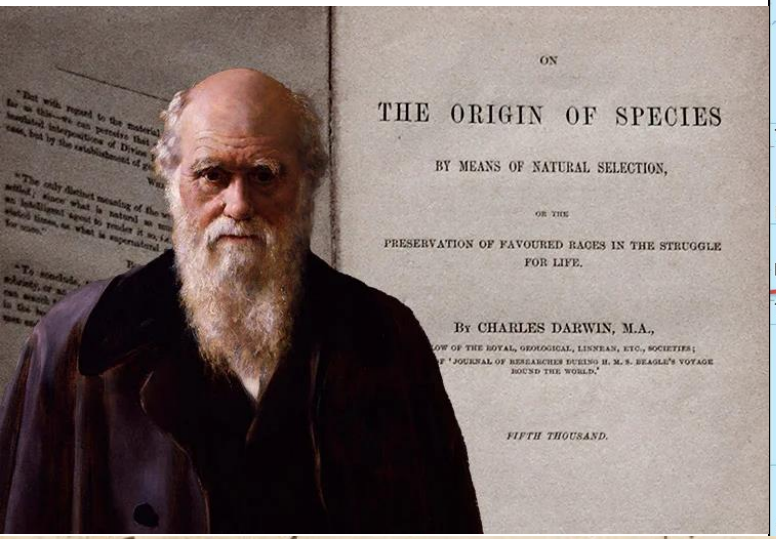


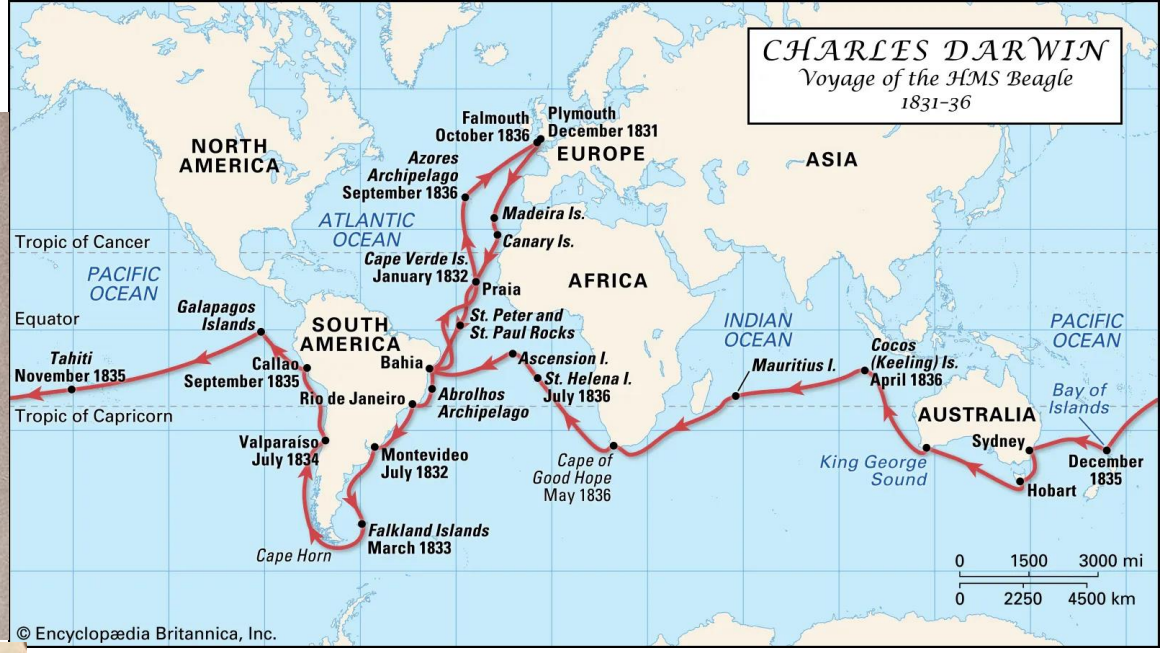
John Hutchinson (1884-1972)

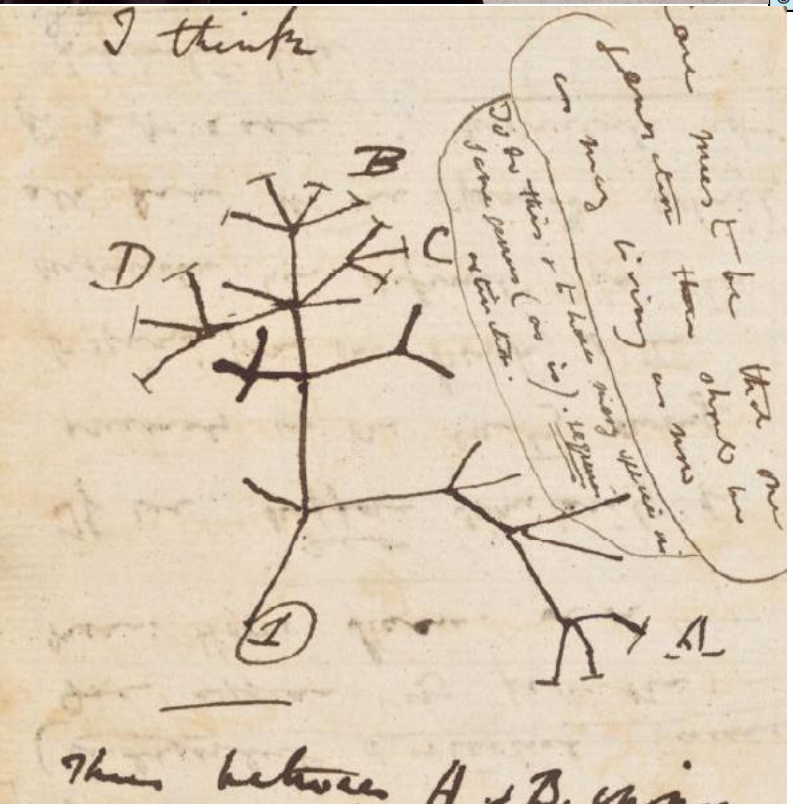


APG Angiosperm Phylogeny Group (1998)

Major Post-Darwinian Classification Systems







- **Engler and Prantl System (1887–1915) – Proposed a phylogenetic classification, arranging plants from simple to complex forms.**
- **Bessey's Cactus System (1915) – Based on evolutionary trends in flowering plants.**
- **Hutchinson's System (1926, 1934, 1959) – Focused on the evolutionary divergence of dicots and monocots.**
- **Takhtajan's System (1954, 1980, 1997) – Considered both fossil records and modern plants.**
- **Cronquist's System (1968, 1981, 1988) – One of the most widely used evolutionary classification systems.**
- **Dahlgren's System (1975, 1980s) – Used anatomical and chemical data for classification.**
- **Thorne's System (1958, 1968, 1992, 2007) – An evolutionary classification that was periodically revised.**
- **APG System (Angiosperm Phylogeny Group) (1998, 2003, 2009, 2016) – Based on molecular phylogenetics and DNA sequencing.**

Species concept

Nomenclature

A species is a group of organisms that may interbreed and produce offspring that is also capable of reproducing the same kind.

SCIENTIFIC NOMENCLATURE / BOTANICAL NOMENCLATE :

Nomenclature deals with the application of a correct name to a plant or a taxonomic group.

- ❖ **We have millions of species distributed in different geographical regions of the world.**
- ❖ **The Scientific names (Botanical name and Zoological name)of the living organism (Plants and Animals) are necessary because the same common name is used for different plants / Animals in different areas of the world.**
- **Swedish Botanist Carolus Linnaeus introduced Binomial Nomenclature.**
- **The Binomial nomenclature uses two Latin words to indicate the genus and the species. The first word is the genus and the second word is the species. Example- the botanical name of Dates is *Phoenix dactylifera***

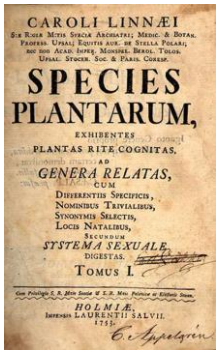
Species Concept

- **Species is the basic unit of classification**
- **Plants in the same species consistently produce plants of the same types**
- **The name of the plants must should be written in italics. For example Phoenix dactylifera**

TAXONOMIC RANKS OF LAND PLANTS	ENDING	EXAMPLE TAXON
Kingdom	(various)	Plantae
Phylum [Division]	-phyta	Magnoliophyta
Subphylum [Subdivision]	-phytina	Magnoliophytina
Class	-opsida	Asteropsida
Subclass	-idae	Asteridae
Order	-ales	Asterales
Suborder	-ineae	Asterineae
Family	-aceae	Asteraceae
Subfamily	-oideae	Asteroideae
Tribe	-eae	Heliantheae
Subtribe	-inae	Helianthinae
Genus	(various)	*Helianthus*
Subgenus	(various)	*Helianthus*
Section	(various)	*Helianthus*
Series	(various)	*Helianthus*
Species [abbr. sp. (sing.), spp. (pl.)]	(various)	*Helianthus annuus*
Subspecies [abbr. subsp. or ssp. (sing.), subspp. or sspp. (pl.)]	(various)	*Helianthus annuus* ssp. *annuus*
Variety [abbr. var. (sing.), vars. (pl.)]	(various)	*Helianthus annuus* var. *annuus*
Form [abbr. f.]	(various)	*Helianthus annuus* f. *annuus*

Classes

1. Monandria- stamen one
2. Diandria- stamens two
3. Triandria- stamens three
4. Tetrandria- stamens four
5. Pentandria- stamens five
6. Hexandria- stamens six
7. Heptandria- stamens seven
8. Octandria- stamens eight
9. Ennandria- stamens nine
10. Decandria- stamens ten
11. Dodecandria- stamens 11-19
12. Icosandria- stamens 20 or more, on the calyx
13. Polyandria- stamens 20 or more, on the receptacle
14. Didynamia- stamens didynamous; 2 short, 2 long
15. Tetradynamia- stamens tetradynamous; 4 long, 2 short
16. Monadelphia- stamens monadelphous; united in 1 group
17. Diadephia- stamens diadelphous; united in 2 groups
18. Polyadelphia- stamens polyadelphous; united in 3 or more groups
19. Syngenesia- stamens syngenesious; united by anthers only
20. Gynandria- stamens united with the gynoecium
21. Monoecia- plants monoecious
22. Dioecia- plants dioecious
23. Polygamia- plants polygamous



- ❖ **Binomial Nomenclature and Carolus Linneaus System of Plant Classification**
- ❖ **Taxonomic Systems of Classification: Ideally our systems of classification should allow us to place similar species of plants together in the same category.**
- ❖ **There are two types of Classification Schemes:**
- ❑ **Artificial taxonomy was a system of grouping unrelated plant species by a common criteria (i.e. a flowers sexual organs)**
- ❑ **Natural classification reflects relationships among taxon**
- ➢ **Carolus Linneaus was a Swedish botanist.**
- ➢ **Carolus Linneaus traveled to Lapland (Blue Lake, CA) and collected large number of plants.**
- ➢ **Carolus Linneaus introduced Binomial Nomenclature.**

Binomial nomenclature = Uses two Latin words to indicate the genus and the species. The first word is the genus and the second word is the species. Example- the botanical name of dates is *Phoenix dactylifera*

- ➢ **Carolus Linneaus published the book 'Species Plantarum' in 1753.**
- ➢ **Carolus Linneaus classified the plants based on the plant's method of reproduction and structure of reproductive parts.**
- ➢ **Produced his sexual system of classification (Artificial classification)**

International Code of Botanical Nomenclature (ICBN)

The current activity of botanical nomenclature is governed by the International Code of Botanical Nomenclature (ICBN) published by the International Association of Plant Taxonomy (IAPT).

The Code is divided into 3 divisions:

I. Principles

II. Rules and recommendations

III. Provisions for the governance of the Code

Principles of ICBN

- ❑ Botanical Nomenclature is independent of Zoological Nomenclature. The Code applies equally to the names of taxonomic groups treated as plants whether or not these groups were originally so treated.
- ❑ The application of names of taxonomic groups is determined by means of nomenclatural types / TYPIFICATION.
- ❑ Nomenclature of a taxonomic group is based upon Priority Of Publication.
- ❑ Each taxonomic group with a particular circumscription, position and rank can bear Only One Correct Name, the earliest that is in accordance with the rules.
- ❑ Scientific names of taxonomic groups are treated as LATIN, regardless of derivation.
- ❑ The rules of nomenclature are Retroactive (Date), unless expressly limited.

- ❖ **Generic Name:** The Generic name is usually a noun and singular, which is spelled or written with a capital letter.
- ❖ **Specific Epithet:** The specific epithet is often an adjective and it is written with a small initial letter.
- ❖ In the hand written manner, both the generic names and specific epithet should be underlined, while if printed it should be in italics.

Synonyms and related terminology

- ❑ **Synonyms:** A name rejected due to misuse or difference in taxonomic judgement.
- ❑ **Basionym:**
  - ➢ The basionym is the first name ever given to a taxon. Further studies and revisions may reject the basionym as the most correct one, but it still is useful as a nomenclatural reference for that species.
  - ➢ Also, according to the priority rules of the ICBN, after a taxonomic revision that results in a species being reclassified in another genus, the specific epithet must remain the same as the one in the Basionym.
  - ➢ A short example: Linnaeus classified the Tea Plant as *Thea sinensis*. Some decades later, Sweet noticed that the genus *Thea* was not really different from the genus *Camellia*, and renamed all the *Theas* as *Camellias*. *Thea sinensis* became *Camellia sinensis*, because he had to keep the specific epithet the same as the original name (Basionym) for that species, given by Linnaeus.
- ❑ **Homonym:** A case in which two or more identical names are baed on different type , of which only one can be a legitimate name , is called as homonym.
- ❑ **Tautonym:** A case in which name of genus and the name of the species is the same.

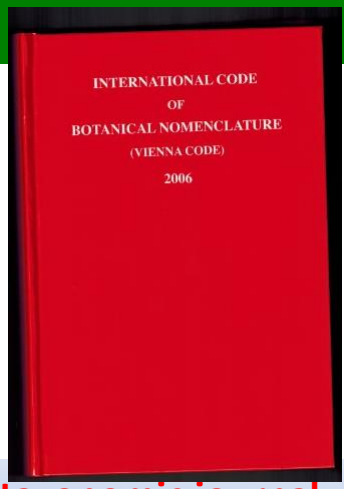
Names of Taxa

Rank	*Ending*	*Example*
Kingdom	-bionta	Chlorobionta
Division	-phyta	Magnoliophyta
	-mycota (Fungi)	Eumycota
Subdivision	-phytina	Pterophytina
	-mycotina (Fungi)	Eumycotina
Class	-opsida	Magnoliopsida
	-phyceae (Algae)	Chlorophyceae
	-mycetes (Fungi)	Basidiomycetes
Subclass	-opsidae	Pteropsidae
	-idae (Seed plants)	Rosidae
	-physidae (Algae)	Cyanophysidae
	-mycetidae (Fungi)	Basidiomycetidae
Order	-ales	Rosales
Suborder	-ineae	Rosineae
Family	-aceae	Rosaceae
Subfamily	-oideae	Rosoideae
Tribe	-eae	Roseae
Subtribe	-inae	Rosinae
Genus	*-us, -um, -is, -a, -on*	*Pyrus, Allium, Arabis, Rosa, Polypogon*
Subgenus		*Cuscuta* subgenus *Eucuscuta*
Section		*Scrophularia* section *Anastomosanthes*
Subsection		*Scrophularia* subsection *Vernales*
Series		*Scrophularia* series *Lateriflorae*
Species		*Rosa canina*
Subspecies		*Crepis sancta* subsp. *bifida*
Varietas		*Lantana camara* var. *varia*
Forma		*Tectona grandis* f. *punctata*

Typification: Type Specimen is the one representative of the taxon.

- ❖ **Holotype:** A specimen designated by the author in the original publication (nomenclatural type).
- ❖ **Isotype:** A duplicate specimen of the holotype collected at the same time and place (may be in other herbarium).
- ❖ **Lectotype:** A specimen chosen from the author's original material when no holotype has been designated.
- ❖ **Neotype:** A specimen selected when all original specimens have been destroyed

Author Citation, Effective Publication and Principle of Priority



Author Citation

- **For a name to be complete, it should be accompanied by the name of the author or authors who first published the name validly. The names of the authors are commonly abbreviated, Example L. for Carolus Linnaeus**
- ***Aizoon canariense* L.**
- ***Tribulus macropterus* var. *arabicus* (Hosni) Al-Hemaid & J. Thomas**

Basic structure of a taxonomic Research papers / Recent publication of a new species in taxonomic journal

Ann. Bot. Fennici 53: 37–39 ISSN 0003-3847 (print) ISSN 1797-2442 (online)
Helsinki 4 January 2016 © Finnish Zoological and Botanical Publishing Board 2016

Silene langshanensis (Caryophyllaceae), a new species from Inner Mongolia, China

Li-Qing Zhao[1,*], Zhi-Ming Xin[2] & Yi-Zhi Zhao[1]

[1] College of Life Science, Inner Mongolia University, Hohhot 010021, China (*corresponding author's e-mail: zhaofeiniu@126.com)
[2] Experimental Center for Desert Forestry, Chinese Academy of Forestry, Dengkou, Inner Mongolia 015200, China

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Zhao L.Q., Xin Z.M. & Zhao Y.Z. 2016: *Silene langshanensis* (Caryophyllaceae), a new species from Inner Mongolia, China. — *Ann. Bot. Fennici* 53: 37–39.

Silene langshanensis L.Q. Zhao, Y.Z. Zhao & Z.M. Xin *sp. nova* (Caryophyllaceae), is described and illustrated from Inner Mongolia, China. It appears to be most closely related to *S. scabrifolia* of *Silene* sect. *Holopetalae*. *Silene langshanensis* can be distinguished by the basally pubescent carpophore, petals with obtuse auricles, stems and leaves with dense, short hairs, and by the glabrous calyx.

In total, there are about 600 species of *Silene s. lato* (Caryophyllaceae) (Zhou *et al.* 2001). They are distributed mainly in the northern temperate regions, but occur also in Africa and South America (Zhou *et al.* 2001). Among these species, 110 are known from China, of which 67 are endemic. Twenty of the endemics (nine species of *Silene s. stricto*, nine of *Melandrium*, one of *Cucubalus* and one of *Lychnis*) are found in Inner Mongolia.

In September 2008 and later, in 2014, the authors Zhao and Xin collected specimens of *Silene* from Langshan in Bayannaoer (Inner Mongolia) from desert steppe communities on mountain slopes at 1150–1400 m a.s.l. After careful study, we concluded that the specimens represented an undescribed species of *Silene*.

Silene langshanensis L.Q. Zhao, Y.Z. Zhao & Z.M. Xin, *sp. nova* (Fig. 1)

HOLOTYPE: China. Inner Mongolia, Bayannaoer, Dengkou, Mt. Langshan, 40°43′58.4″N, 106°22′28.5″E, on stony mountain slopes, 1371 m a.s.l., 9 June 2014 *Li-Qing Zhao, Zhi-Ming Xin, Shuai Qin & Long Chen N14-001* (HIMC). — PARATYPES (all HIMC!): Same location as holotype, 9 June 2014 *Li-Qing Zhao, Zhi-Ming Xin, Shuai Qin & Long Chen N14-002, N14-003, N14-004*; Mt. Langshan, 40°39′27.7″N, 106°23′14.1″E, on stony mountain slopes, alt. 1185 m a.s.l., 10 September 2008 *Li-Qing Zhao & Zhi-Ming Xin N08-001*.

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Silene langshanensis is placed in the section *Holopetalae*, of which five species are now known from China (Zhou *et al.* 2001). It resembles *S. scabrifolia* (*see* Shishkin 1936: 677) but can be distinguished by several characters (Table 1). The following key should be useful when identifying species of sect. *Holopetalae* in China.

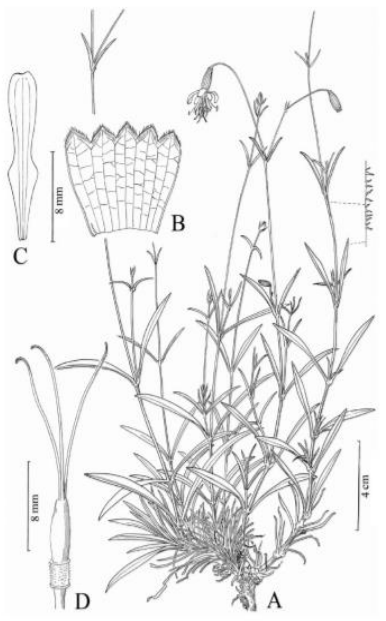

Fig. 1. *Silene langshanensis* (from the holotype, drawn by Ping Ma). — **A**: Habit. — **B**: Calyx. — **C**: Petal. — **D**: Pistil and carpophore.

Table 1. Main morphological differences between *Silene langshanensis* and *S. scabrifolia*.

Character	*S. langshanensis*	*S. scabrifolia* (= *S. komarovii*)
Stem	densely pubescent, upper part glabrescent when flowering	pubescent in lower part, glabrous and viscid above
Basal leaves	oblanceolate, 20–60 × 2–6 mm	spatulate or lanceolate, 60–80 × 5–10 mm
Cyme	1-flowered (rarely 2)	multiflowered
Pedicel	20–60 mm long, glabrescent	5–10 mm long, sparsely pubescent
Calyx	narrowly campanulate, 10–13 × 4–5 mm, glabrous	tubular-clavate, 8–12 × 2–3 mm, glabrous or sparsely villous
Carpophore	shortly pubescent	glabrous
Petal	with obtuse auricles	without distinct auricles
Limbs	yellowish green	yellowish white

1. Leaves ovate-lanceolate, 15–30 mm wide ..... *S. kungessana*
1. Leaves lanceolate or linear, 1.5–10 mm wide 2
2. Leaves linear, 10–30 × 1.5–3 mm ..... *S. holopetala*
2. Leaves oblanceolate or lanceolate, 30–80 mm long, usually more than 4 mm wide 3
3. Stems usually not branched; calyx 6–9 mm; petals pinkish abaxially ..... *S. pseudotenuis*
3. Stems branched; calyx 8–13 mm; petals yellowish green or yellowish white 4
4. Stem pubescent in lower part, glabrous and viscid above; cymes multiflowered; petals yellowish white, without obvious auricles; carpophore glabrous ..... *S. scabrifolia*
4. Stem with dense short hairs, upper part glabrescent when flowering; cymes 1-flowered (rarely 2); petals yellowish green, with obtuse auricles; carpophore basally pubescent ..... *S. langshanensis*

Acknowledgements

We are grateful to Ping Ma for the drawing. This study was financially supported by Natural Science Foundation of Inner Mongolia Autonomous Region (2014ZD02), National Key Basic Research Program of China (2014CB138802) and the Central Public-interest Scientific Institution Basal Research Fund (CAFYBB2014MA016).

References

Shishkin B.K. [Шишкин Б.К.] (ed.) 1936: [*Flora USSR*], vol. 6. — Izdatel'stvo Akademii Nauk USSR, Leningrad. [In Russian].
Zhou L.H., Wu Z.Y., Lidén M. & Oxelman B. 2001: *Silene*. — In: Wu Z.Y. & Raven P.H. (eds.), *Flora of China*, vol. 6: 66–100. Science Press, Beijing & Missouri Botanical Garden Press, Saint Louis.

Effective publication in the journal, available to Botanist

Date of valid publication (principles of priority): If the same species will be published by some one else after this date then the publication will be not valid. (/Principles of Priority).

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Abstract / Summary / Synopsis.

Previously it was required to write in Latin.

In total, there are about 600 species of *Silene s. lato* (Caryophyllaceae) (Zhou *et al.* 2001). They are distributed mainly in the northern temperate regions, but occur also in Africa and South America (Zhou *et al.* 2001). Among these species, 110 are known from China, of which 67 are endemic. Twenty of the endemics (nine species of *Silene s. stricto*, nine of *Melandrium*, one of *Cucubalus* and one of *Lychnis*) are found in Inner Mongolia.

In September 2008 and later, in 2014, the authors Zhao and Xin collected specimens of *Silene* from Langshan in Bayannaoer (Inner Mongolia) from desert steppe communities on mountain slopes at 1150–1400 m a.s.l. After careful study, we concluded that the specimens represented an undescribed species of *Silene*.

Botanical name in Latin

Rank indicated

Silene langshanensis L.Q. Zhao, Y.Z. Zhao & Z.M. Xin, *sp. nova* (Fig. 1)

Type Specimen indicated

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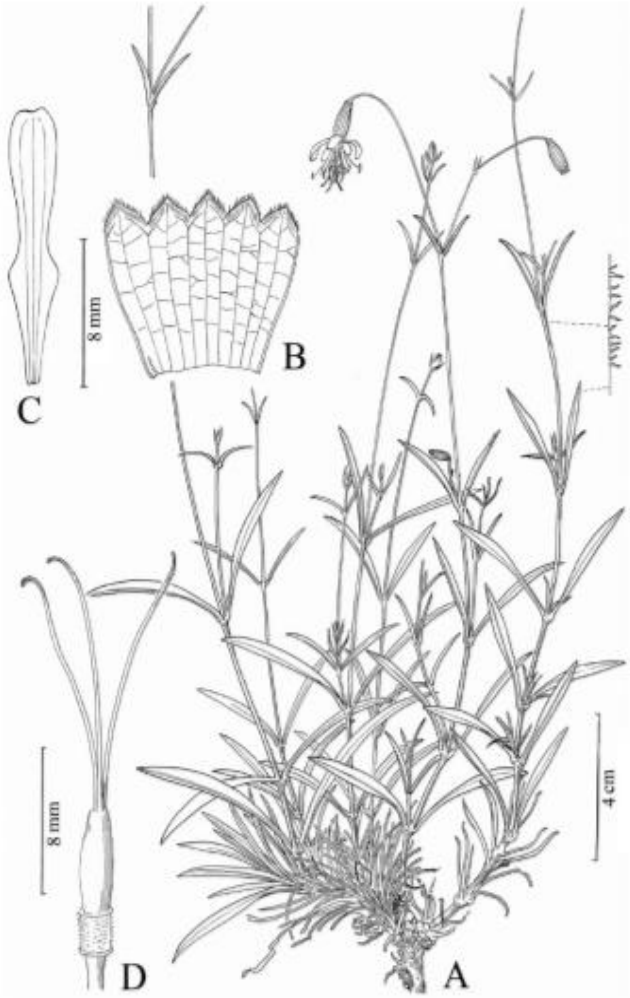
Taxonomic Description



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sometimes violet, narrowly campanulate, slightly inflated in fruit, 10–13 × 4–5 mm, glabrous; calyx teeth broadly triangular-ovate, apex obtuse or acute, margin membranous, ciliate. Carpophore 2–3 mm, basally pubescent. Petals ca. 15 mm, claws cuneate, glabrous, auricles obtuse; limbs yellowish green, narrowly obovate, margin entire or emarginate, coronal scales absent. Stamens and styles prominently exserted; filaments glabrous. Styles 3. Ovary ovate-elliptic, ca. 5 mm long. Capsule 6-valved. Flowering and fruiting in June–September.

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3. Stems usually not branched; calyx 6–9 mm; petals pinkish abaxially .....
3. Stems branched; calyx
or yellow
4. Stem
cyme
obvi
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Acknowledgements

We are grateful to Ping Ma for the drawing. This study was financially supported by Natural Science Foundation of Inner Mongolia Autonomous Region (2014ZD02), National Key Basic Research Program of China (2014CB138802) and the Central Public-interest Scientific Institution Basal Research Fund (CAFYBB2014MA016).

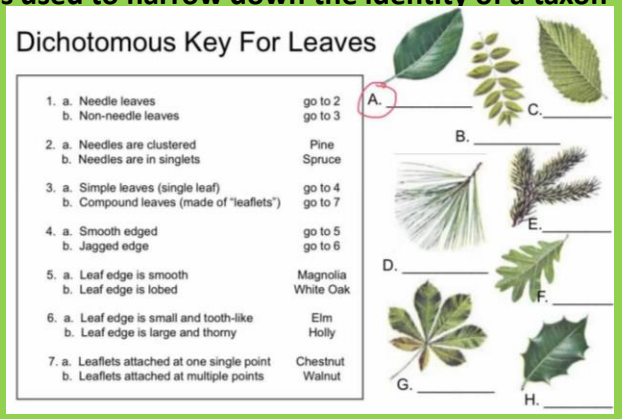
eferences

kin B.K. [Шишкин Б.К.] (ed.) 1936: [*Flora USSR*], vol. — Izdatel'stvo Akademii Nauk USSR, Leningrad. [In ussian].
L.H., Wu Z.Y., Lidén M. & Oxelman B. 2001: *Silene*. In: Wu Z.Y. & Raven P.H. (eds.), *Flora of China*, vol. : 66–100. Science Press, Beijing & Missouri Botanical Garden Press, Saint Louis.

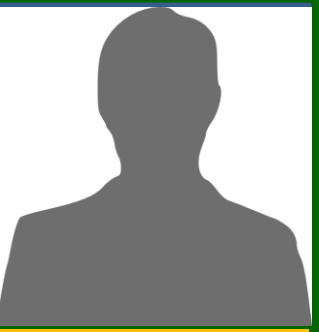
Line drawing

Taxonomic Key for Identification

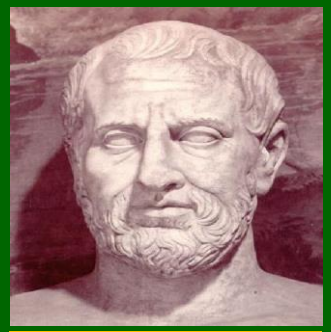
Taxonomic Key: An identification device, consisting of contrasting statements used to narrow down the identity of a taxon



SYSTEM OF PLANT CLASSIFICATION

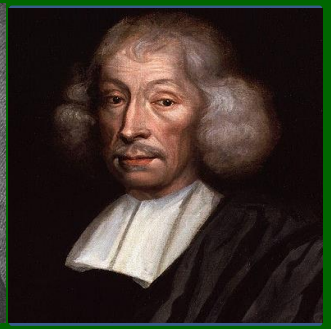


Preliterate Mankind / Folk taxonomies:



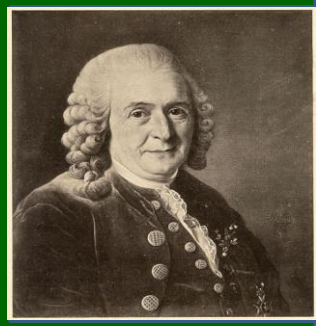
Theophrastus (372 BC to 287 BC):

Andrea Cesalpino (1519-1603)

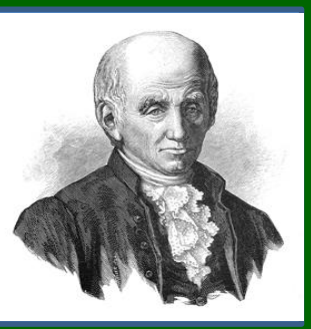


John Ray (1627-1705)

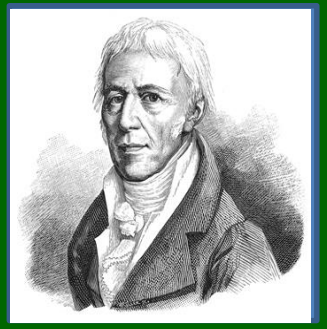
J. P. de Tournefort (1656-1708)



Carolus Linneaus (1753)



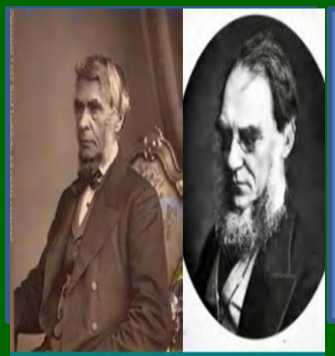
Michel Adanson (1727-1806)

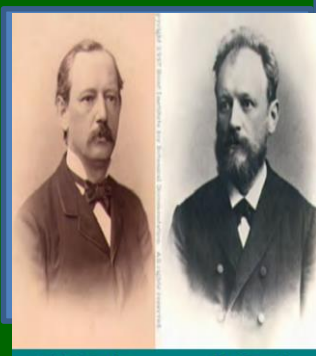


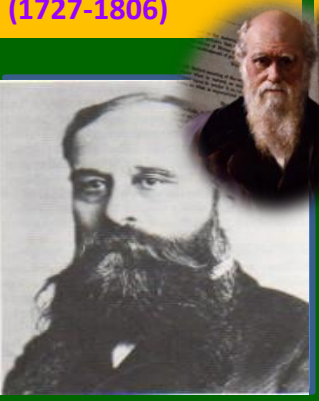
Jean B.P. Lamarck (1744-1829)

Antoine Laurent de Jussieu (1748-1836)

de Candolle (1778–1841)

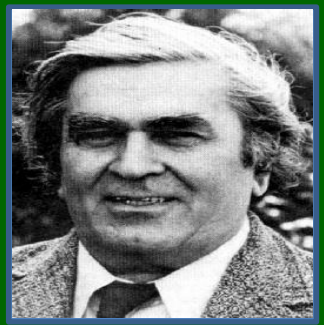






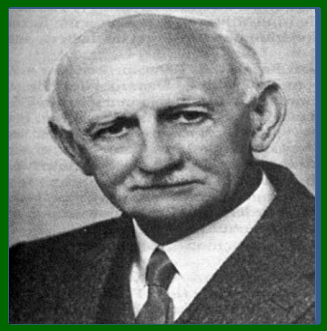
Charles E. Bessey (1845-1915)

Auther Cronquist 1968

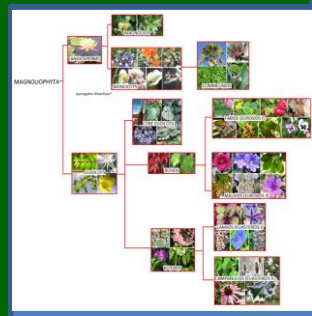


Armen Takhtajan 1969

Rolf Dahlgren (1932-87)

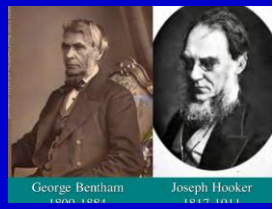


John Hutchinson (1884-1972)



APG Angiosperm Phylogeny Group (1998)

Bentham and Hooker System of Plant Classification



- Bentham and Hooker, two English botanists, represented the most well developed natural system of plant classification. The classification was published in a three-volume work Genera plantarum (1862-83).
- Hooker supervised the publication of Index Kewensis (2 volumes, 1893), listing the names of all known species and their synonyms.
- Many important herbaria of the world have specimens arranged according to Bentham and Hooker system of plant classification.
- Bentham and Hooker recognized three class:

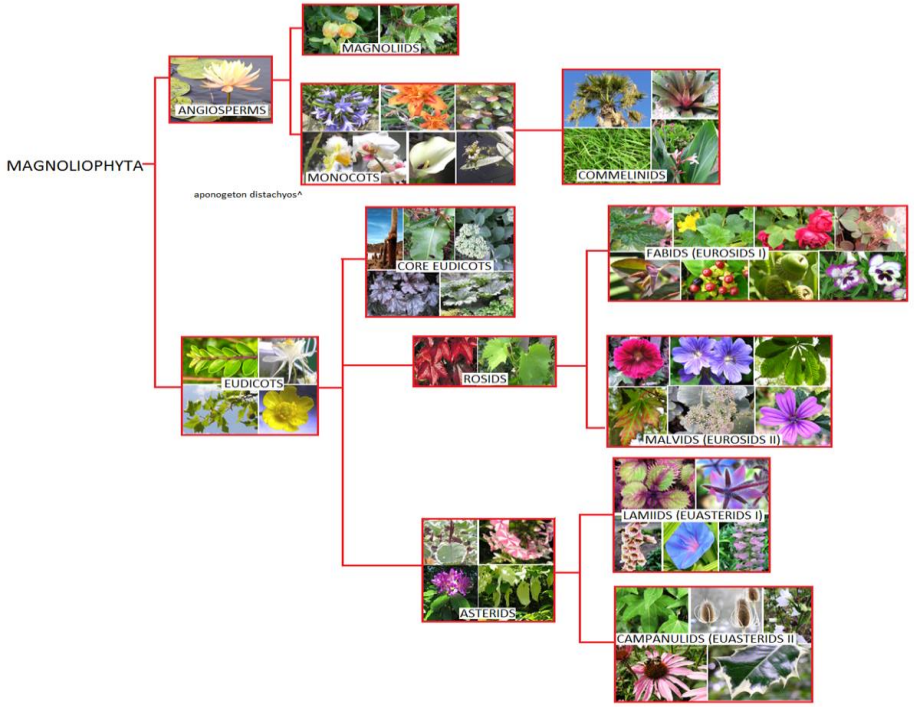
Class Dicotyledones:

Subclass POLYPETALE with three series Series 1. THALAMIFLORÆ, Series 2. DISCIFLORÆ, Series 3. CALYCIFLORÆ;
Subclass DICOTYLEDONES (GAMOPETALÆ) with three series that is Series 1. INFERÆ, Series 2. HETEROMERÆ, Series 3. BICARPELLATÆ, and
Subclass DICOTYLEDONES MONOCHLAMIDEÆ.

Class Gymnospermeæ (Gymnosperms are placed between Dicotyledons and Monocotyledons)

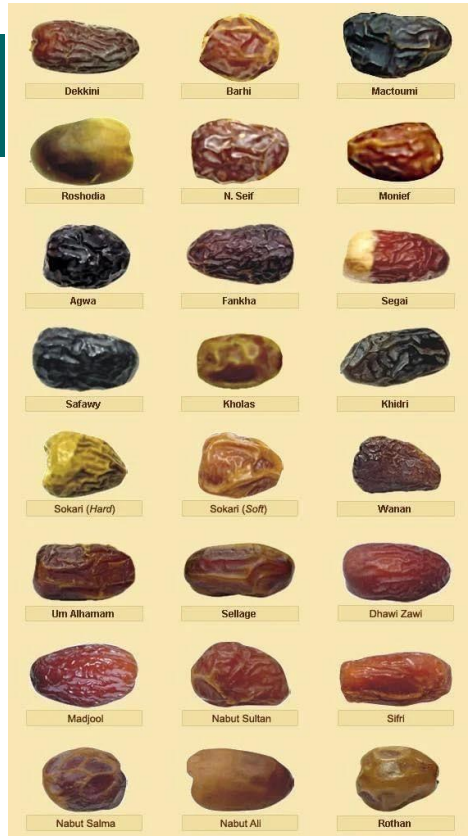
Class Monocotyledones

❖ Angiosperm Phylogeny Group (APG)



- The APG system of flowering plant classification is the modern, mostly molecular-based, system of plant taxonomy for flowering plants (angiosperms) being developed by the Angiosperm Phylogeny Group (APG).
- The APG was first published in 2008.
- Currently the APG IV system recognizes a total of 64 angiosperm orders and 416 families.
- The families in APG classification have been grouped into 40 putative monophyletic orders under a small number of informal monophyletic higher groups: monocots, commelinoids, eudicots, core eudicots, rosids, eurosids I, eurosids II, asterids, euasterids I and euasterids II

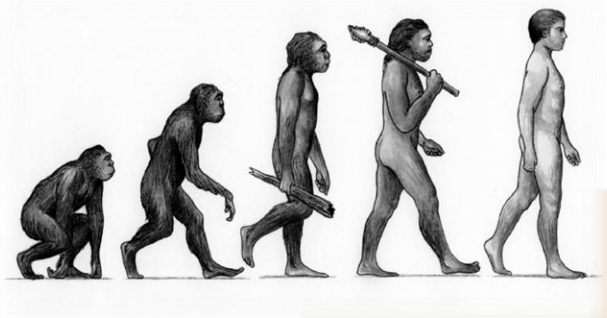
DATES



PALM

MINT


1993
2003
2013
2023



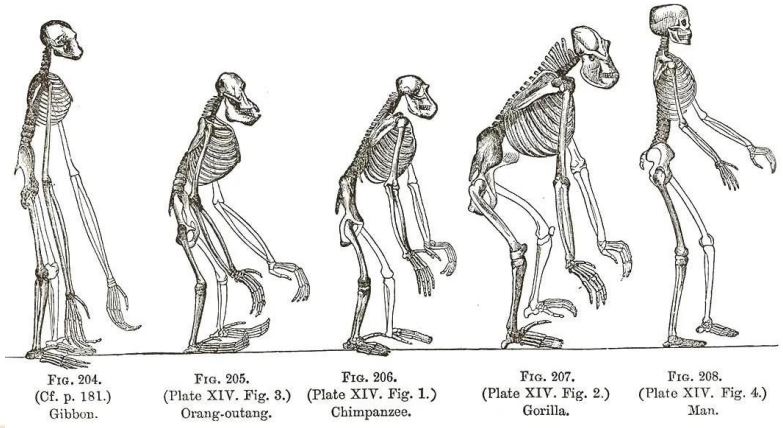
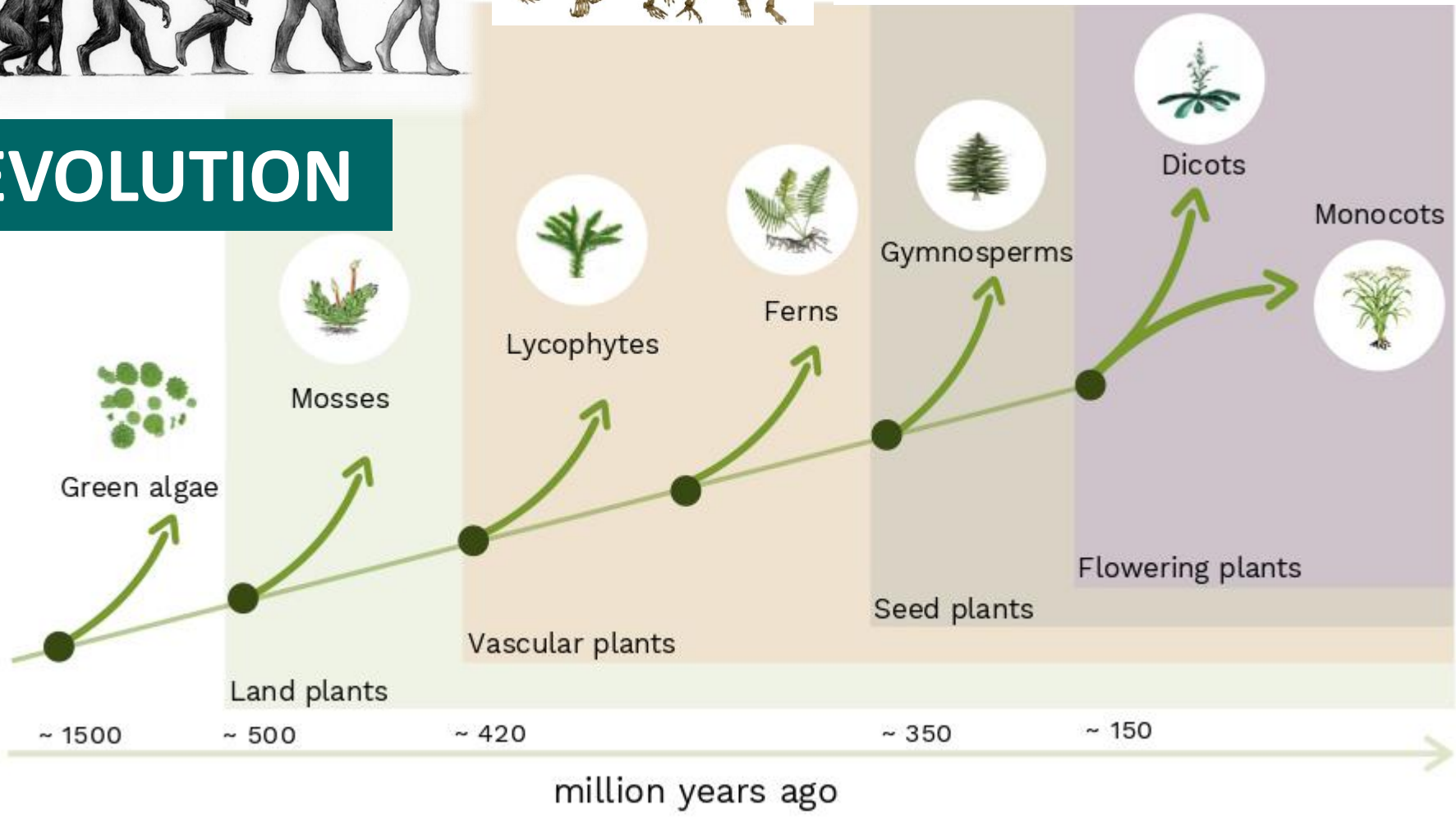


Fig. 204.
(Cf. p. 181.)
Gibbon.
Fig. 205.
(Plate XIV. Fig. 3.)
Orang-outang.
Fig. 206.
(Plate XIV. Fig. 1.)
Chimpanzee.
Fig. 207.
(Plate XIV. Fig. 2.)
Gorilla.
Fig. 208.
(Plate XIV. Fig. 4.)
Man.

EVOLUTION


Green algae
Mosses
Lycophytes
Ferns
Gymnosperms
Dicots
Monocots
Flowering plants
Seed plants
Vascular plants
Land plants
~ 1500
~ 500
~ 420
~ 350
~ 150
million years ago

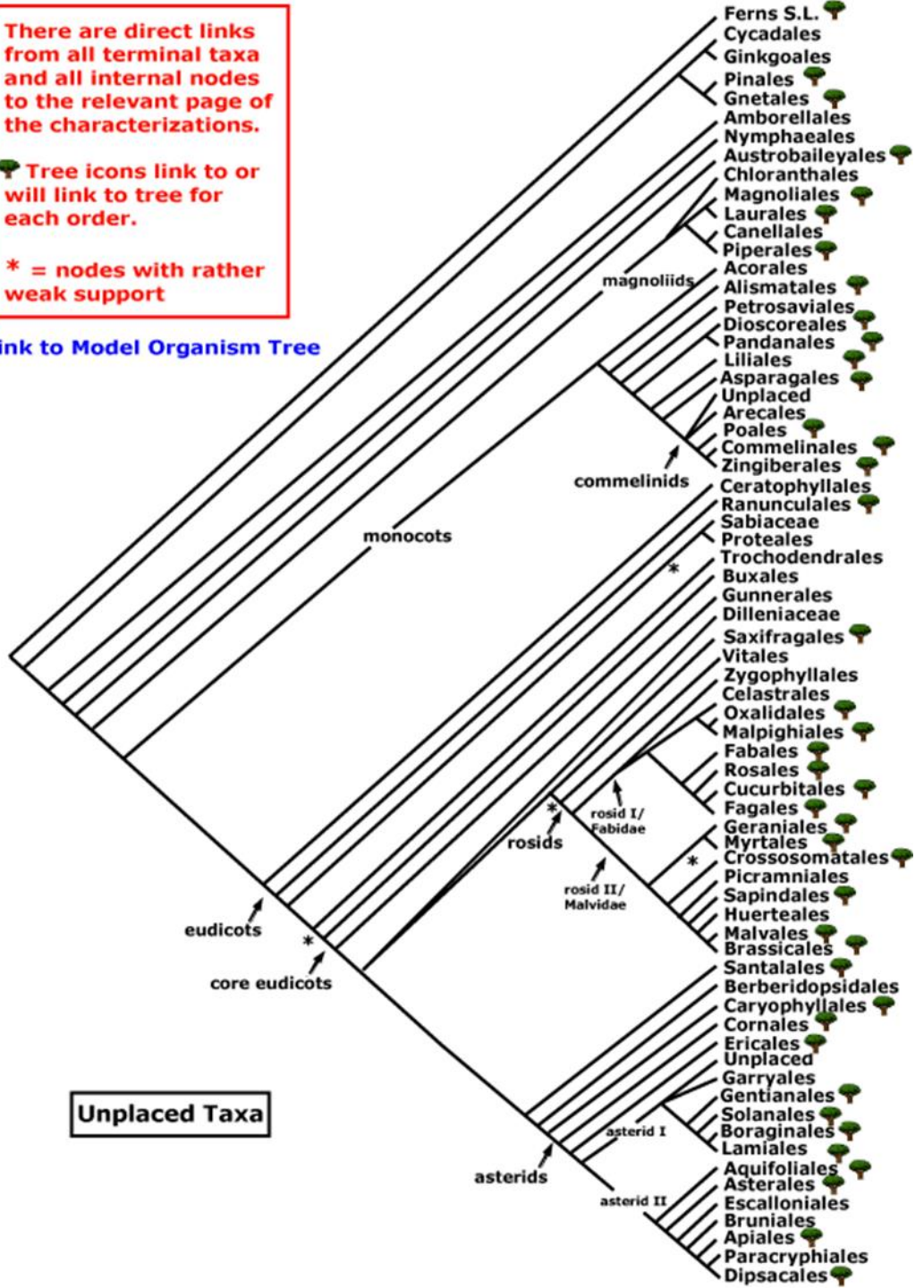
Angiosperm Phylogeny Group (APG)

There are direct links from all terminal taxa and all internal nodes to the relevant page of the characterizations.

Tree icons link to or will link to tree for each order.

* = nodes with rather weak support

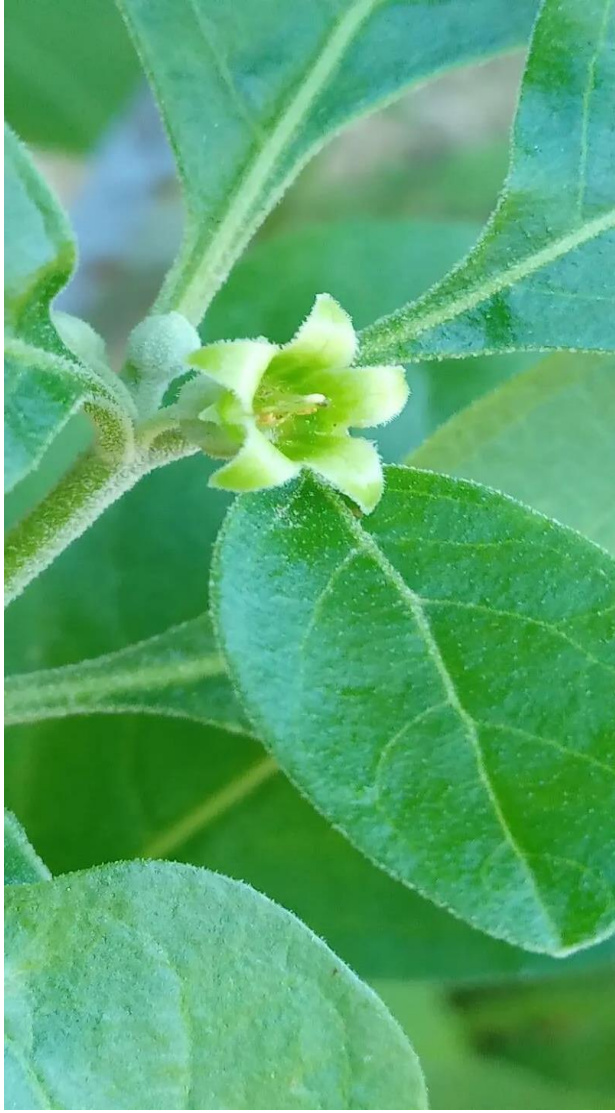
Link to Model Organism Tree



Unplaced Taxa

Morphological variation in *Withania somnifera (Solanaceae)*

From Abha, Saudi Arabia



From Riyadh, Saudi Arabia

Morphological variation in *Panax ginseng* (Araliaceae) and Nomenclature

Page 1 of 1 100 items per page

Family	!	Scientific Name	Authority	Reference	Date
Araliaceae		Panax pseudoginseng	Wall.	Trans. Med. Soc. Calcutta 4: 117	1829
Araliaceae		Panax pseudoginseng var. angustifolius	(Burkill) H.L. Li	Sargentia 2: 118	1942
Araliaceae		Panax pseudoginseng var. bipinnatifidus	(Seem.) H.L. Li	Sargentia 2: 118	1942
Araliaceae		Panax pseudoginseng var. elegantior	(Burkill) G. Hoo & C.J. Tseng	Acta Phytotax. Sin. 11(4): 436	1973
Araliaceae		Panax pseudoginseng subsp. himalaicus	H. Hara	J. Jap. Bot. 45(7): 208–209	1970
Araliaceae		Panax pseudoginseng var. himalaicus	H. Hara	J. Jap. Bot. 45: 208	1970
Araliaceae		Panax pseudoginseng subsp. japonicus	(C.A. Mey.) H. Hara	J. Jap. Bot. 45(7): 209–210	1970
Araliaceae		Panax pseudoginseng var. japonicus	(C.A. Mey.) G. Hoo & C.J. Tseng	Acta Phytotax. Sin. 11(4): 437–438	1973
Araliaceae		Panax pseudoginseng var. major	(Burkill) H.L. Li	Sargentia 2: 119	1942
Araliaceae		Panax pseudoginseng var. notoginseng	(Burkill) G. Hoo & C.J. Tseng	Acta Phytotax. Sin. 11(4): 435	1973
Araliaceae		Panax pseudoginseng var. pseudoginseng			
Araliaceae		Panax pseudoginseng var. wangianus	(S.C. Sun) G. Hoo & C.J. Tseng	Acta Phytotax. Sin. 11(4): 436	1973

Why is experimental taxonomy needed?

- Taxonomic problems arise due to phenotypic plasticity, where the same species shows different forms under different environmental conditions.
- Hybridization between closely related species produces intermediate forms that blur species boundaries.
- Polyploidy and chromosomal variation create multiple cytotypes within a species complex.
- Incomplete or overlapping morphological characters make it difficult to delimit species accurately.
- Wide geographical distribution leads to continuous variation and formation of ecotypes or races.

Taxonomic problems

Why is experimental taxonomy needed?

- Nomenclatural issues arise due to multiple names (synonyms) being assigned to the same taxon by different taxonomists.
- Changes in taxonomic concepts often require frequent name revisions, causing inconsistency in literature.
- Non-compliance with the International Code of Nomenclature (ICN) results in invalid or illegitimate names.
- Artificial and outdated classification systems fail to reflect true evolutionary relationships.
- Integration of new molecular data often leads to reclassification of taxa, disrupting traditional groupings.
- Disagreement among taxonomists on species limits leads to multiple competing classifications.
- Lack of universal acceptance of new classifications creates instability in plant nomenclature and taxonomy.

Key points for first mid term exam

- Experimental plant taxonomy uses multiple scientific evidences to achieve accurate plant classification.
- Anatomical evidence examines internal plant structures such as tissues and vascular arrangements.
- Leaf anatomy provides stable taxonomic characters less affected by environmental variation.
- Stomatal types and epidermal patterns help distinguish closely related species.
- Wood anatomy assists in classification of woody plants and tree taxa.
- Cytological evidence studies chromosome number, structure, and behavior.
- Chromosome counts help determine species relationships and evolutionary trends.
- Polyploidy plays an important role in plant speciation and taxonomic differentiation.
- Karyotype analysis reveals chromosomal similarities among plant species.
- Cytological studies help identify hybrids and evolutionary lineages.
- Chemical evidence uses secondary metabolites as taxonomic markers.
- Alkaloids, flavonoids, and terpenoids support chemotaxonomic classification.
- Phytochemical profiles help identify morphologically similar or cryptic species.
- Chemical variation reflects genetic divergence among taxa.
- Ecological evidence evaluates plant adaptation to habitat and environmental conditions.
- Geographic distribution patterns assist in understanding plant evolution.
- Ecological specialization contributes to species differentiation.
- Environmental factors influence plant morphology but also provide ecological taxonomic clues.
- Integration of anatomical, cytological, chemical, and ecological data strengthens experimental taxonomy.
- Combined evidences produce natural classification systems reflecting evolutionary relationships.

Types of Taxonomy / Taxonomic Studies / Plant Taxonomic Classification

From the various stages of classification, the types of taxonomy are defined: -

❖ **Alpha (α) Taxonomy / classical taxonomy:-**

It involves description and naming of organisms. It is the parent of other types of taxonomy.

❖ **Beta (β) Taxonomy: -**

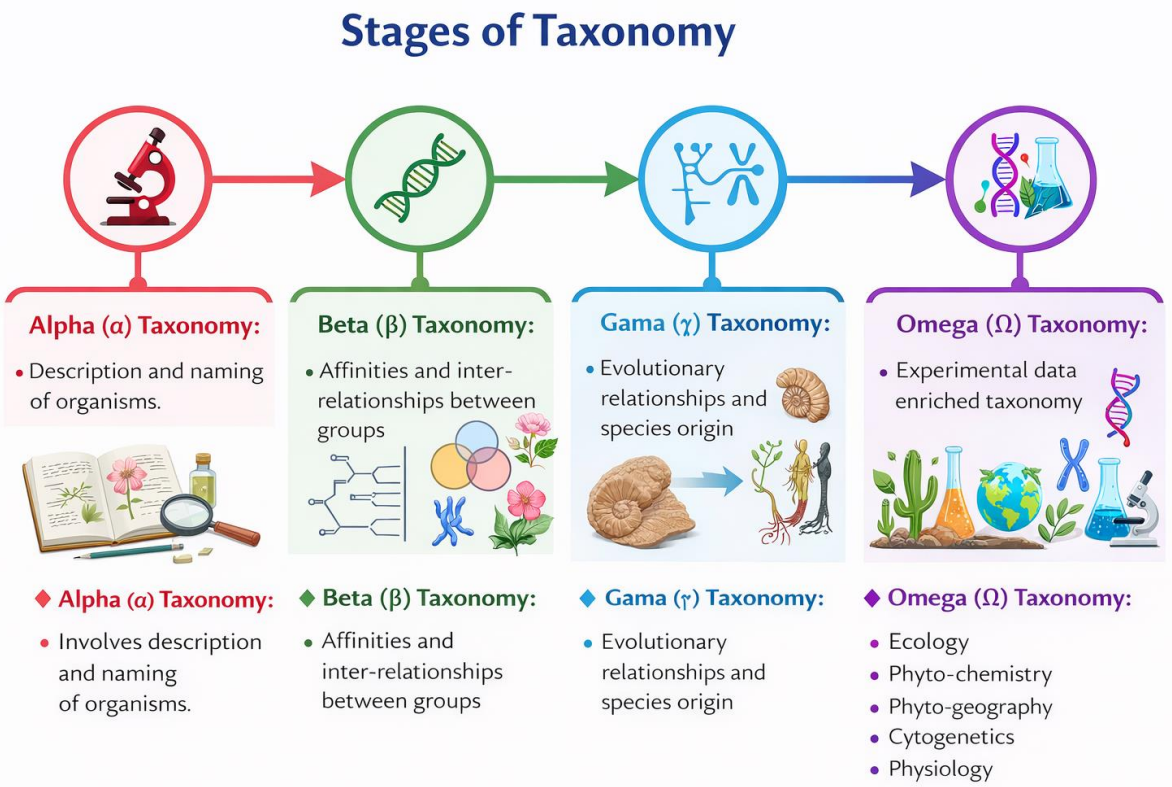
In addition to morphological description, it also involves consideration of affinities and their inter-relationship between separate group of species.

❖ **Gama (γ) Taxonomy: -**

It is concerned with description, inter-relationship and evolution of one species from the other.

❖ **Omega (Ω) Taxonomy: -**

It is the modern experimental taxonomy in which the taxonomic activities have been enriched with data from ecology, phyto-chemistry, phyto-geography, cyto-genetics and physiology coupled with adequate computation.



2. Experimental Methods in Taxonomy

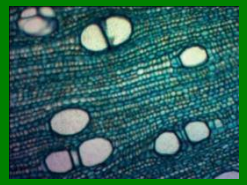
- Experimental taxonomy applies scientific experiments to study plant variation.
- Controlled hybridization experiments test species relationships.
- Cytological analysis examines chromosome number and structure.
- Growth experiments evaluate environmental influence on morphology.
- Chemical analyses reveal biochemical differences among taxa.
- Experimental methods verify natural classification systems.
- Reproductive studies help determine species boundaries.
- Cultivation experiments distinguish genetic and environmental variation.
- Physiological experiments explain adaptive traits.
- Experimental taxonomy strengthens objective plant classification.

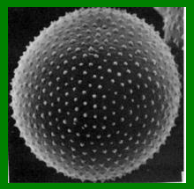
3. Taxonomic Evidences

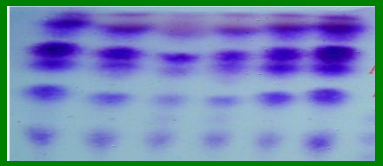
Taxonomic evidence for the establishment of classifications and phylogenies is gathered from a variety of sources

Morphology to Molecules

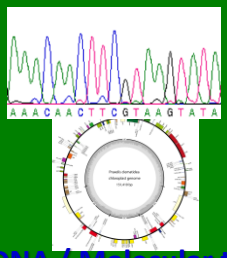

Morphology


Anatomy

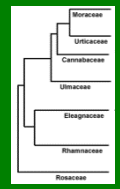

Pollen


Chemistry


Chromosomes



DNA / Molecular taxonomy



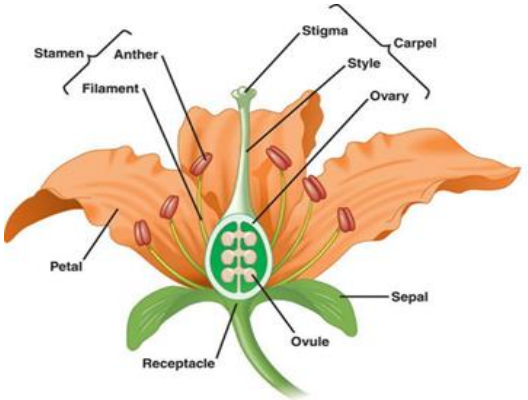
Taxonomic Evidences

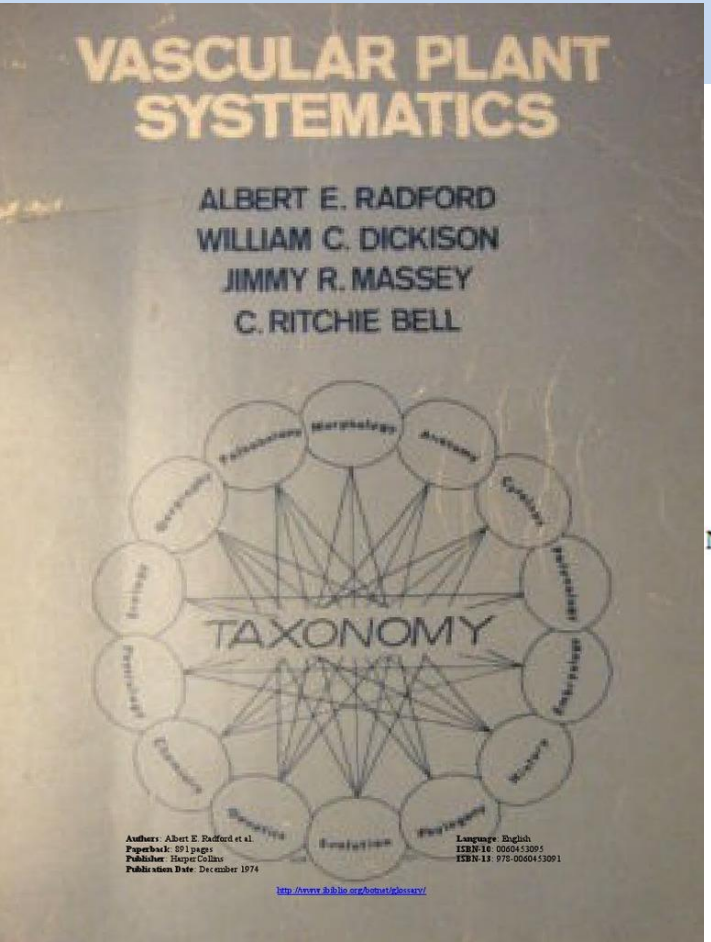
- Taxonomic evidence includes all data used for plant classification.
- Morphological characters provide primary identification features.
- Anatomical traits support taxonomic differentiation.
- Cytological evidence explains evolutionary relationships.
- Palynological characters assist species recognition.
- Embryological features provide stable classification criteria.
- Chemical constituents serve as taxonomic markers.
- Molecular data provide precise evolutionary information.
- Ecological distribution patterns support classification decisions.
- Integrative taxonomy combines multiple evidences for accuracy.

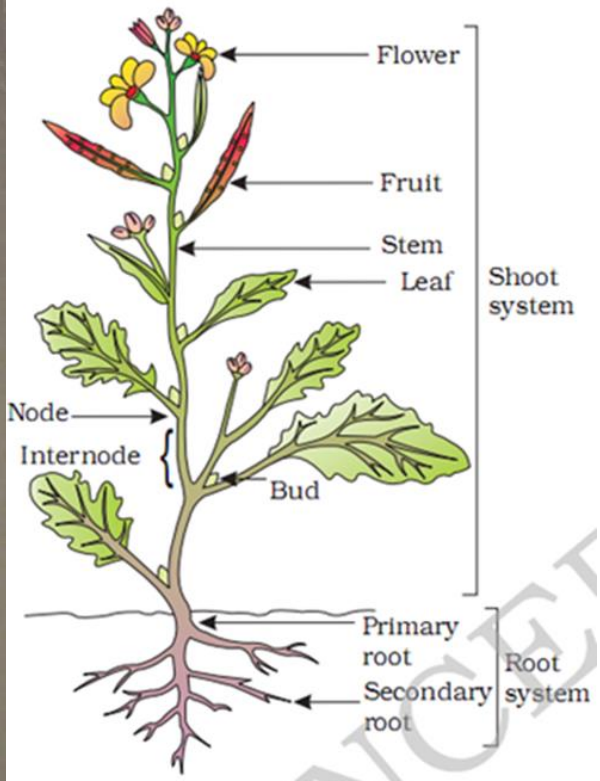
4. Plant Structure as Evidence of Taxonomy

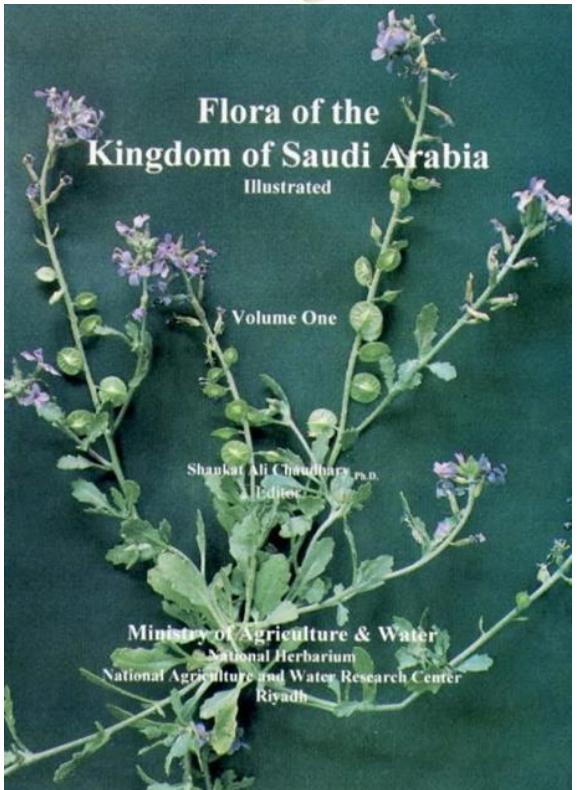
- External morphology provides fundamental taxonomic characters.
- Leaf shape and arrangement aid plant identification.
- Stem structure reflects evolutionary adaptation.
- Root systems provide ecological classification clues.
- Flower structure is highly significant in taxonomy.
- Inflorescence types assist family recognition.
- Fruit morphology supports species delimitation.
- Seed characteristics help distinguish taxa.
- Structural variations reveal evolutionary trends.
- Morphological characters remain essential in plant taxonomy.

Morphological characters provide primary identification features.









Herbarium: Plant collecting, Preservation and Documentation

- **A HERBARIUM is a collection of dried plants systematically named and arranged for ready reference and study.**
- **To make a herbarium specimen, the plant is collected, and notes are made about it. The plant is then pressed until dry between blotters that absorb moisture and mounted onto a herbarium sheet with a suitable label, and stored in steel cabinet arranged into some system of classification.**
- **Herbarium techniques involve : (i) Collection, (ii) Drying, (iii) Poisoning, (iv) Mounting, (v) Stitching, (vi) Labelling, and (vii) Deposition.**







A Typical Herbarium (KSU) in Saudi Arabia

The Herbarium at King Saud University

Ethical responsibility in handling plant materials and reporting experimental findings (CLOS 3.1)

- Plant specimens must be collected responsibly with proper permits and minimal environmental disturbance.
- Endangered and protected species should not be harmed during taxonomic investigations.
- Laboratory handling of plant materials must follow safety and ethical guidelines.
- Experimental data should be recorded accurately without fabrication or manipulation.
- Research findings must be reported honestly with proper citation of sources and collaborators.

Systematic Significance of Micromorphological Characters in Plant Taxonomy

MICOR MORPHOLOGY AS A SOURCE OF TAXONOMIC EVIDENCE

Micromorphological features of the leaf surface, trichomes, and electron microscopy provide crucial taxonomic insights at the family, genus, and species levels.

1. Leaf Surface Micromorphology

Cuticular Patterns: Thickness, ornamentation, and striations help distinguish taxa.
Epicuticular Wax: Crystals, plates, or rod-like structures vary across species.
Stomatal Complex: Arrangement and type aid in family-level classification.

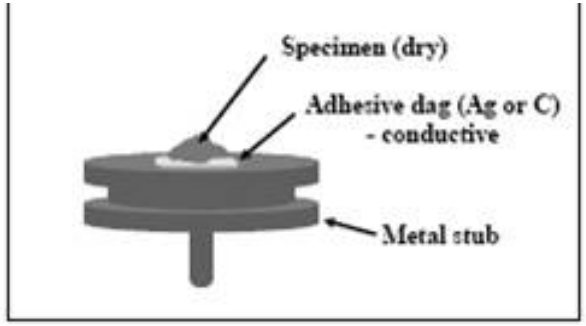
2. Trichomes (Hair-Like Structures)

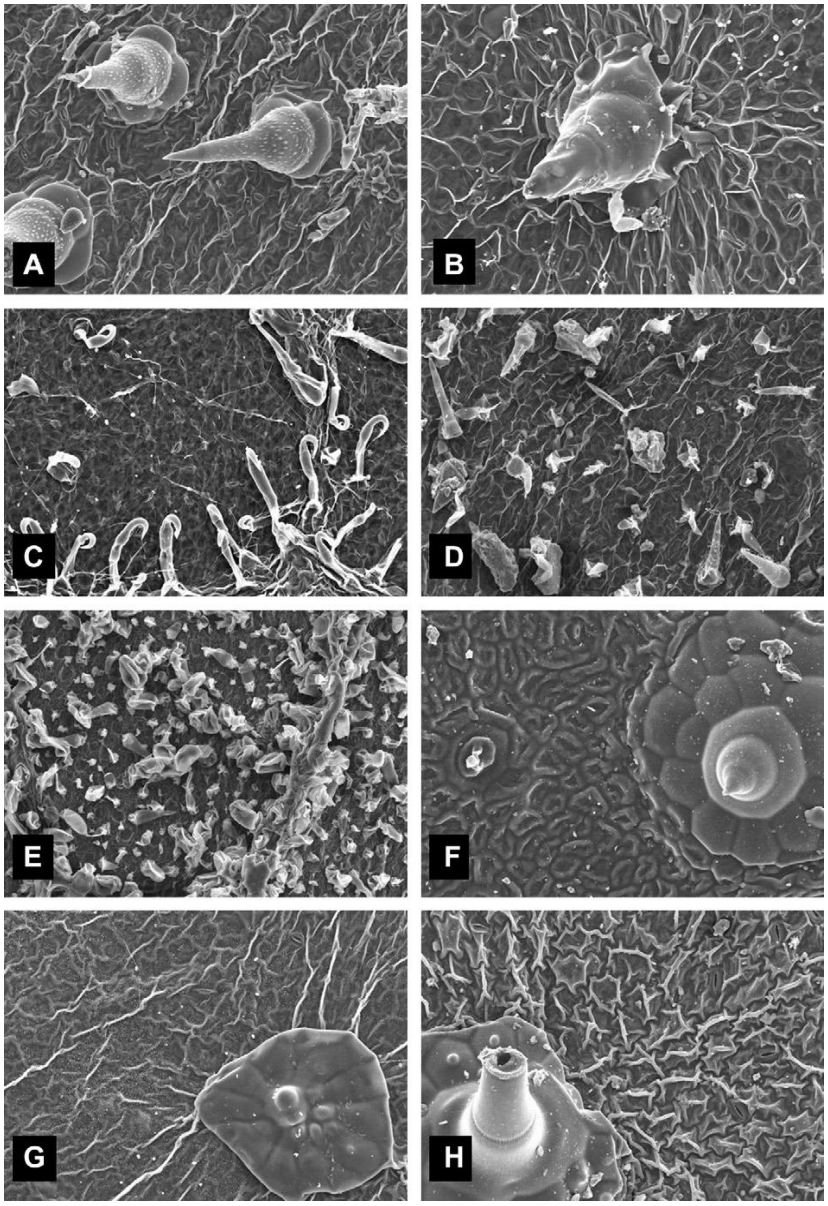
Types: Glandular (secreting oils, resins) vs. non-glandular (unicellular, multicellular).
Distribution: Helps differentiate between closely related species.
Function: Adaptations to environmental stress (drought, herbivory, UV protection).

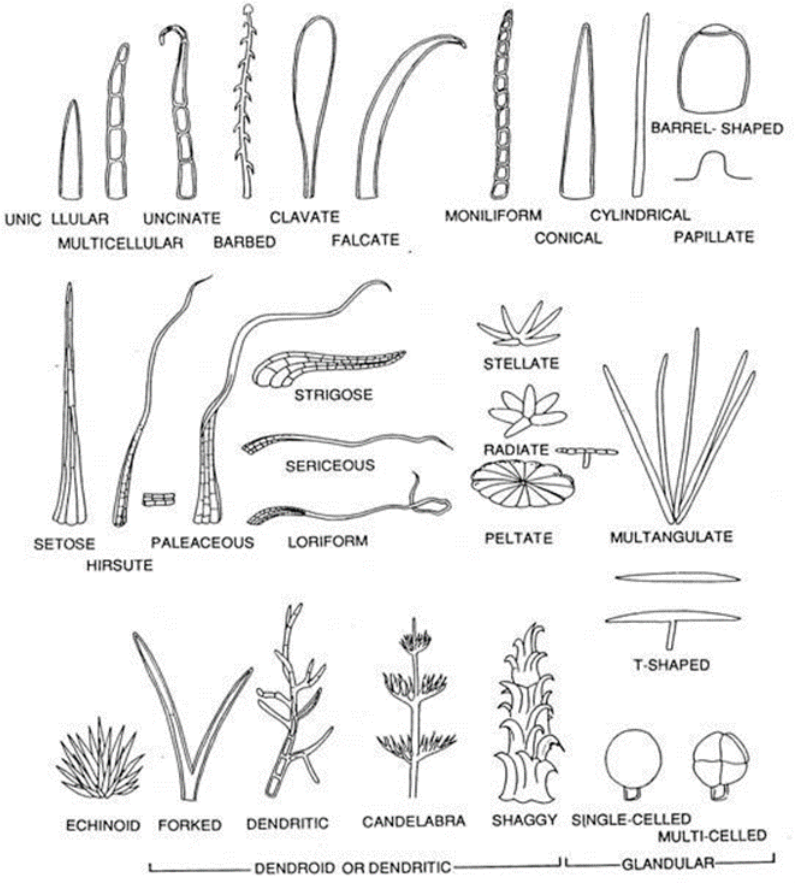
3. Electron Microscopy (Scanning & Transmission EM)

Ultrastructural Details: High-resolution imaging of cell walls, stomata, and glandular structures.
Palynology (Pollen Morphology): Shape, exine sculpturing used in classification.
Seed Coat Micromorphology: Unique textures help in species identification.

SEM







- Trichomes meaning "hair", are fine outgrowths or appendages on plants.
- Ali and Al-Hemaid (2011) studies trichomes of 23 species of the member of the family Cucurbitaceae using Electron Microscope in order to find the systematic significance of micromorphological characters of trichomes

Trichomes morphology in Cucurbitaceae: (A) *Melothria maderspatana* ·300, (B) *Sechium edulae*, (C) *Thladiantha cordifolia* ·300, (D) *Trichosanthes cucu*merina ·300, (E) *T. cucumerina* var. *anguina* ·300, (F) *T. dioica* ·300, (G) *T. lepiniana* ·300, and (H) *T. tricuspidata* ·300.

Systematic Significance of Seed Micromorphology & Electron Microscopy in Plant Taxonomy

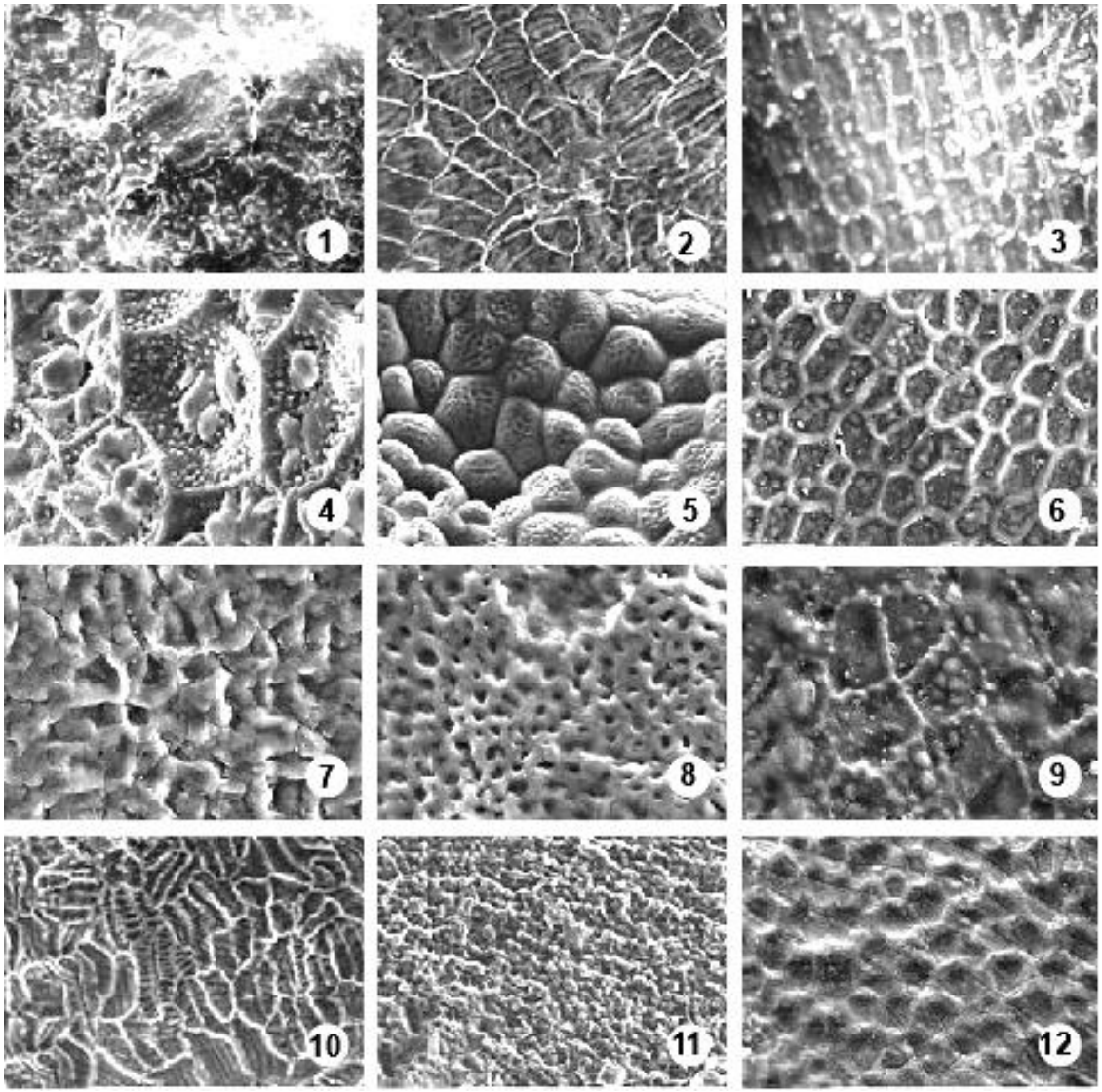
Seed micromorphology, especially observed through **scanning electron microscopy (SEM)**, provides valuable taxonomic and phylogenetic insights at different classification levels.

1. Key Micromorphological Seed Characters

Seed Coat Texture: Smooth, reticulate, striate, tuberculate (species-specific patterns).
Seed Shape & Size: Diagnostic at the genus or species level.
Hilum & Raphe Features: Position and structure help in taxonomic identification.
Epidermal Cell Structure: Unique cell wall ornamentation used for classification.

2. Electron Microscopy (SEM) in Seed Taxonomy

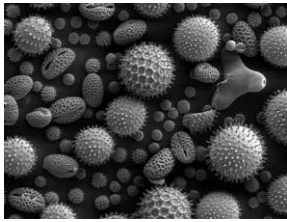
High-Resolution Surface Imaging: Identifies fine sculptural details not visible under light microscopy.
Pollen-Seeds Correlation: Helps in linking reproductive traits to taxonomic groups.
Comparative Studies: Differentiates closely related species or cultivars based on seed coat ultrastructure.



- Spermoderm refers to the pattern present on the seed coat of mature seeds.
- Seed characteristic, particularly exomorphic features as revealed by scanning electron microscopy, have been used by many workers in resolving taxonomic problems (Koul et al., 2000; Pandey and Ali, 2006) and evolutionary relationships (Kumar et al., 1999; Segarra and Mateu, 2001).
- Ali et al. (2003) studied the sppermoderm pattern of the members of the family cucurbitaceae using Electron Microscope in order to find the systematic significance of micromorphological characters seed surface

Scanning electron micrograph of the seed surface in Cucurbitaceae: 1. *Benincasa hispida ×400* (rugulate); 2. *Citrullus colocynthis ×400 (reticulate); 3. Cucumis melo var. agrestis ×400 (reticulate); 4. Diplocyclos palmatus ×1000 (reticulate); 5. Gynostemma laxiflorum ×600 (colliculate); 6. Hemsleya longivillosa ×400 (reticulate); 7. Luffa echinata ×1000 (reticulate); 8. Momordica charantia ×700* (reticulate); 9. *Momordica cymbalaria ×1000 (reticulate); 10. Schizopepon bryoniifolius ×400* (reticulate); 11. *Sicyos angulatus ×300 (rugulate); 12. Trichosanthes cucumerina ×320 (reticulate).*

Systematic Significance of Palynology & Pollen Micromorphology in Plant Taxonomy



Palynology (study of pollen grains and spores) provides crucial taxonomic, phylogenetic, and evolutionary insights. **Scanning Electron Microscopy (SEM)** and **Transmission Electron Microscopy (TEM)** reveal pollen characteristics with high precision, aiding plant classification.

1. Key Pollen Micromorphological Characters

Pollen Shape & Size: Spherical, oblate, prolate (diagnostic at genus/species level).

Aperture Types:

- **Monocolpate:** Primitive type (Magnoliids, monocots).
- **Tricolpate:** Characteristic of eudicots.
- **Porate & Colporate:** Found in advanced taxa.

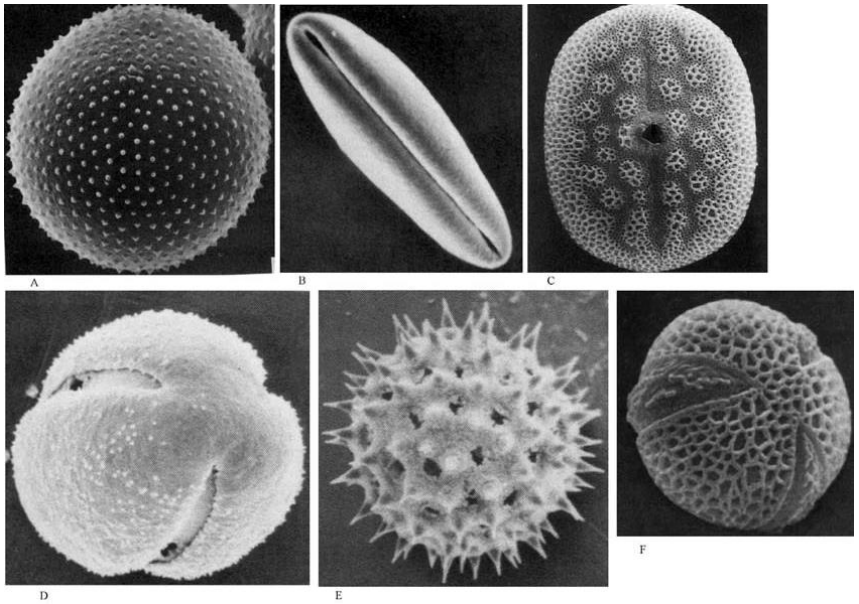
Exine Ornamentation: Reticulate, striate, spinate, psilate (family-specific patterns).

2. Electron Microscopy (SEM & TEM) in Pollen Studies

SEM: Reveals exine sculpturing, spines, and structural details.

TEM: Examines internal pollen wall layers, stratification, and ultrastructure.

Fossil Pollen Studies: Helps trace evolutionary lineages and ancient plant distributions.



SEM of pollen grains. A: Nonaperturate pollen grain of *Persea americana; B: Monosulcate* pollen grain of *Magnolia grandiflora; C: Monoporate pollen grain of Siphonoglossa; D:* Tricolporate pollen grain of *Scaevola glabra; E: Polyporate spinose pollen grain of Ipomoaea wolcottiana; F: Tricolpate pollen grain of Disanthus cercidifolius.*

- Palynology is the study of plant pollen and spores.
- There are two pollen types: monosulcate and tricolpate
- Monosulcate pollen are boat shaped with one long furrow and one germinal aperture (associated with primitive docots and the majority of monocots, the cycads and ferns). Triculpate pollen are found and typically have 3 apertures and is characteristic of the more advanced dicots.

Experiment Techniques:

- Today's strongest compound microscopes have magnifying powers of 1,000 to 2,000X.
- SEM (Scanning electron Microscope) or TEM (transmission electron Microscope) is required to study ultra structure.
- SEM and TEM is costly microscope (price in Million or Million plus Riyal).
- Magnification about 500,000 times.
- Material to be studies kept on aluminum stub, and then placed under vacuum condition (gold coating machine) for gold coating.
- Gold coated biological sample placed in SEM chamber.
- Specimen passed thru electron beam
- Images can be only observed at computer monitor.

Erdtman (1963) used the pollen characters in solving the taxonomic problem of 105 family

5. Plant Anatomy as Evidence in Taxonomy

- Internal plant structure provides reliable taxonomic characters.
- Vascular tissue arrangement helps differentiate families.
- Stomatal types are important anatomical markers.
- Trichome structure aids species identification.
- Wood anatomy assists classification of trees.
- Leaf anatomy reflects ecological adaptation.
- Epidermal cell patterns support taxonomic distinction.
- Anatomical traits are less affected by environment.
- Microscopic structures reveal evolutionary relationships.
- Anatomy complements morphological classification.

Anatomical, cytological, chemical, and ecological evidence are used in experimental plant taxonomy (CLOS 1.1)

- Anatomical characters such as vascular bundle arrangement help distinguish closely related plant taxa.
- Leaf epidermal features including stomata and trichomes provide reliable taxonomic evidence.
- Cytological studies analyze chromosome number and structure to reveal evolutionary relationships.
- Polyploidy and chromosomal variation assist in species delimitation.
- Chemical constituents like alkaloids and flavonoids serve as chemotaxonomic markers.
- Secondary metabolite profiles help identify cryptic species.
- Ecological evidence evaluates plant adaptation to specific habitats.
- Geographic distribution patterns support taxonomic classification.
- Integration of anatomical, cytological, chemical, and ecological data improves natural classification systems.
- Experimental taxonomy combines multiple evidences to achieve accurate plant identification.

Laboratory techniques (microscopy, anatomical, and cytological observation) to collect taxonomic evidence responsibly (CLOS 2.1)

- Light microscopy is used to examine plant anatomical structures accurately.
- Proper specimen preparation ensures reliable anatomical observation.
- Sectioning techniques reveal internal tissue organization.
- Cytological staining helps visualize chromosomes during cell division.
- Microscopic observation assists identification of diagnostic characters.
- Laboratory safety protocols must be followed during specimen handling.
- Ethical collection practices ensure conservation of plant populations.
- Accurate recording of observations maintains scientific reliability.
- Preservation techniques protect specimens for future reference.
- Responsible laboratory practice ensures reproducible taxonomic research.

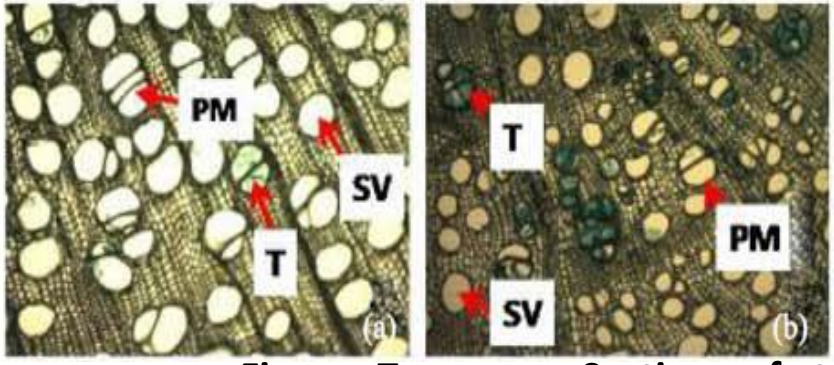
INTERNAL STRUCTURE/ INTERNAL MORPHOLOGY / ANATOMY AS A SOURCE OF TAXONOMIC EVIDENCE

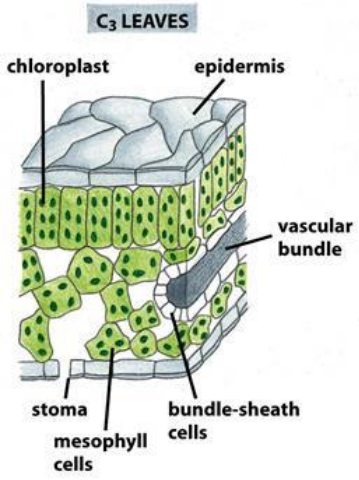
Source of Taxonomic Evidence: Plant Anatomy & Physiology

1. Plant Anatomy (Internal Characteristics)

Vascular Tissues: Xylem (vessel elements vs. tracheids), phloem structure
Leaf Anatomy: Stomata type, epidermal patterns
Secretory Structures: Glandular trichomes, laticifers, resin ducts
Wood Anatomy: Growth rings, fiber arrangement

2. Plant Physiology in Taxonomy
Photosynthetic Pathways: C3, C4, CAM plants
Secondary Metabolites: Alkaloids, flavonoids, essential oils
Growth Responses: Photoperiodism, seed dormancy mechanism





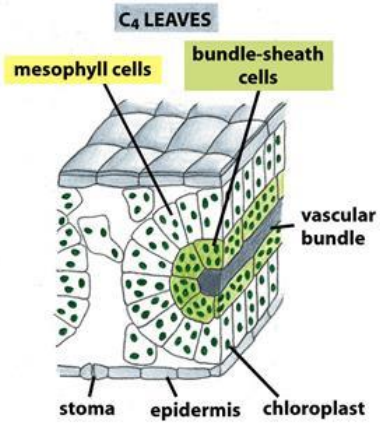
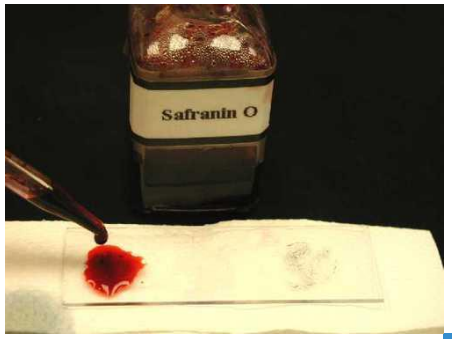
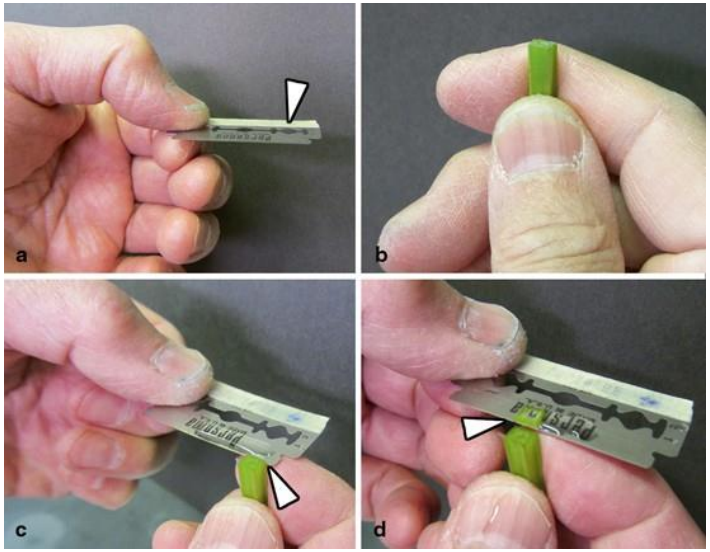


Figure: Transverse Sections of stem *Artocarpus atilis* (a) and *Artocarpus communis* (b). PM: Pore multiple, T=Tylose (Tyloses are outgrowths on parenchyma cells of xylem vessels of secondary heartwood, SV: Solitary vessel

Experimental Techniques:

- **Cutting of thin slices / section (Transverse section or Longitudinal section) of plant organs**
- **Preparation of temporary slides or permanent slides**
- **Observation under light compound microscope using tissue stain like safranin, fast green**





Systematic Significance of Stomata in Plant Taxonomy

Stomatal characteristics provide valuable taxonomic evidence for plant classification and evolutionary studies.

1. Stomatal Types (Based on Structure & Development)

Anomocytic (Ranunculaceous): No distinct subsidiary cells (e.g., Ranunculaceae).

Paracytic (Rubiaceous): Two subsidiary cells parallel to the guard cells (e.g., Rubiaceae).

Diacytic (Caryophyllaceous): Two subsidiary cells at right angles to guard cells (e.g., Caryophyllaceae).

Anisocytic (Cruciferous): Three unequal subsidiary cells (e.g., Brassicaceae).

Actinocytic: Several radially arranged subsidiary cells.

2. Stomatal Distribution Patterns

Amphistomatic: Stomata on both leaf surfaces (adapted to high light environments).

Hypostomatic: Stomata only on the lower surface (common in mesophytes).

Epistomatic: Stomata only on the upper surface (e.g., floating aquatic plants).

3. Evolutionary & Taxonomic Importance

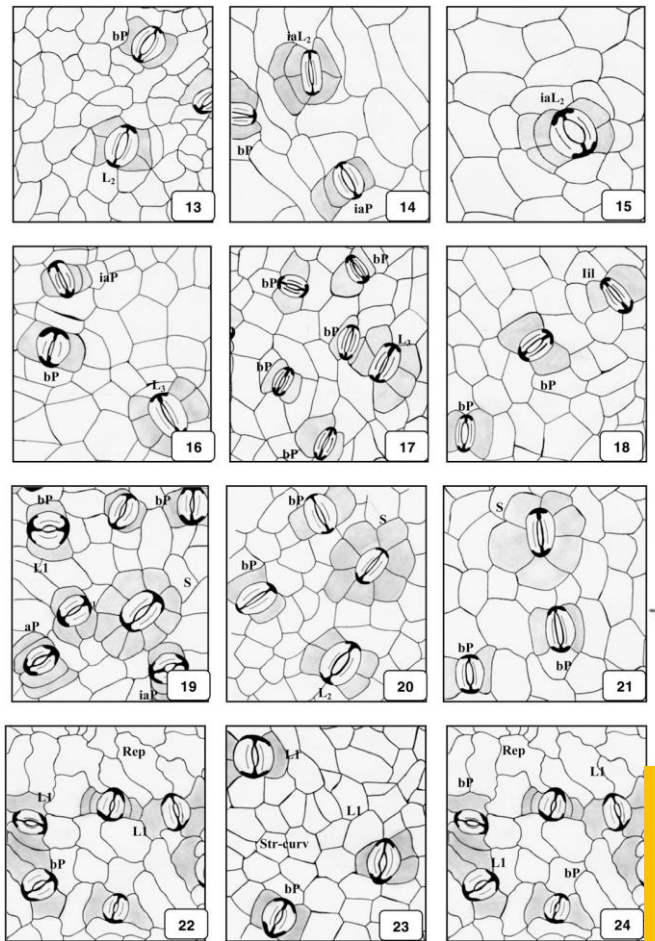
Stomatal types are stable within families and genera, aiding classification.

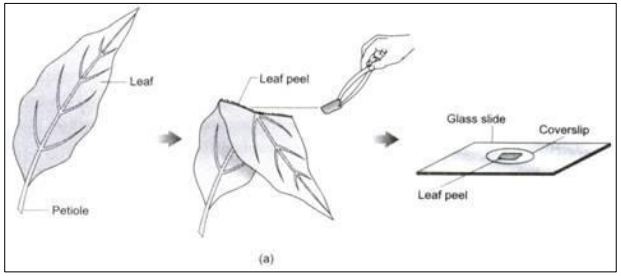
Variations reflect adaptations to ecological conditions (xerophytes, hydrophytes).

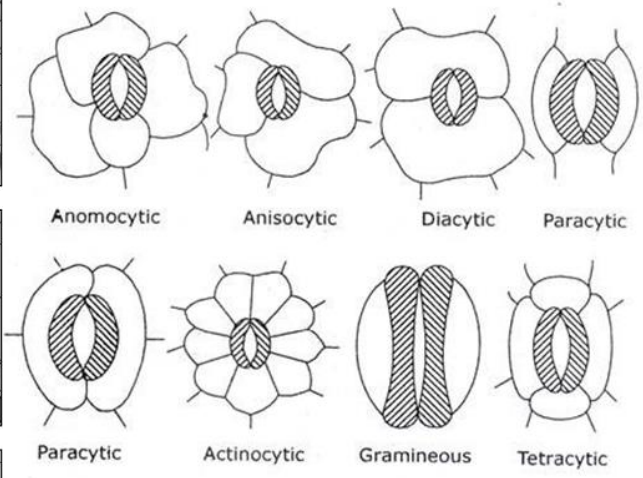
Fossil stomata help in phylogenetic and paleoenvironmental reconstructions.

Experiment Techniques:

- **Usually peeling of leaves and observation under light compound microscope (using tissue stain like safranin, fast green or without stain)**





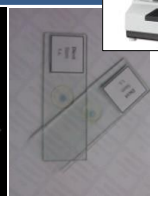
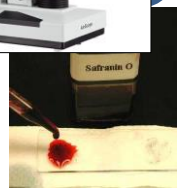


- **FARROKH et al., studies 32 *Salix speices of Salix* Species (Salicaceae) in order to find the systematic significance of trichomes in Angiosperms**

TAXONOMIC EVIDENCES: EMBRYOLOGY






Embryology (study of embryo development) provides valuable taxonomic evidence by revealing stable and conserved traits that help in plant classification and phylogenetic studies.

1. Key Embryological Characters in Taxonomy

Ovule Structure: Anatropous, orthotropous, campylotropous (helps distinguish families).

Embryo Type & Development: Variation in suspensor, cotyledon, and axis structure.

Endosperm Type: Nuclear, cellular, helobial (used to differentiate taxonomic groups).

Embryo Sac Development: Monosporic (Polygonum type), Bisporic, or Tetrasporic (variation across taxa).

Anther & Pollen Development: Tapetum type (glandular vs. amoeboid), pollen wall differentiation.

2. Systematic & Evolutionary Significance

Family-Level Differentiation:

Onagraceae (Endosperm absent) vs. Asteraceae (Cellular endosperm).

Solanaceae (Two-celled pollen) vs. Malvaceae (Three-celled pollen).

Phylogenetic Relationships: Conserved embryological traits indicate common ancestry.

Support for Classification Systems: Confirms or refines groupings based on external morphology.

Station	Time (min)	Solution
1		Water
2	45	70% alcohol
3	45	80% alcohol
4	45	90% alcohol
5	45	100% alcohol
6	60	100% alcohol
7	60	100% alcohol
8	60	Clearing reagent (xylene or substitute)
9	60	Clearing reagent (xylene or substitute)
10	60	Paraffin 1
11	60	Paraffin 2
12	60	Paraffin 3

- Embryology is the branch of biology that studies the prenatal development of gametes (sex cells), fertilization, and development of embryos and seed coats.
- The major embryological character that separates the monocots from the dicots is the number of embryonic cotyledon leaves.
- Embryological features are normally constant at the family level and below.
- The genus *Paeonia* was earlier included under the family Ranunculaceae. But *Paeonia* differs from Ranunculaceae in chromosome number, vascular anatomy, floral anatomy.
- Worsdell (1908) suggested its removal to a distinct family, Paeoniaceae.
- The separation is supported by the embryological features: (i) centrifugal stamens (not centripetal); (ii) pollen with reticulately-pitted exine with a large generative cell (not granular, papillate and smooth, small generative cell); (iii) unique embryogeny in which early divisions are free nuclear forming a coenocytic stage, later only the peripheral part becomes cellular (not onagrad or solanad type); and (iv) seed arillate.

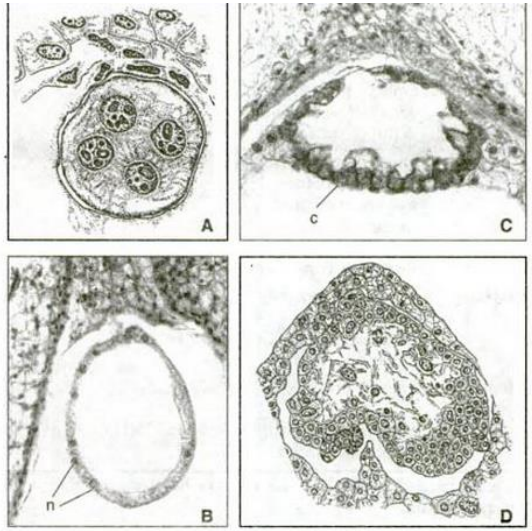


Fig. 12.14 Early stages of embryogenesis in *Paeonia* sp. **A**,**B**. Coenocytic embryo. **C**. Cellularization. **D**. Formation of embryos in the coenocytic-cellular stage. *n*, nuclei; *c*, cells (*from* Czapik and Izmailow, 2001)

TYPE	MEGASPOROGENESIS			MEGAGAMETOGENESIS			
	Megaspore mother cell	Division I	Division II	Division III	Division IV	Division V	Mature embryo sac
Monosporic 8-nucleate *Polygonum type*							
Monosporic 4-nucleate *Oenothera type*							
Bisporic 8-nucleate *Allium type*							
Tetrasporic 16-nucleate *Peperomia type*							
Tetrasporic 16-nucleate *Penaea type*							
Tetrasporic 16-nucleate *Drusa type*							
Tetrasporic 8-nucleate *Fritillaria type*							
Tetrasporic 4-nucleate *Plumbagella type*							
Tetrasporic 8-nucleate *Plumbago type*							
Tetrasporic 8-nucleate *Adoxa type*							

Fig. 3.8 : Development of different types of embryo sac in angiosperms (*after* Maheshwari)
[Micropyle above in all illustrations]

6. Cytological and Chemical Differences and Their Taxonomic Value

Cytology examines chromosome number and structure.

Polyploidy plays an important role in speciation.

Chromosome behavior indicates evolutionary divergence.

Karyotype analysis assists species delimitation.

Chemical composition provides additional classification evidence.

Secondary metabolites differentiate related taxa.

Cytological variation supports phylogenetic relationships.

Chemotaxonomic markers reveal hidden diversity.

Combined cytological and chemical data increase accuracy.

These differences strengthen modern taxonomic systems.

Systematic Significance of Cytology in Plant Taxonomy

Cytology (study of chromosomes and cell structure) provides fundamental taxonomic evidence by revealing **chromosomal number, structure, and behavior**, which help in classifying and understanding plant relationships.

1. Key Cytological Characters in Taxonomy

Chromosome Number:

Stable numbers define taxa (e.g., **Brassicaceae: 2n = 14**, **Poaceae: 2n = 14, 20**).

Polyploidy (triploids, tetraploids) is common in evolution.

Chromosome Structure & Behavior:

Karyotype analysis (size, shape, banding patterns) distinguishes taxa.

Chromosomal rearrangements (inversions, translocations) provide evolutionary insights.

DNA Content & Genome Size:

Differences in genome size help in species differentiation.

Flow cytometry and sequencing assist in phylogenetic studies.

2. Systematic & Evolutionary Significance

Family & Genus Classification: Chromosomal variations help in plant differentiation (e.g., Asteraceae, Fabaceae).

Hybridization & Polyploidy:

Explains speciation and adaptive evolution.

Many crop plants (wheat, cotton) evolved via polyploidy.

Phylogenetic Insights: Chromosomal changes reflect evolutionary history and plant lineage divergence.

TAXONOMIC EVIDENCES: CYTO TAXONOMY

Cytotaxonomy (Chromosome Studies)

Definition: Study of **chromosome number, structure, and behavior** t
classify plants.

Key Aspects:

Chromosome Number – Different species have specific numbers (e.g
Triticum aestivum has 42).

Karyotype Analysis – Examines chromosome shape and size.

Experiment Techniques:

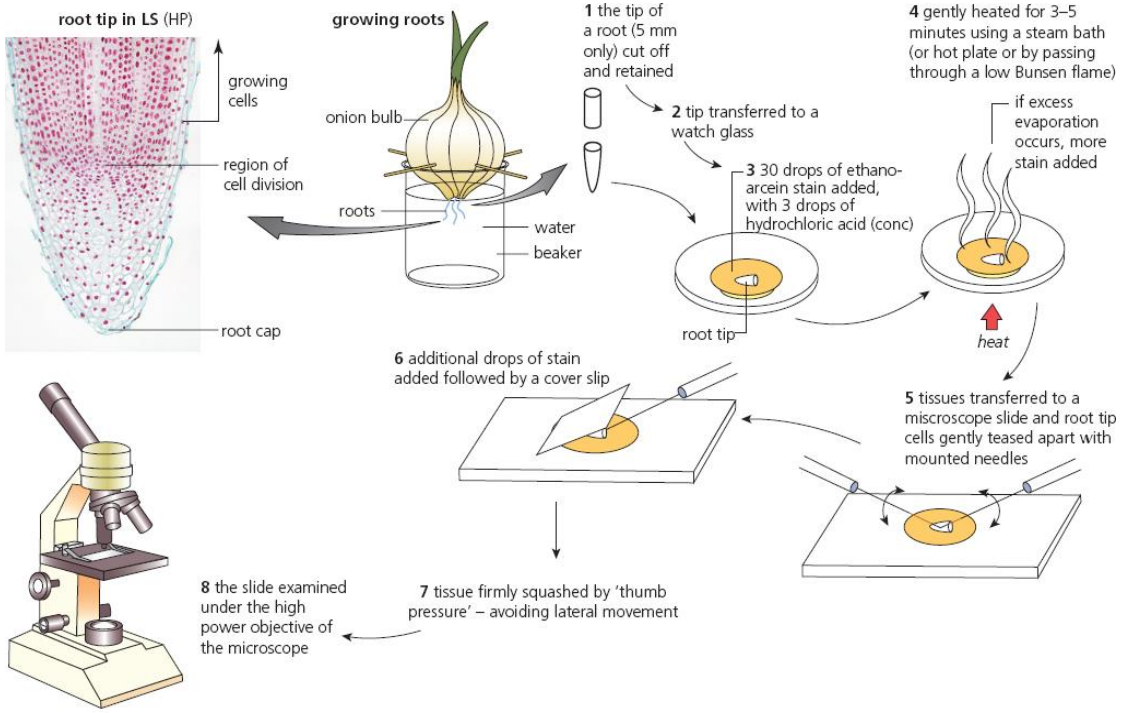
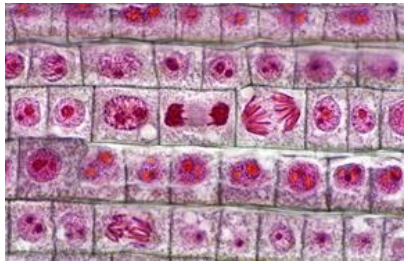
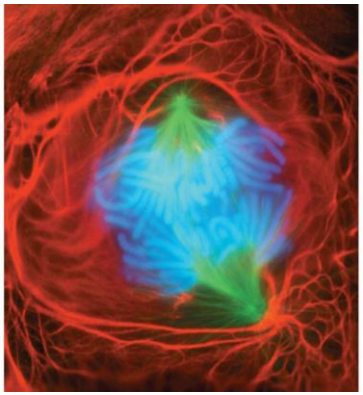


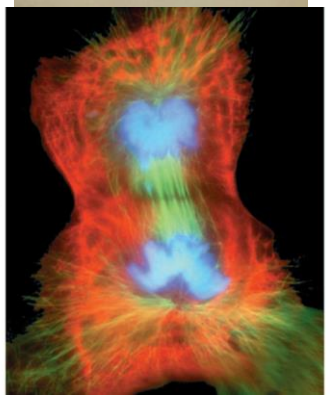
Figure 5.9 Preparing an onion root tip squash with ethano-orcein stain

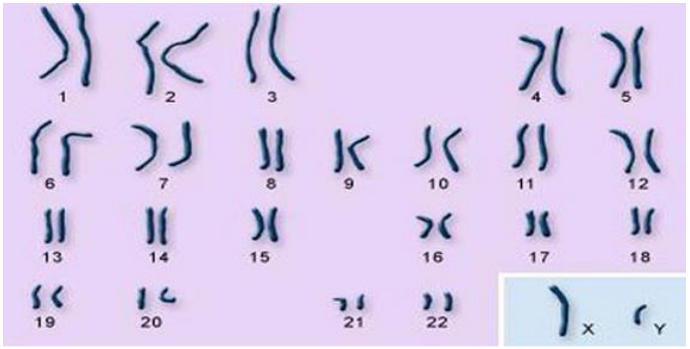
- **Chromosome Set:**

- Number of chromosome can be counted in the metaphase stage of cell division.
- One copy of each of the different chromosomes in the nucleus containing one copy of each different gene.
- Haploid Number (n): The number of chromosomes comprising one set.
- Diploid Number (2n): The number of chromosomes in a cell containing two sets.
- Human Haploid (n)= 23, Diploid (2n)=46
- Dates Haploid (n)= 14, Diploid (2n)=28
- In plants, only information about chromosome number, shape or pairing at meiosis is used for classification purposes.
- The term karyotype is used for the phenotypic appearance for the somatic chromosomes.
- The diagrammatic representation of the karyotype is termed as idiogram.
- The characteristic of chromosome having taxonomic values are: chromosome number, chromosome size, chromosome morphology, and chromosome behavior during meiosis.
- The genus *Yucca* had long been treated as a member if Liliaceae because of the superior ovary. Hutchinson shifted *Yucca* to the family Agavaceae because the genus *Yucca* possess 25 small and 5 large chromosome which is similar to the member of family Agavaceae









Yucca carnerosana

7. Phytochemistry

- Phytochemistry studies chemical compounds produced by plants.
- Secondary metabolites serve as taxonomic indicators.
- Alkaloids help distinguish related species.
- Flavonoid profiles support classification.
- Terpenoids provide chemotaxonomic evidence.
- Chemical variation reflects evolutionary divergence.
- Metabolite analysis clarifies complex taxa.
- Phytochemical data support molecular taxonomy.
- Chemical markers assist medicinal plant identification.
- Chemotaxonomy enhances modern systematic studies.

TAXONOMIC EVIDENCES: CHEMO-TAXONOMY

Chemotaxonomy (Chemical Analysis)

Definition: Uses **chemical compounds** (secondary metabolites) for classification.

Key Chemical Markers:

Alkaloids – Found in medicinal plants (*Papaver somniferum* - Opium poppy).

Flavonoids – Pigments help classify plant families (*Caryophyllales produce Betalains*).

Essential Oils – Common in aromatic plants (*Lamiaceae - Mint family*).

Example:

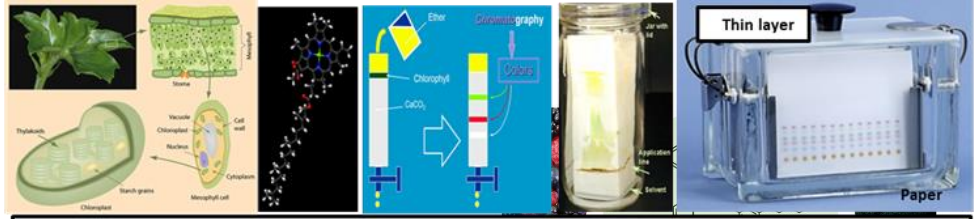
Betalains vs. Anthocyanins – Used to distinguish **Caryophyllales from Polygonales**.

Importance:

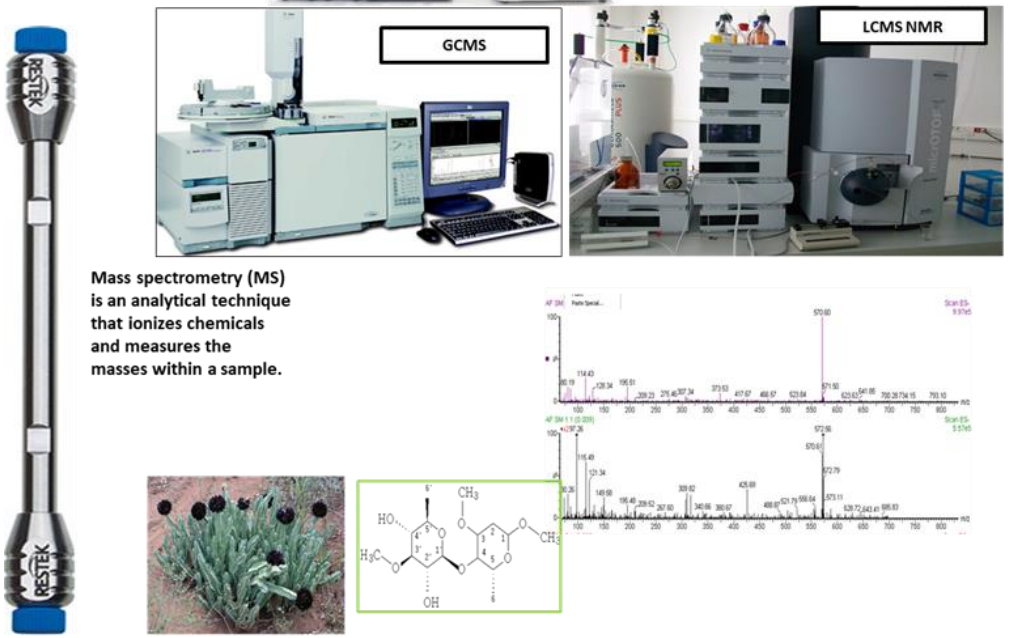
Helps in **medicinal plant classification**.

Differentiates plants with **similar morphology**.

Useful in **pharmaceutical and agricultural research**.

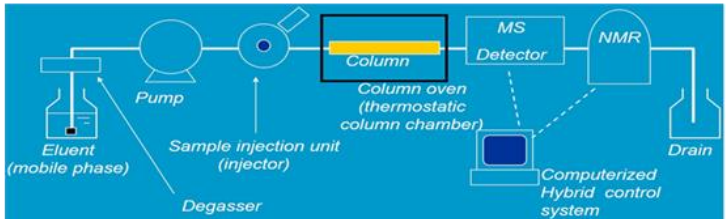


Chromatography is used to separate mixtures of substances into their components. All forms of chromatography work on the same principle. They all have a stationary phase (a solid, or a liquid supported on a solid) and a mobile phase (a liquid or a gas).



Mass spectrometry (MS) is an analytical technique that ionizes chemicals and measures the masses within a sample.

Al-Allah et al., 2018 identified as methyl β-lilacinobioside islated from *Caralluma retrospiciens*



Systematic Significance of Chemotaxonomy in Plant Taxonomy

Chemotaxonomy uses **chemical compounds** (secondary metabolites) to differentiate plants at various taxonomic levels. These biochemical markers provide critical insights into plant relationships, classification, and evolutionary processes.

1. Key Chemical Characters in Taxonomy

Secondary Metabolites:

Alkaloids, flavonoids, terpenoids, and phenolics are commonly used for classification.

Terpenoids: Diagnostic in families like Lamiaceae and Rutaceae.

Flavonoids: Found in family-level distinctions like Rosaceae and Fabaceae.

Essential Oils:

Plant species produce distinct volatile oils (e.g., in mint, lavender) used to identify species and genera.

Amino Acids & Fatty Acids:

Unique amino acid compositions assist in distinguishing plant families.

Proteins & Enzymes:

Specific proteins (e.g., Rubisco) and enzymes can be used for genetic relationships (e.g., peroxidases).

2. Systematic & Evolutionary Significance

Family & Genus Differentiation:

Chemical profiles (e.g., alkaloid presence) help define family boundaries (e.g., Papaveraceae, Solanaceae).

Some compounds are specific to certain lineages, providing strong taxonomic markers.

Evolutionary Insights:

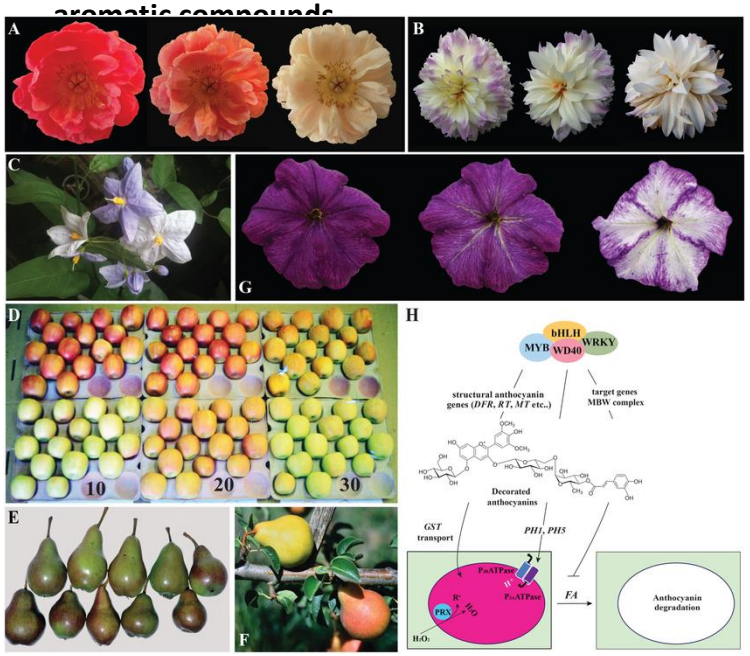
Similarities in chemical composition can indicate common ancestry.

Evolutionary patterns are reflected in the presence or absence of certain metabolites.

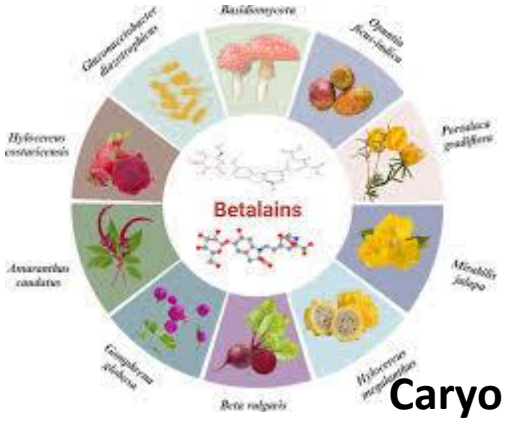
Ecological Adaptations:

Chemical compounds often relate to plant's defense mechanisms or ecological roles (e.g., phenolic compounds in drought tolerance).

- **Caryophyllales** produce **Betalins** (instead of anthocyanins).
- **Polygonales** produce **anthocyanins** (instead of Betalins).
- **Lamiaceae** are known for producing **highly aromatic compounds**



Polygonales



Caryophyllales

8. Eco-Geographical Distribution and Its Taxonomic Importance

- Plant distribution patterns reflect evolutionary history.
- Geographic isolation promotes species differentiation.
- Ecological adaptation influences plant morphology.
- Habitat specialization aids taxonomic recognition.
- Climate affects species variation and classification.
- Endemism provides important taxonomic evidence.
- Biogeography helps trace plant migration routes.
- Ecological niches influence speciation processes.
- Distribution data support phylogenetic studies.
- Eco-geographical analysis strengthens taxonomic interpretation.

Systematic Significance of Ecology in Plant Taxonomy

Erect form of *Euphorbia hirta*

Prostrate form of *Euphorbia hirta*

Contemporary taxonomic challenges related to hybridization, environmental variation, and biodiversity conservation (CLOS 1.2)

- Natural hybridization produces intermediate forms that complicate species identification.
- Introgression between species can obscure taxonomic boundaries.
- Environmental variation causes phenotypic plasticity leading to misidentification.
- Morphological characters may vary due to ecological conditions rather than genetics.
- Climate change alters species distribution patterns affecting taxonomy.
- Habitat destruction threatens rare and endemic plant species. Loss of biodiversity limits availability of taxonomic reference material.
- Conservation priorities require accurate species delimitation.
- Molecular tools are increasingly needed to resolve taxonomic conflicts.
- Modern taxonomy must integrate conservation biology with classification studies.

9. Natural Hybridization

Natural hybridization occurs between closely related species.

Hybrids show intermediate morphological characters.

Hybrid zones reveal evolutionary interactions.

Hybridization contributes to genetic diversity.

It may produce new species through introgression.

Natural hybrids complicate species identification.

Hybrid fertility determines taxonomic status.

Hybridization demonstrates evolutionary relationships.

Genetic exchange influences plant evolution.

Study of hybrids improves taxonomic understanding.

10. Fertility and Its Significance in Taxonomy

- Fertility determines reproductive compatibility among species.
- Fertile hybrids indicate close genetic relationships.
- Sterility suggests taxonomic separation.
- Crossability tests help define species boundaries.
- Reproductive isolation promotes speciation.
- Fertility studies support biological species concepts.
- Seed viability reflects genetic compatibility.
- Pollination success influences classification decisions.
- Reproductive behavior provides evolutionary evidence.
- Fertility analysis is essential in experimental taxonomy.

11. Use of Comparative Experimental Methods in Taxonomy

- Comparative experiments analyze similarities and differences among related taxa.
- Hybridization studies compare reproductive compatibility.
- Growth comparisons reveal phenotypic plasticity.
- Cytological comparisons identify chromosomal variation.
- Chemical comparisons detect metabolite differences.
- Anatomical comparisons reveal structural divergence.
- Comparative methods clarify evolutionary relationships.
- Experimental comparisons help resolve taxonomic confusion.
- Comparative data improve species delimitation.
- These methods contribute to phylogenetic classification.

Experimental taxonomic data using statistical tools to determine similarities and differences among plant species (CLOS 2.1)

- Statistical analysis quantifies variation among morphological characters.
- Cluster analysis groups species based on similarity indices.
- Principal Component Analysis (PCA) identifies key diagnostic characters.
- Numerical taxonomy uses multivariate statistics for classification.
- Similarity coefficients measure relationships among taxa.
- Statistical testing distinguishes significant versus random variation.
- Morphometric analysis supports objective species delimitation.
- Data visualization aids interpretation of taxonomic relationships.
- Statistical tools reduce subjective bias in classification.
- Quantitative analysis strengthens experimental taxonomy conclusions.

Work effectively within a team to conduct and present experimental taxonomic investigations (CLOS 3.2)

- Team members should collaborate respectfully to complete taxonomic experiments efficiently.
- Responsibilities must be shared equally during specimen collection and laboratory analysis.
- Clear communication improves coordination during experimental procedures.
- Group discussions enhance interpretation of taxonomic data and findings.
- Collaborative presentation of results strengthens scientific understanding and teamwork skills.

Key points for Second mid term exam

- Taxonomic problems arise when species boundaries are difficult to define accurately.
- Natural hybridization produces intermediate forms that complicate species identification.
- Hybrid individuals may possess characters of both parent species.
- Introgression between species causes genetic mixing and taxonomic confusion.
- Hybrid fertility influences decisions regarding species classification.
- Environmental variation leads to phenotypic plasticity in plants.
- Phenotypic plasticity may cause morphological differences within the same species.
- Environmental factors such as climate, soil, and altitude affect plant morphology.
- Morphological variation due to environment can result in misidentification of taxa.
- Cryptic species remain undetected when only morphological characters are used.
- Molecular techniques are increasingly required to resolve taxonomic uncertainties.
- Rapid climate change alters plant distribution patterns and taxonomic interpretation.
- Habitat destruction threatens rare and endemic species important for taxonomy.
- Loss of biodiversity reduces available genetic resources for taxonomic studies.
- Conservation biology depends on accurate taxonomic identification.
- Misclassification may lead to ineffective conservation strategies.
- Biodiversity conservation requires integration of ecological and molecular data.
- Invasive species create new challenges in species delimitation and classification.
- Modern taxonomy adopts integrative approaches combining classical and molecular evidence.
- Recognizing contemporary taxonomic challenges improves sustainable biodiversity management.

TAXONOMIC EVIDENCES: MOLECULAR TAXONOMY

Advanced Experimental Approaches in Plant Taxonomy

Introduction
Traditional taxonomy relied on **morphological features**, but modern techniques provide **greater accuracy** in plant classification.
Advanced methods include **Molecular Taxonomy, Cytotaxonomy, and Chemotaxonomy**.

Molecular Taxonomy (DNA Analysis)
Definition: Uses **DNA sequencing** to study genetic relationships between plants.
Techniques:
DNA Barcoding – Uses short DNA sequences to identify species.
RFLP (Restriction Fragment Length Polymorphism) – Identifies genetic differences.
PCR (Polymerase Chain Reaction) – Amplifies DNA for analysis.
Example:
Arabidopsis thaliana genome sequencing helped in plant evolutionary studies.
Importance:
Provides **precise plant identification**.
Helps in studying **evolutionary relationships**.
Useful for identifying **cryptic species** (visually similar but genetically different).

Molecular Systematics

Definition: Molecular systematics uses genetic data (DNA, RNA, proteins) to classify organisms and study their evolutionary relationships.

Objective Approach: Provides more accurate classifications compared to traditional morphology-based taxonomy.

Key Molecular Markers: Uses chloroplast DNA (*rbcL, matK*), nuclear DNA (*ITS*), and mitochondrial DNA.

Techniques Used: PCR amplification, DNA sequencing, and phylogenetic tree construction.

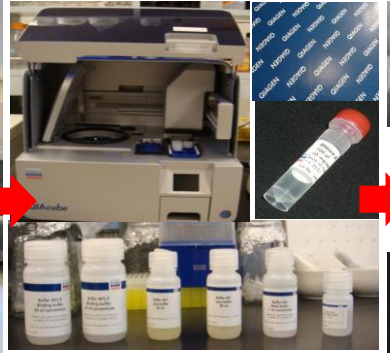
Significance: Helps in species identification, evolutionary studies, and biodiversity conservation.

Molecular systematics

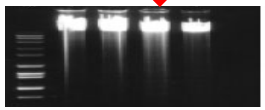
- Molecular systematics deals the utilization of nucleic acid data. As DNA sequence of a gene is constant in a species, hence advantage over morphological data for taxonomic studies.
- Taxonomist use molecular data from three different locations within a plant cell: chloroplast, mitochondrion and the nucleus.
- Molecular systematics involves following steps: (1) Sample collection, (2) DNA extraction, (3) Amplification using PCR –Polymerase chain Reaction, (4) DNA / Gene Sequencing, (5) Analysis of Sequence data.
- DNA barcoding can speed up identification of species. DNA barcoding helps in Wild plant identification / Medicinal plant authentication
- A DNA barcode is a short gene sequence taken from standardized portions of the genome, used to identify species

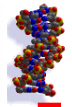

Collection of plant samples


A view of molecular biology laboratory



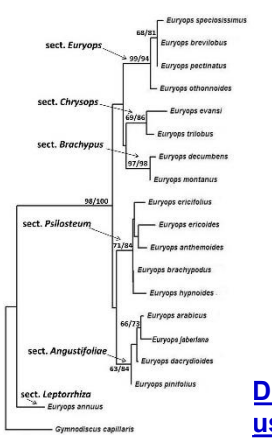
Gel electrophoresis



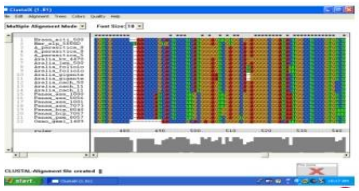


Molecular Biology

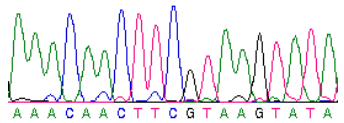
Doyle JJ, Doyle JL (1990) Isolation of plant DNA from fresh tissue. Focus 12:13–15

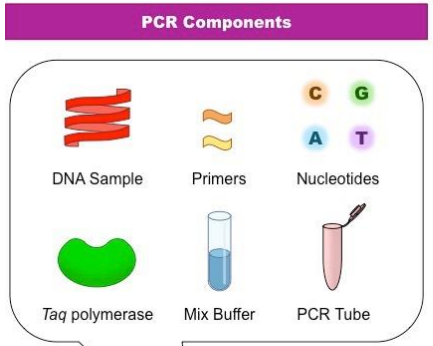


Building Tree



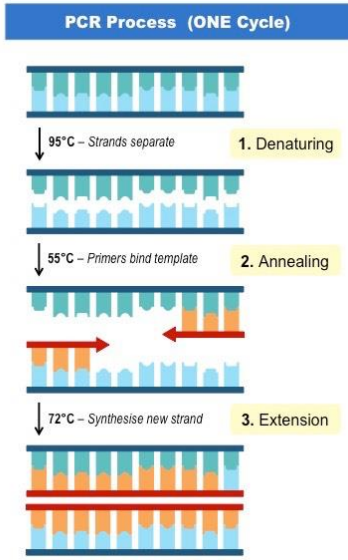
DNA sequence alignment using ClustalX

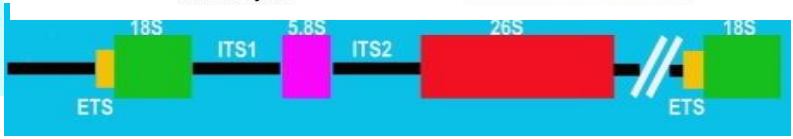


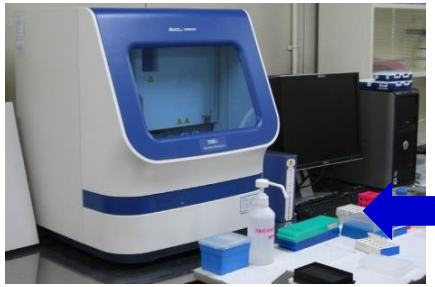


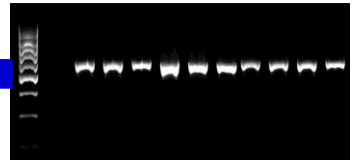

Thermal Cycler

PCR Cycle









Key Molecular Data in Taxonomy

DNA Sequencing:

rDNA (ribosomal DNA): 18S, 5.8S, 28S rDNA regions provide species- and genus-level identification.

Chloroplast DNA: matK, rbcL, and trnL regions are often used for plant family and genus classification.

Mitochondrial DNA: Markers like COX1 and ATP synthase genes reveal evolutionary relationships within certain plant groups.

Molecular Markers:

SSR (Simple Sequence Repeats): Highly polymorphic markers for species identification.

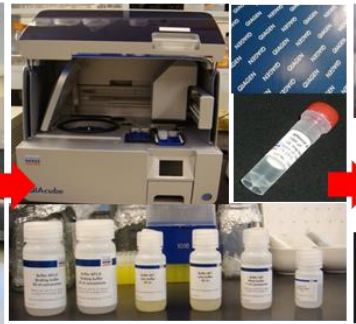
AFLP (Amplified Fragment Length Polymorphism): Used to assess genetic diversity and phylogenetic relationships.

SNPs (Single Nucleotide Polymorphisms): Help refine species boundaries and reveal population-level diversity.

Genome Sequencing:

Full genome sequencing provides the most comprehensive taxonomic data, revealing gene family expansions, genome size, and synteny between species.

Collection of plant samples



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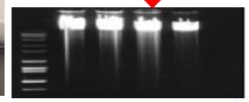
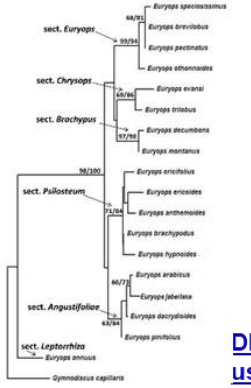


Molecular Biology

A view of molecular biology laboratory

Doyle JJ, Doyle JL (1990) Isolation of plant DNA from fresh tissue. Focus 12:13–15



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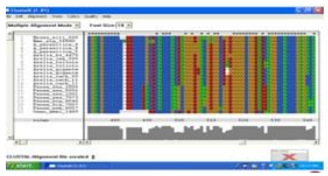

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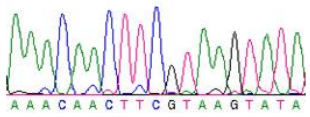
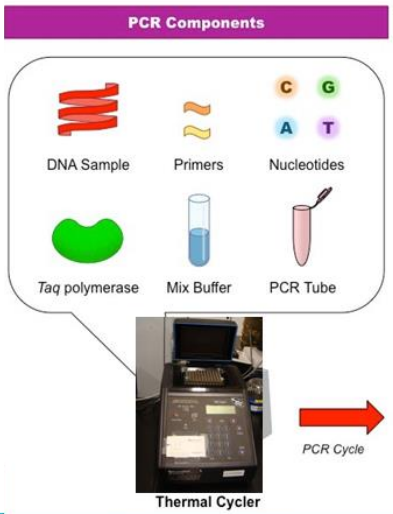
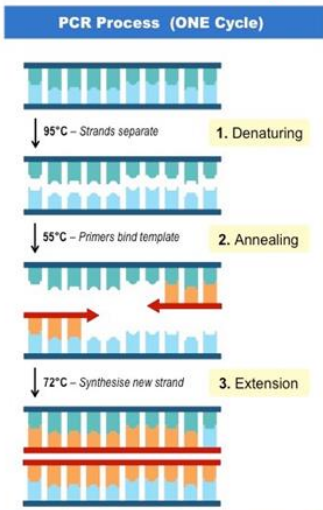
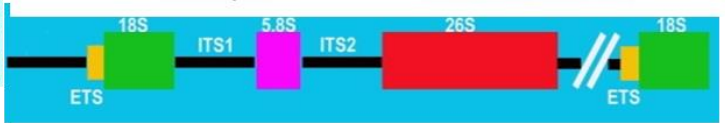
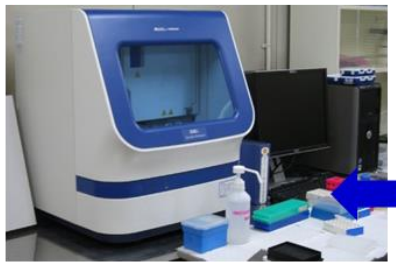
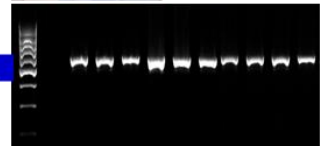












Sampling of leaf material for the molecular taxonomic study and DNA extraction

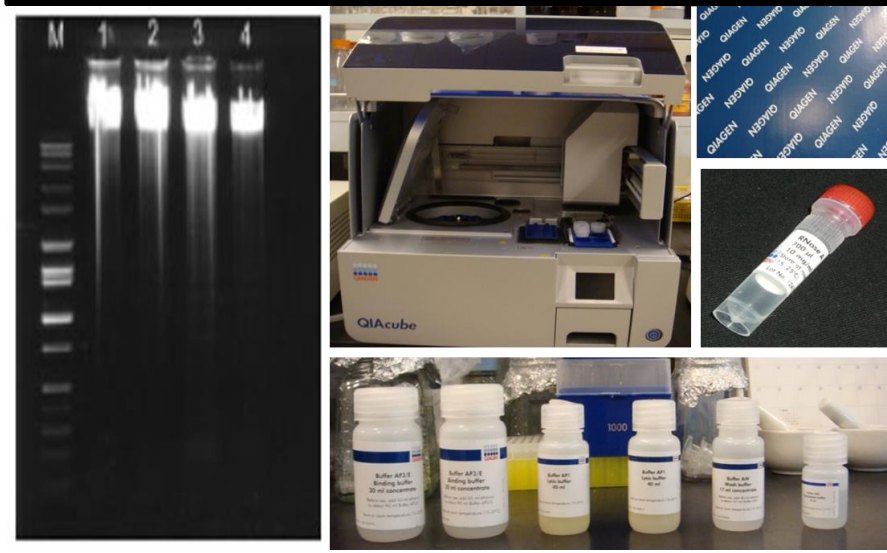
- Doyle and Doyle (1990) is widely used protocol for DNA Extraction from plant tissue. But it involves preparation of several buffer manually. It takes long times. This method atleast take more than one day preparation and about whole day in DNA extraction. It also involves several times centrifugation. This method requires large amount of fresh leaves (10 gram or even more).

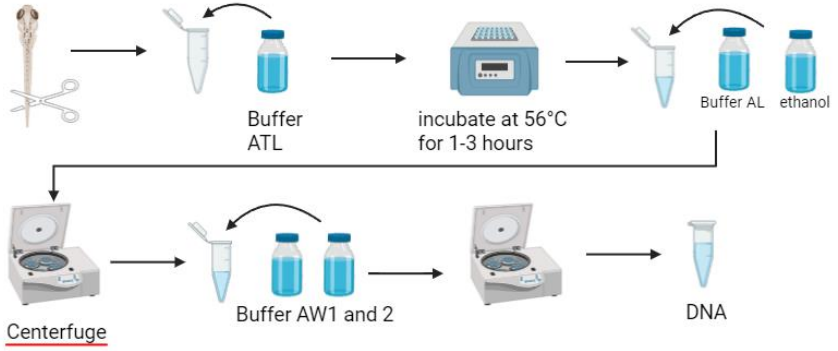
- Doyle JJ, Doyle JL (1990) Isolation of plant DNA from fresh tissue. Focus 12:13–15

- In contrast to manual method, there are several DNA extraction kit and automated DNA extraction machine is available like Qiagen automated DNA extraction machine, and Qiagen DNA extraction Kit.

- In Qiagen DNA extraction all the buffer are provided and ready to use. DNA can be extracted from small amount of 20 mg l dried leaf tissue or from very small piece of leaf collected from even old herbarium specimens. By using Qiagen DNA can be extracted in 3 hours. It do not required centrifugation manually.

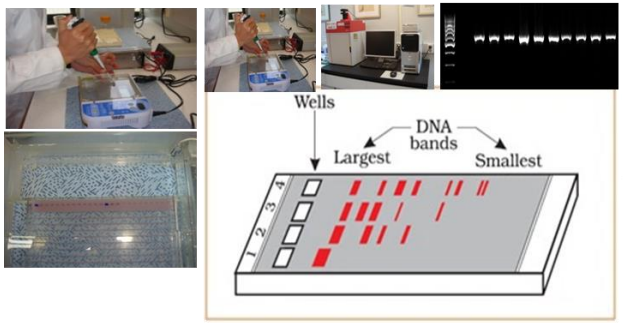
QIAGEN automated DNA extraction method

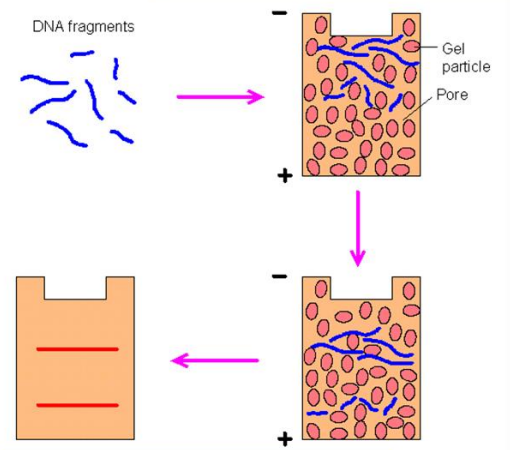


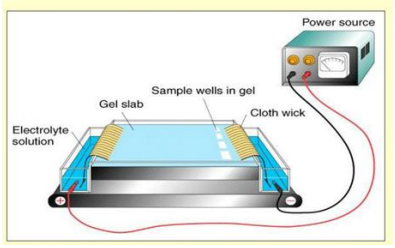


Agarose Gel Electrophoresis

- The main purpose of agarose gel electrophoresis is to determine the presence or absence of genomic DNA or PCR products and quantify the size (length of the DNA molecule).
- Agarose gel electrophoresis is a widely used technique for the preparation and analysis of DNA. Electrophoresis is a method of separating DNA based on the rate of movement while under the influence of an electric field.
- Agarose is a polysaccharide purified from seaweed.
- An agarose gel is created by suspending dry agarose in a buffer solution, boiling until the solution becomes clear, and then pouring it into a casting tray and allowing it to cool. During electrophoresis, the gel is submersed in a chamber containing a buffer solution and a positive and negative electrode.
- The DNA to be analyzed is forced through the pores of the gel by the electrical current.
- Under an electrical field, DNA moves to the positive electrode (red) and away from the negative electrode (black).
- DNA itself is not visible within an agarose gel.
- The DNA visualized by the use of dye that binds to DNA.







Choosing molecular marker, and application of PCR in plant molecular taxonomy / DNA taxonomy

- In DNA sequencing method based practice of plant molecular taxonomy required DNA sequences.

- To obtain DNA sequence of a taxon required extraction of whole genomic DNA first. And then amplification of gene of interest. The amplification using gene interest is achieved by the polymerase chain reaction (PCR). The PCR results into billions of copies of gene of interest which can be observed in a gel under UV light. The amplified DNA later used for the purpose of DNA sequencing. So, for the cloning of the gene of interest using PCR requires primer. The primers are also called as molecular markers. To begin plant molecular taxonomy, selection of molecular marker is very critical and important.

- The most commonly used molecular marker in molecular taxonomy are ITS, rbcL, matK, psb, ndhF, trn gene.
- The molecular marker gene could be coding gene or non coding gene.

- Properties of ideal marker genes
  - A single-copy gene may be more useful than multiple-copy gene
  - The substitution rate should be optimum so as to provide enough informative sites and alignment should be easy.
  - Primers should be available to selectively amplify the marker gene

- The nuclear ribosomal locus coding for the large subunit is represented in tandem arrays in the plant genome.

- ITS is located between the 18 and 26S rRNA genes.

- The 5.8S region on the other hand is only about 160 bp long and highly conserved within major organism groups.

- The ITS region consists of three parts: the ITS1 and ITS2 and the highly conserved 5.8S rDNA exon located in between. The total length of this region varies between 500 and 750 bp in angiosperms while in other seed plants it can be much longer, up to 1,500–3,500 bp.

- Spacer DNA is a region of non-coding DNA between genes.

- In contrast to the coding regions, spacers evolve more quickly, like the internal transcribed spacer (ITS) region, which is extensively used as a marker for phylogenetic reconstruction at different levels.

- The ITS is present in virtually all organisms. The advantages of this region are: (1) easy PCR amplification, with several universal primers available for a various kind of organisms; (2) multicopy structure; (3) moderate size allowing easy sequencing; and (4) it has a high degree of variation even between closely related species.,

- variability is due to frequently occurring nucleotide polymorphisms or to common insertions/deletions in the sequence.

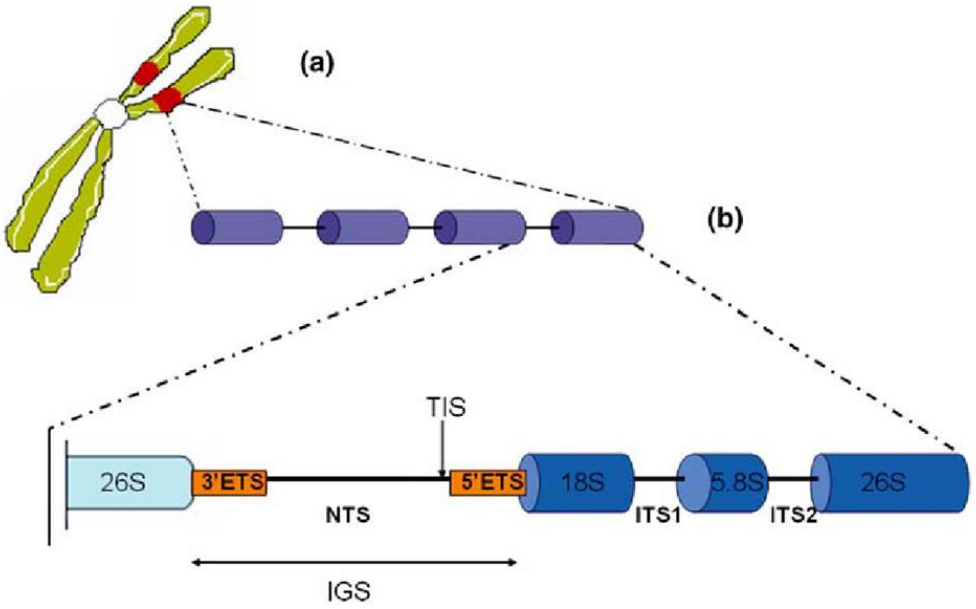
- As DNA of ITS regions is removed and it is not part of the mature RNA molecule, they are considered noncoding regions of the genome

- **A fascinating feature of biological life is the common use of the DNA genetic code and its subsequent processing into functional units of protein through the intermediate RNA molecule.**

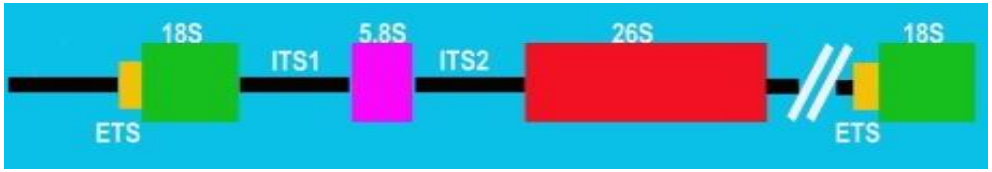
- **The transcription of DNA into RNA and translation of RNA into protein are both highly**
- **regulated and compartmentalized in all living organisms.**

- **The cellular factory responsible for the production of protein is the ribosome. As the essential functions of ribosomes are critical for survival, their physical parameters have been conserved in all forms of life.**

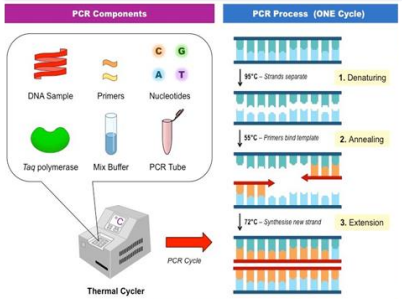
- **Some components within the ribosomal factories have, however, changed sometimes. These similarities, as well as the changes within genetic material can be used as tools for the identification of organisms**

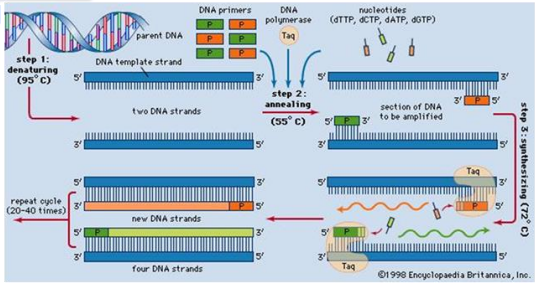


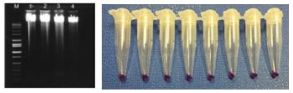
MARKER	SEQUENCE	REFERENCE
ITS1 F	TCCGTAGGTGAACCTGCGG	White et al. (1990)
ITS4 R	TCCTCCGCTTATTGATATGC	White et al. (1990)
rbcLa F	ATGTCACCACAAACAGAGACTAAAGC	Levin (2003)
rbcLa R	GTAAAATCAAGTCCACCRCG	Kress and Erickson (2007)
MatK 390 F	CGATCTATTCATTCAATATTTC	Cuenoud et al. (2002)
MatK 1326 R	TCTAGCACACGAAAGTCGAAGT	Cuenoud et al. (2002)
psbA-trnH F	GTTATGCATGAACGTAATGCTC	Sang et al. (1997)
psbA-trnH R	CGCGCATGGTGGATTCACAATCC	Tate and Simpson (2003)
trn L-F R	GGTTCAAGTCCCTCTATCCC	Taberlet et al. (1991)
trn L-F F	ATTTGAACTGGTGACACGAG	Taberlet et al. (1991)



PCR (Polymerase Chain Reaction)







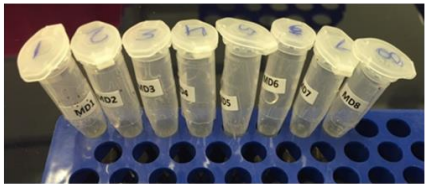
Contents of HF PCR premix Reaction size (20 µl reaction): 1. DNA polymerase 1µl, 2. Each dNTP (dATP, dCTP, dGTP, dTTP) 250 µM, 3. 10X reaction buffer Stabilizer and tracking dye2µl

Template DNA (1µl ~ 100 ng), Primer (1µl each of F and R, 5 ~20 pmole)

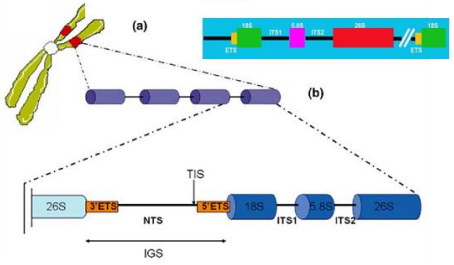
1/10th genomic DNA dilution: Add 10 µl total genomic DNA in 90 µl molecular grade distilled water.

Dilution of primer for stock solution (100 pmoles/ µl): nmols X 10 Distilled water (ddH_2O) = 100 pmoles/ µl (Stock)

MARKER	SEQUENCE	REFERENCE
ITS1 F	TCCGTAGGTGAACCTGCGG	White et al. (1990)
ITS4 R	TCCTCCGCTTATTGATATGC	White et al. (1990)
rbcLa F	ATGTCACCACAAACAGAGACTAAAGC	Levin (2003)
rbcLa R	GTAAAATCAAGTCCACCRCG	Kress and Erickson (2007)
MatK 390 F	CGATCTATTCATTCAATATTTC	Cuenoud et al. (2002)
MatK 1326 R	TCTAGCACACGAAAGTCGAAGT	Cuenoud et al. (2002)
psbA-trnH F	GTTATGCATGAACGTAATGCTC	Sang et al. (1997)
psbA-trnH R	CGCGCATGGTGGATTCACAATCC	Tate and Simpson (2003)
trn L-F R	GGTTCAAGTCCCTCTATCCC	Taberlet et al. (1991)
trn L-F F	ATTTGAACTGGTGACACGAG	Taberlet et al. (1991)

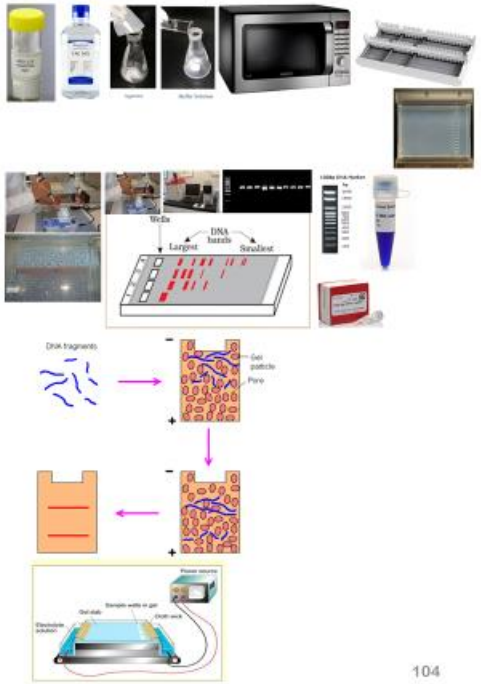


PCR Parameters			
1	Initial Denaturation	94 °C for 5 minutes	
2	Denaturation	94 °C for 1minute	Number of cycles: 40
	Annealing	49 °C for 1minute	
	Extension	72 °C for 1minute	
3	Final extension	72 °C for 5 minutes	
4	Hold	4 °C	∞



Agarose Gel Electrophoresis

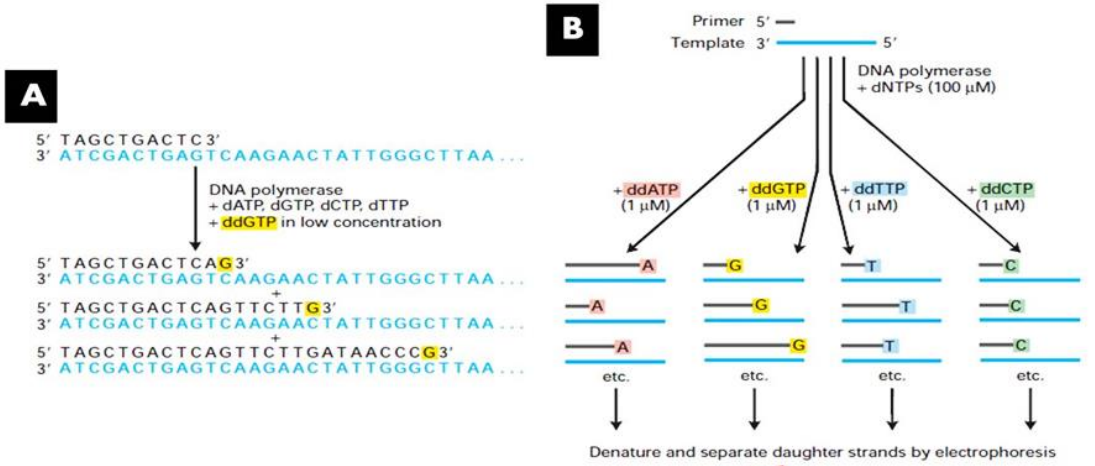
- The main purpose of agarose gel electrophoresis is to determine the presence or absence of genomic DNA or PCR products and quantify the size (length of the DNA molecule).
- Agarose gel electrophoresis is a widely used technique for the preparation and analysis of DNA. Electrophoresis is a method of separating DNA based on the rate of movement while under the influence of an electric field.
- Agarose is a polysaccharide purified from seaweed.
- An agarose gel is created by suspending dry agarose in a buffer solution, boiling until the solution becomes clear, and then pouring it into a casting tray and allowing it to cool. During electrophoresis, the gel is submersed in a chamber containing a buffer solution and a positive and negative electrode.
- The DNA to be analyzed is forced through the pores of the gel by the electrical current.
- Under an electrical field, DNA moves to the positive electrode (red) and away from the negative electrode (black).
- DNA itself is not visible within an agarose gel.
- The DNA visualized by the use of dye that binds to DNA.



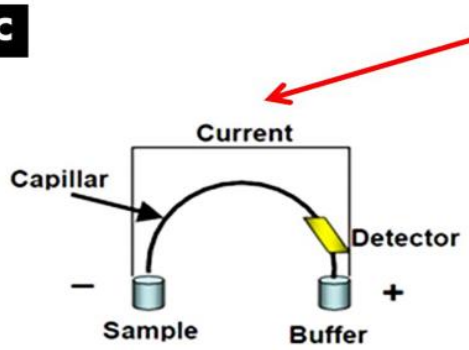
DNA sequencing

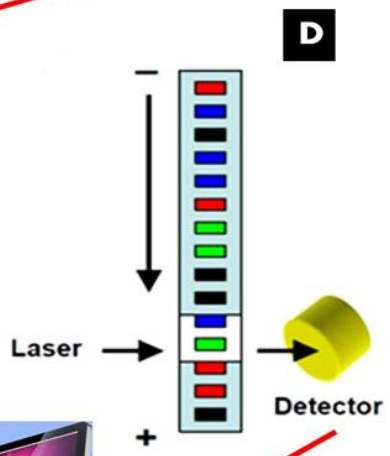
- DNA sequencing is the process of determining the sequence of nucleotides (A, T, C, and G) in a piece of DNA.
- In Sanger sequencing, the target DNA is copied many times, making fragments of different lengths. Fluorescent “chain terminator” nucleotides mark the ends of the fragments and allow the sequence to be determined.
- Next-generation sequencing techniques are new, large-scale approaches that increase the speed and reduce the cost of DNA sequencing.
- Sanger sequencing: The chain termination method
- Regions of DNA up to about 900 base pairs in length are routinely sequenced using a method called Sanger sequencing or the chain termination method.
- Ingredients for Sanger sequencing
- Sanger sequencing involves making many copies of a target DNA region. Its ingredients are similar to those needed for DNA replication in an organism, or for polymerase chain reaction (PCR), which copies DNA *in vitro*. They include:
- A DNA polymerase enzyme
- A primer, which is a short piece of single-stranded DNA that binds to the template DNA and acts as a "starter" for the polymerase
- The four DNA nucleotides (dATP, dTTP, dCTP, dGTP)
- The template DNA to be sequenced
- However, a Sanger sequencing reaction also contains a unique ingredient:
- Dideoxy, or chain-terminating, versions of all four nucleotides (ddATP, ddTTP, ddCTP, ddGTP), each labeled with a different color of dye
- Dideoxy nucleotides are similar to regular, or deoxy, nucleotides, but with one key difference: they lack a hydroxyl group on the 3’ carbon of the sugar ring. In a regular nucleotide, the 3’ hydroxyl group acts as a “hook," allowing a new nucleotide to be added to an existing chain.
- Once a dideoxy nucleotide has been added to the chain, there is no hydroxyl available and no further nucleotides can be added. The chain ends with the dideoxy nucleotide, which is marked with a particular color of dye depending on the base (A, T, C or G) that it carries.
- The DNA sample to be sequenced is combined in a tube with primer, DNA polymerase, and DNA nucleotides (dATP, dTTP, dGTP, and dCTP). The four dye-labeled, chain-terminating dideoxy nucleotides are added as well, but in much smaller amounts than the ordinary nucleotides.
- The mixture is first heated to denature the template DNA (separate the strands), then cooled so that the primer can bind to the single-stranded template. Once the primer has bound, the temperature is raised again, allowing DNA polymerase to synthesize new DNA starting from the primer. DNA polymerase will continue adding nucleotides to the chain until it happens to add a dideoxy nucleotide instead of a normal one. At that point, no further nucleotides can be added, so the strand will end with the dideoxy nucleotide.
- This process is repeated in a number of cycles. By the time the cycling is complete, it’s virtually guaranteed that a dideoxy nucleotide will have been incorporated at every single position of the target DNA in at least one reaction. That is, the tube will contain fragments of different lengths, ending at each of the nucleotide positions in the original DNA (see figure below). The ends of the fragments will be labeled with dyes that indicate their final nucleotide.
- After the reaction is done, the fragments are run through a long, thin tube containing a gel matrix in a process called capillary gel electrophoresis. Short fragments move quickly through the pores of the gel, while long fragments move more slowly. As each fragment crosses the “finish line” at the end of the tube, it’s illuminated by a laser, allowing the attached dye to be detected.

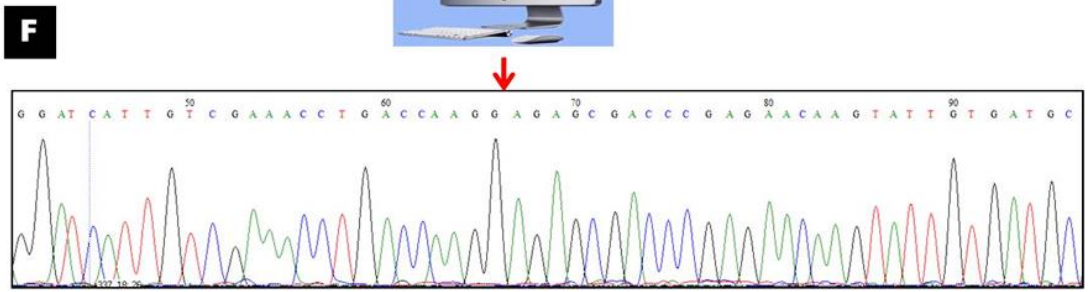
- The smallest fragment (ending just one nucleotide after the primer) crosses the finish line first, followed by the next-smallest fragment (ending two nucleotides after the primer), and so forth. Thus, from the colors of dyes registered one after another on the detector, the sequence of the original piece of DNA can be built up one nucleotide at a time. The data recorded by the detector consist of a series of peaks in fluorescence intensity, as shown in the chromatogram above. The DNA sequence is read from the peaks in the chromatogram.



DNA sequence dataset preparation







gene, partial sequence
GTCGAAACCTGCATAGCAGAACGACCCGCGAACACGTTACACTACCAGGTGAGGGACGAGGGGTGCGCAA
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CGCGGAATGCGCCAAGGAAATCAAACTGAACTGCACGCGTCCCCCCCGTTTGCGGGCGGCGGAAGCGTCT
TTCTAAAACACAAACGACTCTCGGCAACGGATATCTCGGCTCTCGCATCGATGAAGAACGTAGCGAAATG
CGATACTTGGTGTGAATTGCAGAATCCCGTGAACCATCGAGTCTTTGAACGCAAGTTGCGCCCGAAGCCA
TTAGGCCGAGGGCACGTCTGCCTGGGCGTCACACATCGCGTCGCCCCCCAACCCATCACTCCCTTGCGGG
AGTTGAGGCGGAGGGGCGGATAATGGCCTCCCGTGTCTCACCGCGCGGTTGGCCCAAATGCGAGTCCTTG
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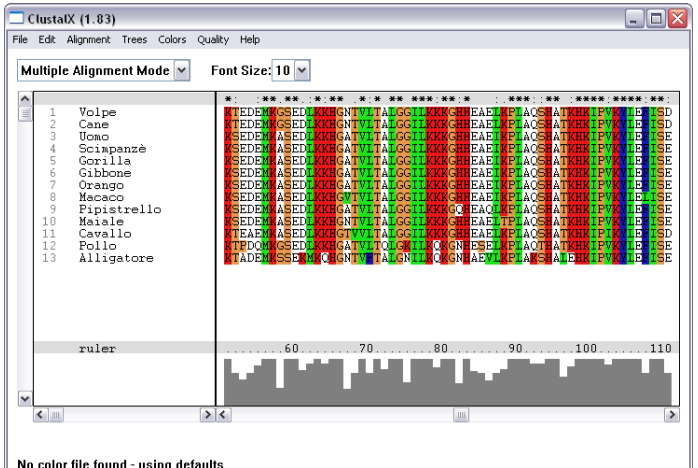

BIOINFORAMTICS

DNA sequence dataset preparation

GTCGAAACCTGCATAGCAGAACGACCCGCGAACACGTTACACTACCAGGTGAGGGACGAGGGGTGCGCAA
GCTCCCCAAGTTTCAAACCCATGGTCGGGGACCACCCTTGGGTGGCCTCGTCCGAACAACGACCCCCCGG
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CGATACTTGGTGTGAATTGCAGAATCCCGTGAACCATCGAGTCTTTGAACGCAAGTTGCGCCCGAAGCCA
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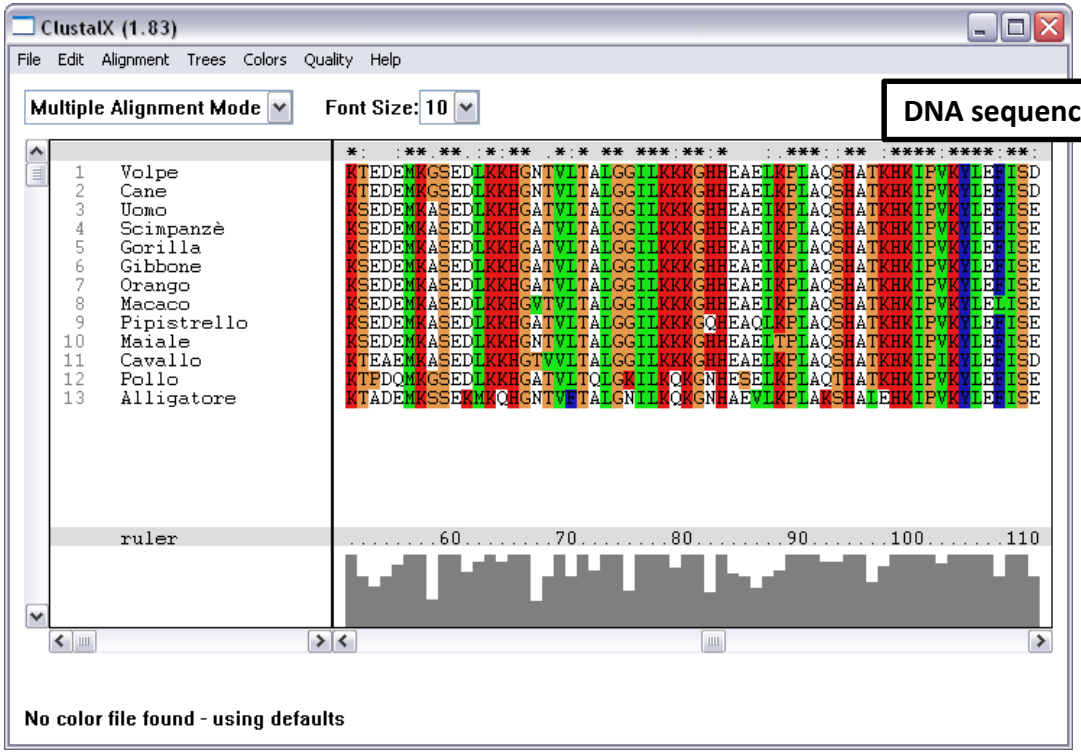
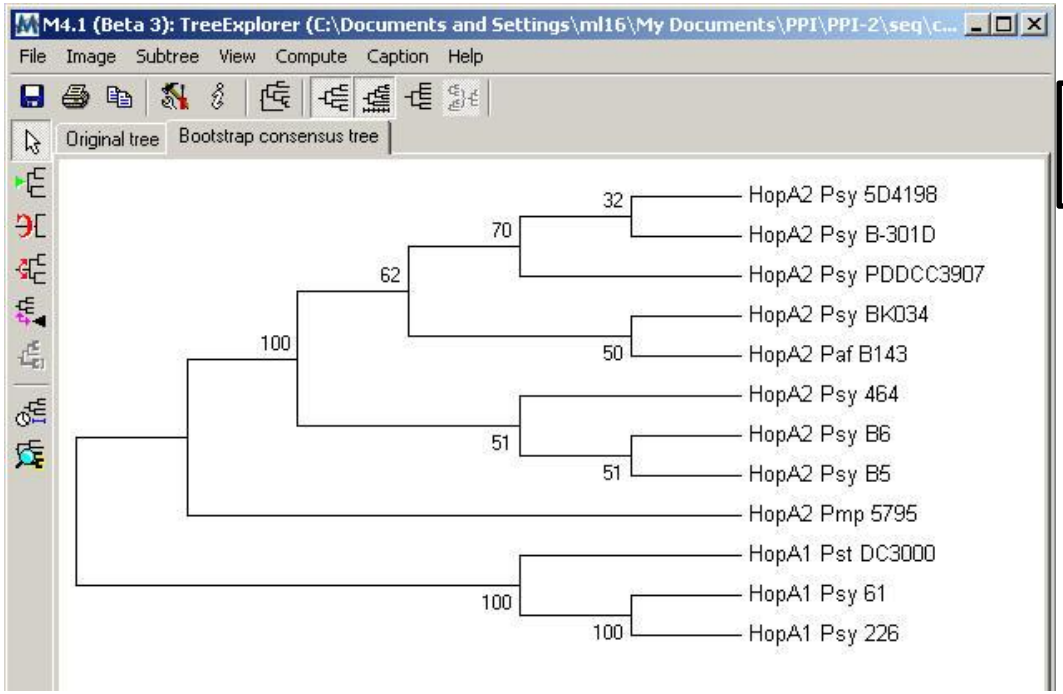


DNA sequence alignment using ClustalX



Molecular Phylogenetic analyses using MEGA

NCBI GenBank

Phylogenetic Implication of Molecular Genotyping of *Euryops jaberiana* Abedin & Chaudhary (Asteraceae)

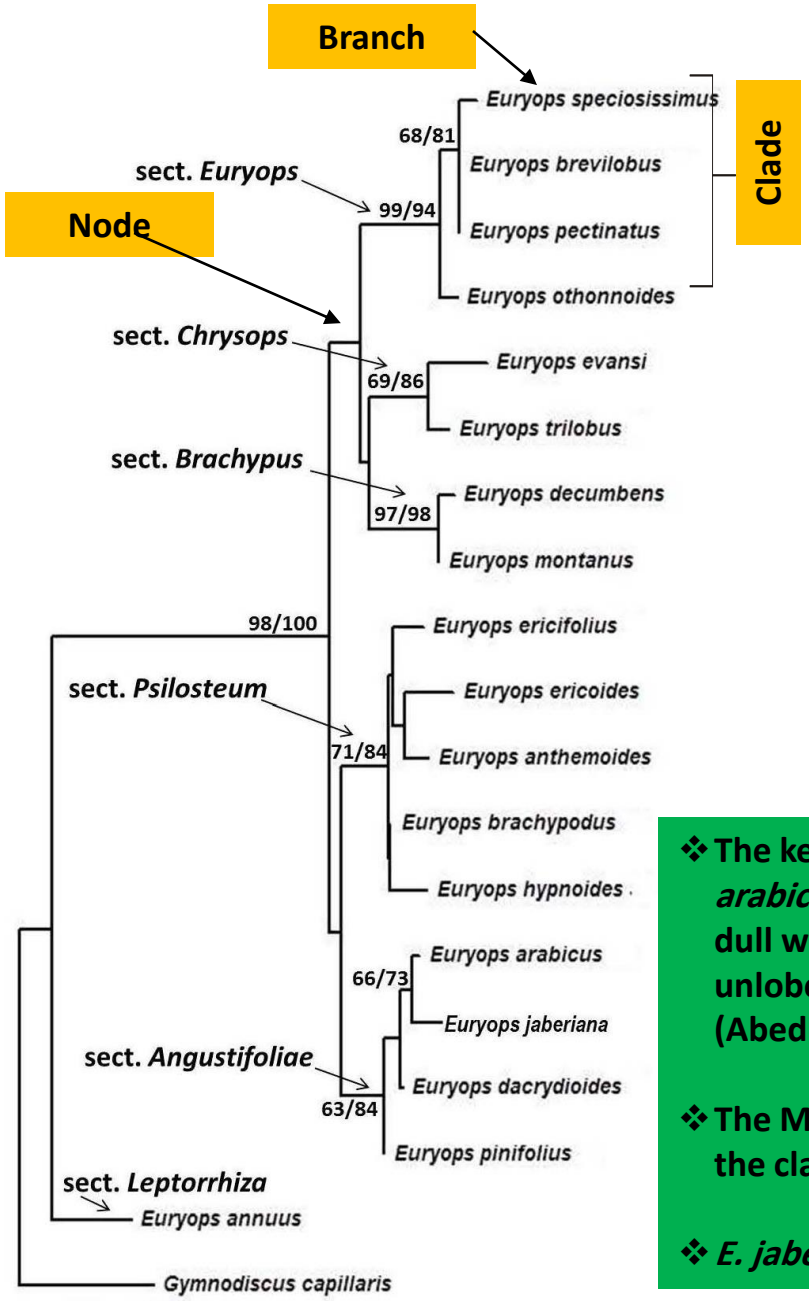
E. arabicus

- In Saudi Arabia, the genus *Euryops* (family Asteraceae) is represented by two species, *viz*. *E. arabicus* Steud. *ex* Jaub. & Spach, and *E. jaberiana* Abedin & Chaudhary.
- *E. arabicus* is is endemic to Arabian Peninsula, while *E. jaberiana* is endemic to northern Saudi Arabia.
- Morphologically *E. jaberiana* very closely resembles with *E. arabicus* / very narrow differences in m morphological characters (Abedin and Chaudhary, 2000).

E. jaberiana

- The taxonomic status of *Euryops jaberiana* Abedin & Chaudhary (tribe Senecioneae, was evaluated (Ali et al., 2016) based on molecular phylogenetic analyses of internal transcribed spacer sequence (ITS) of nuclear ribosomal DNA (nrDNA) in order to ascertain its position within the genus.

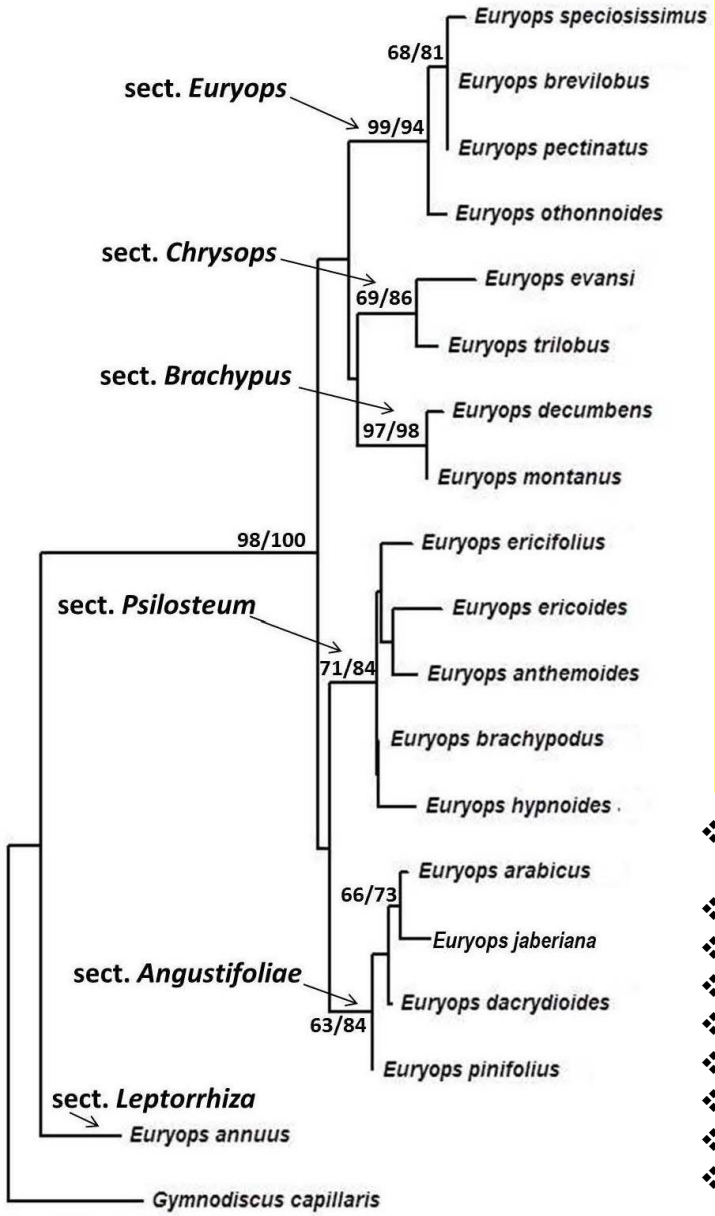
Phylogenetic Implication of Molecular Genotyping of *Euryops jaberiana* Abedin & Chaudhary (Asteraceae) Contd……

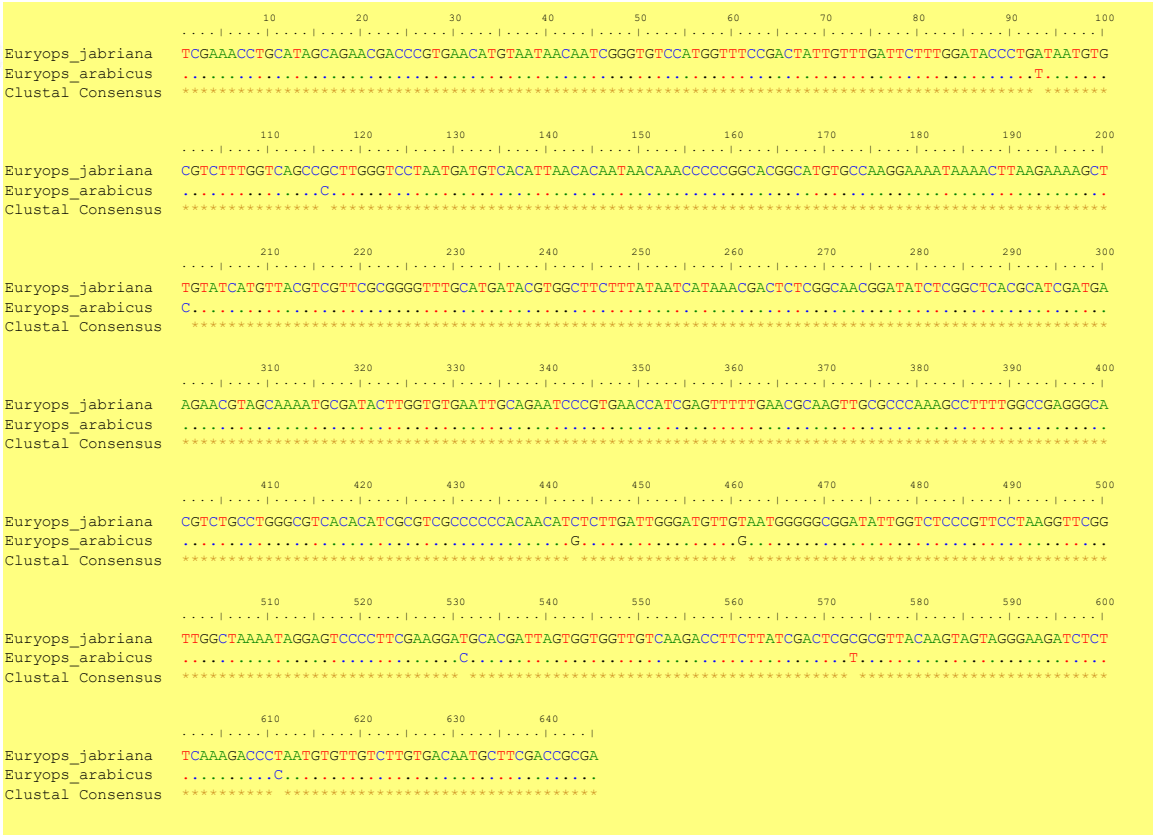


- In molecular taxonomic studies, the most convenient way of presenting taxonomic relationships among a group of organisms is the phylogenetic tree.
- Node: a branch point in a tree
- Branch: defines the relationship between the taxon
- Topology: the branching patterns of the tree
- Branch length: represents the number of changes that have occurred in the branch
- Clade: a group of two or more taxa closed together based on DNA sequences data analsysis
- Maximum parsimony is an optimality criterion under which the phylogenetic tree that minimizes the total number of character-state changes is to be preferred.
- Bootstrap: Bootstrapping is a procedure where DNA sequence data run for the phylogenetic analysis, and the reported value is the percentage of bootstrap replicates, for examples 100 means that the node is well-supported, it showed in all tress.

- The key morphological features which differentiate *E. jaberiana* from *E. arabicus* are: leaves 3-lobed at the tips, pappus hairs transparent or rarely dull white, and achenes glabrescent, while in *E. arabicus*, the leaves are unlobed, pappus hairs are dull white and achene densely lanate hairy (Abedin and Chaudhary, 2000).
- The Maximum Parsimony analyses reveals that *E. jaberiana* nested within the clade of the section *Angustifoliae.*
- *E. jaberiana* shows proximity with *E. arabicus* (66% bootstrap support.

Phylogenetic Implication of Molecular Genotyping of *Euryops jaberiana* Abedin & Chaudhary (Asteraceae) Contd……



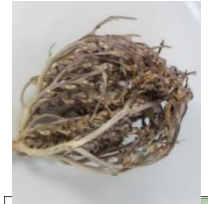


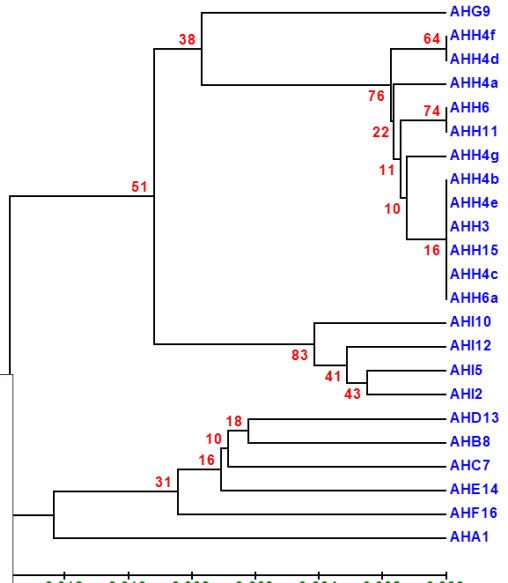
- A total of eight specific nucleotide differences were detected between *E. jaberiana* and *E. Arabicus i.e.* at the alignment position:
- 93 (A →T)
- 116 (G → C)
- 201 (T → C)
- 443 (C → G)
- 461 (T → G)
- 531 (T → C)
- 573 (C → T)
- 611 (T → C)

Thus on the basis of phylogenetic relationships of *E. jaberiana* within the genus and nucleotide differences, Ali et al. (2016) recognized *E. jaberiana* as a distinct species and different from *E. arabicus.*

Assessment of genetic diversity of *Anastatica hierochuntica* (kaff maryam) from Saudi Arabia based on Internal Transcribed Spacer sequences of nuclear ribosomal DNA gene

- *Anastatica hierochuntica* (Rose of Jericho) is among the common medicinal plants widely used in Hijaz, Najd, and Al Rub'Al Khali. The plant is prescribed in folk medicine for difficult labor, uterine hemorrhage and to facilitate the expulsion of dead fetuses. A total number of 23 population of Anastatica hierochuntica from Saudi Arabia were sequenced.
- The resulted UPGMA tree reveals that the populations of different geographic location sampled in the present study grouped into three major group.
- Group I consists of population from Hanifa valley, Summan, Rumah, Hair area, Riyadh, Khurma, and Khoris;
- Group II consists of population from Al-Baha, Jeedah, Ranyah and Zazan; and
- Group III consists of population from Hail, Darb Al Hafer, Qasim Buraydah, Afif, and Marat), and the groups were according to their geographic locations;
- however it was interesting to note that population collected from the geographic location of Haradh and Buseita (Tabarjal) and were nested within the group I and II respectively, which might be due to evolution under reproductive isolation and different environmental conditions, and this may be most probably due to long distance distribution, and possibility of genetic exchange among the populations of *Anastatica hierochuntica* distributed in Saudi Arabia.



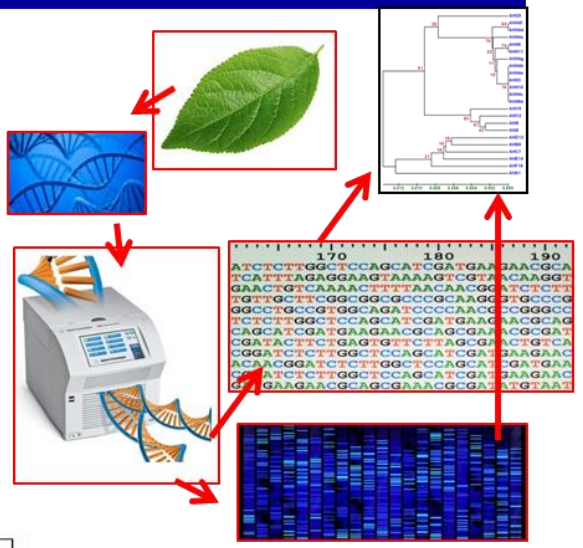


Genetic diversity is the total number of genetic characteristics in the genetic makeup of a species.

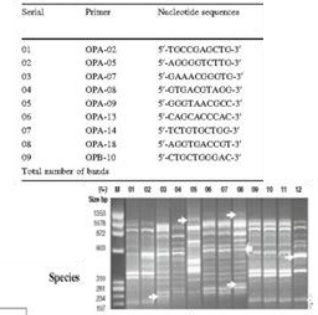
- Molecular analyses comprise a large variety of DNA molecular markers, which can be employed for analysis of variation.

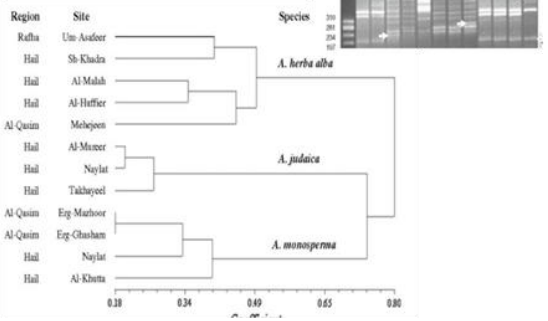
AFLP	Amplified Fragment Length Polymorphism
AP-PCR	Arbitrarily primed PCR
ARMS	Amplification Refractory Mutation System
ASAP	Arbitrary Signatures from Amplification
ASH	Allele-Specific Hybridization
ASLP	Amplified Sequence Length Polymorphism
ASO	Allele Specific Oligonucleotide
CAPS	Cleaved Amplification Polymorphic Sequence
CAS	Coupled Amplification and Sequencing
DAF	DNA Amplification Fingerprint
DGGE	Denaturing Gradient Gel Electrophoresis
GBA	Genetic Bit Analysis
IRAO	Inter-Retrotrasposon Amplified Polymorphism
ISSR	Inter-Simple Sequence Repeats
ISTR	Inverse Sequence-Tagged Repeats
MP-PCR	Microsatellite-Primed PCR
OLA	Oligonucleotide Ligation Assay
RAHM	Randomly Amplified Hybridizing Microsatellites
RAMPs	Randomly Amplified Microsatellite Polymorphisms
RAPD	Randomly Amplified Polymorphic DNA
RBIP	Retrotrasposon-Based Insertion Polymorphism
REF	Restriction Endonuclease Fingerprinting
REMAP	Retrotrasposon-Microsatellite Amplified Polymorphism
RFLP	Restriction Fragment Length Polymorphism
SAMPL	Selective Amplification of Polymorphic Loci
SCAR	Sequence Characterised Amplification Regions
SNP	Single Nucleotide Polymorphism
SPAR	Single Primer Amplification Reaction
SPLAT	Single Polymorphic Amplification Test
S-SAP	Sequence-Specific Amplification Polymorphisms
SSCP	Single Strand Conformation Polymorphism
SSLP	Single Sequence Length Polymorphism
SSR	Simple Sequence Repeats
STMS	Sequence-Tagged Microsatellite Site
STS	Sequence-Tagged-Site
TGGE	Thermal Gradient Gel Electrophoresis
VNTR	Variable Number Tandem Repeats
RAMS	Randomly Amplified Microsatellites

GENETIC DIVERSITY



- Genetic diversity of *Artemisia* in central and north Saudi Arabia based on RAPD





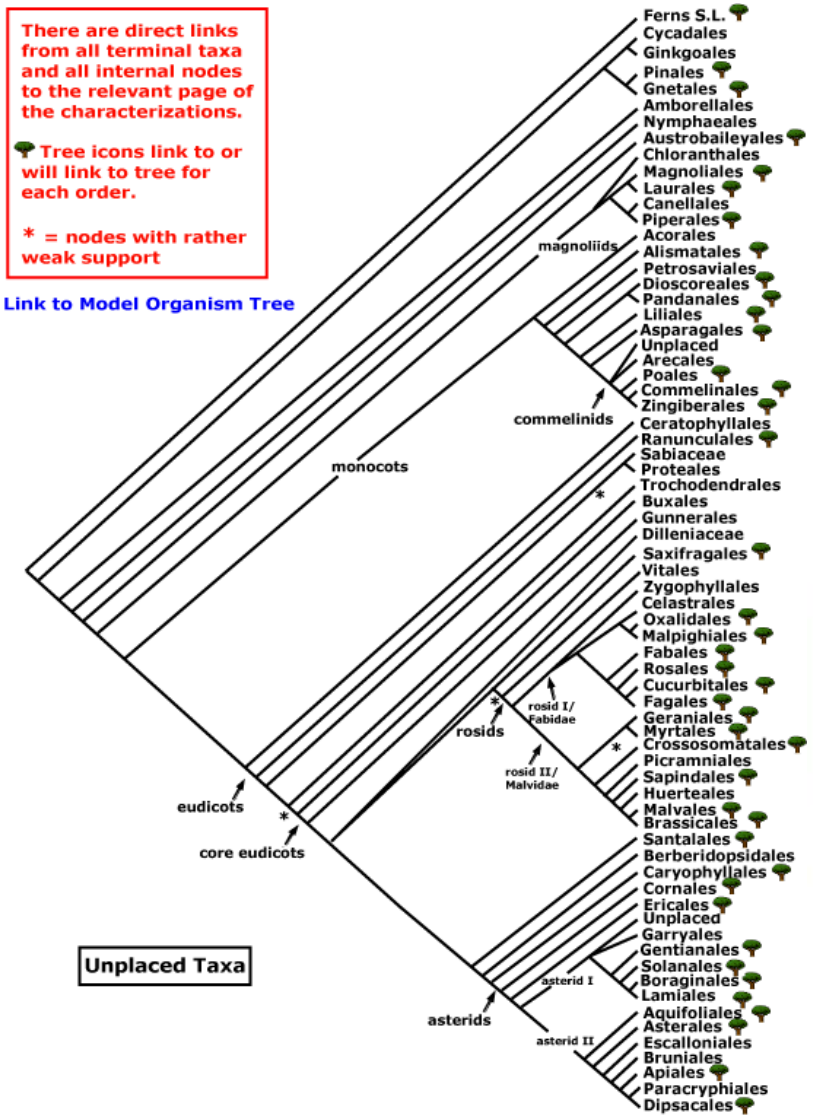
Badr, A., El-Shazly, H.H., Helail, N.S. et al. Genetic diversity of *Artemisia* populations in central and north Saudi Arabia based on morphological variation and RAPD polymorphism. Plant Syst Evol (2012) 298: 871)

There are direct links from all terminal taxa and all internal nodes to the relevant page of the characterizations.

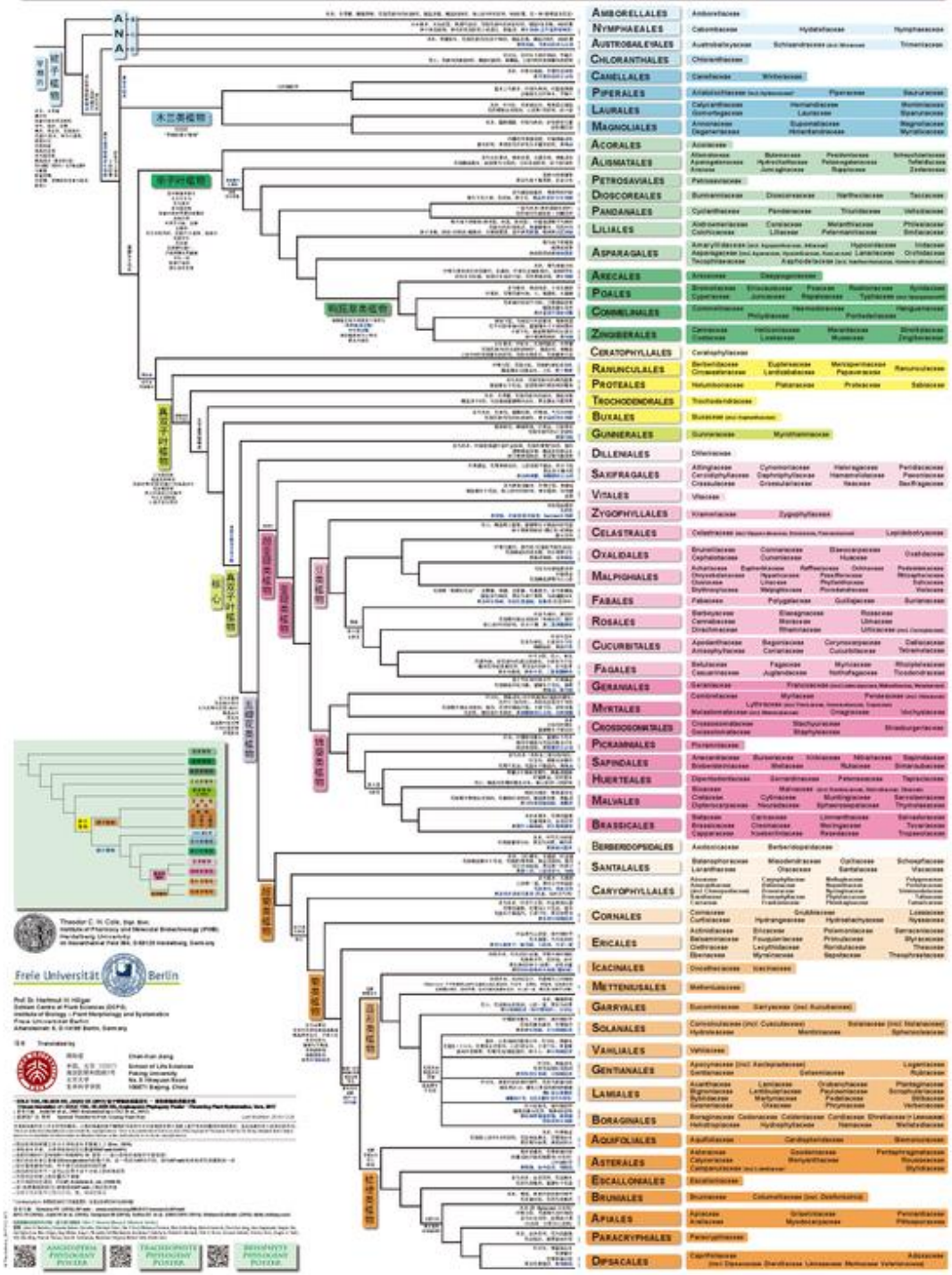
Tree icons link to or will link to tree for each order.

* = nodes with rather weak support

Link to Model Organism Tree



Unplaced Taxa



DNA barcoding

- DNA barcoding is a system for fast and accurate species identification that makes ecological system more accessible by using short DNA sequence instead of whole genome and is used for eukaryotes. The short DNA sequence is generated from standard region of genome known as marker. This marker is different for various species like CO1 cytochrome c oxidase 1 for animals, matK for plants and Internal Transcribed Spacer (ITS) for fungus. DNA barcoding has many applications in various fields like preserving natural resources, protecting endangered species, controlling agriculture pests, identifying disease vectors, monitoring water quality, authentication of natural health products and identification of medicinal plants.

❖**DNA barcoding can speed up identification of species.**

❖**DNA barcoding can provide an avenue to encourage new participants into taxonomy.**

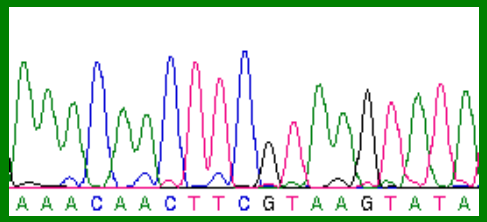
❖**Raw drug authentication / Medicinal plant identification or authentication**

- In DNA barcoding, complete data set can be obtained from a single specimen irrespective to morphological or life stage characters.
- The core idea of DNA barcoding is based on the fact that the highly conserved stretches of DNA, either coding or
- non coding regions, vary at very minor degree during the evolution within the species.
- Sequences suggested to be useful in DNA barcoding include cytoplasmic mitochondrial DNA (e.g. cox1) and chloroplast DNA (e.g. rbcL, trnL-F, matK, ndhF, and atpB rbcL), and nuclear DNA (ITS)
- The term “DNA barcode” for global species identification was first coined by Hebert in 2003.
- The ideal DNA barcode region is reliably amplified and sequenced across large assemblages of taxa and provides a high level of species discrimination

Plant DNA Barcoding

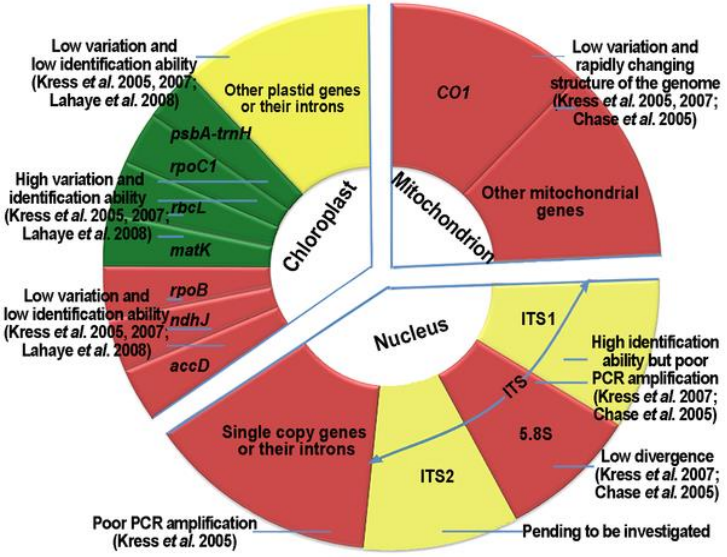
- **Molecular markers such as rbcL, matK, and ITS are widely used in plant systematics.**
- **Plant DNA barcoding identifies species using short standardized DNA regions.**
- **DNA barcodes function as unique genetic identifiers similar to commercial product barcodes.**
- **DNA barcoding helps detect cryptic, rare, and morphologically similar plant species.**
- **Molecular systematics supports revision and improvement of traditional classification systems.**
- **Barcoding plays an important role in biodiversity conservation, ecological monitoring, and medicinal plant authentication.**
- **Integration of molecular systematics with classical taxonomy forms the basis of modern integrative plant taxonomy.**

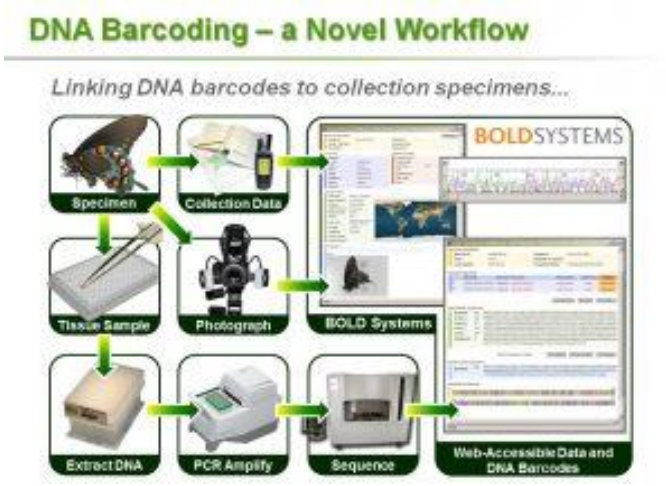
NCBI

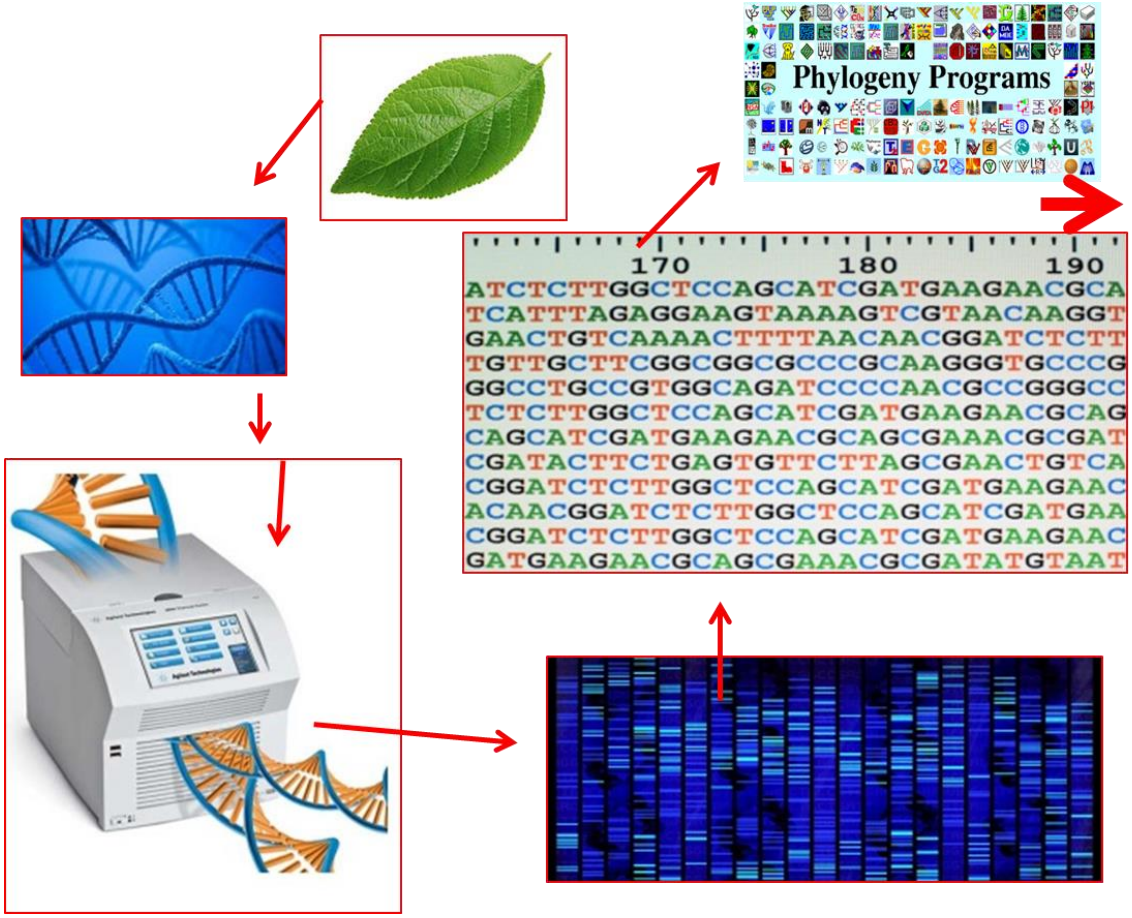


Applications of Plant DNA Barcoding

- DNA barcoding enables rapid and accurate identification of plant species, including unknown or fragmentary samples.
- It is widely used for authentication of medicinal plants and detection of adulteration in herbal products.
- DNA barcoding helps in biodiversity assessment and monitoring of endangered plant species.
- It assists in identifying invasive species and supports ecological and environmental management programs.
- DNA barcoding is applied in forensic botany, agriculture, and conservation genetics for species verification.







- Chen S, Yao H, Han J, Liu C, Song J, et al. (2010) Validation of the ITS2 Region as a Novel DNA Barcode for Identifying Medicinal Plant Species. PLOS ONE 5(1): e8613.
- Yao H, Song J, Liu C, Luo K, Han J, Li Y, et al. (2010) Use of ITS2 Region as the Universal DNA Barcode for Plants and Animals. PLoS ONE 5(10): e13102.
- Zuo Y, Chen Z, Kondo K, Funamoto T, Wen J, Zhou S. (2011) DNA barcoding of Panax species. Planta Med. 2011 Jan;77(2):182-7.

FINAL EXAM (FROM ALL SLIDES)

THANKS

ALL THE VERY BEST