PALYNOLOGY – POLLEN MORPHOLOGY

[T.Y.B.Sc. SEM – V, P – II, U – IV]

"Palynology is a branch of botany that deals with the study of plant pollen, spores and certain microscopic planktonic organisms in both living and fossil forms". It is mainly concerned with the study of pollen grains in plants and has many applications. As pollen and spores are produced in large numbers and dispersed over large areas by wind and water, their fossils are recoverable in statistically significant assemblages in a wide variety of sedimentary rocks. Moreover, because pollen and spores are highly resistant to decay and physical alteration, they can be studied in much the same way as the components of living plants. Identification of pollen and sporemicrofossils has greatly aided delineation of the geographical distribution of many plant groups from early Cambrian time (some 541 million years ago) to the present. Palynological studies using fresh or non-fossilized samples have also been useful in establishing a location or seasonal time frame for crime scenes and have served to determine the agricultural practices and other plant-related activities that occurred at archaeological sites. Use of latest techniques like SEM and TEM have enhanced the research in plant breeding and has become a useful tool for interdisciplinary research.

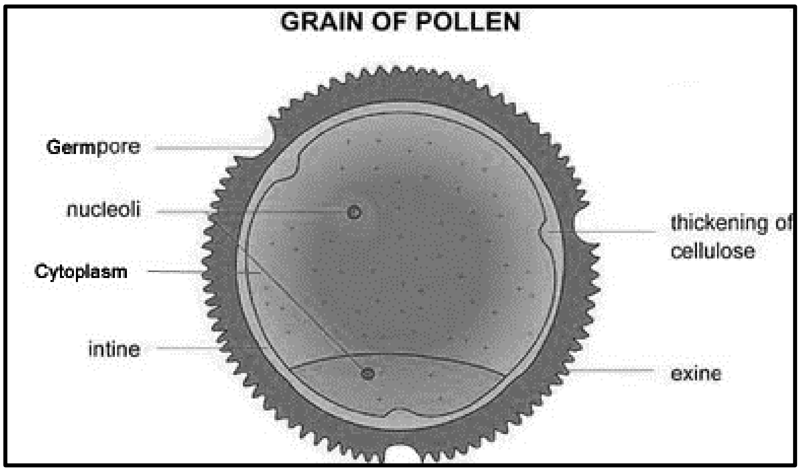
Pollen grains are the male gametophytes of flowering plants. They embody the male partners in sexual reproduction of plants. They are produced in large numbers inside the anthers of stamens and are present everywhere. When shed from the anthers, their moisture level is generally less than 20%. Pollen grains contain two cells inside them, vegetative cell (VC) and generative cell (GC). During shedding, they are either in a 2-celled or 3-celled stage.

Differences between VC and GC: -

Feature	VC	GC
DNA	Remains at 1C level	Increases to 2C level
Nucleus	Low amount of DNA-associated lysine-rich histone	Higher amount of DNA-associated lysine-rich histone
Chromatin	Diffuse	Highly condensed
Metabolism	Active with high levels of RNA, protein synthesis	Almost dormant except for mitotic division in 3-celled pollen

Differences between 2-celled and 3-celled pollen: -

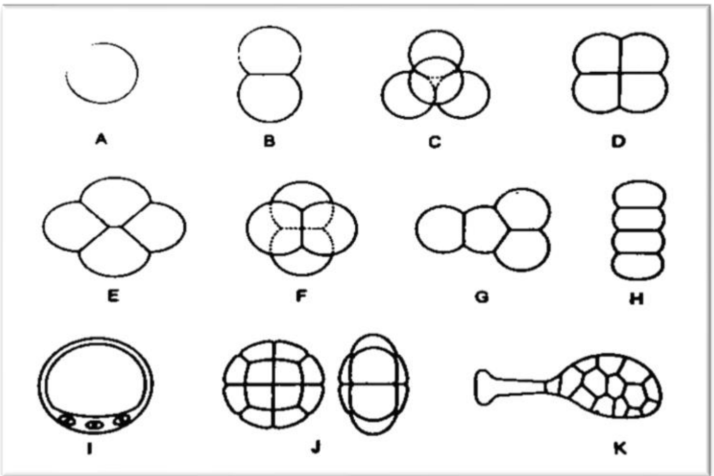
Character	2-celled pollen	3-celled pollen
Viability	prolonged	Short
Storage	Store well	Difficult to store
In-vitro germination	Comparatively easy	Comparatively difficult
Respiratory rate	low	High
Self-incompatibility	gametophytic	sporophytic



The wall of pollen grains has two main concentric layers in it – the inner intine and the outer exine. The morphological characteristics of pollen grains are manifested in the exine. Pollen morphological characteristics have been categorized into different groups – pollen units, polarity, symmetry, shape, size, apertures and sporoderm stratification.

I. POLLEN UNITS

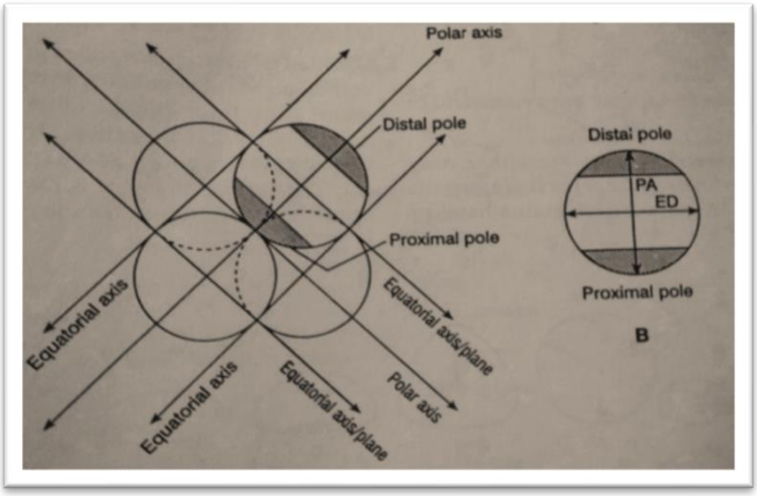
In the anthers of flowers, pollen mother cells originate from the sporogenous tissue of the anther which later divide meiotically to form four pollen grains called tetrad. After this stage, the pollen grains can either remain united or free or can be attached to each other in various ways. The different types of pollen units such produced are as follows:



A – Monad, B – Dyad, C – Tetrahedral tetrad, D – Tetragonal tetrad, E – Rhomboidal tetrad, F – Decussate tetrad, G – T-shaped tetrad, H – Linear tetrad, I – Cryptotetrad, J – Polyads, K - Pollinia

1. **Monad –** The pollen grains do not remain united at maturity and are dissociated into single pollen grain called as a monad.
2. **Dyads –** Pollen grains which are united in pairs and shed from the anthers as doubles are called dyads. Dyads are present in *Scheuchzeria palustris* and other members of Podostemonaceae. The dyads are formed due to incomplete break up of individual grains or monads.
3. **Tetrads –** Four pollen grains are united to form a tetrad. Tetrads are the unseparable products of meiosis. Tetrads are classified into different types based on their arrangement as follows:
    a. **Tetrahedral tetrad –** Pollen grains are arranged in two different planes. Three grains are in one plane and one lies centrally over the other three. Eg, in *Rhododendron*.
    b. **Tetragonal tetrad –** All the four pollen grains are arranged in one plane. Eg., *Typha latifolia*.
    c. **Rhomboidal tetrad –** All pollen grains are arranged in one plane forming rhomboidal shape. Eg., *Annona muricata.*
    d. **Decussate tetrad –** Pair-wise, the pollen grains are arranged at right angles to each other. Eg,.*Magnolia grandiflora*.
    e. **T-shaped tetrad –**The first division of pollen mother cell is transverse to form a dyad. The upper or lower cell of the dyad undergoes a vertical or longitudinal division instead of transverse, yielding either straight or inverted T-shaped configuration. Eg, *Aristolochia.*
    f. **Linear tetrad –** The first division of pollen mother cell is transverse and a dyad is formed. Each cell of the dyad again divides transversely to form a linear tetrad. Eg.*Mimosa pudica*.
    g. **Cryptotetrad or Pseudomonad –** Here tetrads are formed without partition walls between the four compartments. One out of the four nuclei develop normally and the rest three obliterate. Thus, an apparent monad but homologous to the tetrad is formed. Eg., Cyperaceae.
4. **Polyads –** In most of the Mimosaceae members each of the tetrad cells divides once or twice, yielding a group of 8 – 64 cells which remain together after maturity. The compound grains are usually held together in small units and are called polyads. Eg, *Acacia auriculiformis*.
5. **Pollinia –**In members like Orchidaceae, the whole contents of an anther or anther locule which shed as one united mass of pollen called as pollinia.

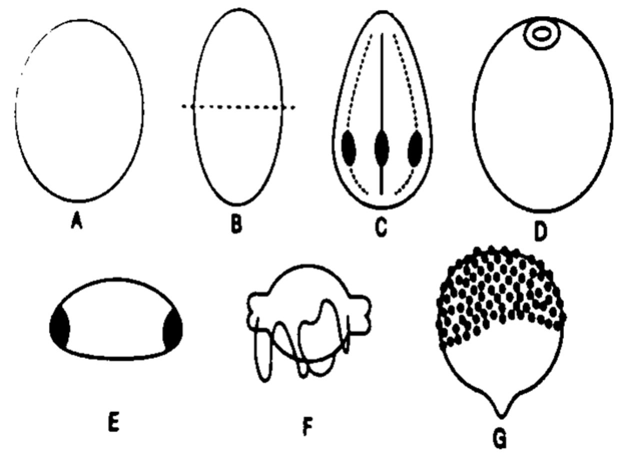
II. POLLEN POLARITY



The orientation of polarity is an important criterion in identification and description of pollen grains. All pollen grains are in tetrad stage during development and the polarity is determined in this stage, prior to their separation.

The part of the pollen grains which is nearest to the centre of the tetrad is the proximal pole and that towards the opposite side is the distal pole. The imaginary line between the proximal and distal pole of the grain is called the Polar Axis (PA) which passes through the centre of the spore to the centre of the tetrad. The plane perpendicular to the PA through the middle of the grain is the Equatorial Plane (EP).

Types of polarity in pollen grains:



[A – Apolar, B – Isopolar, C & D – Heteropolar, E & F – Paraisopolar, G – Cryptopolar]

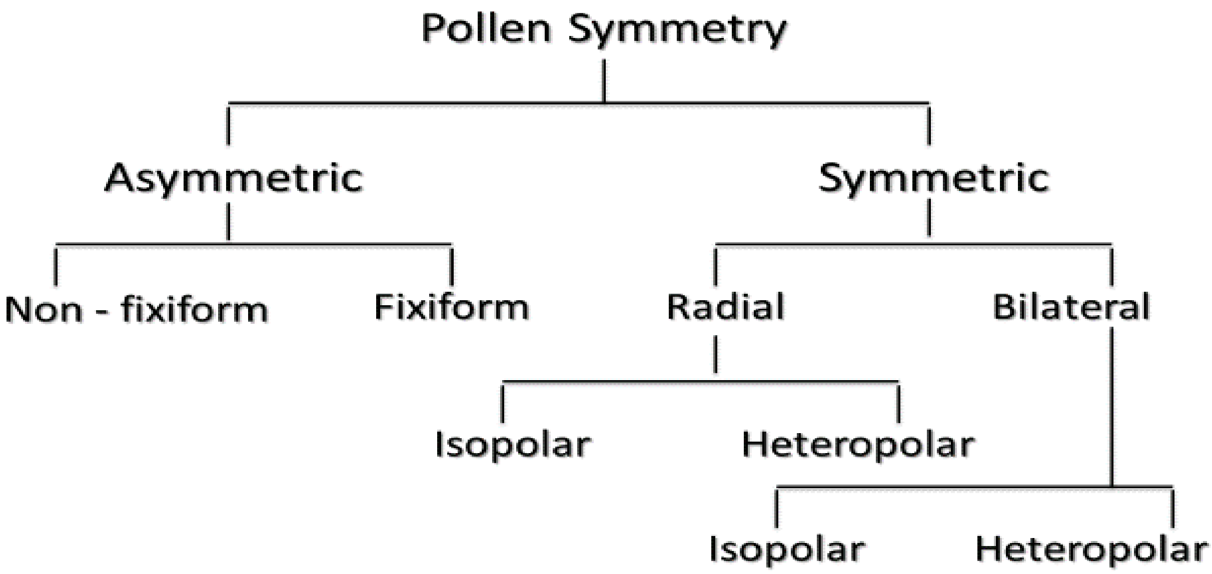
Pollen grains can either be apolar or polar. In apolar spores, poles or polar regions cannot be distinguished in individual spore (monad) after separation from the tetrad. Eg. *Typha*. Polar pollen grains can be of the following types.

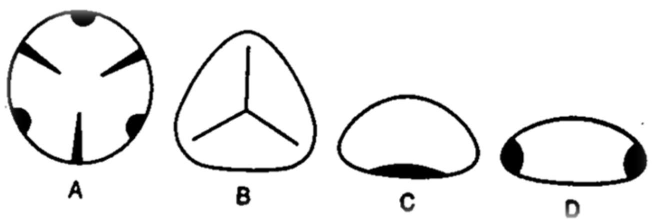
1. **Isopolar –** The distal and proximal faces (above and below the equatorial plane) look alike in this type of pollen grains. Eg. *Calluna*.

2. **Heteropolar –** In such grains the two faces are distinctly different, either in shape, ornamentation or apertural system. Thus, one face may have an aperture and the other may not. Eg. *Lilium*.
3. **Paraisopolar / Subisopolar –** The pollen grains show slight differences between the distal and proximal faces. Their equatorial plane is more or less curved. Eg. *Nivenia*.
4. **Cryptopolar –** In some bryophyte species, the distal and proximal faces have dissimilar sculpturing and lacks the tetrad mark. Such type of spores is called cryptopolar. Eg. *Larix*.

III. POLLEN SYMMETRY

Pollen grains are either symmetric or asymmetric in nature.





Symmetry: A & B – Radially symmetric, C & D – Bilateral symmetry

The asymmetric grains are either non-fixiform (without fixed shape) or fixiform (with a fixed shape). Asymmetrical grains have no plane of symmetry. They occur rarely. Eg. *Papaver argemone*.

The symmetric grains are either radiosymmetric (radially symmetrical) or bilateral (having a single plane of symmetry).

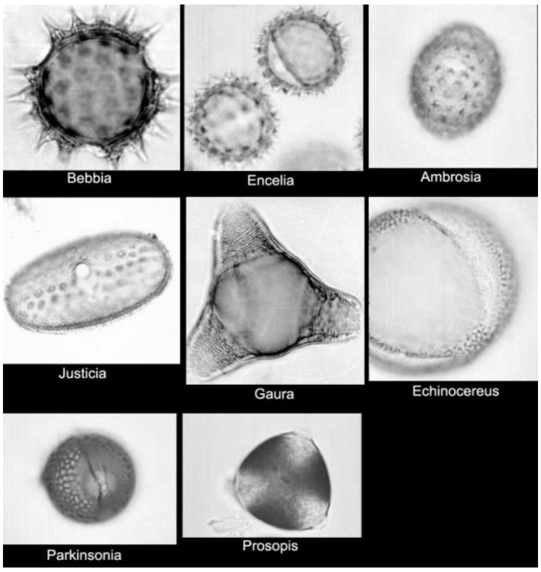
1. **Radiosymmetric pollen –** In this type, the shape is such that any plane including the polar axis that passes through will produce identical halves. So they have more than two vertical planes of symmetry. In isopolar type of radiosymmetry, there is one horizontal and two or more vertical

planes of symmetry. Eg. *Centaurea*. In heteropolar type, there is no horizontal plane of symmetry. Eg. *Osmunda regalis*.

2. **Bilaterally symmetric pollen –** Such pollen grains have two vertical planes of symmetry. The bilaterally isopolar types have three planes of symmetry, one horizontal and two vertical. Eg. *Rungia grandis*. While in some bean-shaped or boat-shaped pollen, there is only one vertical plane of symmetry with an opening towards the end of the grain. Eg. *Picea abies*.

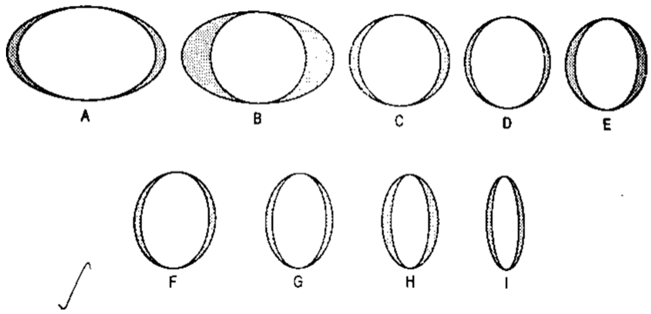
IV. POLLEN SHAPES

The shape of pollen grains varies from one species to another. Shape of pollen is one of the criteria for identification of pollen grains. However, the shape may vary considerably within one grain type or even within one species. Pollen grains are often described by the shape of their outline in both polar and equatorial views. The pollen shapes can vary from circular, elliptical, triangular, rectangular, quadrangular to other geometrical shapes.



G. Erdtman (1952) categorized eight shape classes based on the ratio of Polar Axis (PA) and Equatorial Diameter (ED). In the equatorial view, the ratio between the PA and ED, multiplied by 100 gives the indication of the shape. The different shape classes based on the ratio obtained are stated as follows.

Shape classes	(PA/ED) x 100
Per-oblate	<50
Oblate	50-75
Sub-oblate	75-88
Oblate-spheroidal	88-99
Spheroidal	100
Prolate-Spheroidal	101-114
Sub-prolate	114-133
Prolate	133-200
Per-prolate	>200



Shape classes: A – Peroblate, B – Oblate, C – Suboblate, D – Oblate-spheroidal, E – Spheroidal, F – Prolate-spheroidal, G – Sub-prolate, H – Prolate, I - Perprolate

V. POLLEN SIZE

Pollen grains show a great variety in their sizes. The pollen size ranges from 5 to 200 µm, majority of which are in the range of 15 - 50µm. Smallest pollen grains of about 5 x 2.4 µm is noted in *Myosotis palustris* and some members of Boraginaceae, while the largest pollen grains (>200 µm in diameter) are observed in Cucurbitaceae, Malvaceae and Nyctaginaceae. According to Walker (1971), the pollen of *Cymbopetalum odoratissimum* of Annonaceae is the largest one reported, which measured up to 350 µm. Marine angiosperms like *Amphibolis* and *Zostera*, the pollens are long and filiform up to 5 mm long, as observed by Ducker *et al* (1978). Long pollen grains (>500µm) are also reported in *Crossandra* by Brummit *et al* in 1980.

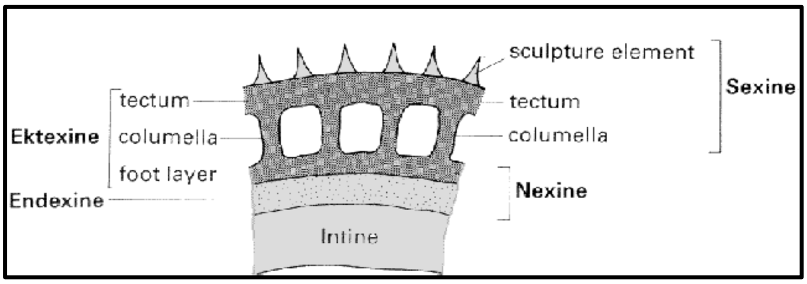
In taking measurements of size, the length of the PA, ED and sometimes Equatorial Breadth (EB) are considered in bilateral grains. In radially symmetrical ones, the PA and the greatest ED can be measured in equatorial view, while the EB can be measured in polar view only. It is also necessary to measure exine elements, taking into consideration the thickness of exine, sexine / nexine thickness ratio and the thickness of the exine projections greater than 0.5µm if any.

Erdtman (1945) categorized the different pollen size classes based on the size expressed as length of the longest axis. The various categories of pollen size are mentioned as follows.

	Pollen size class	Length of longest axis
1.	Very small grains (*Sporae perminutae*)	<10µm
2.	Small grains (*Minutae*)	10 - 25 µm
3.	Medium sized grains (*Mediae*)	25 – 50 µm
4.	Large grains (*Magnae*)	50 – 100 µm
5.	Very large grains (*Permagnae*)	100 – 200 µm
6.	Gigantic grains (*Giganteae*)	> 200 µm

VI. POLLEN WALL (SPORODERM) STRATIFICATION

The pollen wall or the sporoderm is generally stratified or layered. The walls of the mature pollen in angiosperms consist of two fundamentally different layers, inner intine and an outer acetolysis resistant layer called the exine. The exine covers the entire pollen surface except germinal apertures where it is absent or greatly reduced.

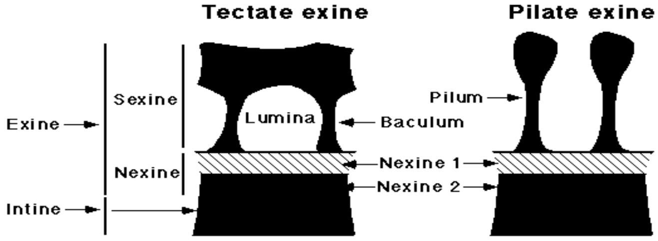


The exine of pollen grains can be divided into an outer sculptured sexine and inner unsculptured nexine. Sexine again consists of two layers – the outer ectexine and inner endexine. The sexine is generally constituted of a set of radially directed rods supporting a roof-like structure (tectum or tegillum), which may be partially perforated or completely absent. Rods supporting the tectum are known as columella, and rods not supporting anything but standing vertically on the nexine are called bacula. Thus, they are respectively known as tectate and pilate pollen grains.

Pollen grain with a tectum which covers most of the surface of the grain is called tectate. Faegri and Iversen (1964) divided tectate grains into three categories:

- *Tectum solidum* – unbroken tectum with or without supratectal processes. Eg. *Zea*.
- *Tectum perforatum* – perforated tectum. Eg. *Stellaria*.
- *Tectum perfossulatum* – fossulated tectum. Eg. *Saxifraga*.

Some of the pollen grains are considered to be an intermediate between tectate and pilate pollen grains. They are called semi-tectate or sub-tectate in which tectum is not continuous i.e. tectum is partially absent.

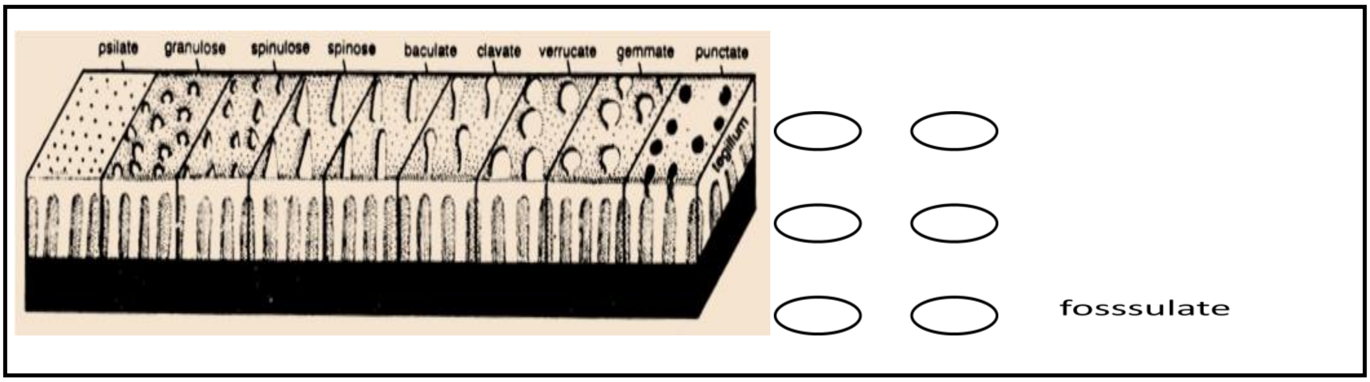


The nexine has been divided into two layers, namely nexine I and nexine II, according to Erdtman (1969). Knut Faegri (1964) proposed an alternative terminology for exine stratification. He recognized two layers of exine, the outer ektexine (including sexine and nexine I) and endexine (nexine II). He designated nexine I as foot layer and considered it to be the basal part of ektexine for its identical chemical composition and staining property as that of sexine.

VII. EXCRESCENCES / OUTGROWTHS

The tegillum / tectum may show presence of extra-exinous material over its surface, which are called as excrescences / outgrowths.

Types of excrescences: -



- Psilate - Sculpturing elements absent. Surface even or diameter of pits < 1µm.
- Punctate / Foveolate - Sculpturing elements absent. Surface even or diameter of pits > 1µm.
- Granulose - Tectum provided with processes in the form of granules.
- Fossulate - Sculpturing elements absent. Surface provided with grooves.
- Spinulose - Sculpturing elements pointed with small spines, less than 3 µm in length.
- Spinose / Echinate - Sculpturing elements pointed with long spines, more than 3 µm long.
- Baculate - Sculpturing elements not pointed. Lower part of element not constricted. Height of element greater than greatest diameter of projection, element cylindrical.
- Clavate - Sculpturing elements not pointed. Lower part of elements constricted. Height of element greater than greatest diameter of projection, club-shaped.
- Verrucate - Sculpturing elements not pointed. Lower part of element not constricted. Greatest diameter of radial projection equal to or greater than height of element, wart-like.

- Gemmate - Sculpturing elements not pointed. Lower part of elements constricted. Greatest diameter of radial projection equal to or or greater than height of the element.

VIII. APERTURES OF POLLEN GRAINS

An aperture is a weak, pre-formed locus on the exine of spore and pollen through which the intra-exinous substance exits and pollen tube emerges during pollen germination. Physiologically it is a germination zone or **harmomegathus**. The first characteristic to be considered when identifying **pollen grains** are the **apertures**. An **aperture** is a thin or missing part of the exine, which is independent of the patterning of the exine.

Apertures may be absent from a pollen grain when they are termed as inaperturate / atreme / non-aperturate; for eg. *Potamogeton*. The sexine of omniaperturate pollen is either absent or very thin. The intine is thicker than exine. Eg. *Canna*.

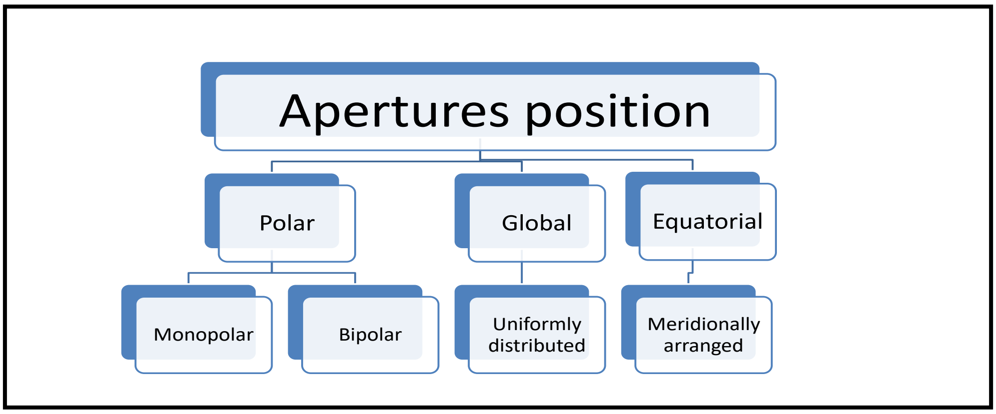
Based on the shapes of apertures, they are of two main types –

- Porate – Pollen grain is said to be porate if the aperture is in the form of a pore, which is rounded or elliptic (ratio between the length and breadth is less than two) and more or less distinct. A pore is formed on the sexine only.
- Colpate – Colpus is an elongated aperture (the ratio between the length and breadth is greater than two) of a pollen grain. A colpus is an ectoaperture and is formed on the sexine only.

Other variations in the apertures can arise out of a combination or differences in the above two types and are named accordingly with suitable prefixes and suffixes.

Position of apertures on pollen grain: -

Apertures on the surface of pollen grain are distributed differently in different species as follows.



IX. NPC CLASSIFICATION

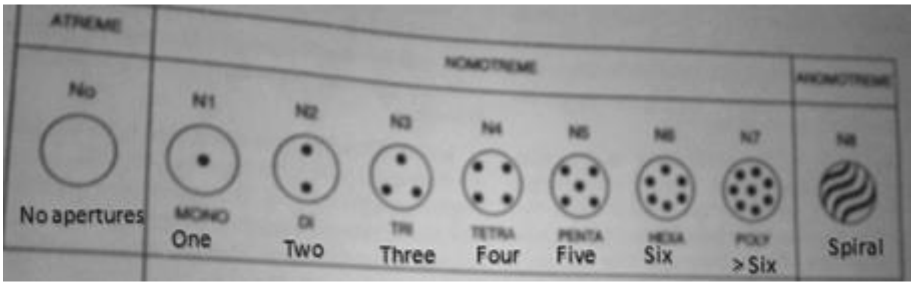
NPC is an artificial system of classification of pollen based on the three features of aperture only i.e. number, position and character. Erdtman and Straka (1961) proposed NPC system of classification and palynologists all over the world accepted it. According to NPC system, each pollen grain has an arithmetic cardinal number consisting of three digits.

- The first digit reveals the absence or presence of an aperture, and when present it mentions the total number of aperture/s.
- The second digit illustrates the position of aperture/s i.e distal, proximal, latitudinal, equatorial, etc. The microspores reveal the full clarity when they are in a tetrad.
- The third digit explains the character of an aperture i.e. circular, oval, elongated, simple or compound, etc.

Thus, 'N' for the number, 'P' for the position and 'C' for the character of an aperture compose the NPC classification.

Classification of aperture based on number (N): -

In NPC system, 'N' denotes the number of apertures present in a pollen grain. Aperturate pollen are divided into seven groups. The groups are mentioned as N_1 to N_7. Each group has a characteristic number of aperture, i.e. N_1 has one aperture, N_2 has two apertures, and so on. The N_7 group has seven or more apertures. N_1 to N_7 groups are also referred to respectively as monotreme, ditreme, tritreme, tetratreme, pentatreme, hexatreme and polytreme. There are pollen grains where apertures are absent. Such pollen grains are called as inaperturate or atreme and they are placed in the N_0 group. Another special group is N_8 termed as anomotreme where the pollen have one or several irregular or irregularly spaced apertures.

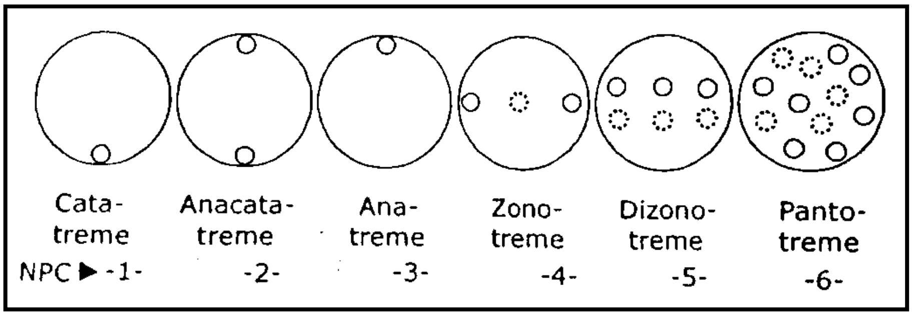


Classification of aperture based on position (P): -

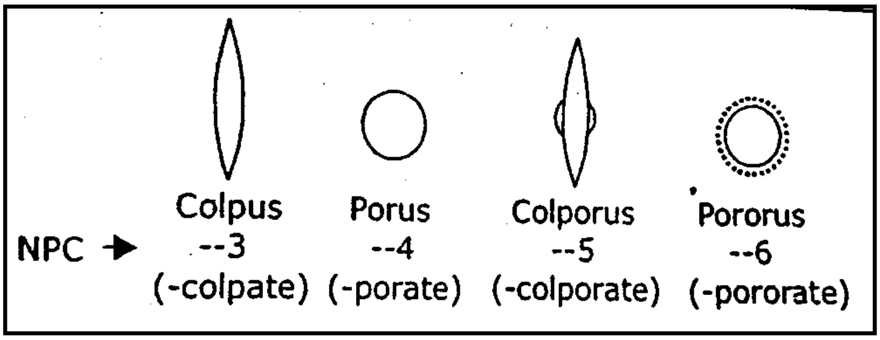
In NPC system, 'P' denotes the position of aperture in pollen. The position may be proximal, distal or equatorial. There are seven groups of apertures based on their position, namely P_0 to P_6.

- Pollen grains having P_0 group have uncertain or unknown position of aperture.
- P_1 groups of pollen are catatreme. Catatreme pollen grains have one aperture that occurs on the proximal part of the grain.
- P_2 groups of pollen are anacatatreme, which means they have two apertures, one of which occurs on the distal pole and the other one on the proximal pole.
- P_3 groups of pollen are anatreme, where the apertures are distal in position.

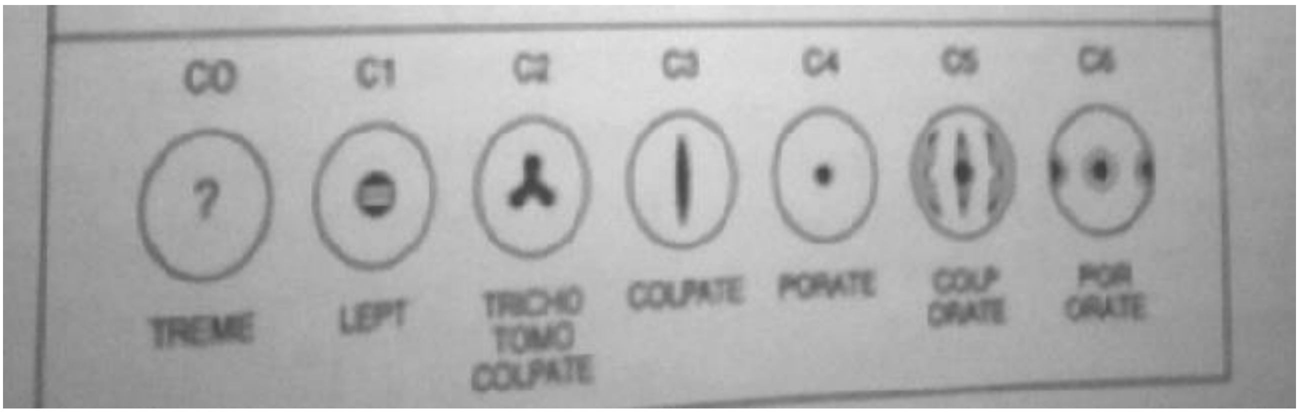
- P_4 groups are called zonotreme, which indicates pollen grains characterized in having apertures on the equator or sub-equator.
- P_5 groups of pollen are dizonotreme. They have apertures arranged in two or more zones, parallel to the equator.
- P_6 groups of pollen are pantotreme, which have apertures scattered over the whole surface uniformly.



Classification of apertures based on Character (C):



In NPC system, 'C' denotes the character of the aperture in a pollen grain. The character groups are seven in all and are mentioned from C_0 to C_6.

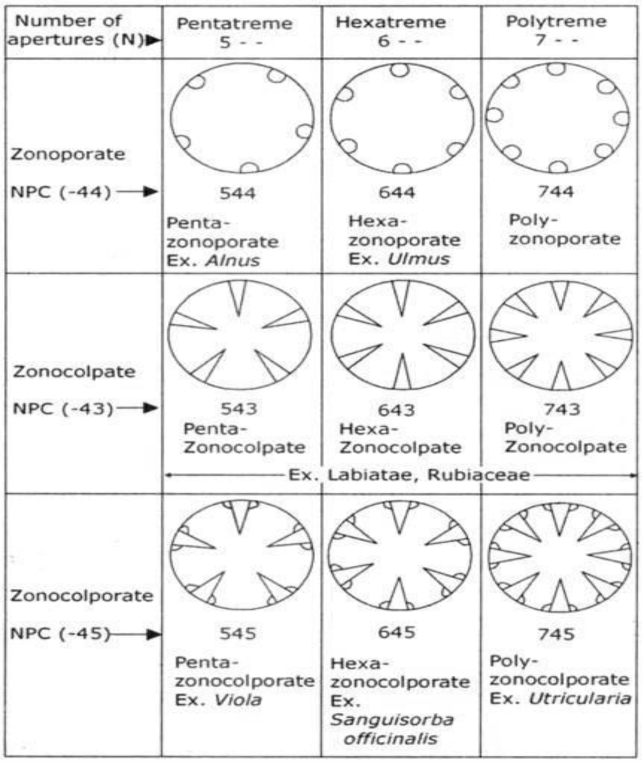


- C_0 groups have apertures whose character cannot be established with certainty.
- C_1 groups have leptoma, which is a thin area, aperture like and functions like an aperture. Pollen grains with one leptoma are termed as monolept. The leptoma may occur on either proximal or distal face and accordingly termed as catalept and analept.

- C_2 groups are trichotomocolpate. It is a three-branched aperture, the branches of which are more than two times longer than breadth. Trichotomocolpate pollen having aperture on proximal face are termed as trilete.
- The group C_3 has colpate pollen.
- Group C_4 comprises porate pollen grains.
- The group C_5 includes colporate grains, which is a combination of C_3 and C_4 types.
- The group C_6 includes pororate pollen. It includes pollen having pores as well as ora i.e. a faint area surrounding the aperture pore.

In NPC classification, a grain is mentioned in three-digit number. For example, 343 instead of $N_3P_4C_3$. Pollen grains having NPC 343 are tritreme, zonocolpate, which is also described as tricolpate pollen. Similarly, NPC 764 characterizes those pollen grains that are polytreme pantoporate, which are also described as pantoporate or polyporate. Pollen grains of Amaranthaceae, Chenopodiaceae, etc have NPC 764. Examples of tricolpate pollen grain i.e. NPC 343 are *Rumex, Tectona*, etc.

First digit (N)	**Second digit (P)**	**Third digit (C)**
100 – Monotreme	010 – Proximal	002 – Trilete
200 – Ditreme	030 – Distal	003 – Colpate
300 – Tritreme	040 – Equatorial	004 – Porate
400 – Tetratreme	060 - Global	005 - Colporate
500 – Pentatreme		
600 - Hexatreme		
700 – Polytreme		
8 – Anomotreme		



Merits of NPC classification: -

- It is a simple system of classification and illustrates the apertures of a pollen grain.
- NPC makes the description of apertures precise.
- With the aid of NPC system, the pollen grains and spores of pteridophyta, monocotyledon and dicotyledon can be differentiated to some extent. Thus, NPC narrows the search list of identification of unknown sporomorphs.
- NPC is supposed to be of primary classificatory character because apertures are most conservative. Sometimes, it becomes possible to identify the family or genus or even species of a pollen grain with the aid of NPC classification in combination with other morphological characteristics.
- Palynologists all over the world accepted NPC classification as it is basically simple and consistent where pollen grains and spores could be arranged easily.
- NPC, sporoderm stratifications, exine patterns, size and shape etc of a pollen grain are genetically stable traits. With the aid of NPC and other characters, a key can be formulated that helps to identify unknown pollen and spores, which becomes an essential pre-requisite in the applied aspects of palynology. The interfamily and intrafamily affinities among taxa to some extent can be determined with the aid of NPC.
- NPC and the various types of exine patterns and ornamentations provide characters of taxonomic significance and thus become one of the sources of alpha taxonomy. Eg., Bombacaceae is separated from Malvaceae.

Demerits of NPC classification: -

- It is an artificial system of classification.
- Syncolpate and parasyncolpate pollen grains do not fit neatly in NPC classification.
- Pollen grains that are characteristically present as aggregates in tetrads (eg. Ericaceae) and polyads (eg. Orchidaceae) are not grouped in the NPC system.

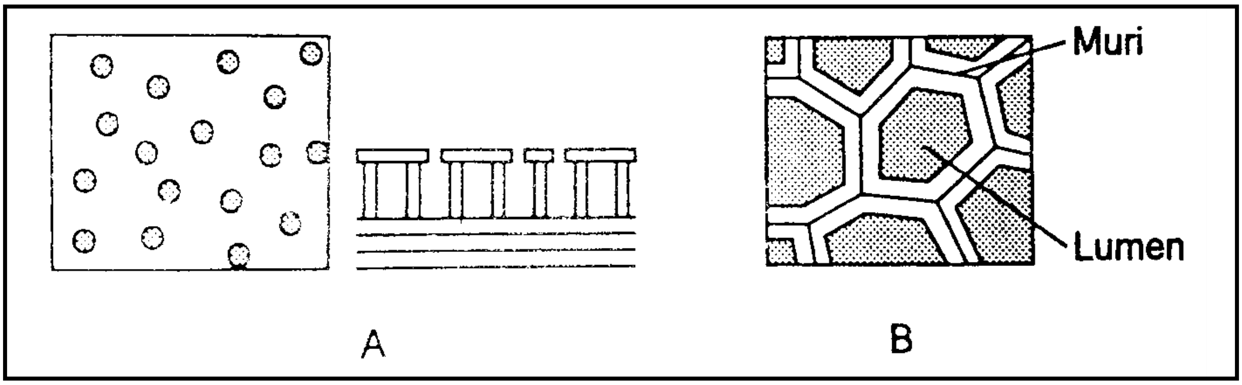
X. EXINE ORNAMENTATIONS / SCULPTURING TYPES ON SUB-TECTATE EXINE

[punctate, reticulate, striate, homobrochate, heterobrochate, simplibaculate, duplibaculate, areolate, caveate, lophate, fenestrate, hamulate, haploxylate, diploxylonoid, metareticulate, urceolate, bireticulate, polumbra, velum, concordant, discordant]

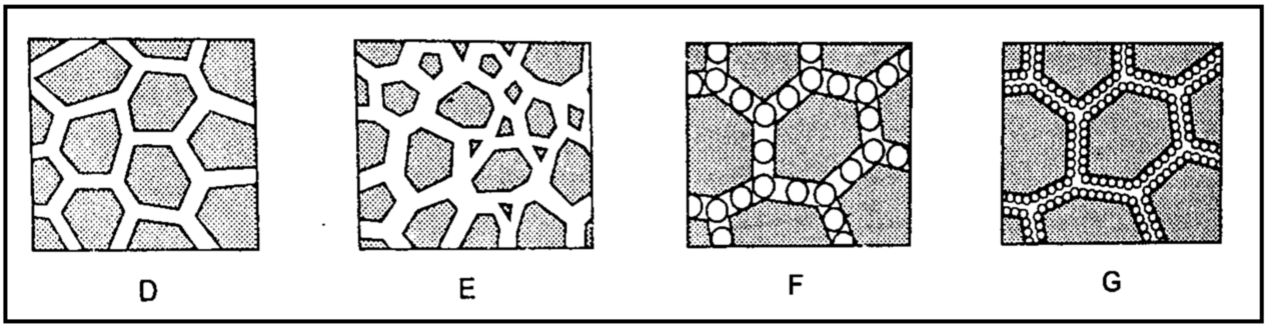
A sculpture on the wall of a pollen grain is a usual feature of the ektexine but may be a perine character. Tectum provided with the processes are referred to with their respective terminology (refer to excrescences / outgrowths). In supra-reticulate grains, the reticulation is on the outside of the tectum, while in infra-reticulate grain, columellae form a reticulation beneath the tectum. The various types of ornamentations on the sub-tectate part are as follows:

1. <u>Punctate</u> – The tectum may be provided with minute perforations having a diameter of more or less 1.0µm called as puncta and the tectum is referred to as punctate. (Fig. A)

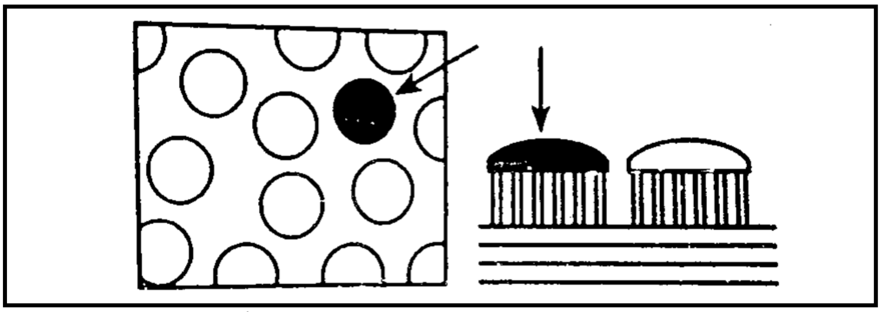
2. Reticulate – If the width of the perforations is more and the sexine displays a net-like pattern usually forming a honey-comb like hexagonal meshes, it is called as reticulum. (Fig. B)



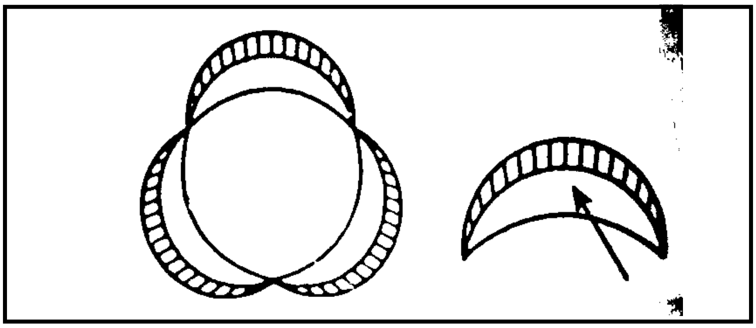
3. Homobrochateand Heterobrochate –A typical reticulum consists of a system of ridges called muri. The muri have an upper tectal part and a lower part consisting of baculae. A mesh consists of a lumen and the adjoining half of the muri. A mesh such formed is referred to as the brochus. A reticulum is said to be homobrochate if the brochi are of more or less the same size (Fig D). It is said to be heterobrochate when brochi are of more or less distinct sizes (Fig E).
4. Simplibaculate and Duplibaculate – The muri in which the upper tectal part is supported by a single row of baculae is called simplibaculate (Fig F) and the muri supported by two rows of baculae is called duplibaculate (Fig G) (eg. *Avicennia*).



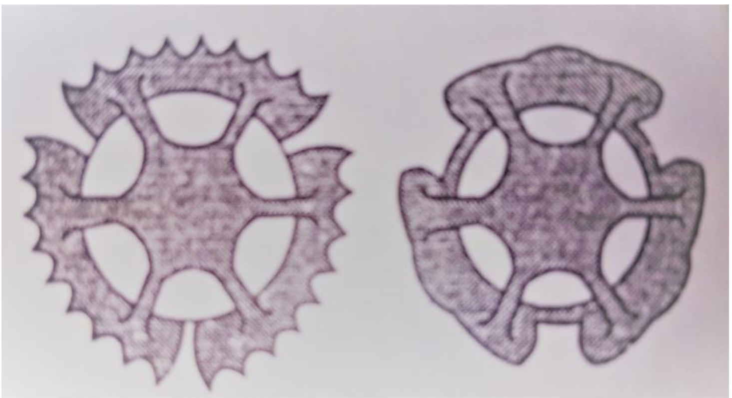
5. Areolate – An ornamentation feature where the ektexine is composed of circular or polygonal areas separated by grooves which form a negative reticulum. A negative reticulum is observed where sexine areas are separated by narrow reticulately arranged grooves. Eg. *Phyllanthus*.



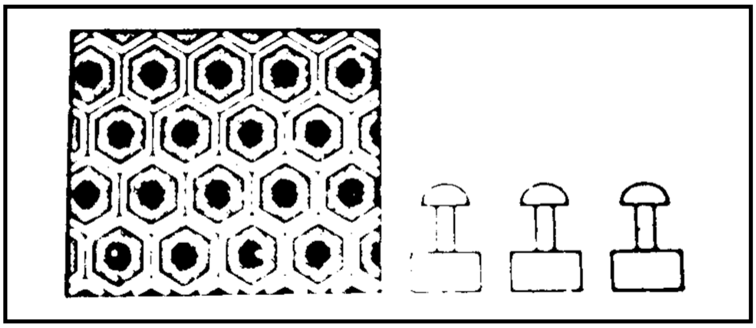
6. Caveate – In some Asteraceae members like *Ambrosia*, a cavity is formed between two the ektexine and the foot layer of the exine extending to the colpus margin where the layers meet. The cavity is called as cavea and the pollen of such type is termed as caveate.



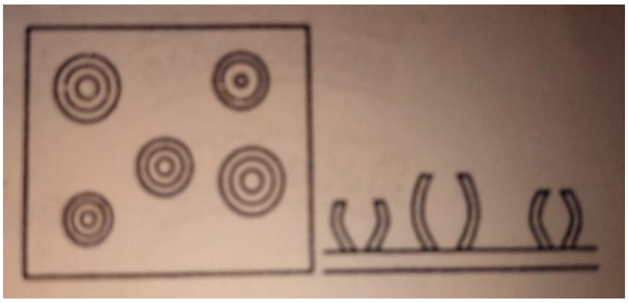
7. Lophate – A lophate pollen grain is the one in which the outer exine is raised in a pattern of ridges (lophae) surrounding depression (lacunae). Eg. *Taxaxacum*.



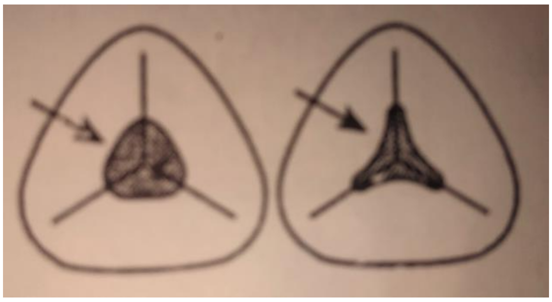
8. Metareticulate – It is a reticulum which is characterized by the consistent presence of one porate aperture in each lumen. Eg. *Kallstroemia*.



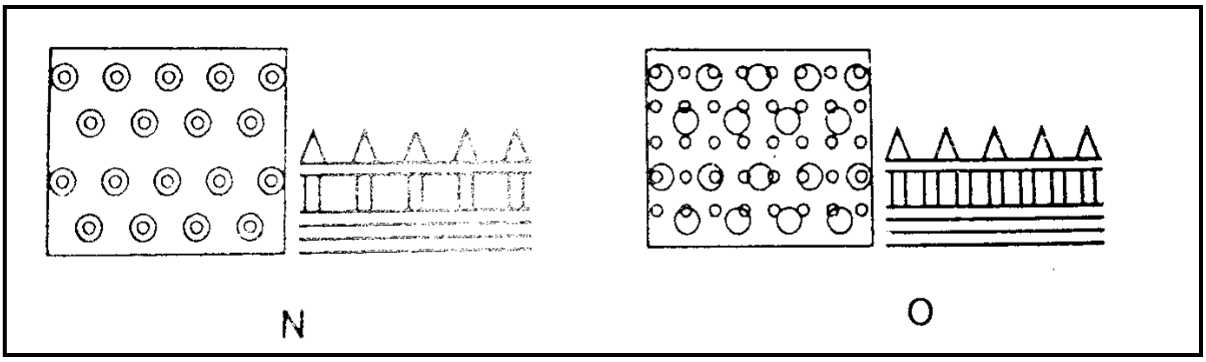
9. Urceolate – It is a type of ornamentation consisting of urn-shaped elements situated on the foot layer. Eg. *Pinanga*.



10. Polumbra – A darkened triangular or sub-circular area centered on the proximal pole is a polumbra. Eg. *Retusotriletes*.



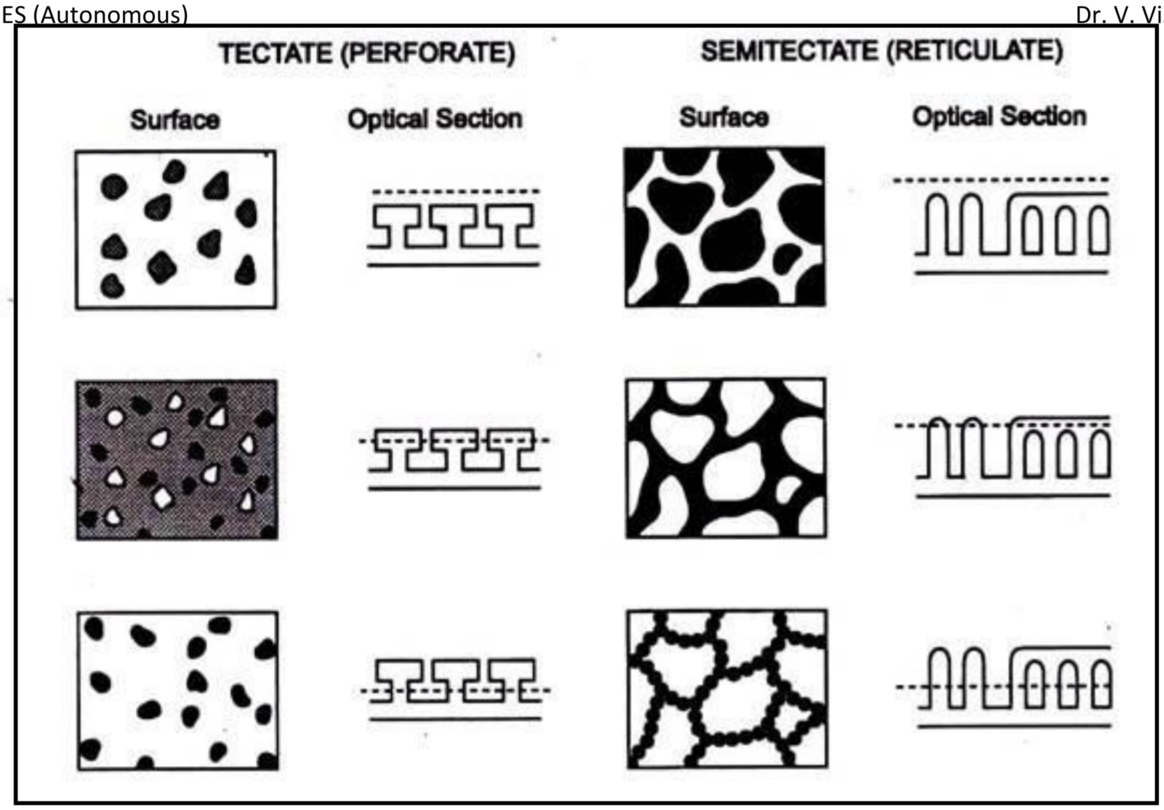
11. <u>Concordant</u> – It is a pattern in a tectate pollen grain in which the arrangement of the columellae is the same as that of the elements upon the tectum. Eg. *Lilium*. (Fig N)
12. <u>Discordant</u> – It is a pattern in a tectate pollen grain in which the arrangement of the columellae is different from that of the elements on the tectum. Eg. *Geranium*. (Fig O)



XI. LO – ANALYSIS

An optical section does not always make the fine structure of the sexine as clear as one might expect. A careful focusing through the sculpturing and patterning presented in a surface view of the grain provides a good deal of information. Erdtman (1952) proposed the term LO – analysis, which is derived from two Latin words '*lux*' means light and '*obscuritas*' means darkness. It is a method of analyzing patterns of sexine organization by means of light microscopy. This method is valuable for elucidating exine patterns.

The surface types show any holes or lower areas to be dark and any raised areas or projecting elements to be light. On focusing carefully down through the exine their appearance would change due to a changing that diffraction images produced. For example, when focused at high level, raised sexine elements appear bright, whereas holes in the tectum are relatively dark. At lower focus, holes become lighter and the sexine elements become darkened.



If a reverse sequence occurred i.e. a pattern of ornamentation that appears to show 'dark islands' at high focus and become bright at low focus, it is given the term 'OL – pattern'. This system works very well as long as the pollen grains are embedded in such a medium having lower refractive index.

XII. SIGNIFICANCE OF POLLEN MORPHOLOGY

1. Morphological characteristics of pollen grains manifested in outermost pollen wall (exine).
2. Stratification of exine along with number, position and character of apertures have been used to classify pollen grains.
3. Orientation of polarity is an important criterion in identification and description of pollen grains.
4. On the basis of apertural characters along with shape, size, surface ornamentation of exine, a comparative study of pollen grains is very useful in systematic consideration.
5. All these aspects and phenomena are very important in research dealing with extant as well as extinct pollen grains.
6. The use of SEM, ultramicrotomy and TEM has aided a new dimension to pollen / spore research.
7. The NPC classification of pollen is done according to Linneaus' sexual system leading to phylogenetic approach to the pollen classification.
8. Pollen and spore morphology deals with borderline fields between palynology and taxonomy, cytology, genetics and other related fields.