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1.MORPHOLOGICAL CLASSIFICATION OF POLLENS AND SPORES

Pollen grains and spores are often described by the shape (non-angular and angular) of their outline both in polar and equatorial views. The shape of the pollen/spores may be circular, elliptical, triangular, rectangular, quadrangular or in other geometrical shapes

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.

The pollen grains do not remain united at maturity, and are dissociated into single pollen grain called monad. Sometimes rarer types like dyads (two pollen grains), Octads (eight pollen grains) and Polyads (many pollen grains) are also observed .

Pollen units

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 the incomplete break up of individual grain or monad.

Tetrads: Four pollen grains are united to form tetrad. Tetrads are the unseparated product of meiosis. Tetrads maybe categorized into different types based on their arrangement

Tetrahedral tetrad: Pollen grains are arranged in two different planes. Three grains are in one plane and one lies centrally over the other three. In some cases, the pollen grains are released from the anther in the tetrad condition. These types of tetrads are called obligate or permanent tetrads, viz., Drymis (Winteraceae), Drosera (Droseraceae), Rhododendron Ericaceae).

Tetragonal tetrad: All the four pollen grains are arranged in one plane e.g., Typha latifolia (Typhaceae), Hedycaria arborea (Monimiaceae).

Rhomboidal tetrad: All pollen grains are arranged in one plane forming rhomboidal shape e.g., Annona muricata (Annonaceae).

Decussate tetrad: Pair-wise the pollen grains are at right angle to each other, e.g., Magnolia grandiflora (Magnoliaceae).

T-Shaped tetrad: The first division of pollen mother cell is transverse to form a dyad. The upper or lower cell of dyad undergoes a vertical or longitudinal division instead of transverse, yielding either straight or inverted T-shaped configuration, e.g., Aristolochia sp.(Aristolochiaceae), Polyanthes sp; (Amaryllidaceae).

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, e.g., Mimosa pudica.

Cryptotetrad or Pseudomonad: Here tetrads are formed without partition walls between the four compartments. One out of the four nuclei develops normally and the rest three obliterate. Thus an apparent monad but homologous to the tetrad is formed (e.g., Cyperaceae.)

Polyads: In most of the Mimosaceae members each of the tetrad cells divides once or twice or more, yielding a group of 8 to 64 cells which remain together after maturity. These compound grains are usually held together in small units and are called polyads e.g., Acacia auriculiformis, Adenanthera pavonina, Calliandra hematocephalla, Samania saman, Albizzia lebbeck.

Pollinia: In Orchidaceae and Asclepiadaceae the whole contents of an anther or anther locule which shed as one united mass of pollen are called Pollinia). The pollinium (singular) apparatus is the functional unit of a “corpusculum” with its two attached arms (translator) and Pollinia. e.g., Calotropis sp., Daemia sp., etc., of the Asclepiadaceae and majority of the family Orchidaceae.

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). Positions on the surface of the grain maybe determined by their latitude, comparing to the latitude on a regular sphere. Similarly, surface features in a pole to pole direction at right angles to the equatorial plane are called meridional.

Polarity

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.

Polarity

The pollen grains showing slight differences between the distal and proximal faces are also called paraisopolar or subisopolar. Say for example, one face (distal) is convex and the other face (proximal) is plane or concave or vice versa. Their equatorial plane is usually more or less curved. Sometimes there are small differences in the surface details of the two poles viz. Carya, Ulmus, etc.

In some bryophyte spores like Calobryum dentatum, Haplomitrium hookeri, the distal and proximal faces have dissimilar sculpturing and lack tetrad mark. This type of spores is called Cryptopolar .

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

In radiosymmetric grain the shape is such that any plane including the polar axis that passes through will produce identical halves. So the radiosymmetric grains have more than two vertical planes of symmetry. Radially symmetrical isopolar grains have one horizontal and two or more vertical planes of symmetry. Radially symmetrical heteropolar grains have no horizontal plane of symmetry.

Bilateral heteropolar pollen grains have two vertical planes of symmetry. Bilateral isopolar grains have three planes of symmetry, one horizontal and two vertical. In some bean- shaped or boat-shaped spore/pollen there is only one vertical plane of symmetry with an opening towards the end of the grain.

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. However, the shape may vary considerably within one grain type or even within one species.

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Various shapes of the pollen grains

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, multiplying by 100 gives the indication of the shape.

Various PA/ED ratios are divided in it to different shape classes, e.g., Prolate, Prolate-spheroidal, Spheroidal, Sub-prolate, Perprolate, Oblate, Oblate-spheroidal, Sub-oblate, Peroblate

Various shapes of the pollen grains

Pollen shape classes

In bilateral grains, pollen are plano-convex, concavo-convex or biconvex in lateral view.

Size:

Pollen grains show a great variety in their sizes. 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 Curcurbitaceae, Nyctaginaceae and Orectanthe ptaritepuiane (Abolbodaceae).

In taking measurements of size the length of polar axis (PA), equatorial diameter (ED) and sometimes equatorial breadth (EB) are considered in bilateral grains.

In radially symmetrical pollen grains 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 0.5 μm if any.

Erdtman (1945) categorized the different pollen size classes based on the size expressed as length of the longest axis.

Apertures:

Morphologically aperture is an opening or thinning of the exine where the in tine is usually thick; physiologically it is a germination zone or a harmomegathus (A mechanism accommodating changes in volume of the semirigid pollen exine) or both.

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

Some taxa have ‘atreme’ (trema, a Greek word means aperture) pollen/spore, i.e., they seem to have no special aperture, are termed as ‘inaperturate’ or non-aperturate.

Majority of the pollen grains described as ‘inaperturate’ seem to be ‘omniaperturate’, that is, the entire pollen wall is made up of a thin exine and a thick intine or at least thick as the exine, for example Canna sp. of Cannaceae. There are two types of apertures known as Pores (Porus, p1. Pori) and furrows (Colpus, p1. Colpi. or Sulcus, p1. Sulci). In most cases the furrows act as harmomegathi.

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 (Fig. 4.7). 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 (N1) with one aperture, Ditreme (N2) with two apertures; Tritreme (N3) with three apertures, Tetratreme (N4) with four apertures, Pentatreme (N5) with five apertures, Hexatreme (N6) with six apertures and Polytreme (N7) having more than six apertures. Irregularly arranged spiral apertures over the surface of the pollen irrespective of their number are designated as ‘Anomotreme’ (N8).

On the basis of the position (P) of apertures, pollen are categorized into seven groups (P0 to P6). In ‘Catatreme’ (P1) pollen aperture is in proximal face, while in ‘Anatreme’ (P3) it is in distal face. The pollen are designated as Anacatatreme’ (P2) where apertures are both in proximal and distal faces.

The pollen grains are referred to as ‘Zonotreme’ (P4), when the apertures are located on the equatorial zone. ‘Dizonotreme’ (P5) are like zonotreme, but with two rows of apertures on the equatorial region. In ‘Pantotreme’ (P6), apertures are globally distributed all over the pollen surface.

Like position groups the character (C) groups are of seven types (C0 to C6). If the character of the aperture is not known, it is designated as C0. Pollen having an aperture like thin area or Leptoma is designated as C1. Pollen with one leptoma is called Monolept, it may be called Cataleft if present in the proximal face, or Analeft if in the distal face.

Spores are microscopic propagative bodies, with a single nucleus, whose primary function is plant dispersal and reproduction. Spores are produced by “lower” plants, which include mosses, liverworts, clubmosses (lycopods), horsetails, and ferns.

Spores, produced in a sporangium (spore case), are initially attached to each other in groups of four, called tetrads. These occasionally remain intact as obligate tetrads, but usually separate, leaving scars or lines of attachment, vestiges reflecting the spore arrangement in the tetrad. Trilete (Y-shaped) scars result from tetrahedral tetrads, and monolete (–shaped) scars result from tetragonal tetrads. This trilete or monolete scar functions as an area of weakness which ruptures, allowing emergence of the developing gametophyte. The trilete or monolete scars may be simple, barely visible traces, or they may be accompanied by a variety of structures including thickened and raised lips, or, in extreme cases, by high membranous extensions . Some spores, called alete, may show no trace of a scar

Trilete spores may be circular to triangular, and monolete spores oval to kidney shaped. The spore wall, or exine, may be a single thin or thick layer, or it may be differentiated into two or more layers. These layers may be separated to varying degrees and each layer may be of different thickness and/or ornamentation.

Diverse spore wall ornamentation reflects interspecific variation. The spore wall may be smooth or ornamented withpits, canals, granules, warts, spines, rods; anchor shaped, drumstick shaped, or complex projections; flanges; or ridges arranged in many different patterns (striate, annulate, reticulate). Spore wall ornamentation may combine two or more sculptural types and may vary from one site to another on individual spores. The spore surface bearing the scar, called the proximal face, commonly has reduced sculpture, reflecting the contact area within a tetrad, compared to the opposite (distal) face . Thickenings (or thinnings) may be restricted to certain areas, for example, at the ends of scars or commonly as a zone around the equator .This ornamentation, along with shape, type of scar, and other structures distinguishes spores and makes them useful for documenting evolving plant assemblages.

Some lower plants are heterosporous; that is, they produce two kinds of spores, small and large, as do some lycopods. The small spores are true microspores that develop into male gametophytes, and the large spores are mega-spores that develop into female gametophytes. Other lower plants are homosporous (=isosporous); that is, they produce usually small, nearly equal-sized (within a species) isospores whose gametophyte performs both male and female functions, as in most ferns. In practice, true microspores, isospores, and small megaspores cannot readily be distinguished from each other.

Some spore-like obligate tetrads of uncertain affinities but possibly associated with the earliest land plants first appear in rocks of the Ordovician Period. Simple trilete spores are found in late Ordovician–early Silurian rocks. Morphologic diversity increased from these initial simple smooth forms. Many distinctive, increasingly complex spore types arose during the Devonian Period, including some with distinctive anchor-shaped projections .

Heterospory developed in plants during the middle Late Devonian and was a major evolutionary step (megaspores are considered the precursors of seeds). Monolete spores became established early in the Pennsylvanian Period, although a few are known from the Late Devonian (e.g., Archaeoperisaccus spp.). Spores are particularly valuable for biostratigraphy in Upper Paleozoic and Mesozoic rocks.

2. STRATIGRAPHICAL AND PALEOENVIRONMENTAL APPLICATIONS AND SIGNIFICANT OF POLLENS AND SPORES IN SEDIMENTARY AND PETROLEUM GEOLOGY

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.

The phases of palynology that deal exclusively with fossils are outgrowths and extensions of techniques and principles developed in the study of peat deposits of northern Europe during the early 1900s. In such research the presence, absence, and relative abundance of the pollen of various species of trees from known depths in the bog were ascertained statistically. Inasmuch as forest composition determines the pollen types trapped on the surface of a bog at any given time, it follows that changes in the pollen content reflect regional changes in forest composition. It was established that alterations in forest makeup were induced by climatic change over the many thousands of years since glacial ice disappeared from northern Europe. A relationship was thus established between the pollen content of the peat, the age (i.e., position in the bog), and climate. Application of such findings proved invaluable in subsequent studies of ancient climate, particularly the glacial and interglacial stages of the Pleistocene Epoch (approximately 2.6 million to 11,700 years ago).