NAME: OKAFOR EMMANUELLA CHINELO

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1. Discuss the morphological classification of pollens and spores

Morphological classification of spores: spores of aquatic fungi engaged in leaf decomposition are plentiful in calcareous streams. These are conidia of ascomycetes, and a smaller number of basidiomycetes, called Ingoldian fungi after C. T. Ingold (1905–2010), who discovered them in the 1930s. It has been suggested that some of the Ingoldian fungi are endophytes and that their colonies are dispersed by leaf abscission. Ingoldian spores are striking for their elaborate shapes, including stars with four limbs connected to a central hub (tetraradiate conidia), crescents sigmoids, commas, and miniature cloves. They form at the tips of conidiophores that develop at the surface of leaves and become concentrated in bubbles of white foam that accumulate around rocks and fallen logs obstructing water flow. Collection of foam samples provides a convenient way to study these fungi and pure cultures can be obtained by harvesting spores from leaves after a short incubation in the lab.

Spores morphology is no more important in determining sedimentation rate in water than it is for spores dispersed in air. The high viscosity of water relative to air slows the sedimentation rate of spores from millimeters *per second* to millimeters *per minute*, but most experiments show that conidia with appendages fall through the water column at the same speed as more compact spores. Indeed, one experiment showed that intact spores of marine fungi settled faster than spores whose appendages had been disrupted by sonication. The unusual shapes of aquatic spores require an alternative explanation.

The most compelling answer is that the broader span of spores with unusual shapes increases the probability that they will collide with submerged plant materials. The largest conidia produced by the Ingoldian *Brachiosphaera tropicalis* have an effective diameter of 0.4 mm. A spherical spore of this diameter would weigh approximately 40 μg; the tetraradiate spore with a central hub and slender arms is 400 times lighter, producing a similar probability of hitting a leaf fragment yet saving a considerable investment in cytoplasm. This calculation is a little simplistic because the spherical spore might reduce its volume of active cytoplasm by expanding a large fluid-filled vacuole. Also, the surface area of the tetraradiate spore is only 30 times less than the surface of the sphere, which means that the economy in cell wall production is more modest than the potential reduction in cytoplasm. Nevertheless, the concept of the spore as a search vehicle probably explains the significance of the beautiful spore shapes in these fungi. The utility of the spore morphology with multiple appendages is

Morphological classification of pollens: Pollen is one of the most important and fundamental branches of palynology. It will not be an exaggeration if pollen morphology is referred to as the mother of palynological studies. Proper identification of pollen and spores both of living and fossil plants is a prerequisite for exploiting their applications. Pollen morphology is the principle tool used for correct identification. The slightest error in identification leads to an erroneous conclusion.

A recent example in this context which can be cited is concerned with the identification of airborne pollen in bangalonre. Due to lack of proper background knowledge of pollen morphology, Cassia pollen were shown to be the second most abundant pollen in Bangalore's atmosphere in a publication by the Asthma Research Society (1979). However, a systematic aeropalynological survey (Agashe et al., 1994) carried out by sound pollen morphological knowledge, proved that Bangalore's atmosphere was rich in Casuarina equisetifolia pollen, which, since it looks superficially similar to Cassia pollen, was earlier identified incorrectly.

Various features of pollen are studied in pollen morphology. Some of these pollen morphological characters are: symmetry, size and shape, pollen wall, exine stratification, ornamentation, furrows/grooves and apertures. The last three characters seem to be the most important pollen morphological characters useful in basic identification and classification of pollen. A number of terms have been coined to describe various pollen morphological characters. At times, confusion arises as the literature abounds with respect to different terminologies used by different palynologists.

MORPHOLOGY OF ANGIOSPERM POLLEN

Pollen grains, when mature and dehisced, show a range of size, shape and even color. Color requires the pollen to be seen, for example the pollen of Willow (Salix) is yellow, Dandelion

(Taraxacum) is orange and Willow Herb/Fireweed (Chamaenerion) is grey. Such a color aspect is of value to beekeepers in identifying pollen source. Most pollen however are yellow when seen en masse on a white background.

The majority of pollen grains range between 20-30 ^m (microns*). Some are very small, for example Forget me not (Myosotis) whose pollen measures 18 ^m. The largest category where size may exceed 100 ^m is exemplified by Rosebay Willow herb/Fireweed (Chamaenerion) whose large triangular pollen measures c. 150 ^m.

The shape of pollen grains is, like size, variable: round, oval (flattered or elongated), long or triangular, semicircular, boat shaped. Others may have several sides (flat or rounded). It is important to bear in mind when examining pollen grains with a view to their identification, that they are the products of a biological system, which is subject to variation, that a degree of care is sometimes needed to interpret what is seen.

The wall (exine) of pollen grains have apertures - Poplar (Populus) is exceptional in lacking them which take the form of simple holes (pores) and furrows (colpi). Pores and furrows may merge or be irregular in appearance.

The exine surface can vary in its structure considerably. It can be smooth, have granules, be striped (striated), have a mesh or network, small holes or pits, or appear dotted (which are the bases of spines more fully seen in the side view. The exine when viewed from the edge, may appear thin or be composed of two or more layers, which may be separated by thick, thin or beaded rods.

Grains are usually simple, separating from the quartet during development in the pollen sac, each having its own complete exine. Some pollen grains are released during dehiscence as quarters - compound grains for example in the Ericaceae and Juncaceae, families. The appearance of the cytoplasm may be as glass (hyaline or granular). Some plant families, for example Asteraceae, show a great variety of forms: grains with large spaces (fenestrae) such as Dandelions (Taraxacum), Hawkweeds (Hieracium) and Sowthistles (Sonchus), whilst others have spines of varying number and length, for example (Senecio). Again, in the Asteraceae family, Mugwort (Artemisia vulgaris) has a three-lobed grain with long rods (tectum) within each lobe separating the exine layers - this grain can be confused with those of Privet (Ligustrum) and grains of

Cruciferae, such as Oil Seed Rape (Brassica napus), which are similarly three-lobed. Pollen of the large family of grasses, Poaceae, have the simplest structure, which is more or less round, thin walled with one single pore. Pollen of cultivated cereal grasses

* Pollen grains are measured in microns. (1 micron = 0.001 mm) magnification for measuring size is usually x 400 or x 1000 under the light microscope.

are usually much larger than their wild relatives - being tetraploid or polyploid genetically.

It is unlikely that genetically modified pollen (GM) can be distinguished from the natural non-GM, morphologically. GM treatment is of no significance to the palynologist working with pollen of wild plants as opposed to pollen of cultivated crop plants.

Pollen grains are reproductive cells (male gametophytes). These specialized cells are provided with an extremely hard outer wall (exine) and an inner softer cellulose wall (intine) surrounding the cytoplasm with the vegetative and generative cells (nuclei), and organelles.

The pollen grains may be single (monads) which is most common, or two-pollen united (diads) for example Scheuchzeria palustris or united in fours (tetrads), or many, for example, multiples of fours (polyads). In Orchidaceae, sclepiaceae and a few other families the grains are united in club-like masses (pollinia)

With tetrads as a starting point we may discern polarity and symmetry. There are different kinds of tetrads, tetrahedral, rhomboidal, tetragonal, linear, etc. In Dicolyledons, the tetrahedral type (two planes) dominates, in Monocotyledons the tetragonal or rhomboidal type occurs (one plane only). The tetrad configuration (different types of tetrads) is often linked to the microspore divisions, for example tetrahedral tetrads (simultaneous), and one-plane tetrads (successive). With reference to this, it is possible to describe the location of various morphological features of the pollen grains and spores. Pollen grains or spores may have similar poles (isopolar), almost similar (subisopolar), or dissimilar poles (heteropolar), e.g. Lycopodium

Spores and Pollens classification

1. Spores are reproductive haploid structures that is adapted for dispersal and surviving for extended periods of time in unfavorable conditions. Spores form part of the life cycles of many plants, algae, fungi and some protozoans. A chief difference between spores and seeds as dispersal units is that spores have very little stored food resources compared with seeds.
2. Spores are usually haploid and unicellular and are produced by meiosis in the sporophyte. Once conditions are favorable, the spore can develop into a new organism using mitotic division, producing a multicellular gametophyte, which eventually goes on to produce gametes.
3. Pollens are produced from the microspore mother cells, but female spores are produced by the megaspore mother cells Pollen grains have two outer coats extine and intine and female spores do not have the extine or intine. Pollens are dispersed by various mechanisms, but female spores are retained within the ovary.
4. Pollens are found inside the pollen sac, and female spores are found inside the ovule. In other words, all pollens are spores, but not all spores are pollens.
5. NPC Classification 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
6. 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.
7. 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.
8. Classification of Aperture Based on Number 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

9. N1 to N7 groups are also referred to respectively as monotreme, ditreme, tritreme, tetratreme, pentatreme, hexatreme, and polytreme (Greek trema means hole, opening, aperture; pl. tremata). There are pollen grains where apertures are absent. Such pollen grains are termed as inaperturate or atreme and they are placed in N0group.
10. Another special group N8—termed anomotreme is created where the pollen grains and spores have one or several irregular or irregularly spaced apertures
11. Classification of Aperture Based on Position 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 apertures based on position namely –P0 to P6. Pollen grains having P0 group have uncertain or unknown position of aperture).
12. P1 groups of pollen and spores are catatreme Catatreme pollen grains have one aperture that occurs on the proximal part of a grain. The proximal part is the face of a pollen grain or spore that faces inward/nearest or toward the centre of tetrad.
13. P2 groups of pollen and spores are anacatatreme 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 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
14. 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 pollen grain is characterized in having apertures on equator or sub-equator
15. 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
16. Pantotreme pollen grains have apertures scattered over the whole surface uniformly. As a rule, pantotreme pollen grains are spheroidal.
17. Classification of Apertures Based on Character In NPC-system ‘C’ denotes the 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 toC6. C0 groups have apertures whose character

cannot be established with certainty. C1 groups of pollen and spore have leptoma (Greek leptoma means thin place).

18. 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
19. 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
20. The group C3 has colpate grains. The group C4 comprises porate pollen grains. The group C5 comprises colporate pollen. The group C6comprises pororate pollen. C3, C4, C5 and C6 groups of apertures are previously discussed under aperture
21. Merits of NPC classification: It is a simple system of classification and illustrates the apertures of a pollen grain and spore. 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.
22. 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 NPC makes the description of apertures precise.
23. 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.
24. 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 NPC, sporoderm stratifications, exine patterns, size and shape etc. of a pollen grain are genetically stable.
25. 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 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

26. Demerits of NPC classification: It is an artificial system of classification. Syncolpate and parasyncolpate pollen grains do not fit neatly in NPC system Pollen grains that are characteristically present as aggregates in tetrads, e.g. Ericaceae, Typhaceae and polyads, e.g. Orchidaceae, Mimosa etc. are not grouped in NPC system
27. NPC-system of classification is always compared with Linnaeus's system of classification, because the latter is also an artificial system of classification. The characters of stamen were the basis of classification. 'Linnaeus accepted the weakness of his classification but claimed that it was propounded mainly as an aid to identification'.
28. This is also applicable to Professor Erdtman. Palynologists from every discipline of palynology utilize Erdtman's NPC classification Other characters related to pollen morphology as an aid to the identification of unknown sporomorphs.

2. Explain and highlight the various applications of pollens and spores in geoscience

THE APPLICATION OF POLLEN can be separated into two distinct areas. The first area is the issue of timing. At what stage of blossom development should pollen be applied to the orchard? The second issue is the manner in which pollen is to be applied; beehive pollen dispensers; ATV or Helicopter applications.

Timing

In general, tree fruit flowers remain receptive to pollination for 12 to 72 hours after the flower has opened, depending upon the tree fruit variety, the nutritional status of the tree as well as environmental conditions. Flowers remain receptive to pollination for a shorter period of time when weather conditions are hot and dry.

During cool, moist conditions, flowers remain receptive to pollination for a longer period of time, but this longer receptivity is quite often offset by the slower growth of the pollen tube which occurs during cool weather. The EPP (Effective Pollination Period) is most directly dependent upon the nutritional condition of the orchard and the temperature.

It is important to closely examine the bloom of your orchard.

1. To assess the stage of development

2. To assess the coordination of the bloom between the pollinizer variety and the main crop variety.

3. A sampling of flowers should be made to assess any frost damage that may have occurred.

Determining the Stage of Development

It is fairly easy to determine the stage of development your bloom is in, as well as the flowers receptivity to pollination. Pick a newly opened flower from the block you want to pollinate. Examine the anthers; the little yellow sacks or in the case of Pears, the pink to red sacks which surround the stigmas, the center of the flower. These are the flower's anthers, the sponge like sacks which hold the pollen.

To the naked eye, the anthers have a smooth, deeply colored appearance before they have begun to dehisce (shed) their pollen. Under the microscope, the anthers have an appearance similar to that of a sponge, with a pock-marked surface which retain the pollen grains.

When the anthers have dehisced their pollen, they begin to shrivel and turn brownish in color. From the time the flower first opens, to the time that the anthers dehisce their pollen, this is the period in when the flower is the most receptive to pollination.

Number of Applications

One problem that can exist even during ‘normal years’, is that there may be little coordination between the bloom of the main crop and that of the pollinizer variety. This may be true in specific areas of the orchard or across the entire block.

To combat this problem, we recommend that pollen be applied with two or more applications over the course of the bloom period. The reason for this recommendation, is that even during seasons when flowers of a particular section of trees or for the entire orchard are blooming fairly evenly, there is still a timing difference between the opening, receptivity and pollen availability between flowers.

By planning for two or more applications of pollen to be applied to the orchard, most of the bloom can be effectively covered. In cooler climates, the opening of flowers may be more extended, requiring a longer pollen application period. In warm climates, be prepared to quickly apply as much pollen as possible, for the bloom may not remain receptive to pollination for a long period of time.

The application of spores

Spore, a reproductive cell capable of developing into a new individual without fusion with another reproductive cell. Spores thus differ from gamates, which are reproductive cells that must fuse in pairs in order to give rise to a new individual. Spores are agent’s asexual reproduction, whereas gametes are agents of sexual reproduction. Spores are produced by bacteria, fungi, algae, and plants.

Bacteria spores serve largely as a resting, or dormant, stage in the bacterial life cycle, helping to preserve the bacterium through periods of unfavorable conditions. Spore production is particularly common among *Bacillus* and *Clostridium* bacteria, several species of which are disease-causing. Many bacterial spores are highly durable and can germinate even after years of dormancy.

Among the fungi, spores serve a function analogous to that of seeds in plants. Produced and released by specialized fruiting bodies, such as the edible portion of the familiar mushrooms, fungal spores germinate and grow into new individuals under suitable conditions of moisture, temperature, and food availability.

Many larger algae reproduce by spores and are also capable of sexual reproduction. A number of red algae species produce monospores (walled nonflagellate spherical cells) that are carried by water currents and form a new organism upon germination. Some green algae produce nonmotile spores, called aplanospores, whereas others produce motile zoospores, which lack true cell walls and bear one or more flagella. The flagella allow zoospores to swim to a favorable environment in which to develop, whereas monospores and aplanospores must rely on passive transport by water currents.

3. **Explain the stratigraphical and paleoenvironmental applications and significance 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.

In the oil industry, palynology is a stratigraphic tool especially useful in the study of rocks deposited in continental, coastal, and shallow-marine settings. Palynological analyses are used mainly for chronostratigraphic correlations, paleoenvironmental studies, and the evaluation of potential source rocks. The integration of palynology with other geological disciplines, such as sedimentology, geophysics, geochemistry, and petrophysics, is needed for geological modeling and petroleum system studies, which in turn are essential for planning and developing better exploration strategies and for optimizing reservoir exploitation.

The recent development of new geological concepts and methods, such as sequence stratigraphic analysis and high-resolution three-dimensional (3-D) seismic technology, has caused significant changes in stratigraphic work. In palynology, and in general in biostratigraphy, the classical qualitative or semiquantitative studies based on selected marker taxa have been enhanced with modern quantitative methods that use the whole palynological assemblage (including particulate organic matter), high-resolution sampling, and multivariate statistical methods.