Palynology

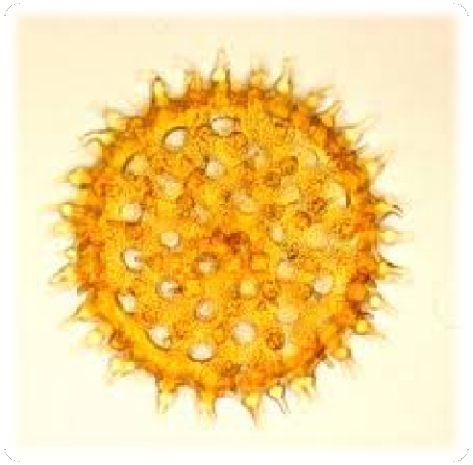
Princy

Palynology?.....

- Palynology, a word coined by Hyde and Williams (1944), was defined by them as "the study of pollen and other spores and their dispersal, and applications thereof'.

- The term includes both modem and fossil pollen and spores.

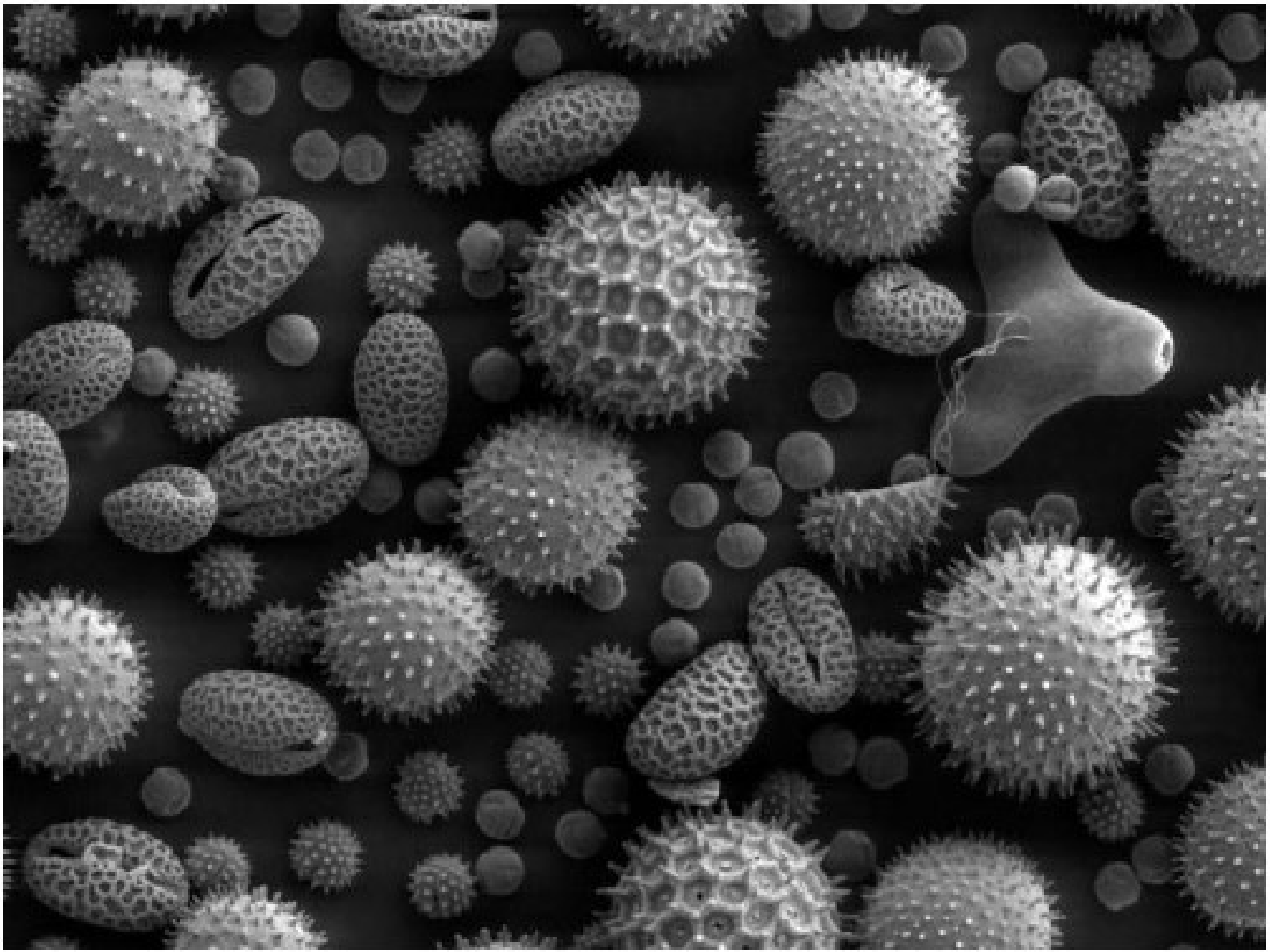
- The word “palynology” has been adapted from a Greek word ‘*Paluno’* that means “sprinkled”. Thus, palynology is the study of small *sprinkled things.*



- The glossary of pollen and spore terminology was first presented to the International Palynological Community (IPC)

- **POLLEN:**
- The microspores of seed plants (Linnaeus, 1751).

- **SPORES:**
- A general term for the usually microscopic, unicellular, asexual, re- productive units of cryptogams.



Scanning Electron Microscope (SEM) image of miscellaneous pollen particles

A brief history

- 1640 – **Nehemiah Grew** – 1st microscopically observed pollen in Britain.

- 1809 – **Robert Brown** – 1st noted the importance of pollen in systematic studies of spermatophytes.

- 1838 – **Goeppert** – 1st described fossil pollen/spores.

- 1873 – **Dr. D. D. Cunningham** – the first report of an illustrated account of airborne bio-particles including pollen grains, fungal spores, insect fragments, scales from Calcutta.

- 1884 – **Schopf *et al***., - 1st microphotograph of fossil spore (*Reinschospora*) was published.

- Holocene sediment analysis for pollen –

  by **Gunnar Erdtman – Father of Palynology**

  Knut Faegri

  J. Iversen

  Franz Firbas etc.

Scanning Electron Microscope

+

Transmission Electron Microscope

+

Ultramicrotome

} **New era of Palynology**

Palynology as an interdisciplinary science

- In earlier literature palynology was only restricted to the study of pollen grains and spores.

- Presently it is considered as an interdisciplinary science which deals with the study of extant and extinct ***palynomorphs***.

Applications

- **1. Palynotaxonomy and evolutionary studies.**

- **2. Aerobiology and Allergy study** – involves geographic distribution and seasonal production of pollen and its impact on susceptible individuals causing pollinosis.

- 3. Melissopalynology – study of pollen and spores found in honey.

- **4. Forensic palynology** – study of pollen and other palynomorphs for evidence in criminal investigations

- 5. Biostratigraphy and geochronology - to correlate strata and determine the relative age of a given bed, formation or stratigraphic sequence.

- 6. Palaeopalynology – to reconstruct the past vegetation (land plants) and marine and freshwater phytoplankton communities, and thus interpret past environmental and palaeoclimatic conditions.

- 7. Palynology for improvement of crop plants.

Applications

- **Geology**
- **The Palaeoenvironment**
- **Geoengineering/geoarchaeology**
- **Archaeology**
- **Human diet**
- **Palaeobotany**
- **Oil industry**

Gunnar Erdtman – Father of Palynology

Father of Indian palynology

- Parmeshwaran Krishnan Kutty Nair (P. K. K. Nair)

Palynology depends mainly on four characteristics of pollen and spores:

(1) Their greater resistance to degradation than most other plant parts, thus facilitating their survival as fossils

(2) Their small size, mostly less than 200 microns, so that they are transported and deposited as sedimentary particles

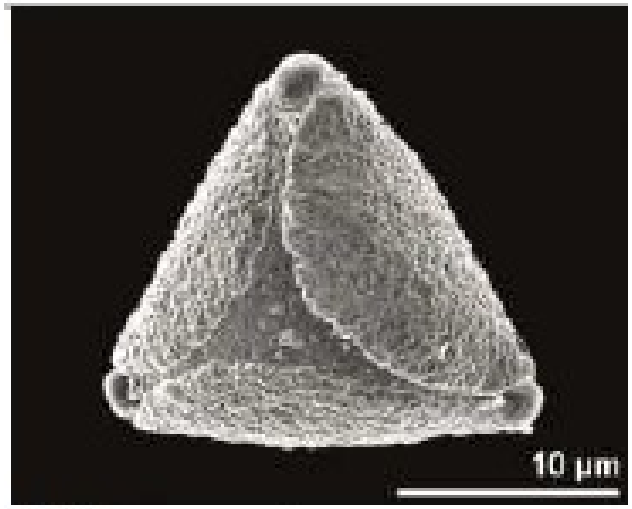
(3) Their morphological complexity, so that can be distinguished and characterized

(4) Their production in enormous numbers.

Terminologies….

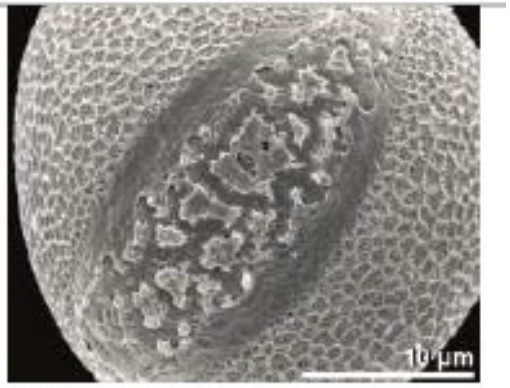
- Sporoderm:- The covering or coating of a spore.

- Aperture:- is a region of the pollen wall that differs significantly from the rest of the wall in its morphology and/or anatomy, and is presumed to function usually as the site of germination and to play a role in harmomegathy.

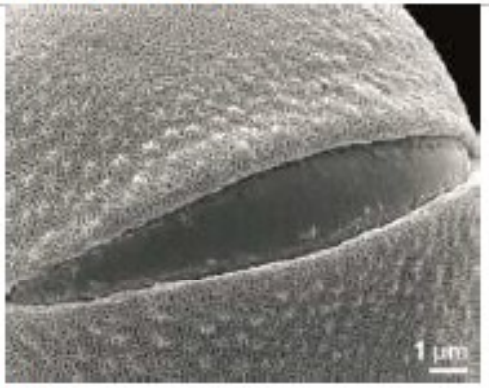


Callistemon coccineus

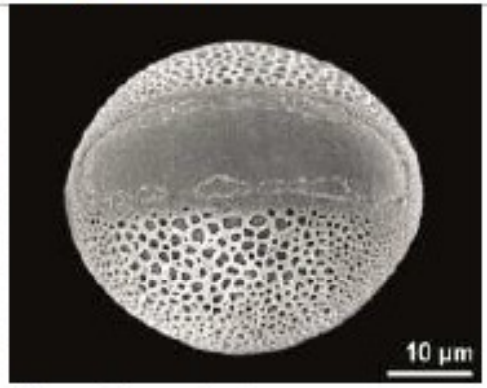
Convolvulus tricolor



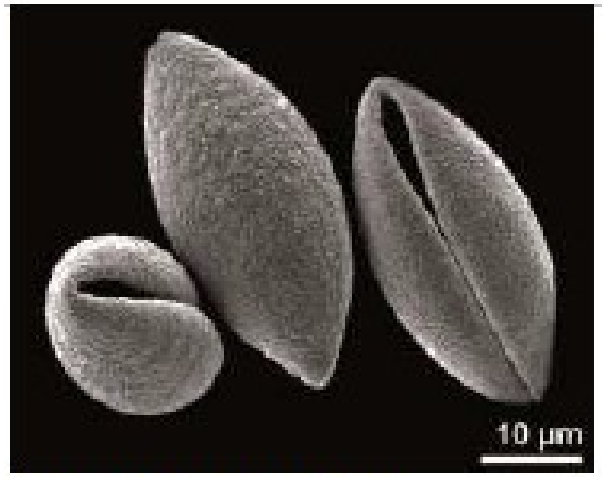
Galeopsis tetrahit



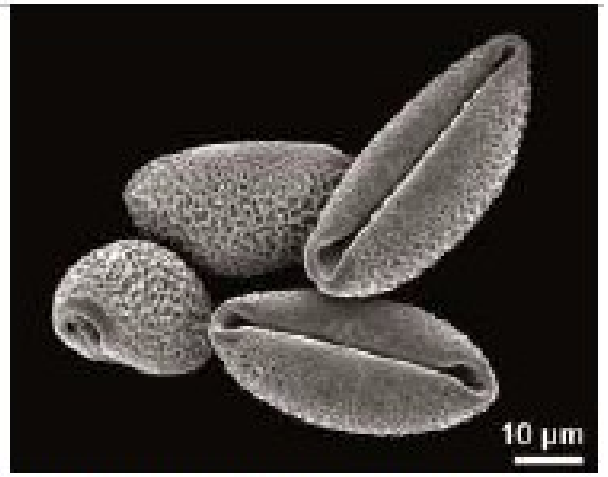
Melampyrum subalpinum



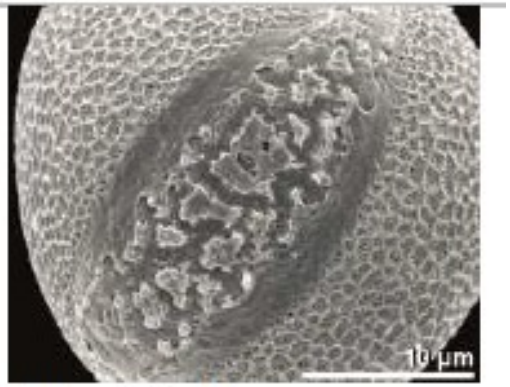
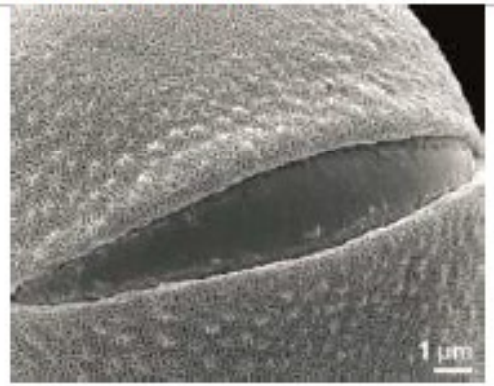
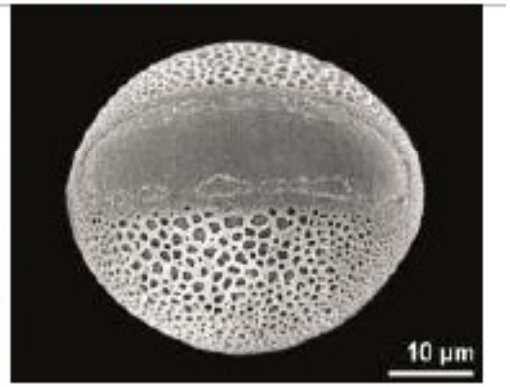
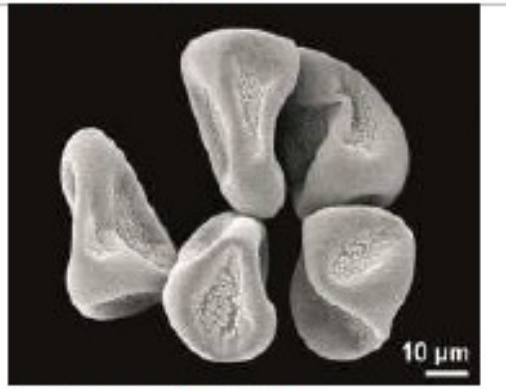
Doryanthes palmeri



Ginkgo biloba (dry pollen)



Lysichiton americanus (dry pollen)

aperture membrane	exine layer covering an aperture; aperture membrane can be smooth or ornamented Comment: The terms "smooth" and "ornamented" should be used when the feature is remarkably expressed.		
aperture membrane ornamented		 *Convolvulus tricolor*	 *Galeopsis tetrahit*
aperture membrane smooth		 *Melampyrum subalpinum*	 *Doryanthes palmeri*
aperture sunken	infoldings of dry pollen as a consequence of harmomegathy	 *Orthilia secunda* (dry pollen)	 *Carex alba* (dry pollen)

- In general, the pollen wall (sporoderm) of seed plants consists of two main layers:

- The **outer exine** and the **inner intine.**
- The exine consists mainly of sporopollenins, which are acetolysis- and decay-resistant biopolymers.

- The intine is mainly composed of cellulose and pectin.

Sporopollenin – diamond of the plant kingdom

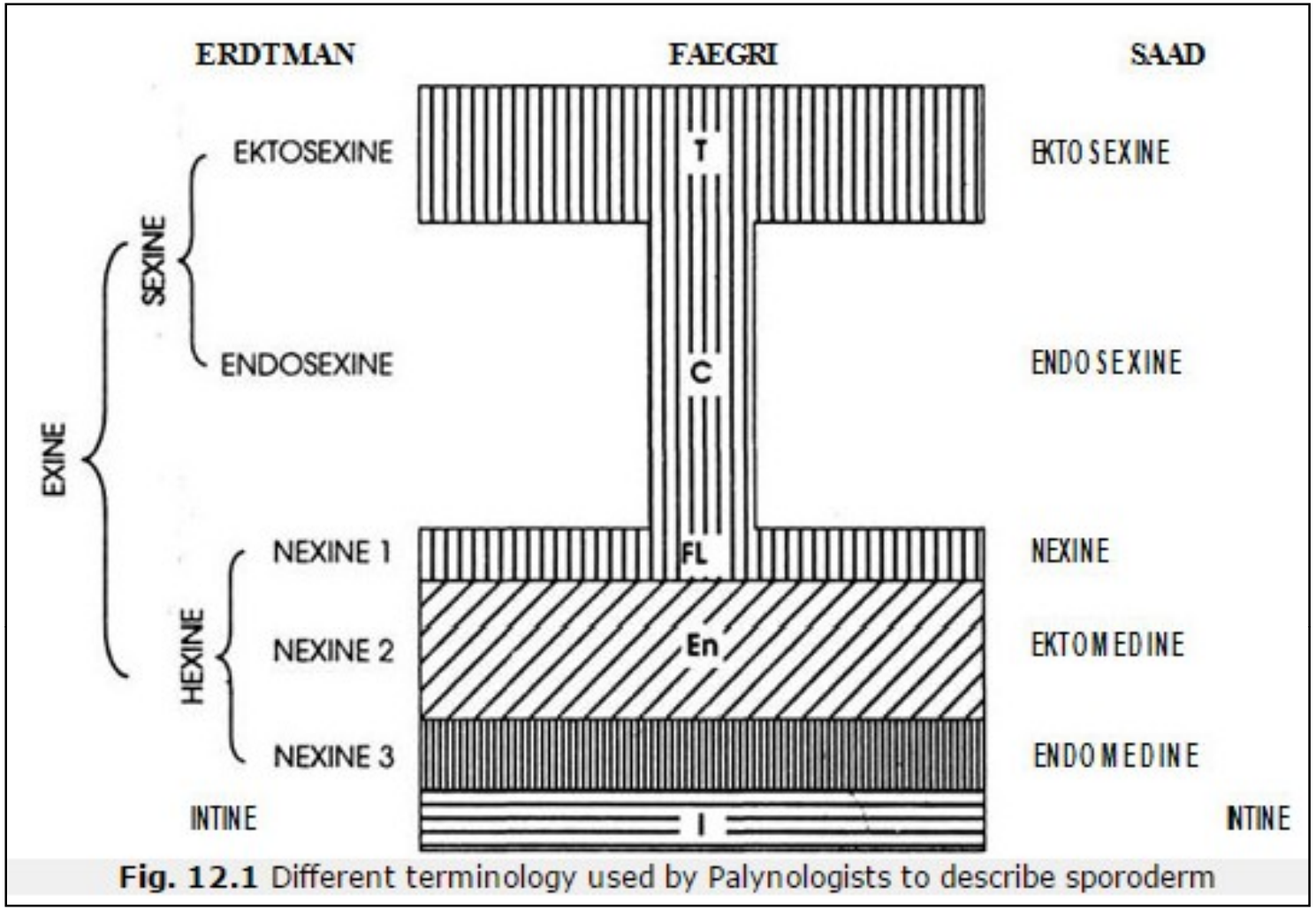


Fig. 12.1 Different terminology used by Palynologists to describe sporoderm

Different palynologists use different terms to describe the coats of pollen grains. Erdtman described the outer coat as exine and inner as intine. The exine consists of an outer layer, the sexine ('S' for sculptured wall of exine) and inner layer, the nexine ('n' for non sculptured). The sexine may consist of layers, the outer ektosexine and an inner, the endosexine. The nexine may be divided into three layers and known from the outer side towards the inner side as nexine 1, nexine 2 and nexine 3.

Pollen Wall Structure

Knut Faegri

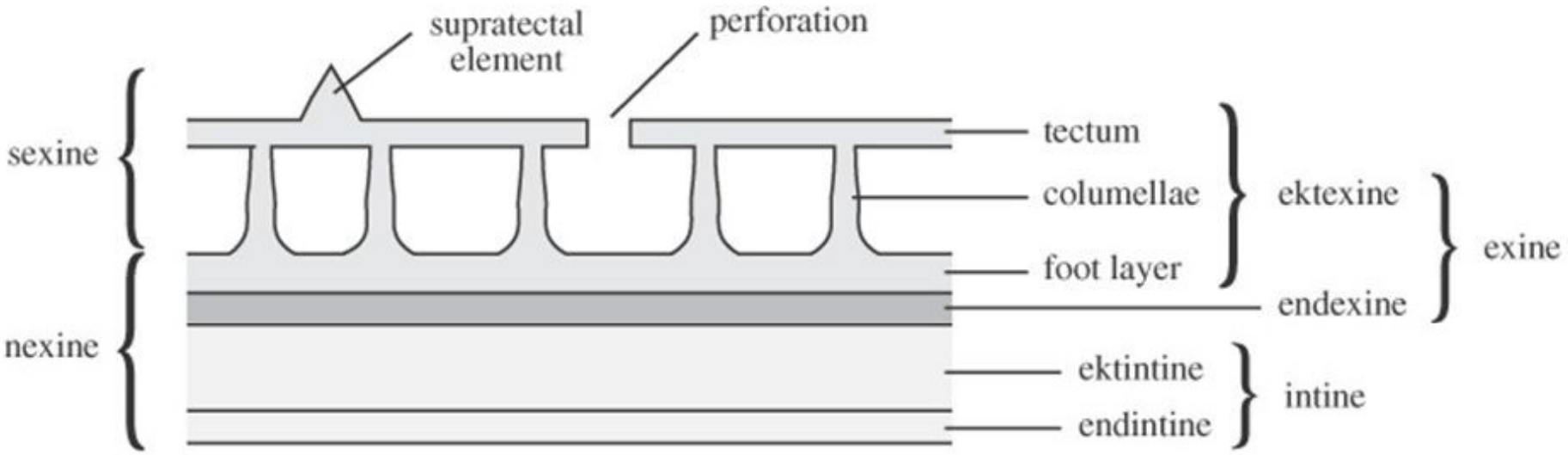


Figure 12.8 Pollen wall structure.

Tectate –columellate pollen wall

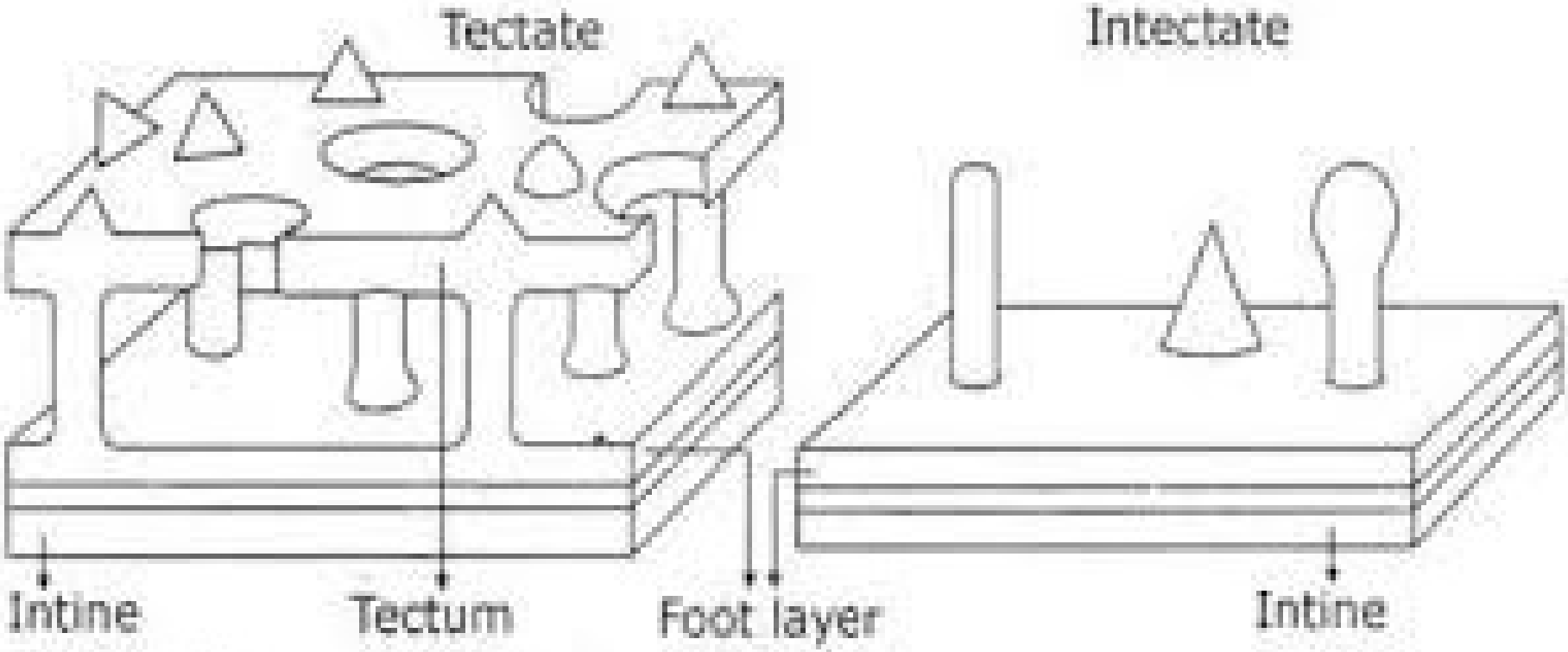
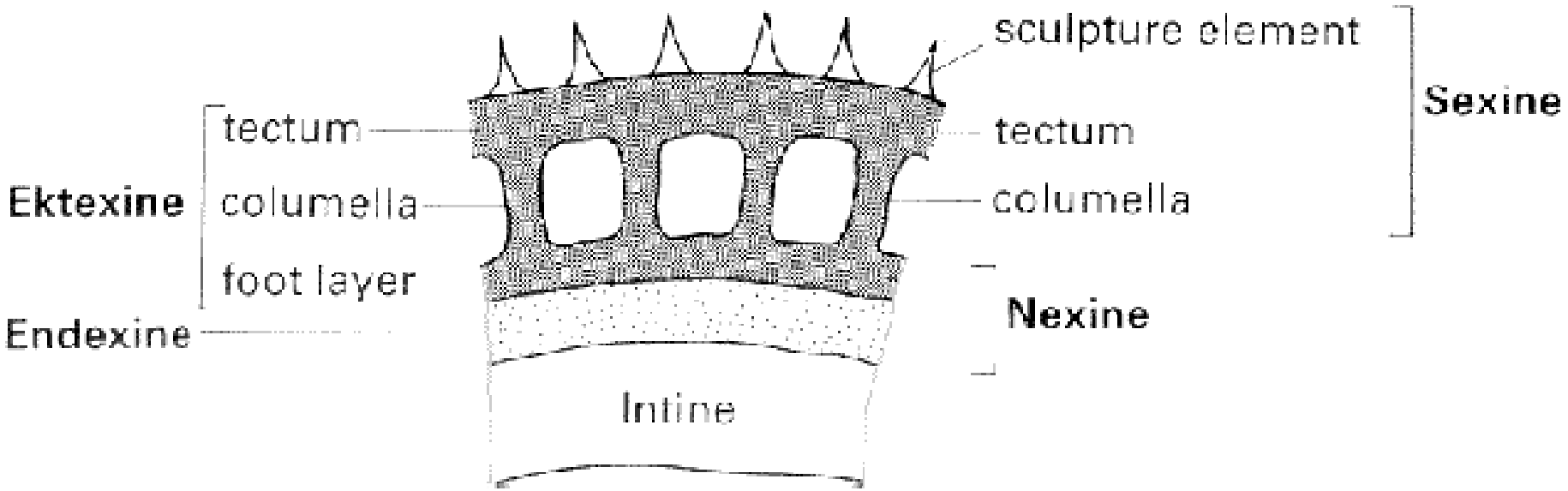


Figure 4.4

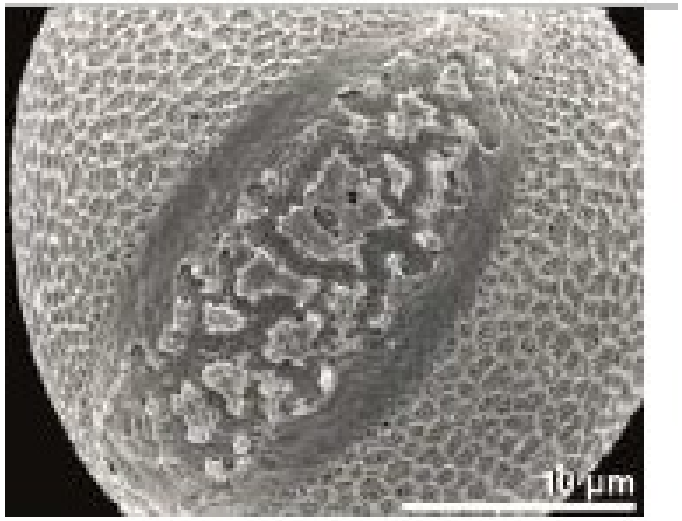
Diagrammatic representation of three dimensional view of a portion of sporoderm illustrating tectate and intectate pollen.


sculpture element
Sexine
tectum
tectum
Ektexine
columella
columella
foot layer
Nexine
Endexine
Intine

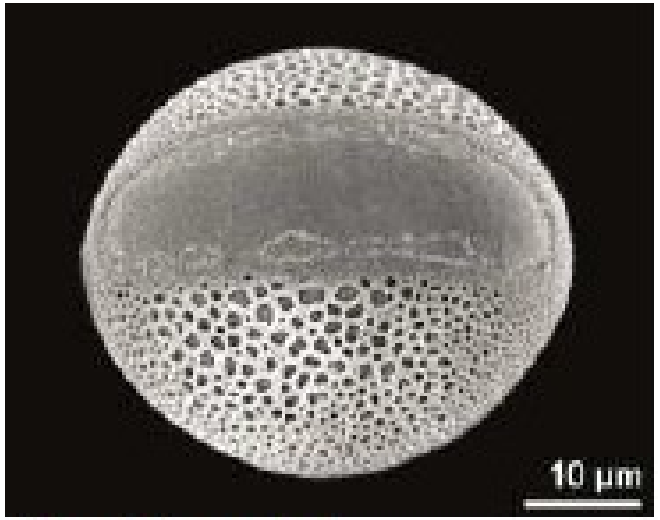
- Furrow like aperture when sited at one of the two (distal or proximal) poles of the grain is referred to as a **sulcus.**

- Whereas if such apertures are located along the equator and their number per grain is two or more, they are termed as **colpi** (sing: **colpus**)

- Colpi - are any thinning, thickening or other modification of the wall of pollen or spores that serve as an exit for its contents or to allow shrinking and swelling of the grain in response to changes in moisture content.
- Colpi are fissure-like apertures while pores are round.



Galeopsis tetrahit



Doryanthes palmeri

- **Laesura: -**The proximal aperture of trilete and monolete spores. Trilete spores possess three laesurae which radiate from the proximal pole and monolete spores possess one laesurae which has its centre at the proximal pole (Erdtman, 1952).

- Lete is always used as a suffix to denote the absence or presence of laesura(e). Laesura is the scar mark of a spore. The mark represents the original contact of spores at their tetrad stage.

Trilete spores

Monolete spores

- The laesura is the mark at the proximal pole of the spore, and is an 'aperture' in the exine.

- In tetrahedral spores it is triradiate (trilete laesura), and in bilateral spores appearing as a straight line ('monolete' laesura).

- Only these two types commonly occur among modern pteridophyta, and their spores are either trilete or monolete, ('alete', spores, that is devoid of a laesura, are reported infrequently, for example Equisetum).

- Pore - A general term applied in palynology to a circular or elliptic aperture

- **Monoporate: -** Pollen grains provided with a single pore (Traverse, 1988).

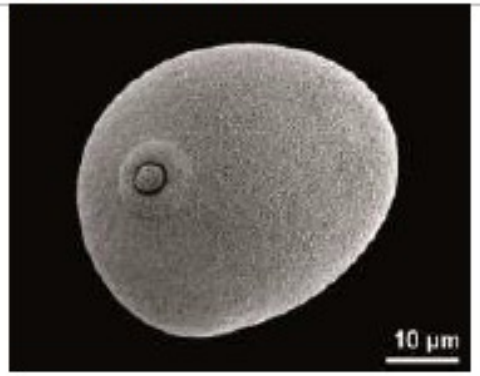
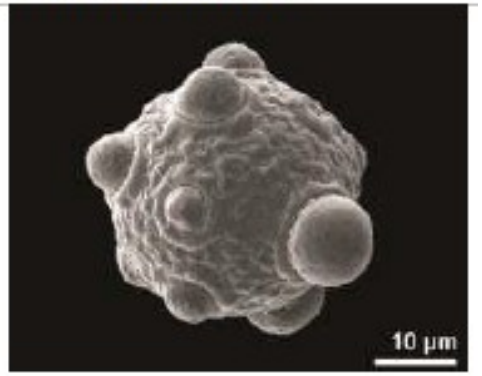
- **Monosulcate:-** Having a single germinal furrow or colpus or sulcus.

- **Tricolpate / tricolprate :-** Three ectocolpi, three compound apertures

- **Anastomose:-** Muri radiate out in numerous directions.

- **Muri:-** A ridge that is part of the ornamentation

- **Rugulate**:- Ornamentation pattern consisting of radial projections elongated

		Callistemon coccineus	*Leucadendron brunioides*
annulate	pollen grain with an annulus or annuli	 *Secale cereale* (ulcerate)	 *Fumaria vaillantii* (pantoporate)
annulus (pl. annuli)	ring-like thickening of the pollen wall surrounding a porus or ulcus	 *Trichosanthes anguina*	
aperture	region of the pollen wall which differs significantly morphologically and/or anatomically from the rest of the pollen wall, presumed t function usually as germination site and to play a role in harmomegathy		

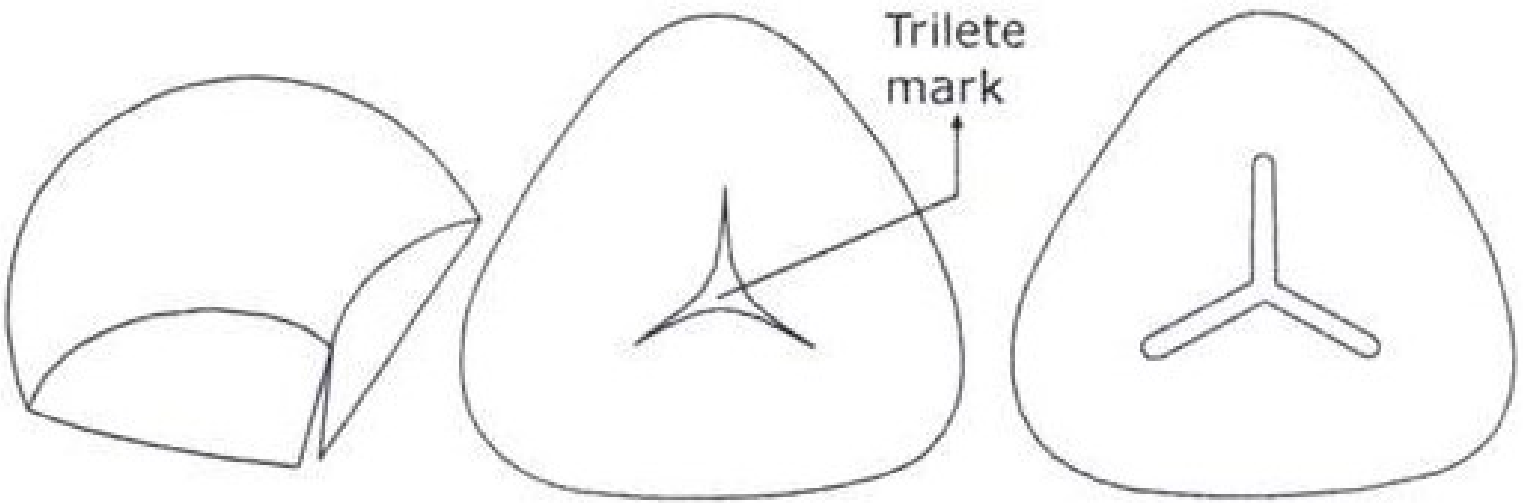


Figure 4.20

Diagrammatic representation of different types of aperture.

Pollen characters have been grouped into seven categories

1. Aperture type
2. Pollen wall architecture
3. Pollen unit
4. Polarity
5. Symmetry
6. Shape
7. Size

Pollen morphology

- A diagrammatic representation of the main morphological features of a palynomorph (preferably pollen grains or spores) is called **palynogram**.

Mature pollen is shed in **dispersal units**. The post-meiotic products either remain permanently united or become partly or usually completely disintegrated.

- In the latter case the dispersal unit is a single pollen grain, a **monad**;

- If the post-meiotic products remain united, **dyads** (a rare combination), **tetrads** or **polyads** (**massulae**, **pollinia**) are the result.

- **Pollinaria** are dispersal units of two pollinia including the sterile, interconnecting appendage.

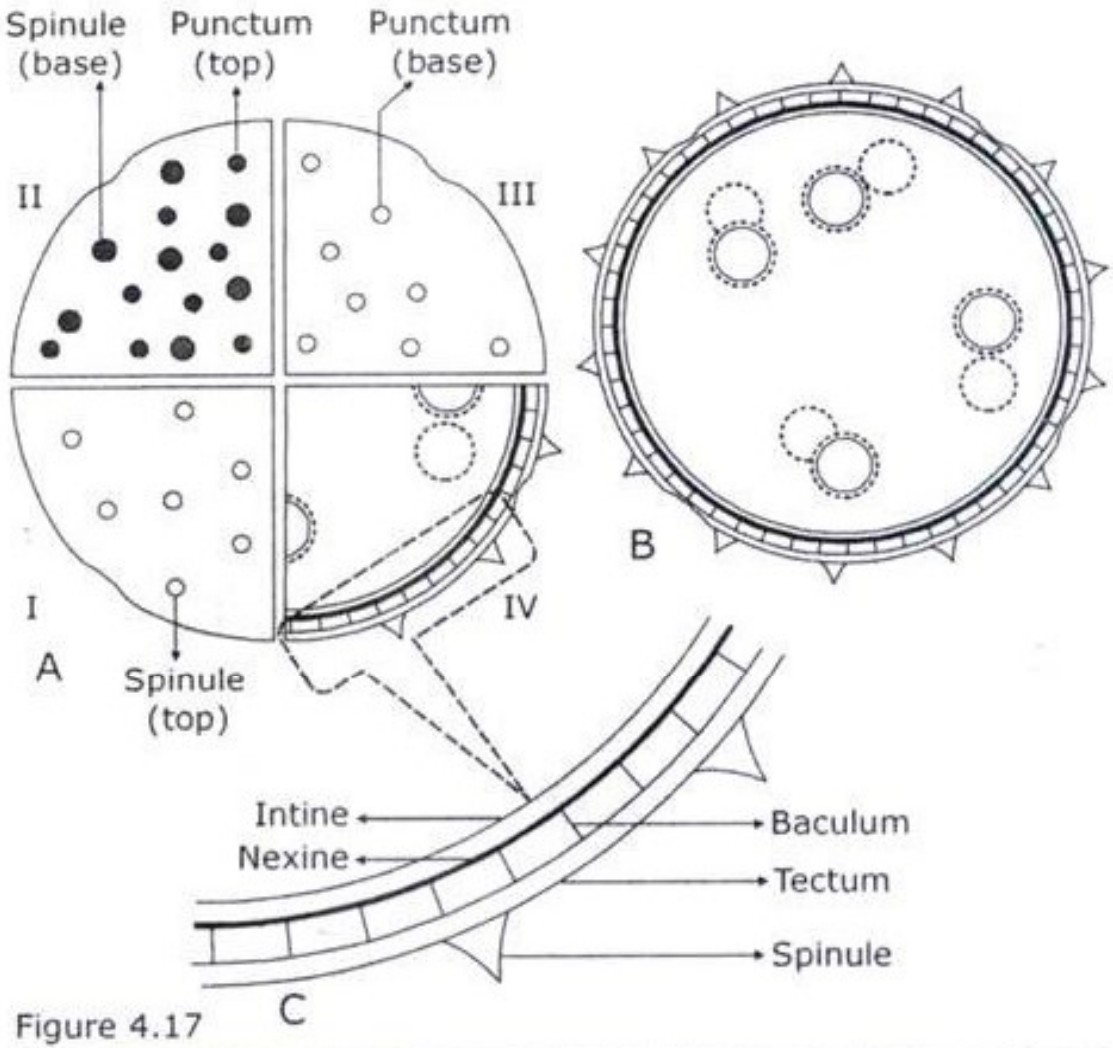


Figure 4.17

Diagram illustrating palynogram. *Drypis spinosa*. A. Pollen in four different foci. I. First focus showing top of spinule. II. Second focus showing base of spinule and top of punctum. III. Third focus showing base of punctum. IV. Portion of pollen in optical section that is magnified in C. B. General view of pollen showing the distribution of apertures and optical section. C. A portion of pollen showing layers of exine and intine.

1. Pollen Units:

- The pollen grains are produced within the anther of the flower.

- Pollen mother cells originate from the sporogenous tissue of the anther which later divide meiotically to form four pollen grains called tetrad.

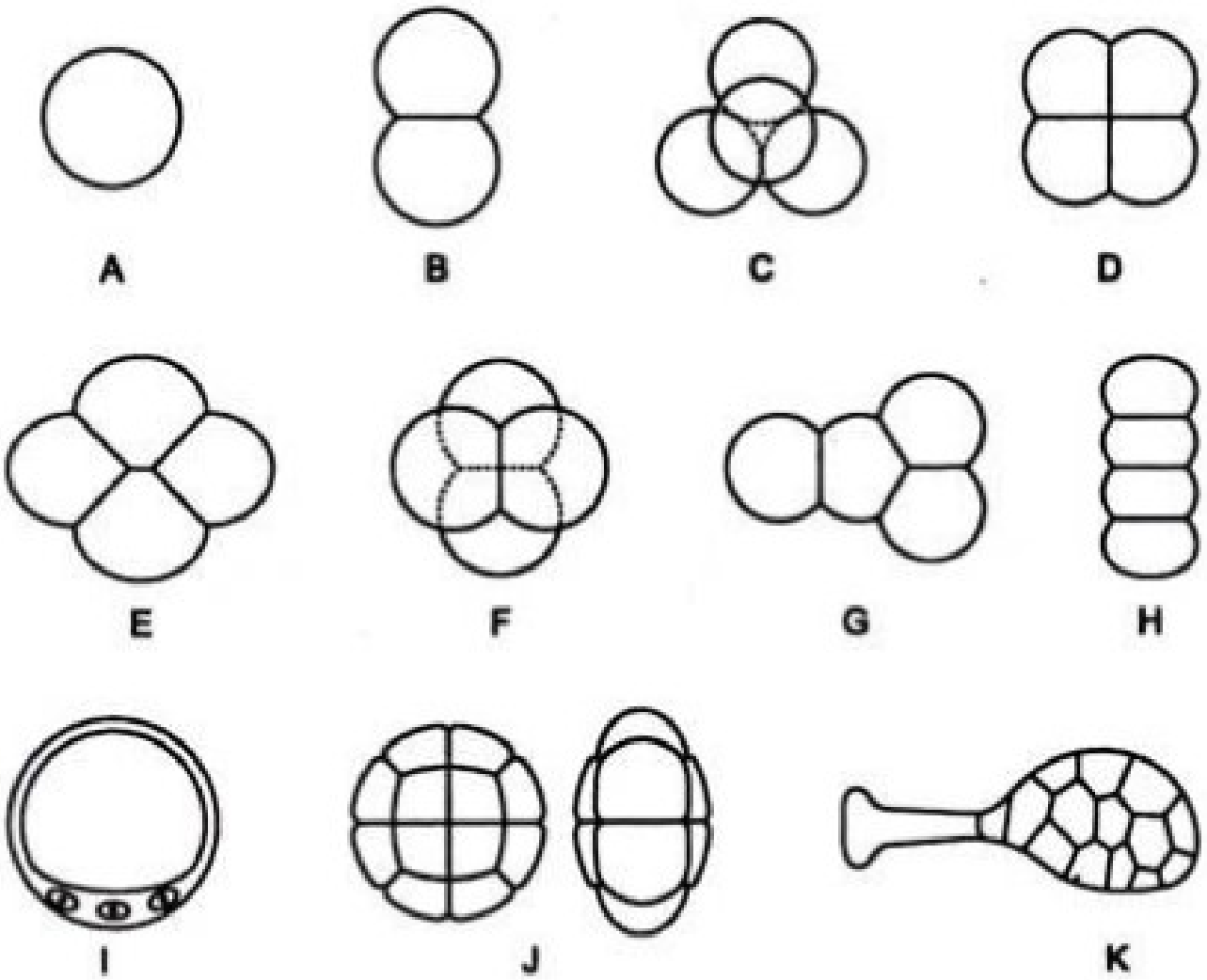
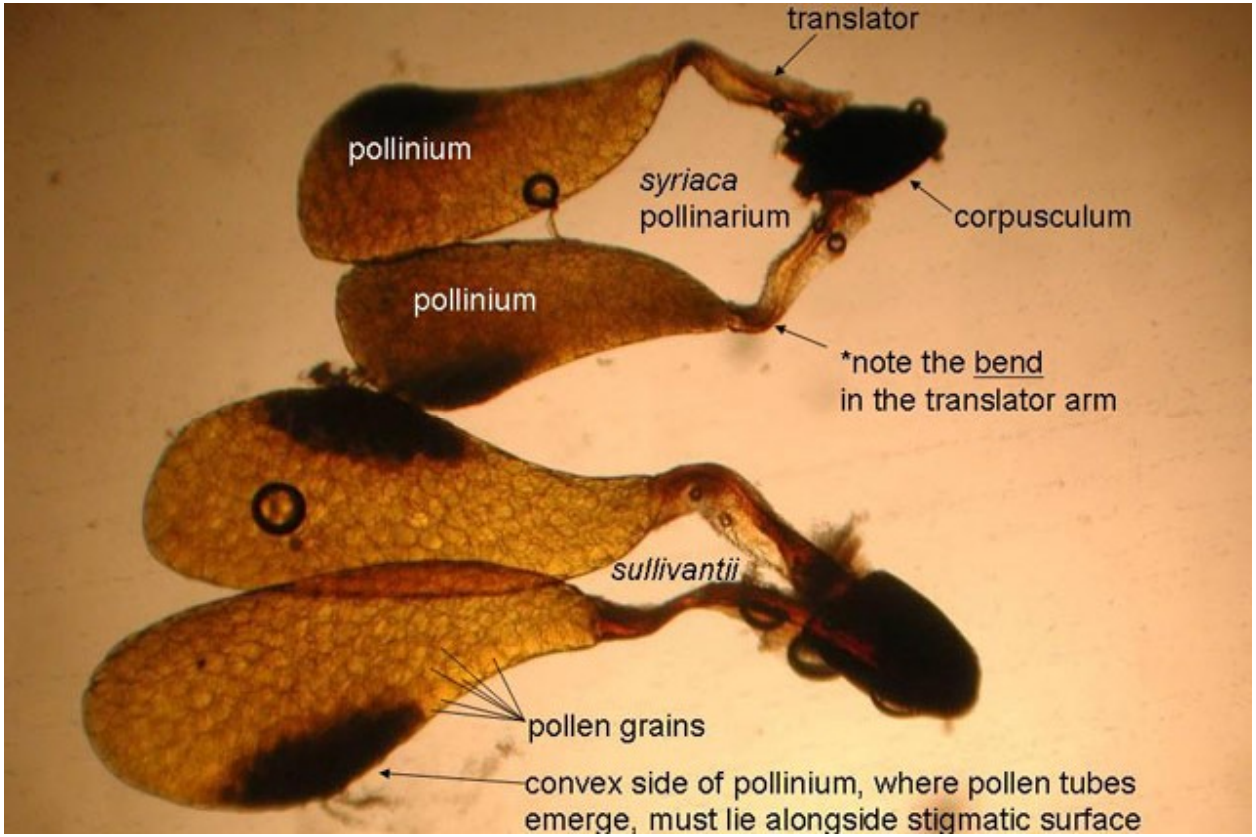


Fig. 4.1 : Pollen units (A = Monad, B = Dyads, C = Tetrahedral tetrad, D = Tetragonal tetrad, E = Rhomboidal tetrad, F = Decussate tetrad, G = T-Shaped tetrad, H = Linear tetrad, I = Cryptotetrad, J = Polyads, K = Pollinia)


translator
pollinium
syriaca
pollinarium
corpusculum
pollinium
*note the bend
in the translator arm
sullivantii
pollen grains
convex side of pollinium, where pollen tubes
emerge, must lie alongside stigmatic surface

2. Polarity:

- The orientation of polarity is an important criterion in identification and description of pollen grains, as apertural position is of primary phylogenetic and functional significance. 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 polar axis through the middle of the grain is the equatorial plane (equatorial diameter -ED).

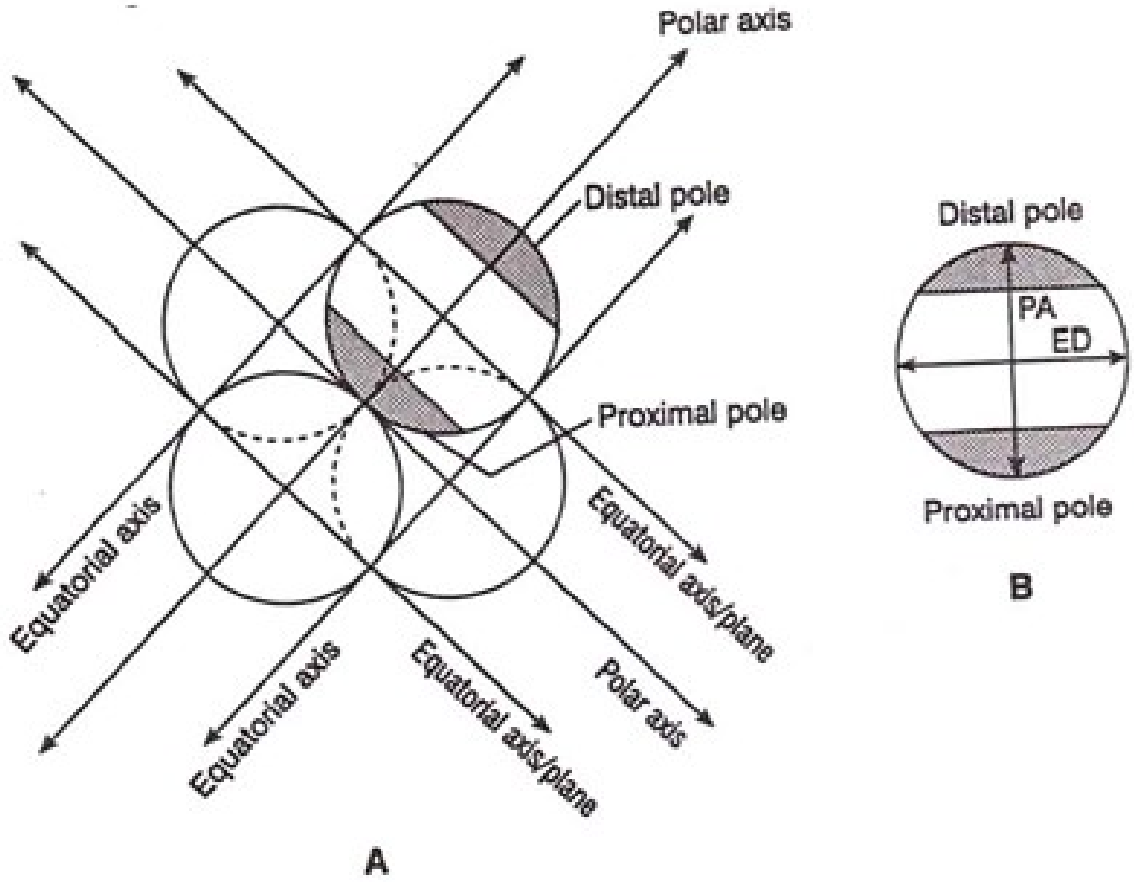
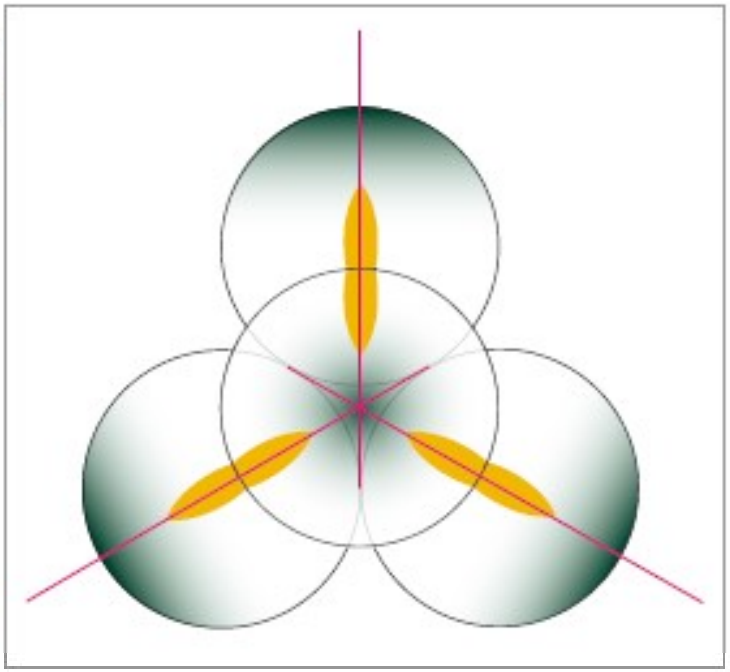
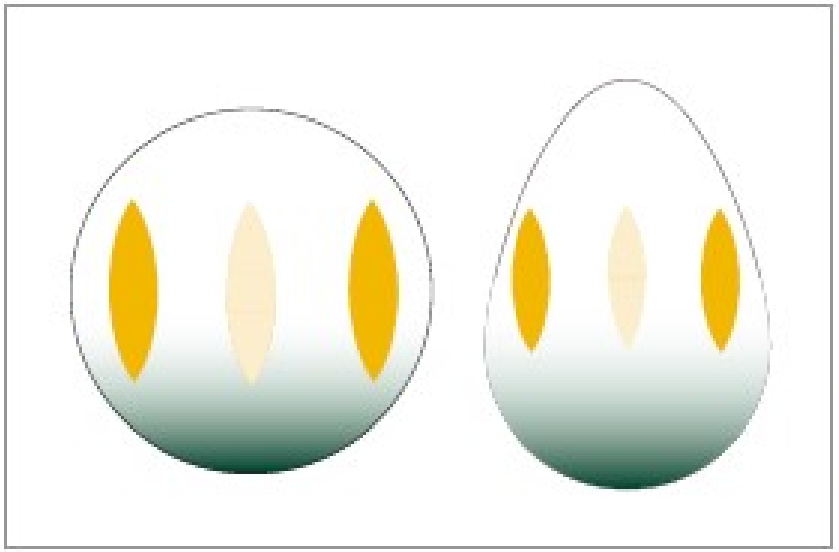


Fig. 4.2 : Polarity (A = Showing polarity in terad stage; B = Showing the length of polar axis (PA) and breadth of equatorial diameter (ED) in a monad grain)

Tetrad stage
orientation of
microspores



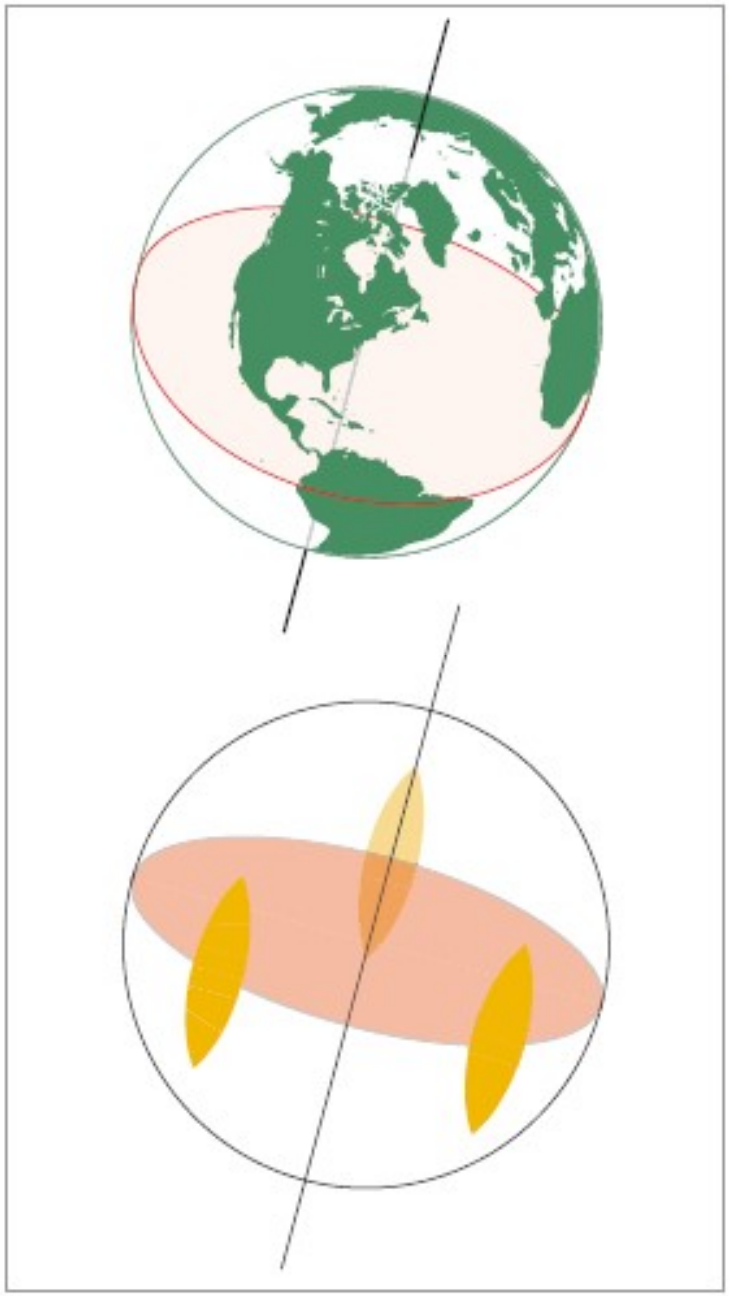
distal poles
shaded green



Polarity

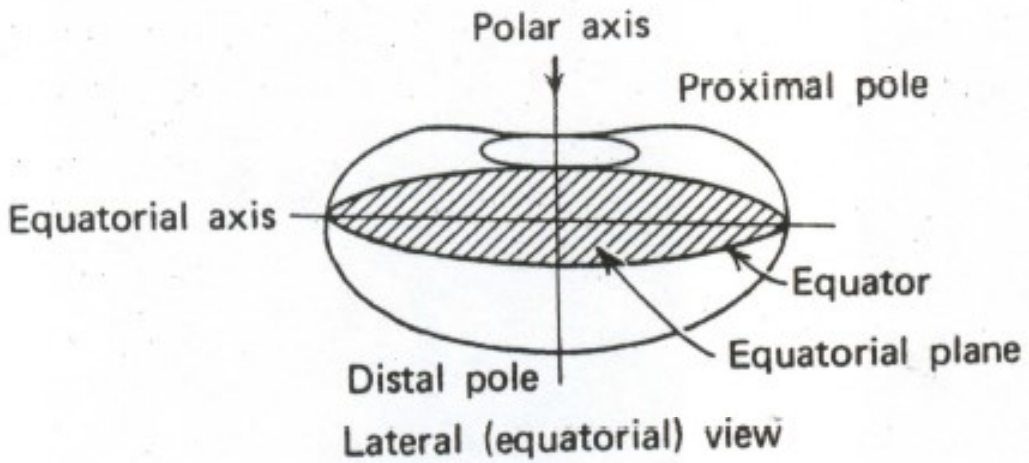
left:
isopolar

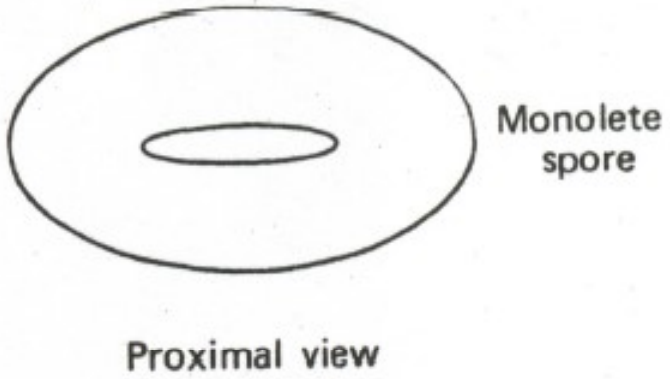
right:
heteropolar

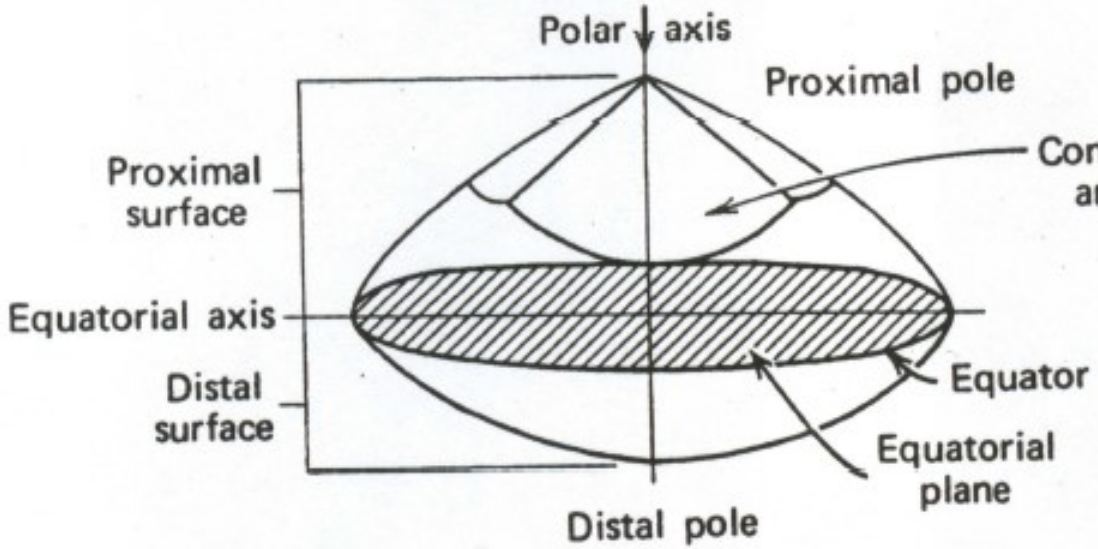


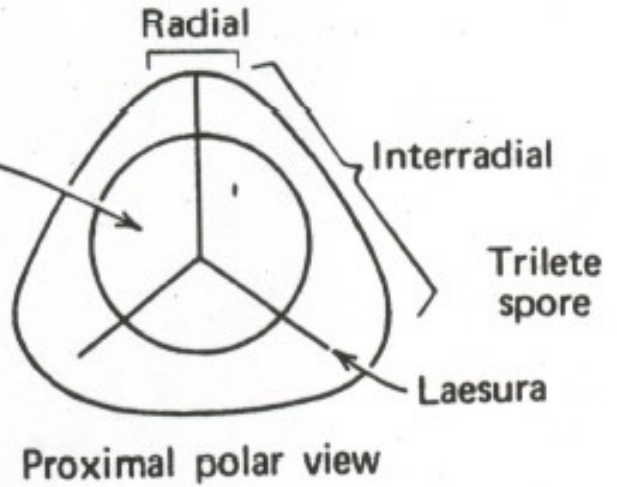
Polar axis and equatorial plane

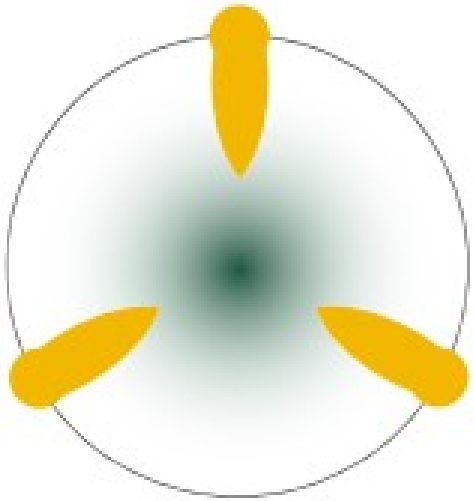
POLARITY AND SHAPE

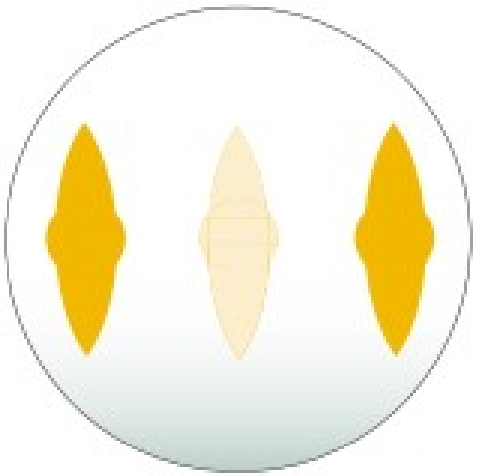


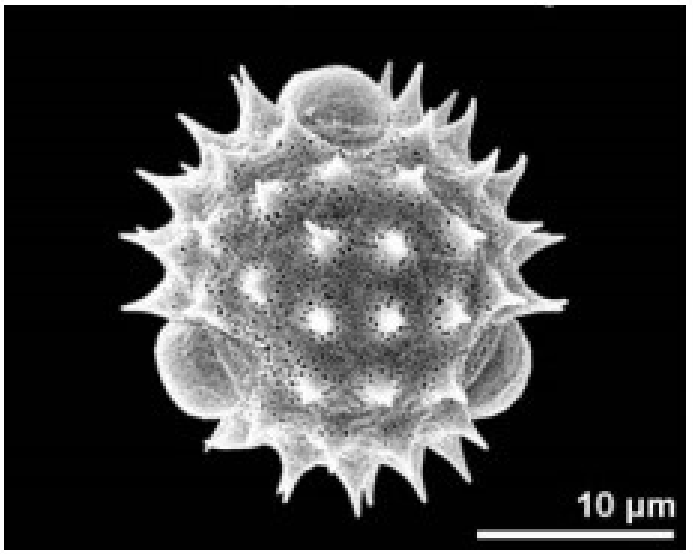


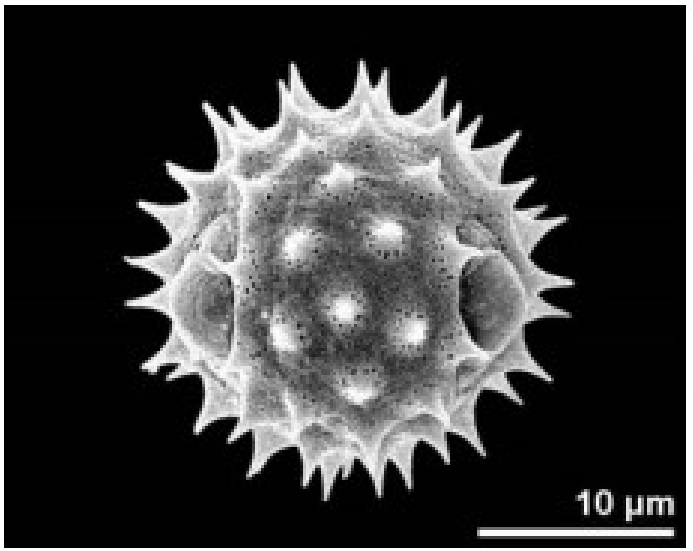












Pollen grain polarity dicots

Bellis perennis
Asteraceae

polar view

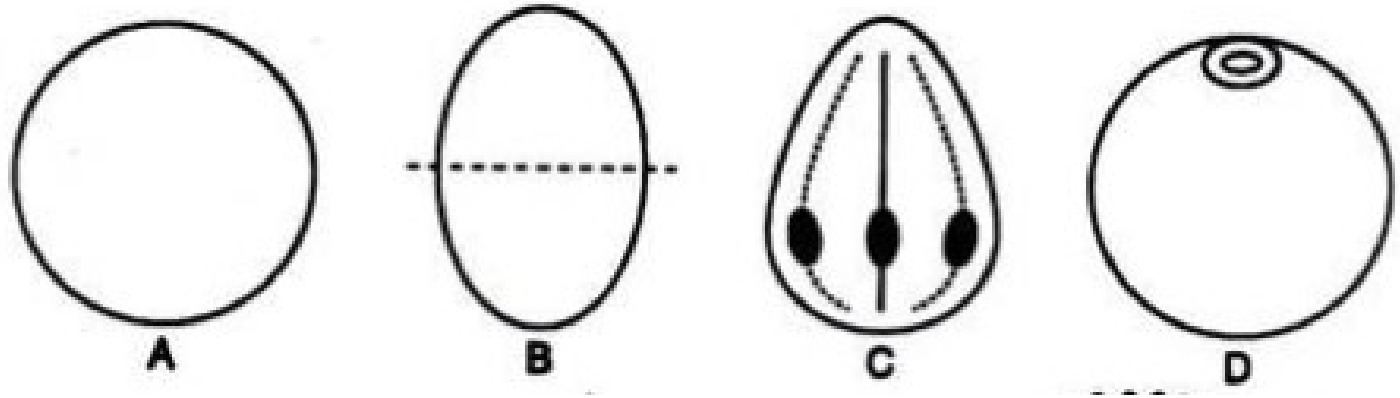
equatorial view

- The pollen grains maybe either apolar or polar.

- In apolar spores, poles or polar regions cannot be distinguished in individual spore (monad) after separation from tetrad.

- Among the polar types the pollen grains are either isopolar or heteropolar depending upon the demarcation between two equal or unequal polar faces, respectively.

- In isopolar grains the distal and proximal faces (above and below the equatorial plane) look alike.
- In heteropolar grains the two faces are distinctly different, either in shape, ornamentation or apertural system. Thus one face may have an opening (aperture) and the other not.



- A – Apolar
- B – Isopolar
- C&D -heteropolar

Impression mark

A mark on the proximal face of a pollen grain retained from the post-meiotic stage. This mark can be linear from tetragonal tetrads or Y-shaped from tetrahedral tetrads.

3. Symmetry:

- Pollen grains or spores are symmetric or asymmetric.

- The asymmetric grains are either
- non- fixiform (without fixed shape) or
- fixiform (with fixed shape). Asymmetrical grains have no plane of symmetry. They are rare in occurrence.

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

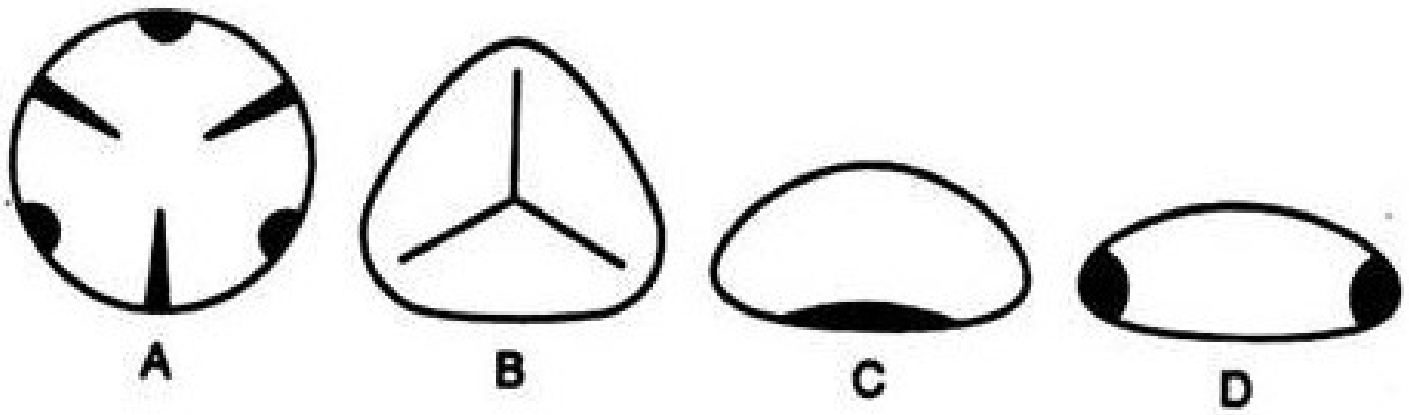


Fig. 4.4 : Symmetry (A & B = Radially symmetric, C & D = Bilateral)

4. Shape

- The shape of the pollen grains varies from species to species. Shape of the grains is found to be useful in spore/pollen identification.

- Pollen grains and spores are often described by the shape (non-angular and angular) of their outline both in polar and equatorial views.

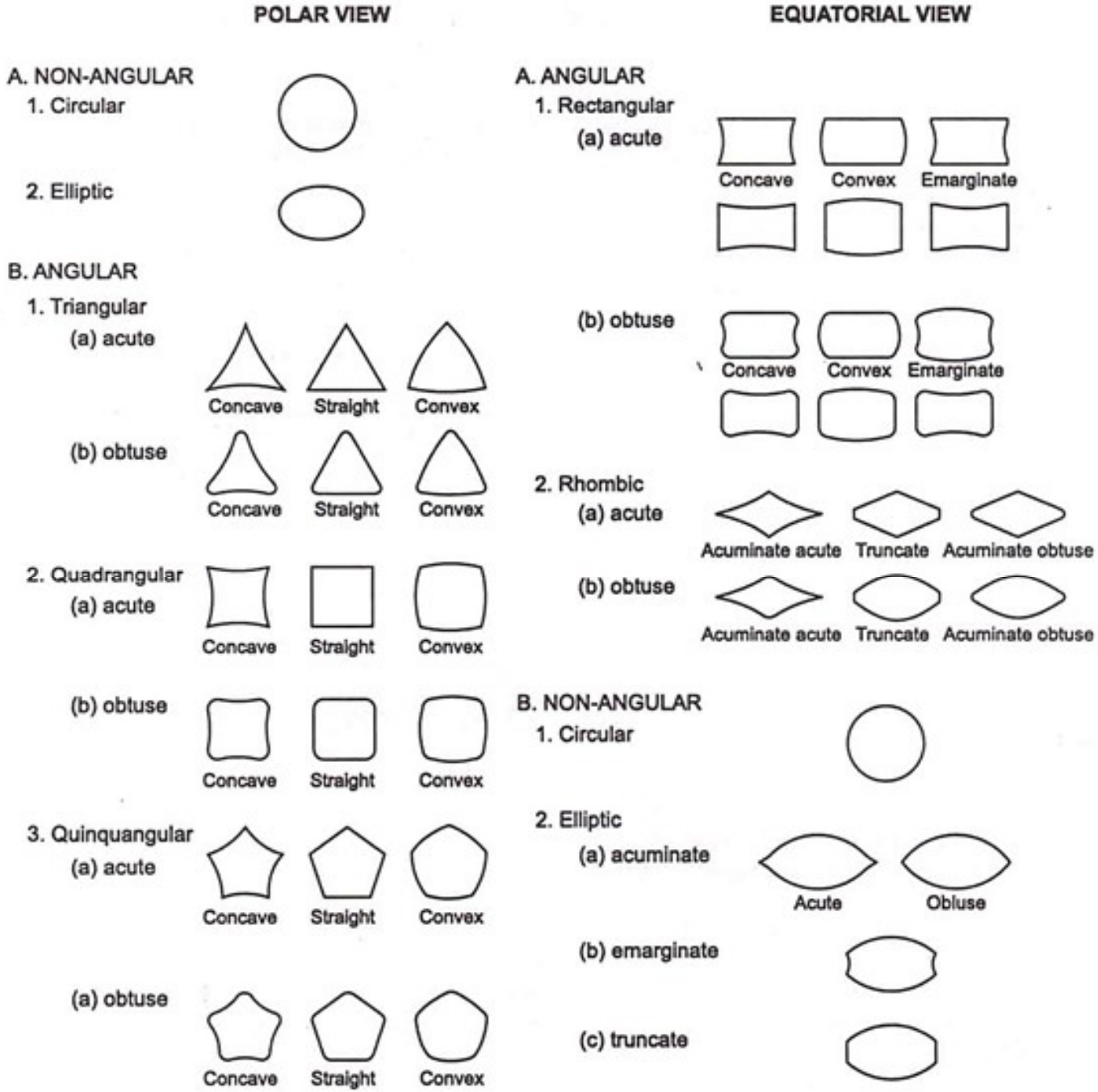


Fig. 4.5 :Shapes of grains in polar and equatorial views

Apertures

- **Morphologically aperture is an opening or thinning of the exine where the intine is usually thick; physiologically it is a germination zone or a harmomegathus.**

- With regard to their position the apertures are polar, global or meridional.

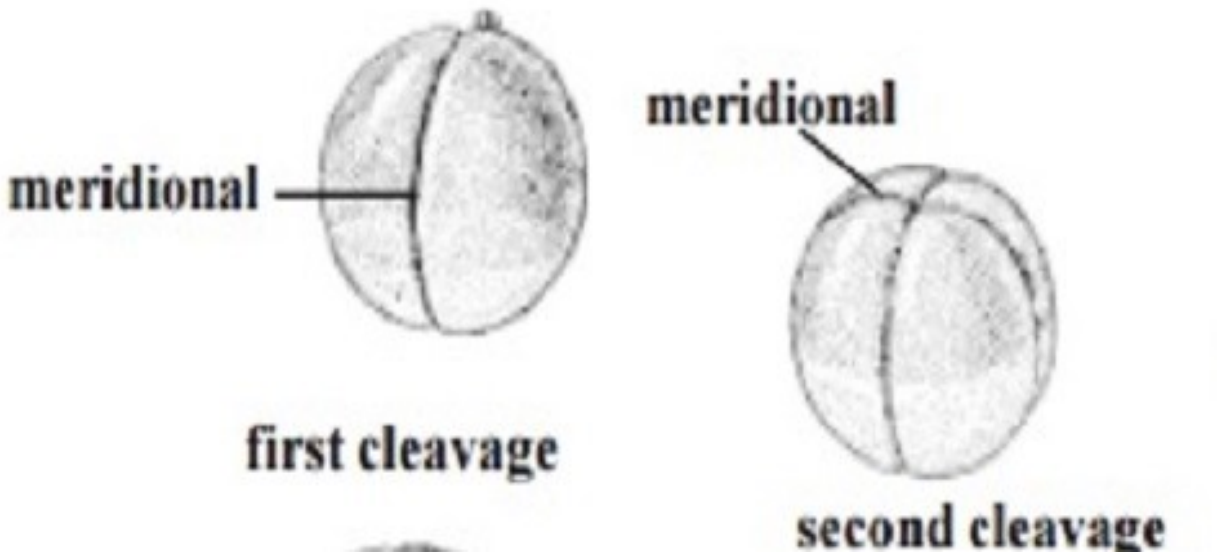
- The polar apertures are either monopolar (either in proximal or in distal pole) or bipolar (both in proximal and distal face).

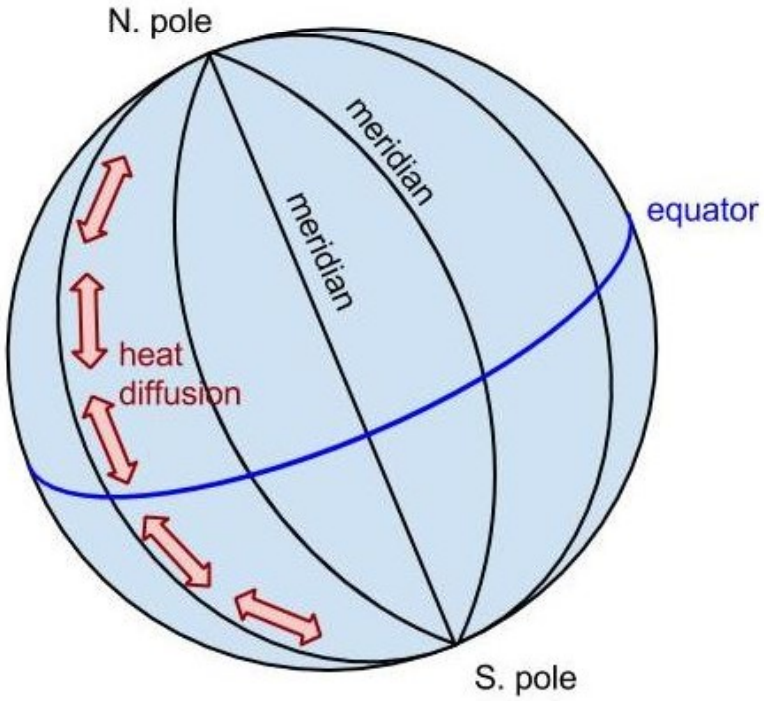
- Global apertures are uniformly distributed over the pollen/spore surface.

- Equatorial apertures are meridionally arranged.

Functions of aperture

- Passage for the emergent pollen tube.
- Site of storage and release of gametophyte proteins including enzymes and recognition substances.
- Harmomegathy – volume change accommodations.


meridional
first cleavage
meridional
second cleavage


N. pole
meridian
meridian
equator
heat
diffusion
S. pole

NPC classification:

- G. Erdtman (1969) proposed NPC-System pollen/spore classification **based on the apertures,**
- Their Number (N-whether single or two or many),
- Position (P- polar: distal or proximal; global; meridional) and
- Characters (C – circular or elongated) with regard to microspore tetrad.
- Under this system the term ‘treme’ (aperture) has been used for preparing keys for the classification of the pollen grains/spores.

- The pollen number (N) groups are of nine types.
- The grain without aperture is named “Atreme” and is designated as No

- Depending upon the number of apertures, the types of pollen are Monotreme (N_1) with one aperture
- Ditreme (N_2) with two apertures;
- Tritreme (N_3) with three apertures,
- Tetratreme (N_4) with four apertures,
- Pentatreme (N_5) with five apertures,
- Hexatreme (N_6) with six apertures and
- Polytreme (N_7) having more than six apertures.

- Irregularly arranged spiral apertures over the surface of the pollen irrespective of their number are designated as ‘Anomotreme’ (N_8).

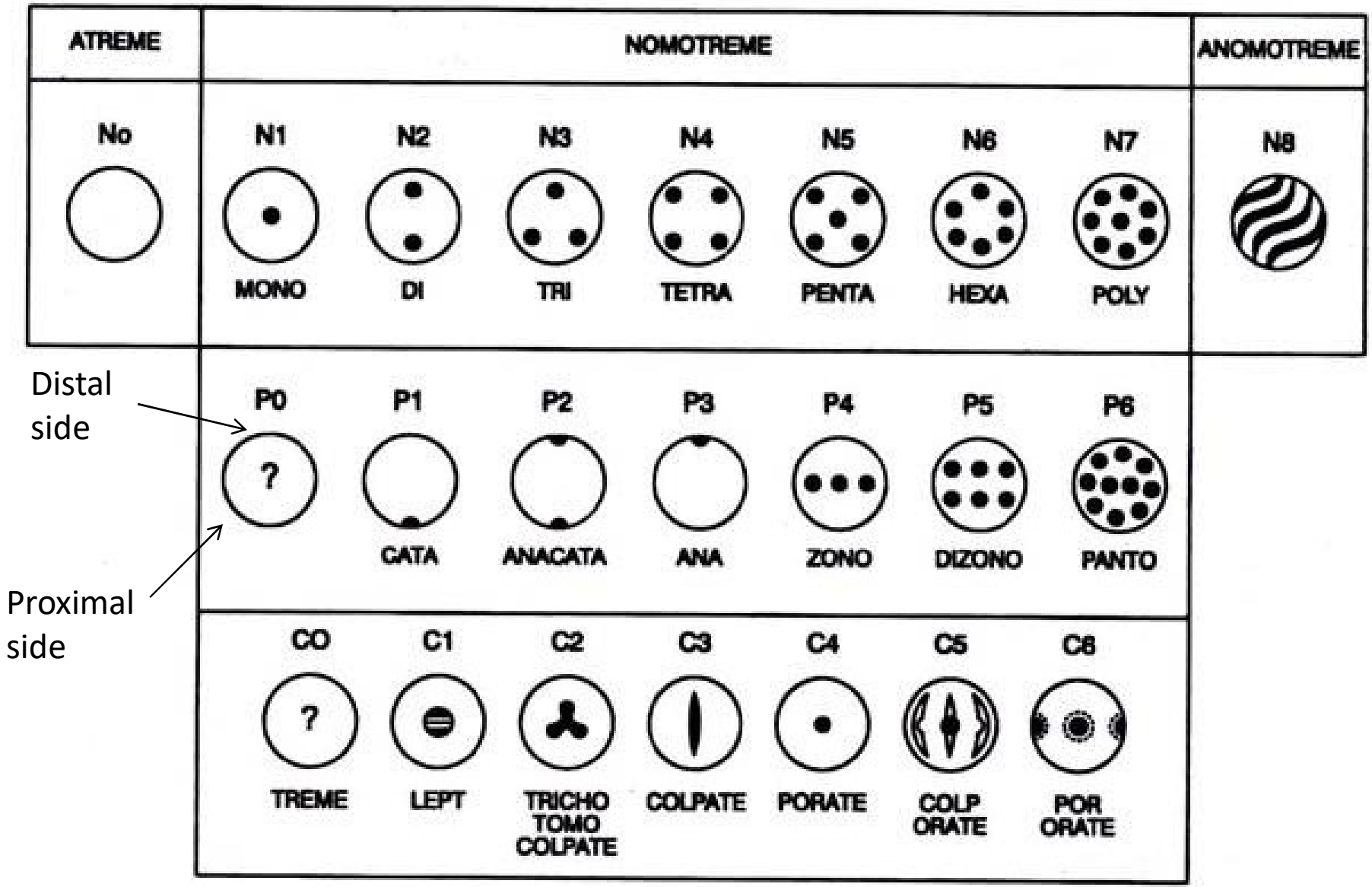


Fig. 4.7 : NPC classification of pollen (*after* Erdtman, 1969)

On the basis of the position (P) of apertures,

- Pollen are categorized into seven groups (P_0 to P_6).
- In 'Catatreme' (P_1) pollen aperture is in proximal face,
- while in 'Anatreme' (P_3) it is in distal face.
- The pollen are designated as Anacatatreme' (P_2) where apertures are both in proximal and distal faces.
- The pollen grains are referred to as 'Zonotreme' (P_4), when the apertures are located on the equatorial zone.
- 'Dizonotreme' (P_5) are like zonotreme, but with two rows of apertures on the equatorial region.
- In 'Pantotreme' (P_6), apertures are globally distributed all over the pollen surface.

- Like position groups the character (C) groups are of seven types (C_0 to C_6).

- If the character of the aperture is not known, it is designated as C_0.
- Pollen having an aperture like thin area or Leptoma is designated as C_1.
- Pollen with one leptoma is called Monolept, it may be called Catalept if present in the proximal face, or Analept if in the distal face.

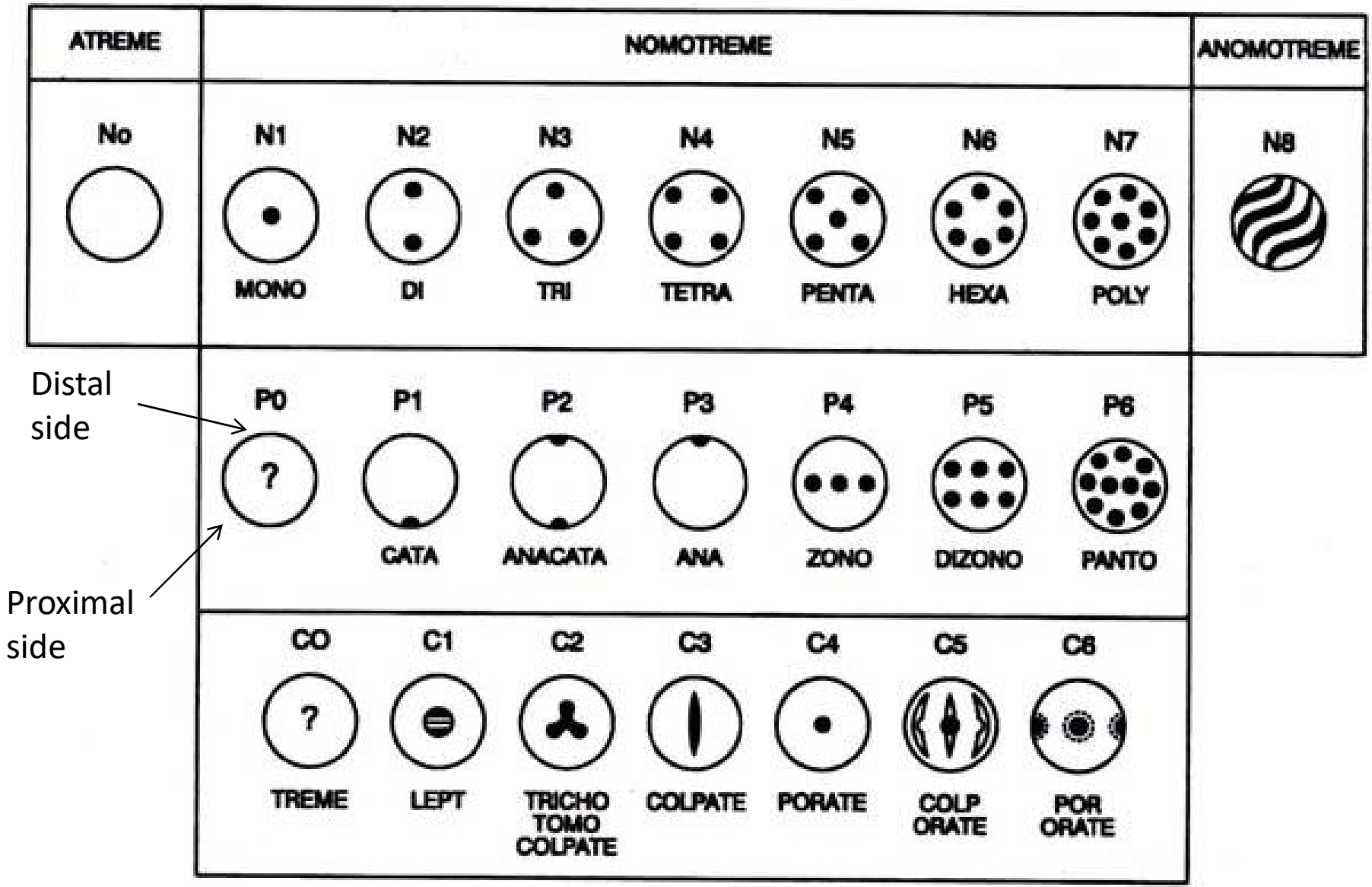


Fig. 4.7 : NPC classification of pollen (*after* Erdtman, 1969)

- Pollen with three- slit like colpus are called Trichotomocolpate which belongs to C_2 category.
- The remaining character classes i.e.,
- C_3 -Colpate (with colpa i.e. furrow),
- C_4 - Porate (with pore i.e. circular aperture),
- C_5 - Colporate (both with colpa and pore/ora apertures),
- C_6 - Pororate (aperture with pore and ora) respectively.

- Based on NPC classification, each pollen type is designated by using a three digit number.
- The first digit denotes the number of aperture, for example, 100 is assigned to monotreme,
- 200 to ditreme,
- 300 for tritreme,
- 400 for tetratreme,
- 500 for pentatreme,
- 600 for hexatreme,
- 700 for polytreme, and
- 8 for anomotreme.

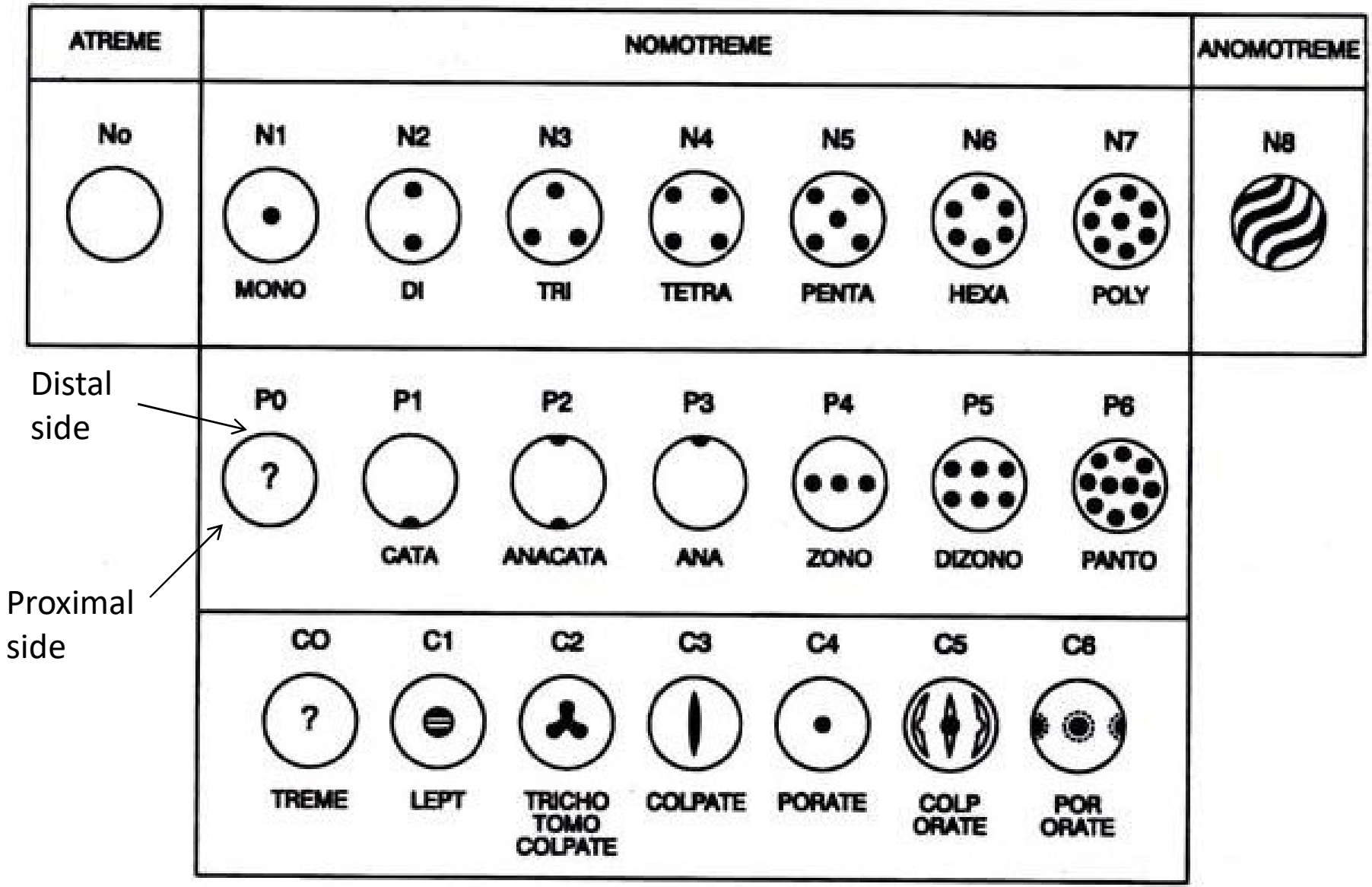


Fig. 4.7 : NPC classification of pollen (*after* Erdtman, 1969)

- The second digit denotes the position of the aperture,
- e.g. 010 to proximal aperture,
- 030 for distal aperture,
- 040 for equatorial aperture,
- 060 for global aperture.

- The third digit denotes the characters of the aperture, e.g.,
- 002 for trilete,
- 003 for colpate,
- 004 for porate,
- 005 for colporate.

- Therefore, the number 112 is assigned to trilete grains, similarly 133 to monosulcate/colpate grains, 343 to tricolpate and 345 to tricolporate grains, etc.

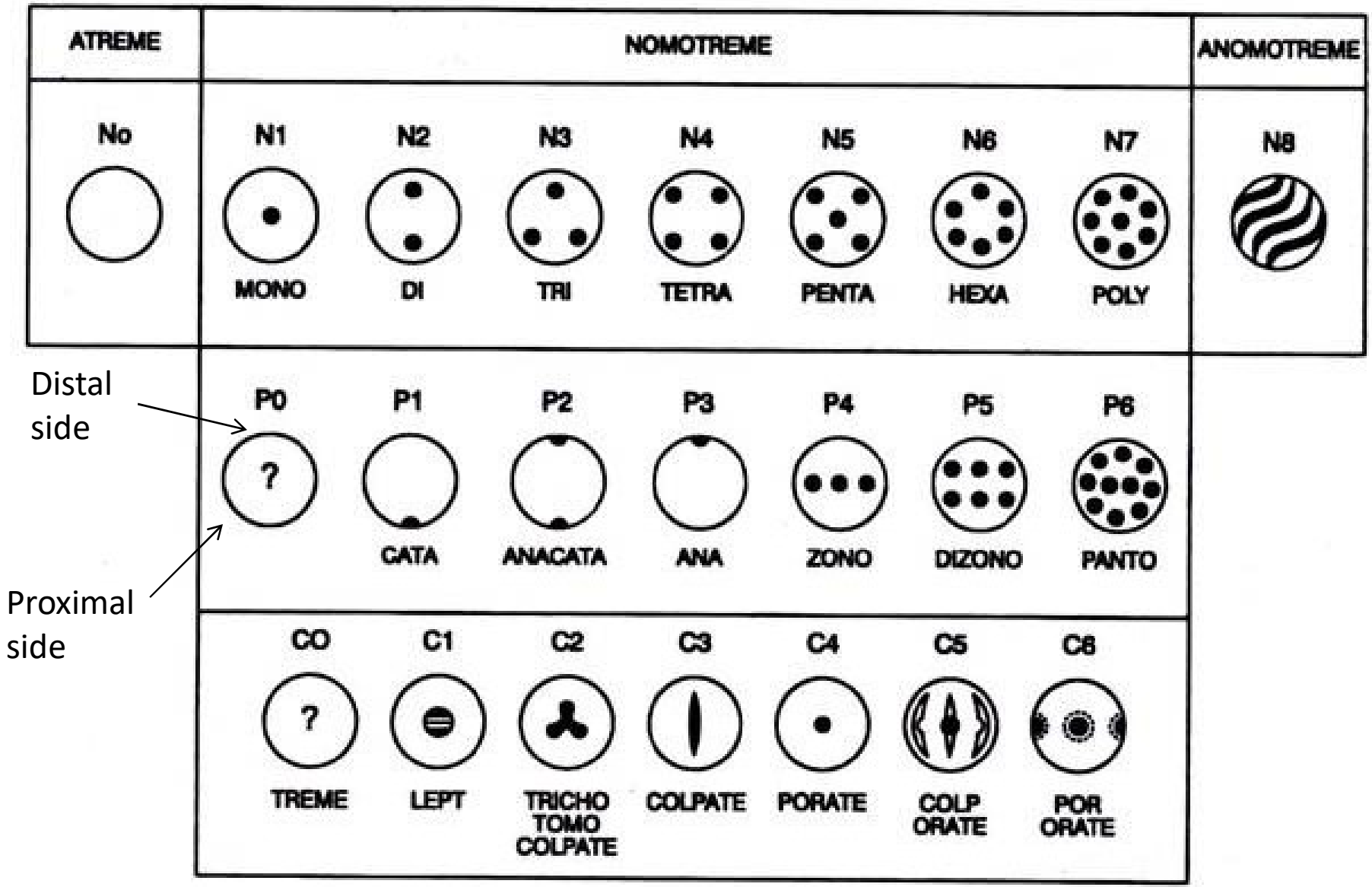


Fig. 4.7 : NPC classification of pollen (*after* Erdtman, 1969)

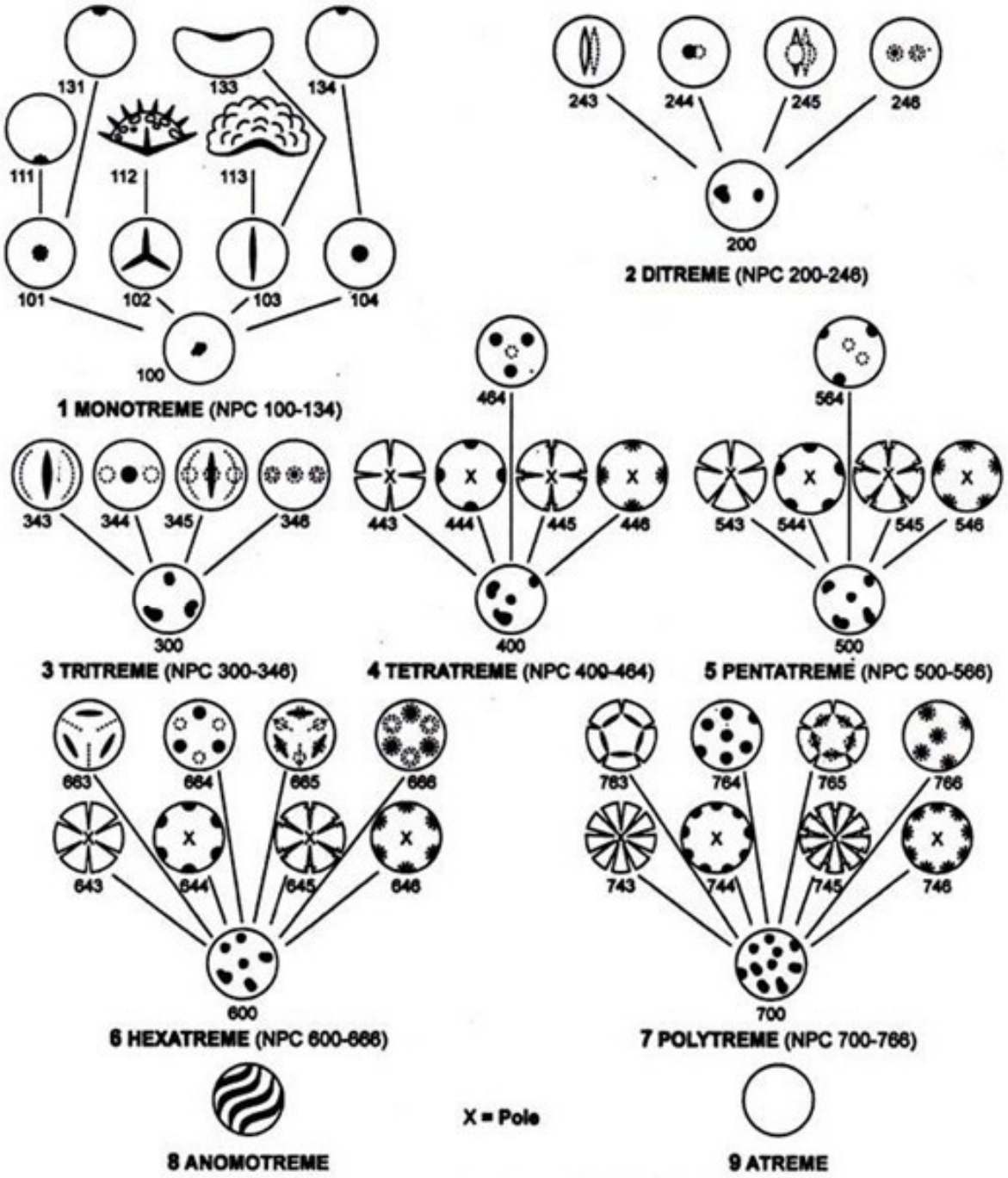
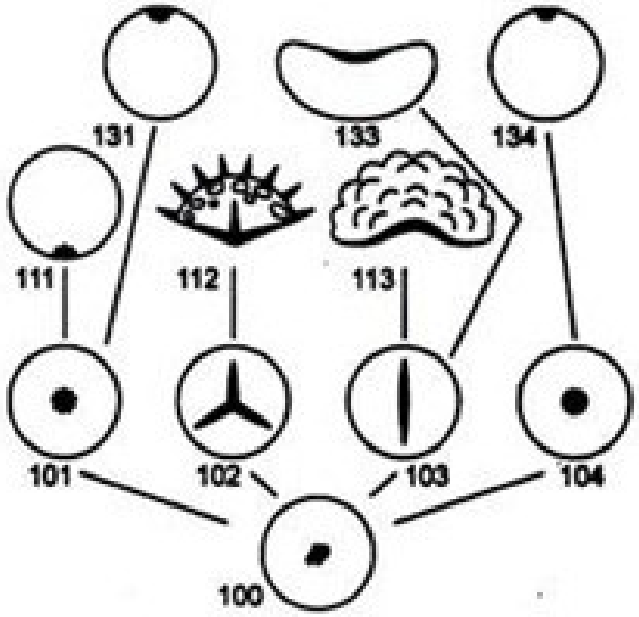
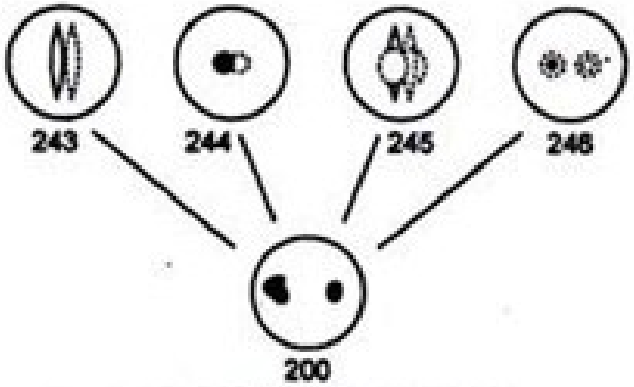


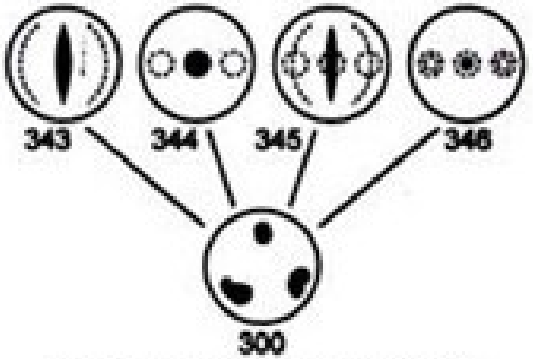
Fig. 4.8 : Pollen types designated by three digit numbers



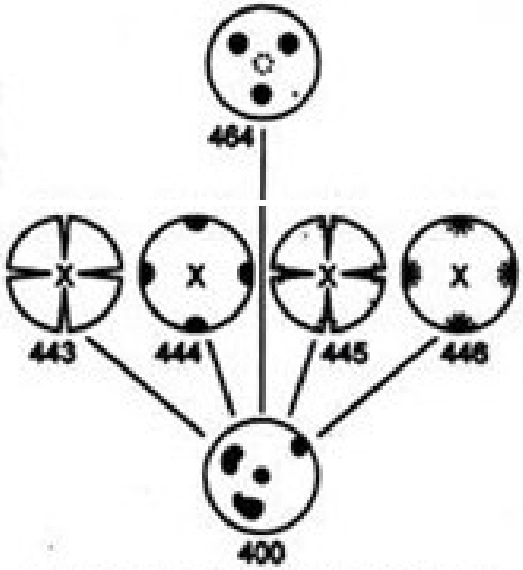
1 MONOTREME (NPC 100-134)



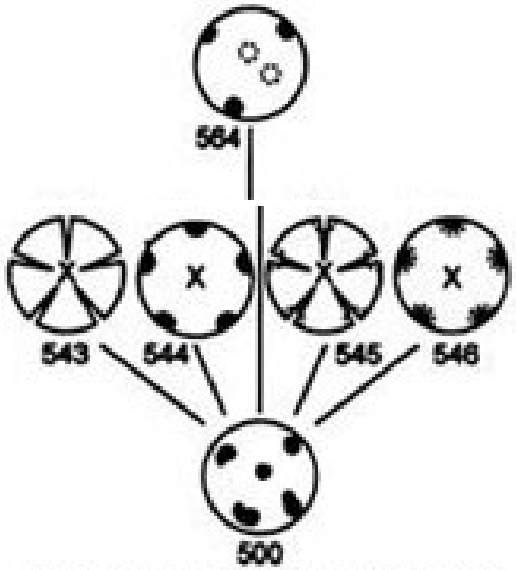
2 DITREME (NPC 200-248)



3 TRITREME (NPC 300-348)



4 TETRATREME (NPC 400-464)



5 PENTATREME (NPC 500-566)

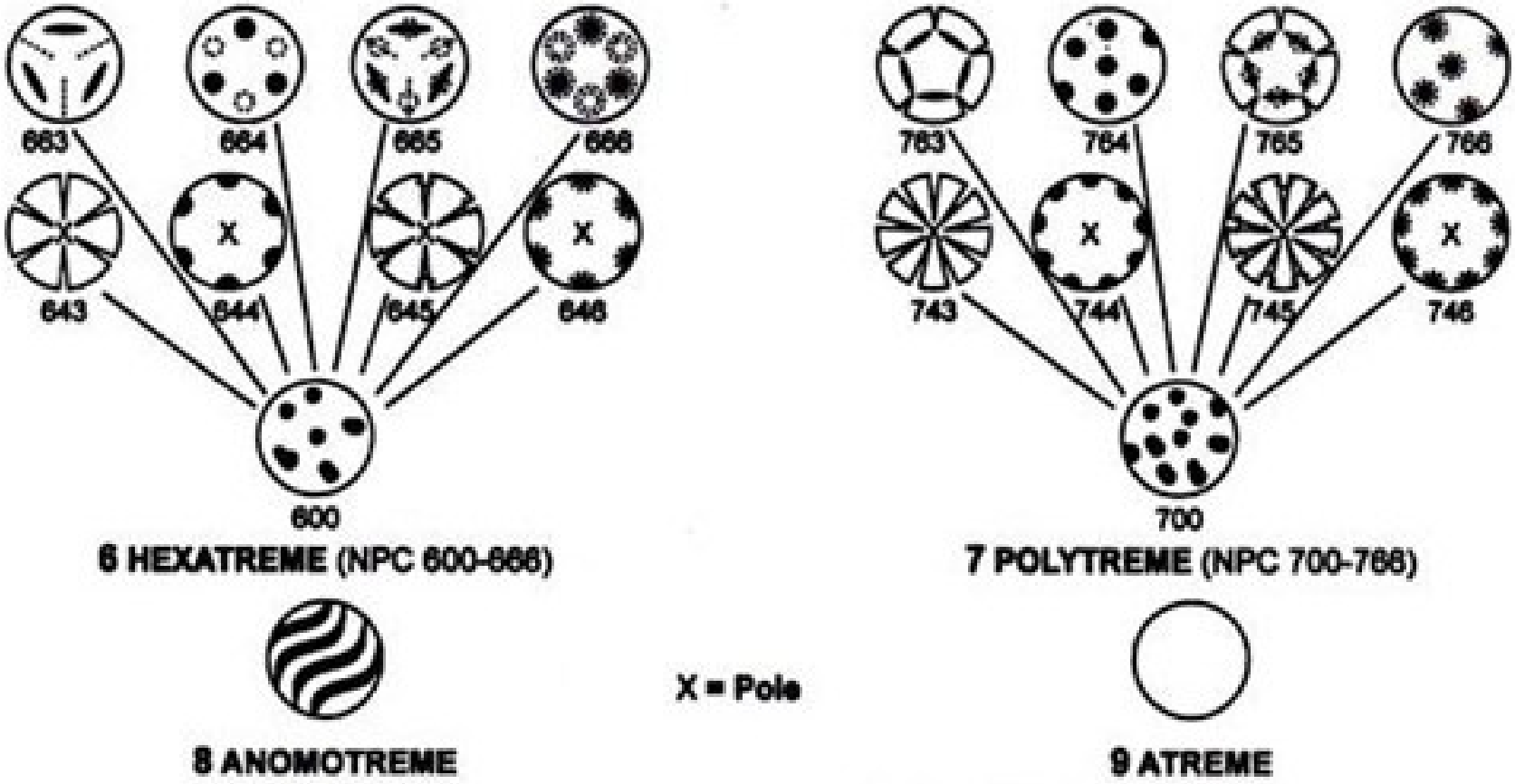


Fig. 4.8 : Pollen types designated by three digit numbers

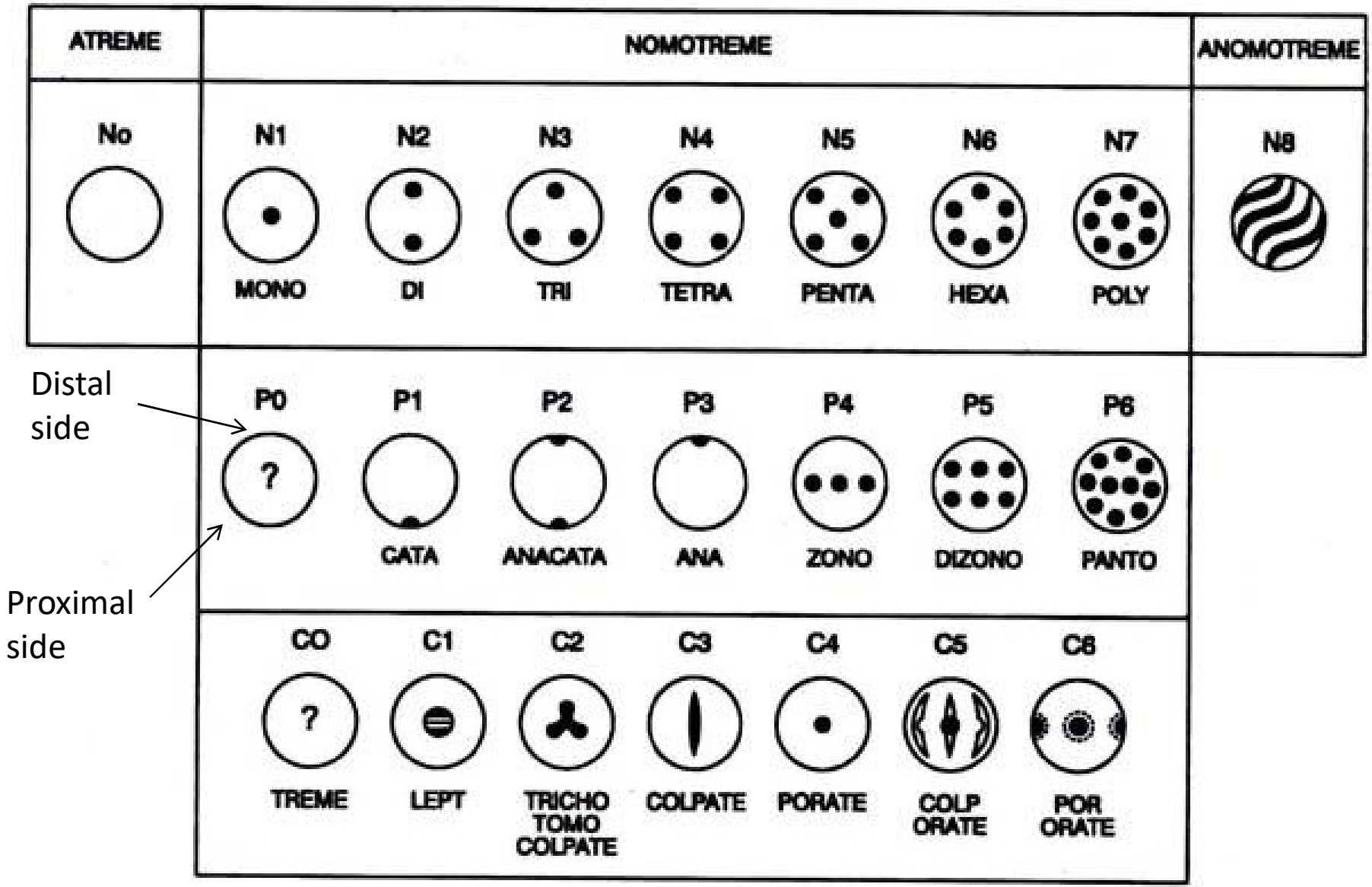
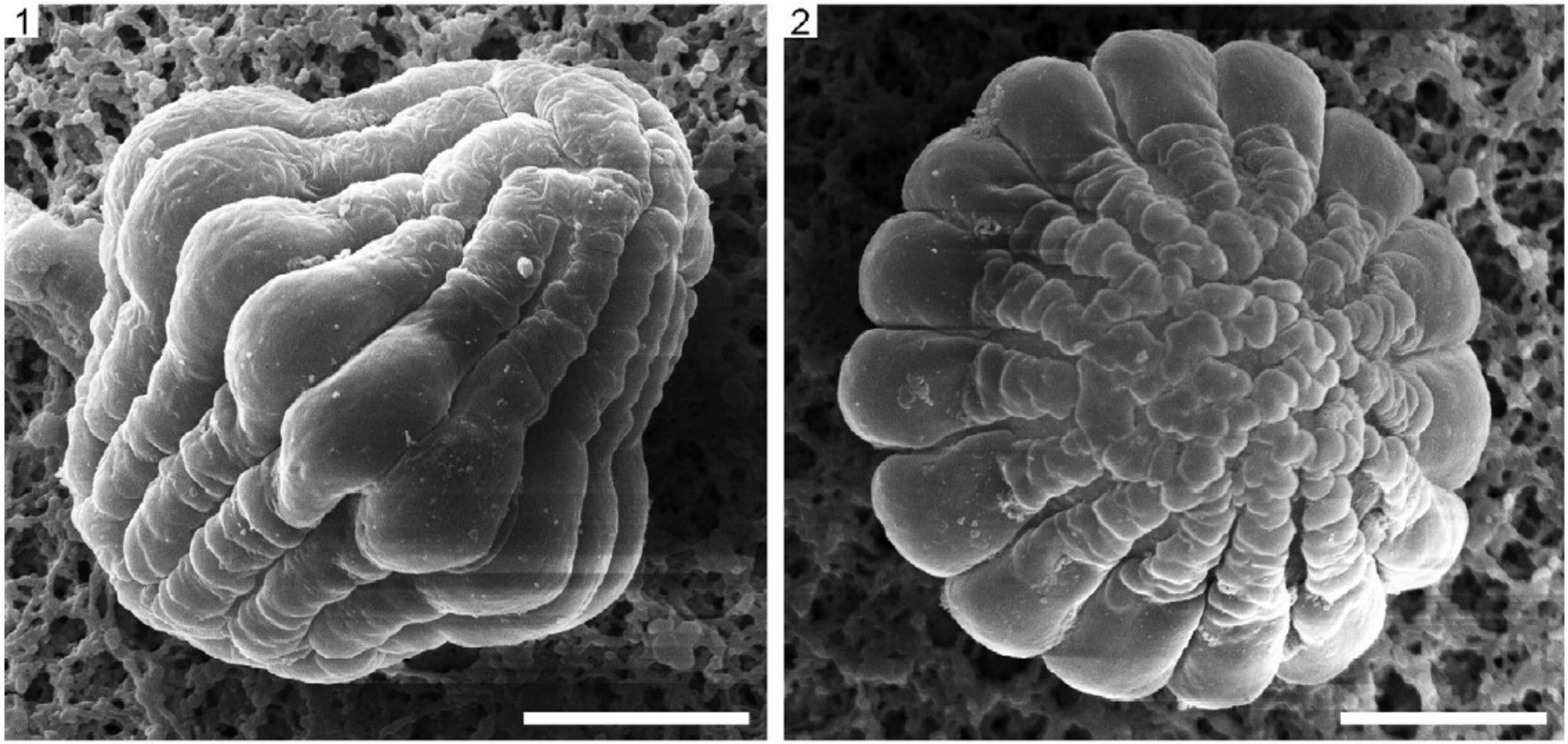
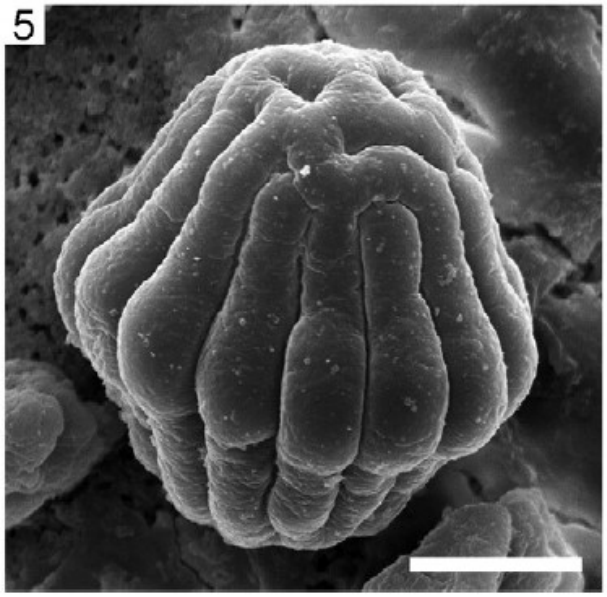


Fig. 4.7 : NPC classification of pollen (*after* Erdtman, 1969)

SEM images of pollen of *Utricularia*

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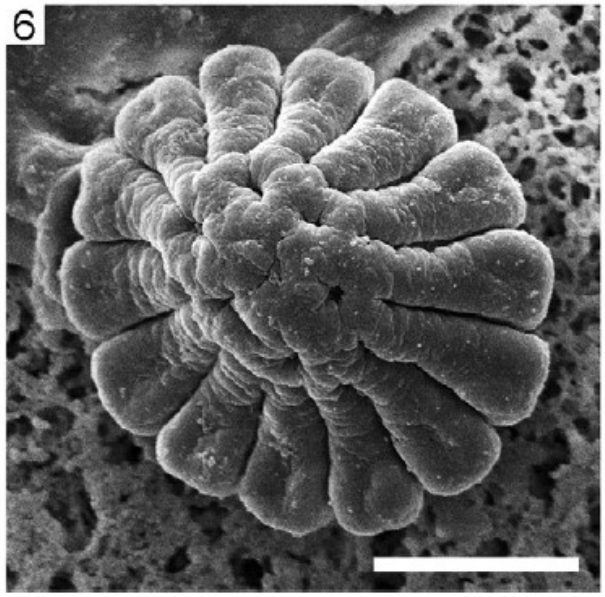
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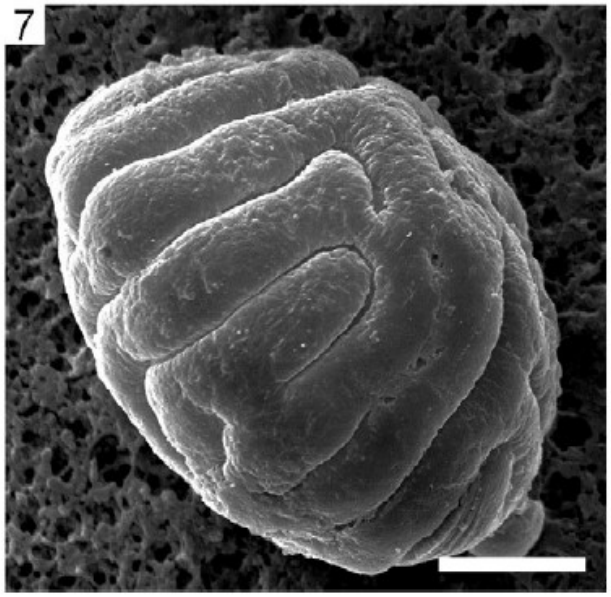
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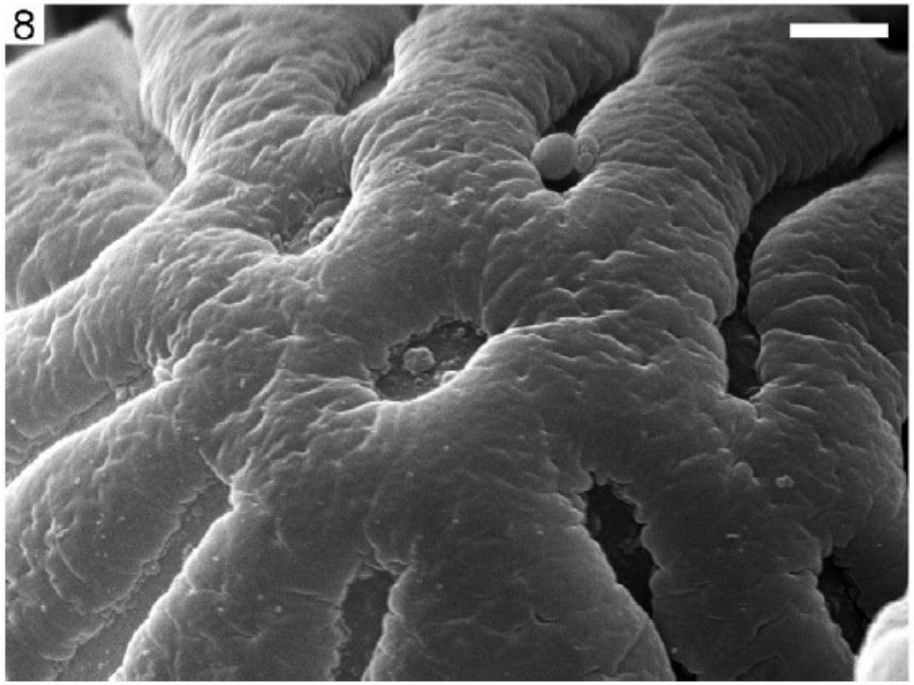
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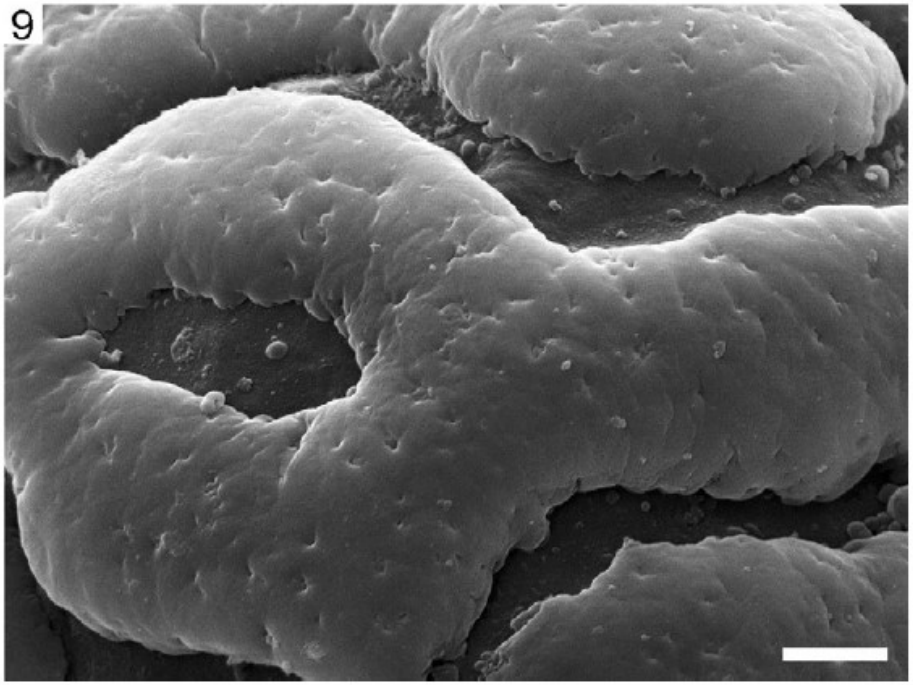
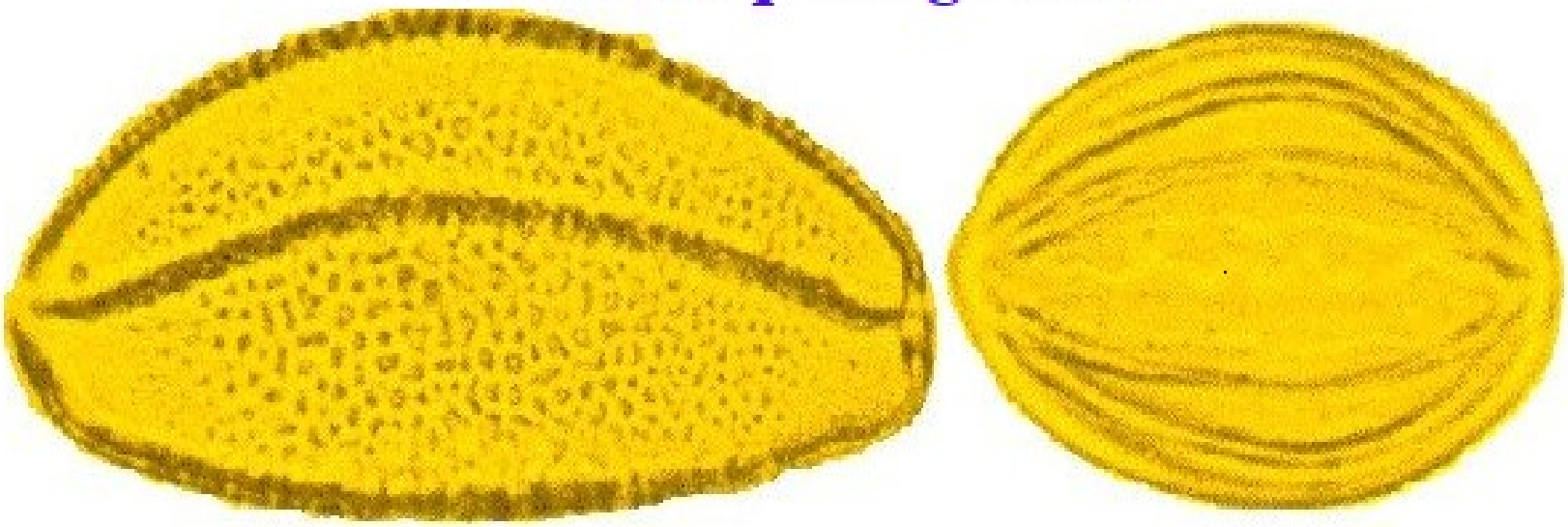

9

Trilete spores

Monolete spores

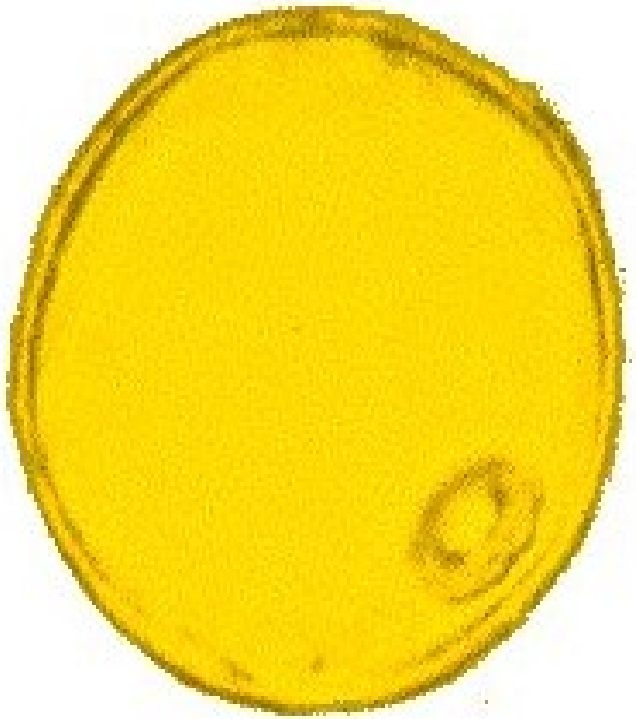
Bisaccate grains

Monocolpate grains



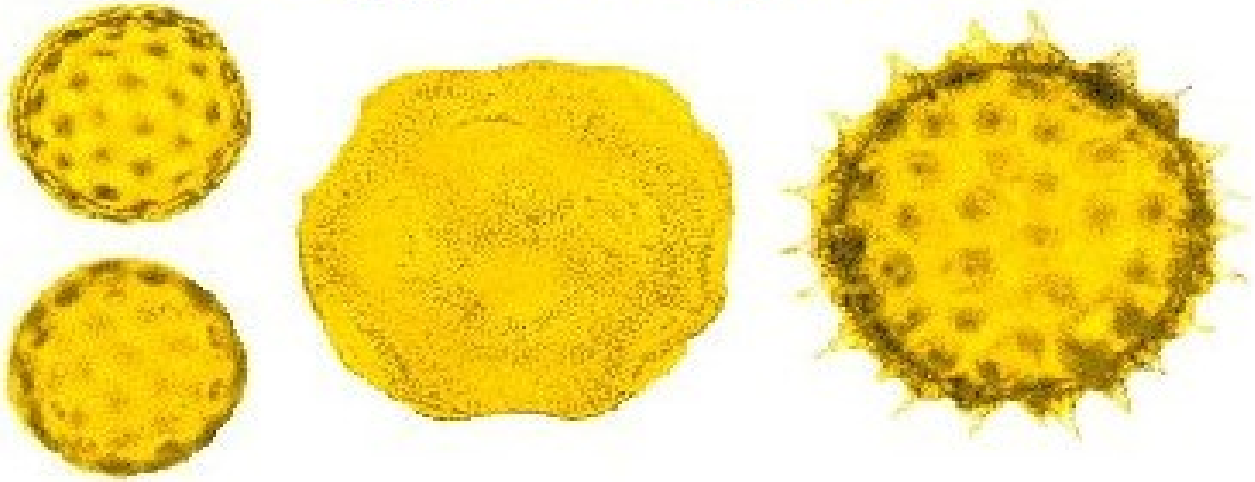
Tricolpate grains

Monoporate grains

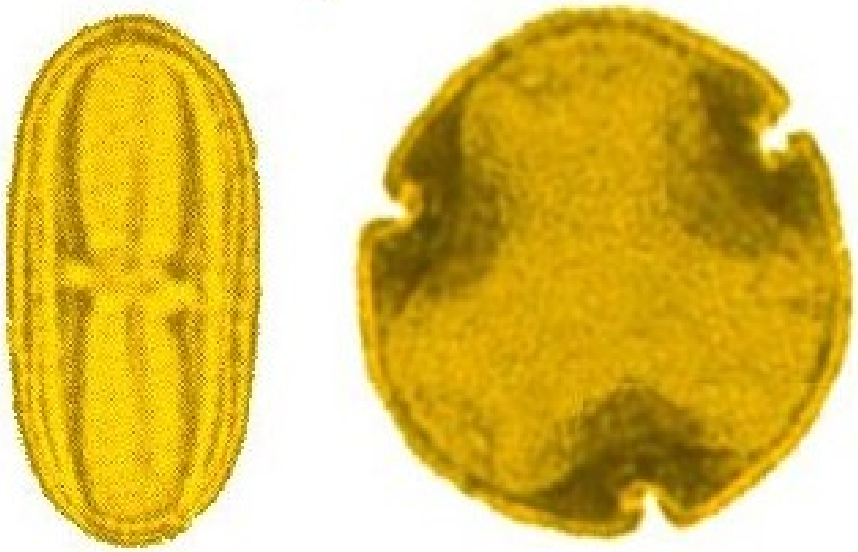


Triporate grain

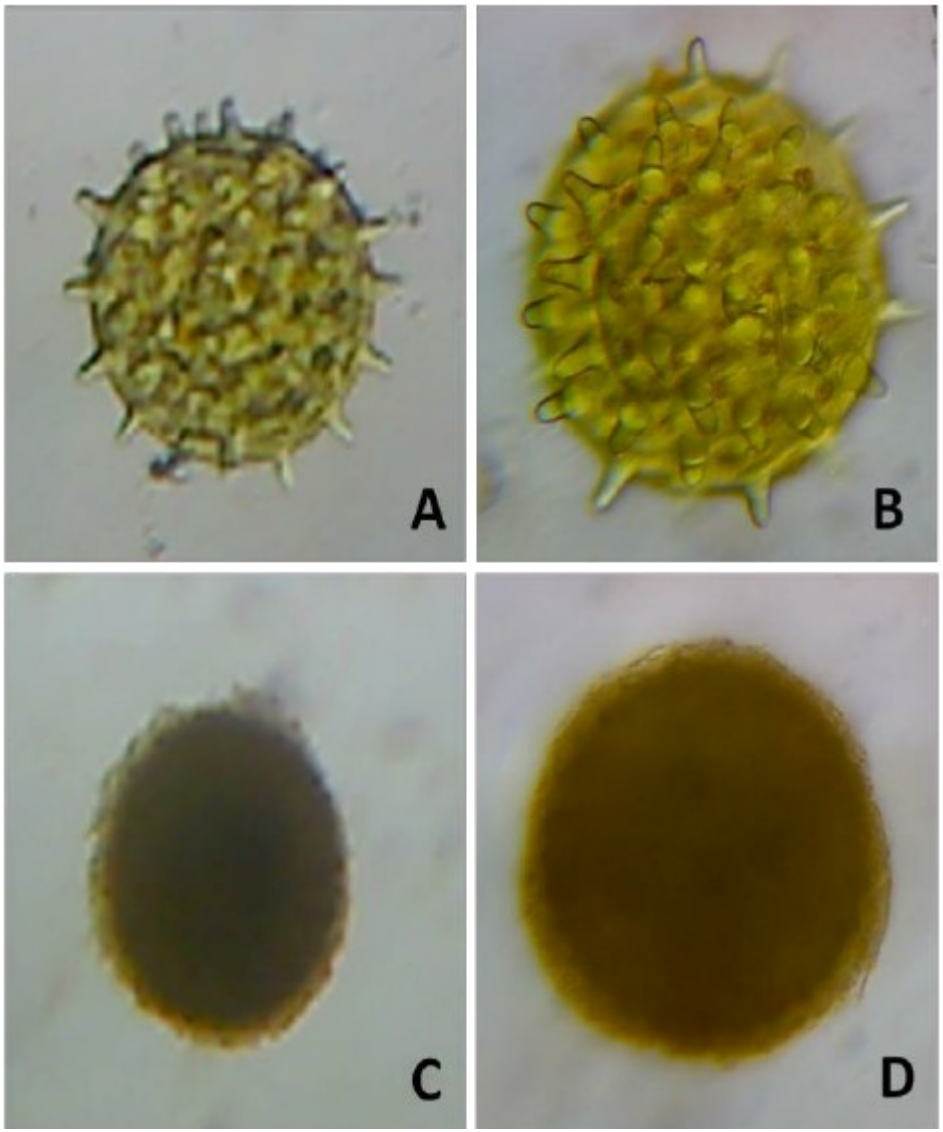
Polyporate grains

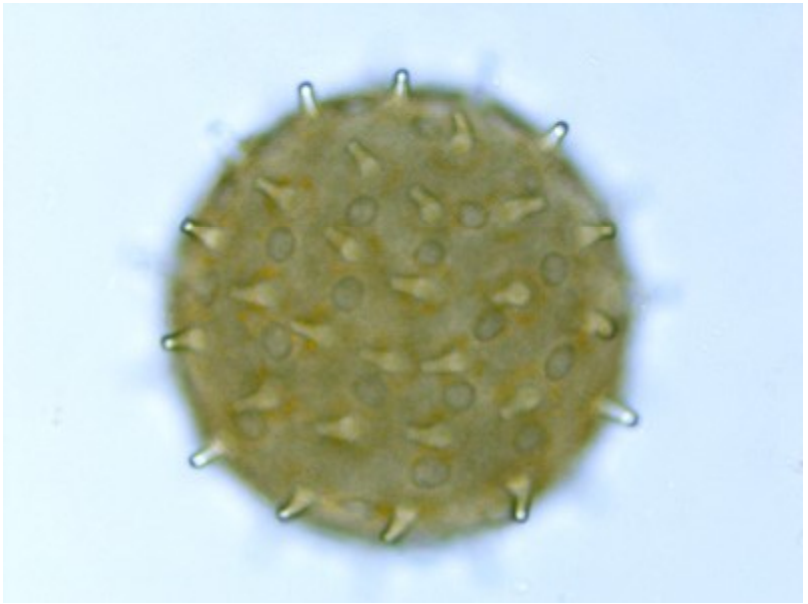


Tricolporate grains

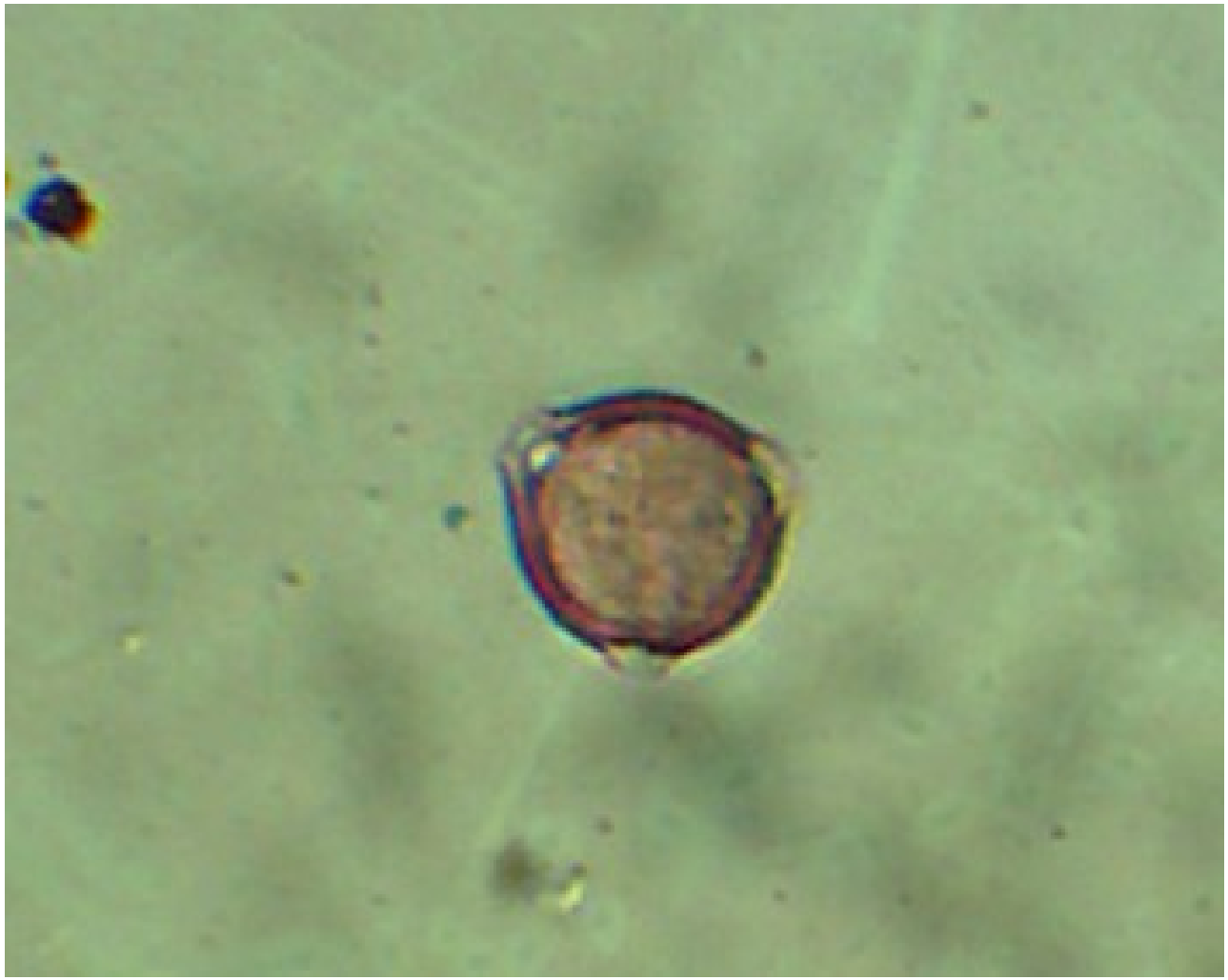


Hibiscus





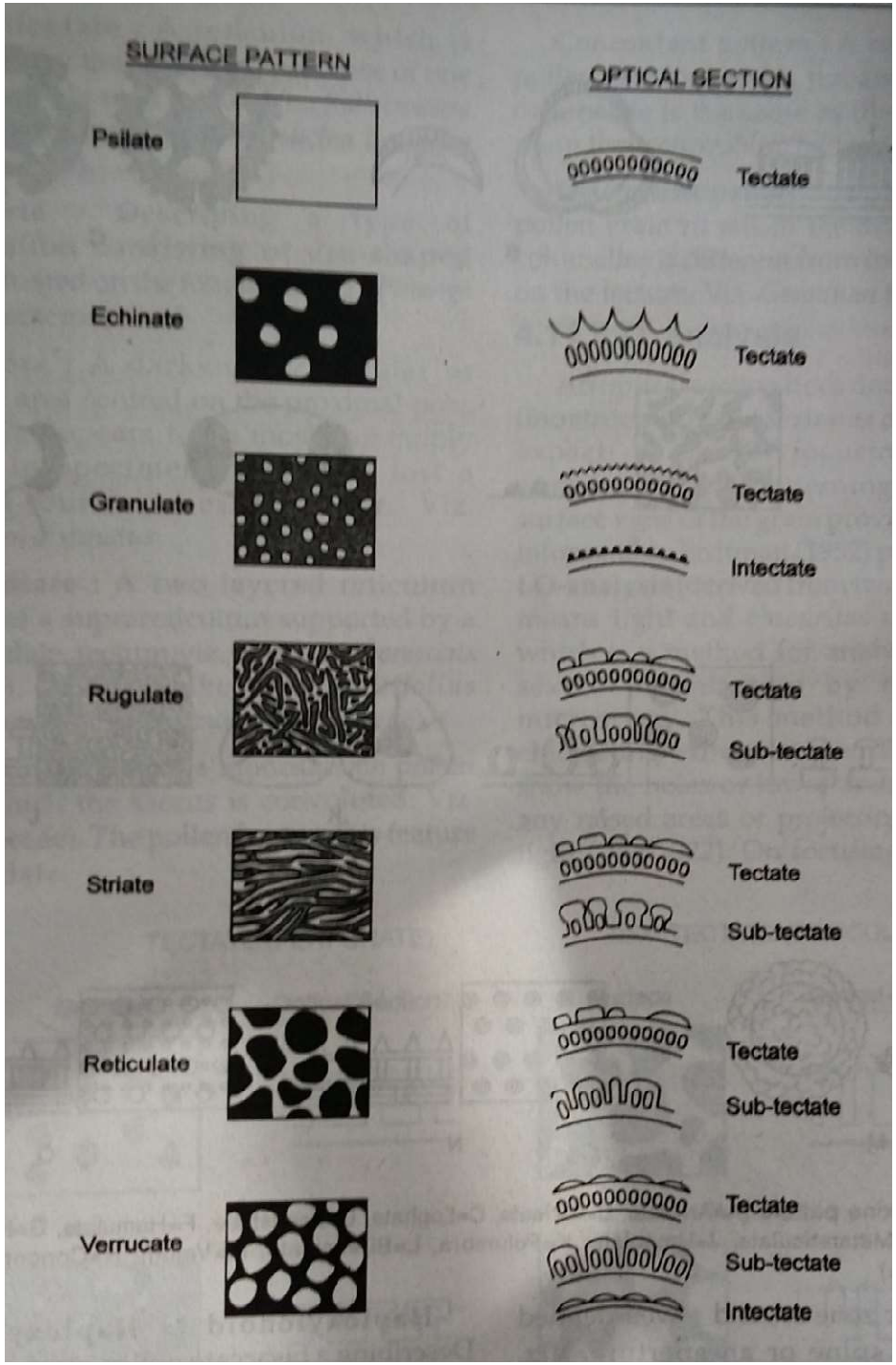
Dentella



Pollen characters have been grouped into seven categories.

1. Aperture type
2. Pollen wall architecture
3. Pollen unit
4. Polarity
5. Symmetry
6. Shape
7. Size

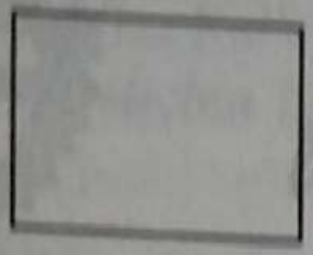
Pollen wall architecture/ ornamentation

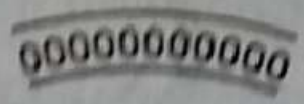


SURFACE PATTERN

OPTICAL SECTION

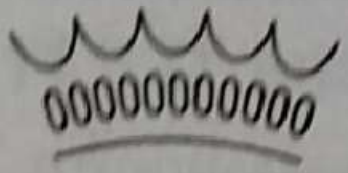
Psilate





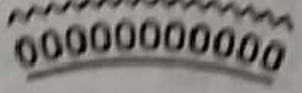
Tectate

Echinate

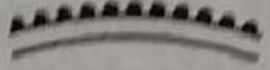


Tectate

Granulate

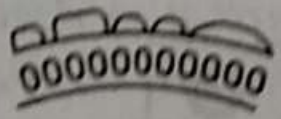


Tectate



Intectate

Rugulate



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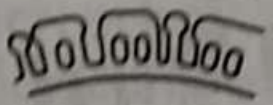
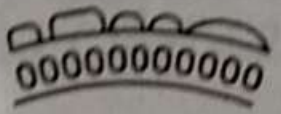


Sub-tectate

Striate



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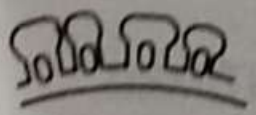
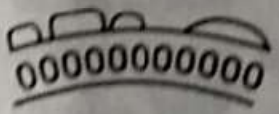
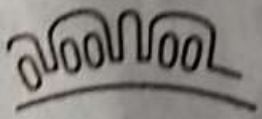


Sub-tectate

Reticulate

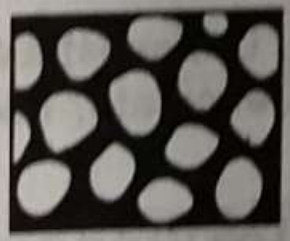


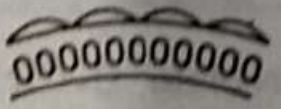
Tectate



Sub-tectate

Verrucate





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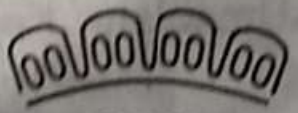
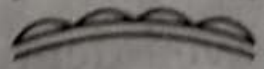
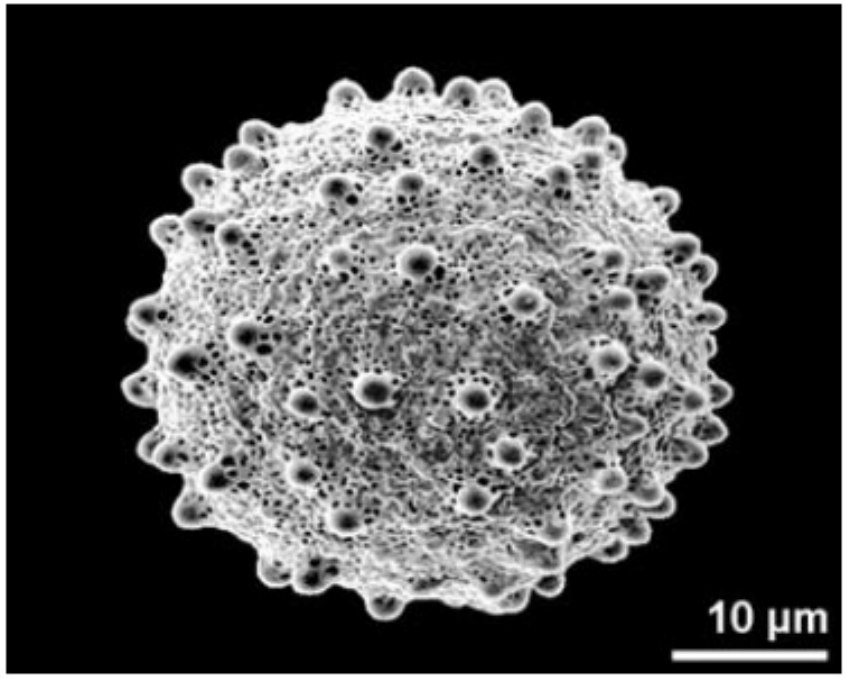


Sub-tectate



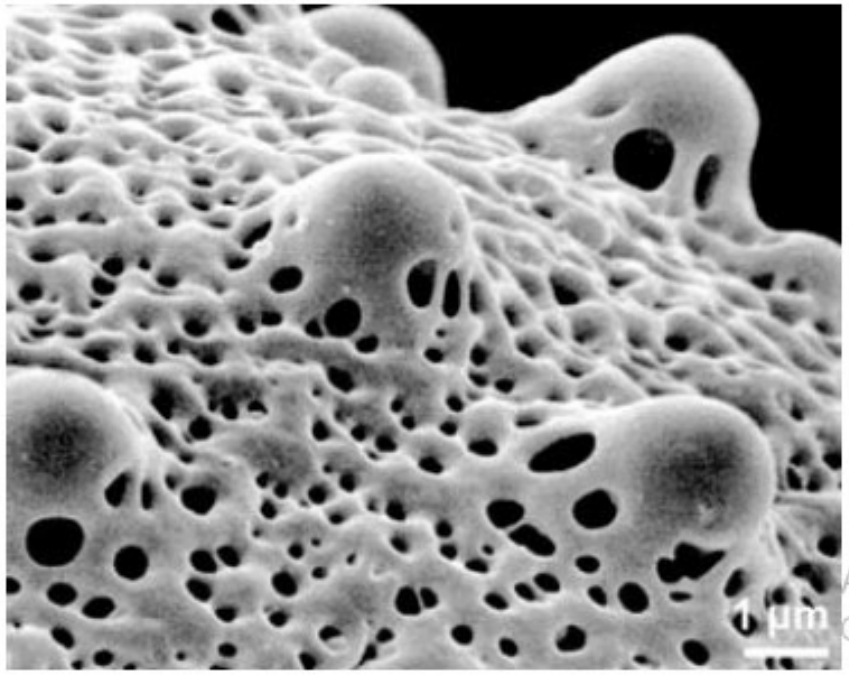
Intectate



Combination of ornamenting characters

Aristolochia arborea
Aristolochiaceae

inaperturate, spheroidal
verrucate, perforate

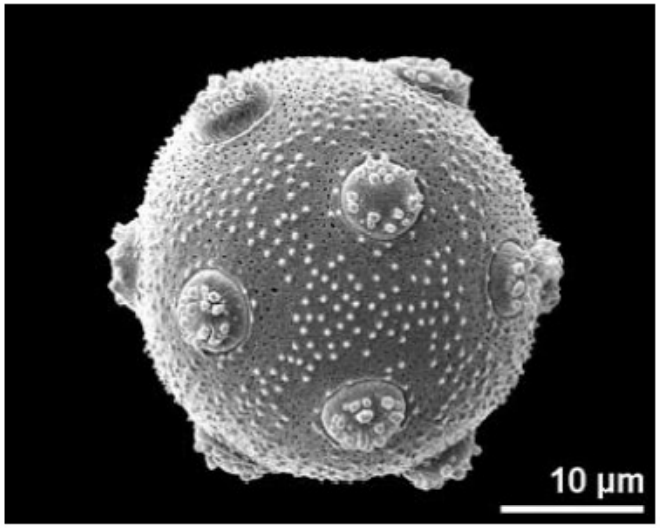


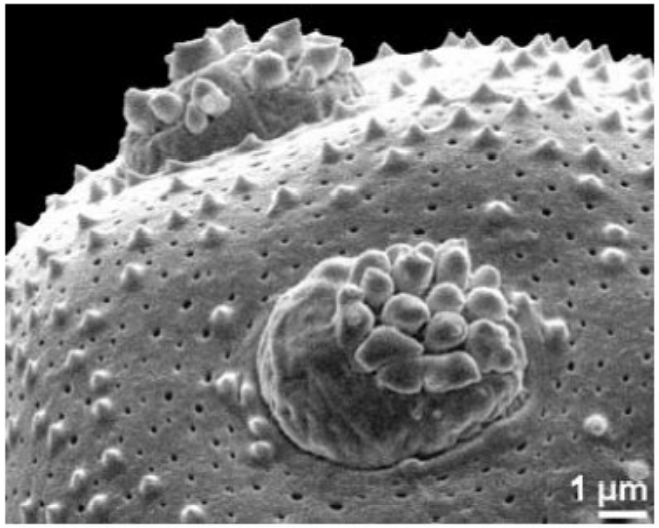
surface detail
verrucae and perforations

Combination of ornamenting characters

Stellaria media
Caryophyllaceae

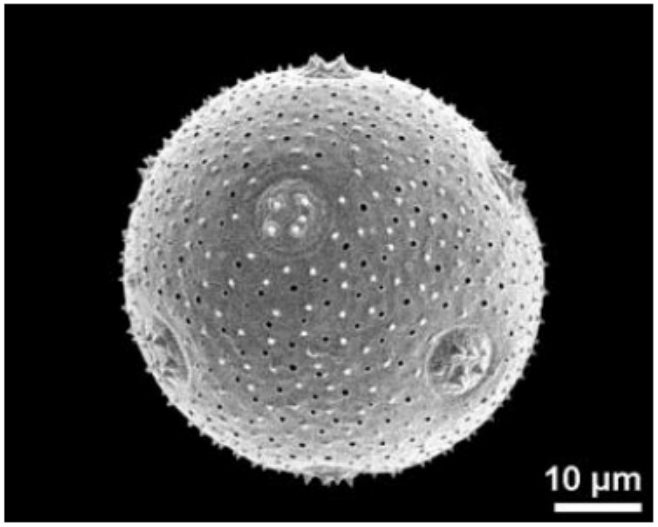
microechinate, perforate

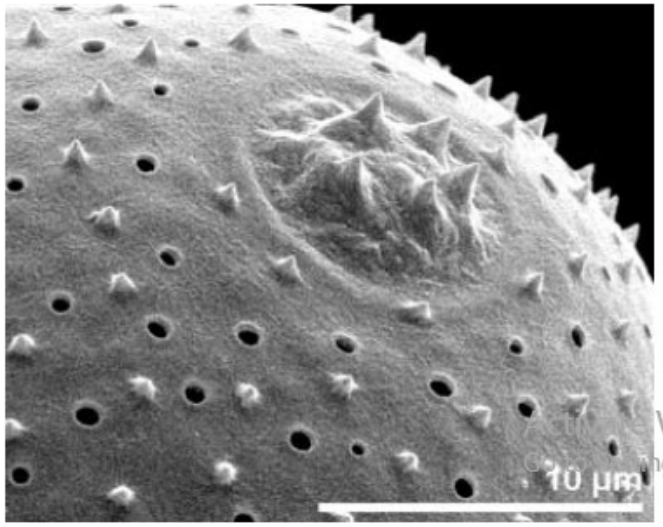




Saponaria officinalis
Caryophyllaceae

microechinate
and perforate



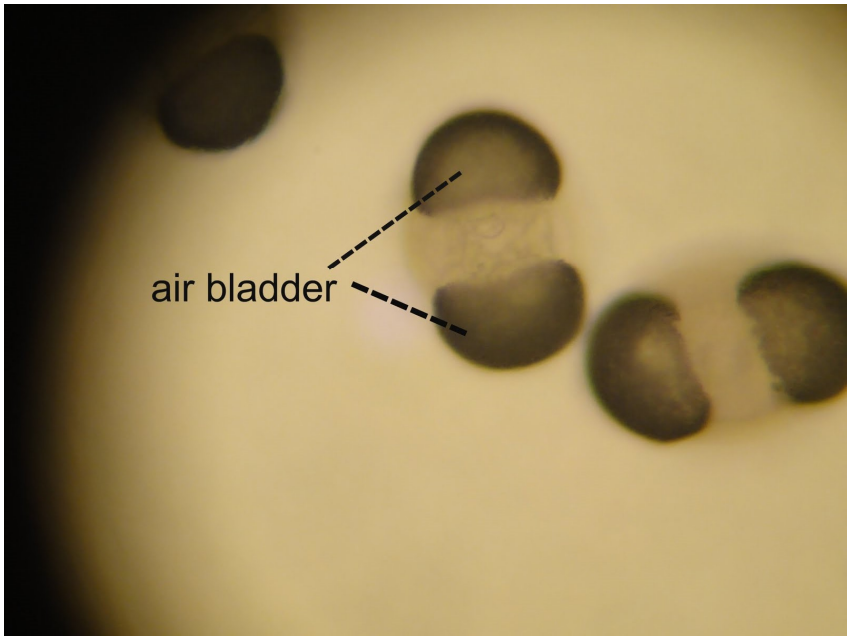


Pollen size

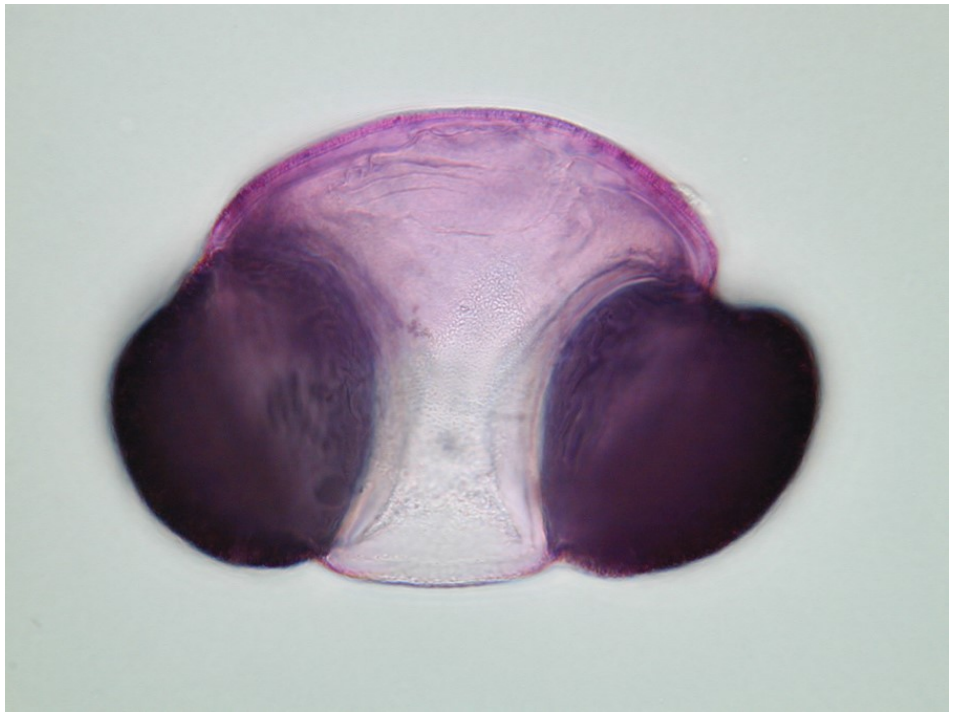
- Pollen grains show a great variety in their sizes.
- Largest pollen grains (> 200 µm in diameter) are observed in Cucurbitaceae, Nyctaginaceae etc.
- Erdtman (1945) categorized the different pollen size classes based on the size expressed as length of the longest axis.

Pollen size classes	Length of longest axis
• Very small grains	< 10 µm
• Small grains	10 - 25 µm
• Medium sized grains	25 - 50 µm
• Large grains	50 -100 µm
• Very large grains	100-200 µm
• Gigantic grains	>200 µm

Special pollen structures - bladders



- Pollen grain consisting of a body with bladders. E.g. *Pinus, Picea*
- In case of *Pinus*, 2 laterally placed air bladders help in wind pollination.



Viscin threads

- Tapetal cells have the function of secreting sporopollenin precursor.

- They also result in the formation of specialized structures, which characterize some families.

- In Onagraceae tapetal cells play a role in formation of fine flexible threads, known as viscin threads, in continuation with the outer layer of the exine.

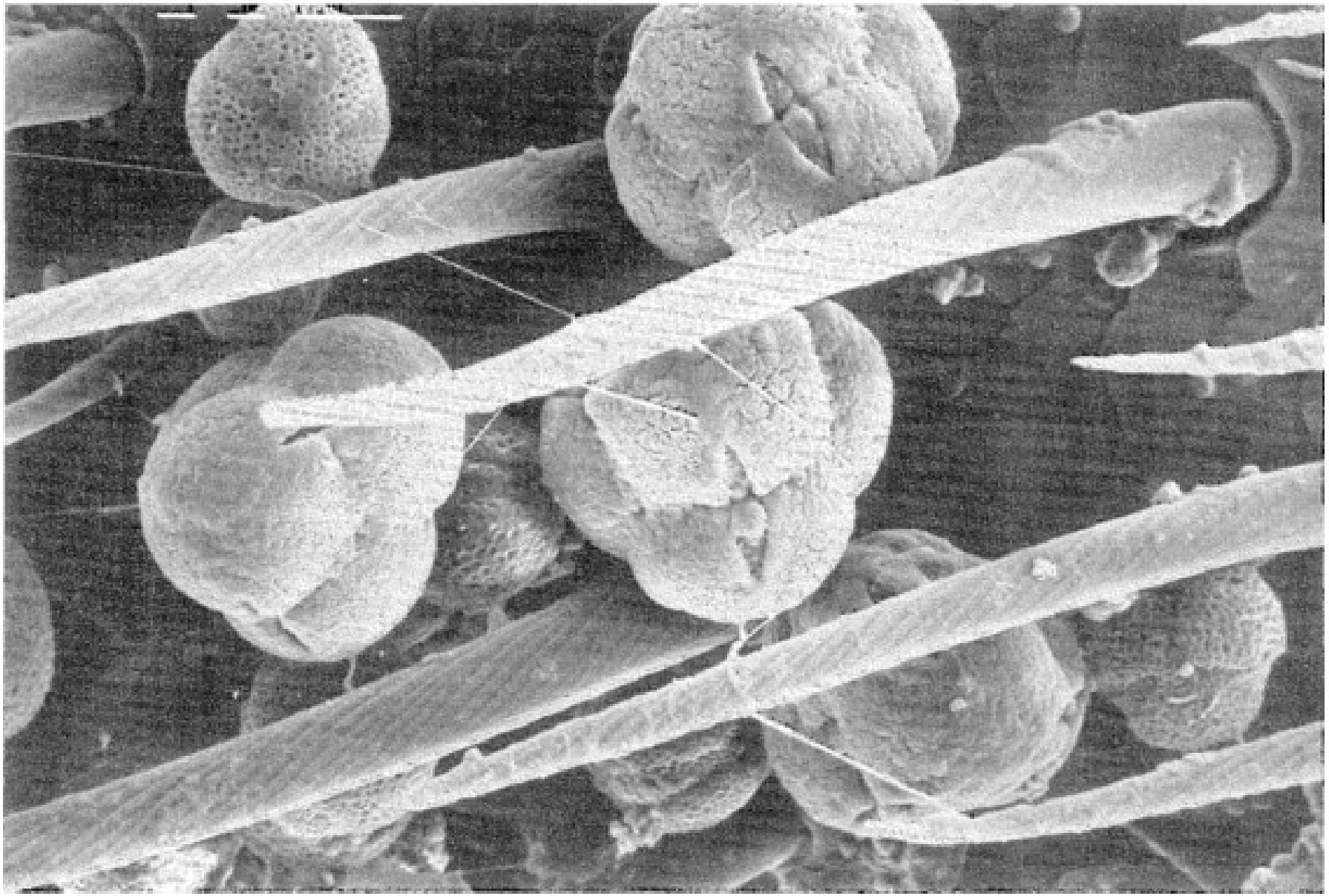
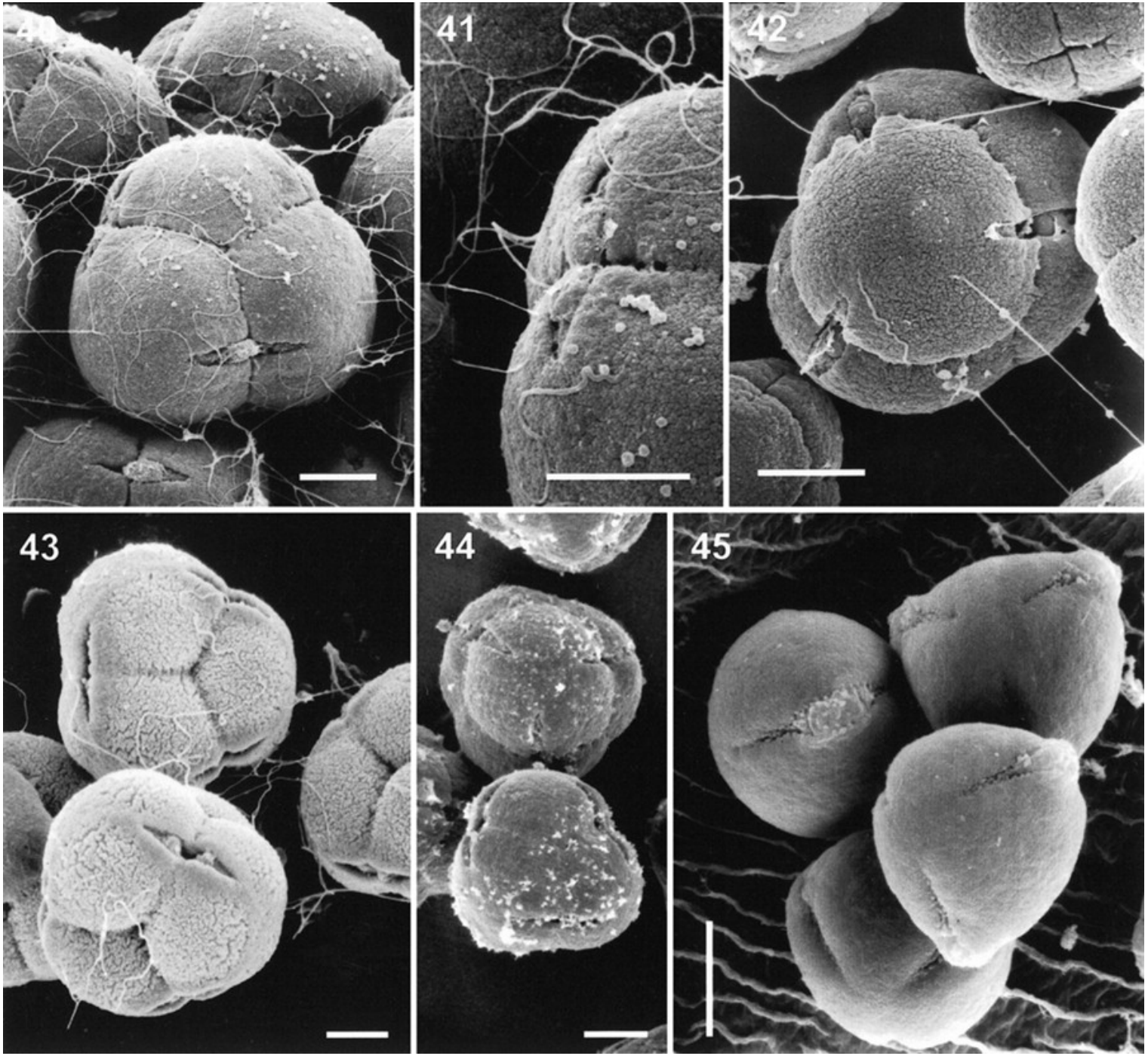
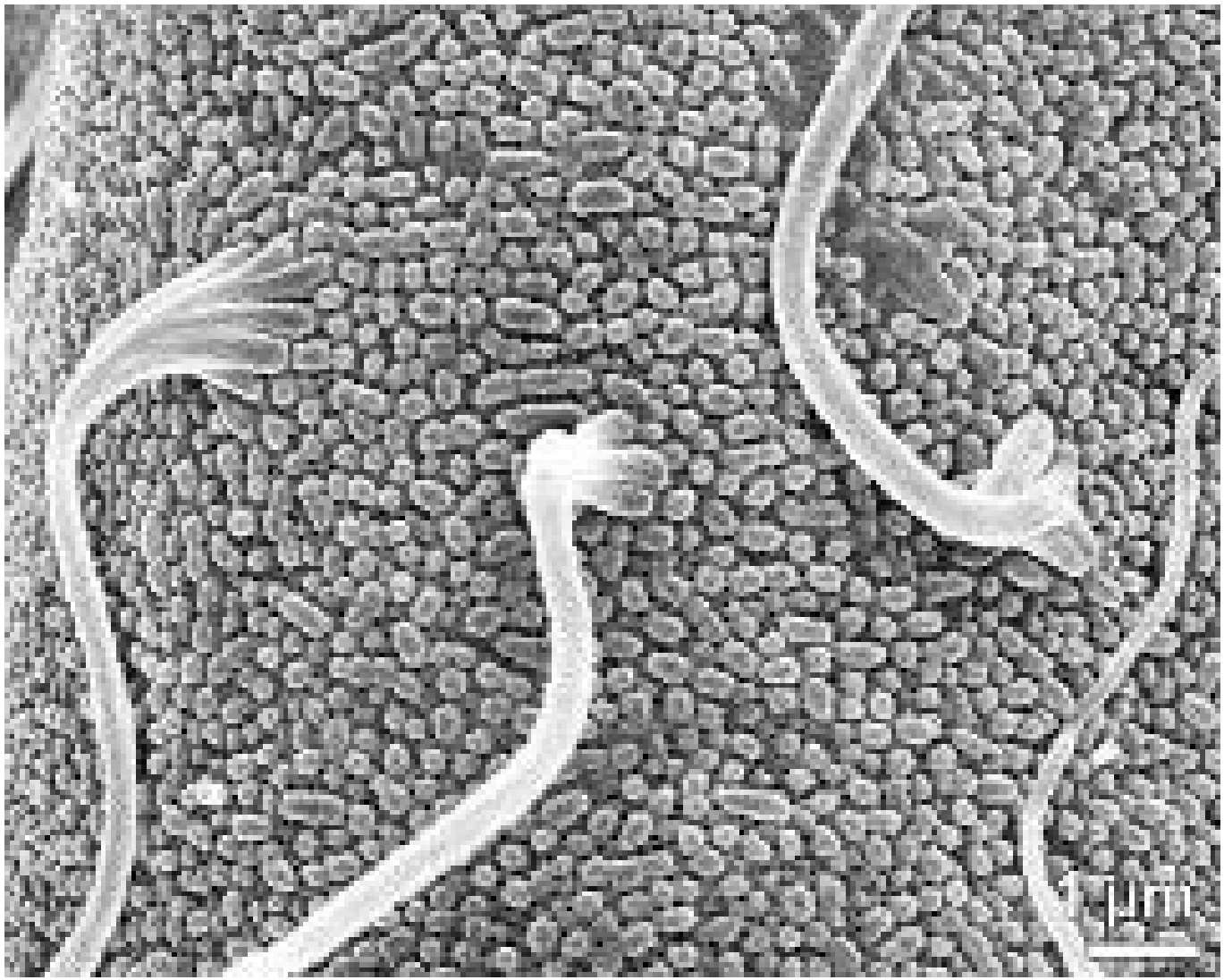


Fig. 5. The viscin threads on tetrads of *Rhododendron schlippenbachii* adhere like ropes to the bristles of a flower-visting insect. SEM (the long bar indicates 10 μm).


41
42
43
44
45

Viscin threads originating from exine



Pollenkitt

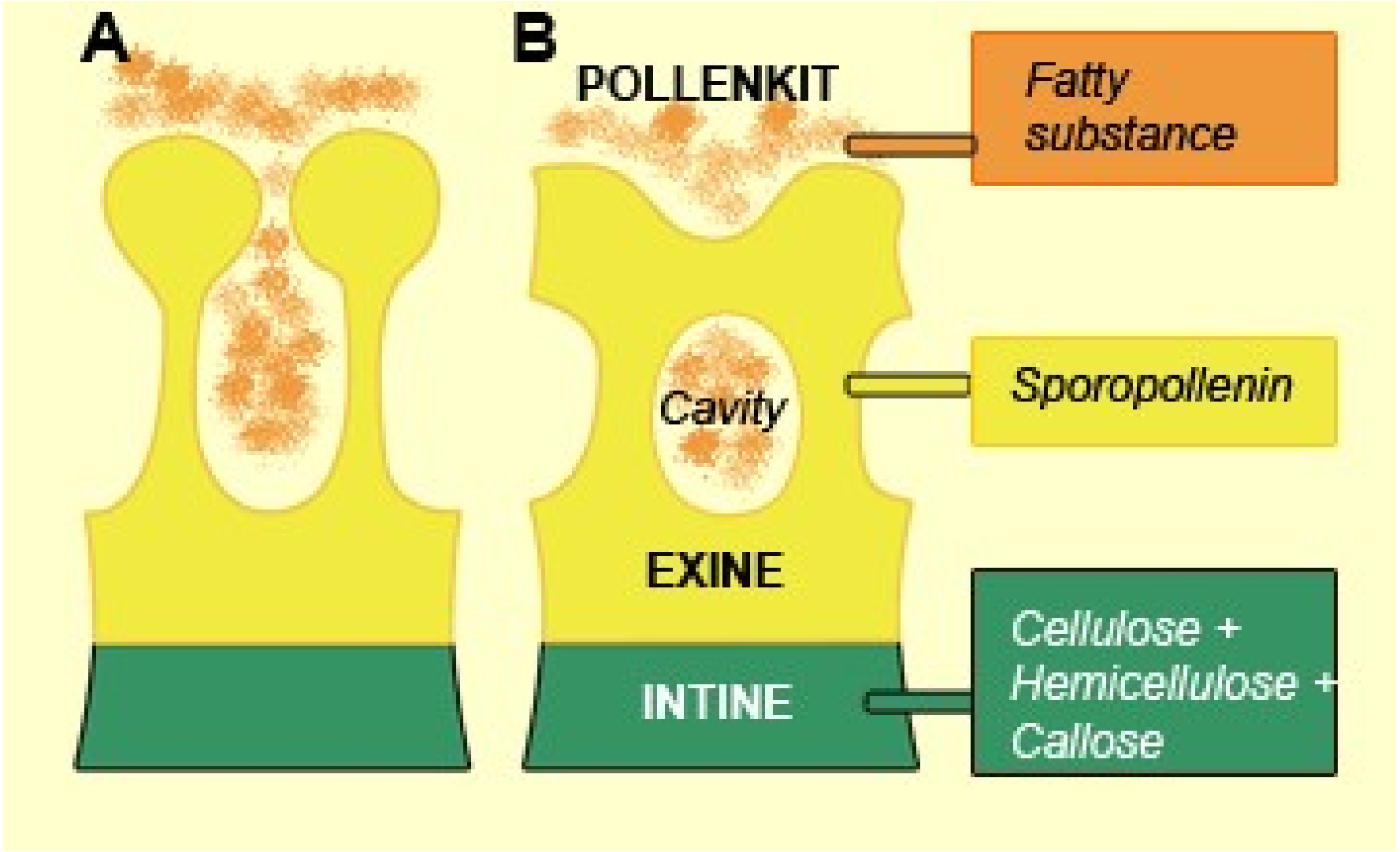
- The principle of **attachment of pollen grains to flower-visiting insects** is quite different in entomophilous angiosperms depending whether pollenkitt or viscin threads are the pollen adhesives.

- Pollenkitt is to be found in all angiosperm families investigated up to now, but viscin threads occur only in a small number.

- **Pollenkitt and viscin threads are analogous vehicles in pollination ecology**.

- In all anemophilous angiosperms, the pollen is dry, not sticky and does not clump together, while in **zoophilous (mostly entomophilous) angiosperms the pollen transfer by animals depends mainly on the, adherence of sticky, clumping pollen grains to the flower visitor**.


10 µm


A
B
POLLENKIT
Fatty substance
Cavity
Sporopollenin
EXINE
INTINE
Cellulose + Hemicellulose + Callose

- Such pollen attachment is caused by pollen aggregation or “pollen cementing” realized by two principally different modes:

  1. By sticky, viscous pollenkitt

  2. By non-sticky, non-viscous viscin thread (seen in families – Onagraceae, Ericaceae and Caesalpiniaceae)

- **Pollenkitt** can be defined as a complex mixture of lipid, viscous substances (including carotenoids), produced by the plastids of the anther tapetum and deposited on the pollen surface and/or in the exine cavities of pollen grains.

- **Viscin threads** facilitate the pollen movement from the anther towards the stigma. The threads are neither sticky nor viscous like the pollenkitt, they contain sporopollenin, and they are attached to the exine.

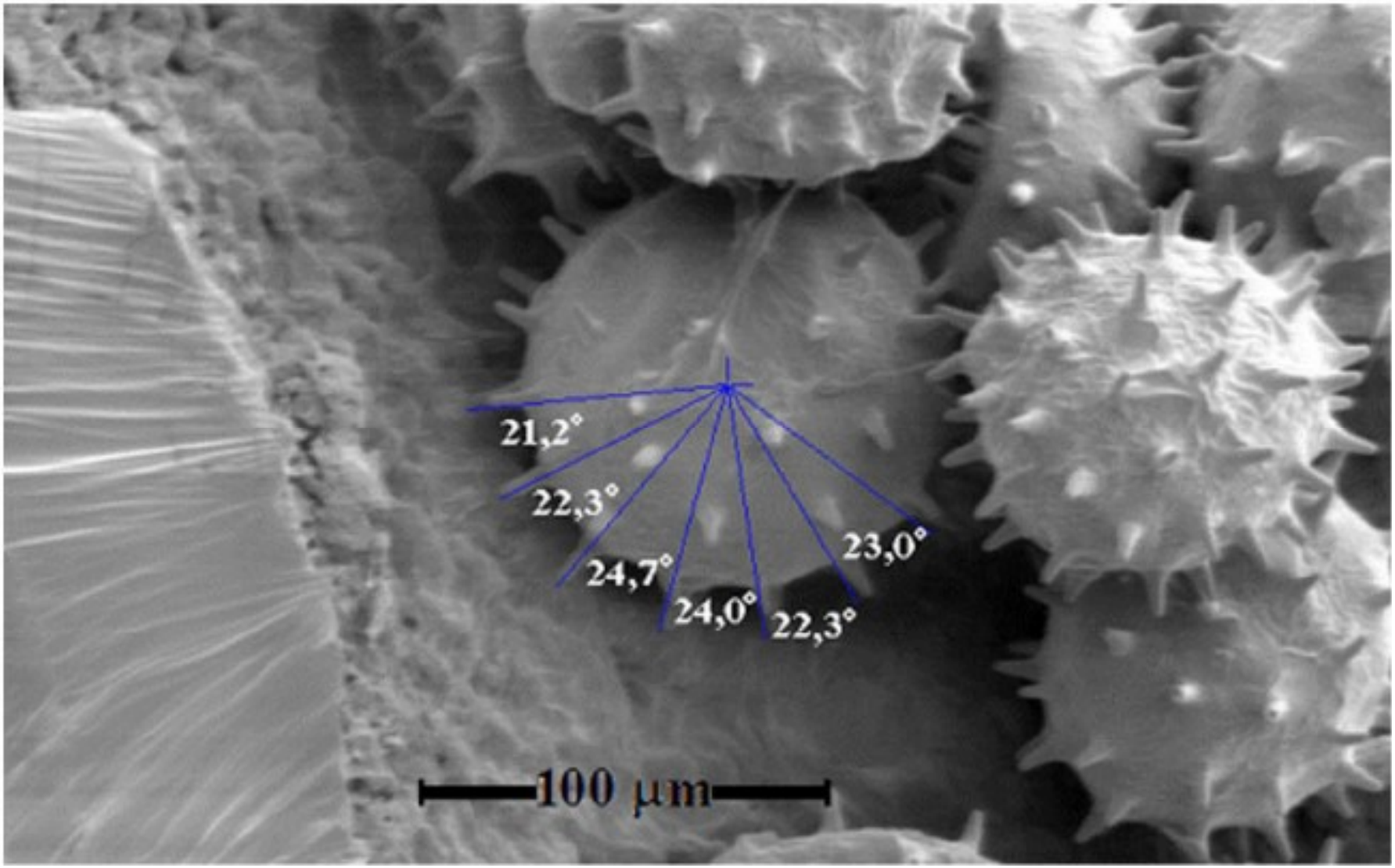
Spines/Spikes

- The spikes on the surface of pollen grains increase the chance of the grains being part of a successful fertilization. Not all pollen grains have spikes.

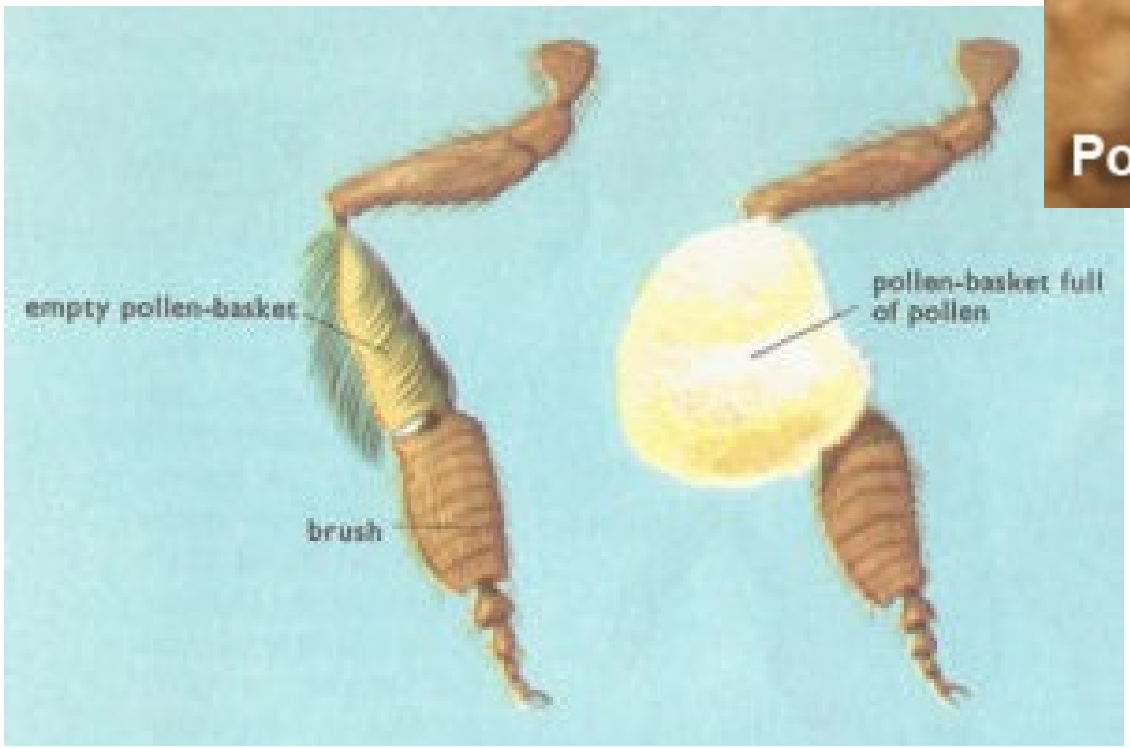
- Some plants produce echinate pollen, i.e. pollen grains with spines.

- Spiny pollen grains are known from many species of the Malvaceae, some species of the Convolvulaceae, Cucurbitaceae and Asteraceae.

- Bumblebees are unable to collect spiny pollen grains, because they cannot compact them in their pollen baskets


21,2°
22,3°
24,7°
24,0°
22,3°
23,0°
100 µm

- The **pollen basket** or corbicula (plural corbiculae) is part of the tibia on the hind legs of certain species of bees. They use the structure in harvesting **pollen** and carrying it to the nest or hive.



Thank you