VIDYASAGAR UNIVERSITY

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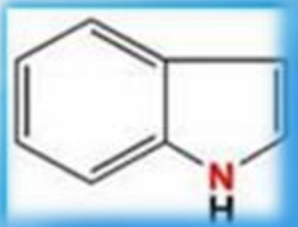
4. Concept of taxonomic characters:

Chemotaxonomy or Chemical Taxonomy: Its applications in Taxonomy



Lecture for 4th Semester Special Paper

(BOT 402A) :

Angiosperms Taxonomy and Molecular Systematics

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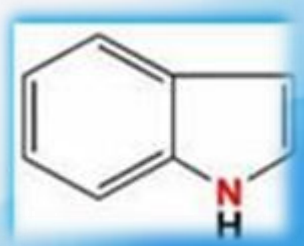
Vidyasagar University

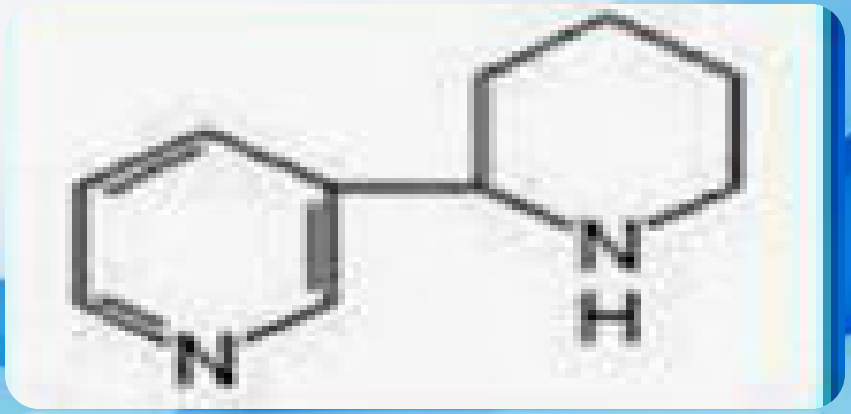
28th March, 2020

Chemotaxonomy

OR



Chemical Taxonomy



What is Chemotaxonomy?

- Taxnomy is the theory and practice of classification.
- This system of classification relies on the chemical similarity of a taxon, i.e.it is based on the existence of relationship between constituents in various plants.
- It is the latest system of classification that gives more scope for understanding the relationship between chemical constituents, their biosynthesis and their possible action.

"Study of the chemical variation in a diversity of organisms, and their relationships."

- The classification of plants on the basis of **chemical contents** is called **chemotaxonomy or chemical taxonomy**

Purpose of chemotaxonomy

The evidence is used in classification of plants into 2 main purposes.

1. To improve the existing system of plants differentiation.
2. To develop the present day knowledge of natural relationship of plants.

- Three broad categories of compounds are used in chemotaxonomy:
  primary metabolites
  secondary metabolites
  semantices

Primary metabolites, are parts of vital metabolic pathways, most of them are of universal occurrence and is utilized by the plant itself for growth and development.
Eg: Starch, chlorophyll, aleurone grain, citric acid, aconitic acid, etc.

Secondary metabolites present in plant, is used for protection and defence.
Eg: Glycoside, alkaloid, volatile oil, flavonoid and plant phenol.

- The phenolics, alkaloids, terpenoids and non-protein amino acids, are the four important and widely exploited groups of compounds utilized for chemotaxonomic classification.

- These groups of compounds exhibit a wide variation in chemical diversity, distribution and Function.

- The chemical constituents of plants **differ from species to species.**
- Restricted to **certain taxa**
- They are the **valuable characters** for plant classification

The following chemicals are present in plants for plant classification

a. Non - protein amino acids

b. Phenolics

c. Betalins

d. Alkoloids

e. Terpenoids and steroids

f. Crystals

g. Immunological reactions

a. Non-Protein Amino Acids

- There are **300 non – protein amino acids** in plants.
- Some are **restricted to certain groups** alone
- They are **used to classify and distinguish** the taxa from others.

Ex.

- Lathyrine – in Genus ***Lathyrus***
- Azetidine – 2 – carboxylic acid – in Genus **Liliaceae, Amaryllidaceae and Agavaceae**
- Non protein amino acids – in **Fabaceae**

b. Phenolics

- **Derivatives** of phenolic compounds
- Plants are classified on the basis of **specific phenolic compounds**

Examples

- **Leucoanthocynin** – abundant in woody plants
- **Flavonols** and **methoxycinnamic acid** – in herbaceous plants
- **Ellagic acid** – in tribe ***Kerrieae*** of ***Rosaceae***
- **Isoflavone iridin** in section ***Pogonivis*** of ***Iris***
- Absence of **Iridin** – ***Iris flauissima*** was removed from this section

c. Betalins

- Betalins are derivatives of **phenols** serving as pigments.
- They are present in **ten families**
- The position of ***Cactaceae*** was disputed for many years.
- On the basis of the presence of **betalin,** the position in ***Centrospermae*** is confirmed

d. Alkaloids

- Alkaloids are compounds, containing heterocyclic nitrogen, basic character and complex molecular structure. Such compounds are restricted to plant kingdom.

- **True alkaloids** have a nitrogen-containing nucleus derived from biogenetic amine.

- **Proto alkaloids** – derived from amino acids, but lack a heterocyclic ring.
- Natural protoalkaloids are usually simple amines e.g. ephedrine , mescaline.
- Some times they may be precursor of true alkaloids.

- **Pseudo alkaloids** biologically unrelated to amino acids.
- Most of them derived from- terpenes, sterols , nicotinic acid or purines.

- Alkaloids are **nitrogen containing compounds** with a **heterocyclic ring.**
- There are about **5000 alkaloids** in angiosperms.
- They are used as a **source** for plant classification

Occurrence and Distribution

- Higher plants particularly in the dicotyledons ,abundance in the Angiosperms families Apocynaceae, Papaveraceae, Ranculaceae, Rubiaceae, Rutaceae, Solanaceae, but less frequent in lower plants and fungi.

  In plants, alkaloids, due to their basic nature, generally exist as a salt of organic acid like, oxalic acid, citric acid, malic acid,, tartaric acid, tannic acid etc.

- Some alkaloids like narceine and nicotine are occurring free in nature.
- A few alkaloids occur as glycoside of sugars like glucose, rhamnose, and galactose. E.g. alkaloids of solanum and veratrum groups as amides (Piperine), as esters (Atropine, Cocaine) of organic acid.

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Criteria for using Alkaloids in Taxonomy

A. Definition of alkaloids

B. Definition of alkaloid plants

C. The type of alkaloids that can be distinguished

D. Homologous and analogous characters

A. Definition

- "Alkaloids are more or less toxic substances which act primarily on CNS. They have a basic character, contain heterocyclic nitrogen, and are synthesized in plants from amino acid and or their immediate derivatives . They are of limited distribution in plant kingdom."

  But such definition excludes a number of nitrogen containing plant constituents, which are normally thought as alkaloids.

E.g. Biological amines like ***Ephedrine,Hardenine,*** **Betain ,Cholin, Muscarine**

- All such alkaloids are separately referred as ***protoalkaloids or biological amines*** *or* **amino alkaloids.**

- But when protoalkaloids and true alkaloids occur in same genus or family, both are usually classified as alkaloids.
- Ex. – Hardenine, Mescaline in cactaceae family.

Another group of nitrogen compounds that fall outside our definition of alkaloids are ***mono, sesqui,di-terpenes, steroids, nicotinic acid, purines.***

- These can also be classified according to precursor on which they are based and collectively called as pseudo alkaloids or alkaloid imperfecta.

Ex . **Conessine, Caffeine.**

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B. Definition of Alkaloids in Plants

There is no sharp dividing line between alkaloids containing plants and alkaloids free plants.

From practical point of view, we can define lower limit as ***0.01% of dry weight***. Another characteristic of ***true alkaloid*** is that it always contains more than one alkaloid.

E.g. **Ricinine** is only alkaloid in ***Ricinus communis*** and ***Genitianine*** only alkaloid in ***Gentianaceae,*** that's why these two bases have been kept outside the class of true alkaloids.

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C. The Types of Alkaloids that can be distinguished:

- It has been found that amino acids ***phenylalanine, ornithine, tryptophan, lysine, histidine, Anthranilic acid*** are primary precursors of alkaloids in plants.

Each of these amino acid can be regarded as starting point for synthesis of one or more types of alkaloids.

- Therefore we may put the alkaloids into families corresponding to six amino acids mentioned above.

- There are also numbers of alkaloids which can be regarded as hybrids.

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- There are about **5000 alkaloids** in angiosperms.
- They are used as a **source** for plant classification

Examples

- Isoquinoline – *in Papaveraceae*
- Lupin – *Fabaceae*
- Tropane – *Solanaceae*
- Genera *Genista, Ammodendron and Adenocarpus* of *Fabaceae* once widely separated then grouped together in the tribe *Genisteae* due to the presence of ammodendrine – histrine
- Morphine – *Papaver somnifer*
- Coniine – *Apiaceae*

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- ***Phenylalanine family*** **–**Hardenine, Ephedrine, Anahaline group, Papaverine group, Morphine group.

- **Tryptophan family** - Ajamaline, Yohimbine, vinblastine etc.

- **Ornithine family** - Hygrine, Atropine, Ecgonine etc .

- **Lysine family** - Coniine, Anabasine etc.

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D. Homologous and Analogous Chemical Characters

Two similar substances or even same substance may be isolated from two different plants and are taxonomically important if the compounds are derived from exactly same metabolically process.

But same compounds or similar compounds are produced by different metabolic pathways in different plants.

E.g.

Anabasine *in* ***Nicotiana*** *genus* (Solanaceae family) is formed from one molecule of ***lysine*** on the other hand in **Leguminosae family** two molecules of lysine are involved. Thus it seems that Anabasine of Solanaceae is not equivalent (homologous) to that in Leguminosae.

- Similarly quinine has been isolated from several unrelated genera.

The **quinoline alkaloids** of **cinchona bark** are obviously quite different structurally from **yohimbine alkaloids** from **yohimbe bark** but they are closely related biosynthetically and this points to a close relation between the plants in which they occur.

- Generally **ornithine** and **lysine** families of alkaloids are closely related. Therefore, they should be treated as one unit from chemotaxonomic point of view.

Some of the examples of Alkaloid distribution and Significance in Taxonomy

- Alkaloids are not universally accumulated by plants; some families are rich in alkaloidal species, such as
  Berberidaceae, Leguminosae, Solanaceae, Rutaceae, Rubiaceae, Compositae, Liliaceae and Orchidaceae

- **Papaveraceae** is rich in **isoquinoline alkaloids**
- **Legumes** are rich in **lupin alkaloids**
- **Solanaceae** is rich in **tropane alkaloids**
- **Rubiaceae** is rich in **quinoline alkaloids**

Some alkaloids are restricted to only very certain plants
e.g.

- **Morphine** is restricted to ***P. somniferum***
- **Coniine** is restricted to **umbeliferous sp.**
- **Strychnine** is restricted to **strychnos** species

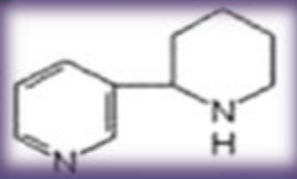
- Accumulation of **Isoquinoline** alkaloids in families ***fumariaceae and Papaveraceae,*** indicate that there is close relationship between two families. Both families accumulate **Isoquinoline** alkaloids, and always contain **Protopine.**

There are instances where alkaloid biosynthesis can be helpful to chemotaxomist for arranging the species within genus according to their alkaloid content.

In the case of genus ***argemone,*** which is difficult to classify purely on the basis of morphological grounds, the species can be arranged into three groups on the basis of their alkaloid content.

- Group I contains alkaloid of ***Protopine and Berberine*** but not ***pavine type.***
- Group II contains all three types.
- Group III contains only pavine types.

Evidences from Basic Moiety Pyridine and Piperdine



The parent base pyridine occurs in some plants as

- **Lobeline** obtained from ***Lobelia inflata*** family **Lobeliaceae**.
- **Nicotine** obtained from ***Nicotiana tobaccum*** *family* **solanaceae .**
- **Anabasine** obtained from ***Nicotiana gluaca*** family **chenopodiaceae.**
- **Anabasine** occurs in tobacco, where it is formed from lysine and nicotinic acid. In the legume and chenopod species where **Anabasine** also occurs, it can be synthesized from two molecules of lysine.

Isoquinoline Alkaloids

Isoquinoline Alkaloids

- Isoquinoline alkaloids are obtained from following plants.
  - **E.g. Papaverine** is obtained from ***P. somniferum*** family **Papaveraceae**
  - **Berberine** is obtained from ***Hydrastis canadensis*** family **Berberidaceae**

- The amino acid phenylalanine and tyrosine act as precursor for isoquinoline nucleus.
- ***Hydrastine*** which is found in ***Berberidaceae and Rannunculaceae.***

Tropane Alkaloids

Tropane alkaloids

- Among the best-known members of the group are the solanaceae alkaloids, which are very characteristic of the solanaceae. ***Atropine and Hyoscyamine*** serve as example.

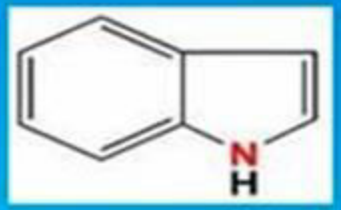
- ***In erythroxylum,*** cocaine alkaloids are found which are same in nucleus but do not occur in the solanacae.

- Ornithine is the precursor

tropane

Indole Alkaloids

Indole Alkaloids



Indole alkaloids are found in following plants.

- ***Physostigmine*** obtained from ***Physostigma venonsum*** *family* ***Leguminosae.***
- **Yohimbine** obtained from ***Rauwolfia serpentina*** **family Apocyanaceae.**
- **Vinblastine** obtained from ***Catharanthus roseus*** family **Apocyanaeae.**
- **Indole alkaloids** origination from Phenylalanine as in **Erythria alkaloids** (Leguminosae) such as **Erysopine.**
- In most cases e.g. **Tryptamine (Loganiaceae)**, **yohimbine** (Apocyanaceae) and **strychnine** (Loganiaceae) the parent compound is **tryptophan.**

e. Terpenoids and Steroids

- Terpenoids are **unsaturated hydrocarbons** derived from **isoprenes.**

  Eg. Carotenoids, iridoids

- Steroids are **saturated hydrocarbons** with four rings in their structure.

Ex.

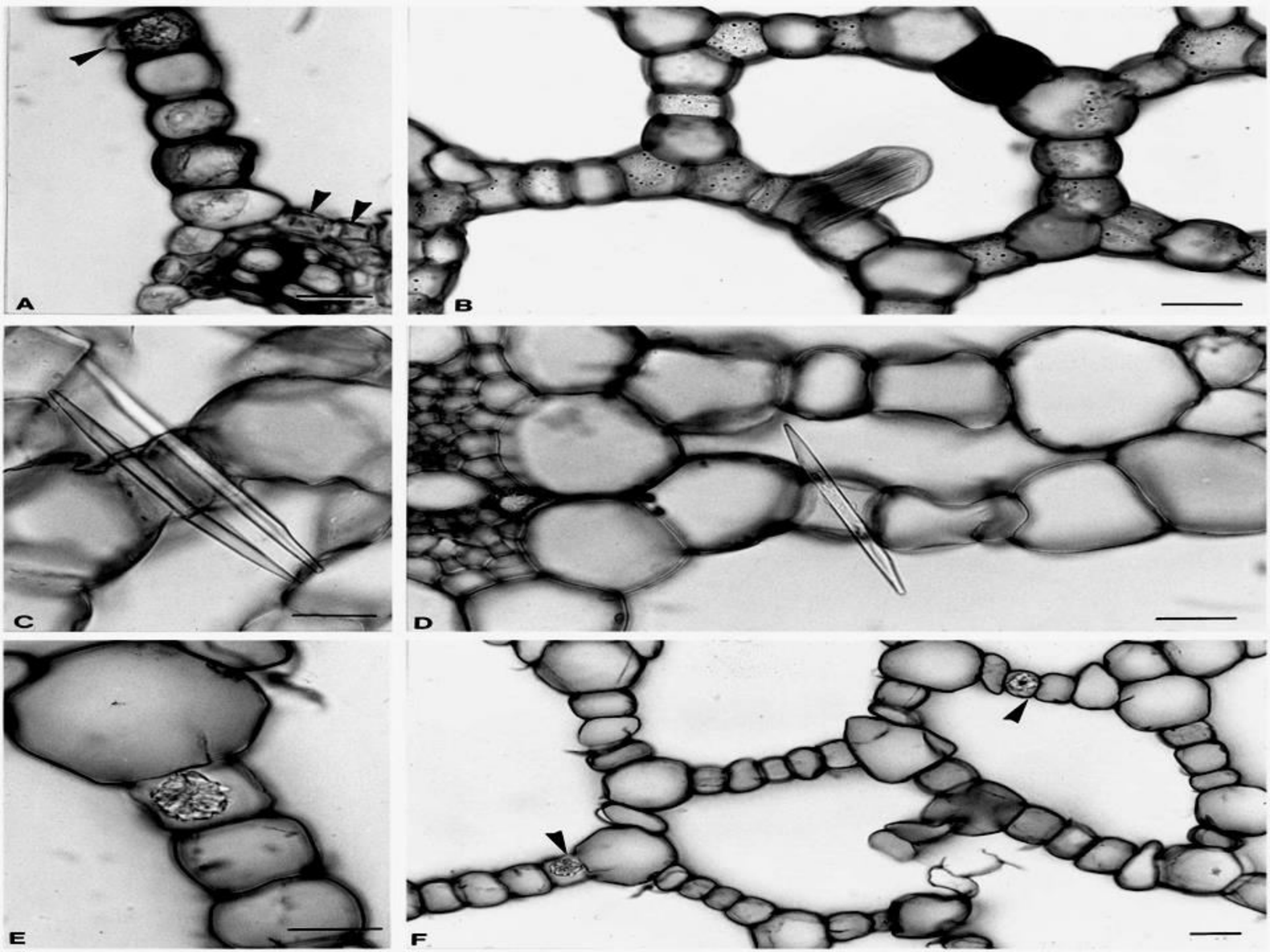
- The tribes *Genisteae* of *Fabaceae* and of *Asteraceae* - **petal carotenoids**
- **Arspernloside** – *Rubiaceae*
- **Acubin** – *Coenaceae, Scrophulariaceae* and *Orobanchaceae*
- *Buddleia* contains **acubin** in the family *Buddleiaceae*
- **Cucurbitins** are present in *Cucurbitaceae*

f. Crystals

- Some plants have **raphide crystals** in different parts of their body
- The **forms of crystals** are used to some extent in the classification of plants

Ex.

- **Presence and absence of raphides** are used in the grouping of plants in the family **Rubiaceae**
- **Calcium oxalate crystals** are present in the **ovary walls** of the members of **Asteraceae**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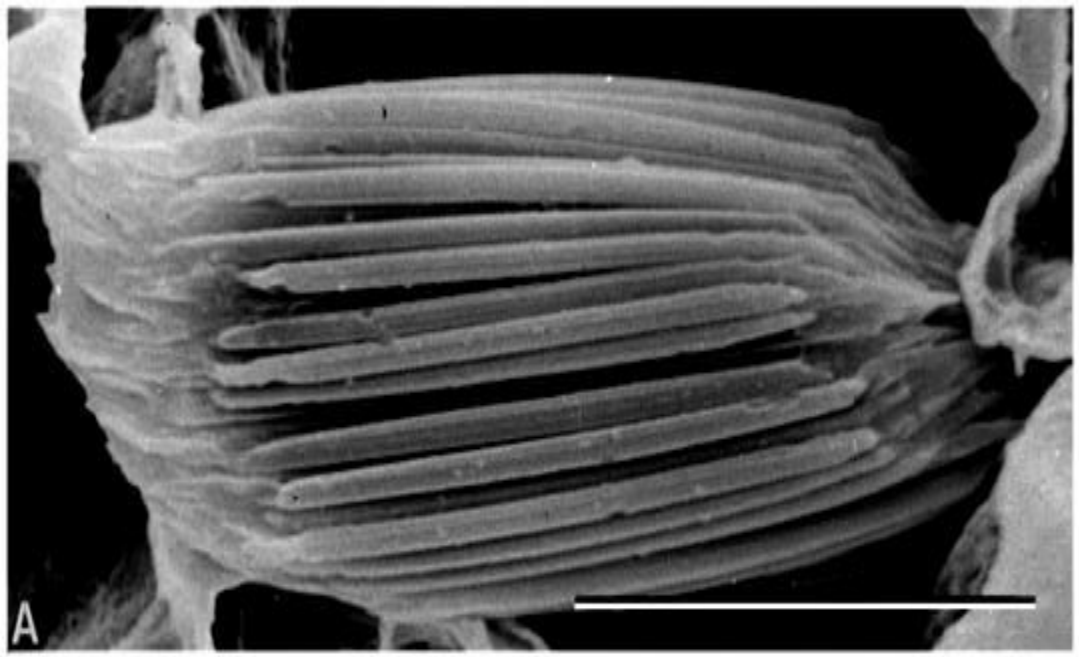
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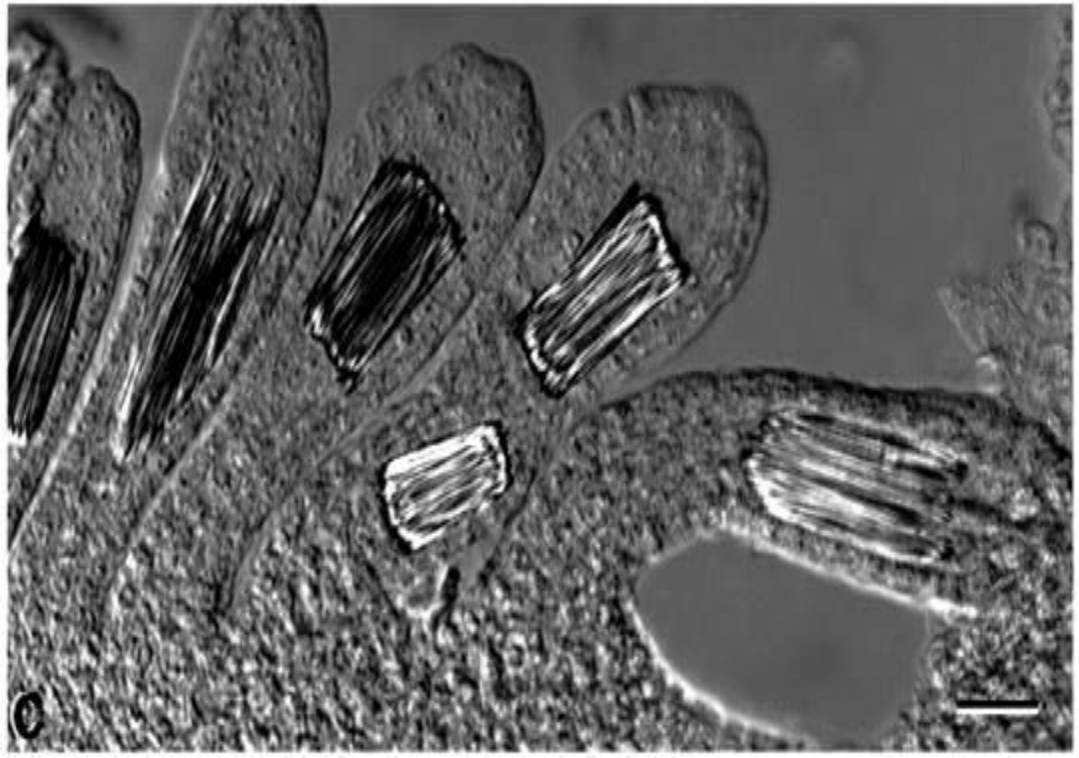
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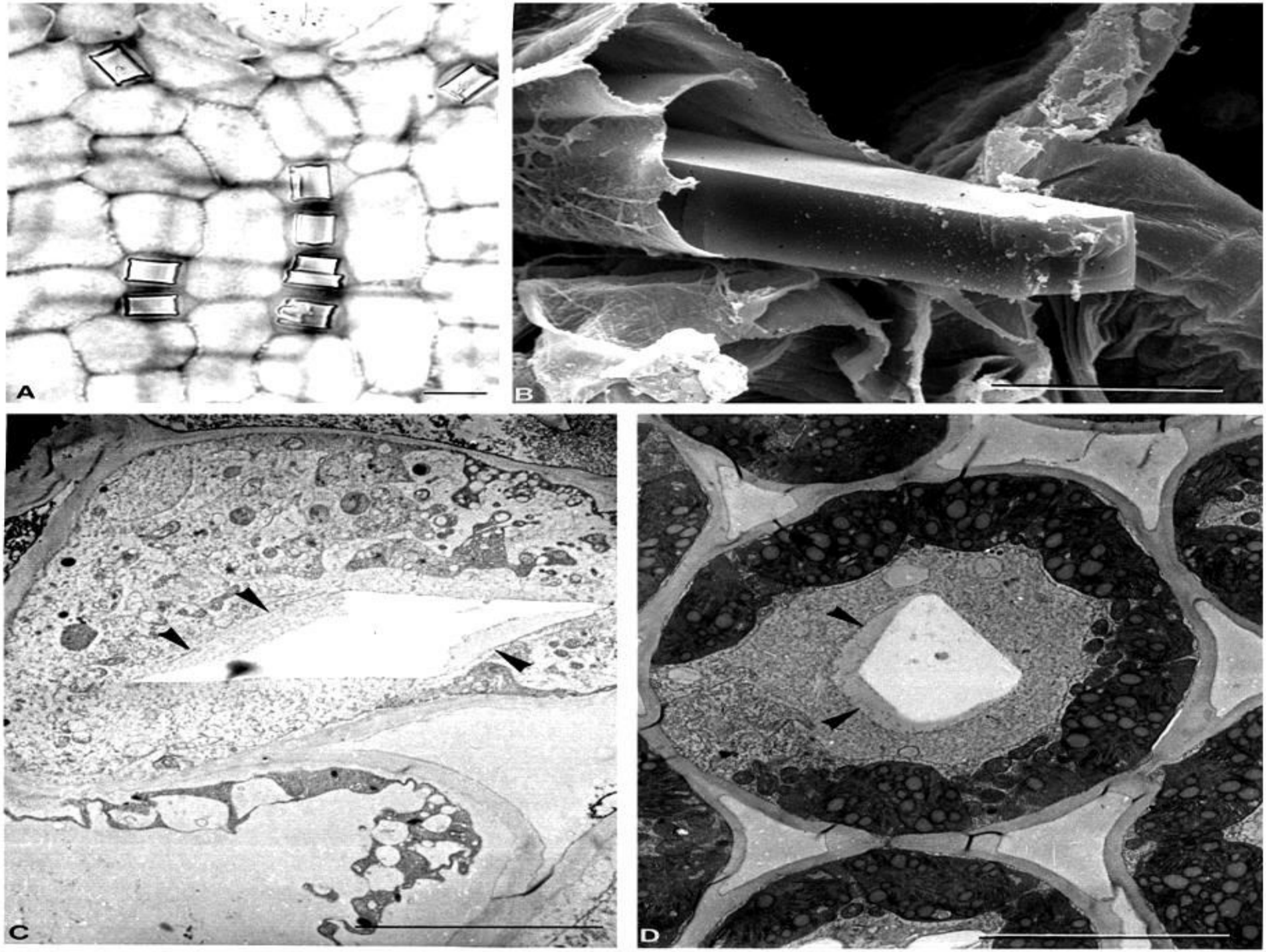
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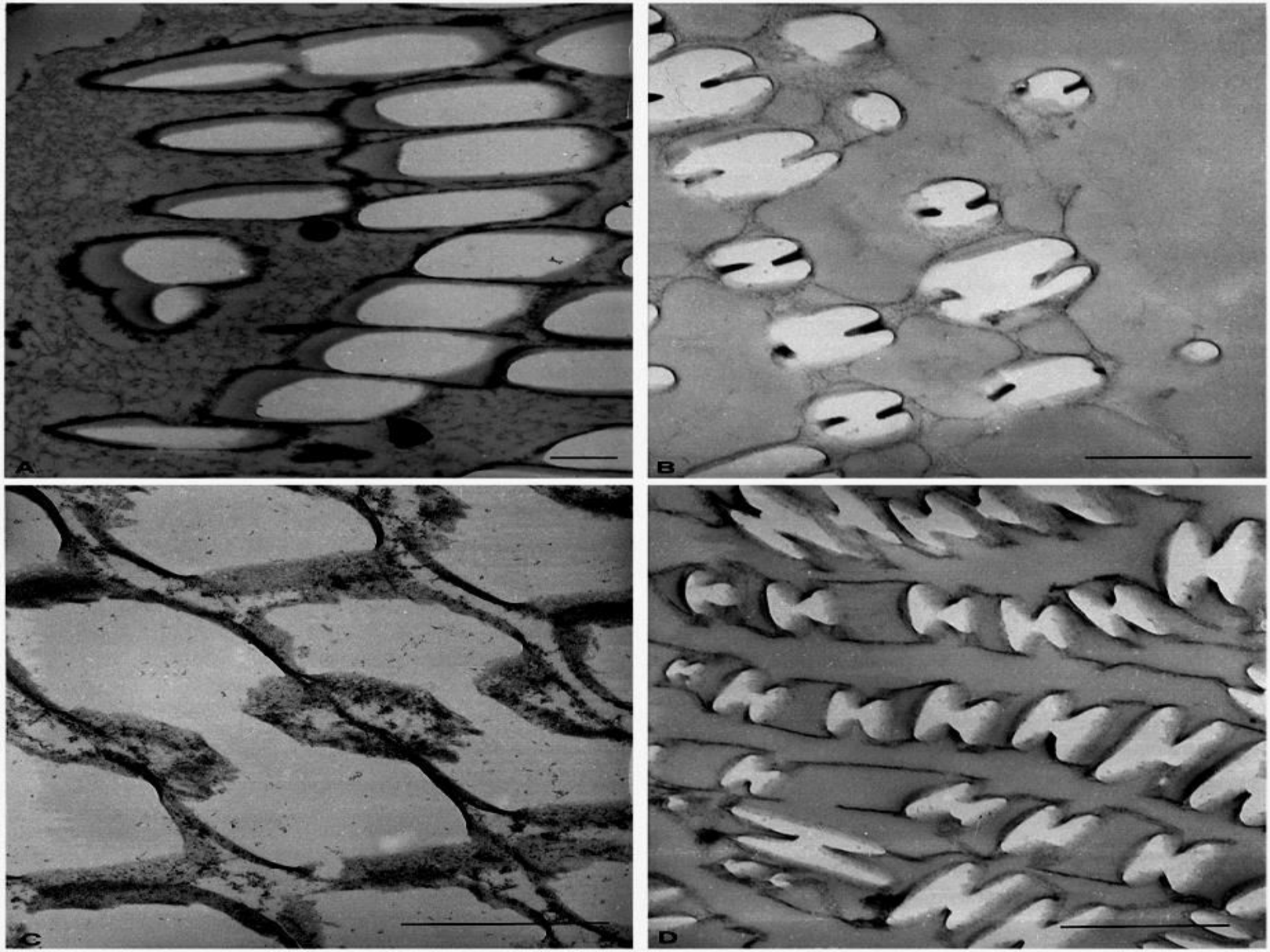
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g. Immunological reactions

- The **storage protein** or pollen protein is **injected from the plant body** to a test animal usually mouse or rabbit
- The test animal produces **antiserum** against that protein
- The antiserum is **mixed** with the plant extract to **detect the precipitate** formed by **antigen – antibody reaction**

- The **nature and amount of precipitate** indicate the **relationship of the protein** to the plant.
- **High rate of precipitation** indicates **closeness** of the plants.
- **Low precipitation** shows that the two plants are **not related.**
- This type of study is also known as **serotaxonomy**

Examples

- Closeness of ***Delphinium*** to ***Aconitumis*** confirmed by serological studies
- ***Hydrastatis*** placed in ***Berneridaceae*** is found to be more related to ***Ranunculaceae***
- Serological method is also useful in the classification of the members of ***Fabaceae, Bromus, Potato*** etc.

Acknowledgements:

I would like to thank our *Honourable Vice Chancellor* **Professor Ranjan Chakarborti** for giving me the opportunity to contribute in E-learning process which will be very much helpful for our students during unprecedented situation due to **CORONA Virus (COVID-19)**.

Thank You