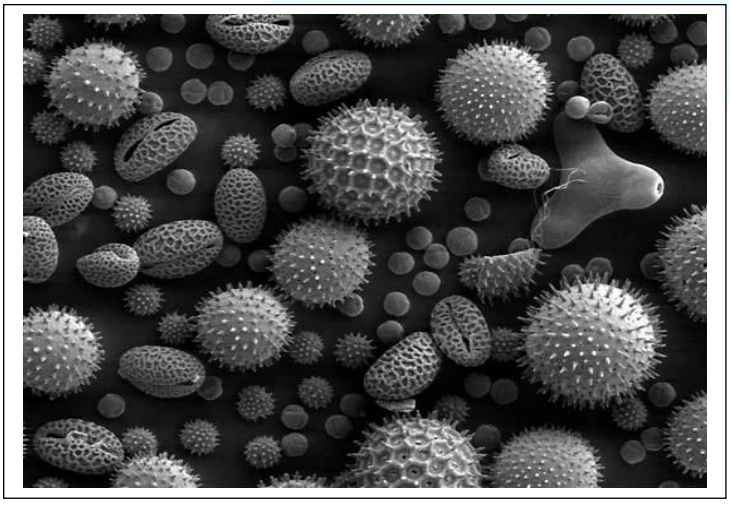
PALYNOLOGY

- Palynology scientific discipline concerned with the study of plant pollen, spores, and certain microscopic planktonic organisms, in both living and fossil form.
- The field is associated with the plant sciences as well as with the geologic sciences, notably those aspects dealing with stratigraphy, historical geology, and paleontology.
- Palynology also has applications in archaeology, forensic science and crime scene investigation, and allergy studies.
- Accordingly, the scope of palynologic research is extremely broad, ranging from the analysis of pollen morphology with electron microscopes to the study of organic microfossils (palynomorphs) extracted from ancient coals.

POLLEN GRAIN

- 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 spore microfossils 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.
- Important, too, is the fact that the evolutionary sequence of organisms based on the large fossil remains of plants in sedimentary rocks is recorded by the sequence of plant microfossils as well.
- Such microfossils are thus useful in determining geologic age and are especially important in sediments devoid of large fossils.
- Because of their abundance and minute size, microfossils can be extracted from small samples of rock secured in drilling operations.
- Palynological analysis therefore is of practical application to petroleum exploration and to other geologic research involving subsurface sediments and structures.
- Palynology is also invaluable to evolutionary and taxonomic research and can help to delineate phylogenetic relationships between fossilized and extant plants.

POLLEN

- Pollen a mass of microspores in a seed plant appearing usually as a fine dust. Each pollen grain is a minute body, of varying shape and structure, formed in the male structures of seed-bearing plants and transported by various means such as wind, water, insects, etc. to the female structures, where fertilization occurs.
- In angiosperms, pollen is produced by the anthers of the stamens in flowers.
- In gymnosperms, it is formed in the microsporophylls of the microstrobili (male pollen cones).

- Pollen consists of one or more vegetative cells and a reproductive cell. A pollen grain itself is not the male gamete.
- In angiosperms and certain gymnosperms, the vegetative cell forms the pollen tube that grows to meet the unfertilized ovules, and the reproductive cell is the source of the sperm.
- Most pollen grains consist of three distinct parts.

1. Central cytoplasmic part: The source of nuclei responsible for fertilization.

2. Wall of the grain:

a) Intine:
- Inner layer
- Consists at least in part, of cellulose or hemicellulose.

b) Exine:
- Outer layer
- outer and most durable layer
- The exine is very resistant to disintegration, treatment with intense heat, strong acids, or strong bases has little effect upon it.

- The constituents of the exine have been termed sporopollenins.
- The internal parts of the pollen grain are easily broken down, whereas the exine layer, and thus the general form of the pollen grain, is easily preserved in various kinds of sediments; the quality of preservation may vary with different environments.

SAGE POLLEN

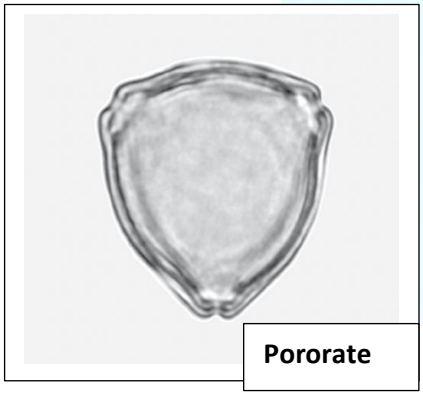
- Because of their high resistance to decay, their widespread dispersal by wind and water, and their abundant production by plants, pollen grains are very common constituents of geologic sediments, both recent and ancient.
- Because of these features, pollen grains have provided much information on the origin and geologic history of terrestrial plant life.
- Additionally, given their remarkably symmetrical structure and surface patterns, fresh and preserved pollen grains are readily recognizable under the microscope.
- Characteristics such as the exine sculpturing and the size and number of apertures through which the pollen tubes grow are useful as taxonomic tools.
- The structure of a pollen grain is oftentimes so distinctive that in some cases species may be identified by pollen grains alone.
- Nearly all angiosperm and gymnosperm plant families and many genera can be identified solely by their pollen grains.
- The study of pollen and spores is known as palynology.
- Pollen is produced in such quantities that it is a significant component of the airborne constituents of Earth's atmosphere, especially in areas over continents.
- The proteinaceous substance in many pollen grains (namely, ragweed and many grasses) induces an allergic reaction commonly known as hay fever.
- Frequently local governmental authorities publish pollen counts, estimates of the concentration of pollen grains in the air, for the purpose of indicating the relative discomfort that may be experienced by sufferers from hay fever and similar allergies.

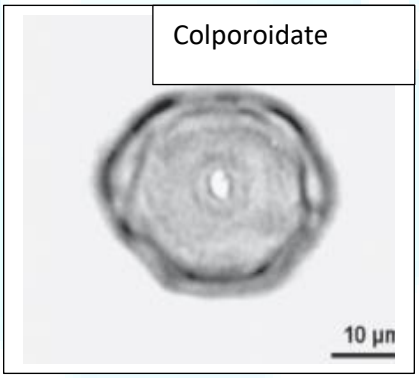
POLLEN MORPHOLOGY AND ULTRASTRUCTURE

Pollen Apertures

- An aperture is a region of the pollen wall that differs significantly from its surroundings in morphology and/or anatomy.
- The aperture is presumed to function as the site of germination and to play a role in harmomegathy.

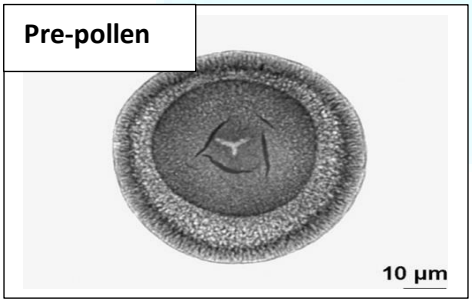
- Pollen grains lacking apertures are called inaperturate. The aperture definition fits both angiosperm and gymnosperm pollen, but in gymnosperms the type of aperture (e.g., leptoma; germination area) usually differs from that in angiosperms.
- The polarity of the pollen grain determines the aperture terminology. A circular aperture is termed a **Porus** if situated equatorially or globally, if situated distally, it is called an **ulcus**.
- An elongated aperture is termed a **colpus** if situated equatorially or globally; if situated distally, it is termed a **sulcus**.
- A combination of porus and colpus is termed a **colporus**; colpori are situated equatorially or globally.
- In **heteroaperturate** pollen two different types of apertures (single and/or combined) are present in a combination of colpi with colpori or pori.
- A circular or elliptic aperture with indistinct margins is termed a **poroid**. Additional rare combinations of ecto and endoapertures, mostly observed in LM, include **pororate** and **colporoidate**.



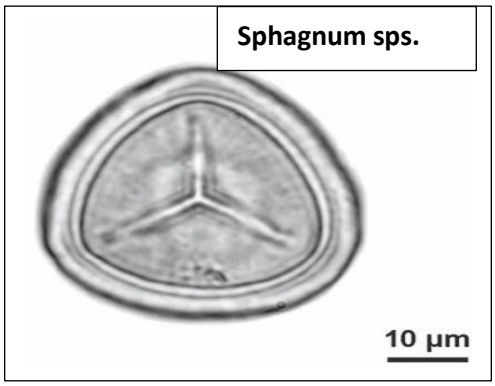


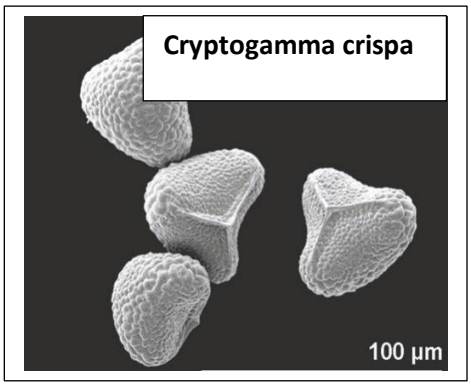
- Pollen grains that have compound apertures composed of circular ectopori and endopori are termed pororate.
- Compound apertures composed of a colpus (ectoaperture) with an indistinct endoaperture are termed colporoidate.
- The number of equatorial apertures (pori, colpi, colpori) is indicated by the prefixes di-, tri-, tetra-, penta- or hexa-. Writing numbers instead of prefixes is in common use, e.g., 4-porate or tetraporate, 6-colpate or hexacolpate.

- For pollen grains with more than three apertures, positioned at the equator, the term stephanoaperturate (stephanoporate, stephanocolpate, stephanocolporate) is used together with the aperture number (e.g., stephano(4)porate or 4-porate, stephanoporate).
- Pollen grains with globally distributed apertures are termed pantoaperturate.
- Apertures are normally covered by an exinous layer, the aperture membrane.
- The aperture membrane can be ornamented, e.g., covered with various exine elements, or it is psilate (smooth).
- The aperture can also be covered by an operculum, a distinctly delimited exine structure, covering the aperture like a lid.
- Number, type, and position of apertures are genetically determined and usually the same within a species, but may also vary (e.g., *Alnus* is usually 5-porate, but number of pori can vary from 3 to 6).
- A pseudocolpus occurs in heteroaperturate pollen and is presumed to be non functional.
- Pseudocolpi mostly alternate with colpori (e.g., in Boraginaceae, Lythraceae) or are flanking each colporus (in Acanthaceae).
- Pre-(prae-)pollen is characterized by proximal and sometimes additional distal apertures, and by presumed proximal germination. Pre-pollen are microspores of certain extinct basal seed plants occurring from the Late Devonian until the Cretaceous.

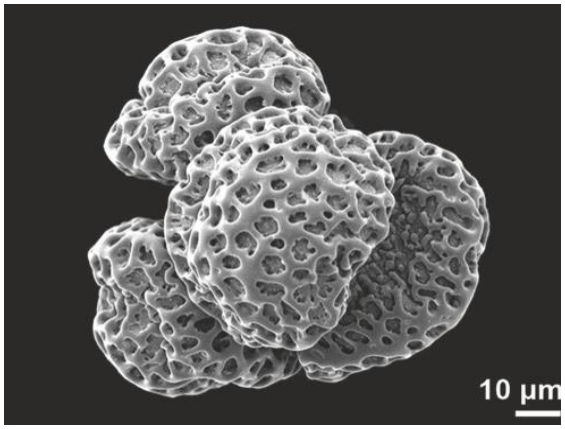


- Proximal germination is typical for spores. Spores germinate at the tetrad mark (Fig. 11), the so called laesura.
- Tetrad marks in different species are;

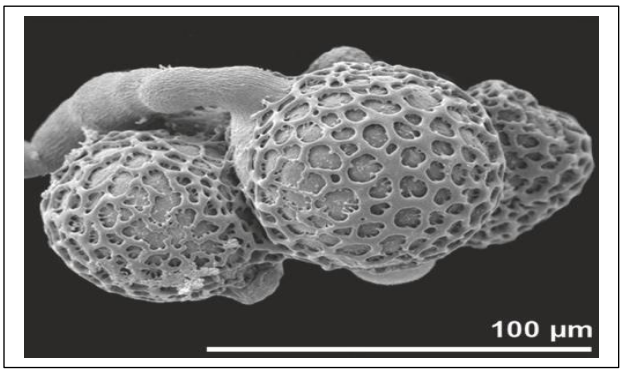




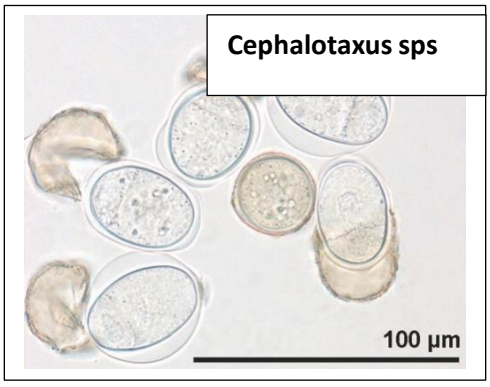
- The tetrad mark is situated at the proximale pole (proximal germination). Proximal germination is a rare exception in seed plants, e.g., *Beschorneria yuccoides* (Agavaceae) and *Annona muricata* (Annonaceae). In the two cases, this proximally situated aperture (germination area) is functionally replacing the dysfunctional sulcus.
- Dry tetrad of *Beschorneria yuccoides* are shown below;

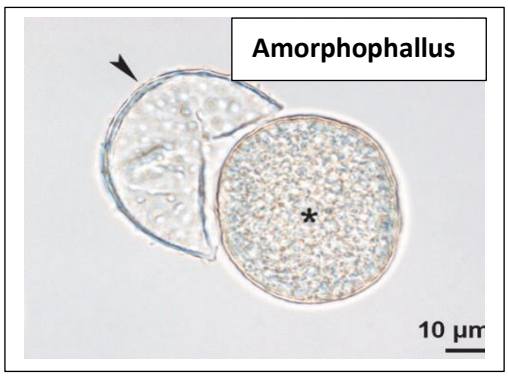


- Germinated tetrad of *Beschorneria yuccoides* are shown below;

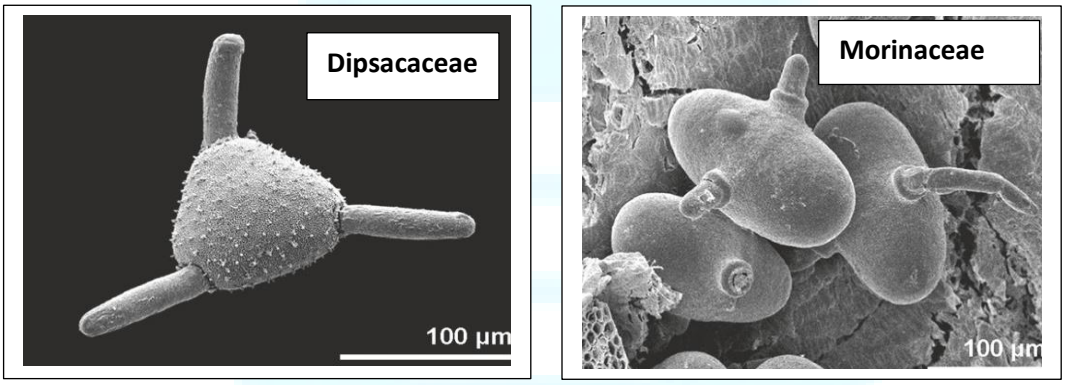


- In *Beschorneria*, pollen grains forming the tetrads are loosely interconnected and separate frequently. In this special case, the sulcus (distal) is not functional, whereas the proximal face, with a highly reduced exine, functions as germination site.
- In *Annona*, the microspores rotate within the tetrad during development and the original distally placed sulcus becomes proximally positioned.
- The aperture usually acts as the (exclusive) germination site. In inaperturate angiosperm pollen the pollen tube can protrude at any given site.
- In taxoid gymnosperm pollen the exine ruptures during hydration at a specialized region, the leptoma, and is subsequently shed.
- The protoplast (enclosed by the intine) is released and a pollen tube can be formed anywhere (resembling functionally an inaperturate pollen grain).
- Furthermore some angiosperm taxa shed the exine before pollen tube formation, e.g., in some Annonaceae, Araceae. Within the Araceae, a shed pollen wall has been observed in several taxa, e.g., *Amorphophallus*, *Taccarum*.
- The exine pollen wall shedding of different species are;





- The outer pollen wall (composed of polysaccharide) splits immediately in water and sheds soon after wards. Subsequently, the naked protoplast is floating in water and germinates about 1 hour after shedding.
- During germination, usually a single pollen tube is formed. In some cases, instant pollen tube-like structures are simultaneously developed at all apertures.
- The formation of these pollen tube like structures, in relation with moisture, is interpreted as a pre-germinative process that takes place during dehiscence.
- Instant pollen tubes of some families are;

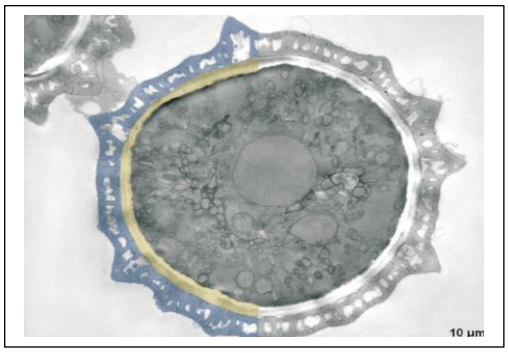


Pollen Wall

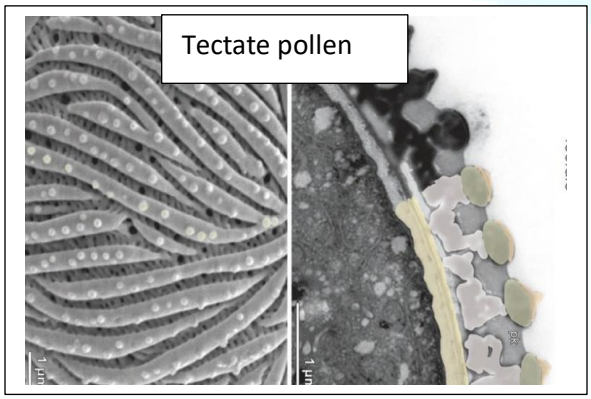
- The he internal construction of the pollen wall is termed structure. Ornamenting elements on the pollen surface (ornamentation) are summarized under the term sculpture or sculpturing. However, it is not always possible to distinguish between structure and sculpture (e.g., free-standing columellae).

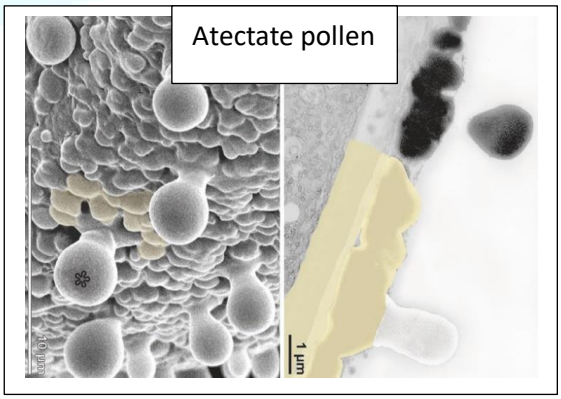
Structure

- In general, the pollen wall (sporoderm) of seed plants is formed by two main layers: the outer exine and the inner intine.
- *Ambrosia artemisiifolia*, Asteraceae, cross section showing both intine (yellow) and exine intine are shown below;



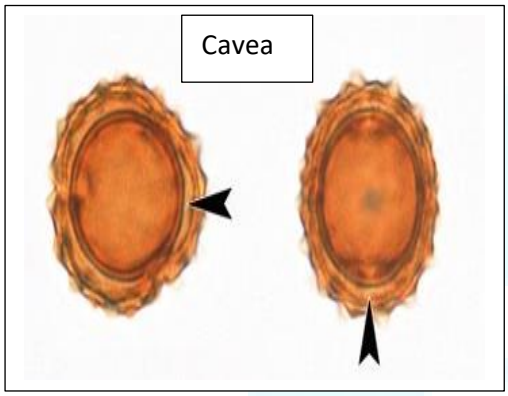
- The exine consists mainly of sporopollenin, which is an acetolysis and decay resistant biopolymer.
- The intine is mainly composed of cellulose and pectin.
- Commonly, the pollen wall in aperture regions is characterized by the reduction of exine structures or by a deviant exine, and a thick, often bilayered intine.
- Two layers within the exine are distinguished: an inner endexine and an outer ectexine.
- In tectate pollen the ectexine usually consists of a basal foot layer, an infratectum (e.g., columellae) and a tectum, the endexine is a mainly unstructured layer.
- There are many deviations from this principal construction: layers may be thickened, variably structured or lacking. When the pollen grain is lacking a tectum it is termed atectate.





- In apertural regions the pollen wall is generally characterized by a different exine construction.

- The terms sexine for the outer, structured, and nexine for the inner, unstructured exine layer are widely used in light microscopy, but do not fully correspond to ect- and endexine, respectively.
- When a cavity between the sexine and nexine is present in the interapertural area, this is termed cavea.
- *Xanthium spinosum*, Asteraceae, acetolyzed pollen in polar (left) and equatorial (right) view showing exine cavity (cavea) between sexine and nexine (arrowheads) are shown below;



Sporopollenin

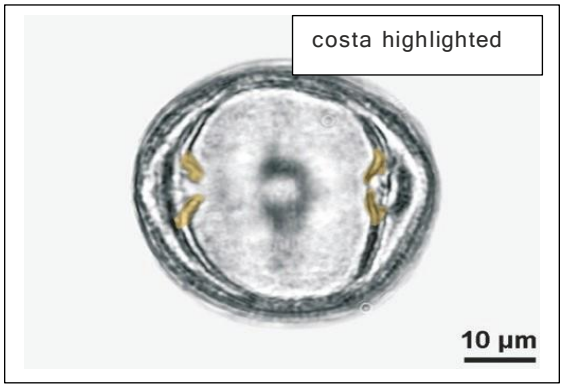
- John and Braconnot introduced the terms "pollenin" and "sporonin" for the resistant exine material of pollen and spores. Zetzsche et al. then combined the terms into "sporopollenin," that is the major component of the exine found in most pollen and spores, except in filiform seagrass pollen.
- Sporopollenin is a complex biopolymer and extremely resistant to decay as well as to chemical and mechanical damage.
- However, in the environment, both biotic and abiotic factors are involved in pollen decomposition.
- Biotic factors are, for instance, the intrusion of bacteria and fungi.
- Abiotic factors include the pH-value of the substrate, oxidation/reduction, autoxidation by UV-light and oxygen, destruction due to mechanic impact, water or fire and rapid changes in moisture levels.
- The preservation status and the amount of pollen and spores in sediments depends on several factors, including rapid anaerobic burial and embedding

in mud or peat, absence of any microbial destruction or sapropel, and the exclusion of oxygen.

- Recent studies on the composition of sporopollenin suggest that it may have two different types of chemical structures, oxygenated aromatic compounds and aliphatic compounds.
- Although its exact structure remains unknown, sporopollenin is believed to compose oxidative polymers of carotenoids, polyunsaturated fatty acids, and conjugated phenols.
- Some authors are using the plural form "sporopollenins," because there is evidence for several types of sporopollenin in ferns, gymnosperms, and angiosperms.
- Investigation of fossil pollen and spores revealed that fossilized sporopollenin appears chemically very different to sporopollenin found in modern plants.
- During fossilization (coalification) and by diagenetic processes the chemical composition of sporopollenin is modified.

The angiosperms pollen wall

- In angiosperms the ectexine consists in general of tectum, **infratectum**, and foot layer.
- The outer layer, the more-or-less continuous tectum, can be covered by supratectal elements.
- The infratectum beneath is columellate or granular (a second layer of columellae may form an internal tectum).
- Even the alveolate infratectum, that by definition is restricted to gymnosperms, can also be found in some angiosperms.
- The foot layer may be either continuous, discontinuous or absent.
- The endexine can be described as continuous or discontinuous, spongy or compact, overall present, in apertures only, or even completely absent.
- Some typical deviations of the wall thickness are termed: arcus, annulus, tenuitas and costa (a thickening of the nexine/ endexine bordering an endoaperture.



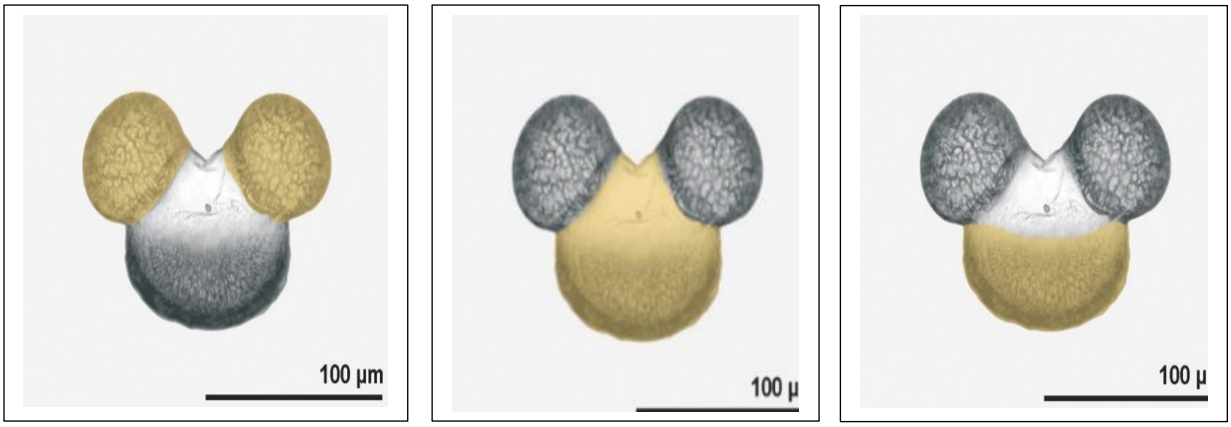
The gymnosperms pollen wall

- The basic stratification (ectexine, endexine, and intine) of the gymnosperm pollen wall is identical to that of angiosperms.
- The gymnosperm pollen wall differs from that of an angiosperm by having
  1) A lamellate endexine in mature pollen
  2) An infratectum that is never columellate.
- The infratectum is either alveolate or granular.
- A special terminology applies to saccate pollen, i.e. in Pinaceae and Podocarpaceae.
- Saccus is anexinous expansion forming an air sac, with an alveolate infratectum.
- Corpus is the central body of a saccate pollen grain. Cappa is the thick walled proximal face of the corpus.

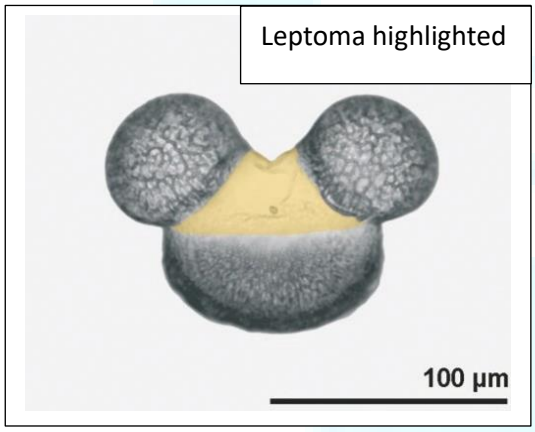
Sacci highlighted

Corpus highlighted

Cappa highlighted

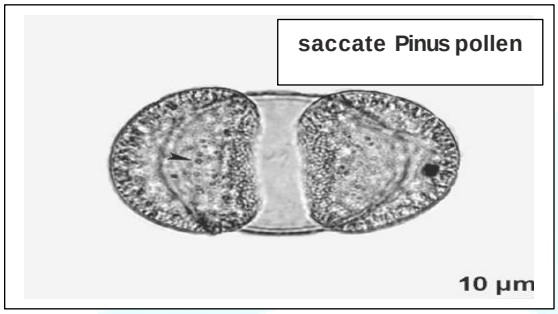


- Leptoma in conifer pollen refers to a thinning of the pollen wall on the distal face, presumed to function as germination area.



- Most frequently, two sacci are present (e.g., *Abies*, *Pinus*, *Picea*; Pinaceae), in some taxa even three (*Dacrycarpus*, *Microstrobus*; Podocarpaceae), or only a single one (*Tsuga*; Pinaceae).
- The function and evolutionary significance of saccate pollen have been subject of much confusion.
- The sacci of Pinaceae and Podocarpaceae are reported to play an aerodynamic role, thus being of adaptive significance for wind pollination.
- In fact, their functional role is to float in a liquid pollination droplet towards the ovule.

- The flotation system is interpreted as ancestral in conifers. The absence of sacci in, e.g., Cupressaceae and Taxaceae might reflect the loss of "drop mechanism," correlated with the change of pollination mode (shift to upwards orientation of the ovules).
- In *Pinus*, pollen can be grouped into two morphotypes of systematic value.
- The Pinus subgenus Strobus (haploxylon) type is characterized by pollen grains with broadly attached half spherical air sacs in LM the leptoma shows dotted thickenings (seen as dark spots).

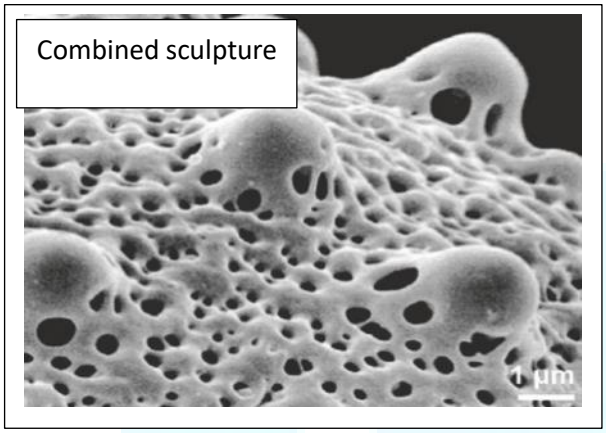


- The *Pinus* subgenus *Pinus* (diploxylon) type is characterized by pollen grains with narrowly attached, spherical air sacs often with nodula on nexine area the leptoma does not show any thickenings.

Sculpture: Ornamentation

- The terms ornamentation and sculpture applies to surface features of a pollen.
- The term sculpture is restricted by some authors to surface features in tectate pollen grains.
- Sculpture elements (saccate Pinus pollen) can be extremely variable in both size and shape.
- Based on size many sculpture/ornamentation elements smaller than 1 µm can be described with the prefix micro- (1–0.5 µm) or nano- (0.5–0.1 µm). Also, the boundary between two ornamentation types can be diffuse. For example, "gemmae" and "clavae" are very variable and sometimes hard to differentiate.

- Combinations of different sculpture/ornamentation elements are common, such as the combination reticulate and foveolate, or echinate and perforate.
- With a combined sculpture, the pollen ornamentation should then be described in a defined order, with the most eye-catching feature mentioned first, followed by the others.
- Combined sculpture elements; verrucate, perforate are shown below;



- For example, *Aristolochia* pollen is verrucate perforate, as the verrucae are more prominent than the small perforations. In the Caryophyllaceae, there are numerous, more or less regularly arranged microechini and perforations.
- In some taxa the microechini are more prominent (microechinate perforate), in others the perforations (perforate microechinate).

NPC CLASSIFICATION OF POLLEN AND SPORE WALL

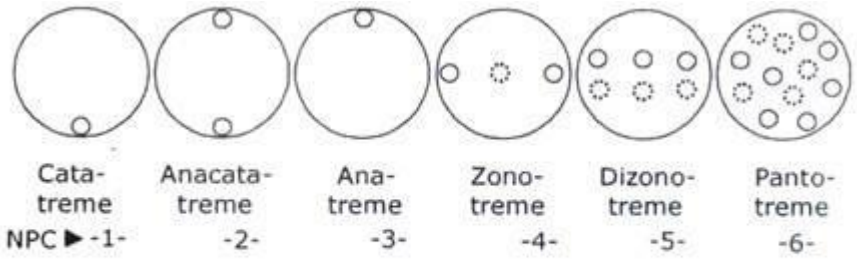
- NPC is an artificial system of classification of pollen and spore based on the three features of aperture only, i.e. number, position and character.
- Erdtman and Straka (1961) proposed NPC classification and palynologists all over the world accepted it.
- According to NPC system each pollen grain has an arithmetic cardinal number consisting of three digits. The first digit reveals the absence or presence of aperture, and when present it mentions the total number of aperture(s) present in a pollen grain.

- The second digit illustrates the position of aperture(s), i.e. distal, proximal, and latitudinal, meridonial, equatorial etc. The microspores reveal the position of aperture(s) with full clarity when they are in tetrad.
- The third digit explains the character of an aperture, i.e. circular/oval or elongated, simple or compound etc. 'N' from number, 'P' form position and 'C' from character of aperture compose the NPC-classification.

i. Classification of Aperture Based on Number(s):

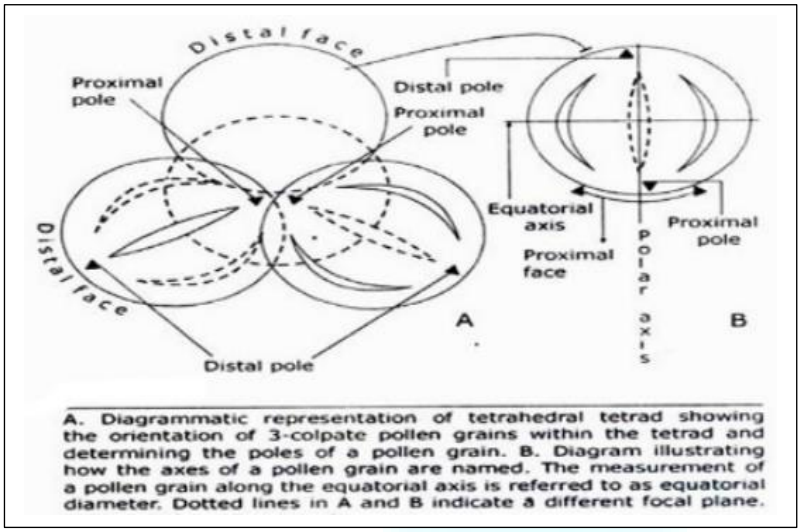
- In NPC system 'N' denotes the number of aperture(s) present in a pollen grain. Aperturate pollen, i.e. pollen having apertures are divided into seven groups.
- The groups are mentioned as N1 to N7. Each group has characteristic number of aperture, i.e. N1 has one aperture and N2 has two apertures and so on. The N7 group has seven or more apertures.
- N1 to N7 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 termed as inaperturate or atreme and they are placed in N0 group.
- Another special group N8 termed anomotreme is created where the pollen grains and spores have one or several irregular or irregularly spaced apertures.

ii. Classification of Aperture Based on Position (P):



Schematic representation of position (P) of aperture(s) only in pollen and its number in NPC.

- In NPC system 'P' denotes the position of aperture in a pollen grain and spore.
- The position may be proximal, distal and equatorial. There are seven groups of aperture based on position namely P0 to P6. Pollen grains having P0 group have uncertain or unknown position of aperture.
- P1 groups of pollen and spores are catatreme (Gr. Kata = down; -treme is suffix used as a synonym of aperture).
- Catatreme pollen grains have one aperture that occurs on the proximal part of a grain. The proximal (L. proximus, nearest) part is the face of a pollen grain or spore that faces inward/nearest or toward the centre of tetrad.
- P2 groups of pollen and spores are anacatatreme (Greek ana = up). Anacatatreme pollen and spores have two apertures.
- One aperture with its centre occurs at the proximal pole. The other aperture with its centre occurs on the distal pole. The distal (L. distalis, remote, outer) part is the face of a pollen grain and spore that faces outward, i.e. away from the centre of tetrad and opposite the proximal part (Fig. 4.31).



A. Diagrammatic representation of tetrahedral tetrad showing the orientation of 3-colpate pollen grains within the tetrad and determining the poles of a pollen grain. B. Diagram illustrating how the axes of a pollen grain are named. The measurement of a pollen grain along the equatorial axis is referred to as equatorial diameter. Dotted lines in A and B indicate a different focal plane.

- P3 groups of pollen and spores are anatreme, i.e. the aperture is distal in position.
- P4 groups of pollen and spore are zonotreme. A zonotreme (zono-a prefix used to indicate the equatorial/subequatorial region) pollen grain is characterized in having apertures on equator or sub-equator.
- The equator is the part of a pollen grain or spore that runs midway between the proximal and distal poles and perpendicular to polar axis.
- P5 groups of pollen and spore are dizonotreme.
- Dizonotreme pollen grains have apertures arranged in two or more zones. The apertures occur parallel to equator. P6 groups of pollen and spore are pantotreme (Greek pan, gen. Pantos, all, wholly).
- Pantotreme pollen grains have apertures scattered over the whole surface uniformly. As a rule, pantotreme pollen grains are spheroidal.

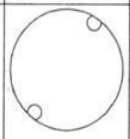
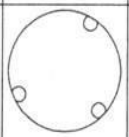
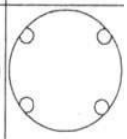
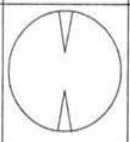
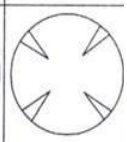
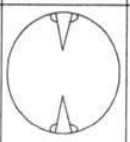
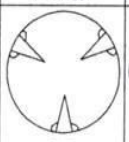
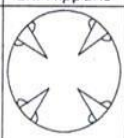
iii. Classification of Apertures Based on Character (C):

- In NPC-system 'C' denotes the character (C; L. character) of an aperture in a pollen grain and spore.
- The character groups of pollen and spore are seven and they are mentioned as C0 to C6. C0 groups have apertures whose character cannot

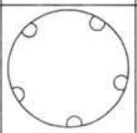
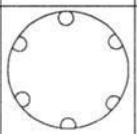
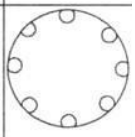
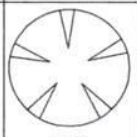
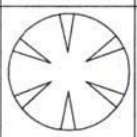
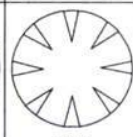
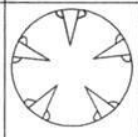
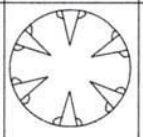
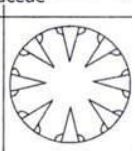
be established with certainty. C1 groups of pollen and spore have leptoma (Greek leptoma means thin place).

- Leptoma is a thin area, aperture like and functions like an aperture. Pollen grains having one leptoma are termed as monlept. The leptoma may occur on either proximal-or distal face of a pollen grain and spore and accordingly termed as catalept and analept.
- C2 groups are trichotomocolpate (Gr. Tricha, in three parts; tome, cut; kolpos, depression, furrow). Trichotomocolpate is a three- branched aperture, the branches of which are more than two times longer than breadth. Trichotomocolpate pollen and spores having aperture on porximal face are termed as trilete.
- The group C3 has colpate grains. The group C4 comprises porate pollen grains. The group C5 comprises colporate pollen. The group C6 comprises pororate pollen.

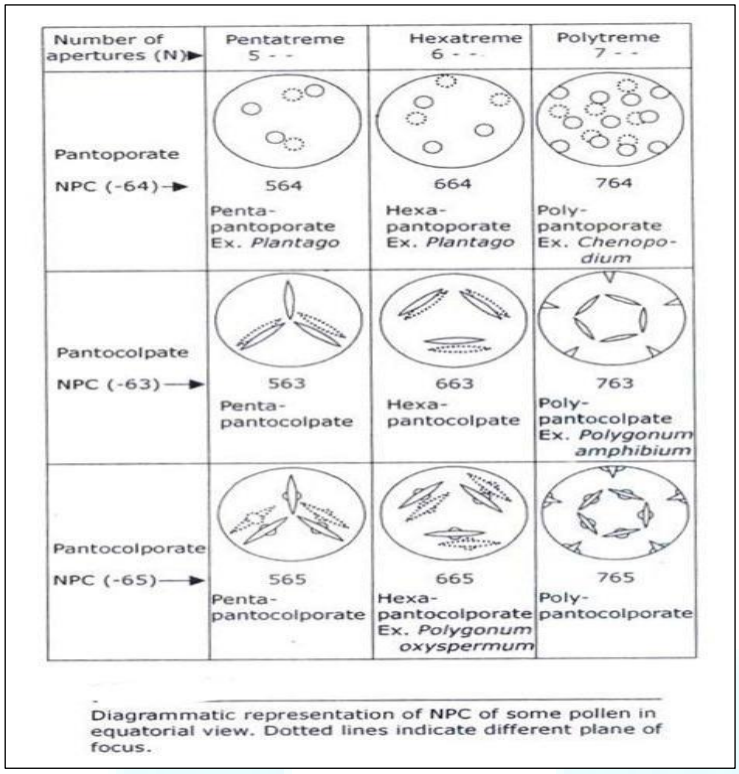
- In NPC classification a grain is mentioned in three-digit number. e.g. 343 instead of N3P4C3. Pollen grains having NPC 343 are tritreme zonocolpate, which is also described as tricolpate pollen.

Number of apertures (N) ▶	Ditreme 2 - -	Tritreme 3 - -	Tetratreme 4 - -
Zonoporate NPC (-44) ▶	 244 Di-zonoporate Ex. *Colchicum*	 344 Tri-zonoporate Ex. *Betula*	 444 Tetra-zonoporate Ex. *Alnus*
Zonocolpate NPC (-43) ▶	 243 Di-zonocolpate Ex. *Tofieldia*	 343 Tri-zonocolpate Ex. *Acer*	 443 Tetra-zonocolpate Ex. *Hippuris*
Zonocolporate NPC (-45) ▶	 245 Di-zonocolporate Ex. *Justicia simplex*	 345 Tri-zonocolporate Ex. *Lippia alba*	 445 Tetra-zonocolporate Ex. *Rumex*

Diagrammatic representation of NPC of some pollen in polar view.

Number of apertures (N) ▶	Pentatreme 5 - -	Hexatreme 6 - -	Polytreme 7 - -
Zonoporate NPC (-44) ▶	 544 Penta-zonoporate Ex. *Alnus*	 644 Hexa-zonoporate Ex. *Ulmus*	 744 Poly-zonoporate
Zonocolpate NPC (-43) ▶	 543 Penta-Zonocolpate	 643 Hexa-Zonocolpate	 743 Poly-Zonocolpate
	Ex. Labiatae, Rubiaceae		
Zonocolporate NPC (-45) ▶	 545 Penta-zonocolporate Ex. *Viola*	 645 Hexa-zonocolporate Ex. *Sanguisorba officinalis*	 745 Poly-zonocolporate Ex. *Utricularia*

Diagrammatic representation of NPC of some pollen in polar view.



Diagrammatic representation of NPC of some pollen in equatorial view. Dotted lines indicate different plane of focus.

- 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*, *Vitex*, *Tectona*, *Argemone* etc.

Merits of NPC classification:

1. It is a simple system of classification and illustrates the apertures of a pollen grain and spore.
2. NPC makes the description of apertures precise.
3. With the aid of NPC pollen grains and spores of pteridophyta, monocotyledon and dicotyledon, to some extent, can be differentiated. Most of the spores of pteridophyta are monolete or trilete. Monocots are characterized by inaperturate, monosulcate and monoporate pollen grains.

Dicots, with a few exceptions, have pollen grains that are mostly with three meridonial furrows and polyaperturate. Thus NPC narrows the search list of identification of unknown sporomorphs.

4. NPC is supposed to be of primary classificatory character because apertures are most conservative. It is supplemented by surface ornamentation, size and shape etc. of a pollen grain. Sometimes it becomes possible to identify the family or genus or even species of a pollen grain with the aid of NPC in combination with other morphological characters.
5. Palynologists all over the world accepted NPC-classification as it is basically simple and consistent where pollen grains and spores could be arranged easily. This helps to identify unknown sporomorphs.
6. NPC, sporoderm stratifications, exine patterns, size and shape etc. of a pollen grain are genetically stable. This property is utilized for various purposes and the followings are a few illustrations. With the aid of NPC and other characters a key can be formulated that helps to identify unknown pollen and spores.
    - Identification of pollen and spores is the essential prerequisite in the applied aspects of palynology, i.e. aeropalynology, melissopalynology, forensic palynology and palaeopalynology etc.
    - The interfamily and intra-family affinities of taxa, to some extent, can be determined with the aid of NPC. As for example the family Gramineae seems to be closely related to Restionaceae, Centrolepidaceae and Flagellariaceae, because pollen grains of above taxa are monoporate.
7. NPC and the various types of exine patterns and ornamentation provide characters of taxonomic significance and thus become one of the sources of alpha taxonomy.
    - Example: Bombacaceae is segregated from Malvaceae; Zingiberaceae, Cannaceae and Musaceae are amalgamated into Scitamineae.

Demerits of NPC classification:

1. It is an artificial system of classification.
2. Syncolpate and parasyncolpate pollen grains do not fit neatly in NPC system.

3. Pollen grains that are characteristically present as aggregates in tetrads, e.g. Ericaceae, Typhaceae and polyads, e.g.
4. Orchidaceae, Mimosa etc. are not grouped in NPC system.
5. NPC-system of classification is always compared with Linnaeus's system of classification, because the latter is also an artificial system of classification.
6. The characters of stamen were the basis of classification.
7. Linnaeus accepted the weakness of his classification but claimed that it was propounded mainly as an aid to identification'. This is also applicable to Professor Erdtman.
8. Palynologists from every discipline of palynology utilize Erdtman's NPC classification and other characters related to pollen morphology as an aid to the identification of unknown sporomorphs