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Photoatlas of specific and indicator forms of phytoliths

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Contens

Introduction

Historically, phytoliths are considered to be the intercellular and intracellular structures of plants of exclusively biogenic silica. Their main characteristics are morphological specificity for the cells of many plants, in particular for cereals and sedges, as well as the ability to persist for a longer period of time in soils and bottom sediments than pollen and spores. This allows phytoliths to be a successful addition to other methods of micropaleontological analysis in paleoecological research and archeology (Rovner. 1971; Piperno. 1985; Blinnikov. 2005; Bobrov, 2007; Ball, Ehlers, Standing. 2009; Neumann et al., 2017; Sharma et al., 2019).

The use of phytolith information give encouraging perspectives to paleofloristic studies. In the proposed Photoatlas of phytoliths, from the author's point of view, the most characteristic and indicator forms of phytoliths for each of the studied plant species are given.

Characteristics of phytolith analysis and its use in modern research

Phytolith composition. The method of X-ray diffraction analysis showed the similarity of phytoliths with natural opal (SiO2 x nH2O). At the same time, the possibility of identifying silica bioliths as both opal and alpha-quartz is indicated (Hayward and Parry, 1973). In a recent work, using the ultrastructure of *Hordeum vulgare* phytoliths as an example, it was shown that the phytolithic complex is an anisotropic composite consisting of at least 3 components - siliceous bodies, a matrix between phytoliths, and globular inclusions (probably not mineralized (Kornas et al., 2017).

Dimensions. Up to 75% of all phytoliths are in fractions less than 0.02 mm (Wilding and Dress, 1971). The informative value of the morphometric analysis of phytoliths formed under different conditions is an important indicator of environmental conditions (Ball et all. 2009).

Phytolith morphology. The morphological analysis of phytoliths is of great importance. At the same time, the dominance of C3 phytoliths indicates a cold period, while C4 phytoliths indicate a warm one (Phytolith Analysis.htm). Saddle and lobe morphs related to C4 characterize warm conditions. An increase in the number of festucoid forms (C3) indicates a cold phase of the climate and indicates the progressive development of meadows. In the first case, phytoliths are larger in size, long (polylobate trapezoidal particles), and in the second, short and simpler shapes (two-lobed short, saddle-shaped short, truncated conical, trapezoidal short particles). The morphological features of phytolithic complexes of different families have long been the subject of study. In particular, sedge (Ollendorf, 1992; Ball et al., 1999; Honaine et all, 2009; Colomonova et al., 2018; Bobrov et al., 2001; Stevanato et al., 2019), cereals (Lisztes-Szabo et al., 2014; Rudall et al., 2014; Shakoor, Bhat, 2014; Novello, Barboni, 2015).

Features of phytolithic analysis. Three main properties of biogenic silica can be noted, which make possible to use it as an indicator of the conditions of biogeocenoses.

1) The aboveground part of plants produces phytoliths in an amount sufficient to reflect the composition of the vegetation associated with them. Phytoliths have a specific morphology associated with the plant taxa that formed them.

2) The preservation of biogenic silica is sometimes estimated at tens of thousands of years or more, which characterizes the phytolithic complexes as one of the most stable soil characteristics.

3) Silica bioliths have a limited ability to move both through the air and over the soil surface and within the soil profile.

Phytolith analysis has several advantages over the spore-pollen method, the most important of which is the much weaker, compared to pollen, the introduction of phytoliths from the surrounding phytocenoses. Phytoliths enter the soil when vegetation dies; they are never released into the air in quantities comparable to pollen emissions from wind-pollinated plants. There is no doubt that the parallel carrying out of phytolithic and spore-pollen analyzes will make it possible to obtain mutually complementary data on the composition of vegetation of the past. An extensive library of phytolith analysis publications can be found at https://www.academia.edu/Documents/in/Phytolith_Analysis?page=1.

Out of 140 publications in which the results of research in archeology, paleosoology, paleocology, and ethnobotany are presented, only 6 consider phytolithic plant complexes in it (Albert et al., 2008). However, in the Botanical Garden of the Southern Cross University of Sydney (Australia), a specially created laboratory, which includes a team of scientists of 7 employees, research is currently being carried out on phytolithic complexes of plants from various taxonomic groups (Lentfer, 2014). The working herbarium includes 113 plant species. The purpose of the study is to compile a phytolithic database of various plant species in Australia. The general list of plants includes representatives of 56 families. Analysis of the list shows that only a small group of families aroused particular interest among researchers, in each of which more than 2 species were studied. These are Apocynaceae, Arecaceae, Convolvulaceae, Euphorbiaceae, Malvaceae, Moraceae, Musaceae, Piperaceae, Poaceae, Rubiaceae, Solanaceae, Zingiberaceae, Pteridophyta. Most families are dicotyledonous. These are mainly ornamental plants such as bindweed, others are used as a spice, such as pepper and ginger. This interest of Australian scientists indirectly indicates that it is in these plant families the indicator forms of phytoliths can be found, and the Atlas of Australian phytoliths can be used in paleoecological studies.

In 2006, the Phytolith Research Institute was established in India (http://www.phytolithresearch.com/). It is the only private institution in Asia dedicated to the application of phytolith analysis in a variety of interdisciplinary sciences. The institute includes a laboratory, microscopes, a reference library and a herbarium. The research institute provides services to the international community for the analysis of samples in archeology, ecology, agronomy and other related sciences. The most famous use of phytolith research is the identification of ancient agricultural lands, the determination of the time of domestication of agricultural plants such as corn, arrowroot, rice, bananas, wheat, and barley (Hodson et al., 2008). Therefore, most publications provide data on the morphology of phytoliths of agricultural plants, in particular, rice in north-central India (Harvey, 2005; Saxena et al., 2013).

In the Americas, the time and place of domestication of corn is of particular interest. Analysis of phytolithic complexes of the annual grass teosinte *(Zea mexicana*), a wild relative of corn, showed the possibility of using statistical methods to determine the taxonomic relationship of this cereal with corn (Hart et. Al., 2011). Traditional studies of the last 20 years in ethnobotany have recognized the work on the phytolith analysis of the domestication of bananas in the tropics (Ball et all., 2006). The identification of banana phytoliths has helped to establish the timing of the domestication of bananas in New Guinea (Lentfer, 2009). Climatic conditions have been determined in relation to soil moisture of agricultural lands and the use of fire for cooking in one of the regions of Turkey in the Neolithic time (Shillito, 2011). Phytolith analysis also involves food products, in particular, grain products (Chen, 2013). The shape of phytoliths can provide information about the type of cereals. The Lower Pleistocene spectra of phytoliths are discussed in a publication for Georgia (Messager et al., 2010).

Increasingly, work in archeology or paleoecology is carried out using phytolith analysis, since silicified plant cell replicas make it possible in some cases to identify specific plant species. The latter refer either to ecofacts, that is, they characterize a certain type of herbaceous vegetation or to artifacts, that is, they are able to answer the question - which plant species were used for food or for certain economic needs and in ceremonial rites, that is, were part of the cultural context of the culture under study (Shishlina et al., 2018). The works with the analysis of phytoliths of regional floras are of the greatest interest. But such studies are few. In one of the latest and most interesting works, a phytolith analysis of the surface layer of soils from 25 loci of an ecological transect crossing the Mozambique rift along geographic, altitude, climatic, and botanical gradients was carried out (Mercader, 2017). The analysis confirmed the possibility of detecting changes in the composition of forest / grassland plants.

The results of phytolithic studies of modern African soils show that: 1) it is possible to separate different plant zones according to phytolith spectra, with the exception of the Masai steppe region of Somalia, in which phytolithic spectra are close to the spectra of the region, 2) different morphological types of phytoliths occur in different plant zones; 3) there are problems in the interpretation of the results, but they can be overcome in the future with the help of additional studies on the altitude gradients of landscapes in the Masai region of Somalia in East Africa, as well as with the expansion of species definitions of phytolith types and subtypes, their systematization and further analysis of the studied herbarium material (Barboni et al., 2007).

An overview of phytolithic studies with bibliography is given in the publication on Southeast Asia (Kealhofer, Piperno, 1998). This article shows the results of studies of phytolith forms in a wide range of 77 families of monocotyledonous and dicotyledonous plants. A total of 800 samples from different parts of plants of 377 species were studied, with the isolation of diagnostic forms of phytoliths from 9 monocotyledonous and 26 dicotyledonous families. In representatives of a number of families, diagnostic forms of phytoliths were not found, and the list of plants in which such forms were found was reduced by half. Judging by the photographs, some of the phytoliths can be named conditionally as diagnostic forms. The same comment can be attributed to a significant number of publications by other authors. One of the directions of phytolithic analysis in paleoecology and archeology is determination of the age of soils and sediments using radiocarbon dating (Santos et al., 2010). It is based on the extraction of occluded carbon from a concentrated mass of phytoliths

Summarizing the results of the work of many researchers, it can be noted that the stability of phytoliths, and, consequently, the nature of their accumulation and distribution in the soil profile is determined by a number of factors: 1) soil and climatic conditions (first of all, the pH value, the composition of the soil solution), biological activity, granulometric and mineralogical composition of the soil, the degree of its moisture; 2) physicochemical characteristics of phytoliths of each type of vegetation. These questions in a broader context are of understandable interest (Nawaz et al., 2019). In most archaeological and paleoecological sites, phytoliths of the Poaceae family make up the most informative part of phytolithic analysis (Neumann et al., 2017), along with the sedge family.

However, there are a number of problems in phytolith analysis, some of which were highlighted at the end of the 20th century (Rovner. 1996). This is an inventory of phytoliths of regional floras, despite the fact that such works have begun to appear more and more frequently in recent decades (Zurro et al., 2016). A thorough preliminary study of the forms of phytoliths from modern species growing in the study area or in the vicinity is necessary. In addition, it should be noted that illustrated atlases of spores and pollen have long been used in scientific practice, while it is not yet possible to compile at least a preliminary atlas of plant phytoliths for any vast territory. It was noted that the problem of accumulating information on the diversity of phytolithic forms can be solved by joint efforts of scientists from different countries through a gradual study of local spectra (Pipierno, 1988).

The preservation of phytoliths of different forms is assessed in different ways. Previously, the facts of finding phytoliths in paleosols and layers estimated the age of phytoliths at hundreds of years, and sometimes tens of thousands of years (Wilding, 1967). The earliest finds of phytoliths were made in coprolites of dinosaurs from Late Cretaceous (Prasad et al., 2005). At the same time, attention is drawn to the fact that there is a problem of cleaning carbon included in phytoliths from extraneous organic compounds (Piperno, 2016). Recent studies have shown that different phytolith morphotypes are subject to dissolution at different rates, which can lead to distorted morphological spectra and, accordingly, incorrect interpretation of paleoecological conditions (Cabanes, Shahack-Gross. 2015)

Another very important area of research is the use of phytolith analysis for plant biosystematics and phylogenetic studies. Evolutionary trends of different parts of plants appear to be varied and different when compared, for example, vegetative structures (stem, leaves, buds), root systems and generative organs (flowers, fruits and seeds). On the basis of the obtained results of phytolithic analysis of sedges (Bobrov et al., 2001), some preliminary conclusions can be drawn: a) phytolith complexes can be used in the taxonomy of sedges as an addition to the final answer in case of difficult situations in determining their place in the family; b) mainly specific phytoliths can be used for the taxonomy of sedges and other plants; c) vicarious sedge species can also be differentiated by their phytolith spectra. Among the siliceous formations in sedge and cereal plants, there are some forms that are specific to the sedges or only to cereals (groups of specific forms). First of all, this refers to phytoliths that are hexagonal in plan, with a pointed, centrally located cone-shaped outgrowth of phytoliths, which are characteristic only of some species of sedges (*C. tomentosa, C. distans, C. stenophylla)*.

The presence of the same complexes of phytoliths in different taxonomic groups of plants can be considered as evidence of their possible phylogenetic relationships and unity. Being mostly replicas of tissue cells of plant vegetative organs, similar phytolith complexes emphasize their ancient evolutionary relationship and, from this point of view, can be used in the analysis of the evolution and phylogeny of plants. Despite these often significant problems, phytolith analysis is developing extremely dynamically and brings impressive results in a significant number of studies. Twenty years ago, a monograph with almost 500 photographs of phytoliths of 151 plant species was published (Gol'eva, 2001). Unfortunately, the photographs were taken using only a scanning electron microscope. This Atlas was the result of a great and fruitful work, but for practical purposes it is advisable to also have photographs from a light microscope, on which all practical work is usually carried out.

Photoatlas. The main idea of this Photoatlas is to identify and show the characteristic and indicator forms of phytoliths, mainly cereals and sedges. Plants for phytolith analysis were collected during expeditions, from a personal collection and provided by the Department of Geobotany, Faculty of Biology, Moscow State University. The number of studied plant species is 152, of which 94 were investigated using a light biological microscope, 54 - using an electron scanning microscope. The samples were sieved in water suspension (50 ml of water for 5g of soil, pores 0,5 mm in diameter) to separate coarse mineral grains and organic residues. Soil samples for phytolith analysis were boiled for 1 hour in 20% H_2O_2, then 10% HNO_3 was added. The suspension was washed with distilled water and sieved to separate coarse mineral grains. A total of 300 phytoliths were counted for each sample under magnification of 200.

This Photoatlas of phytoliths includes 806 photographs. Of these, 552 photographs were obtained using a light biological microscope Carl Zeiss Axioplan-2 and 254 photographs of a Jeol 6060 scanning electron microscope. Each photograph was processed in the editing programs Corel Photo-Paint X4, FSViewer and Photoshop 7. The subject of analysis on a light biological microscope was vegetative organs of ninety-nine plants, on a scanning electron microscope, fifty-six. Some of the plants were selected on the territory of Russia and in the herbarium of the Faculty of Biology of Lomonosov Moscow State University. From the point of view of the author and his practical experience, the Atlas presents the most characteristic morphotypes of phytoliths of various plants for the reconstruction of both ecofacts and artifacts, and the author hopes that the Atlas will be useful in paleoecological and archaeological research. The grouping of phytoliths by morphotypes and the analysis of the similarities and differences of morphotypes in different groups of plants remained outside the scope of this Atlas, since this analysis is an independent line of research that can be implemented on the basis of the International Phytolith Code (Madella et al., 2005).

List of researched plants

(LM – light microscope, **EM -** electron scanning microscope)

Apiaceae

Astrantia biebersteinii FISCH. & C.A.MEY. Astrantia are native to Central, Eastern and Southern Europe and the Caucasus. **LM**

Asteraceae

Achillea millifolium L. grows the mildly disturbed soil of grasslands and open forests, native to Eurasia. **LM**

A. campestris L. is native to a wide region of Eurasia and North America. **LM**

A. lerchiana Weber ex Stechm. is native to eastern and the Caucasus, grows on sandy soils. **EM**

Cannabaceae

Cannabis sativa L. is indigenous to eastern Asia but now of cosmopolitan distribution due to widespread cultivation. **LM-EM**

Dioscoreaceae

Dioscorea caucasica Lipsky is native to west Caucasus, where it grows in broadleaved forests (400-1000 м a.s.l.). **LM**

Fabaceae

Galéga orientális Lam. is native to the Caucasus, prefers deep, light, friable, well-drained, higher-pH soils. It is quite tolerant of winter cold, but late-season frosts can damage fresh growth. It is somewhat tolerant of drought and flooding. It does not do as well on acidic, peaty, or water-logged soils. **LM**

Ericaceae

Rhododendron luteum Sweet is native to southeastern Europe and southwest Asia. **LM**

R. ponticum L. is native to southern Europe and southwest Asia. **LM**

Fagaceae

Castanea sativa L. is native to Southern Europe and Asia Minor, and widely cultivated throughout the temperate world. **LM**

Poaceae

Aegilops cylindrica Host el-lm is native to Southern Europe and Russia. **LM-EM**

A. triunciolis L. is native to Eastern and Mediterranean Europe and Western Asia, thrives in mainly rocky, serpentine soil, but also does well in grasslands and ruderal/disturbed ground as well as oak woodlands. **LM**

Agropyron cristatum (L.) Gaertn. EL prefers well drained, deep, loamy soils of medium and moderately coarse texture, can tolerate salinity in the range of 5 to 15 mS/cm and prefers moderately alkaline conditions, extremely drought tolerant. **EM**

A. cristatum ssp. *desertorum* (Fisch. ex Link) A. Löve, is native in Russian and Siberian steppes. **LM**

A. fragile (Roth) A. Löve. Europe, Eurasia. **LM**

A. intermedium el (*Thinopyrum intermedium* (Host) Barkworth & D.R. Dewey) is native to Europe and Western Asia. syn. Many scientific binomial names. **EM**

Agrostis capillaries L. is native to Eurasia and has been widely introduced in many parts of the world. Colonial bent grows in moist grasslands and open meadows, and can also be found in agricultural areas, roadsides, and invading disturbed areas. grows in neutral to acidic soils. **EM**

A. gigantea Roth is native to Europe, can be found in open woodland, rough grassland, hedgerows, roadsides and waste ground, and as a weed on arable land. **LM**

A. sp. **LM**

Alopecurus pratensis L. is native to grasslands of Europe and Asia, common on moist, fertile (especially neutral) soils, but avoids waterlogged, light or dry soils. **LM-EM**

Anthoxanthum odoratum L. is native to acidic grassland in Eurasia. **LM**

Arundo donax L. is native to the Mediterranean and Middle East, forms dense stands on disturbed sites, sand dunes, in wetlands and riparian habitats. **LM**

Arrhenatherum elatius (L.) P. Beauv. ex J.Presl & C.Presl is common in the temperate regions of Europe. **LM-EM**

Bambusa sp. 1 **LM**

Bambusa sp. 2 **LM**

Bambusa sp. 3 **LM**

Bambusa is a large genus of clumping bamboos. They are native to Southeast Asia, China, Taiwan, the Himalayas, New Guinea, Melanesia, and the Northern Territory of Australia.

Bothriochloa ischaemum (L.) Keng is native to Europe, Asia, and Africa. **LM**

Brachiaria eruciformis (Sm.) Griseb. synonim *Echinochloa eruciformis*. *Brachiaria* can grow in many environments, from swamps to shady forest to semidesert, but generally do best in savannas and other open tropical ecosystems such as in East Africa. **LM**

Brachypodium pinnatum (L.) BEAUV. It is found in Russia in the European part, in Siberia, in the Caucasus. Outside Russia, lives in Central and Atlantic Europe, in the Mediterranean, Central Asia, Japan and China. It occurs sporadically. It lives on open and or sparse afforested slopes of the banks of rivers and lakes, on the edges and floodplain meadows. **LM**

B. rupestris (Host) Roem. & Schult. synonim *Brachypodium pinnatum* (L.) P. Beauv. is widespread in temperate regions of the Northern Hemisphere, grows in calcareous grassland. **EM**

B. sp. Genus is a widespread across much of Africa, Eurasia, and Latin America. **LM**

Briza australis Prokudin el *синоним Briza media* L. is native in temperate regions of the Northern Hemisphere, grows in dry calcareous grassland. **EM**

Bromus arvensis L. is native to southern and central Europe, grows along roadsides, in disturbed areas, and in fields. **LM-EM**

B. commutatus Schrad. found throughout Europe, N. Africa, W. Asia in meadows, wasteground, road verges, hayfields and rough grassland. **EM**

B. tectorum (L.) Nevski. is native to Europe, southwestern Asia, and northern Africa, grows in many different climates, primarily in the 150-560 mm precipitation zone. It will grow in almost any type of soil, including B and C horizons of eroded areas and areas low in nitrogen. It has invaded the natural ecosystems of the steppe. **LM-EM**

B. japonicas Thunb. is native to Eurasia, grows in fields, waste places, road verges, sand dunes, is intolerant of alkaline soils. **LM-EM**

B. riparius REHMANN Canada and Asian meadow brome. **EM**

B. scoparius L. is native from to the Mediterranean to northwestern China and northwestern India. **LM**

B. squarosus L. is native to Russia and Europe, common in overgrazed pastures, fields, and road verges. It prefers loamy or alluvial soils. **EM**

B. sterilis L. is native to Europe, northern Africa, western and middle Asia, Caucasus, can be found along roadsides, hedge bottoms. Known as malicious weed plant. **LM-EM**

Calamagróstis arundinacea (L.) Roth is native to Eurasia, China and India. **LM**

Calamagrostis canescens (Weber) Roth *is* native to Europe and western Siberia. Growing, usually in wet areas. **EM**

C. epigeios (L.). Roth is native to Eurasia and Africa, can be found from average moisture locales to salt marsh and wet habitats. **LM**

Cenchrus longispinus (Hack.) Fern. Europe, Asia Africa,: Morocco, South Africa, North America: Canada, Mexico, USA. Oceania: Australia. Contaminated regulated products and regulated territories: First of all, it is a row crop (crops of corn, sunflower, vegetables, melons and vineyards), the species is suppressed in continuous sowing crops. **LM**

Colpodium versicolor (Steven) Schmalh. is native to Iran, Iraq, Turkey, Caucasus. **LM**

Dactylis glomerata L. is native throughout most of Europe, temperate Asia and northern Africa. **LM**

Echinochloa crus-galli (L.) Beauv is common from boreal moist to wet through tropical very dry to moist forests. Succeeds in cool regions, but better adapted to areas where average annual temperature is 14-16°C. Adapted to nearly all types of wet places, grows on variety of wet sites such as ditches, low areas in fertile croplands and wet wastes, often growing in water. **LM**

E. sp. **LM**

Elymus caninus L. is native to Europe. **EM**

Elytrigia gracillima (Nevski) Nevski. It grows in the temperate climate of Eurasia from Central Europe in the west to China in the east and from Poland in the north to Pakistan in the south. **LM**

Elytrigia pseudocaesia (Pacz.) Prokudin Europa. **EM**
Elytrigia is a genus of about 20–40 species of grasses, native to temperate regions of the Old World, in Europe, Asia, and northwest Africa.

Festúca glauca Vill. tolerates dry and low nutrient soils. **EM**

F. sulcata **(**Hack.) Nym. Eurasia. Synonim *Festuca valesiaca* Schleich. ex Gaudin em-lm is native to Europe and Asia. **LM-EM**

F. valesiáca SCHLEICH. EX GAUDIN It grows in the temperate climate of Eurasia from Central Europe in the west to China in the east and from Poland in the north to Pakistan in the south. Steppe plant. **LM-EM**

Hieróchloe repens (HOST) P. BEAUV. em Eastern Europe, the Caucasus, Western Siberia and Central Asia. In the center of the European part of Russia, it mainly grows in black soil regions and less often in northern ones. A rare plant of the Republic of Tatarstan and in the Ulyanovsk region. Found in the Chuvash Republic in the Cheboksary district. Dry meadows, steppes, slopes, sands, forest glades, shrubs. **EM**

Helictotrichon schellianum (HACK.) KITAG. SAME AS *Helictotrichon hookeri* subsp. *schellianum* (HACK.) TZVELEV. East European-Asian species. The European part of the range covers the forest-steppe and steppe regions of Ukraine, the Lower Don and Trans-Volga; in Asia, the species is distributed from Siberia and northeastern regions of Central Asia to China and Japan. Throughout the range, it grows in the steppes, in forest glades, upland meadows, in sparse oak forests. **LM**

Hólcus lanátus L. is native in northern Europe, a hardy pasture grass. **EM**

Hordeum mirinum L. is native to Europe, northern Africa and temperate Asia. **LM-EM**

H. violaceum Boiss. et Huet is common in Caucasus, Middle East, Iran, grows on meadows, stony slopes, upper alpine zone. **LM**

H. vulgare L. is one of the first cultivated grains, particularly in Eurasia as early as 10,000 years ago. **LM**

Imperata cylindrica (L.) P. Beauv. native to tropical and subtropical Asia, Micronesia, Melanesia, Australia, Africa, and southern Europe, a highly flammable fire-adapted species. **LM**

Koelēria cristata (Ledeb.) Schult. is widespread across much of Eurasia and North America, occurs in a large number of habitat types. **EM**

K. glauca (Schrad.) DC. is mainly distributed in eastern Central Europe, with its western outposts in the coastal dunes of Jutland and inland dunes in the Rhine Valley. **LM-EM**

Lolium perenne L. grows in dunes and other sandy places, native to Europe, Asia and northern Africa. **LM**

Melica gracilis Aitch. & Hemsl is common in most temperate regions of the Eurasia, predominantly in the forests. **LM**

Molina arundinacea Karl Foerster is native to damp moorland in Eurasia and northern Africa. **LM**

Oplismenus undulatifolius (Ard.) P. Beauv. is native to South Asia, East Asia, Southeast Asia, Australia, and Southern Africa. **LM**

Panicum miliaceum L. was first domesticated before 10,000 BCE in Northern China. The crop is extensively cultivated in China, India, Nepal, Russia, Ukraine, Belarus, the Middle East, Turkey, Romania, and the United States. **LM**

Paspalum sp. **LM**

Pennisetum orientale Rich is native to North West Asia and North Africa. **LM**
Paspalum is a genus widespread across much of Asia, Africa, Australia, and the Americas.

Phleum nodosum L. is common in forest and forest-steppe of northern Eurasia, grows on meadows. **LM**

P. phleoides (L.) H. Karst. is native to most of Europe, North Africa, and temperate Asia, prefers lighter soils and grows on chalk downland. **LM-EM**

P. pratense L. is native to most of Europe except for the Mediterranean region, grows well in heavy soil, and is noted for its resistance to cold and drought, and thus ability to grow in dry upland or poor sandy soils. **LM**

Phragmites australis (Cav.) Trin. ex Steud. found in wetlands throughout temperate and tropical regions of the world. (leaves). **LM**

P. australis (culm). **LM**

Piptatherum virescens (Trin.) Boiss. South of Russia, steppe. **LM**

P. sp. They are widely distributed across much of Eurasia, North Africa, and North America. **LM**

Poa angustifolia L. is native to Eurasia. **LM-EM**

P. bulbosa L. is native to Eurasia and North Africa, but it is present practically worldwide as an introduced species. **LM**

Puccinellia burragensis TZVELEV: endemic to Taymyr, Siberia, grows in tundra. **LM**

P. convolute (HORNEM.) FOURR. is native to most Eurasia, North Africa, common on salty soils. **LM**

Secale cereale L. is one of a number of species that grow wild in central and eastern Turkey and in adjacent areas. Domesticated rye occurs in small quantities at a number of Turkey Neolithic sites, but is otherwise absent from the archaeological record until the Bronze Age of central Europe. **LM**

Sesleria alba SM. is native in east Mediterranean, Crimea and Caucasus. **LM**

Setaria pumila (Poir.) Roem. & Schult. is native to Europe, grows in lawns, sidewalks, roadsides, cultivated fields. **LM**

Sorghum halepense (L.) Pers. is native in Mediterranean, but grows throughout Europe and the Middle East, occurs in crop fields, pastures, abandoned fields, rights-of-way, forest edges, and along streambanks. It thrives in open, disturbed, rich, bottom ground, particularly in cultivated fields. **EM**

Stipa capillata L. grows in the meadow and highland steppes of the southern Russia, in the Caucasus, Western Siberia, Central Asia. **EM**

S. dasyphylla (CZERN. EX LINDEM.) TRAUTV.); grows from east Europa to West Siberia. **LM-EM**

S. lessingiana EM TRIN. & RUPR. is native in southeastern Europe, Caucasus, Western Siberia, Central Asia. **EM**

S. longifolia BORBÁS = *S. pennata* L. is native in southern Europe, Caucasus, Western Siberia, Central Asia. **EM**

S. pennata L. The plant is widespread in the steppes of Russia and Kazakhstan, also some small islands are found in the forest-steppe zone of Western Siberia on the warm southern slopes. **EM**

S. pulcherrima K.KOCH is native in northern Africa, southern Europe, Caucasus, Western Siberia, Central Asia. **EM**

Stipagrostis plumosa (L.) Munro ex T.Anderson. Middle East, Northeast Africa, deserts and semi-deserts. **LM**

Tragus racemosus (L.) ALL. Is native in Africa and Eurasia. **LM**

Triticum aestivum L. is a cultivated wheat species. **LM**

Cyperaceae

Carex acutiformis Ehrh. t is native to parts of northern and western Europe, where it grows in moist spots in a number of habitat types. **EM**

C. buekii Wimm. southern Europe to the Volga. Pre-Caucasian, Caucasian, Caucasian. Meadows on fresh salted soils, ditches. **LM-EM**

C. brevicollis D.C. Southern Europe, Moldova, Caucasus, northern Turkey. Open broad-leaf forests, hillside slopes. **LM**

C. colchica J.GAY common on sandy soils in the steppe zone of Europe, is brought into the forest zone, on the seaside sands of the Baltic Sea coast. **LM-EM**

C. cuspidata Host forests and dry meadows in Western Europe, Crimea, Caucasus**. LM-EM**

C. depauperata Curtis *ex* Stokes broad-leaved forests in the lower mountain belt of Central and southern Europe, Caucasus, and Crimea. **LM**

C. depressa ssp. *transsilvanica* (Schur) K.Richt. Europa. **EM**

C. distans L. is native to Europe and North Africa. It is part of a complex of similar species that occur across Eurasia. grows in moist meadows, often on sandy or rocky soils. They can grow in brackish marshes and are especially common along coastlines. **EM**

C. divulsa STOKES is native to Europe, Caucasus, grows in broadleaved forests. **EM**

C. flava L. is common from Europe to Western Siberia, growing on damp meadows and so-called minero-swamps with pH of about 7. **LM-EM**

C. grioletii Roem. *ex* Schkuhr, in of the middle and lower forest belt Caucasus including the northern regions of Turkey and Iran. **LM-EM**

C. hirta L. is native across Europe. **EM**

C. holleriana Asso grows broad-leaved forests of the lower and middle zones of mountains in Crimea, Caucasus, northern Africa. **LM**

C. humilis Leyss. is a disjunctive European-Siberian species with distribution limited to he hills with black-earth limestone soils in the steppe zone. **EM**

C. melanostachys M. Bieb. *ex* Willd. It occurs on flat peaks and gentle areas of the northern and western slopes within 1700-1900 m above sea level. The peaty soil with a close level of permafrost. **EM**

C. micropodoides V.I. Krecz. Caucasian alpine meadows. The species is close related to the European species *C. pyrenaica* Wahlenb. and Siberian *C. micropoda* C.A.Mey. **LM**

C. mingrelica Kük. Caucasian alpine meadows. **LM**

C. montana L. is native to most Europe, tolerant of alkaline soils and temperatures down to -23 C. **EM**

C. oreophila C.A. Mey. Greater Caucasus (upper Kuban, center and east), Klukhor pass, South Ossetia, Georgia (Lagodekhi environs), Karabakh, South Transcaucasia; West Asia: Turkey, Northern Iran, Northern Iraq. Caucaus alpine, meadows in forest zone. **LM**

C. otrubae (*Carex cuprina* (SÁNDOR ex HEUFF.) NENDTV. ex A.KERN., 1863**)** grows predominantly in steppe zone of northern Eurasia on salt marshes, bottom of beams. **LM-EM**

C. pendula HUDS. is native to western, central and southern parts of Europe, occurs in woodland, scrubland, hedges and beside streams, preferring damp, heavy clay soils. **LM**

C. riparia Curtis, has a broad distribution over Europe and Western and Central Asia, can form large stands along slow-flowing rivers, canals, on the edges of lakes, and in wet woodland, in tall-herb fens. **EM**

C. stenophylla Wahlenb. Asia. North America. **EM**

C. strigosa Huds. wet places, valleys of streams in broad-leaved forests, more often in the foothills in southern Europe, Caucasus, northern Iran. **LM**

C. tomentosa L. synonim *Carex filiformis* grows on meadow and steppe habitats. **EM**

C. turcestanica Regel. Uzbekistan. Two vertical plant belts - a tree-shrub and belt of subalpine "steppes" with sporadically meeting lawns. Actually alpine vegetation is barely expressed, due mainly to the configuration of this mountain range. Grows on rocky soils in dry steppes, semi-desert in southern Western Siberia and Central Asia. **LM**

C. vesicaria L. is an essentially Holarctic species, grows in wet habitat, including many types of wetland, and areas that are soaked or submerged during the spring and dry over the summer. **LM**

C. vulpina L. grows on marshy meadows, grass-sedge swamps, less often in wet forests. **LM**

Cyperus fuscus L. is native to much of Europe, Asia and North Africa, grows on wet meadows, on the banks of rivers and lakes, the outskirts of swamps. **EM**

Kobresia stenocarpa (Kar. & Kir.) Steud. is common on wet meadows at the upper mountain belts. **LM**

Sciprus sylvestris L. (leaves). A genus of grass-like species in the sedge family Cyperaceae. They mostly in habit wetlands and damp locations. Is widespread in Eurasia grows in moist places: swamps, lake shores, wet forests and wet meadows. **LM**

S. sylvestris (culm). **LM**

Schoenoplectus triqueter (C.C. Gmel.) Palla is native to Europe, Asia and North Africa, Caucasus and the Middle East to the Far East, Japan, India and Pakistan, as well as in North Africa. It is found along the banks and along river deltas, in swamps, in ditches. **EM**

Sch. tabernaemontani Zebrinus. It can be found throughout much of the world. It grows in moist and wet habitat, and sometimes in shallow water. **EM**

Agricultural plants (LM)

Panicum miliaceum
Triticum aestivum
Secále cereal
Hordeum vulgare

Results of phytolith analysis of plants examined using an light microscope

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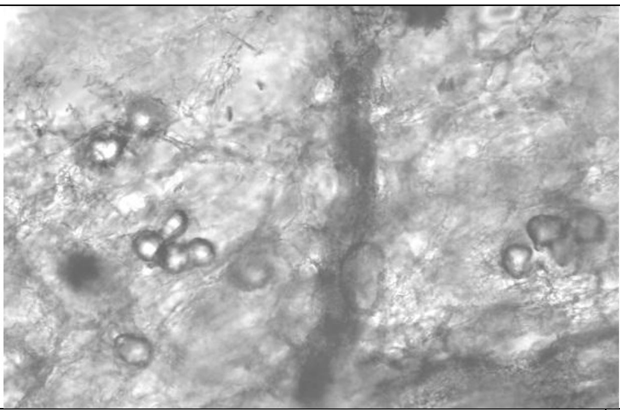	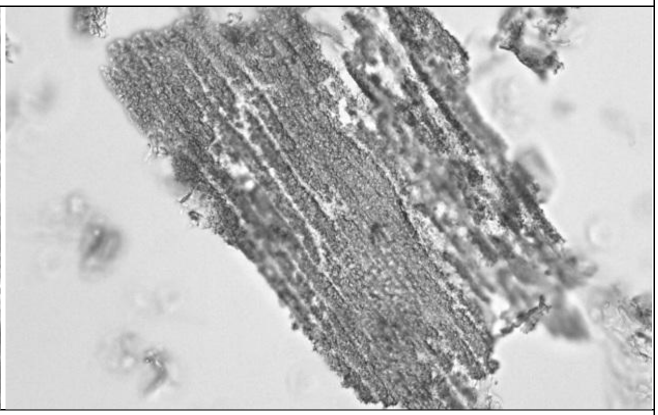
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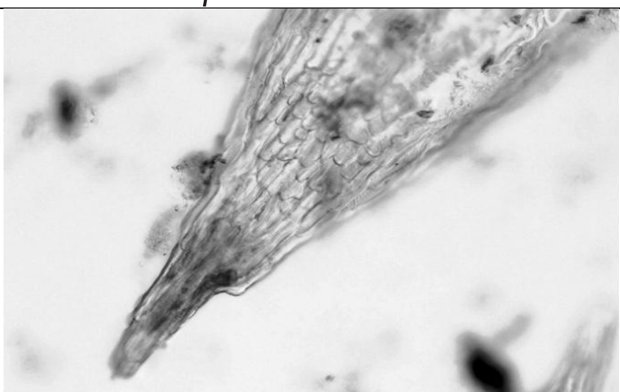	
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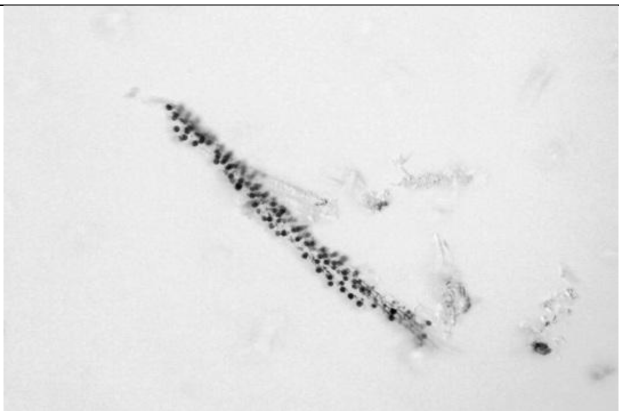	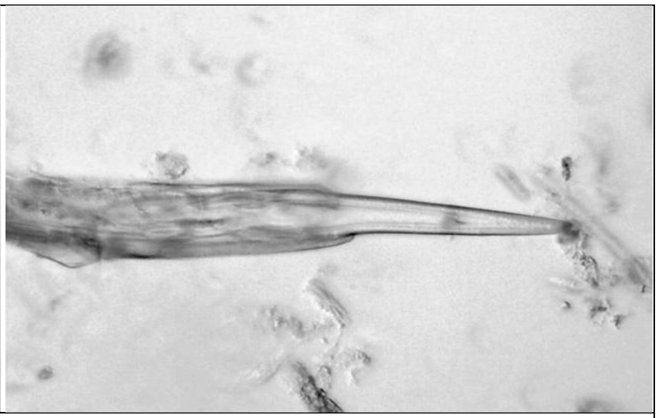
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	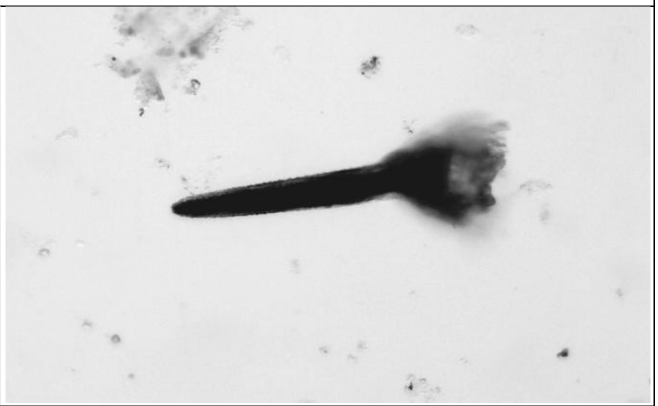
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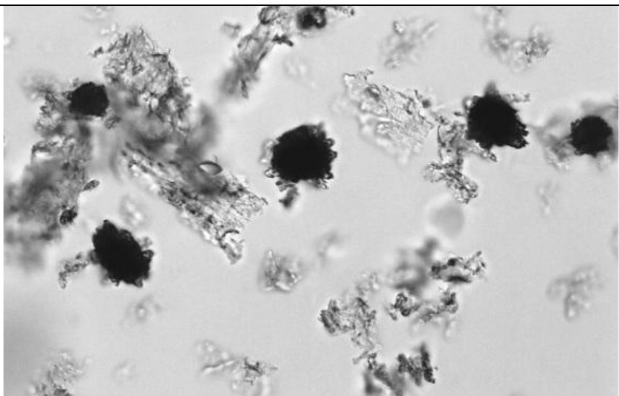	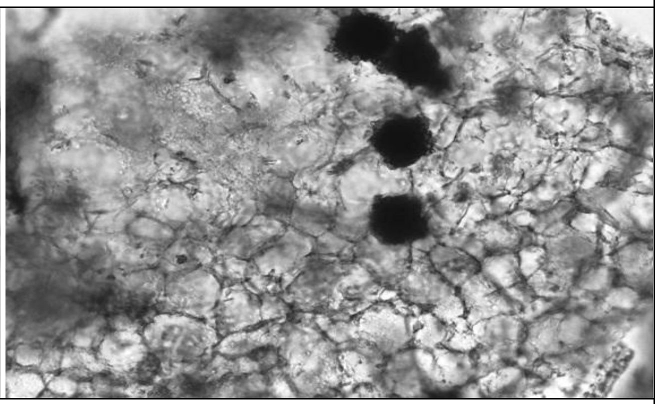
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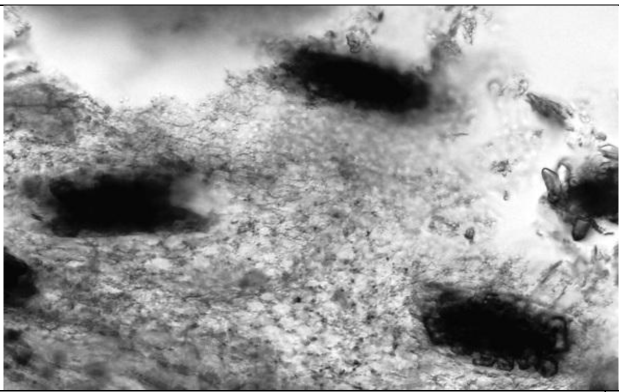	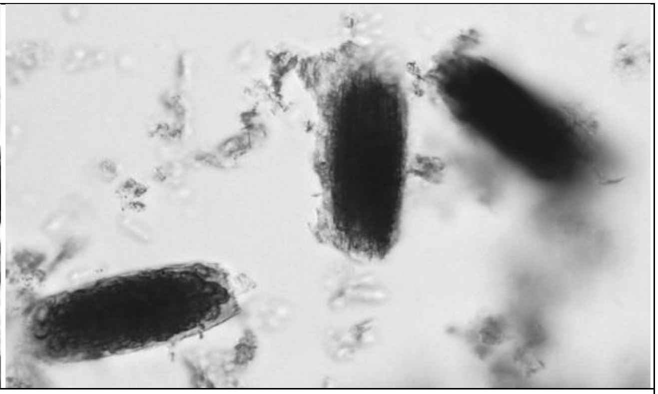
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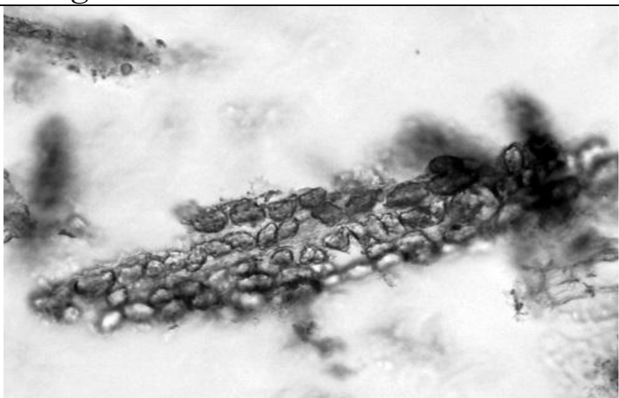	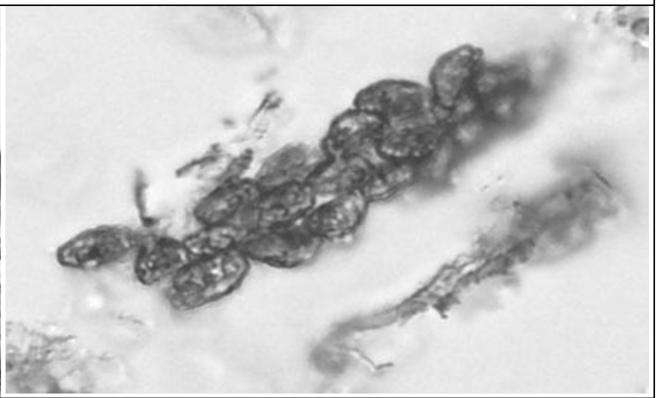
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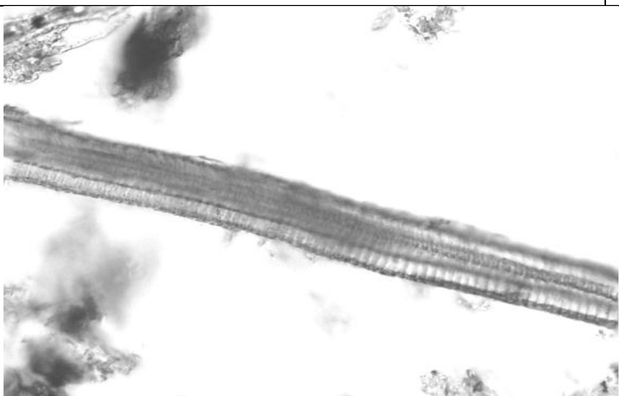	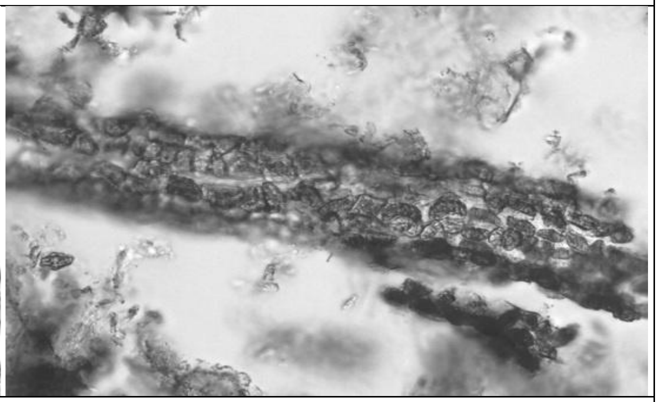
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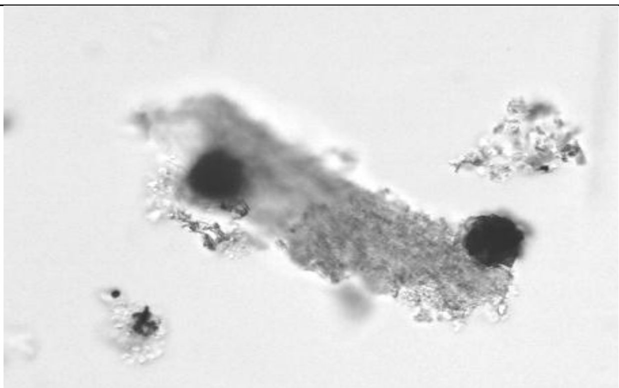	
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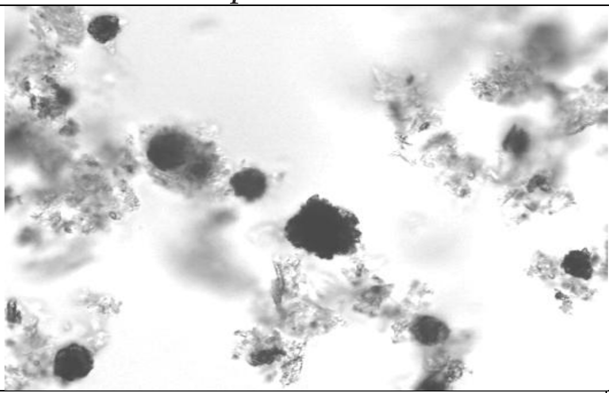	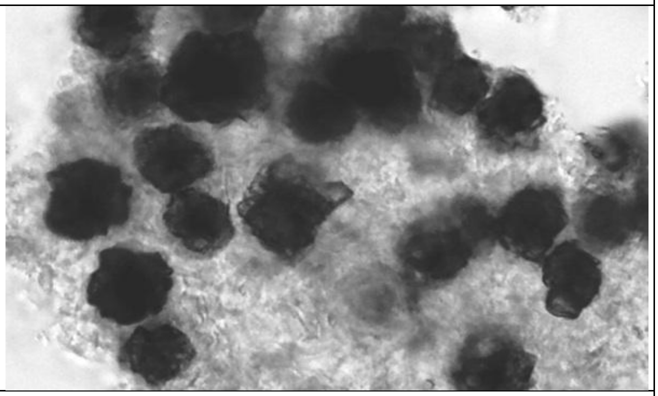
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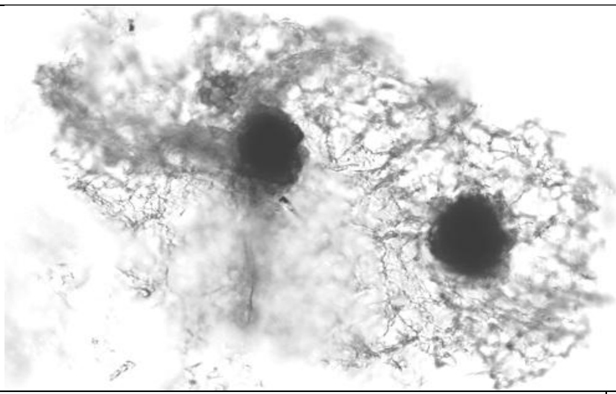	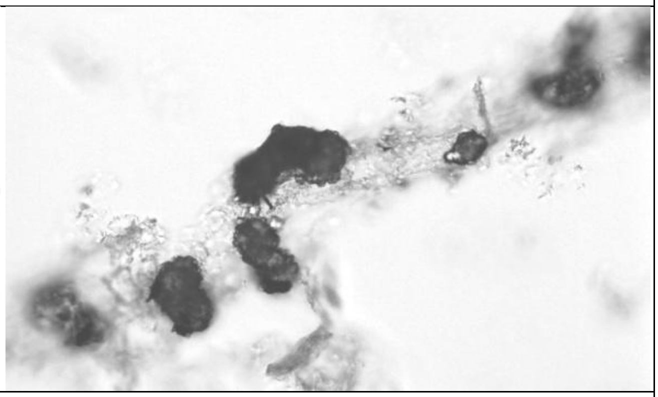
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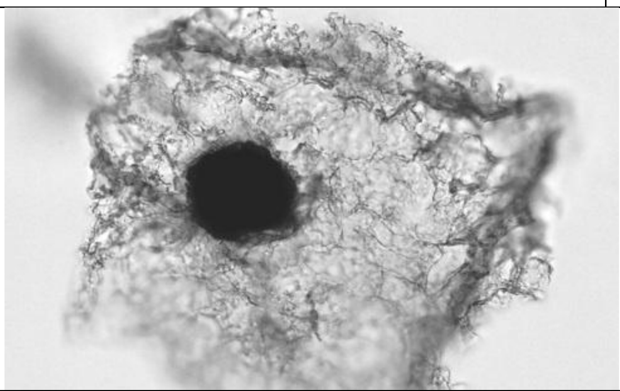	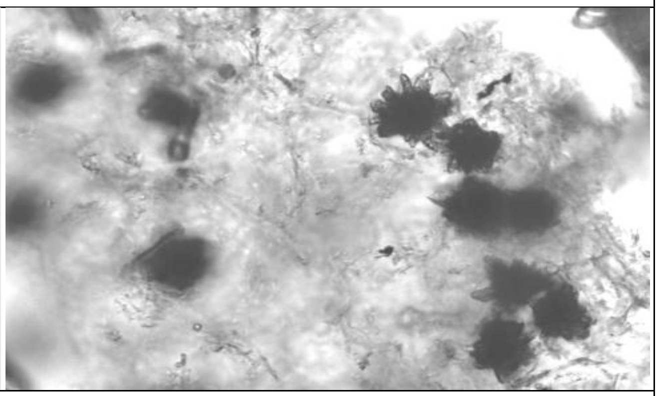
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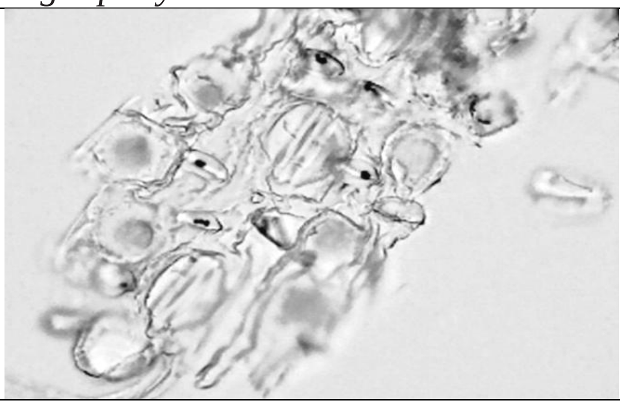	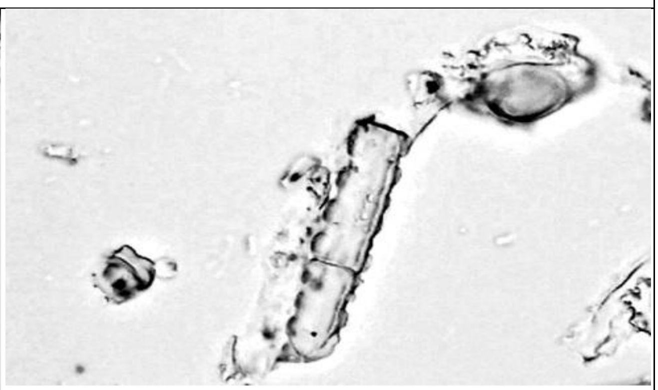

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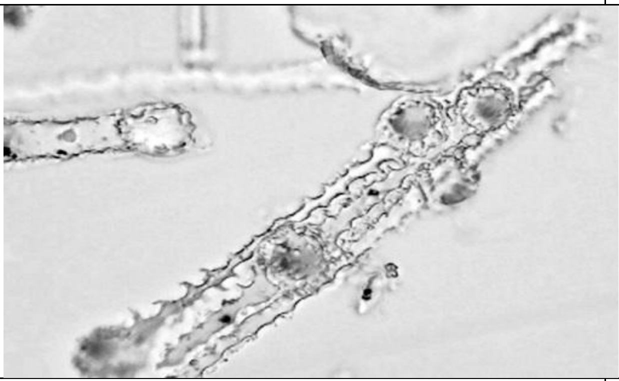
<tr><td></td><td></td></tr>
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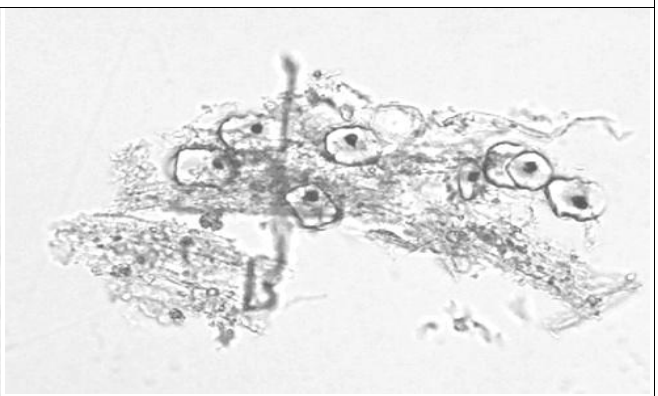
<tr><td></td><td></td></tr>
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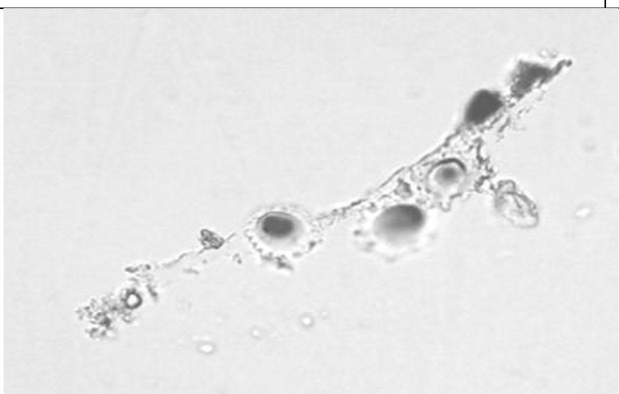
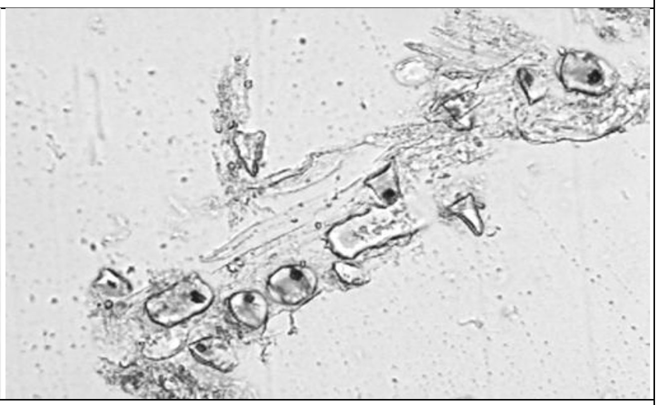
<tr><td></td><td></td></tr>
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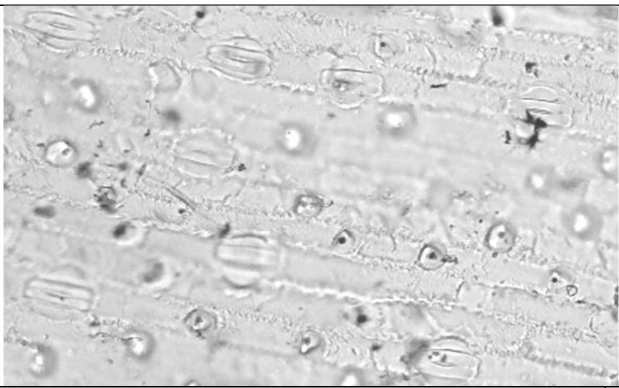	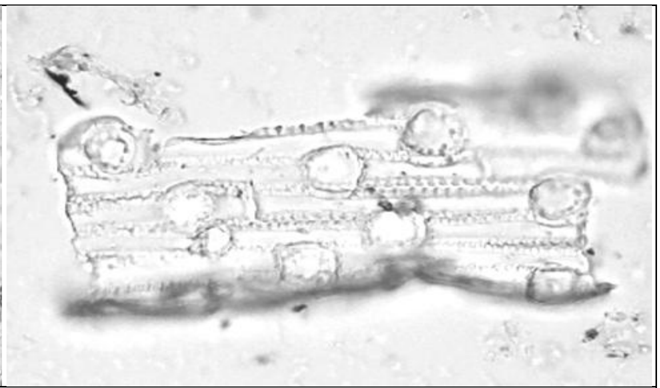
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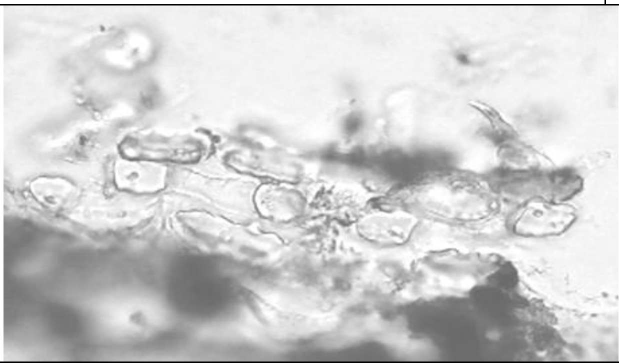	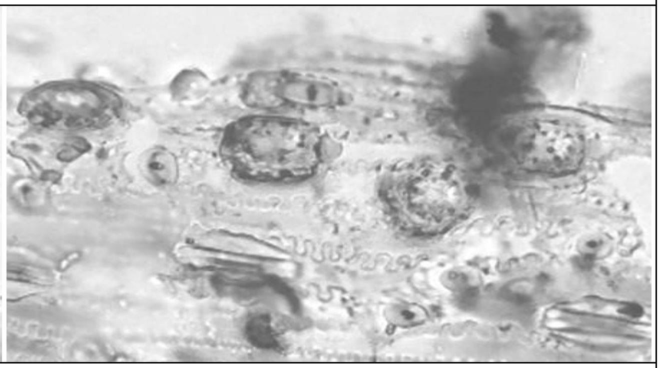
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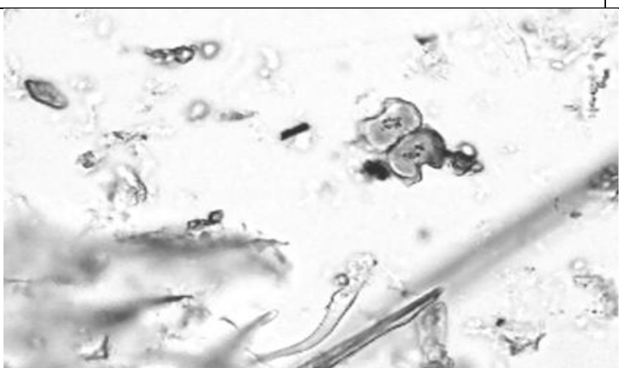	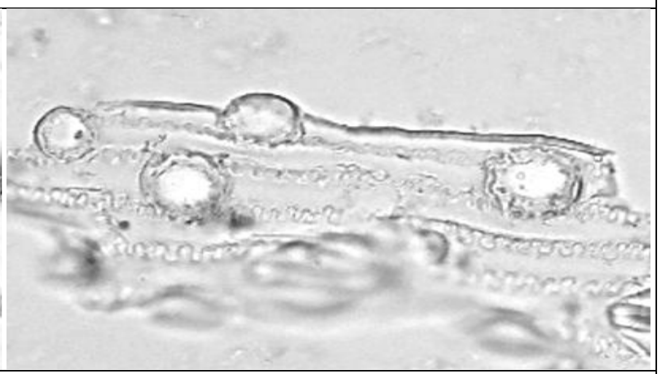
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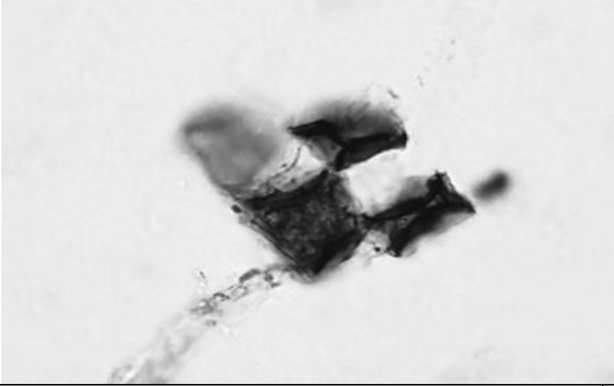	
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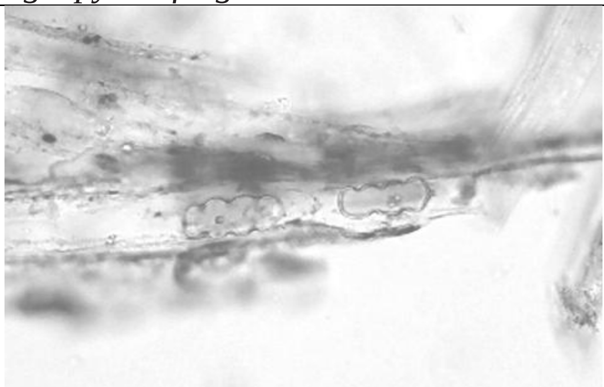	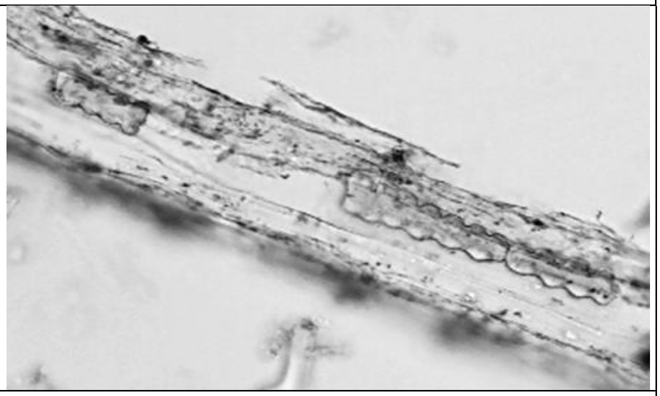
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	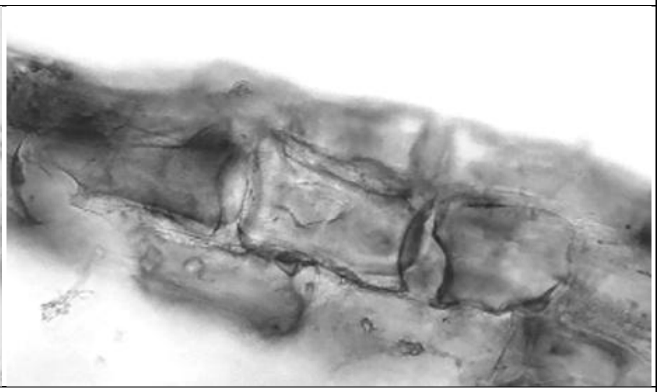
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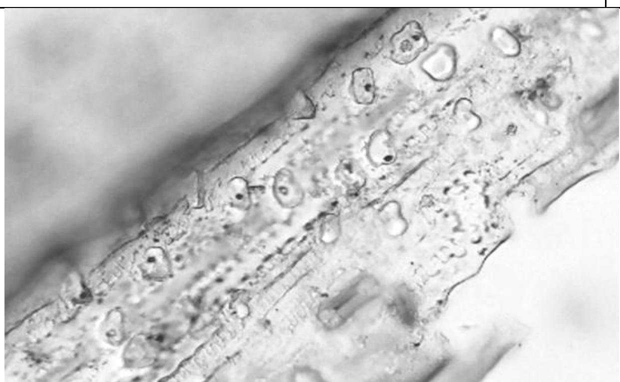	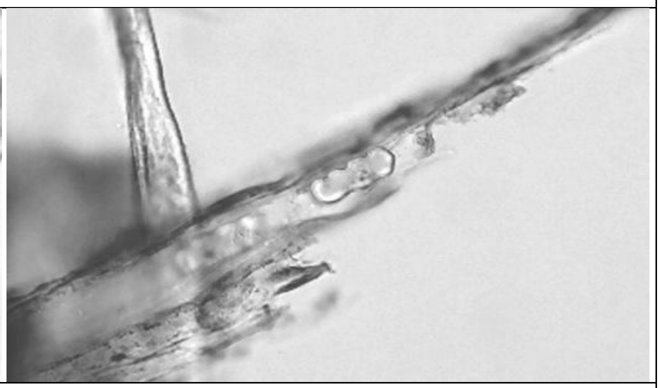
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	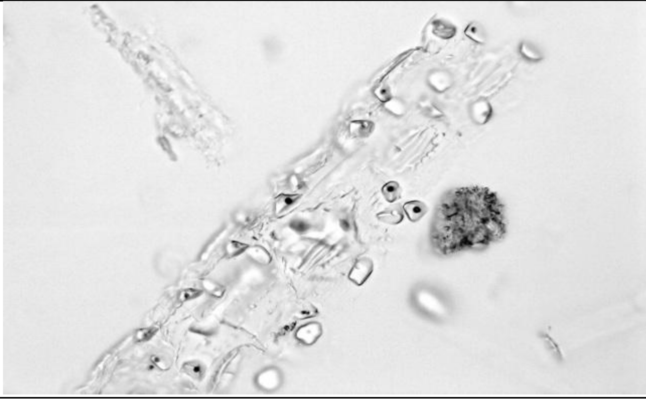
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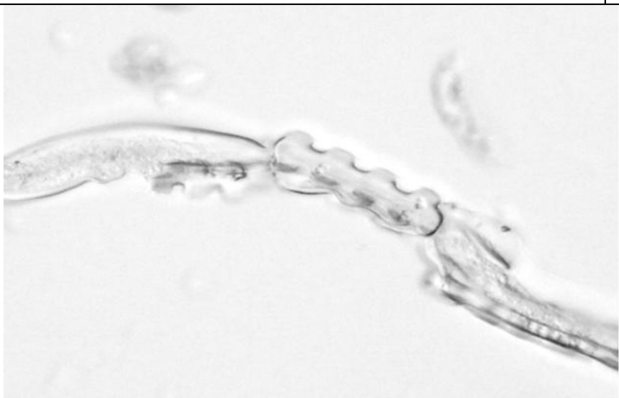	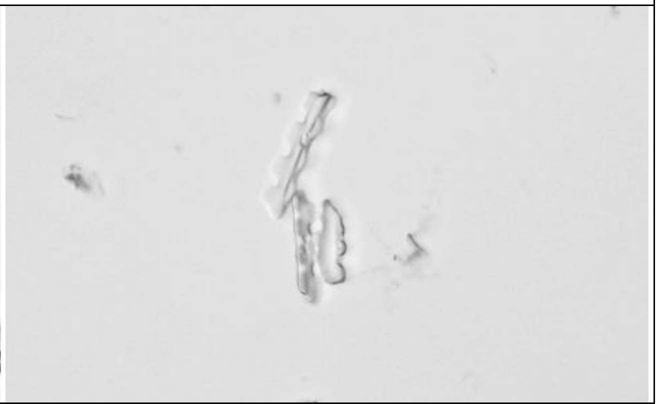
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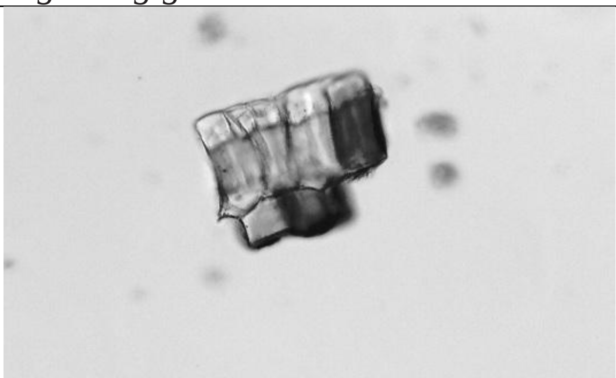	
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	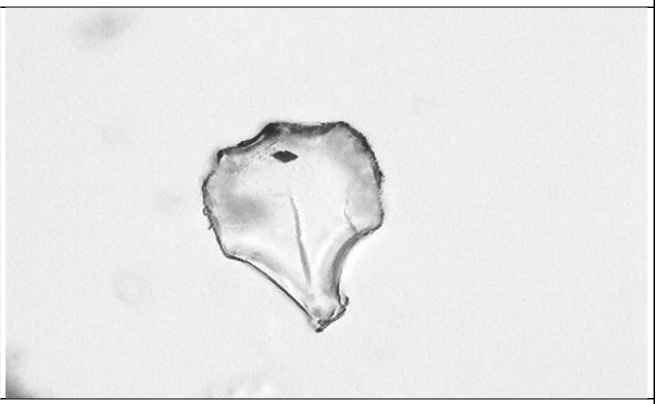
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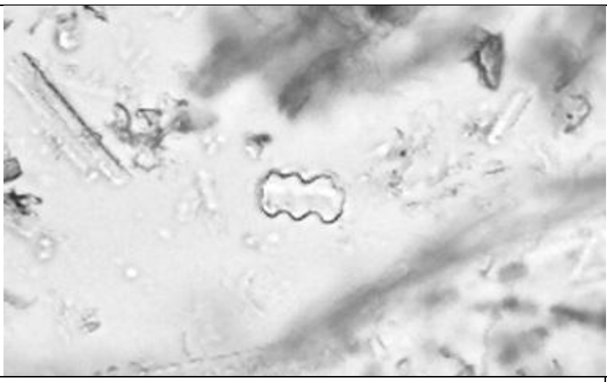
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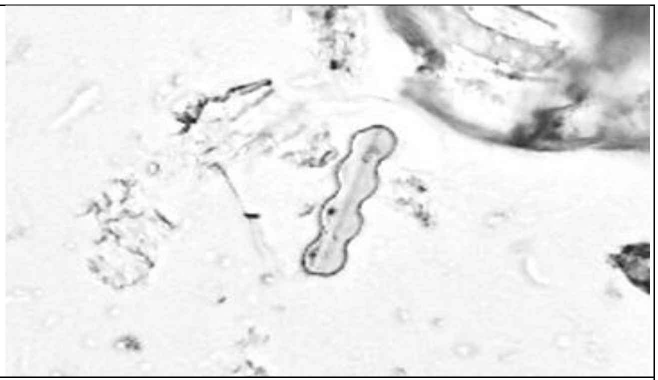
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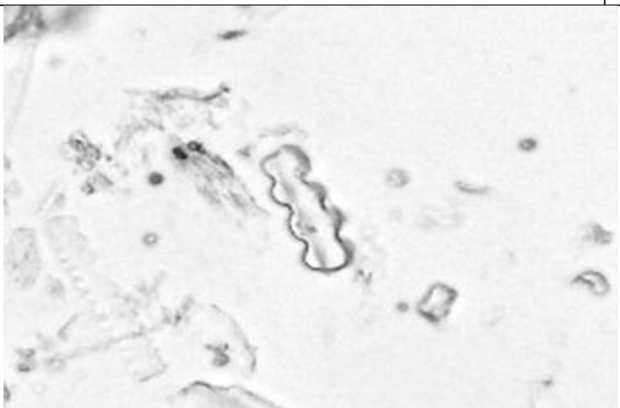
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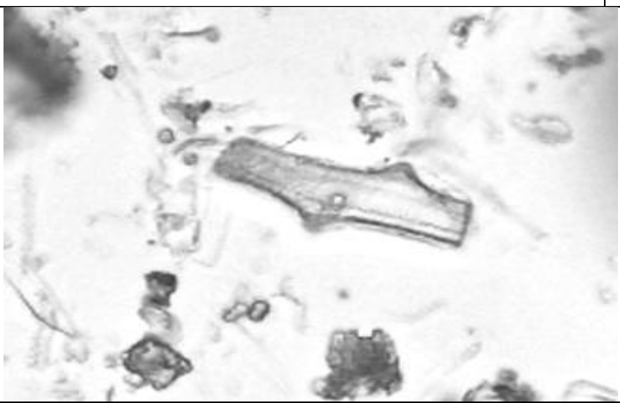
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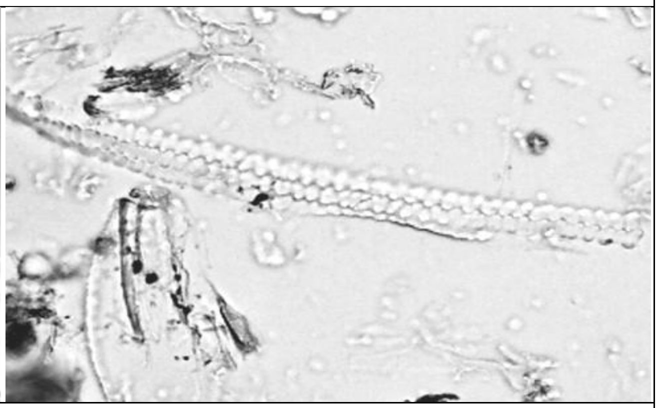
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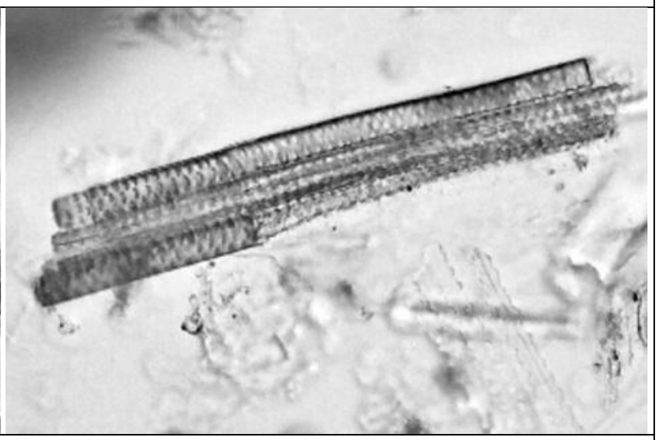
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Alopecurus pratensis	
	
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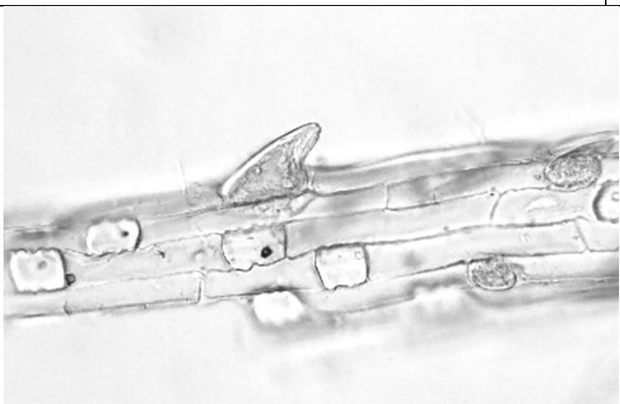	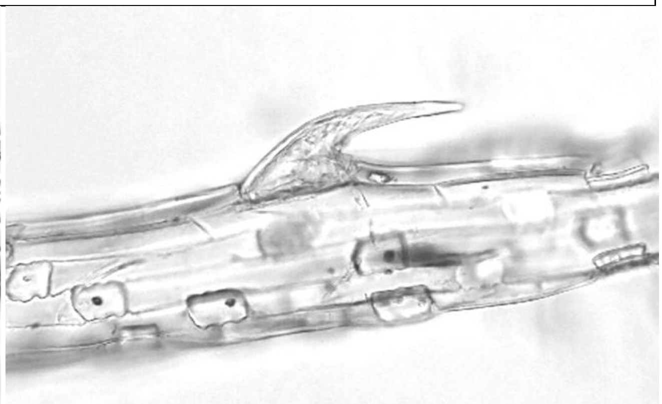
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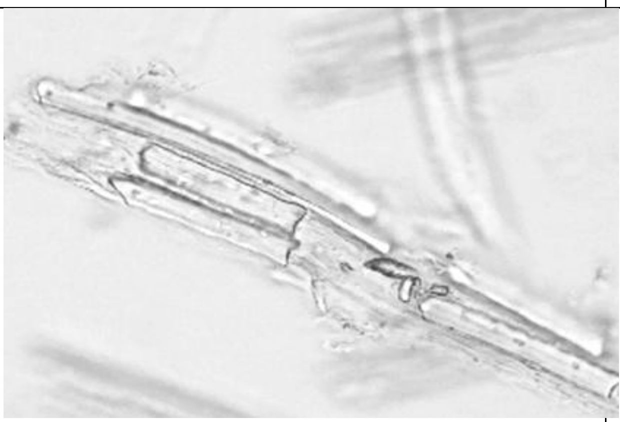	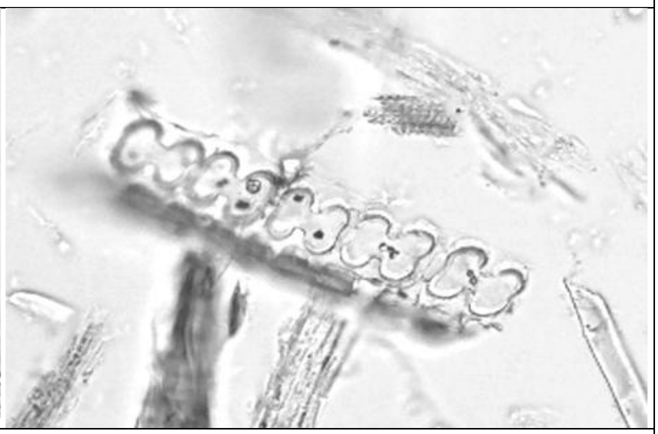
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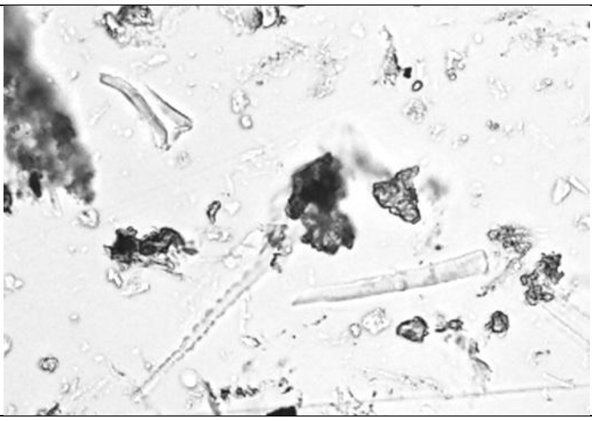
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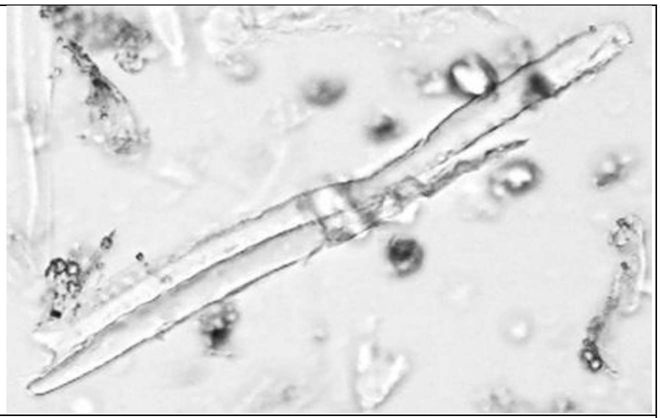
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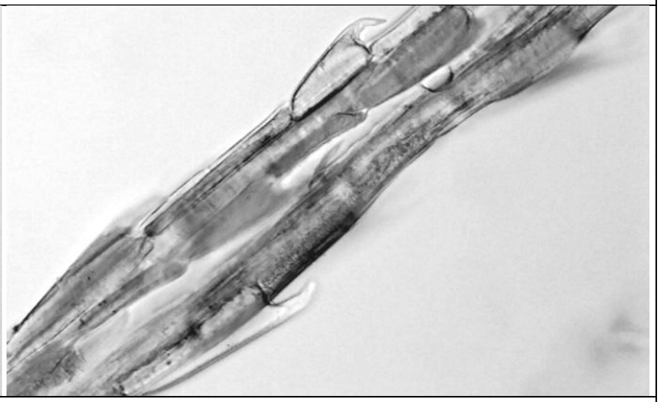
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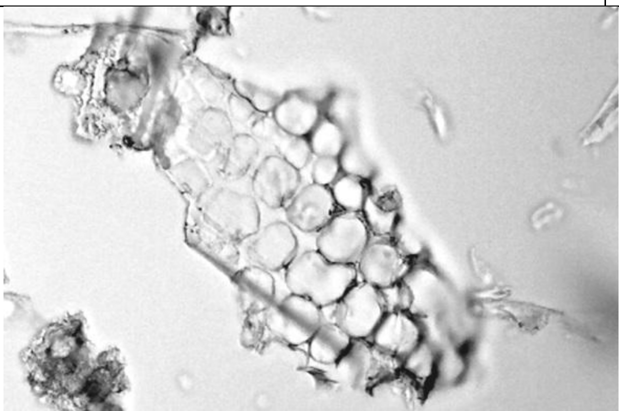
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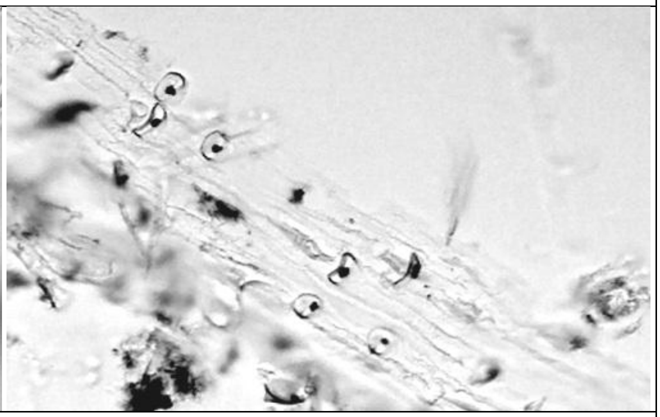
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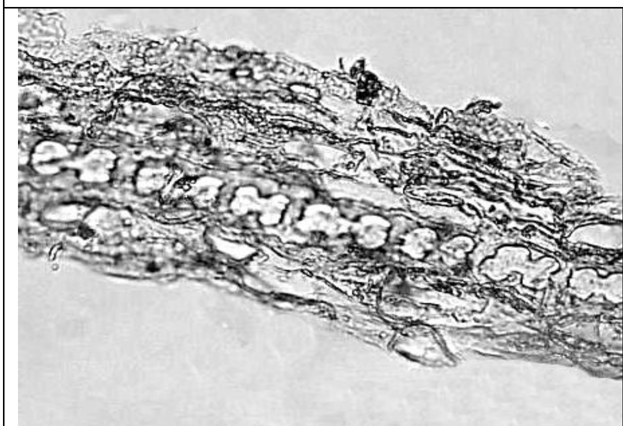

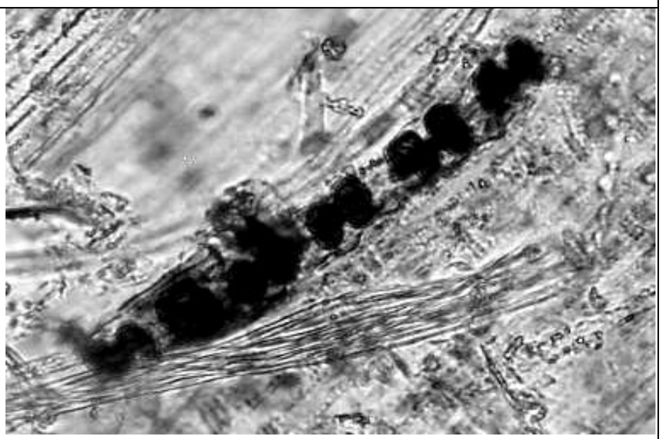

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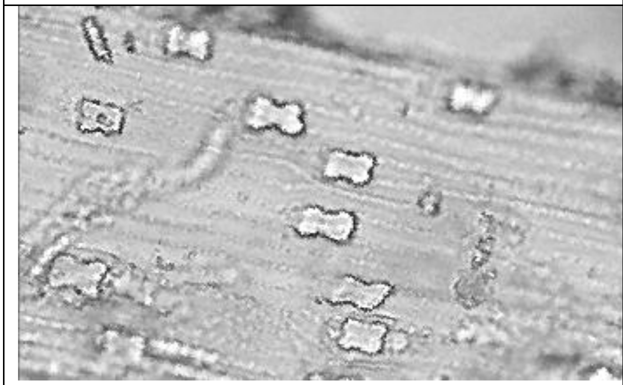	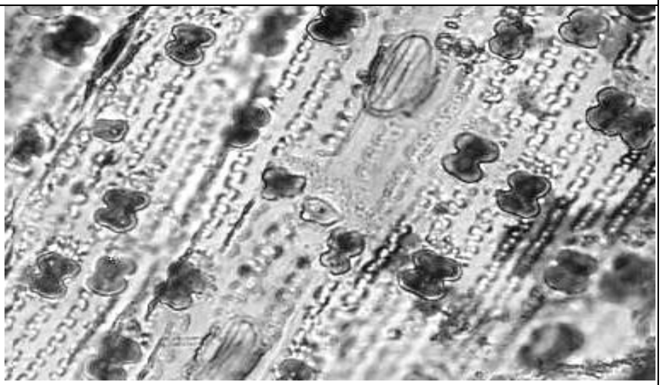
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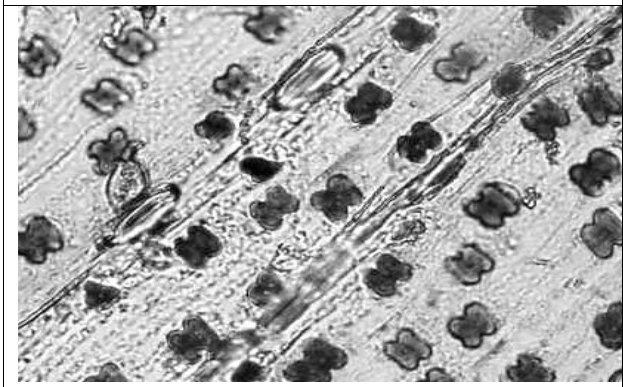	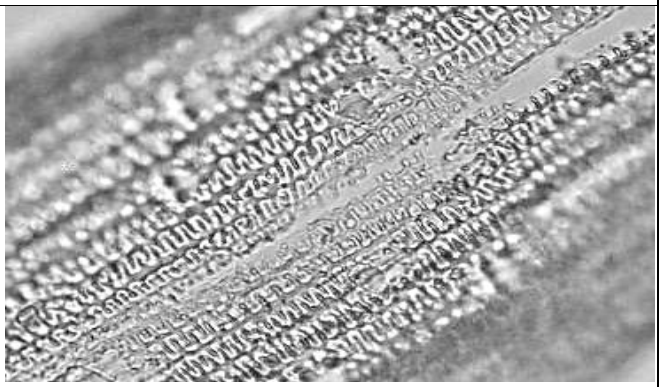
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 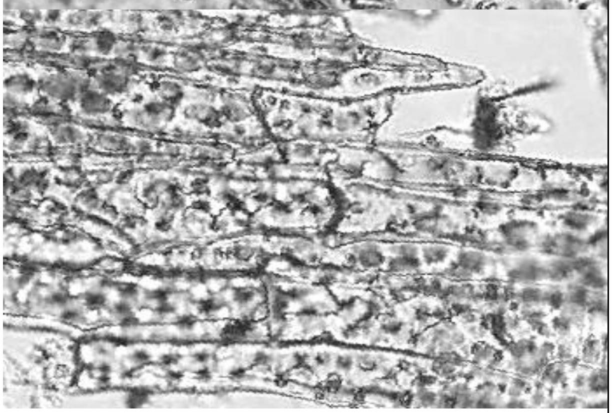	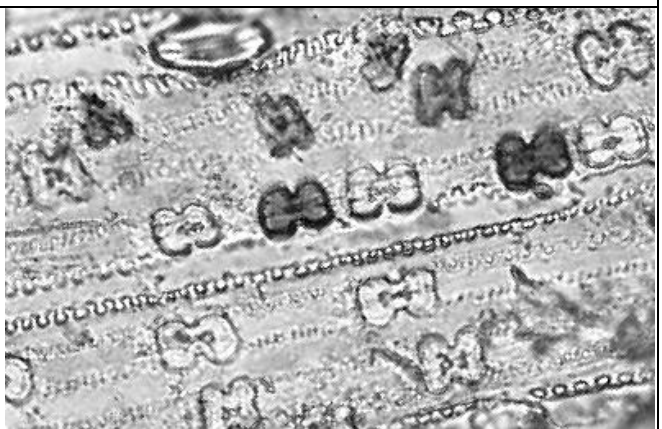 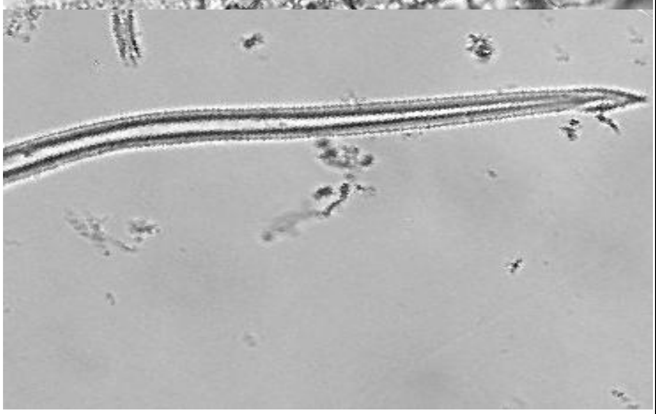
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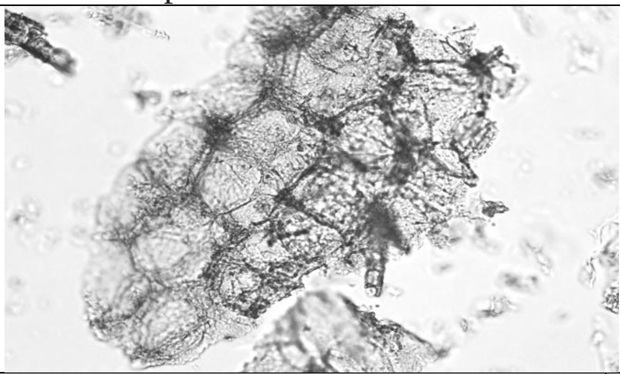	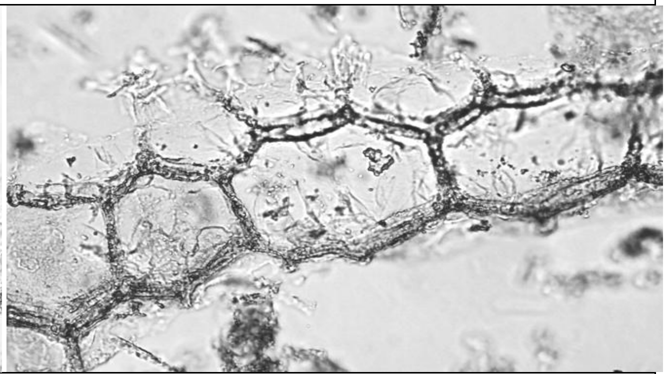
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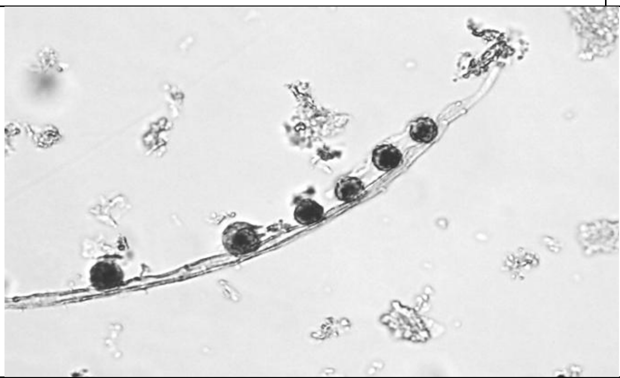	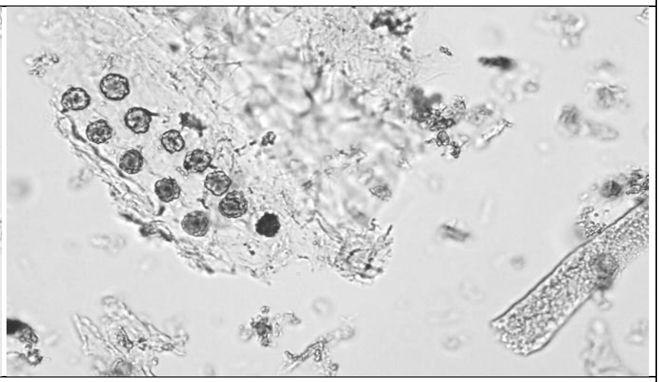
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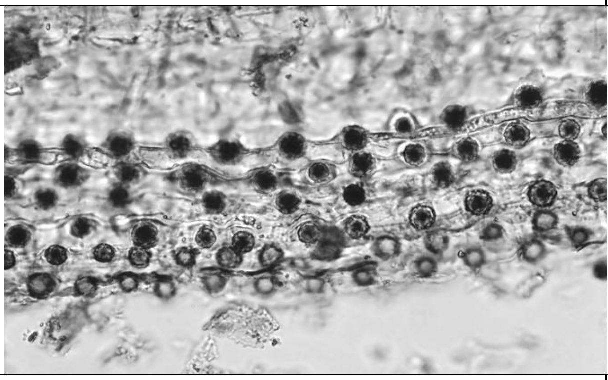	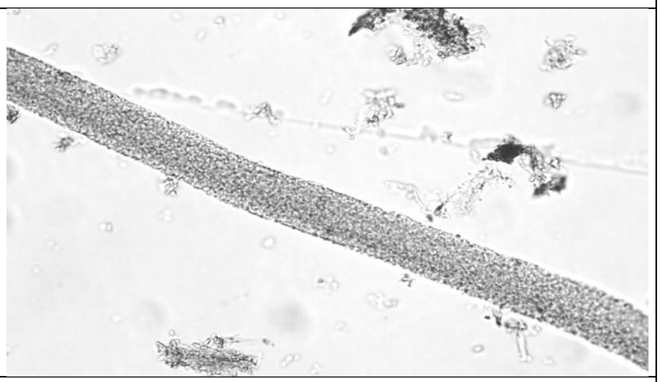
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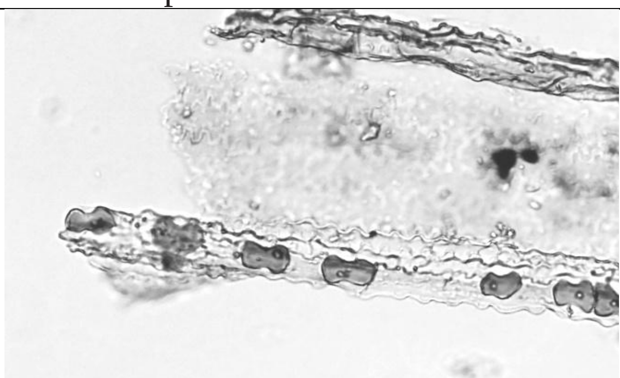	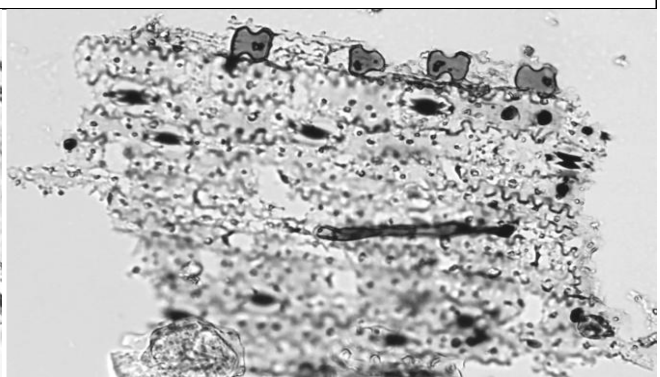
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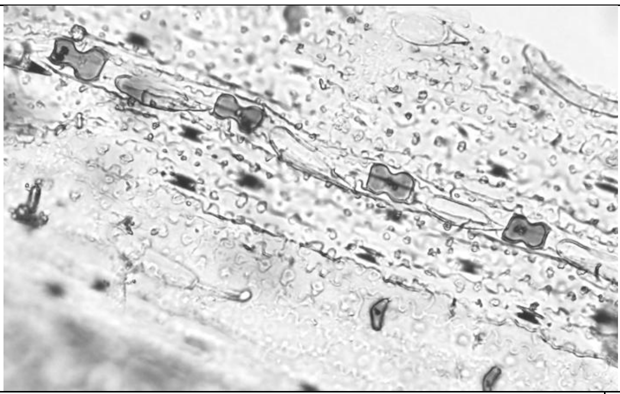	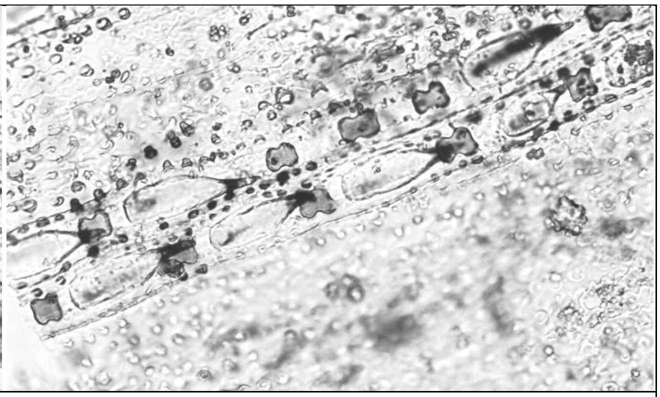
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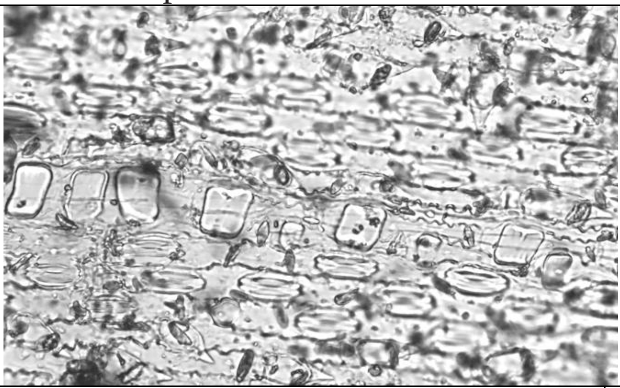	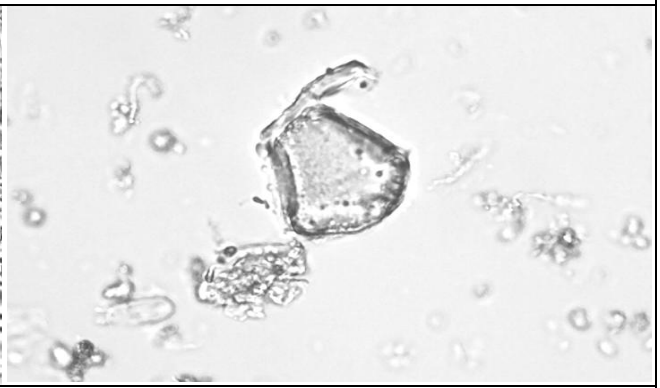
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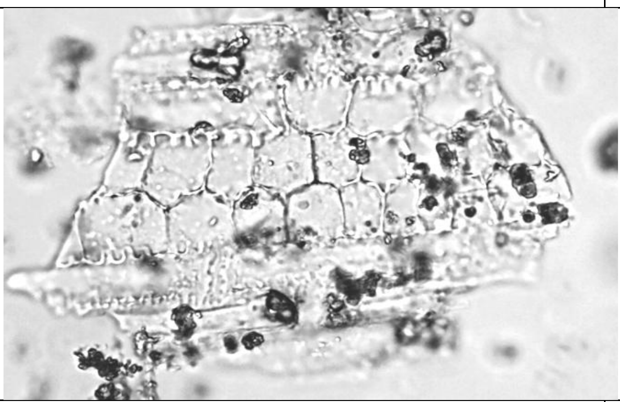	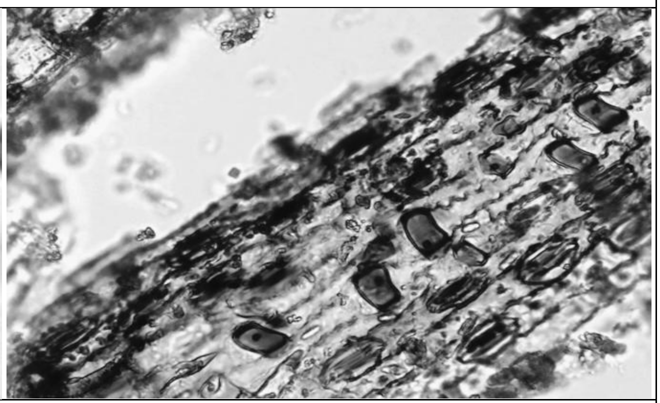
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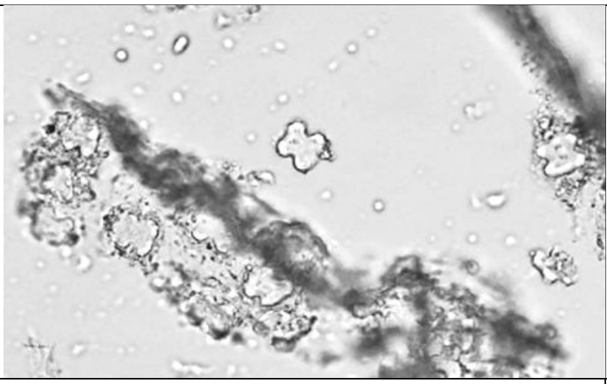	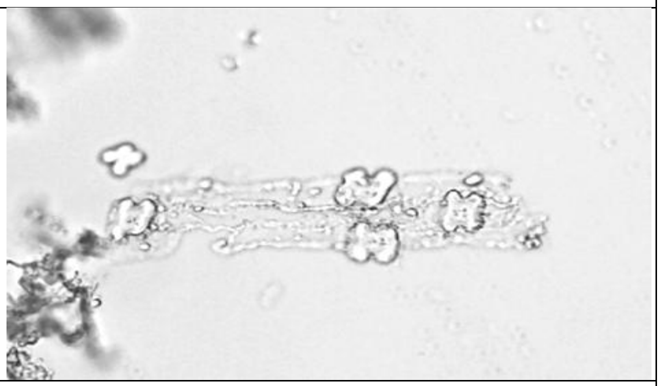
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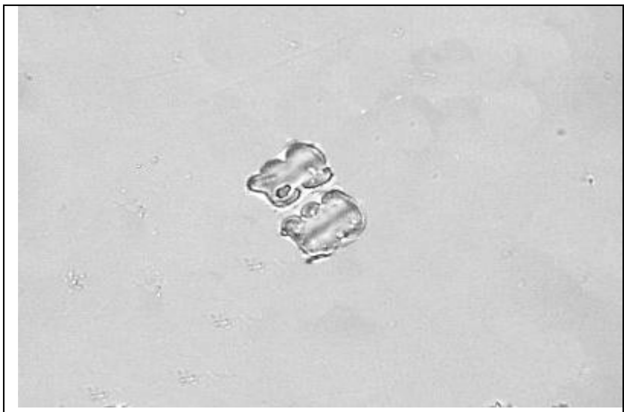	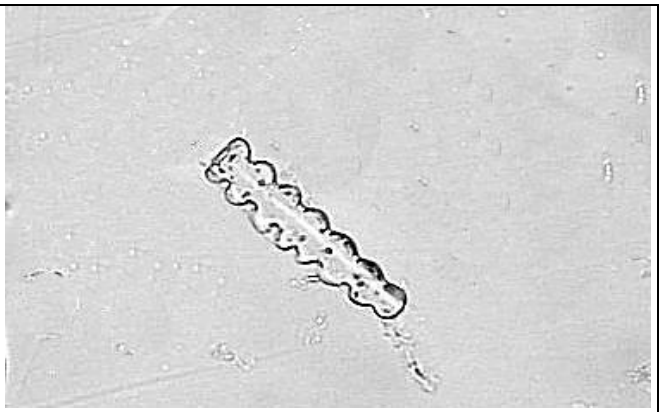
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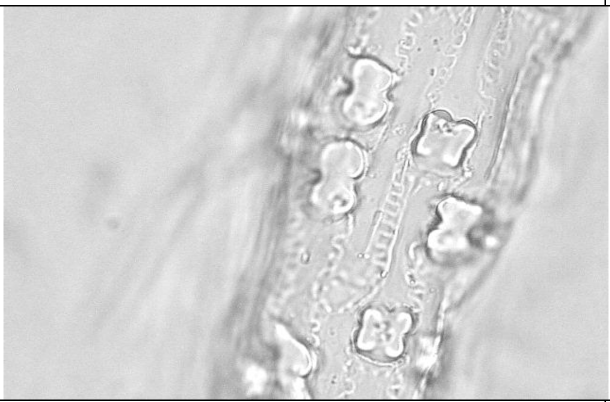	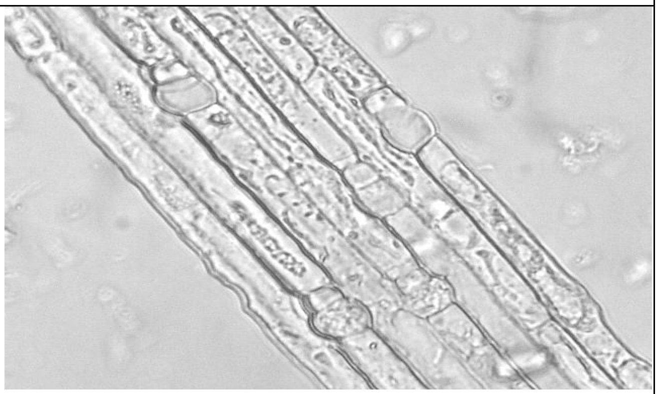
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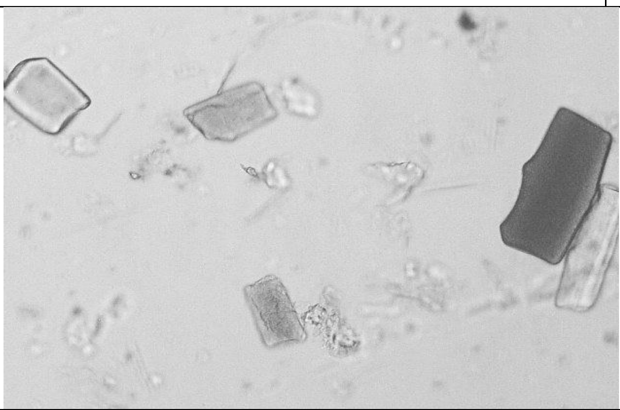	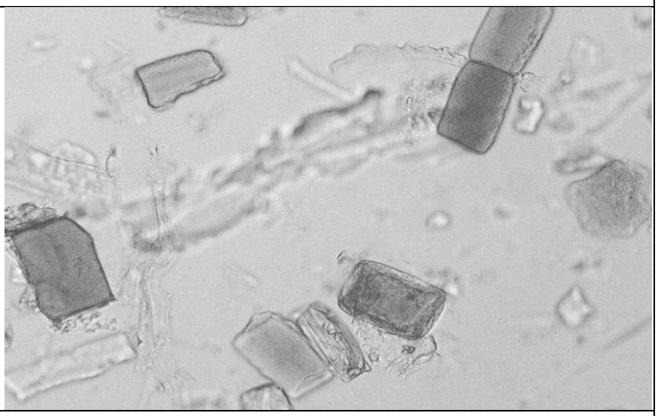
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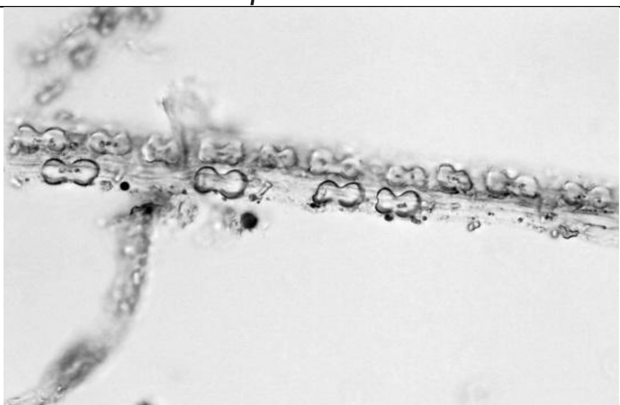	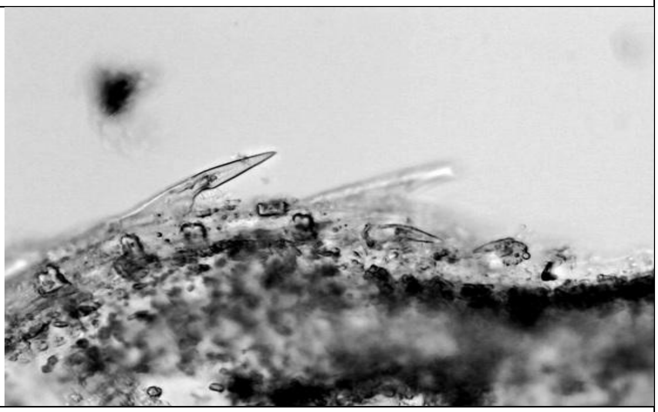
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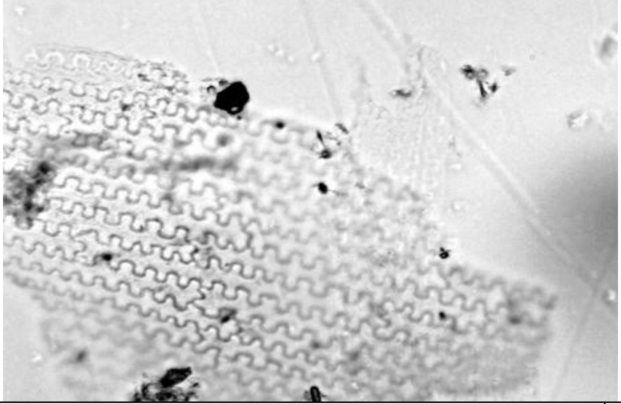	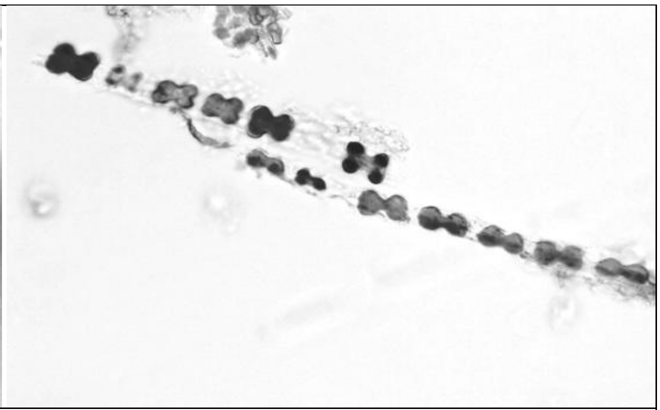
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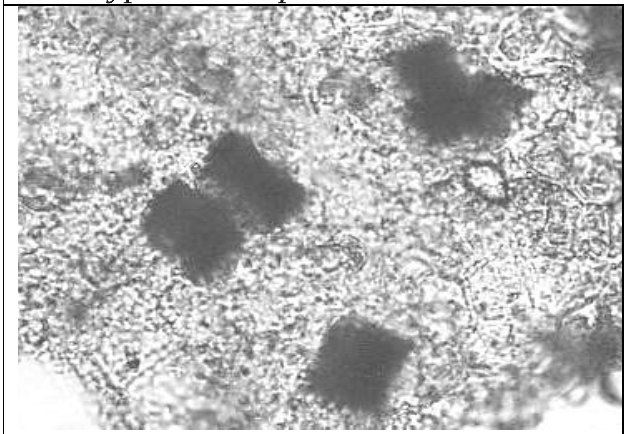	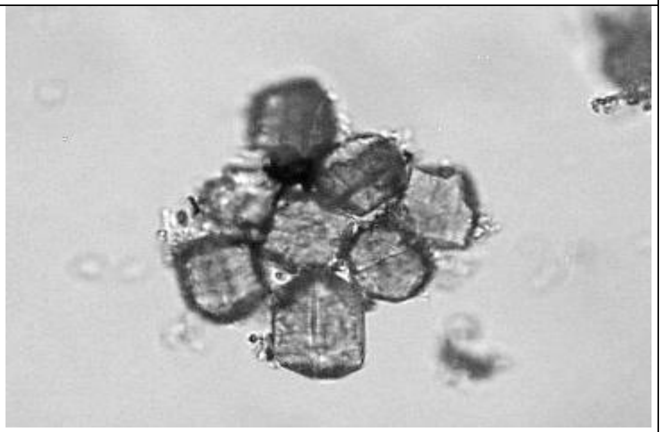
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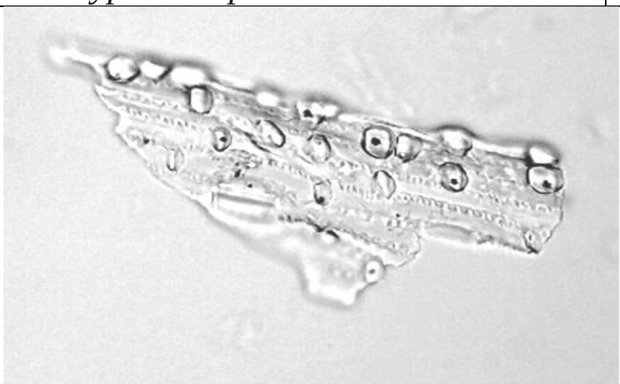	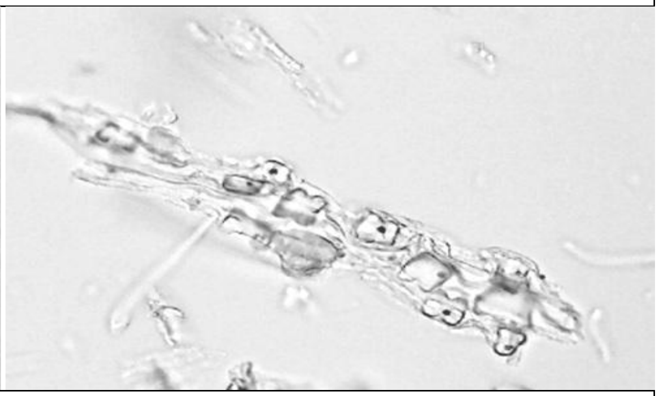
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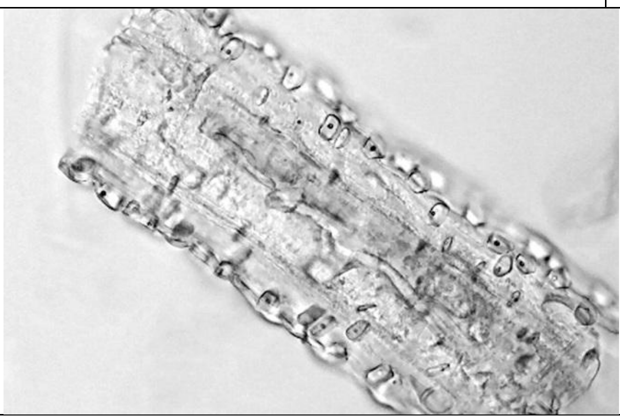	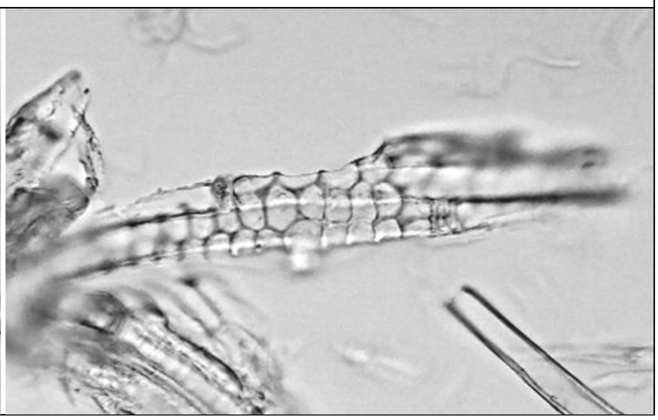

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	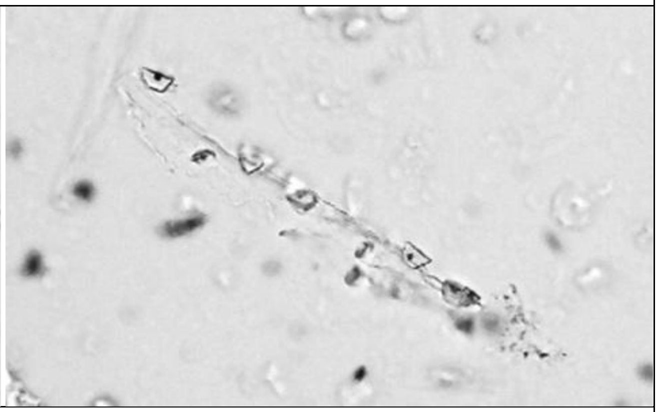
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	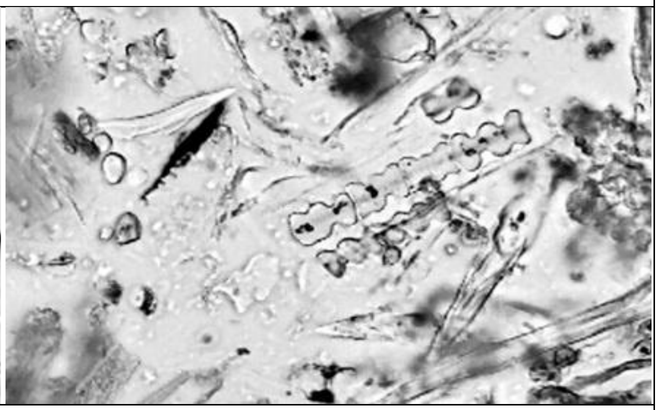
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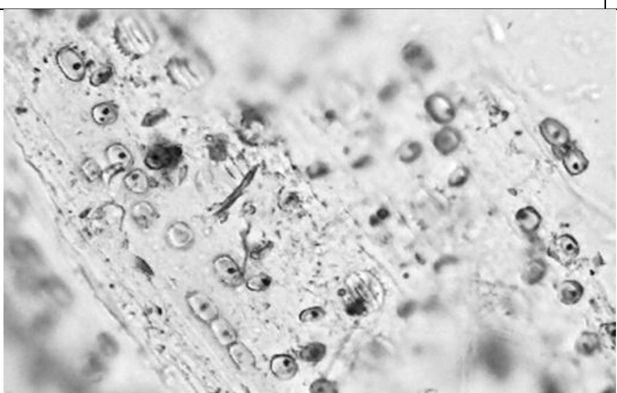	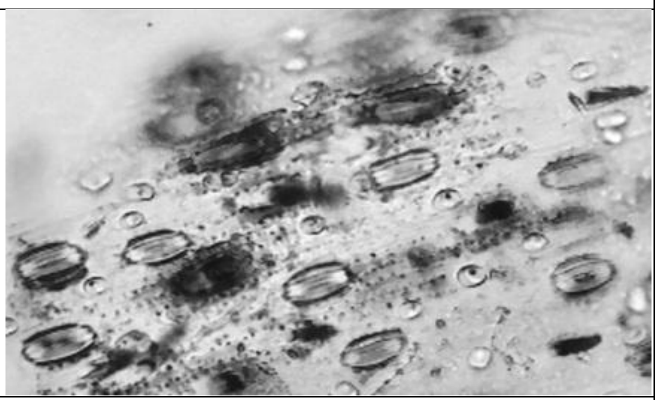
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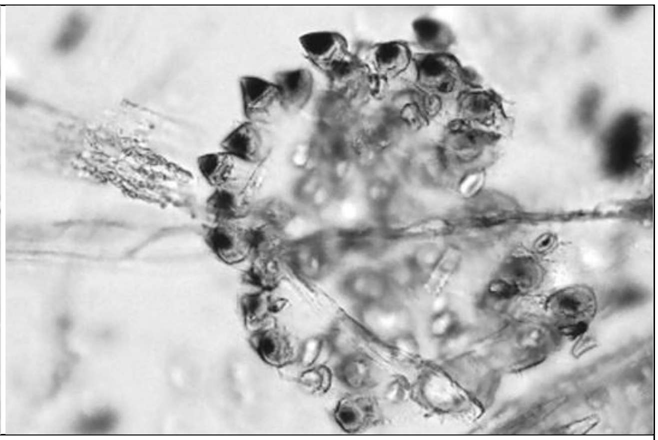

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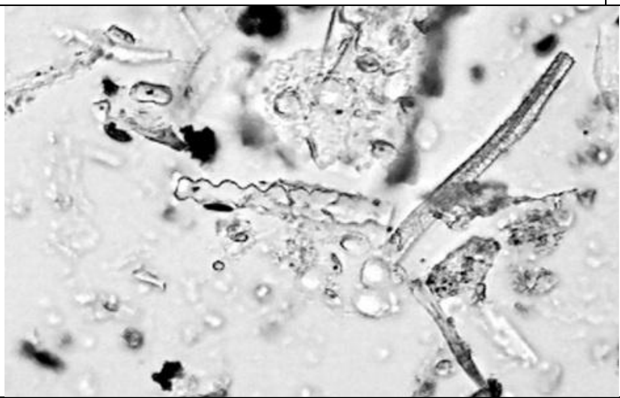

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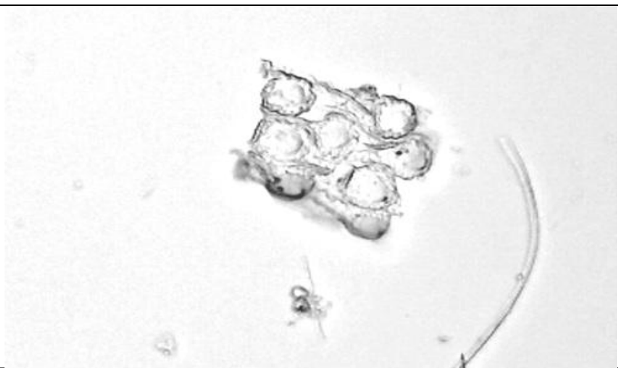

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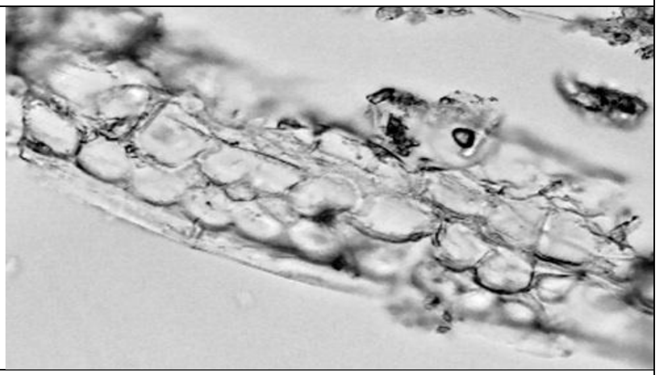

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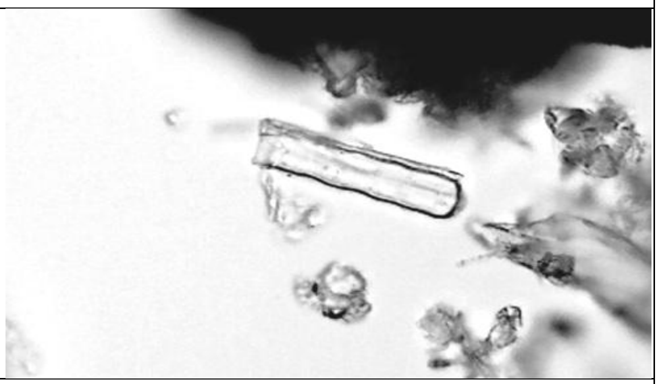

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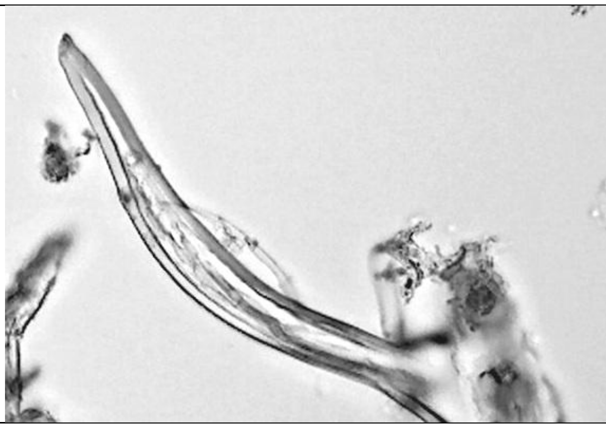

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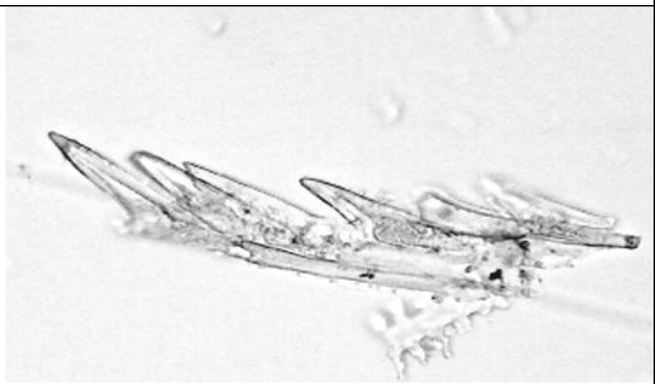

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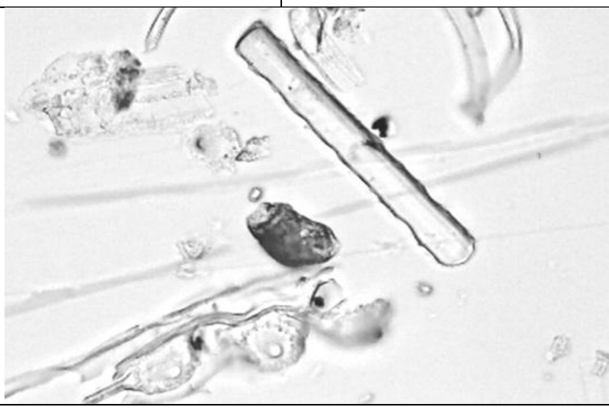

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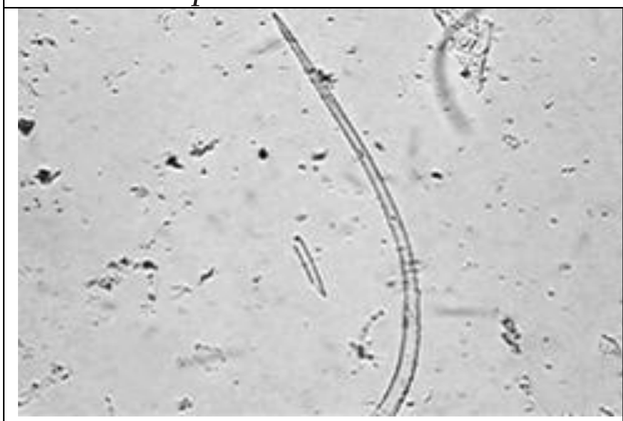

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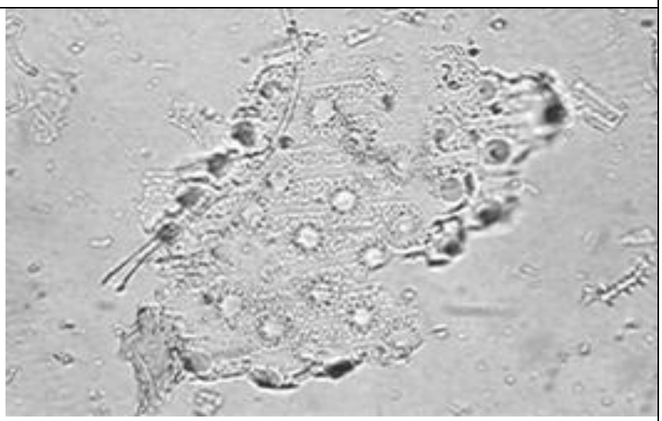

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	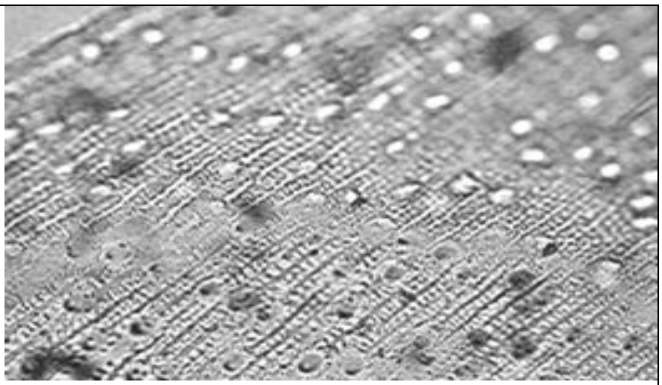
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	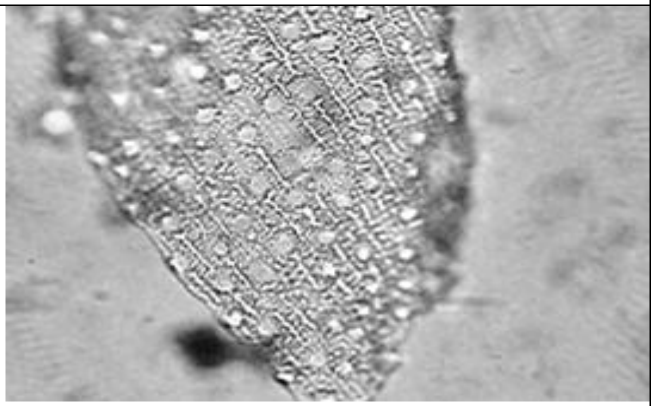
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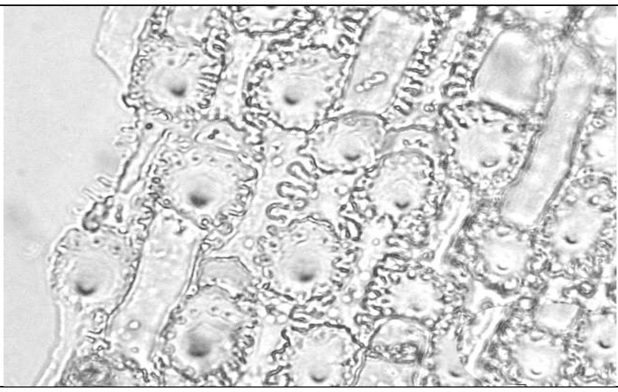	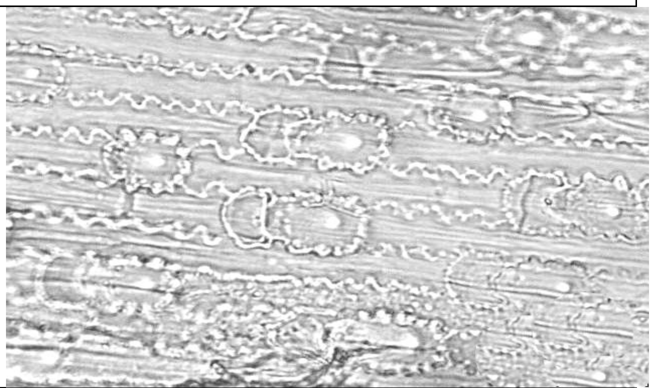
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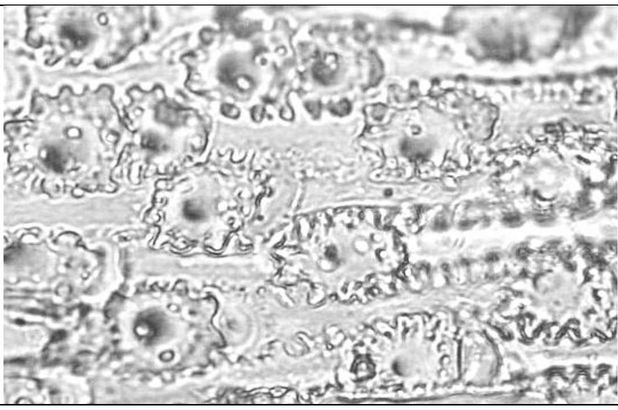	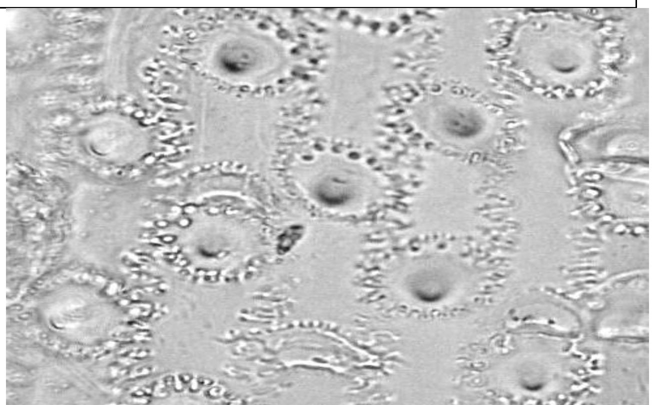
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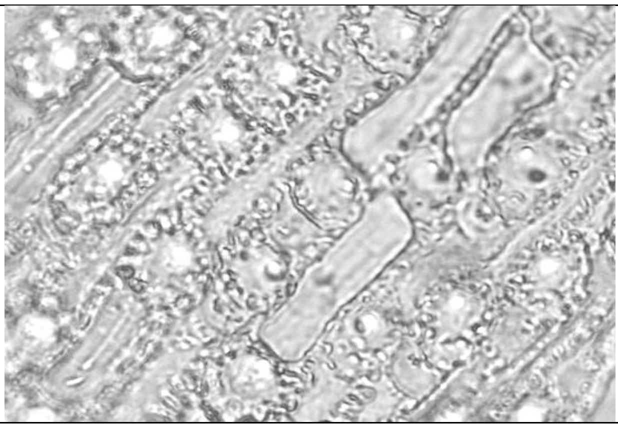	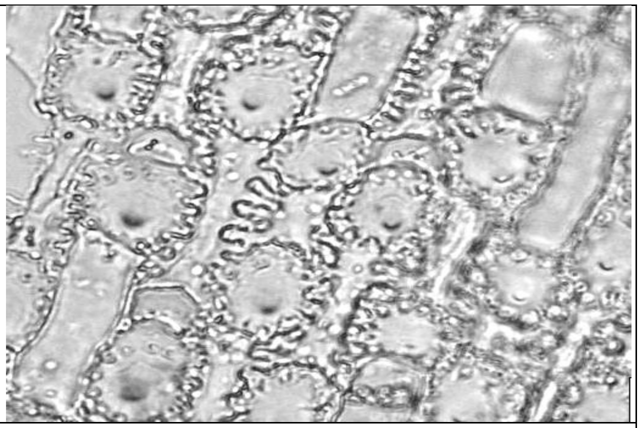
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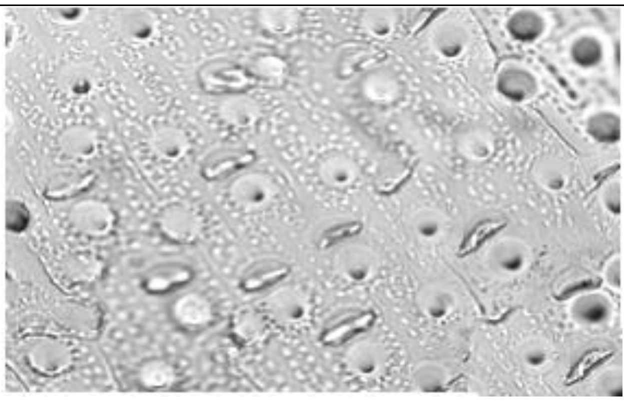	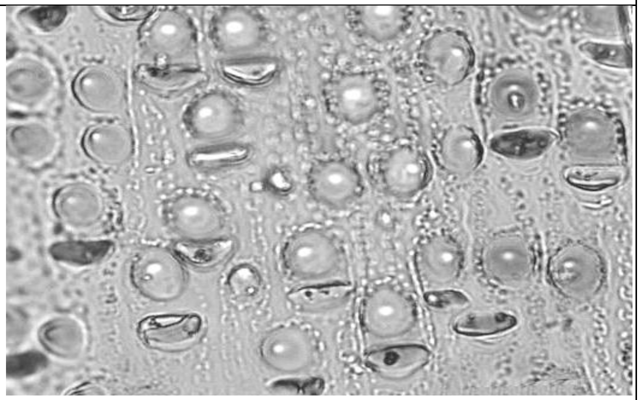
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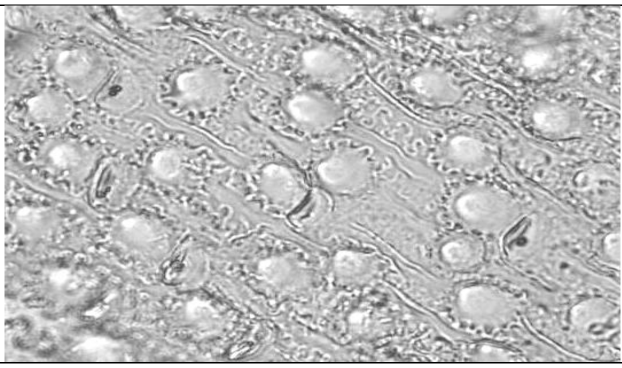	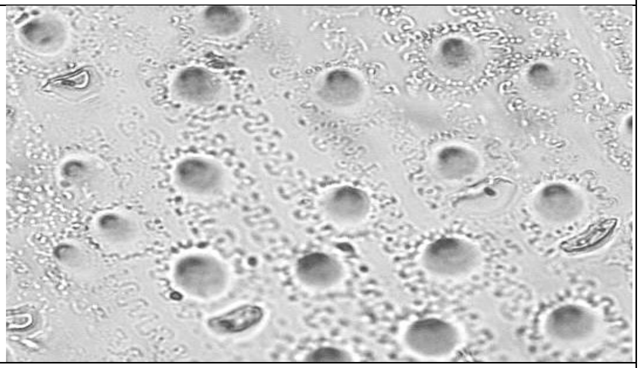
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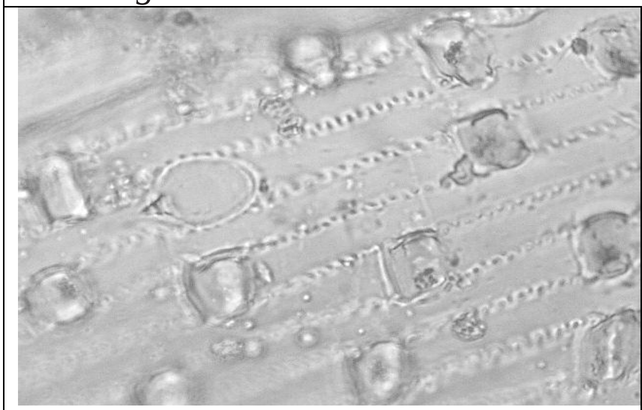	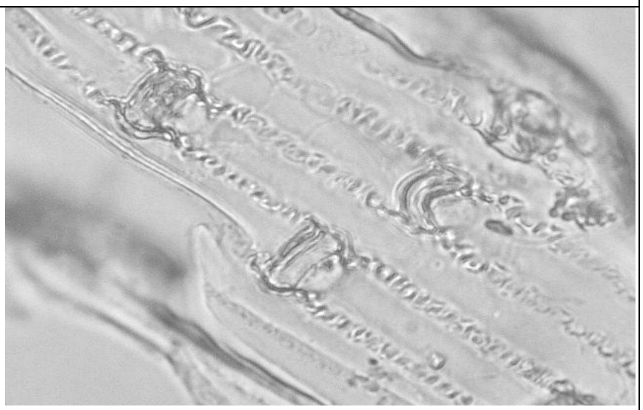
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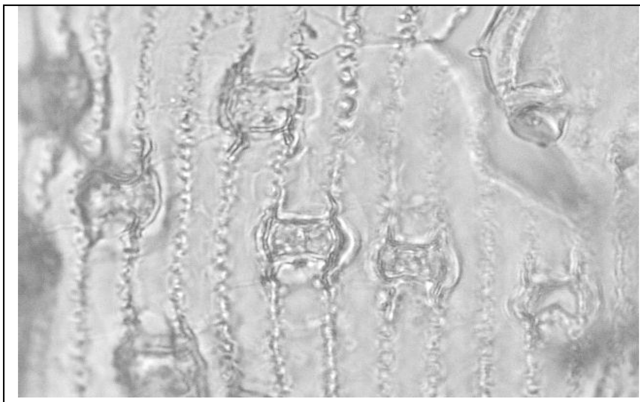	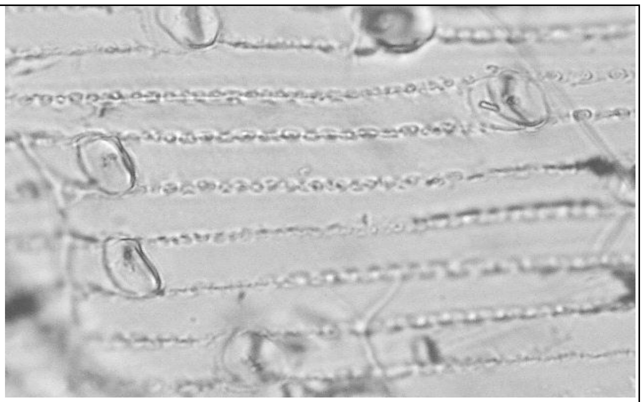
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	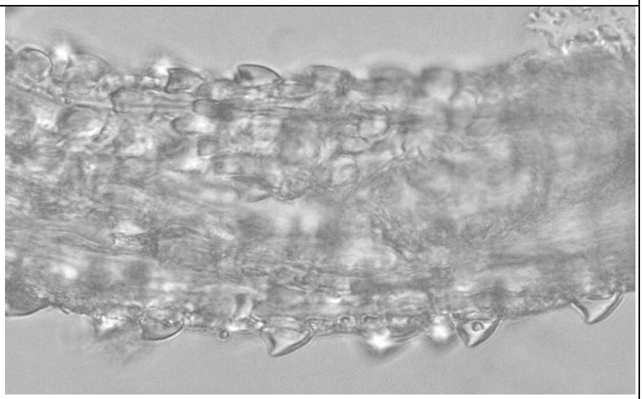
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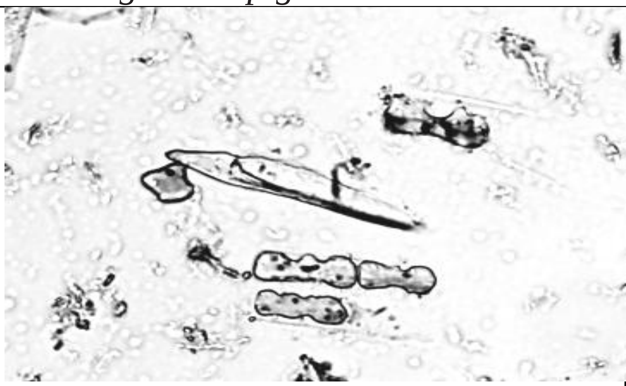	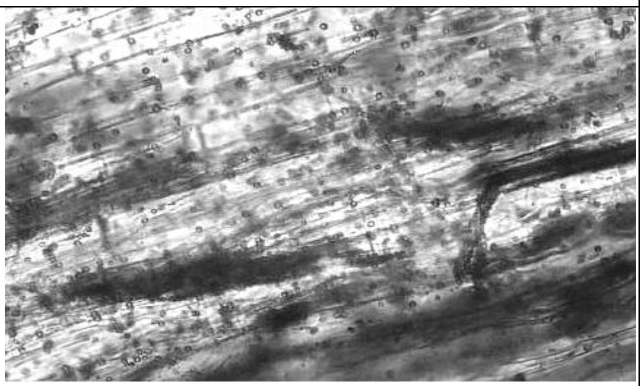
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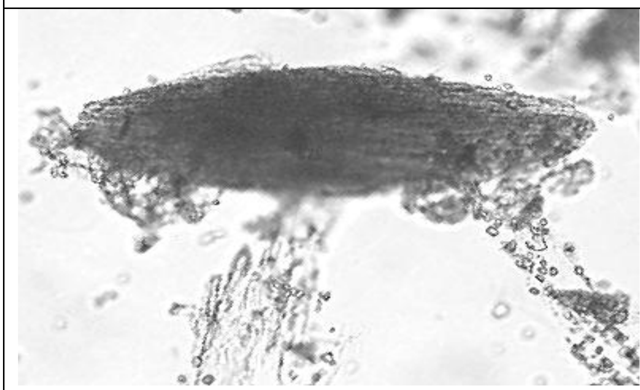	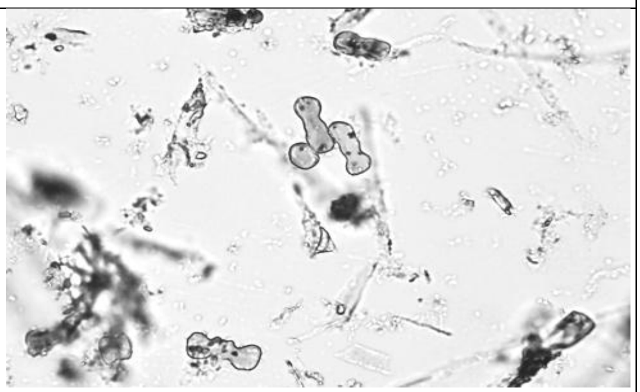

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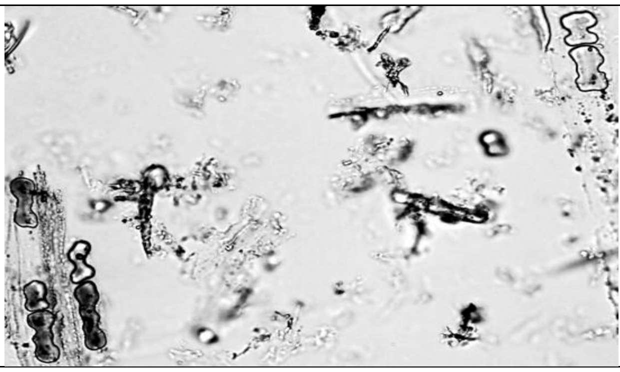	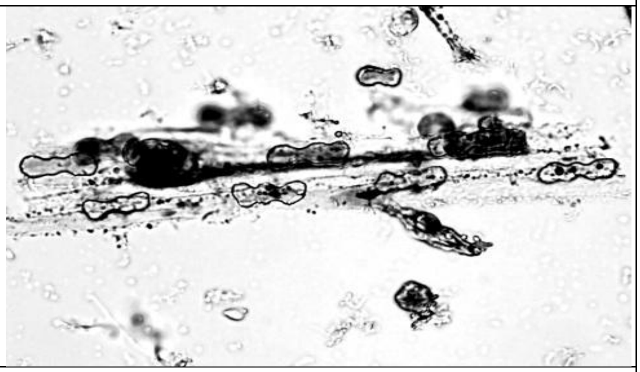
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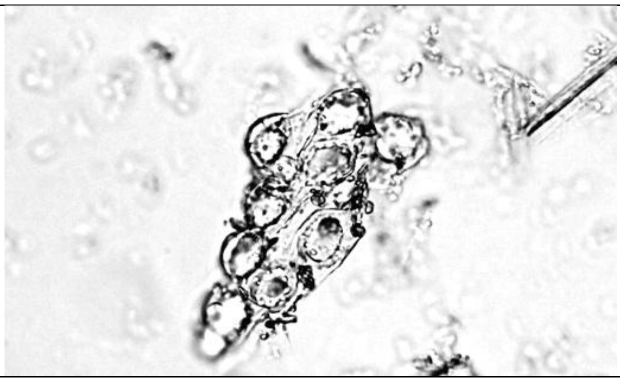	
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	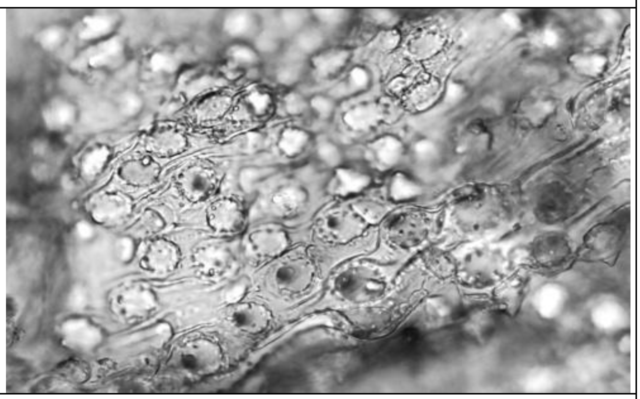
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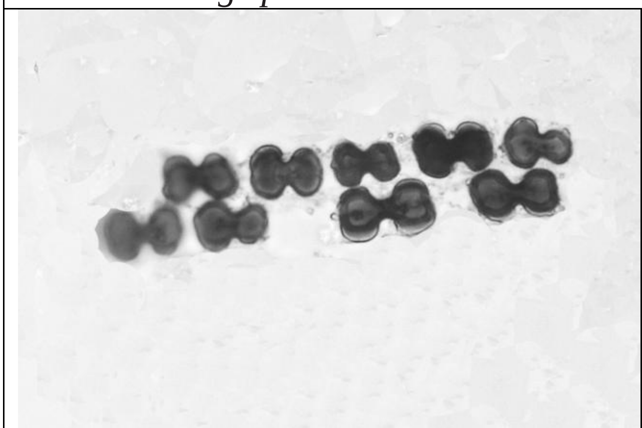	
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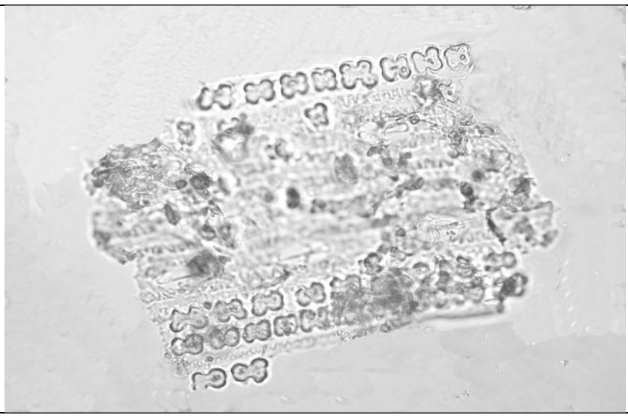	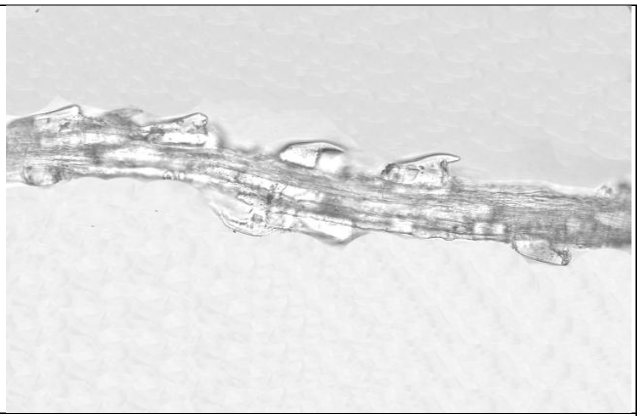
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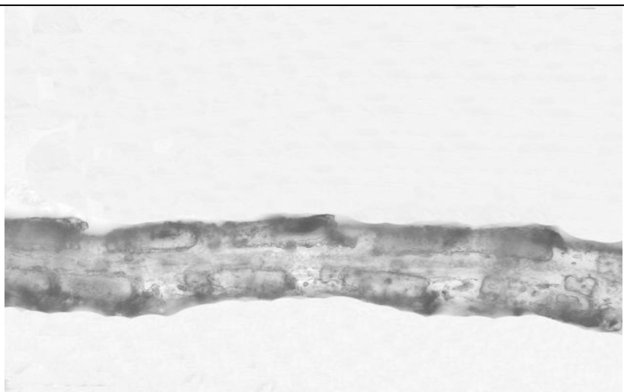	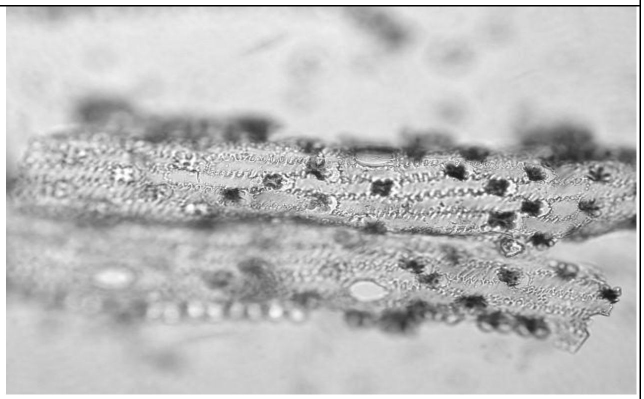
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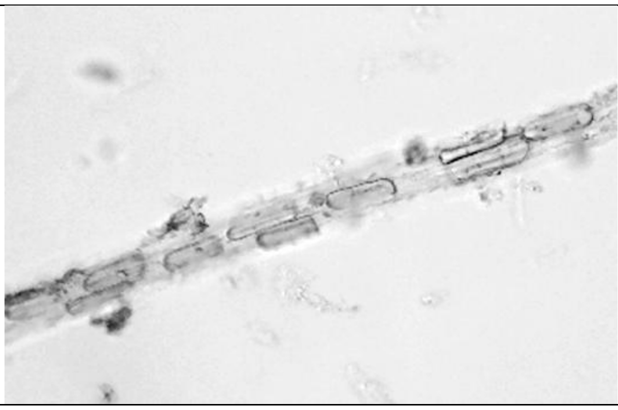	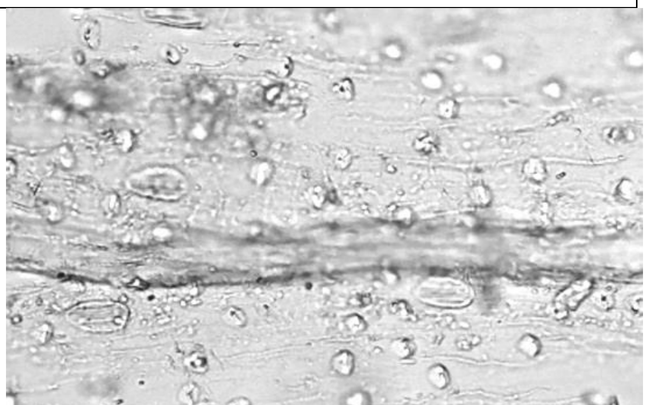
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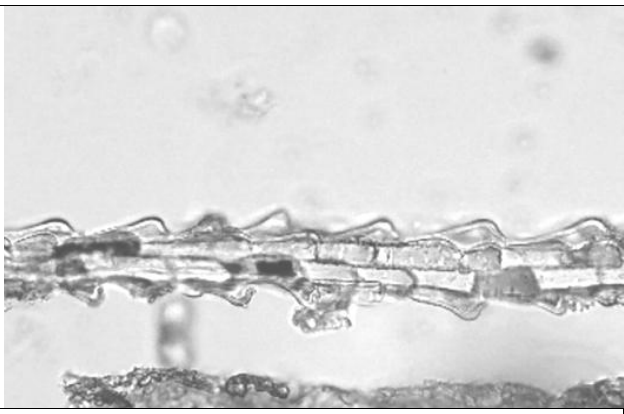	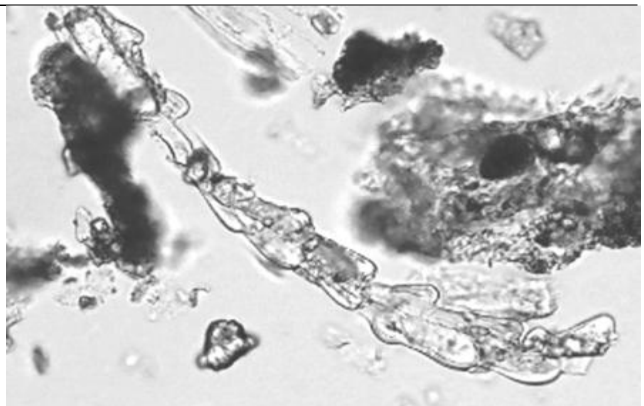
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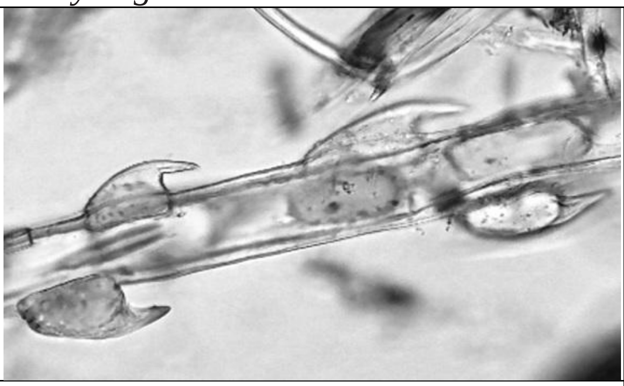	
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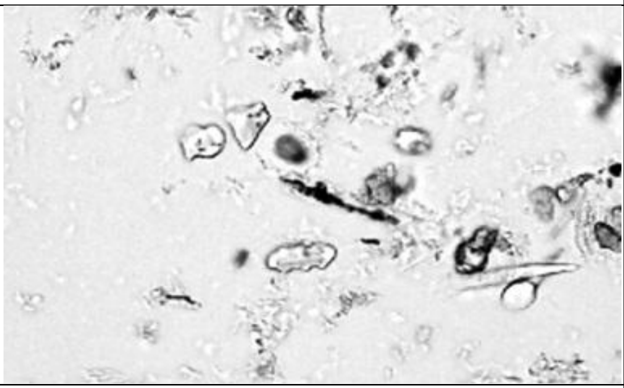	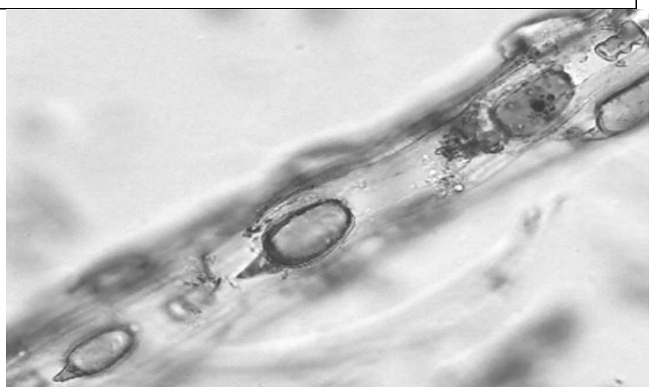
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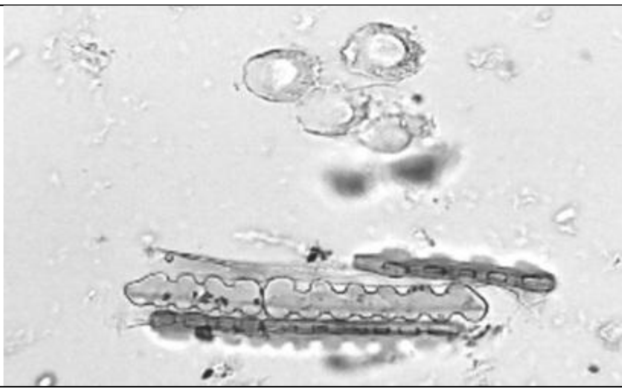

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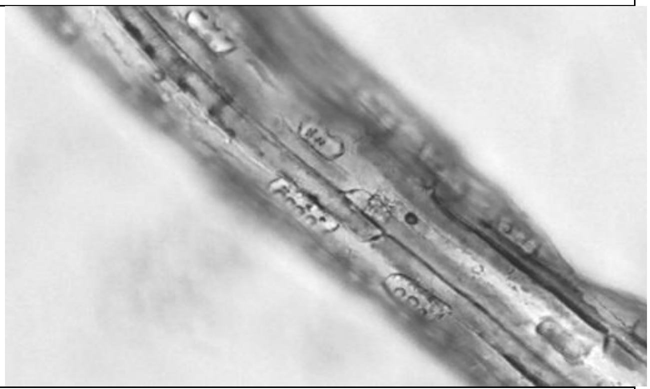

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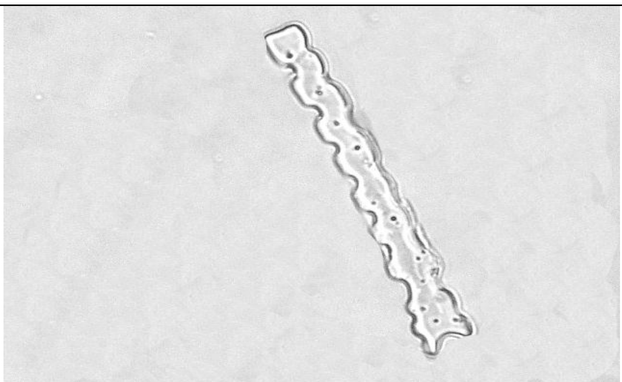

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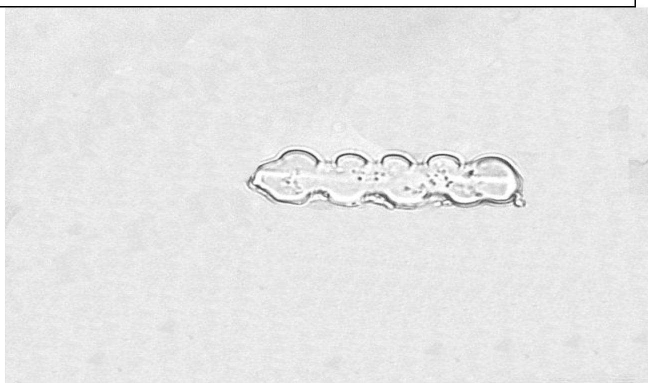

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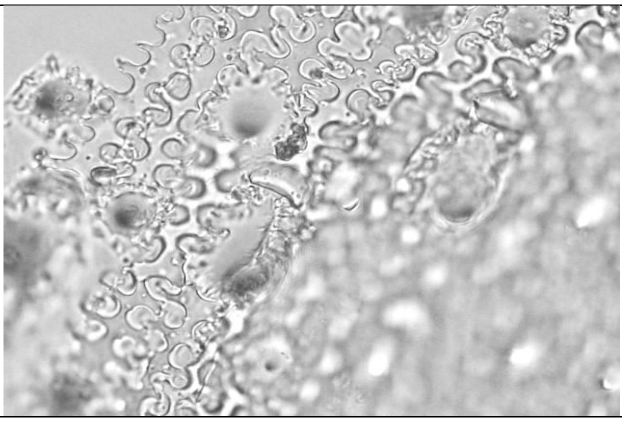

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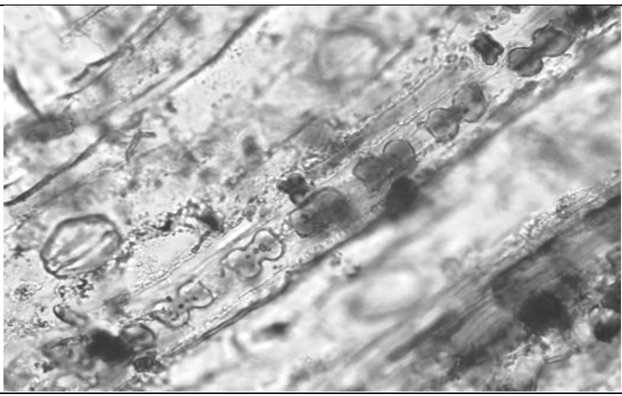
12

Echinochloa crus-galli



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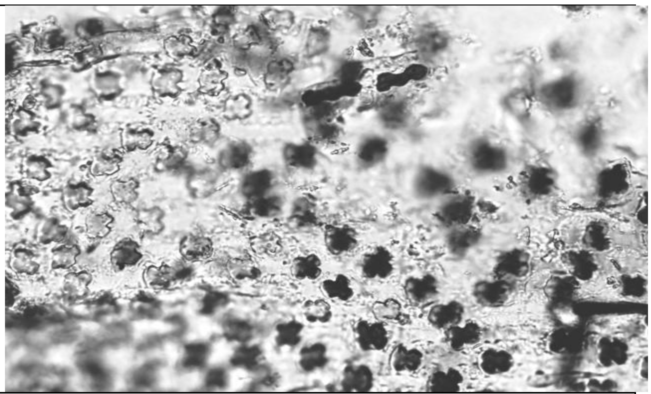

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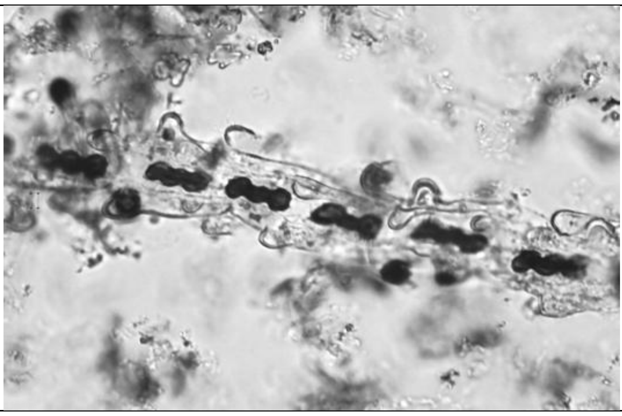

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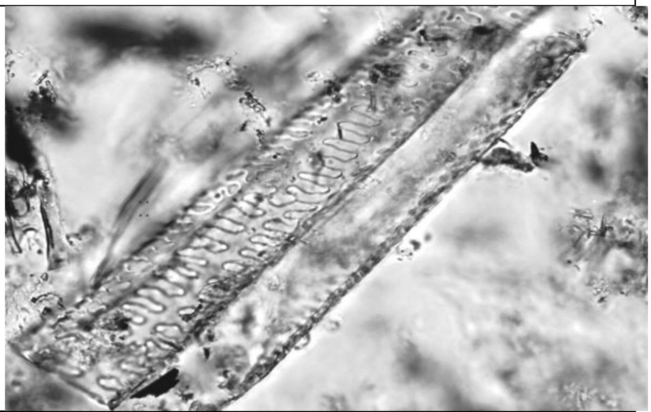

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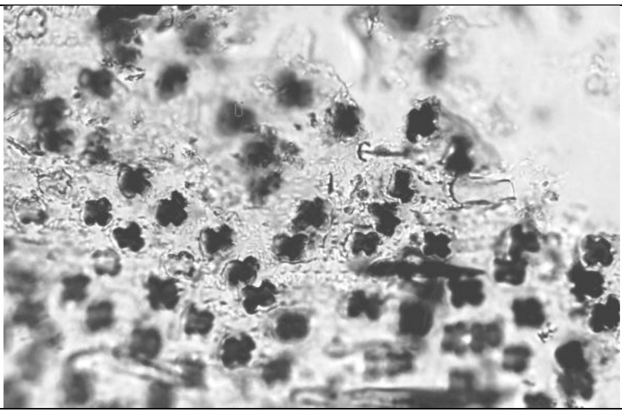

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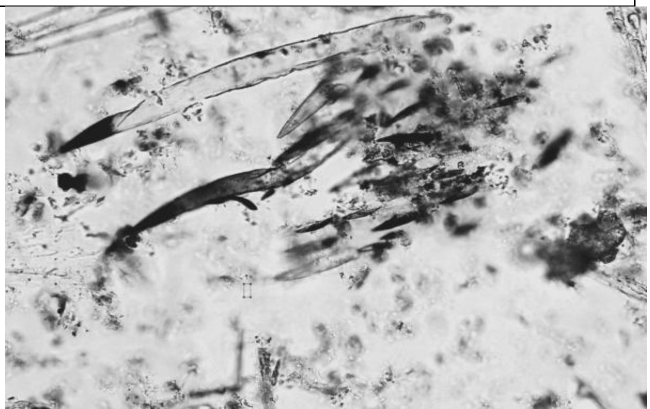

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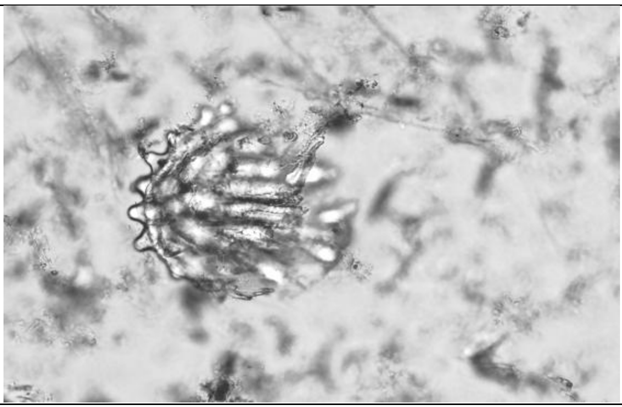

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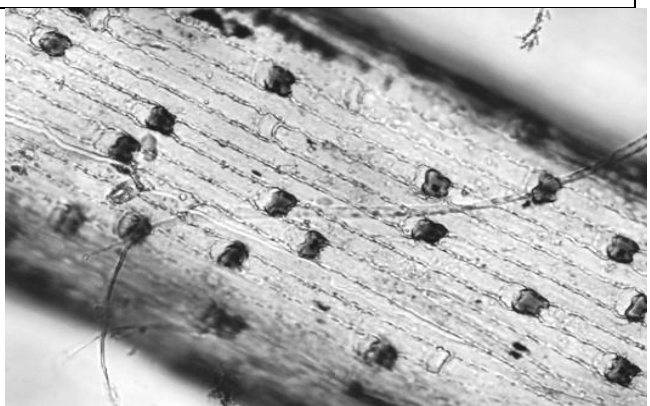

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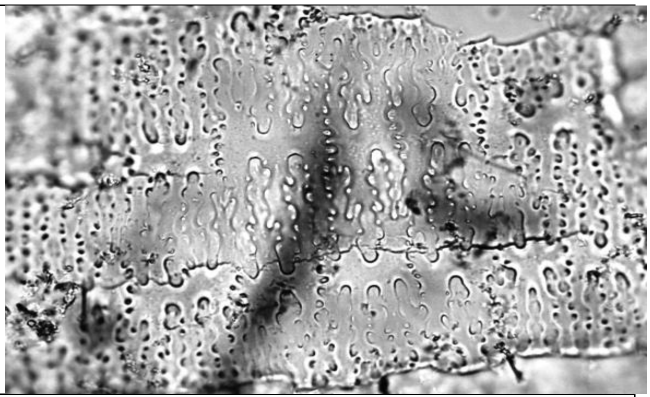

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Echinochloa sp.

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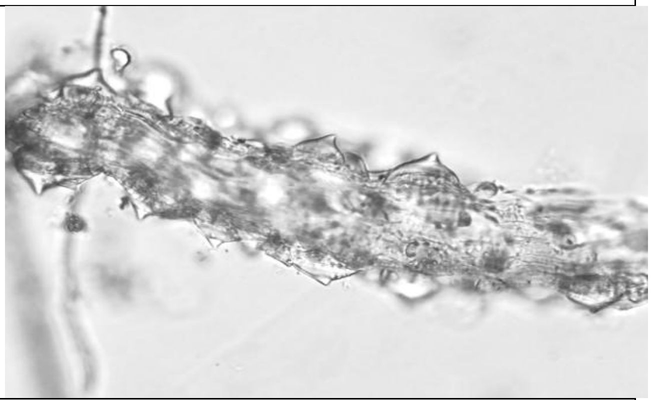

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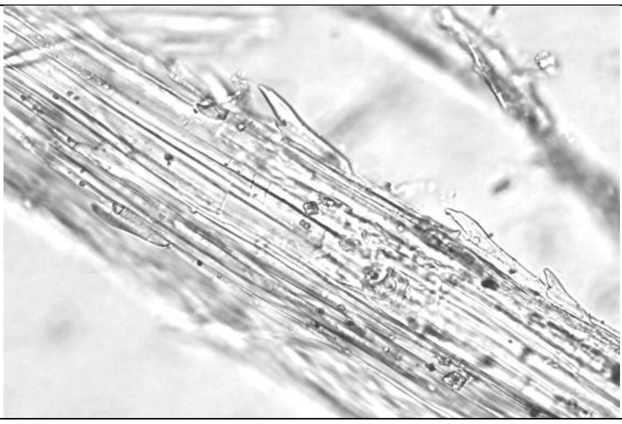

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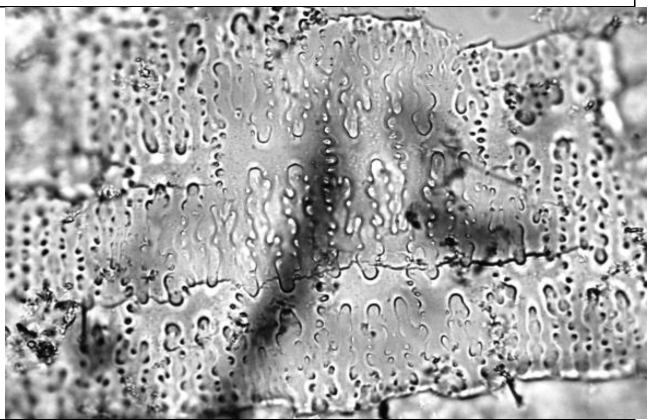

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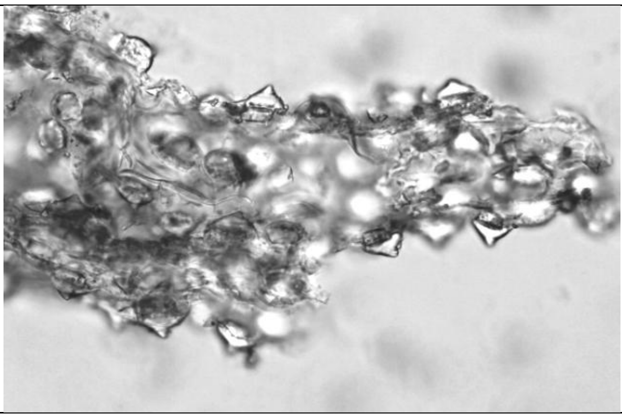

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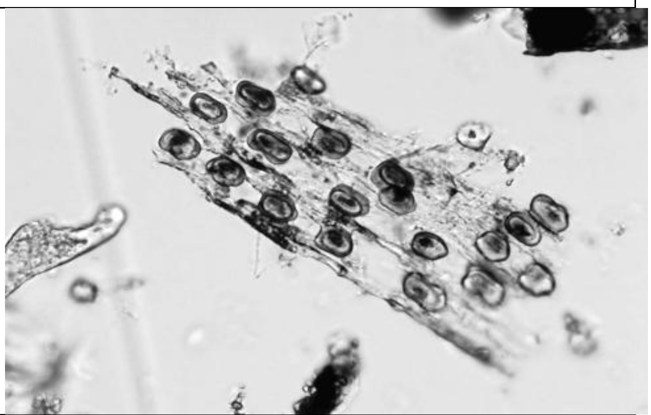

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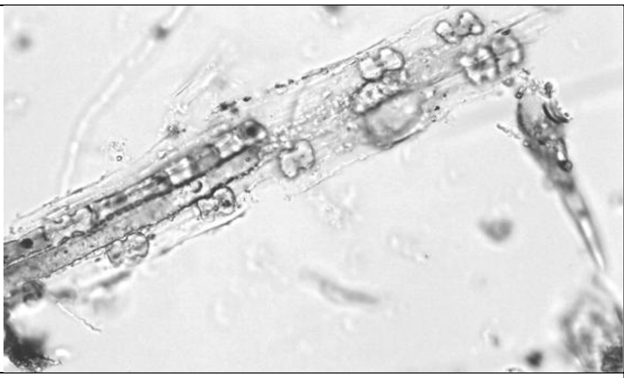
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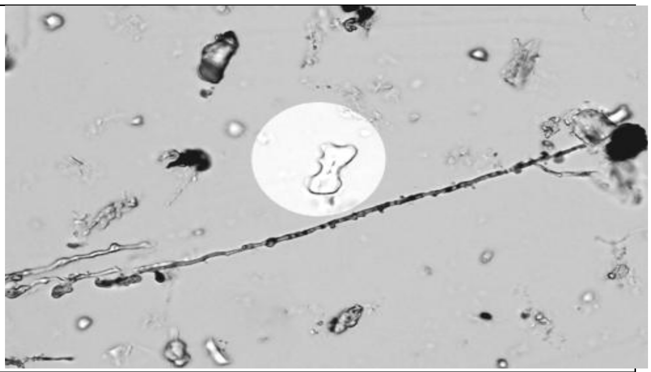
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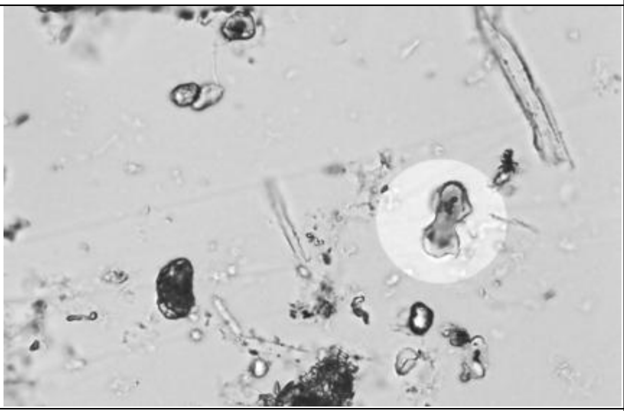
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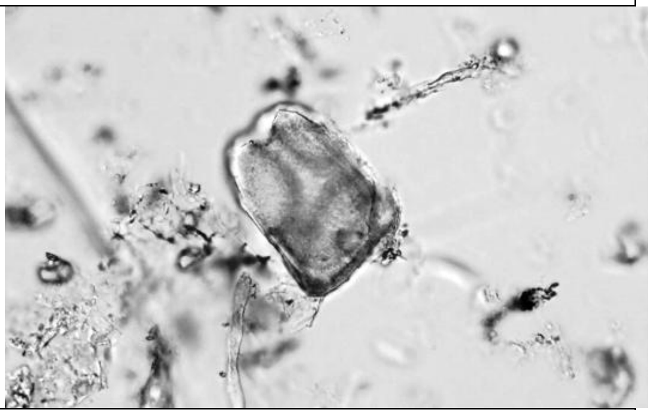
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Elytrigia gracillima


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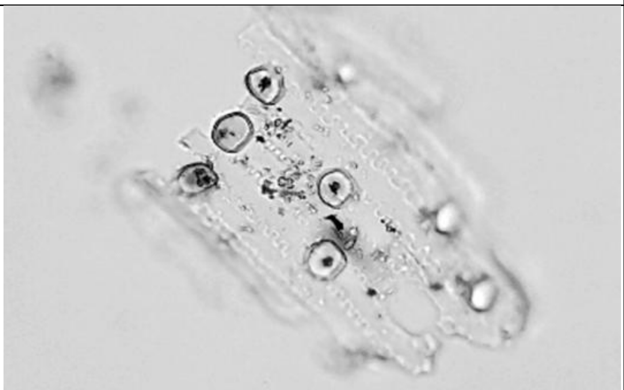
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	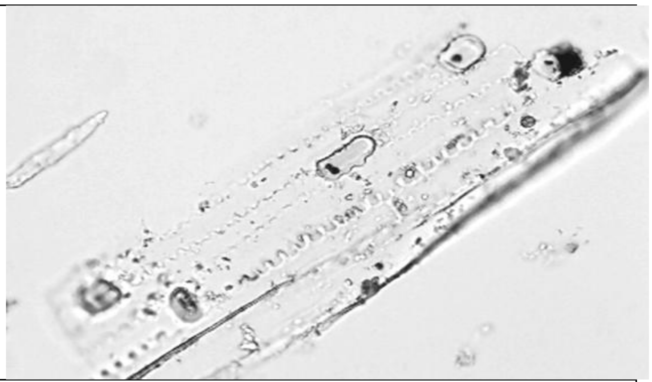
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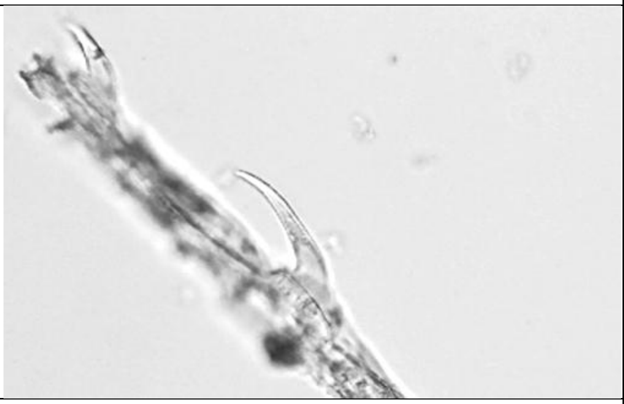	
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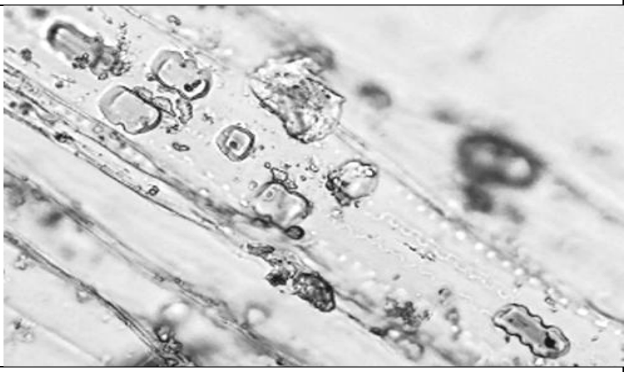	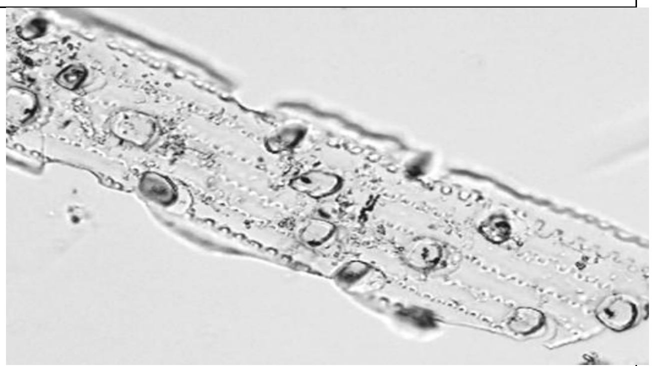
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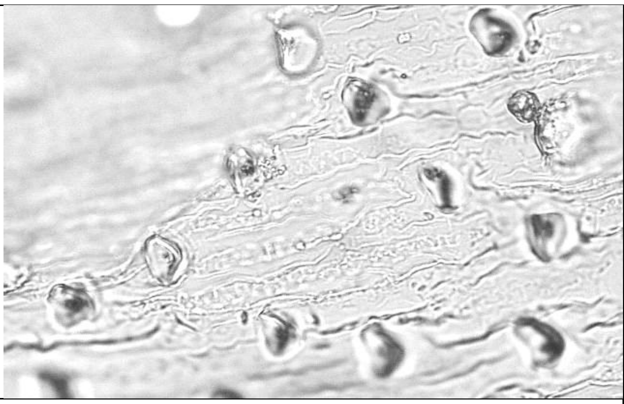	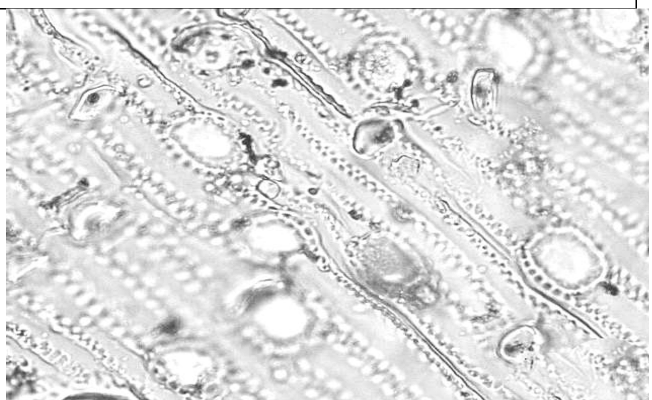
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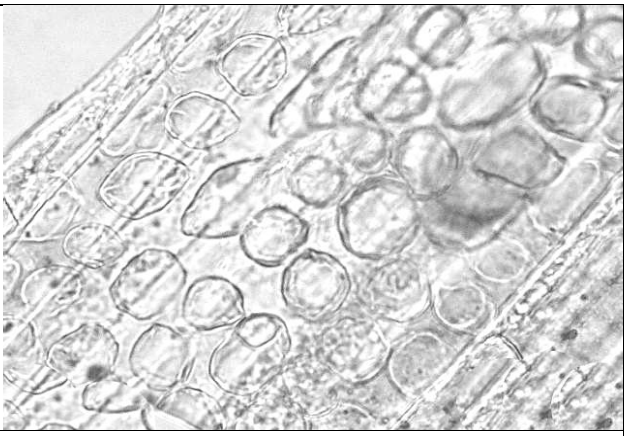	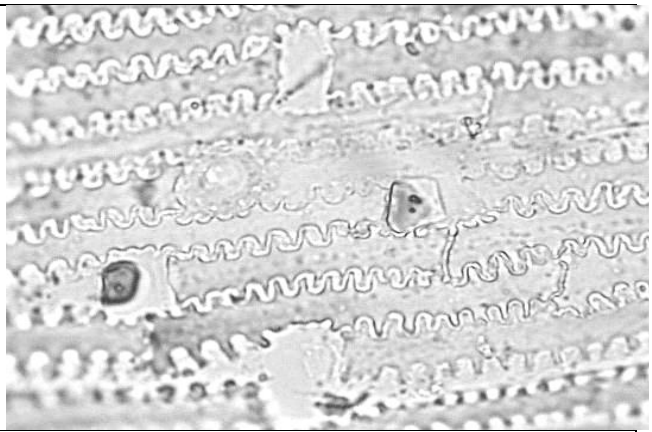
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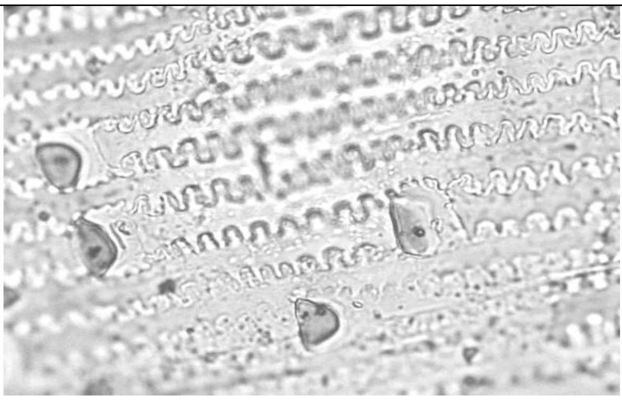	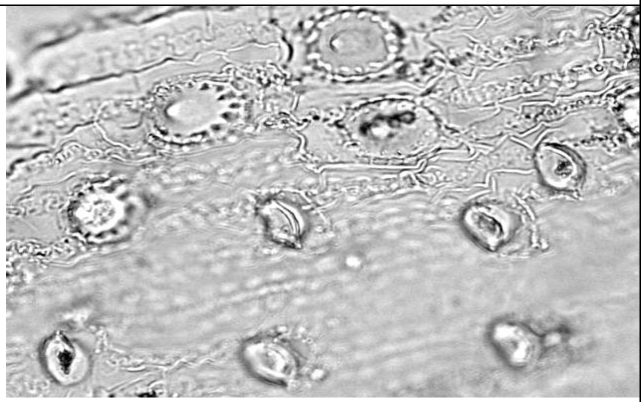
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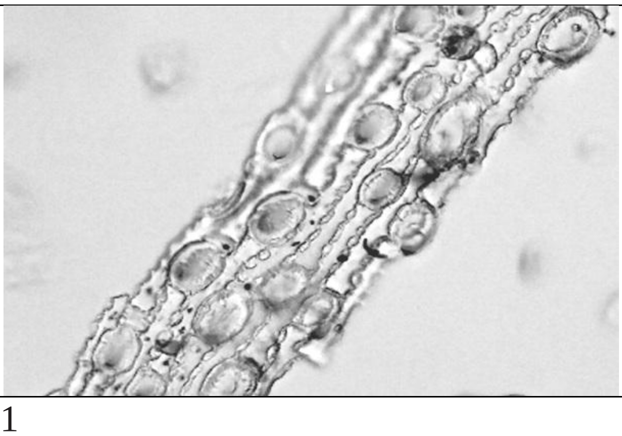
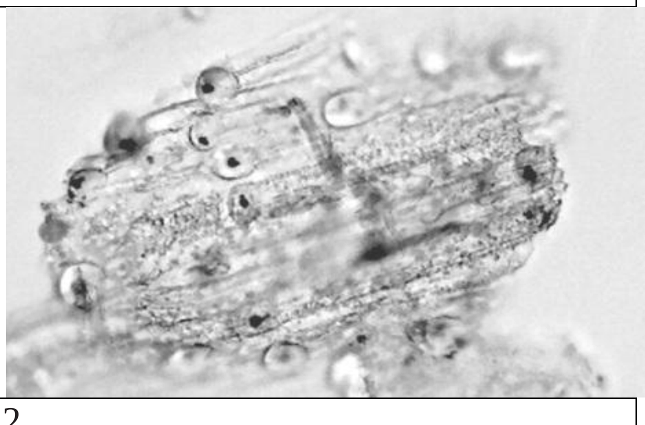
Helictotrichon schellianum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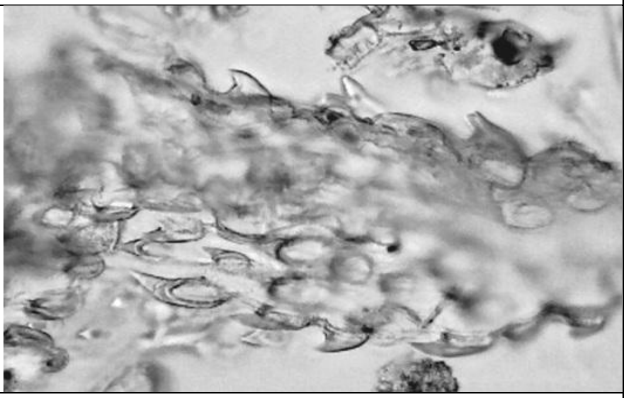	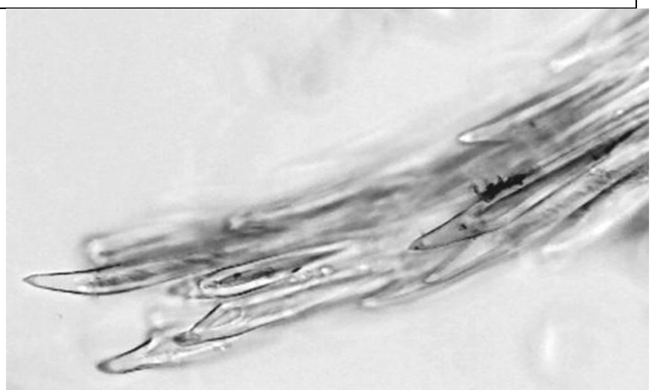
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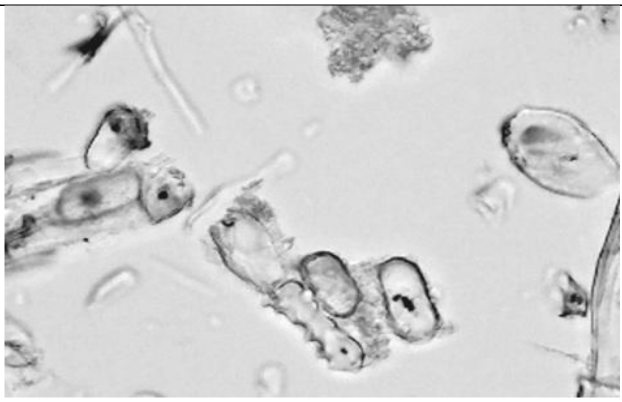	
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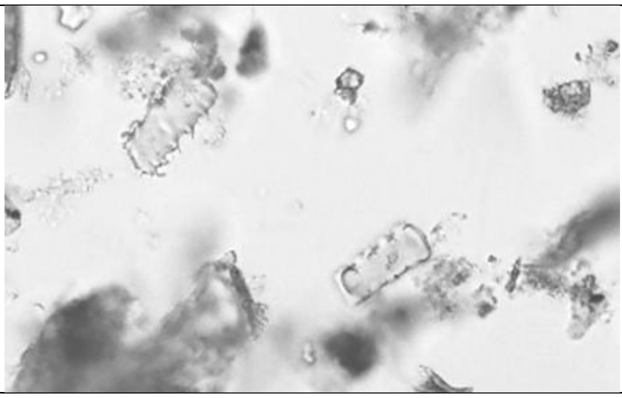	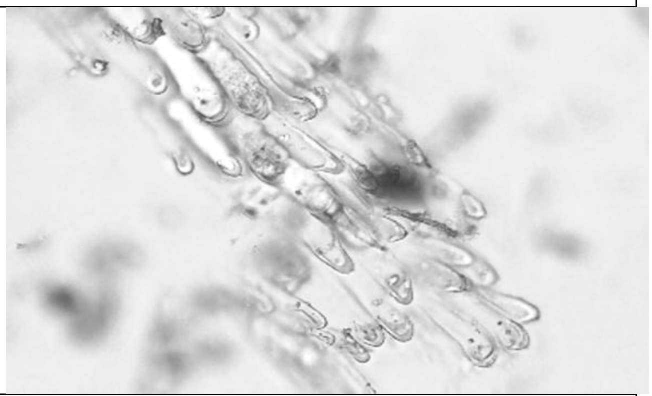
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	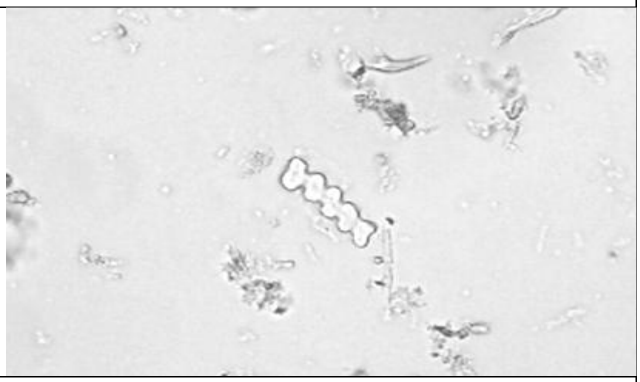
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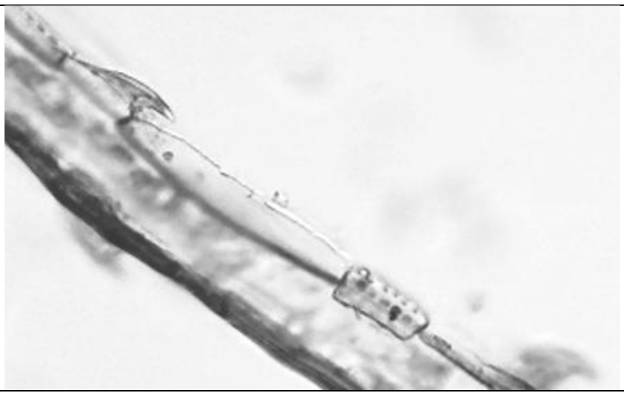	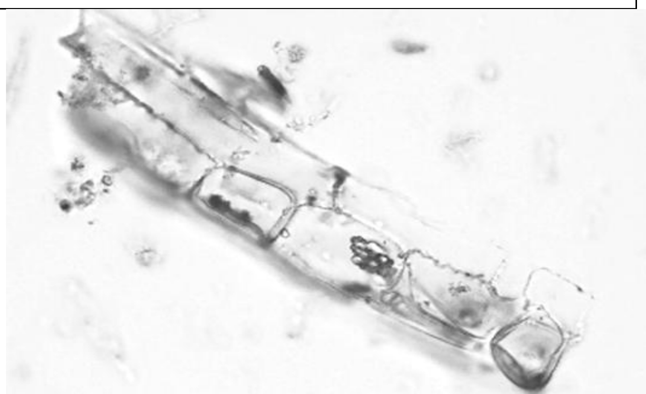
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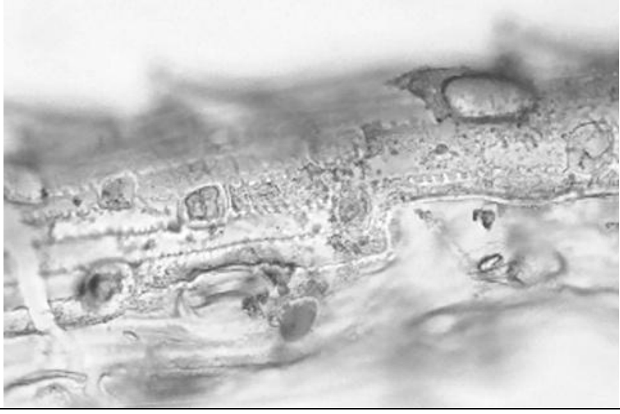
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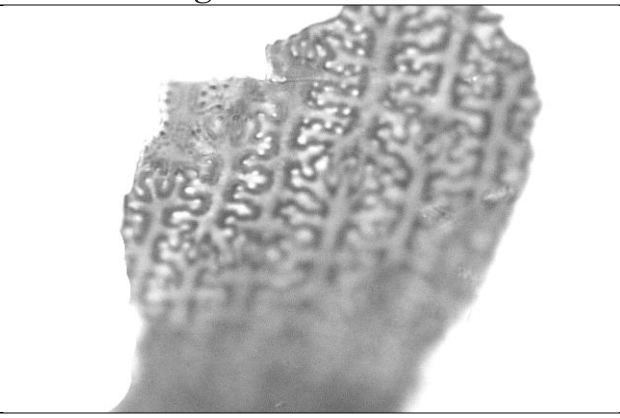
Hordéum vulgáre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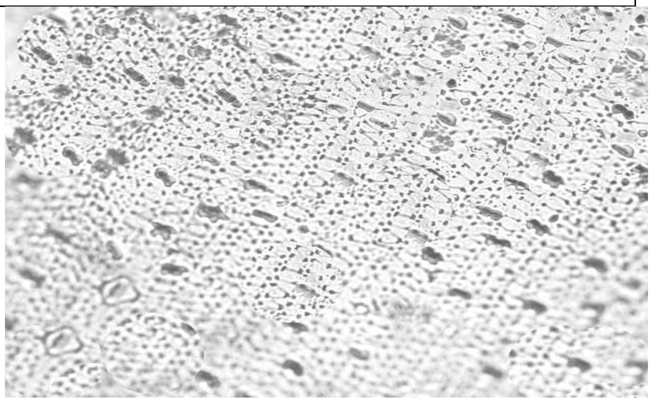
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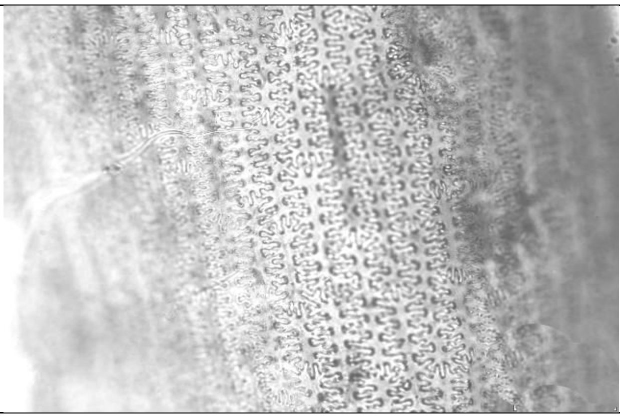
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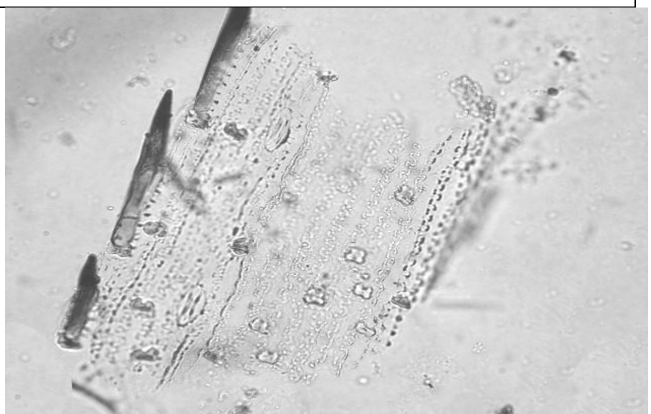
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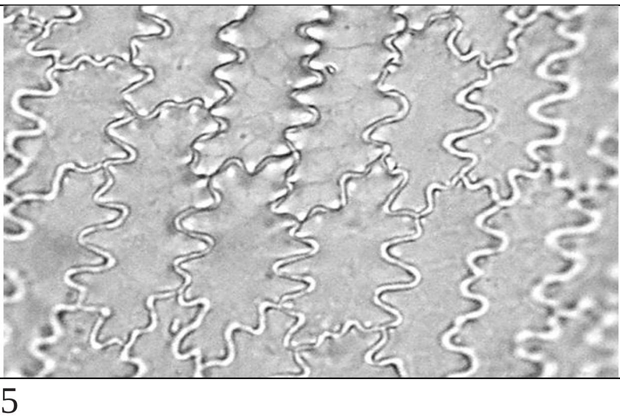
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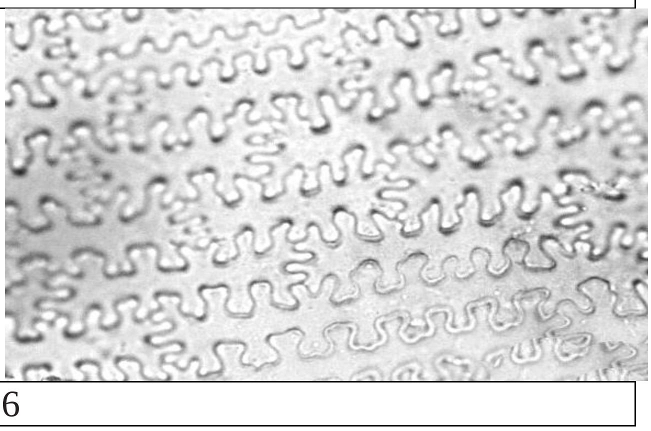
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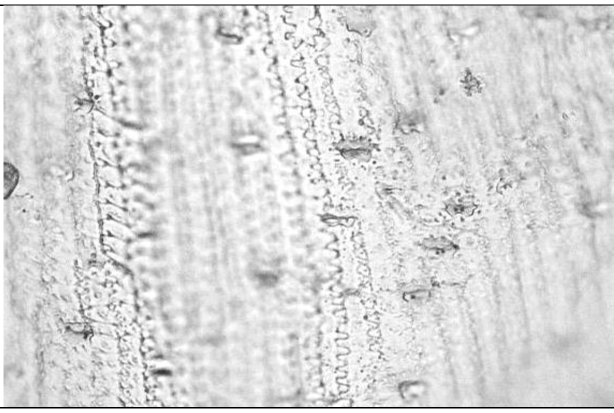

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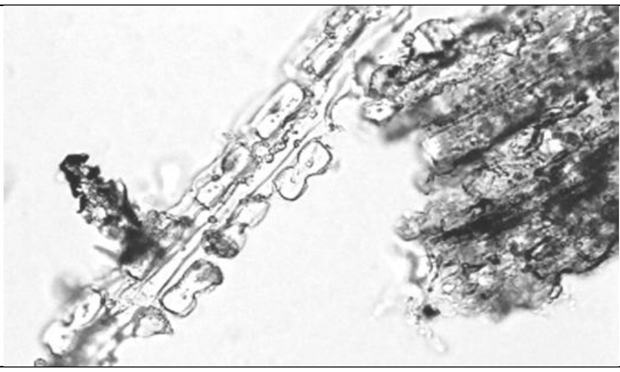
Festuca sulcata



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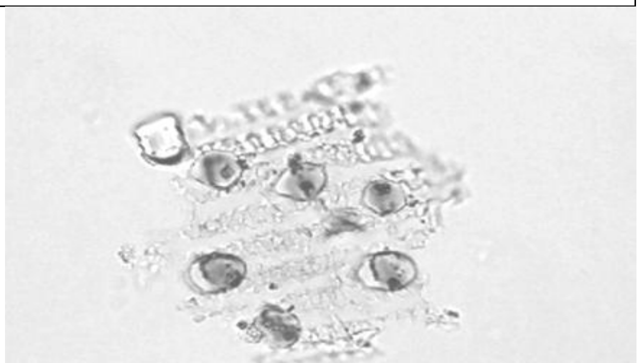

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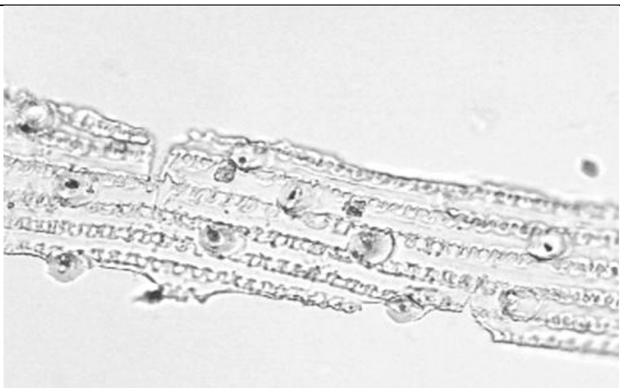

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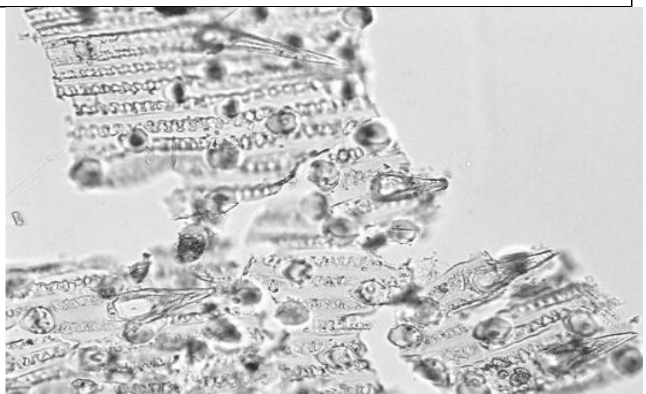

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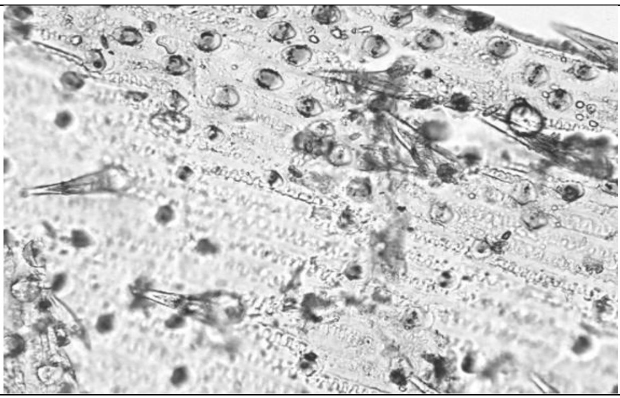

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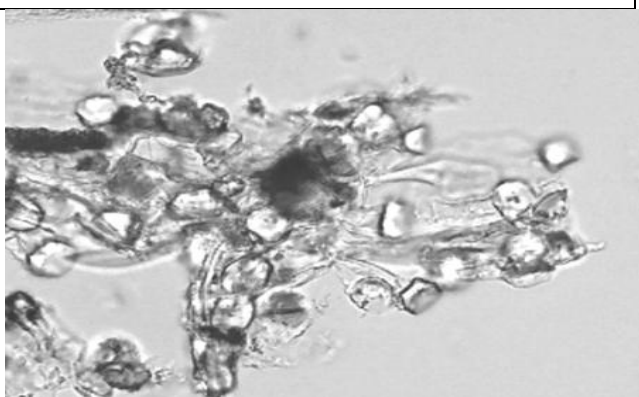

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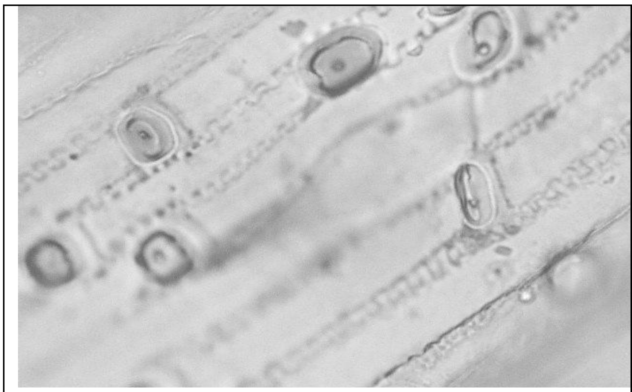
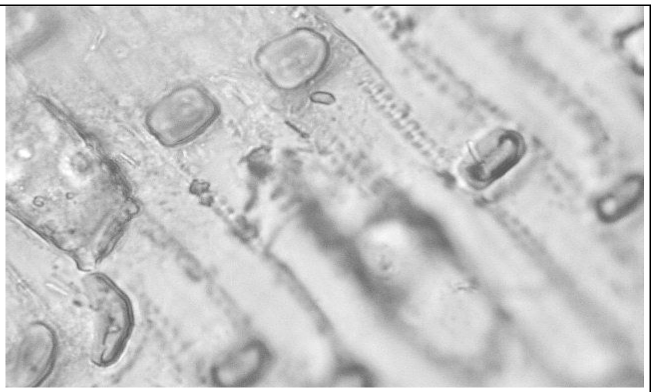
Festúca valesiáca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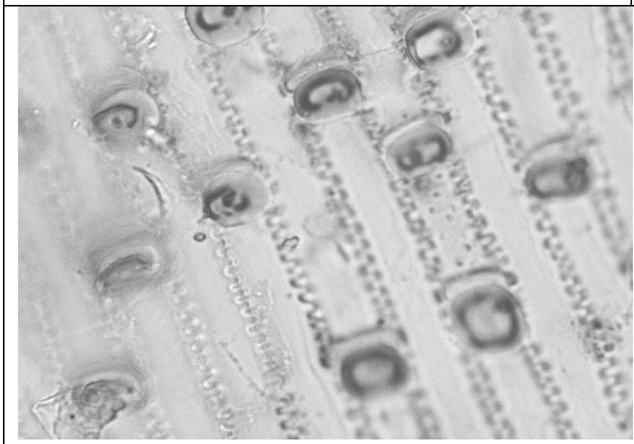	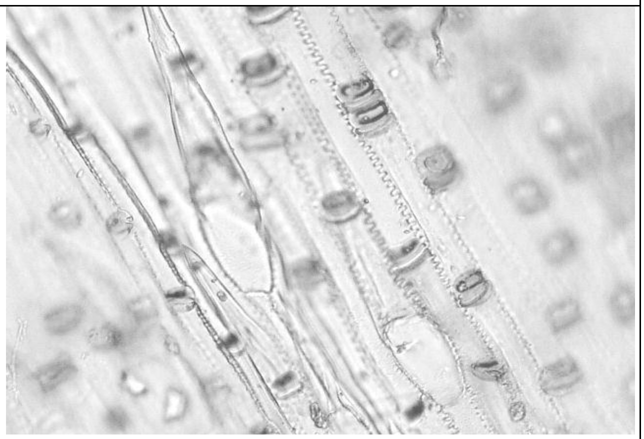
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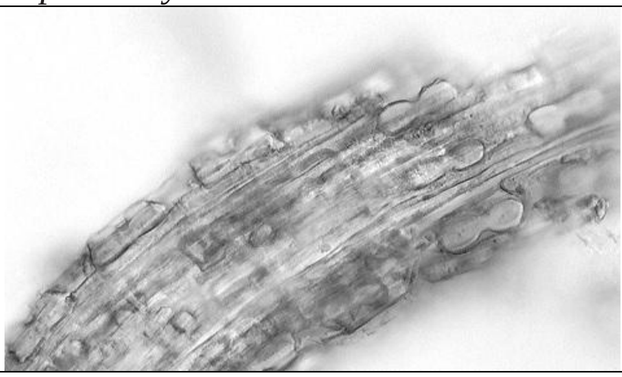	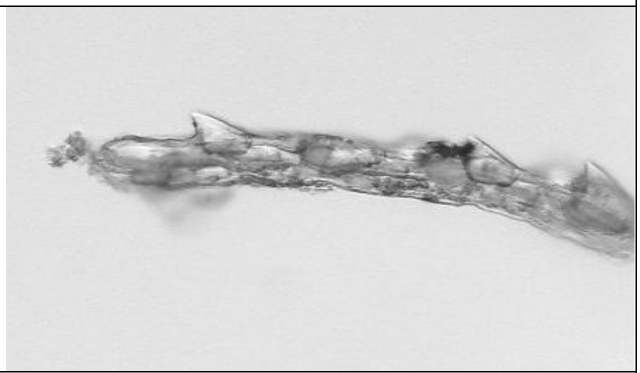
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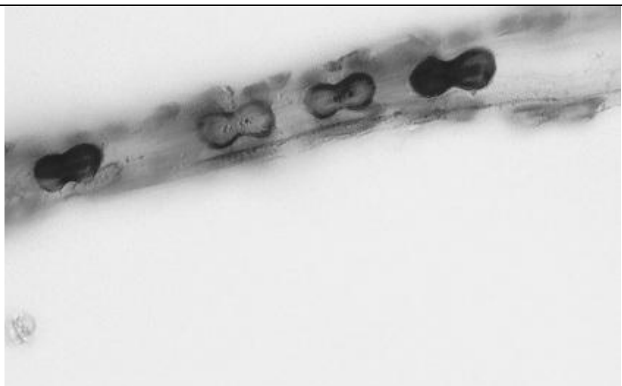	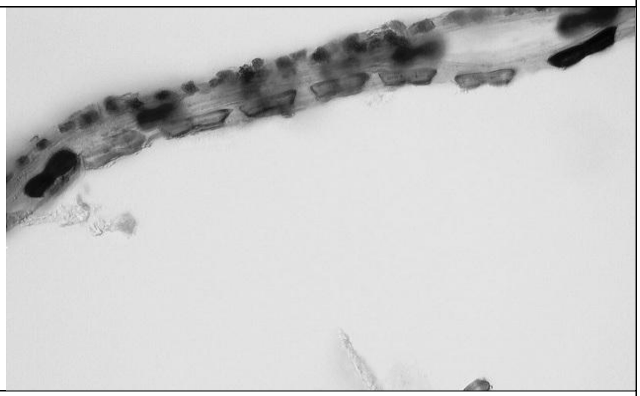
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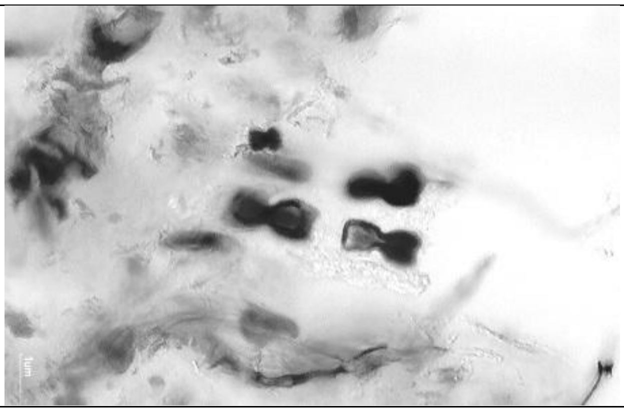	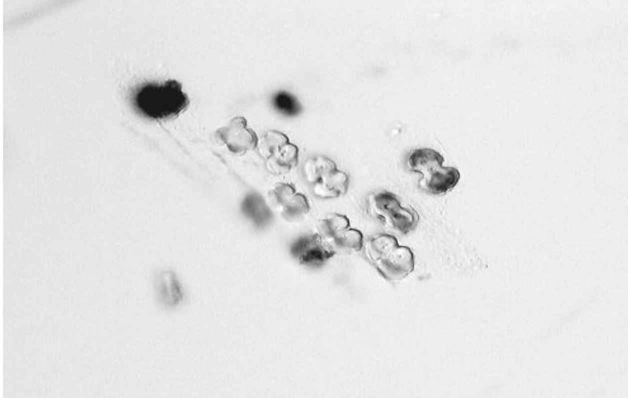
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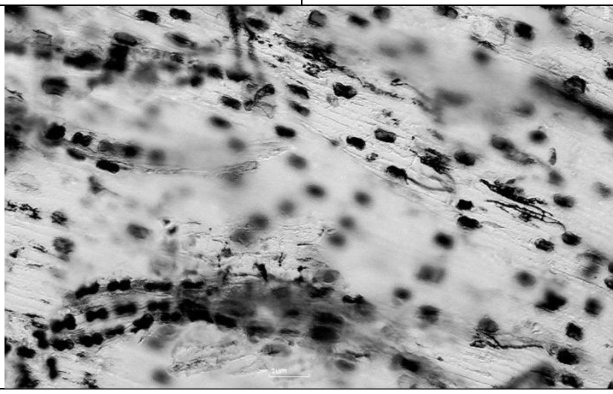

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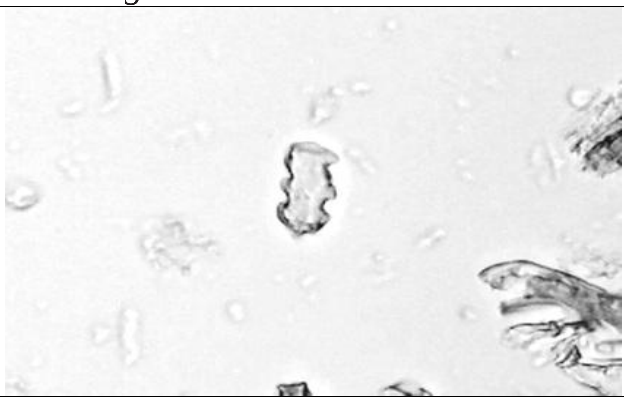
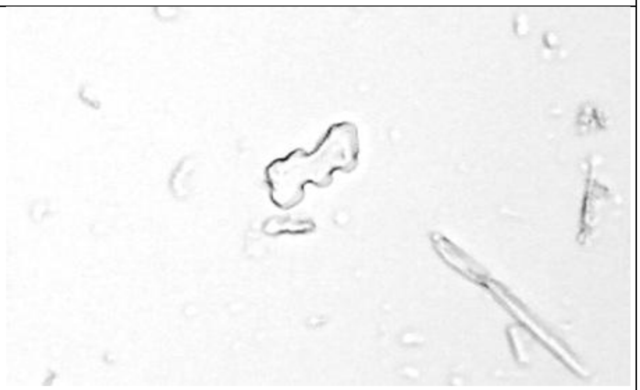
Koleria glauca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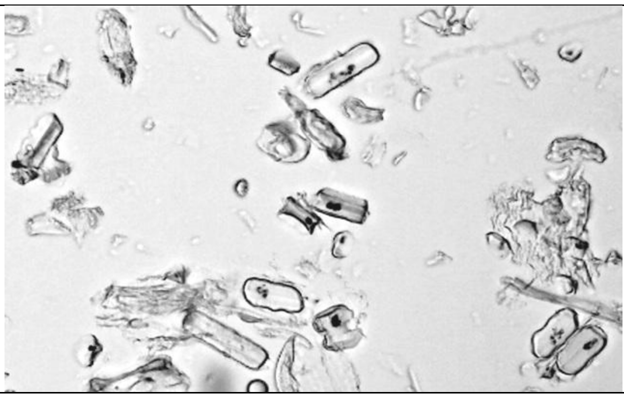	
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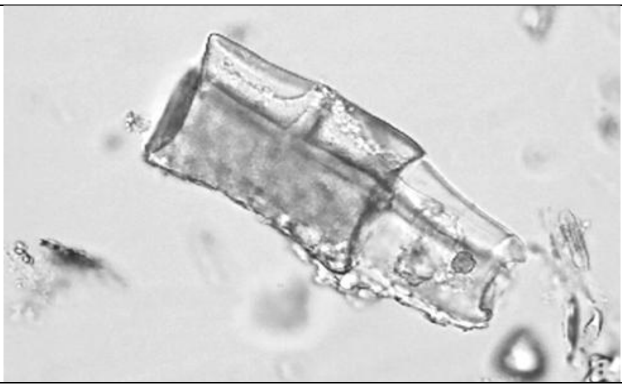
Lolium perenne



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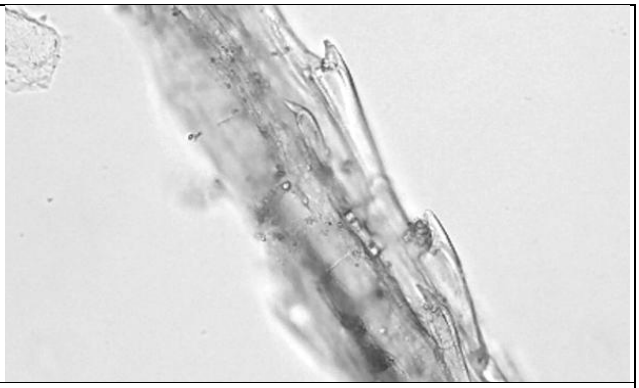

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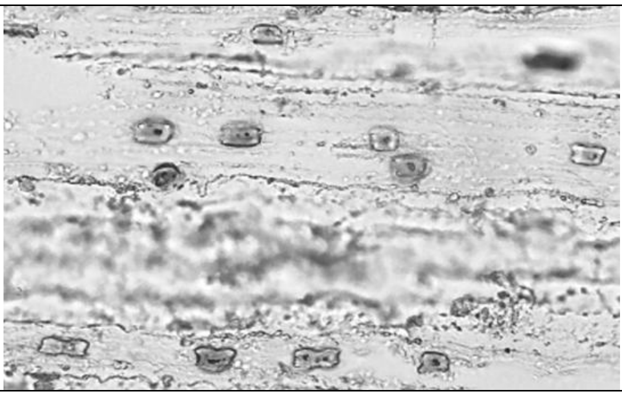

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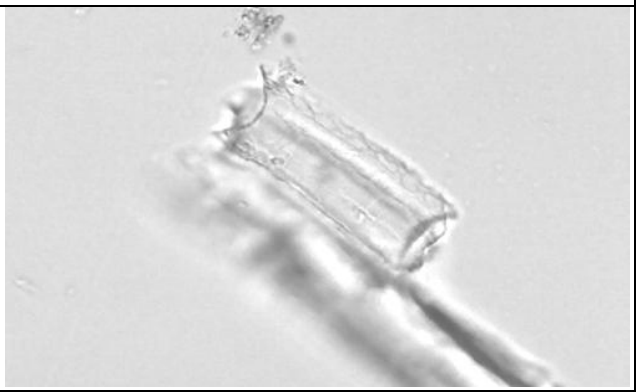

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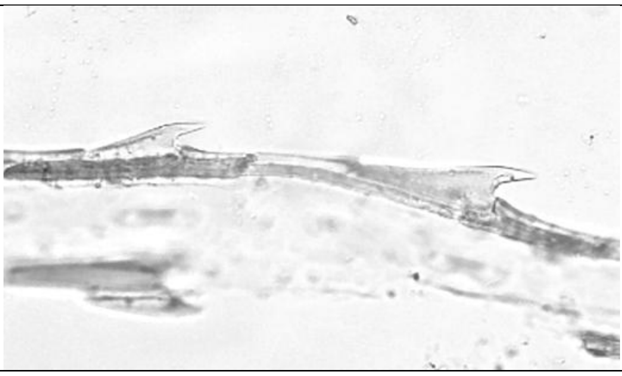

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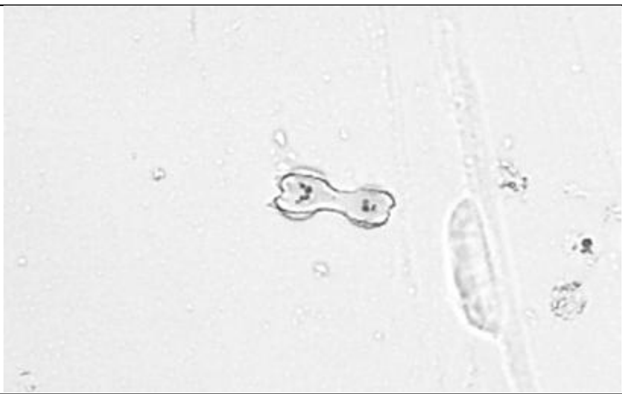

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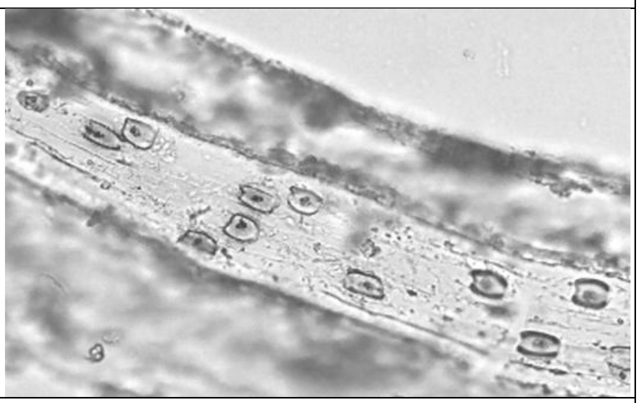

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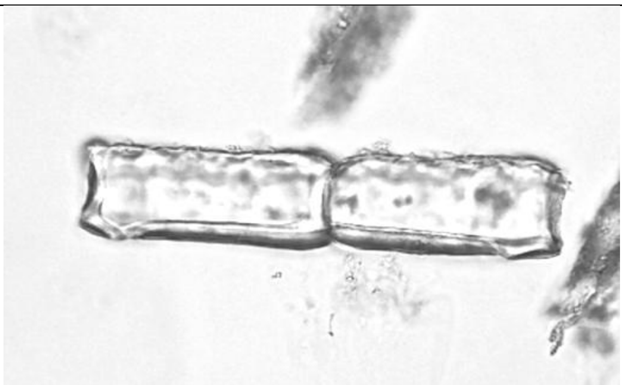

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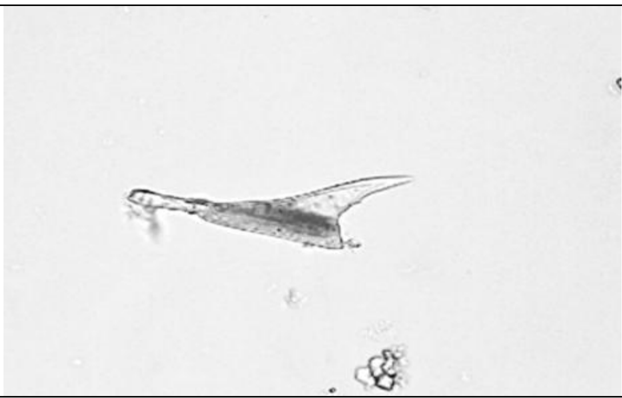

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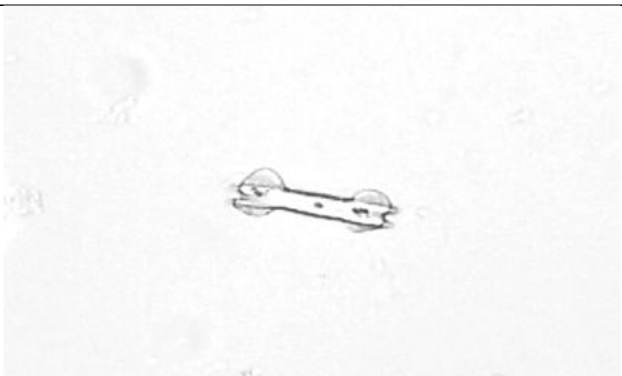

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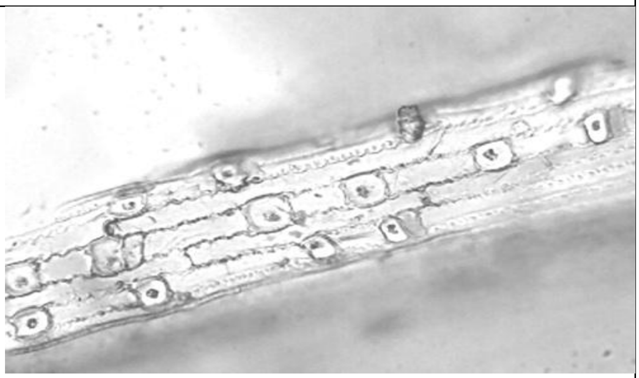

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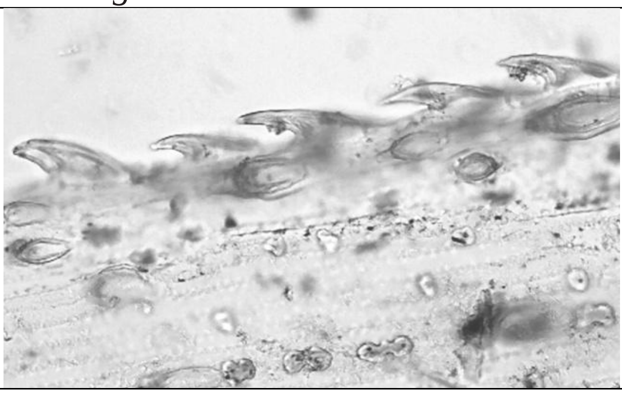
Melica gracilis



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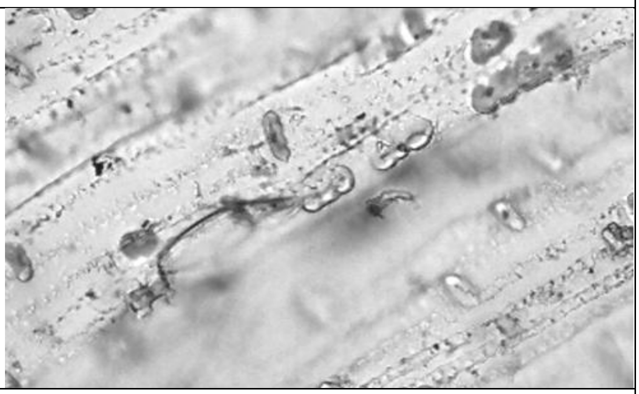

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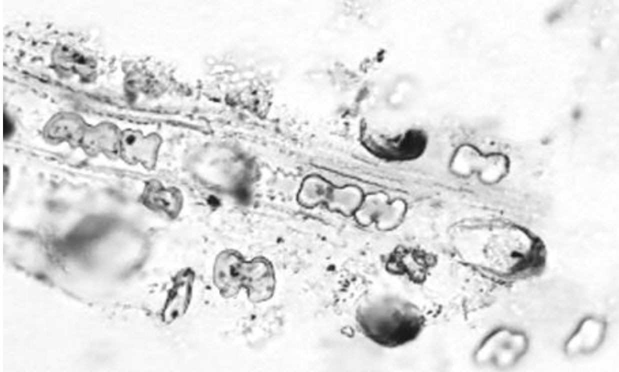	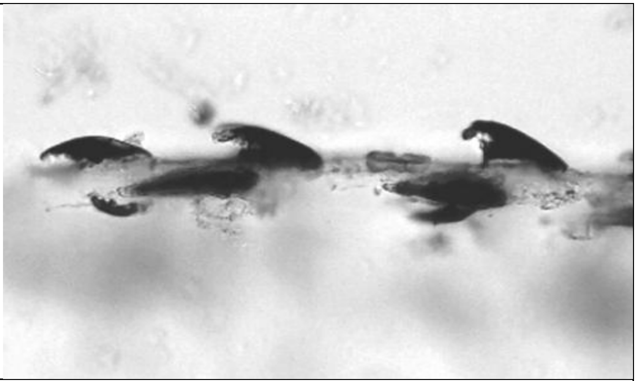
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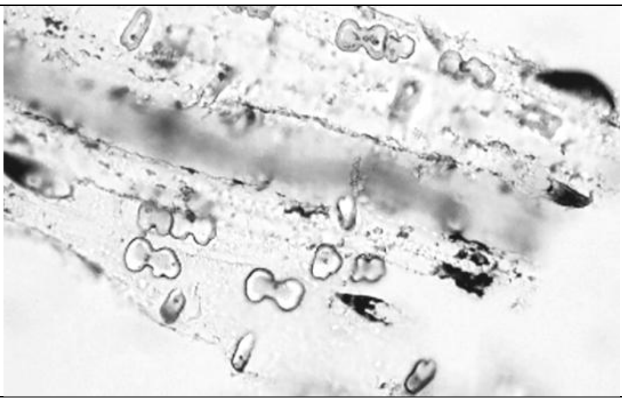	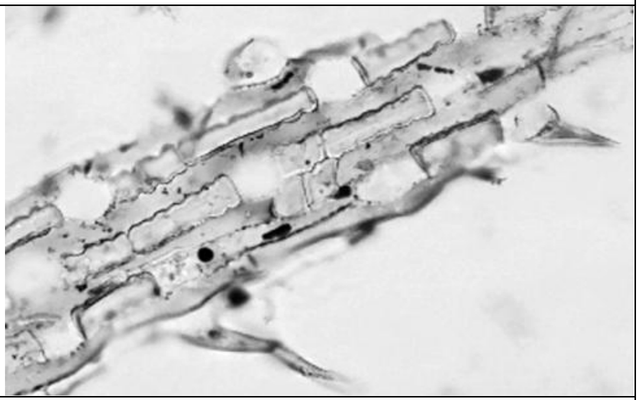
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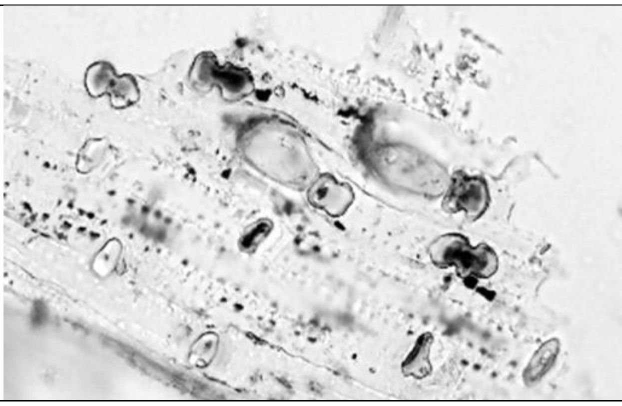	
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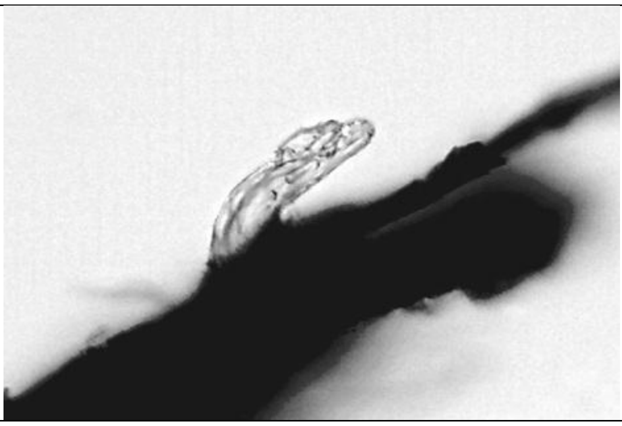	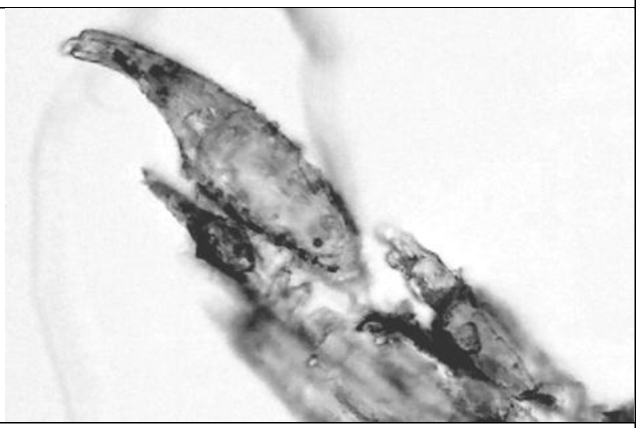
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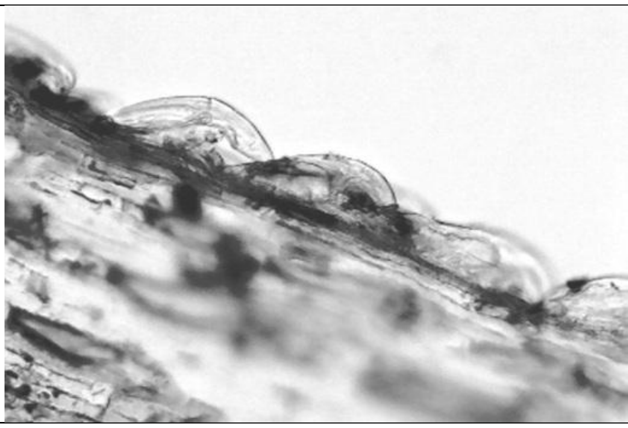

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Oplismenus undulatifolius

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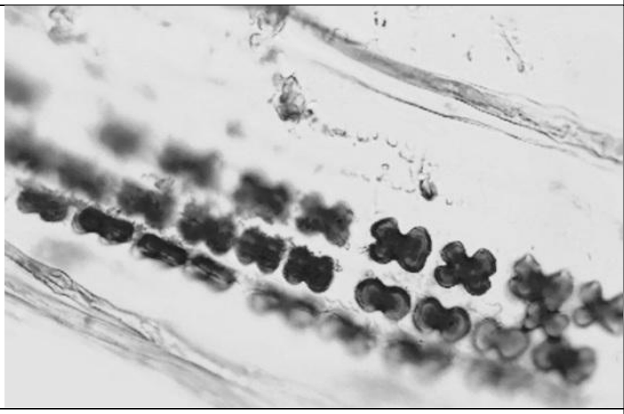

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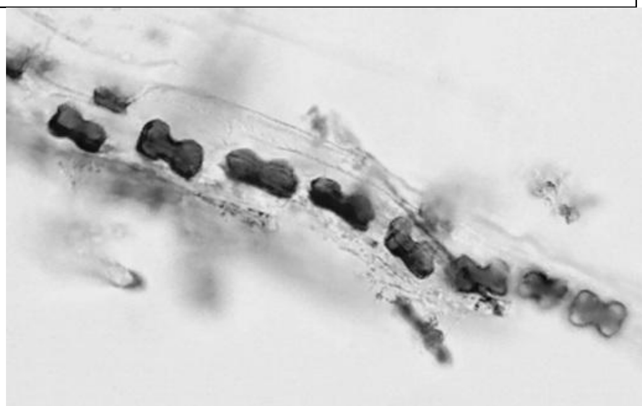

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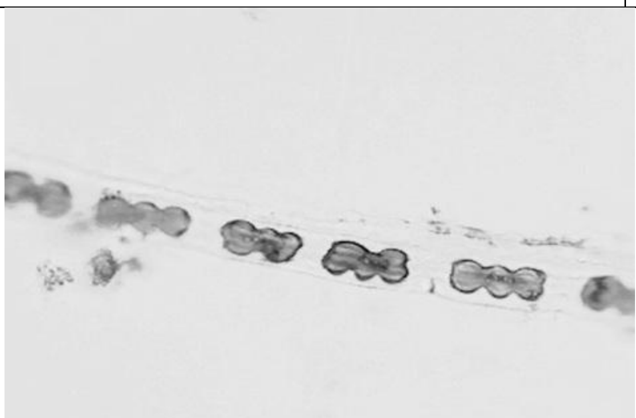

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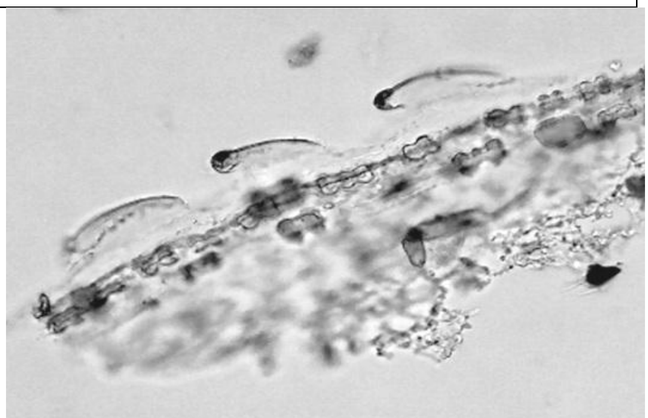

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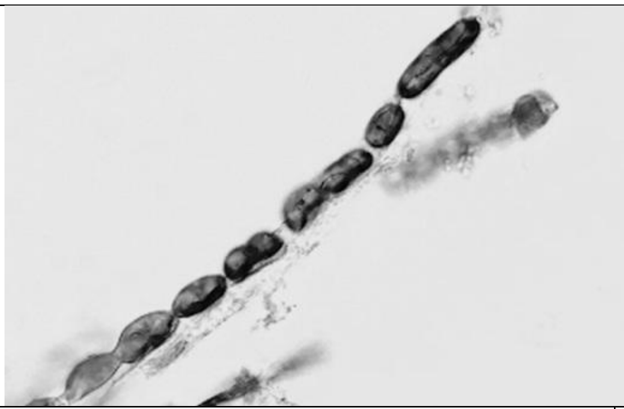	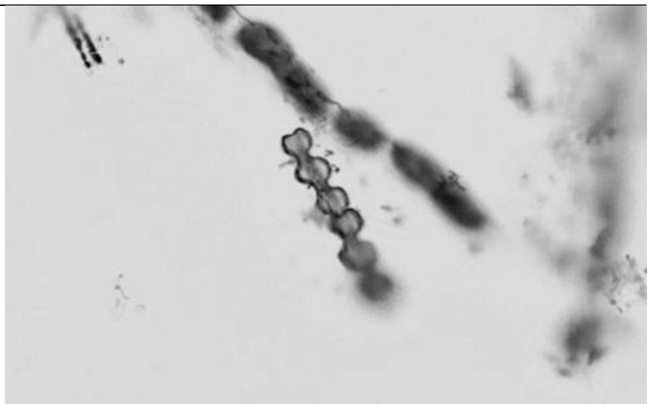
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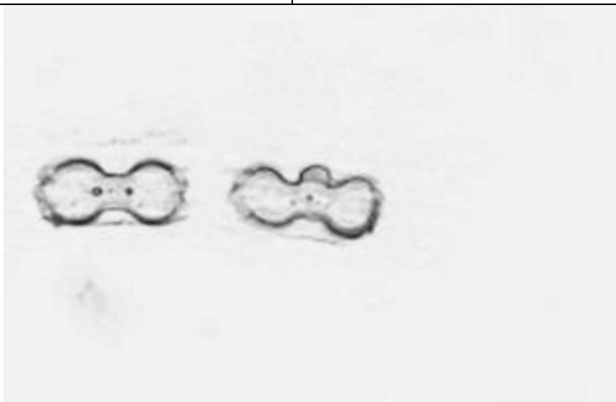

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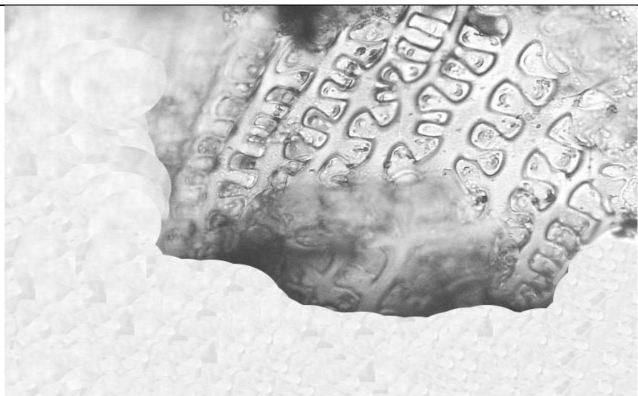
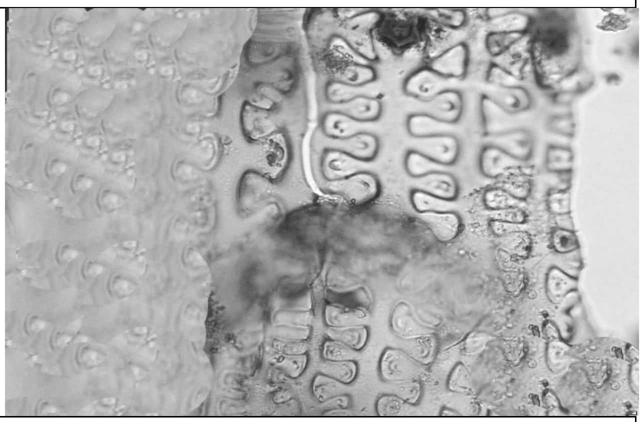
Panicum miliaceum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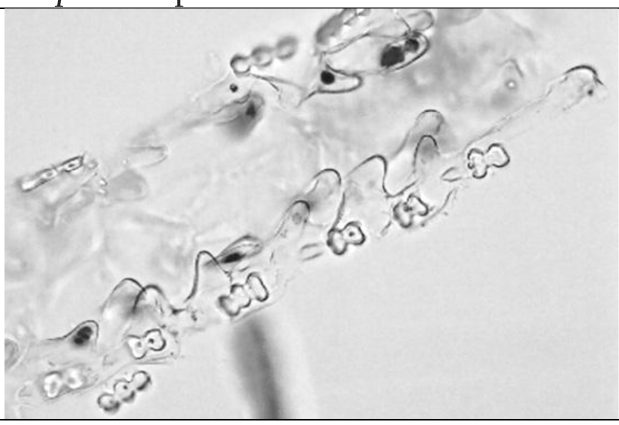
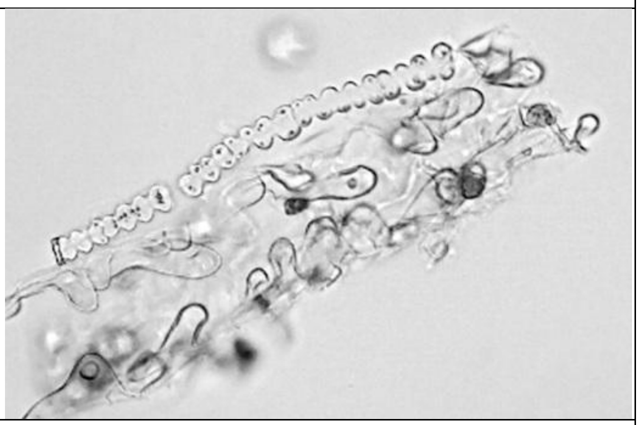
Paspalum sp.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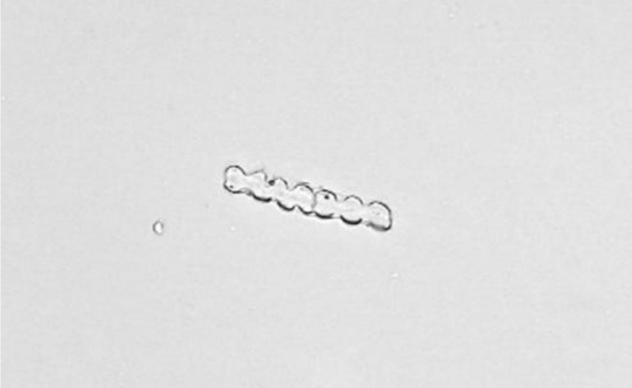	
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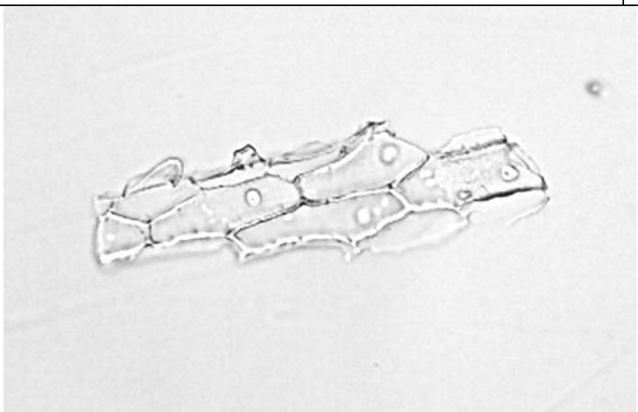	
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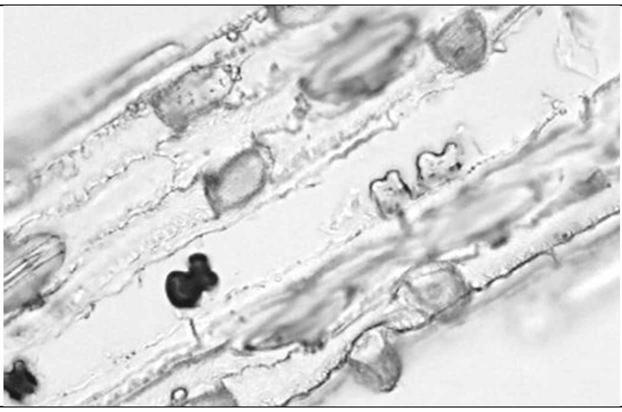	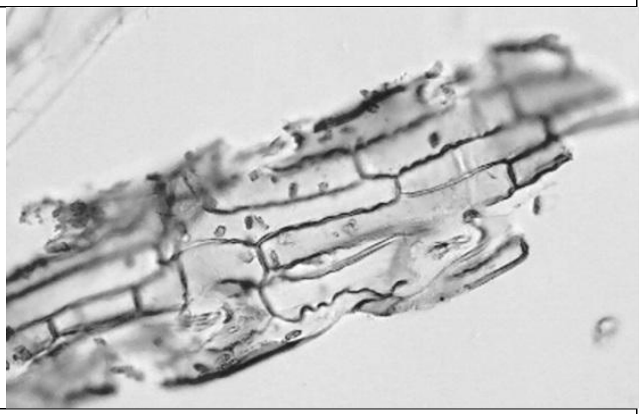
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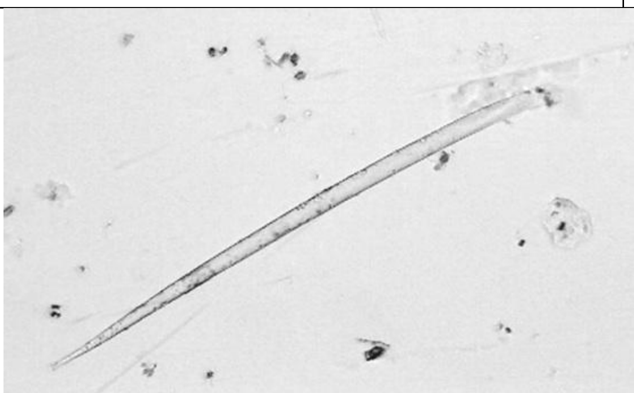	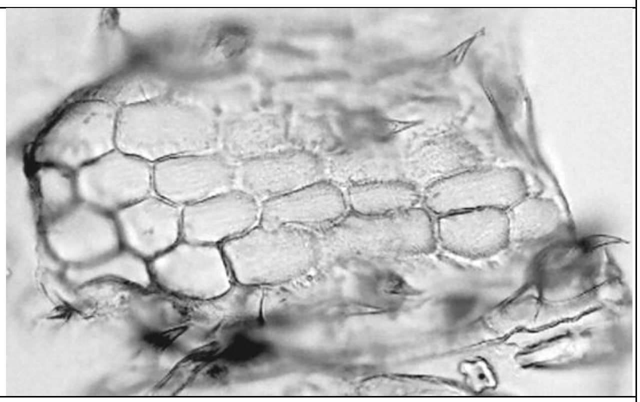
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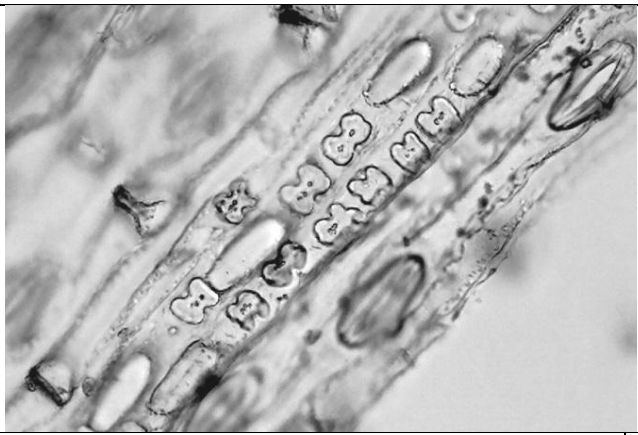	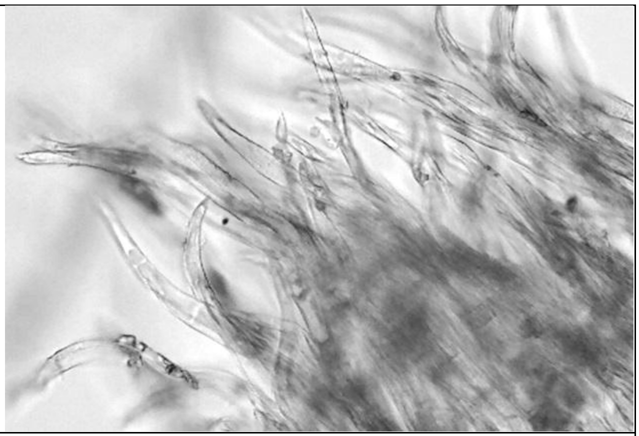
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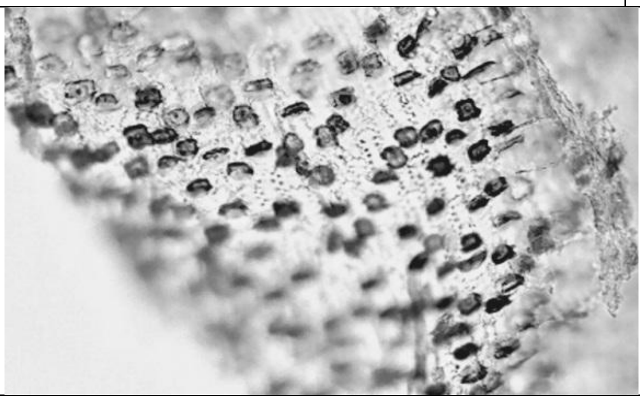	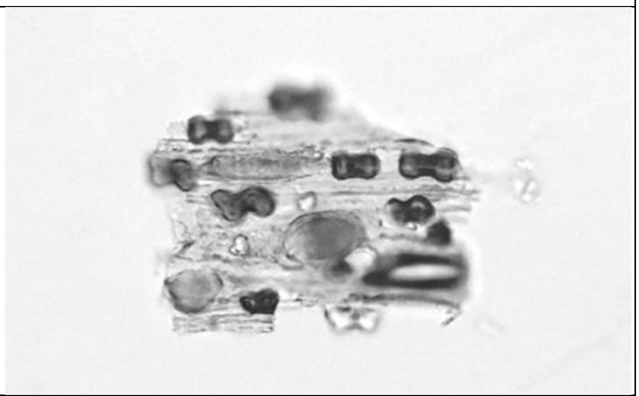
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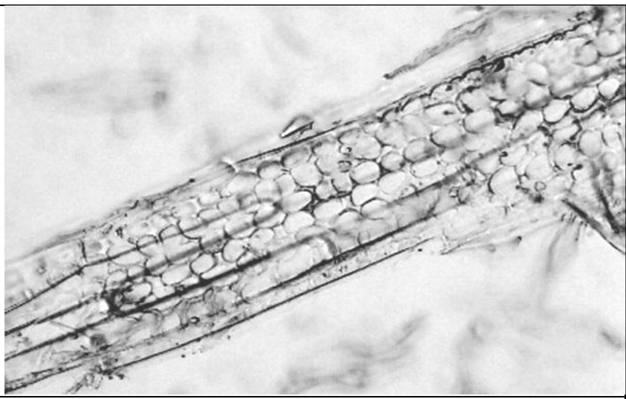	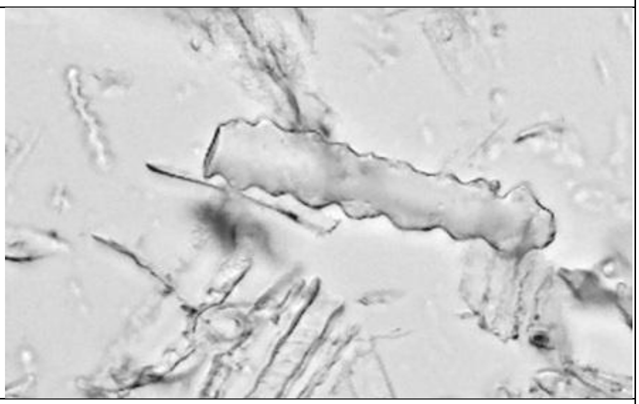
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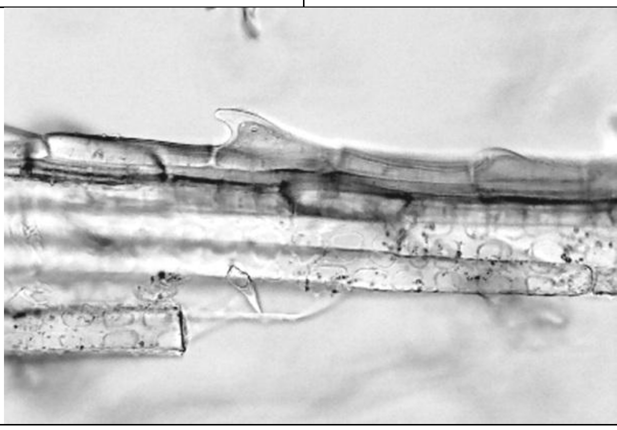	
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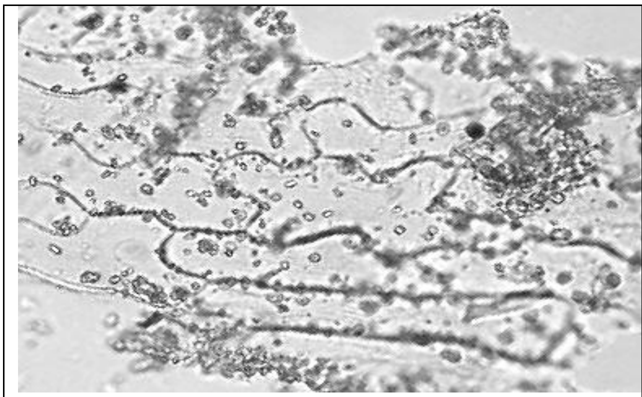	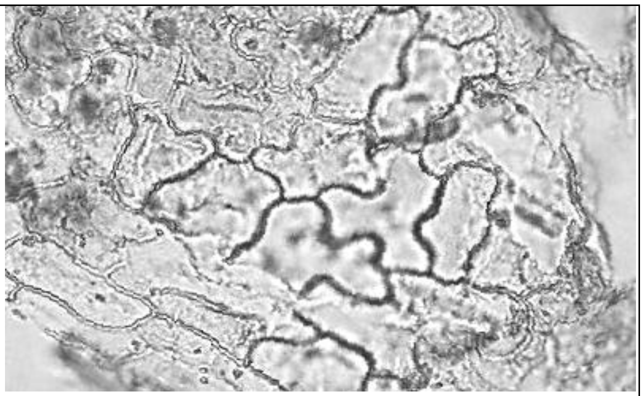
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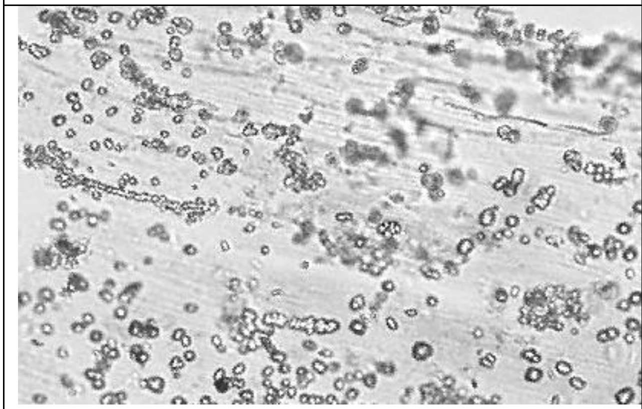	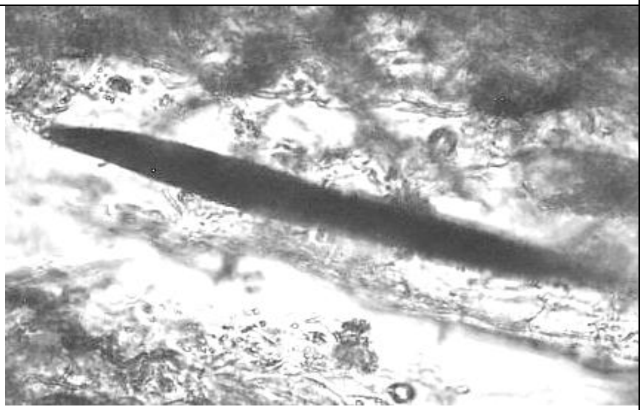
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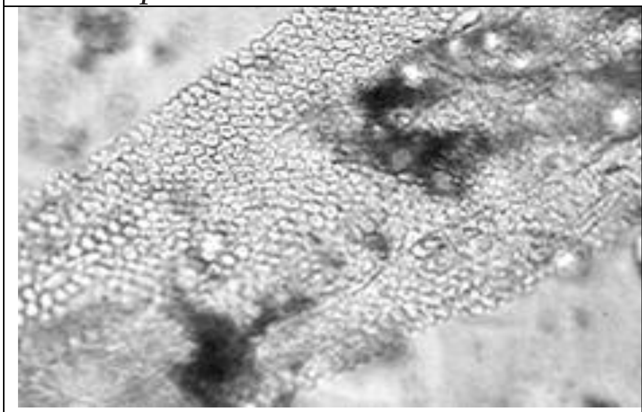	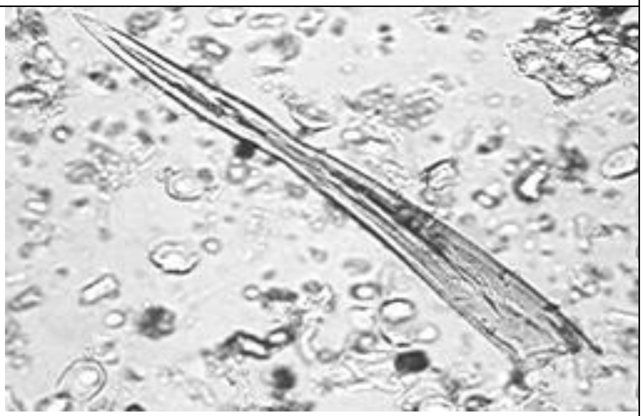
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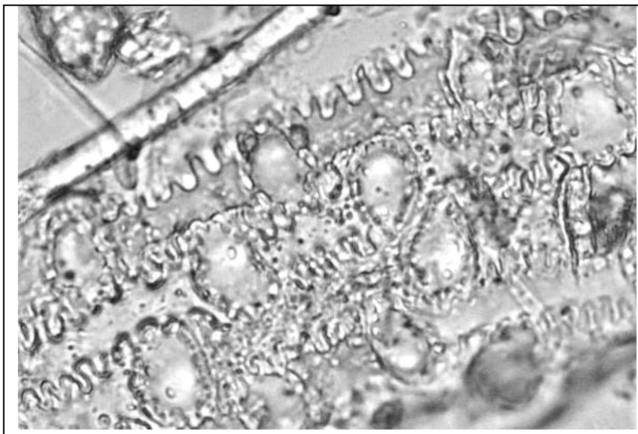 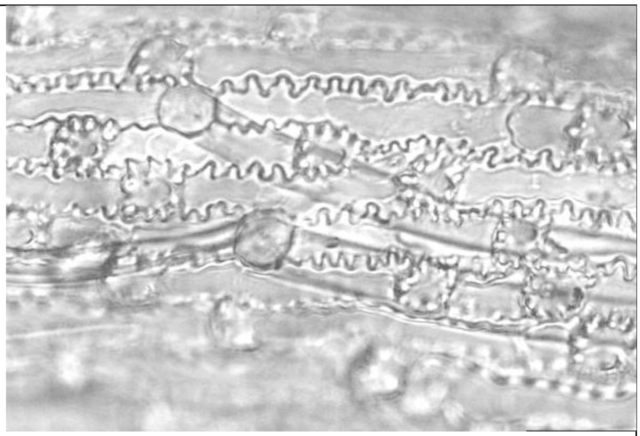

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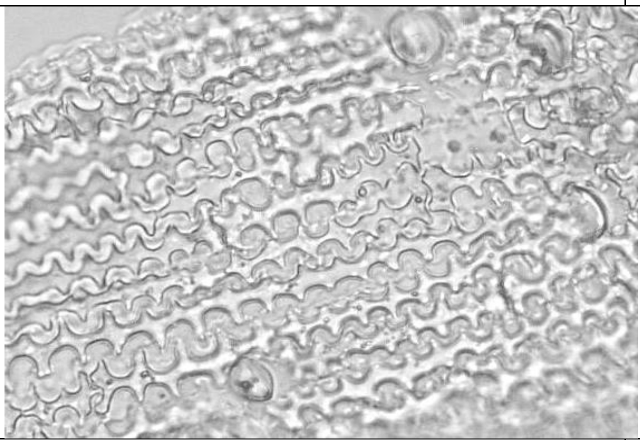
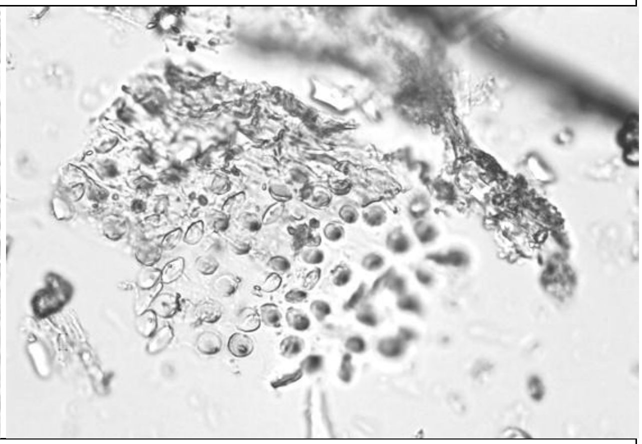
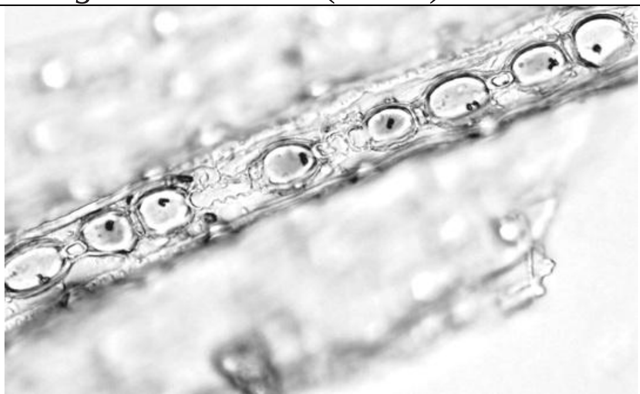
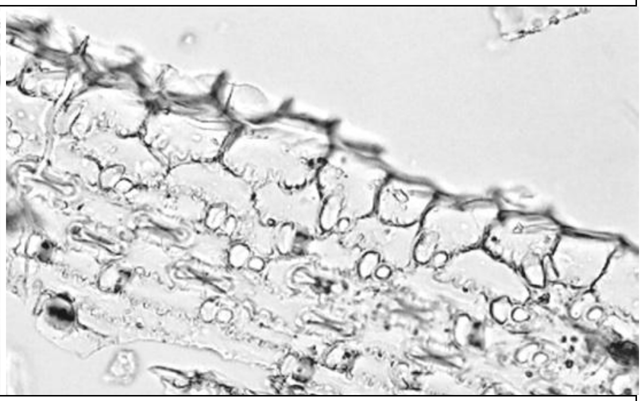
 

5 | 6

Phragmites australis (leaves)

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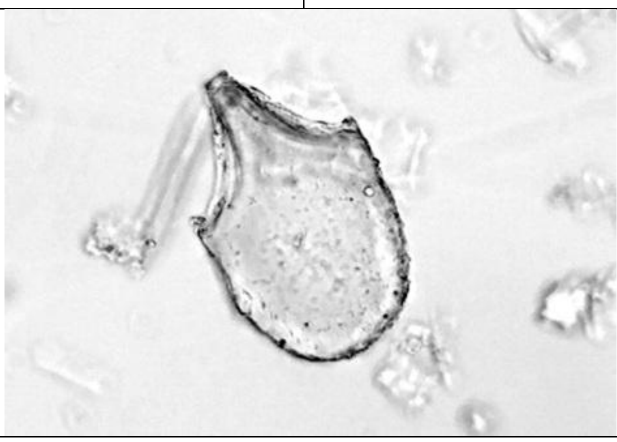

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	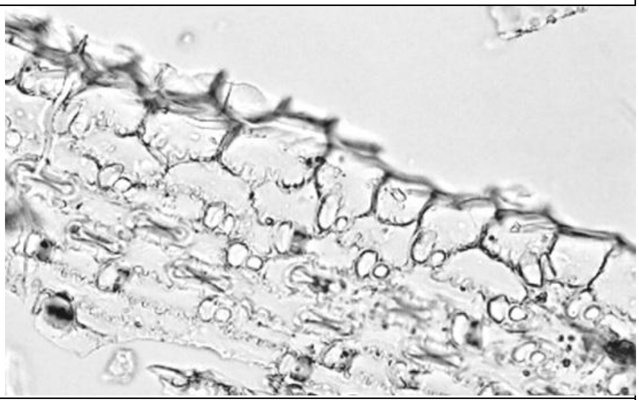
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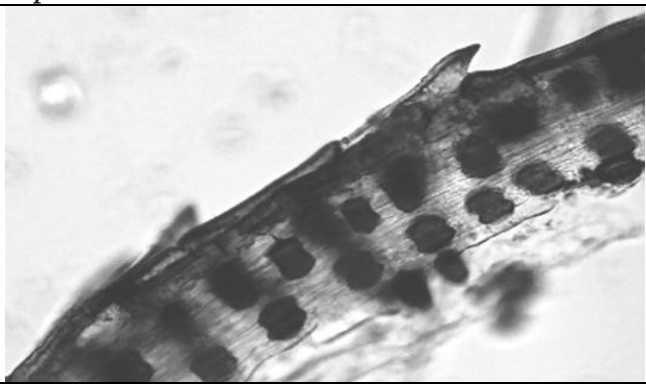	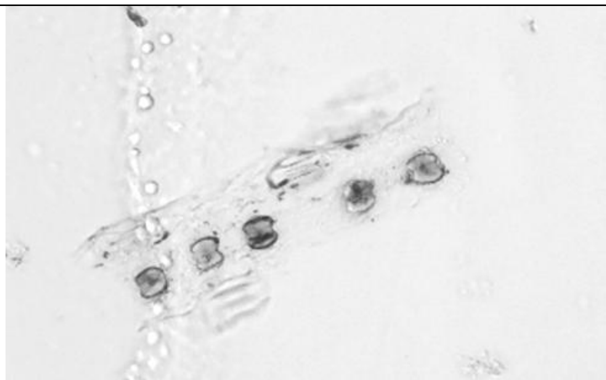
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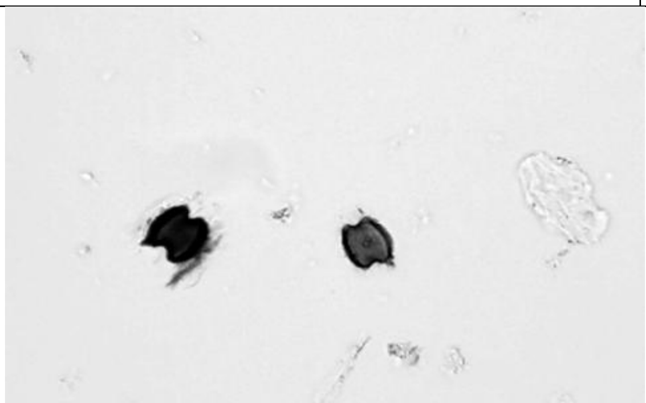	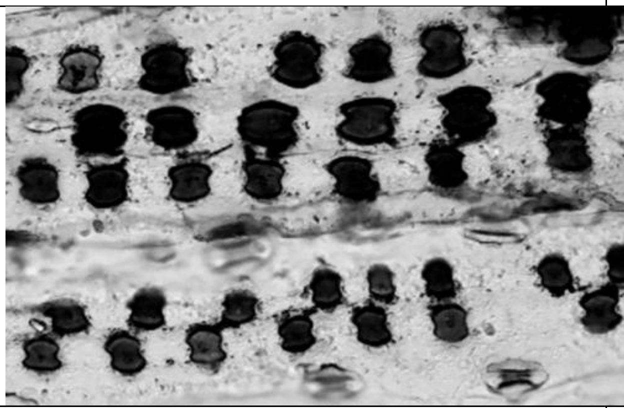
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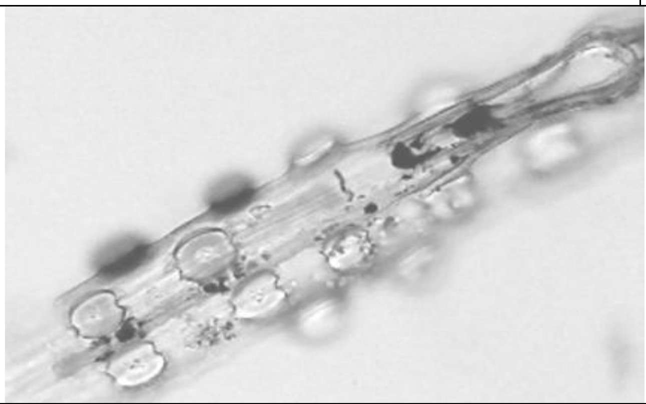	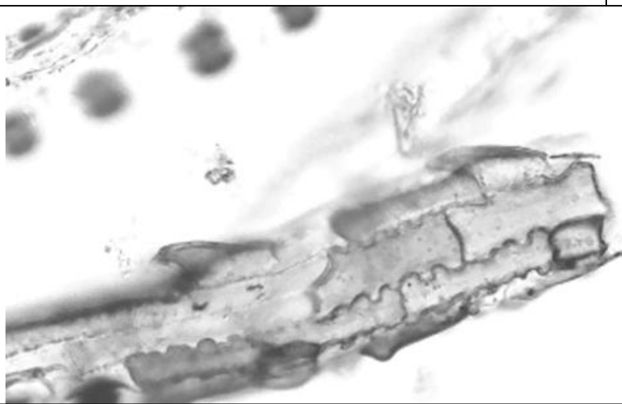
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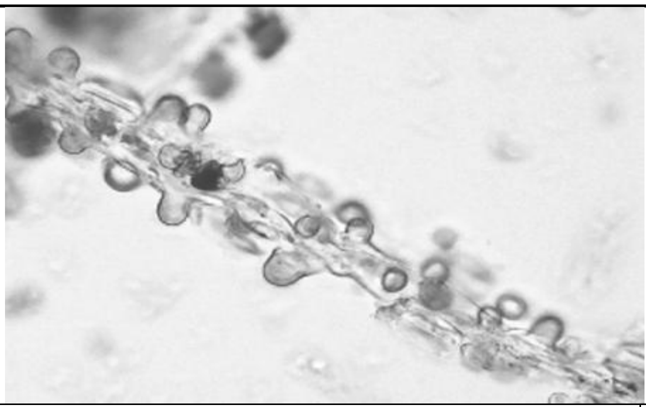	
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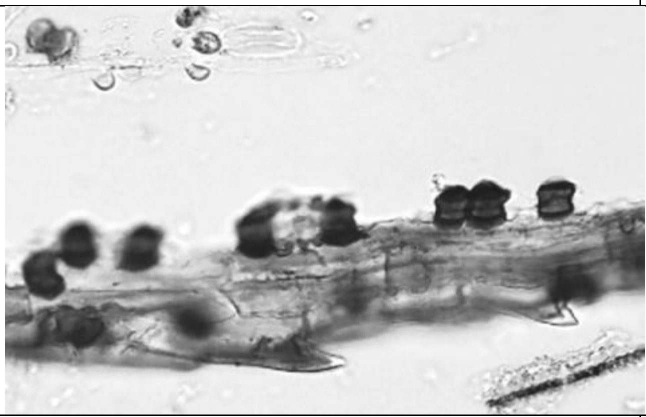	
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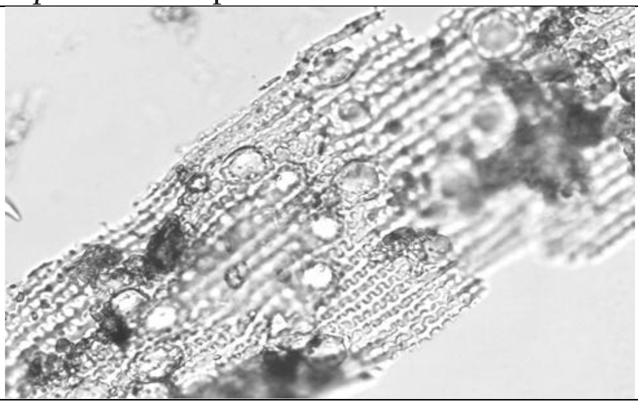	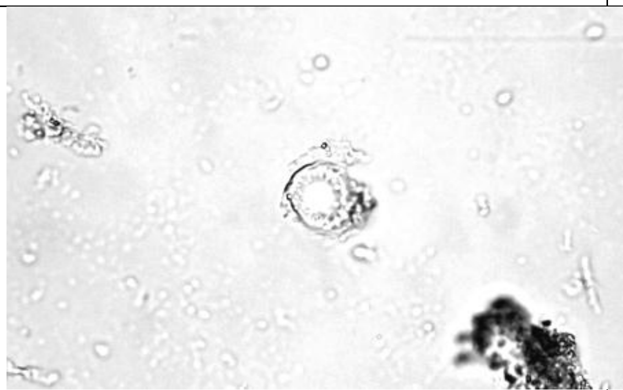
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	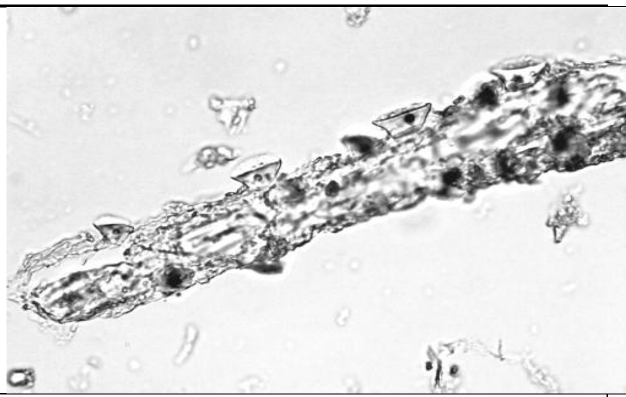
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	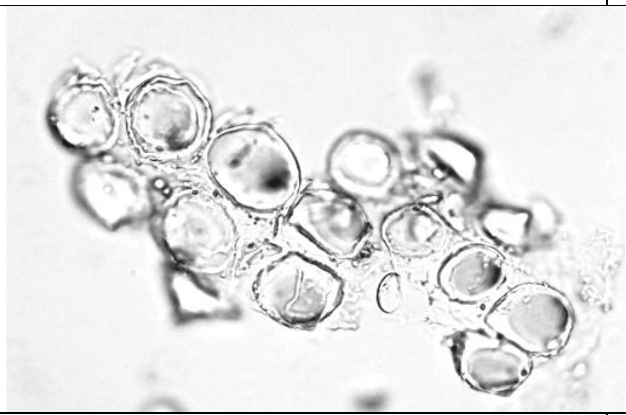
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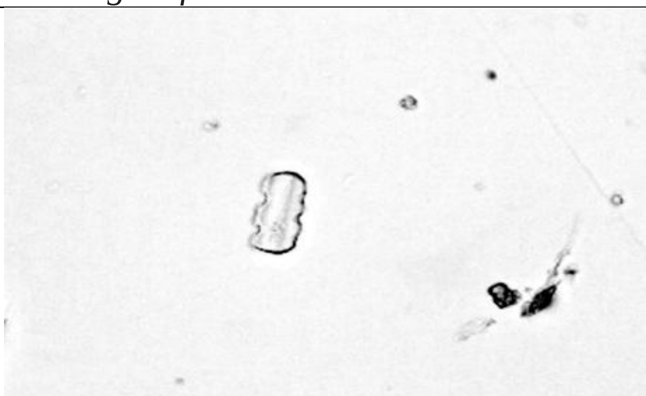	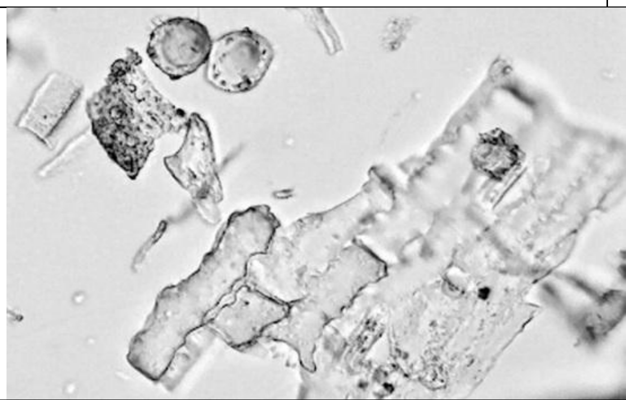
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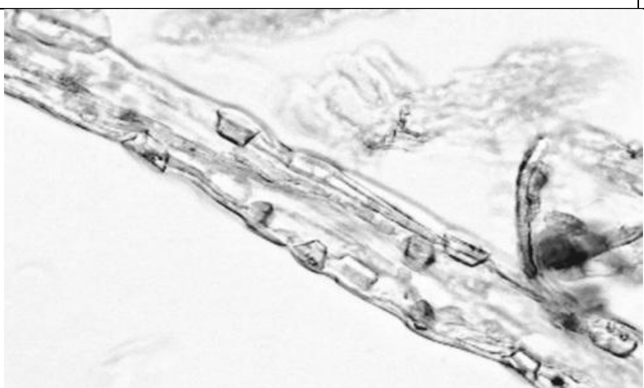	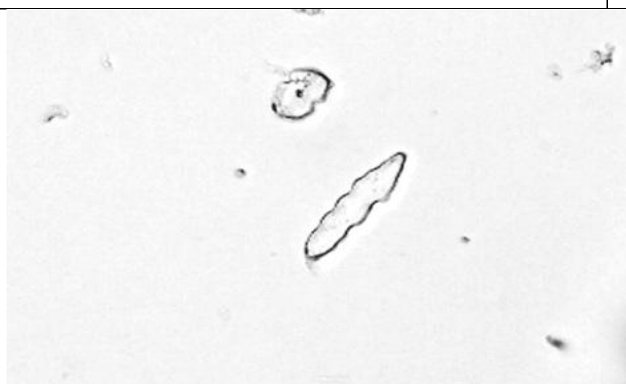
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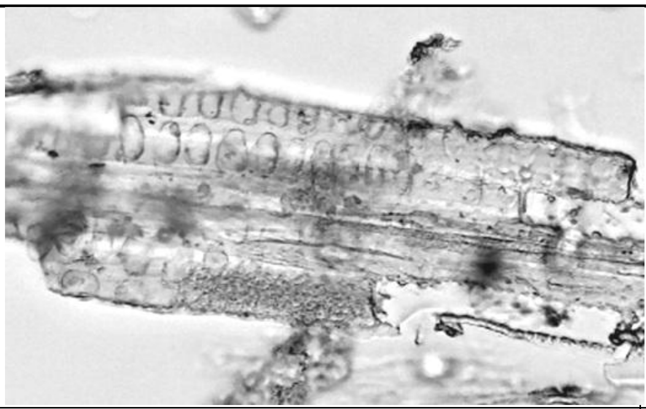	
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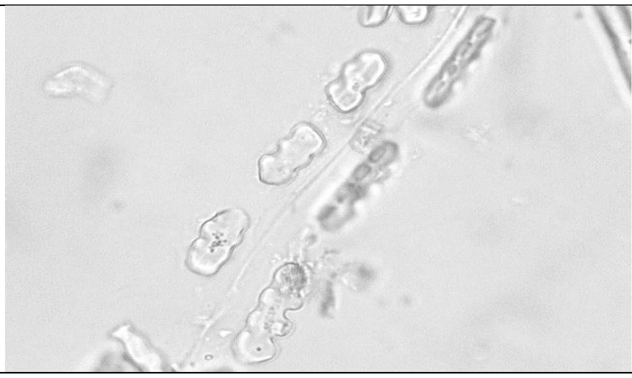	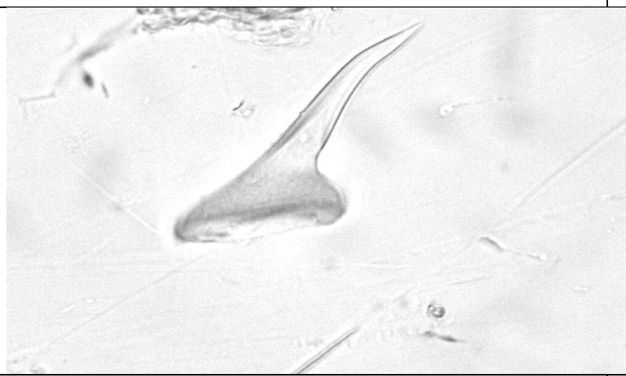
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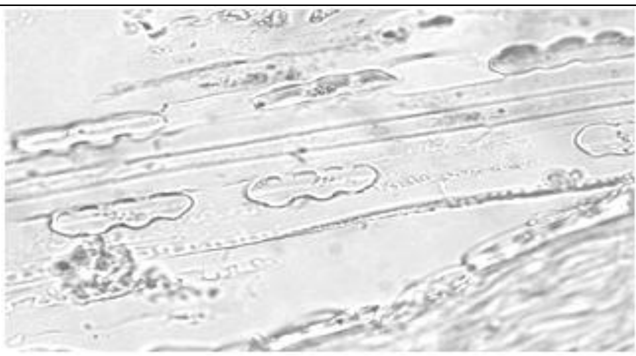	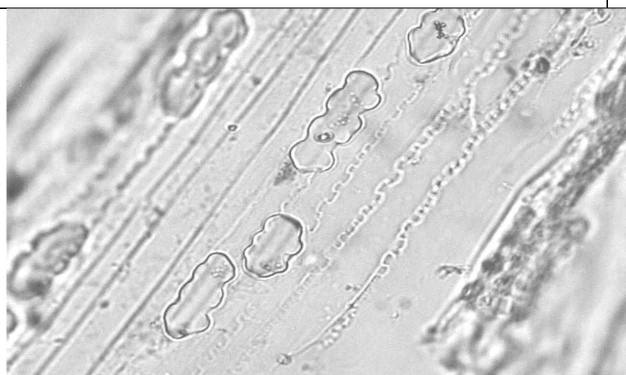
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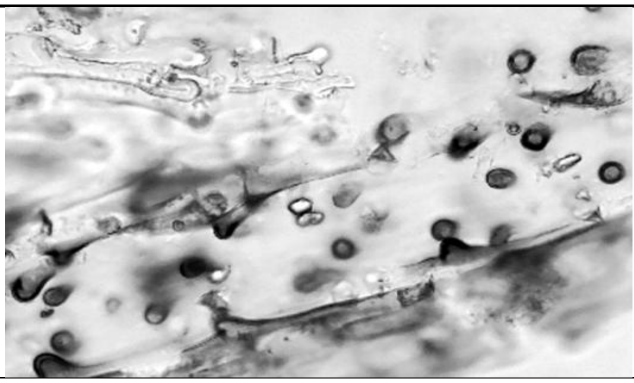
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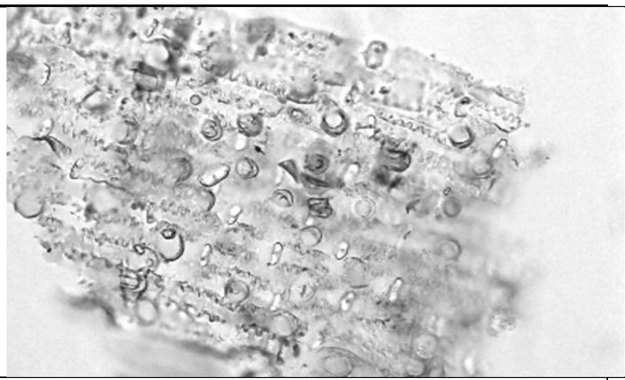
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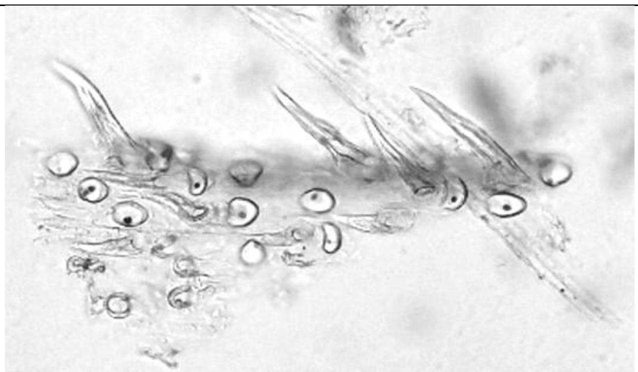
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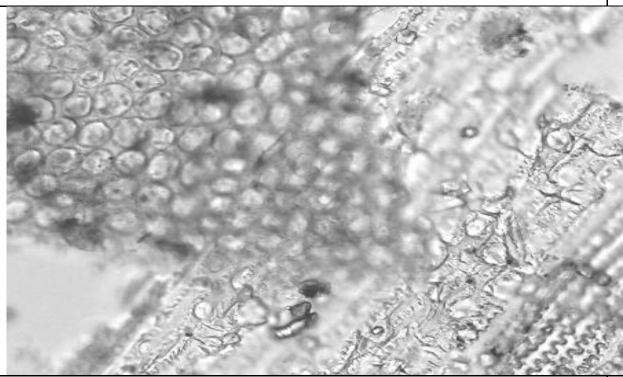
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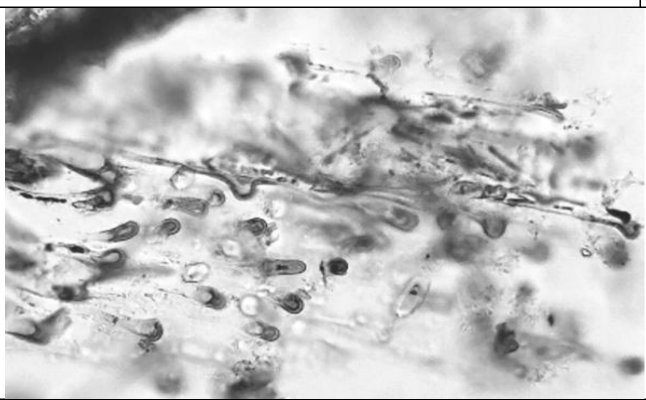
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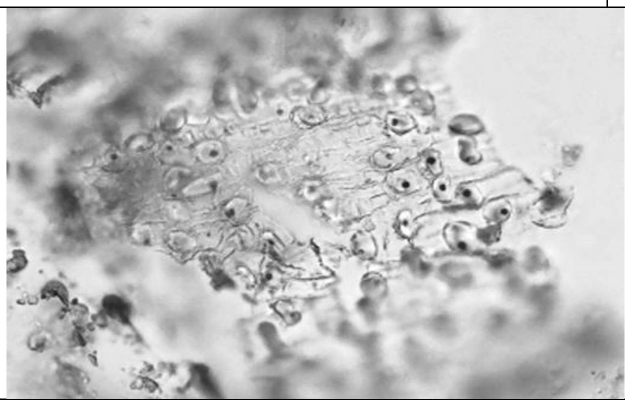
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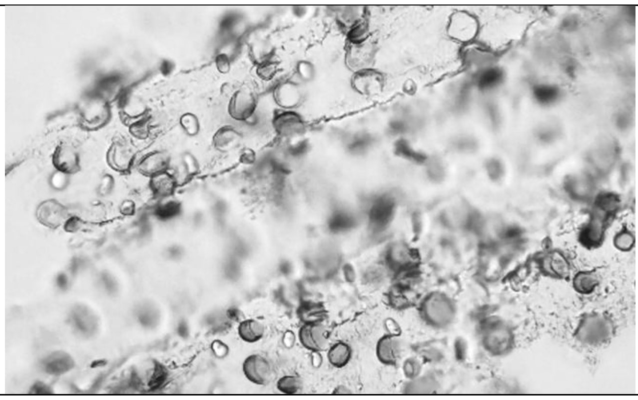
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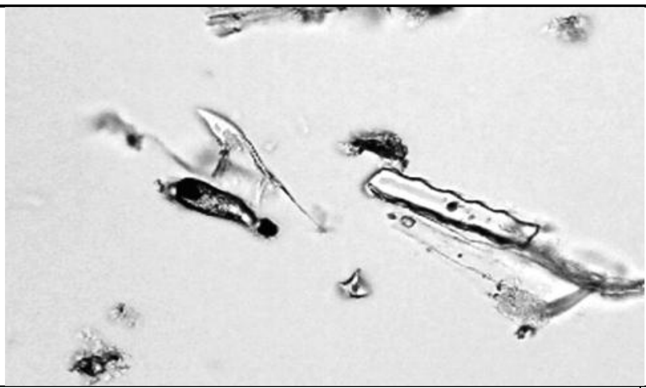
Puccinellia convolute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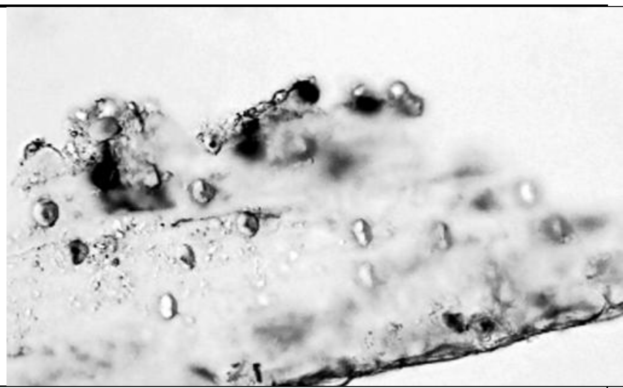
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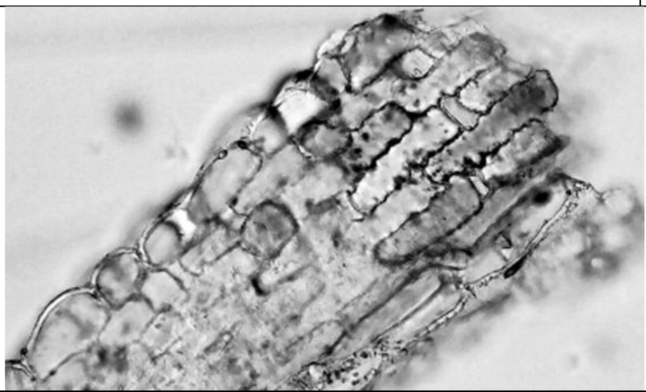
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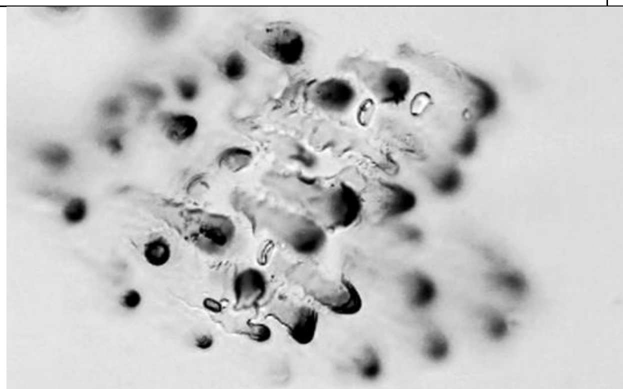
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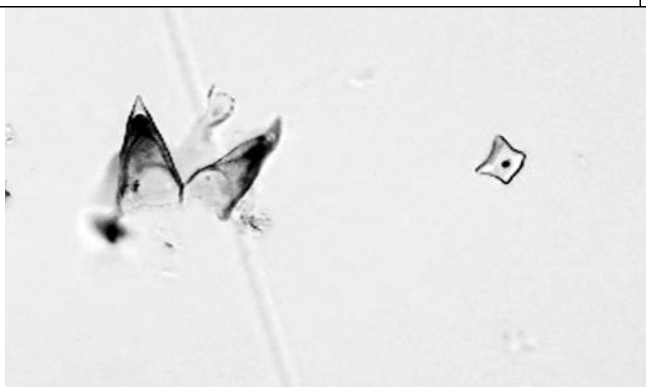
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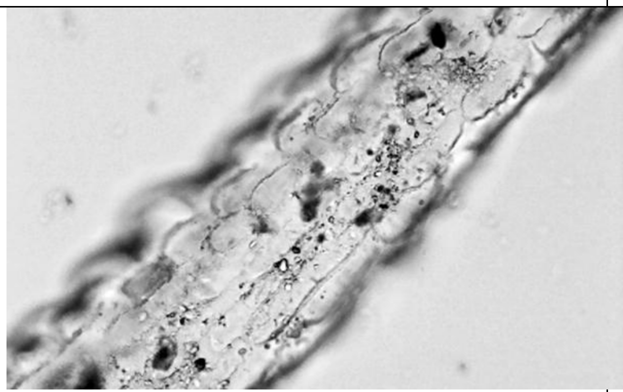
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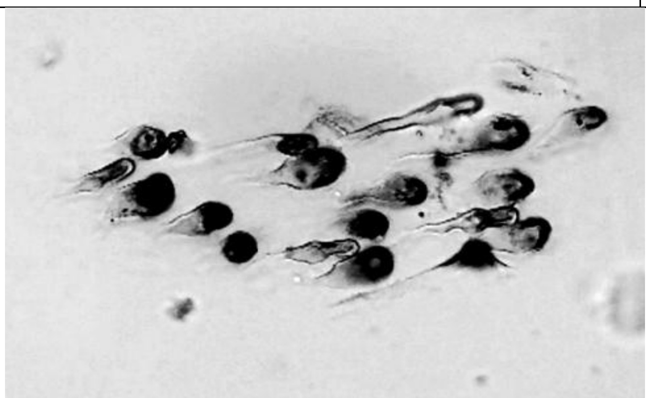
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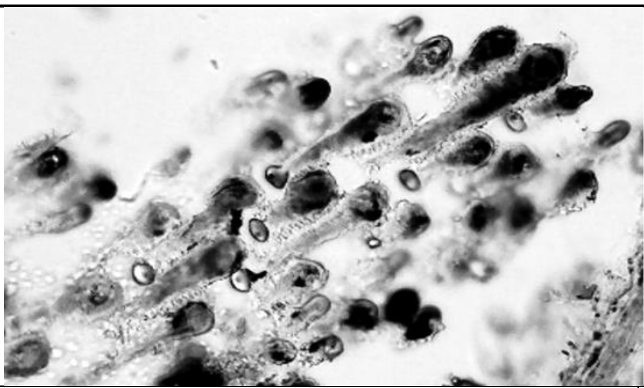 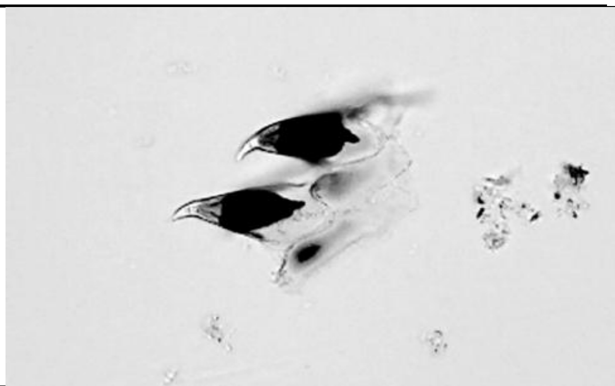

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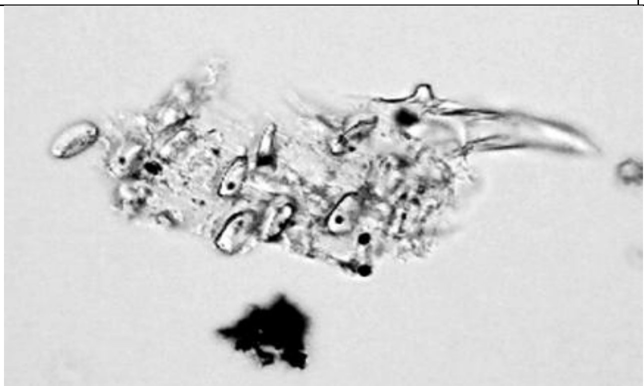 

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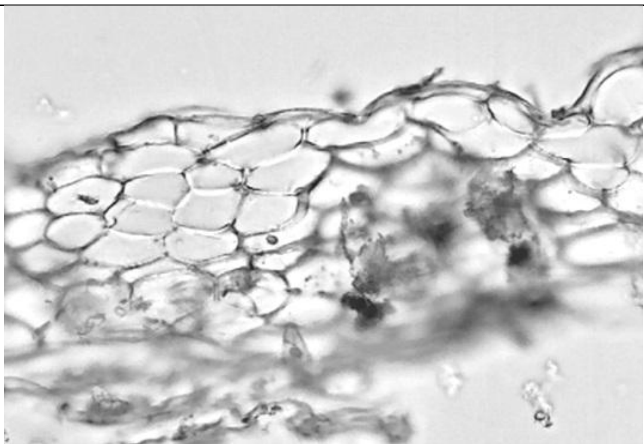 

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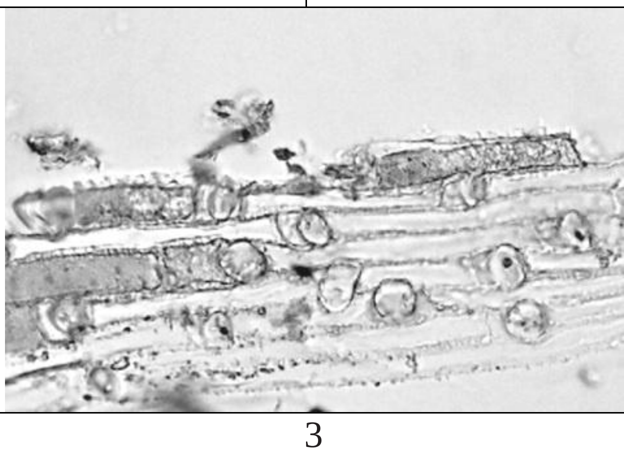

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	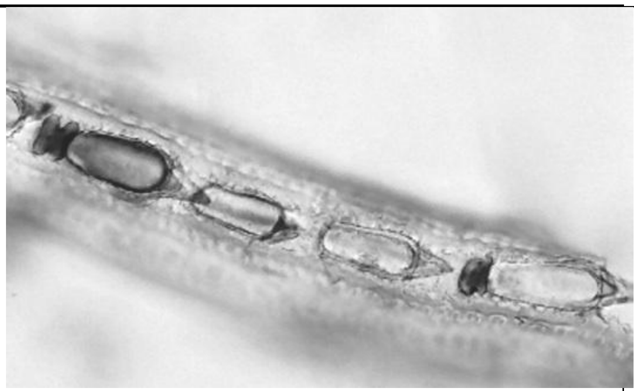
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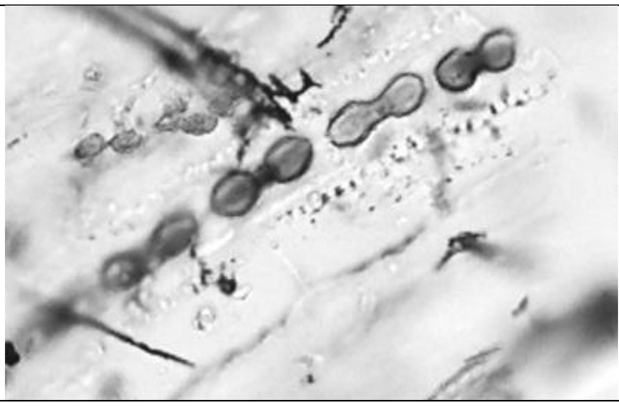	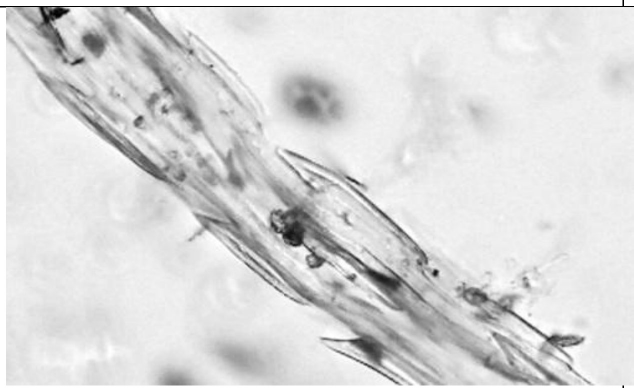
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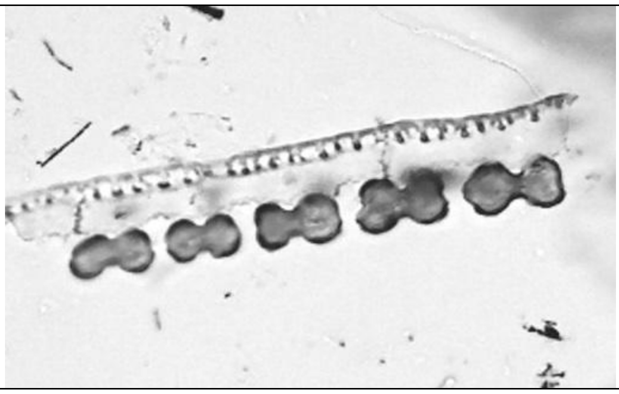	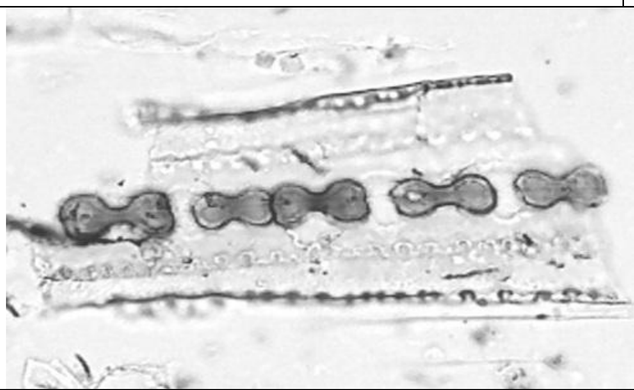
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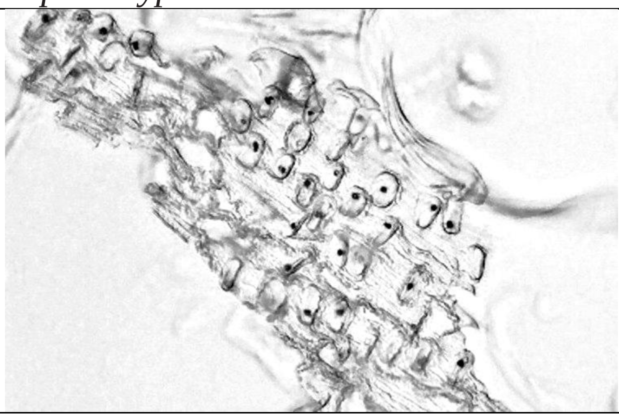	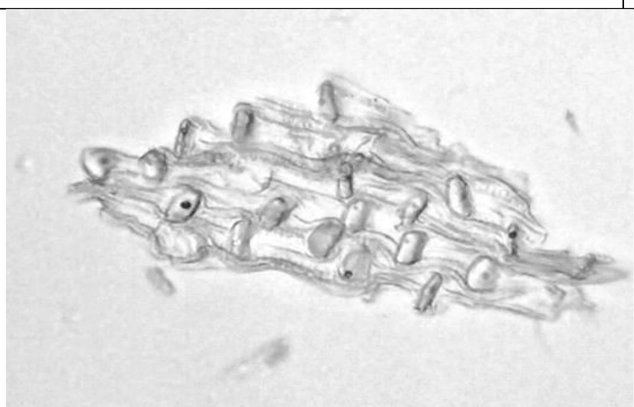
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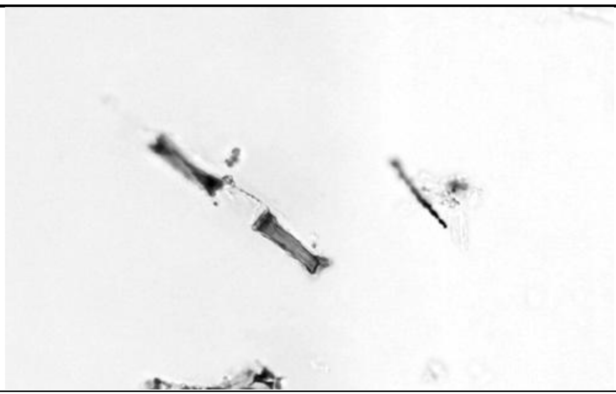	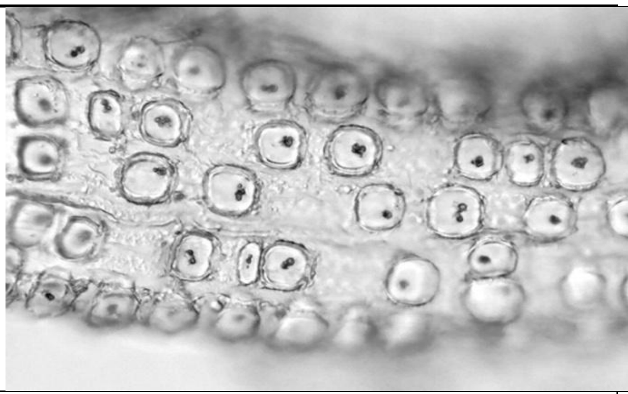
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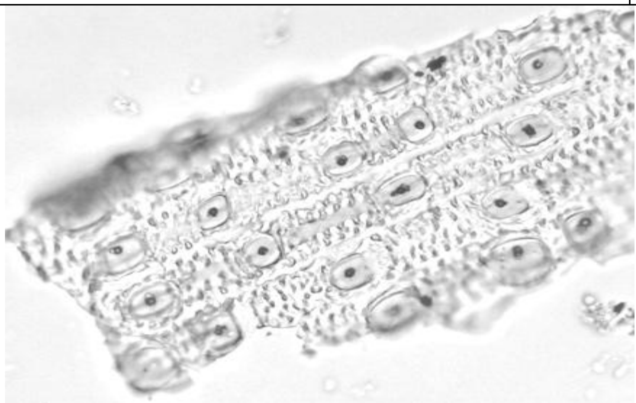	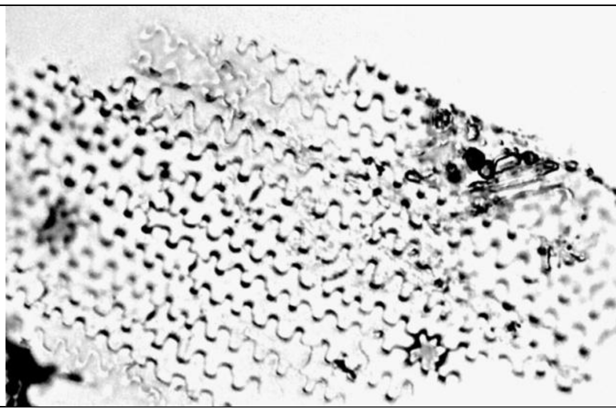
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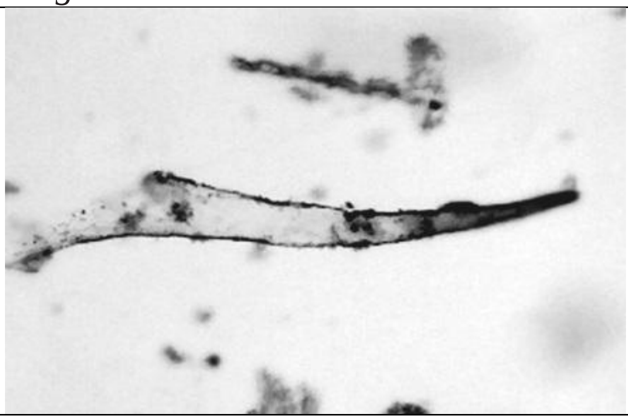	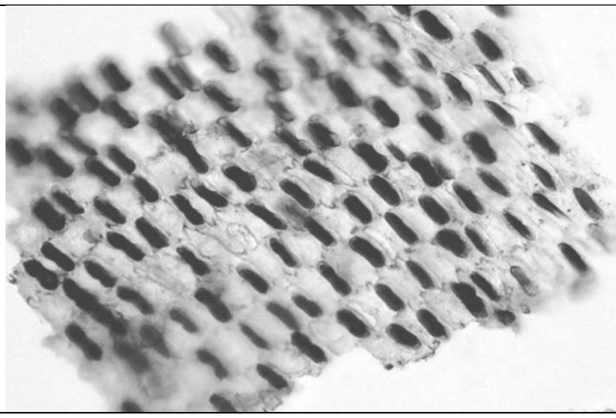
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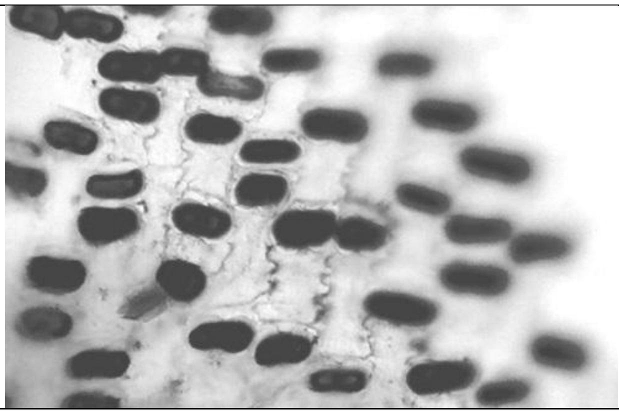	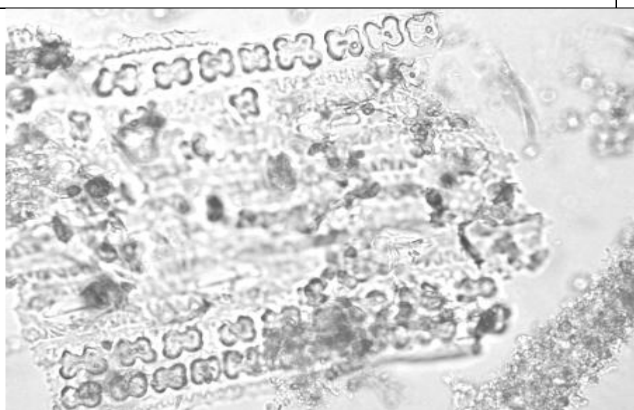
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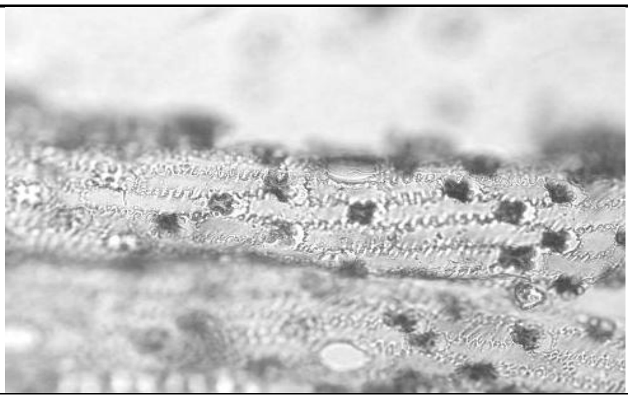

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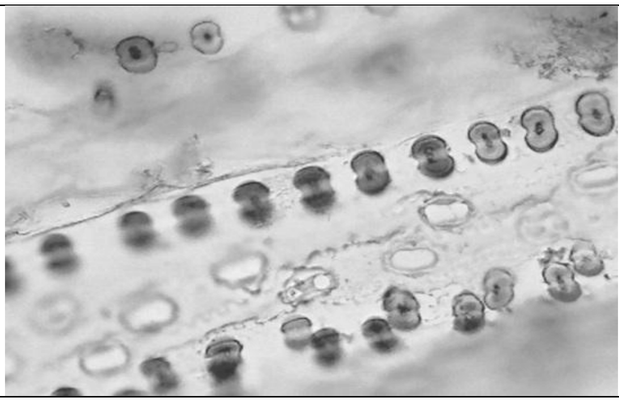

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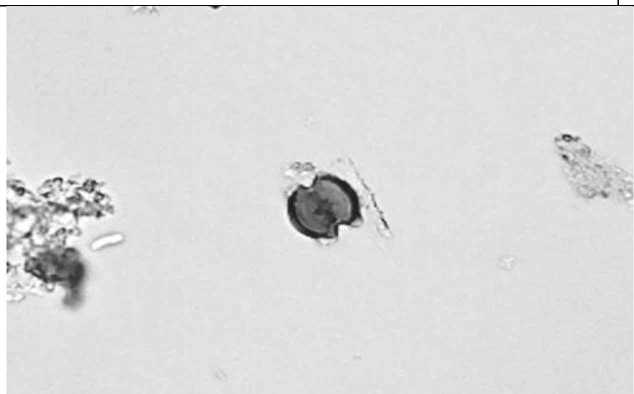

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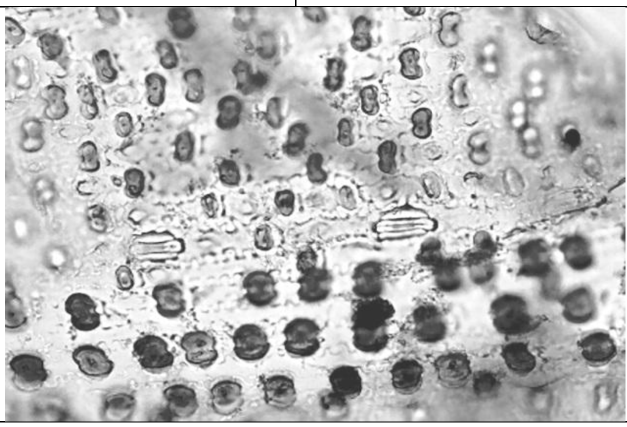

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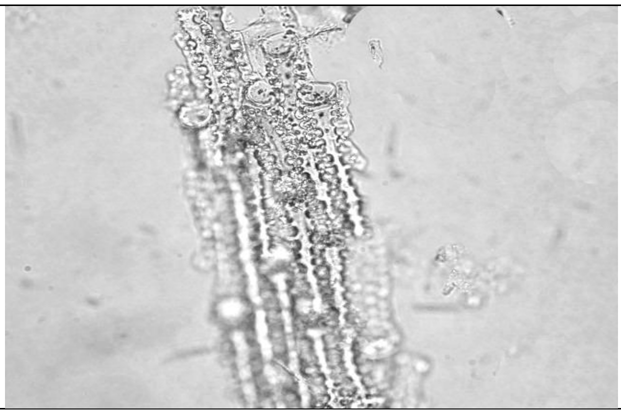

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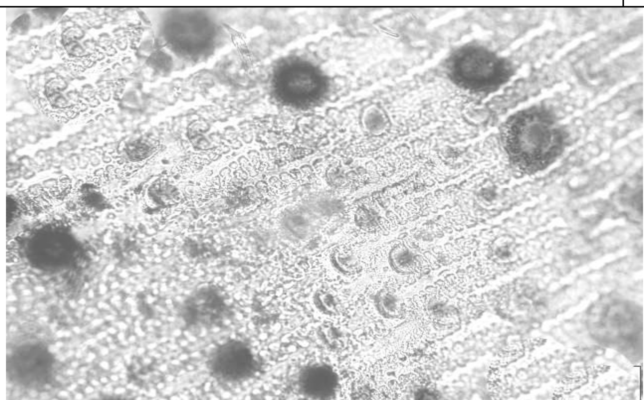

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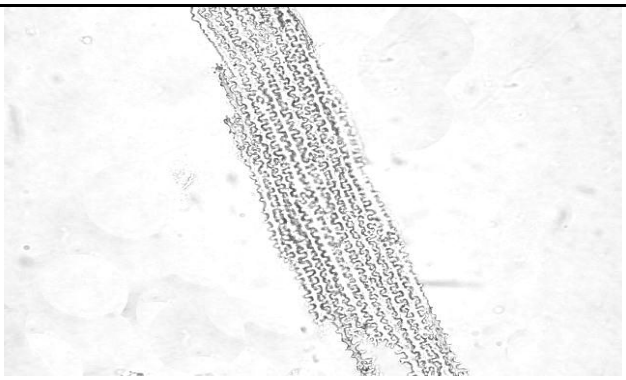 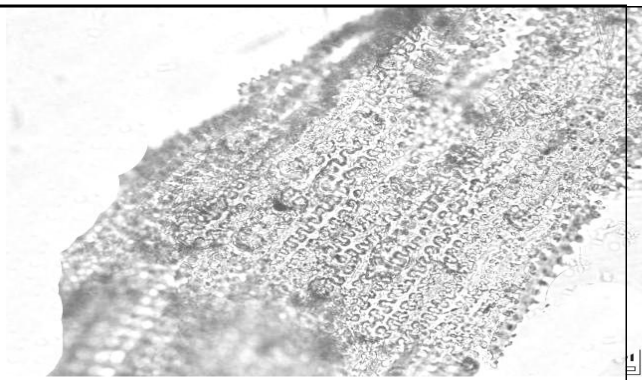

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Cyperaceae:

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 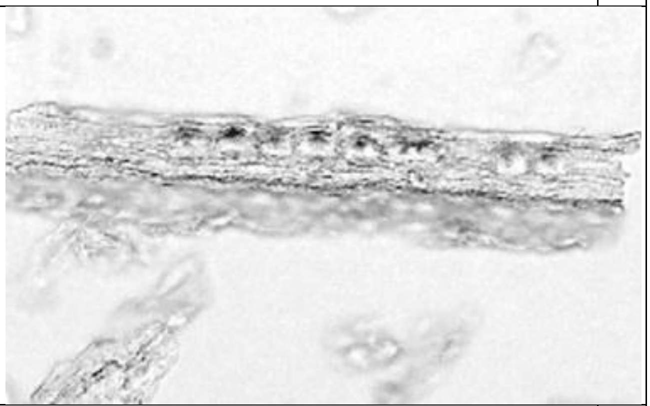

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 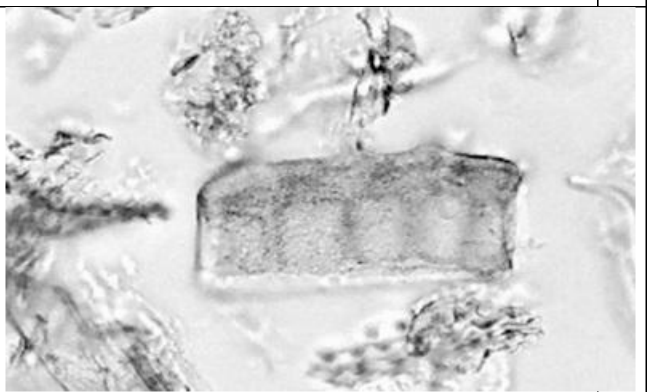

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	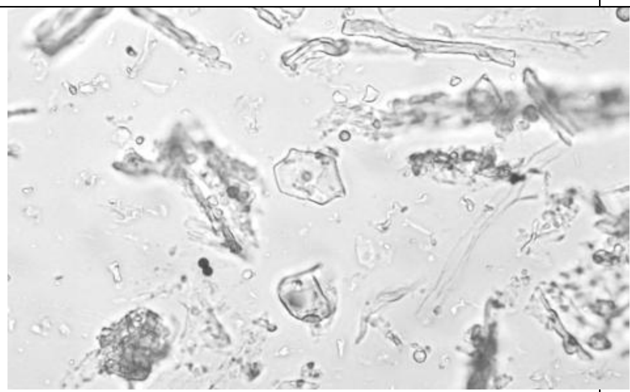
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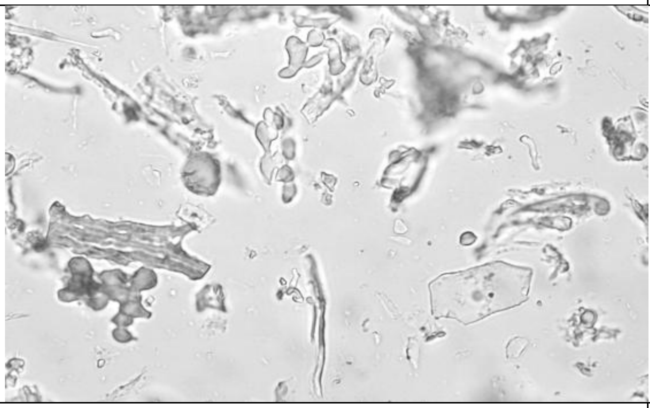	
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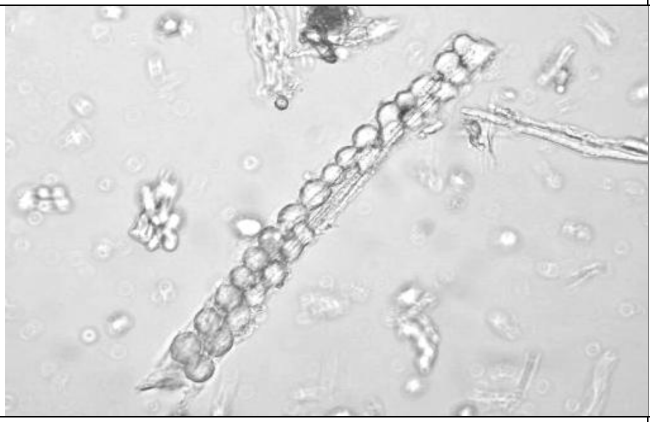	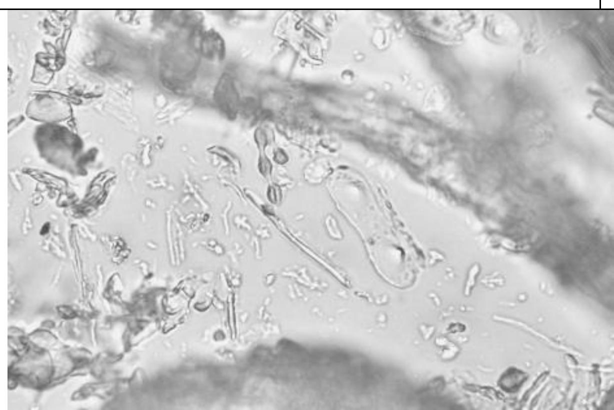
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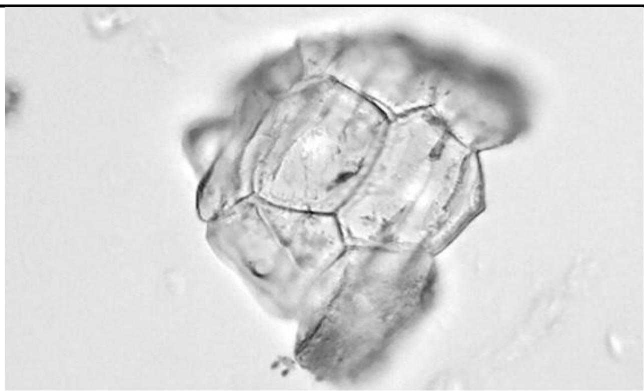	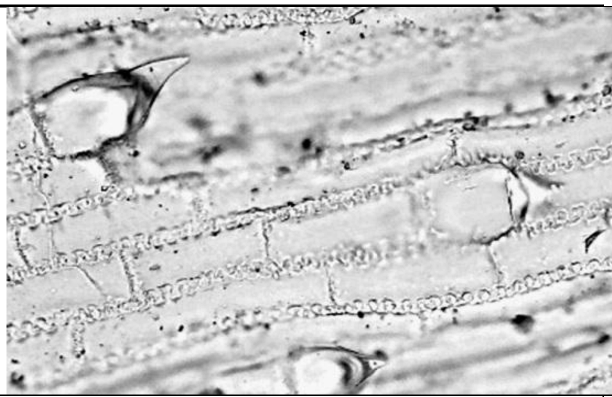
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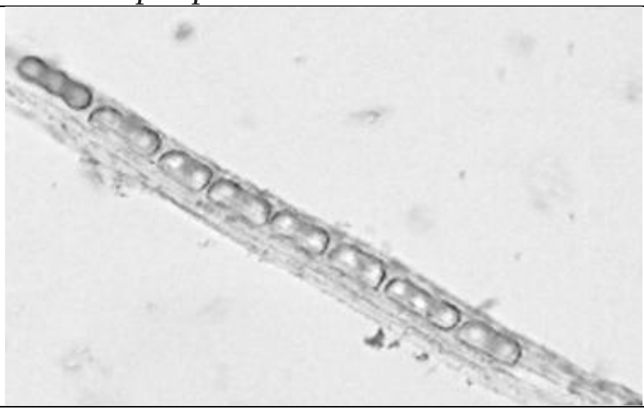	
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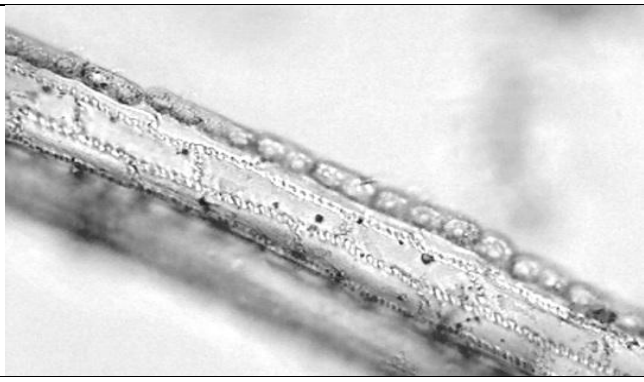	
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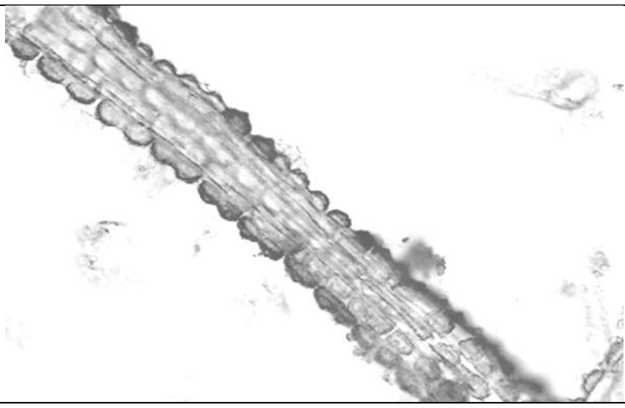	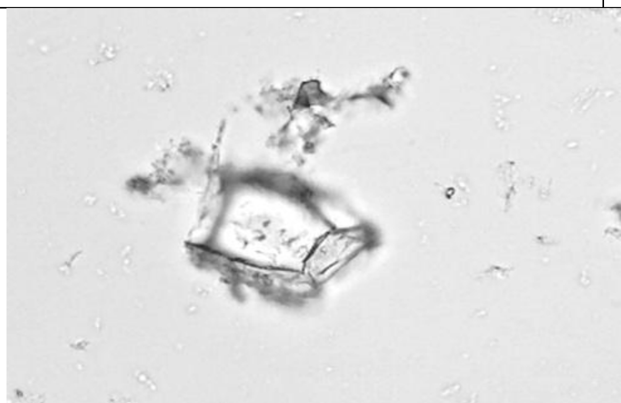
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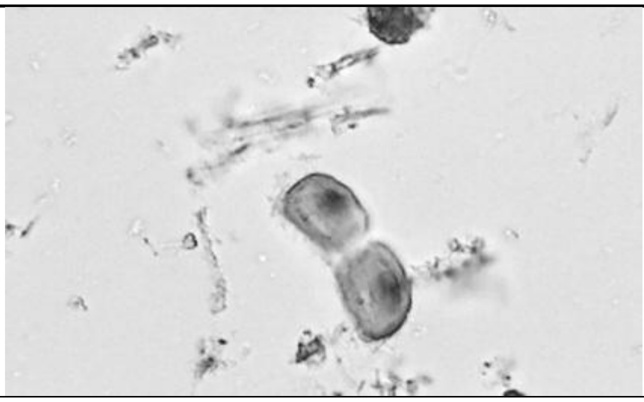	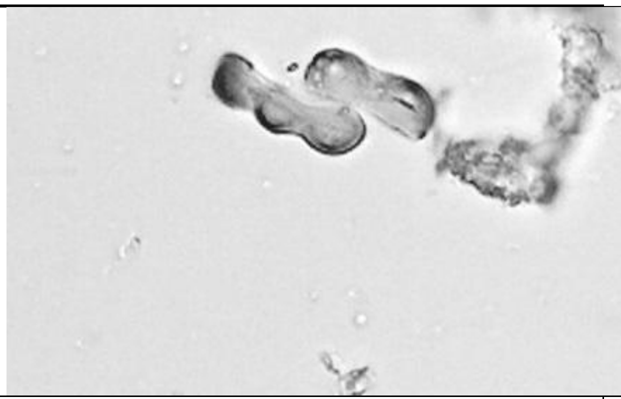
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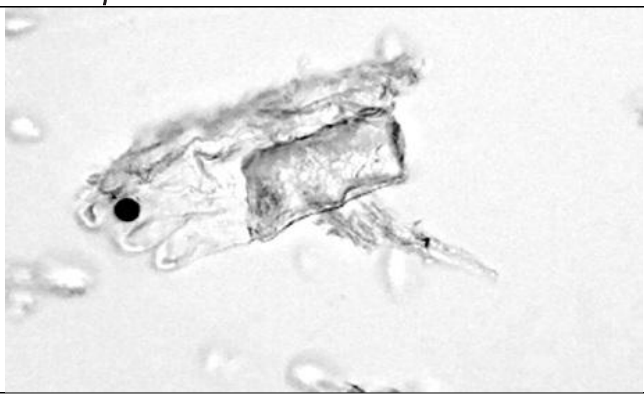	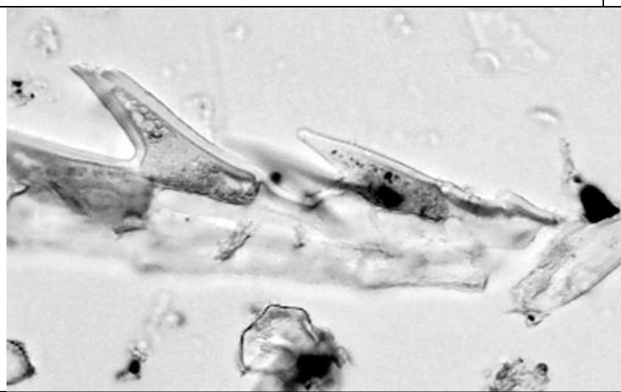
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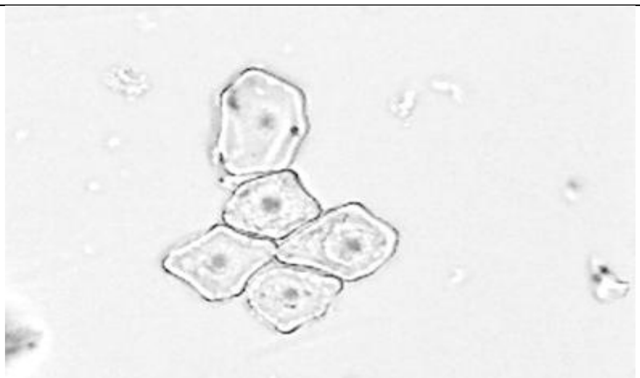	
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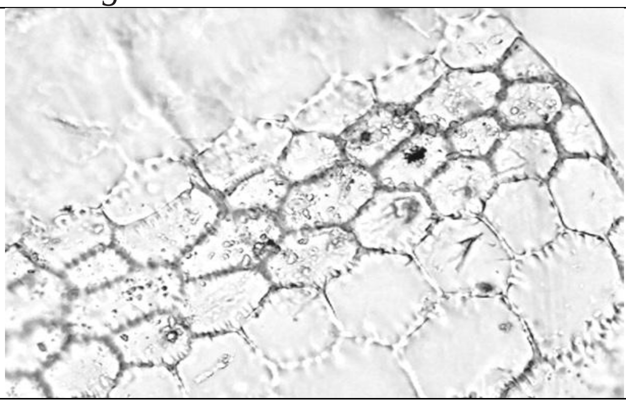	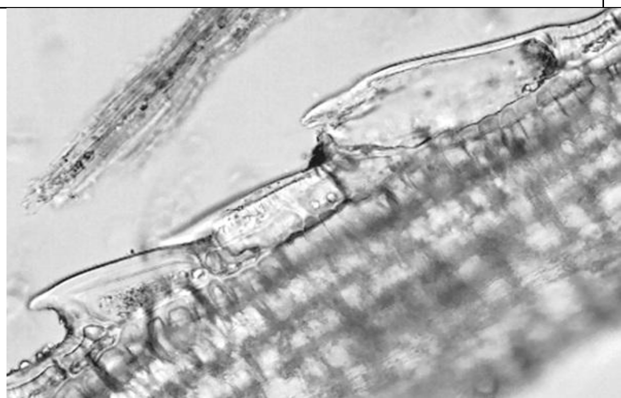
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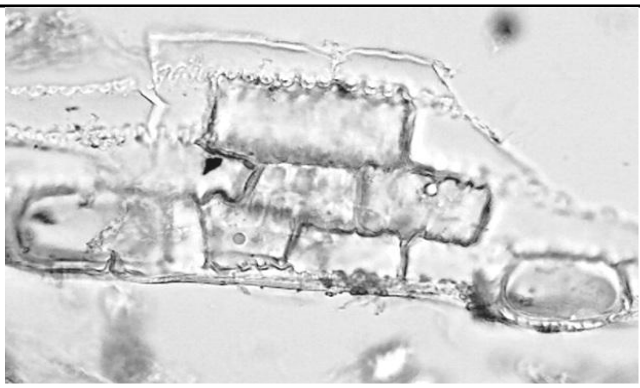	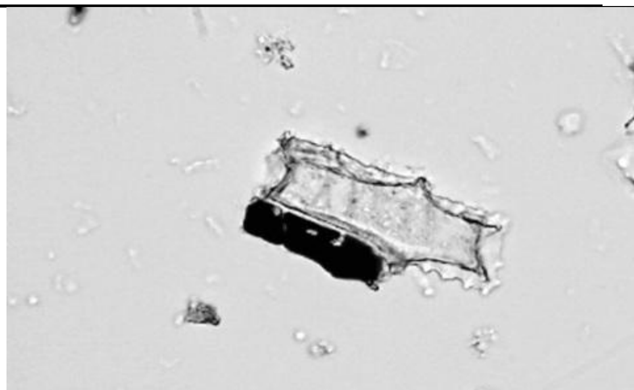
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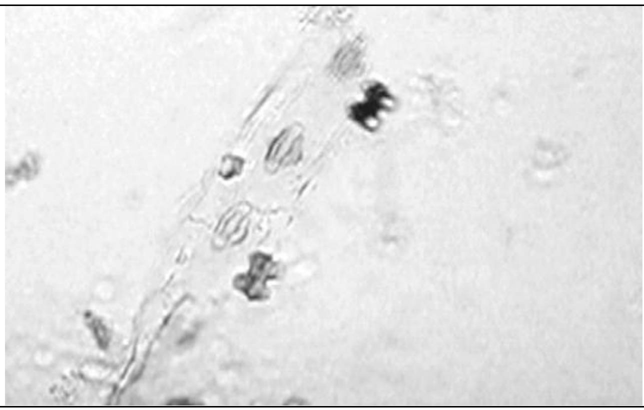	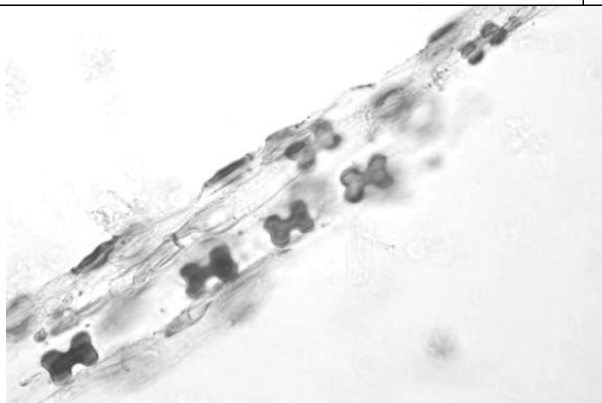
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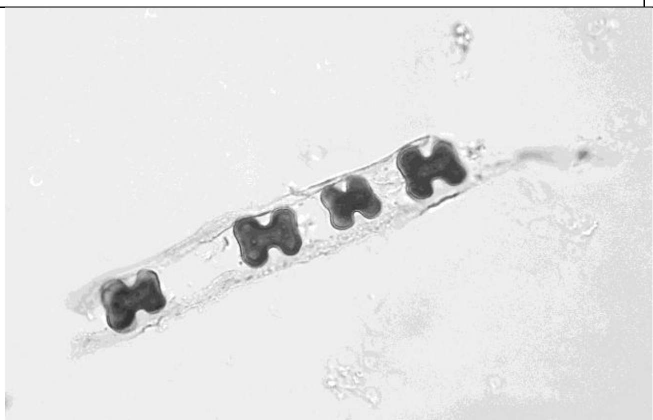	
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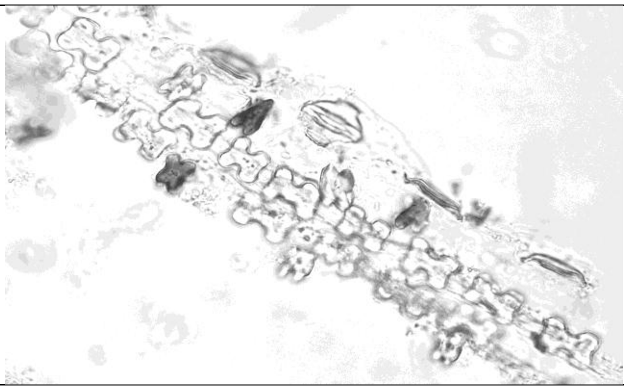	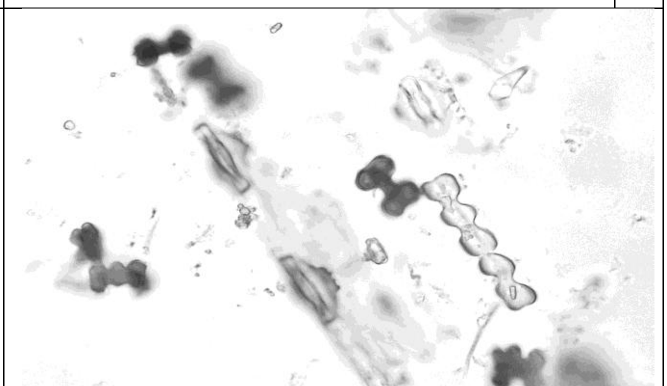
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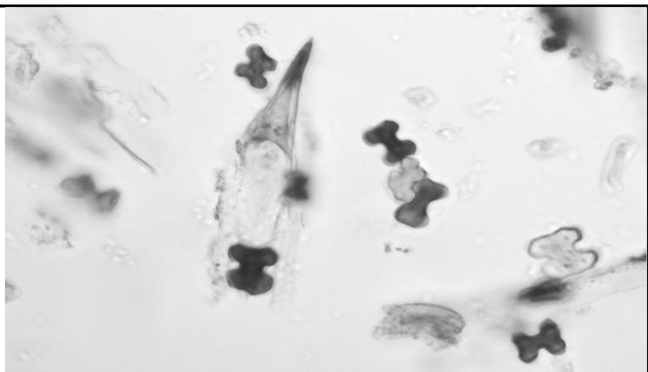	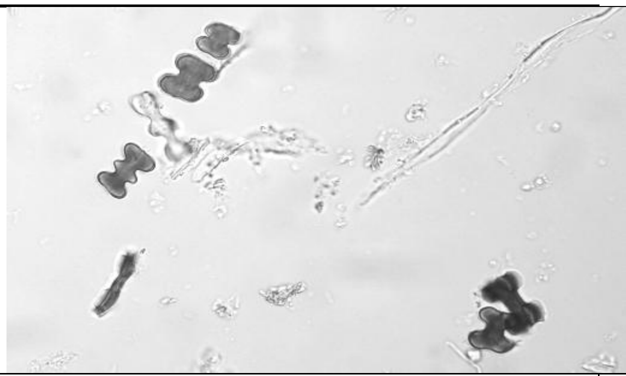
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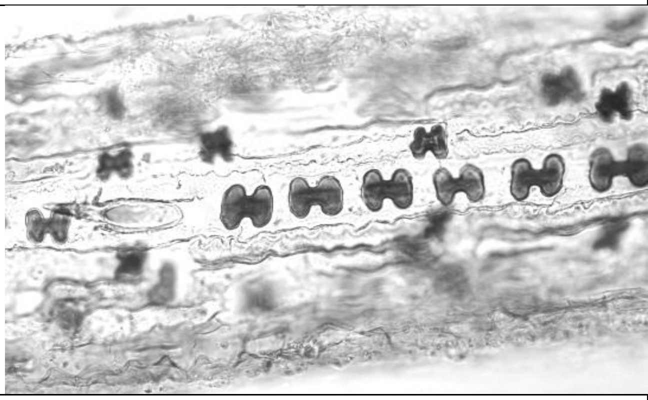	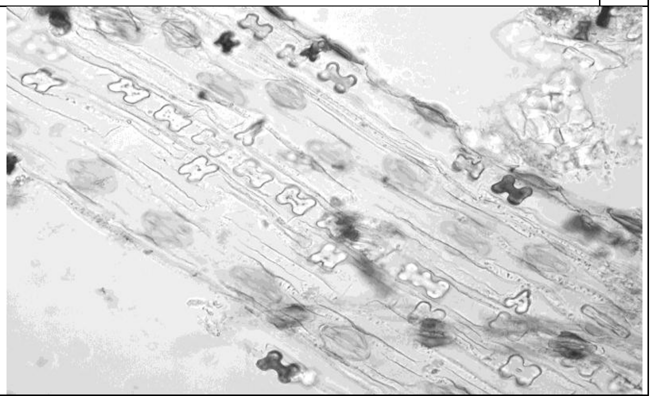
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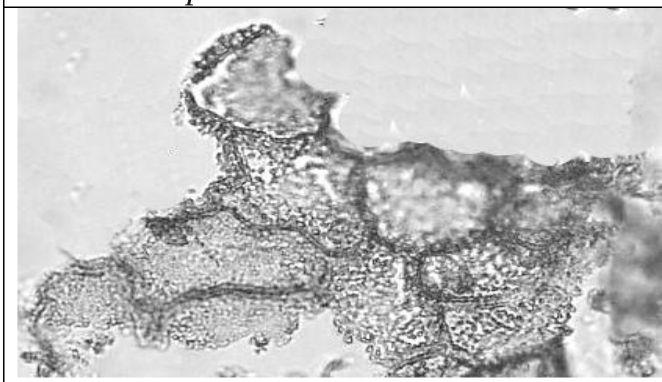	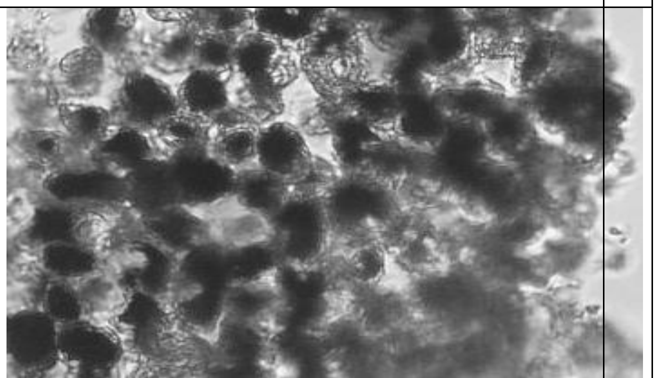
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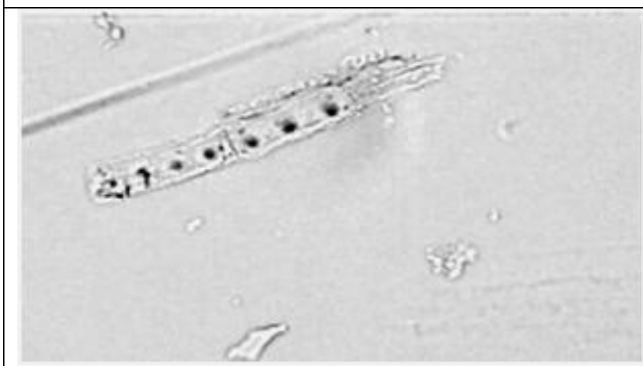	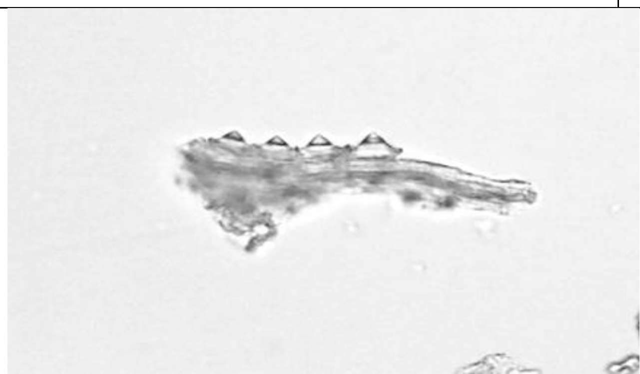
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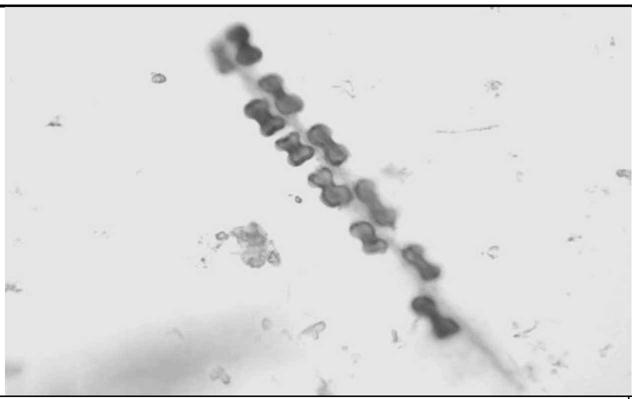	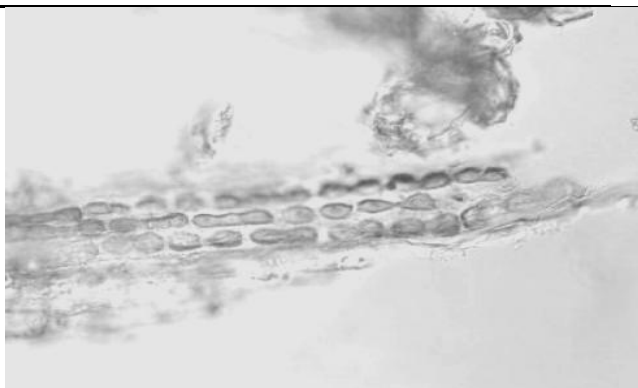
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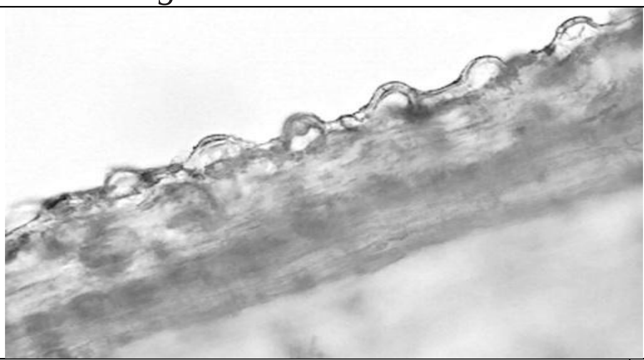	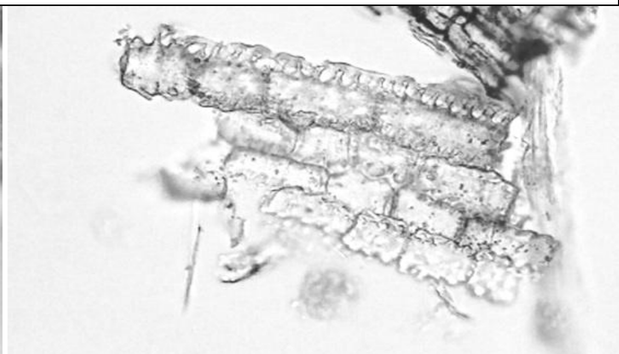
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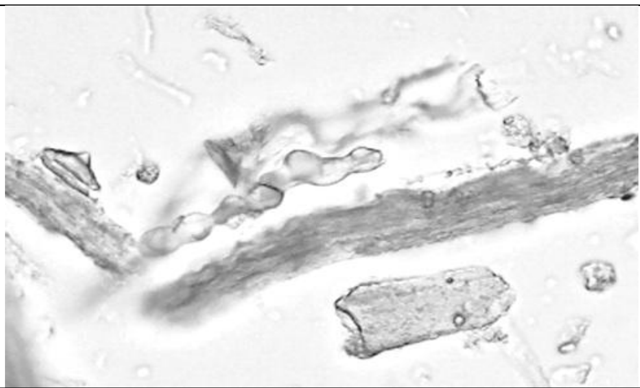	
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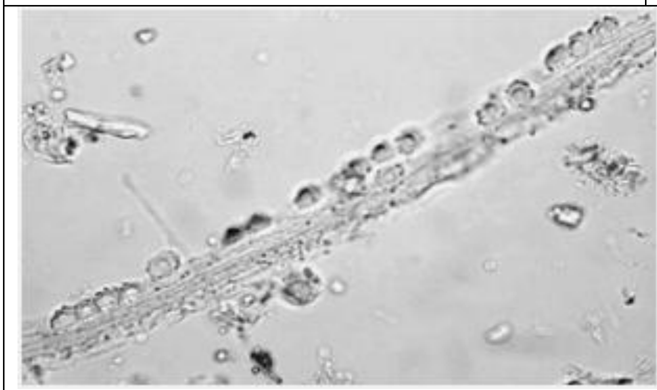	
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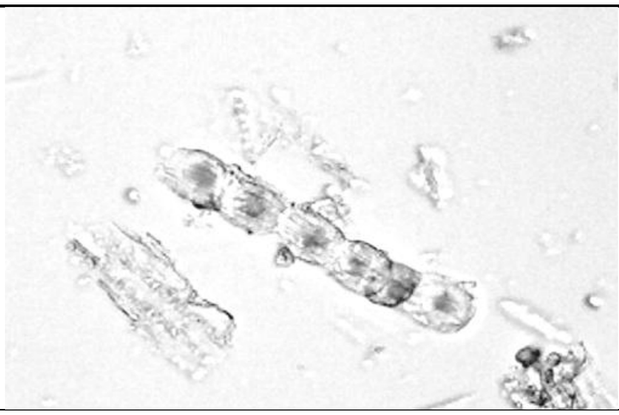	
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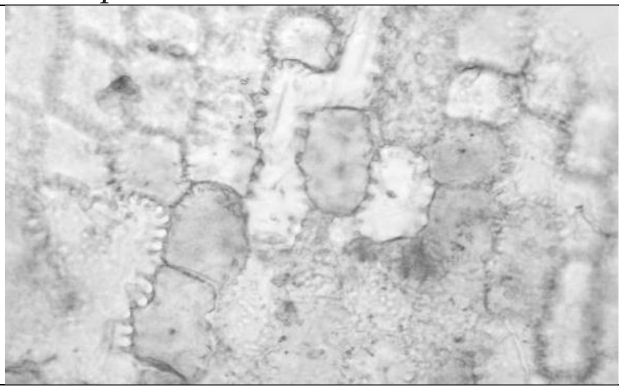	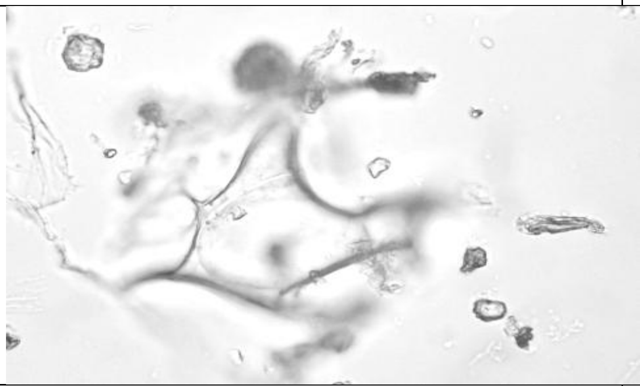
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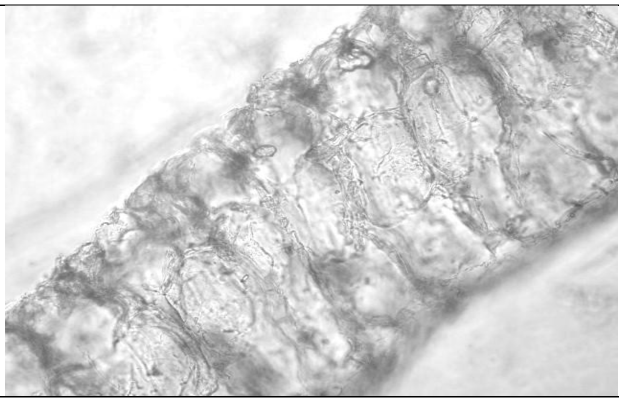	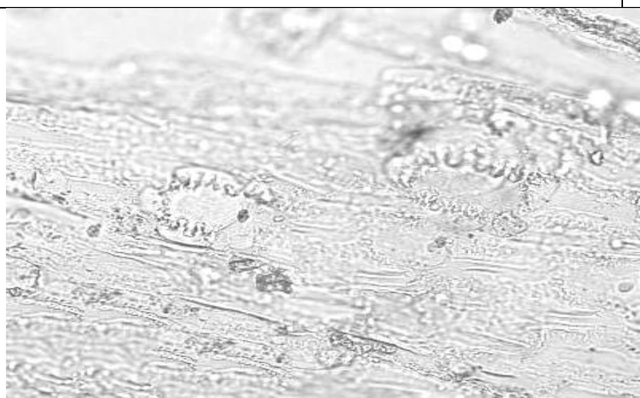
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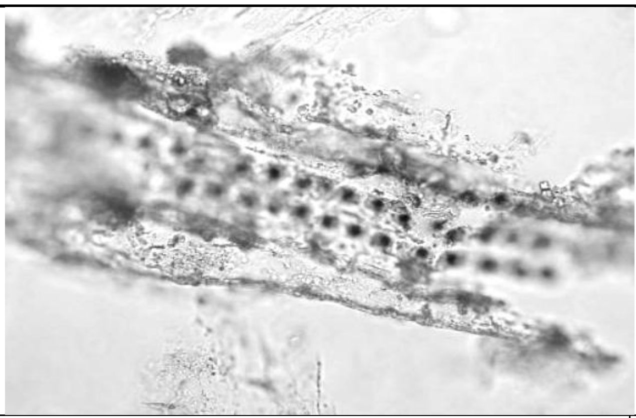	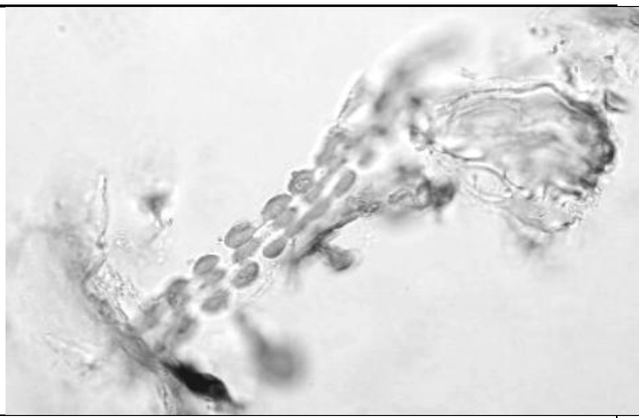
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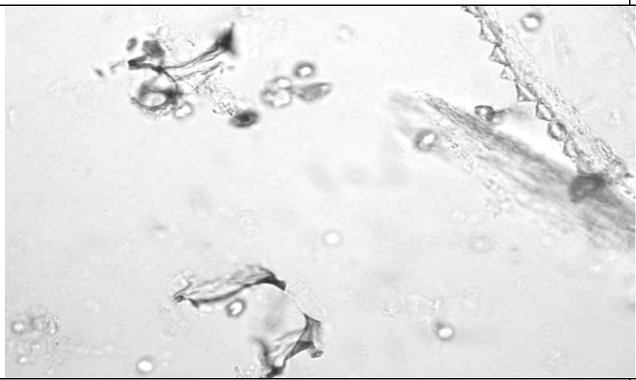	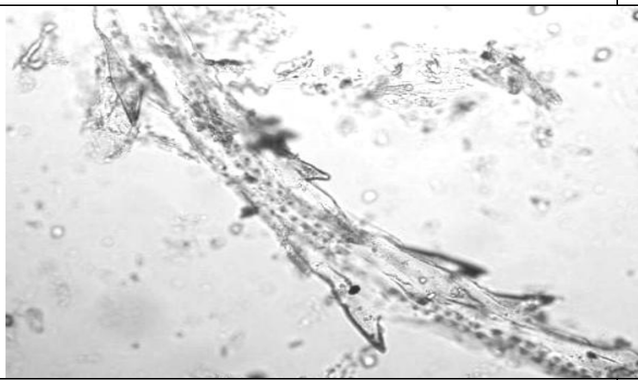
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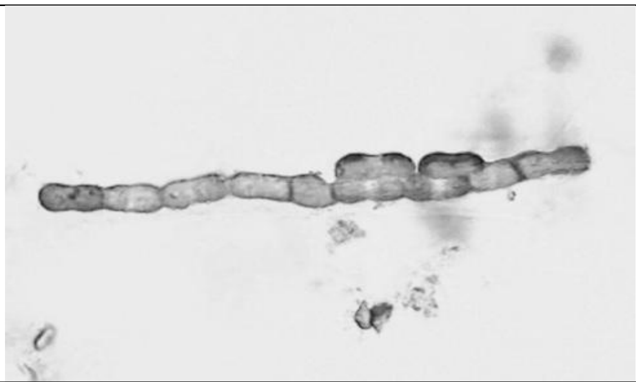	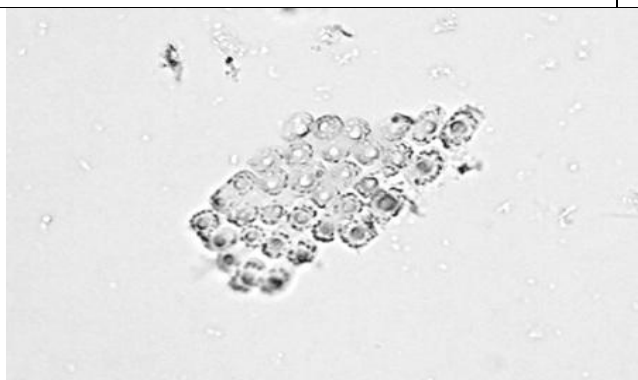
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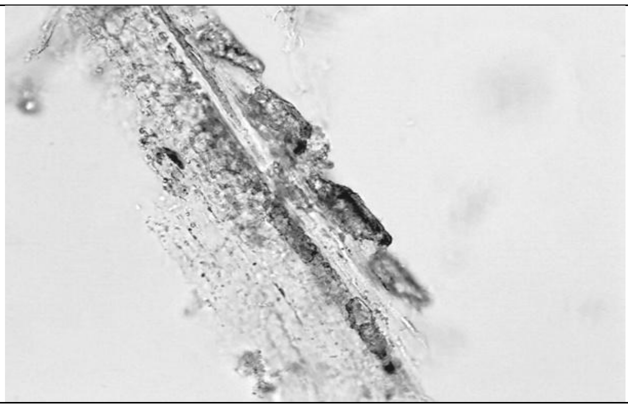	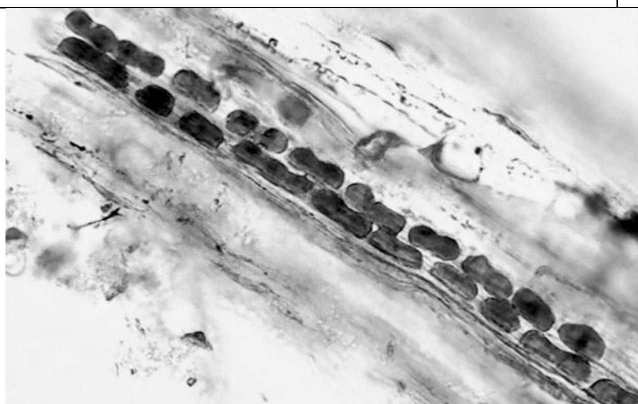
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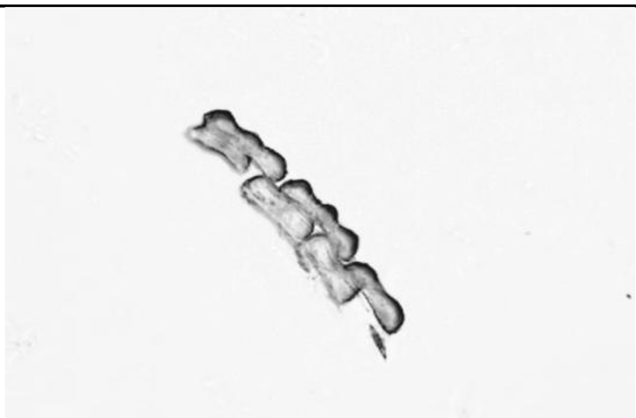
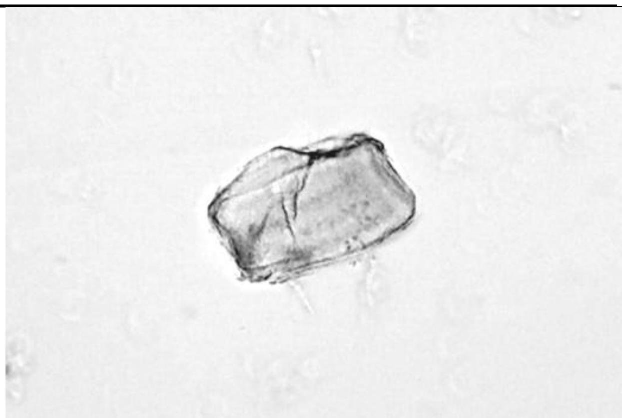

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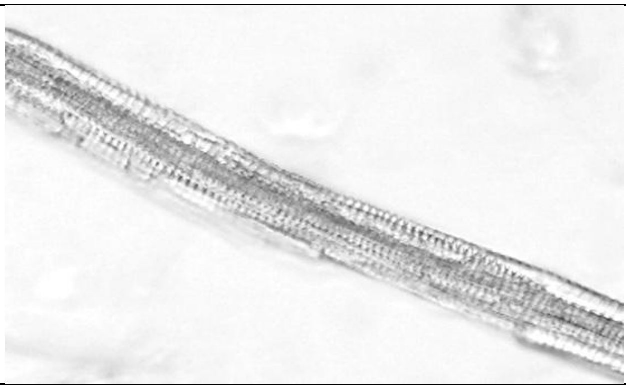
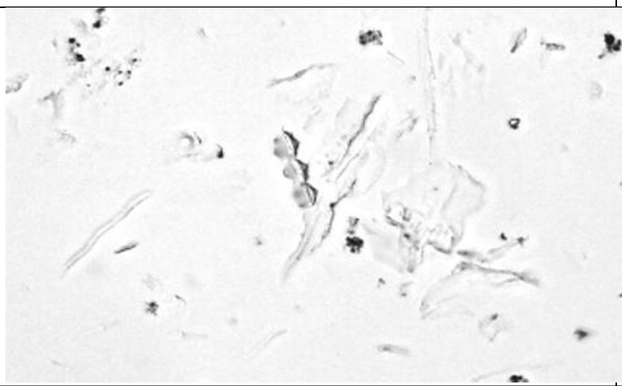

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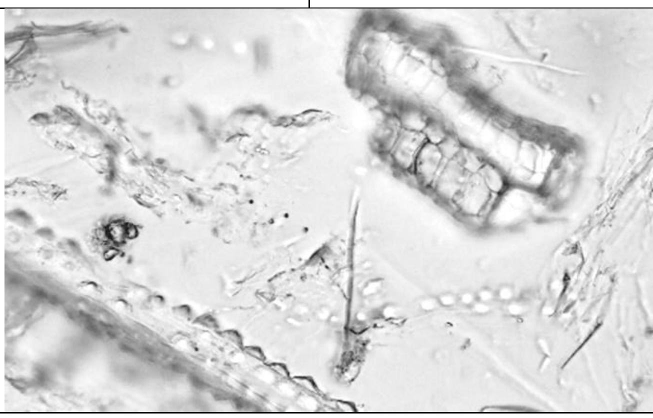

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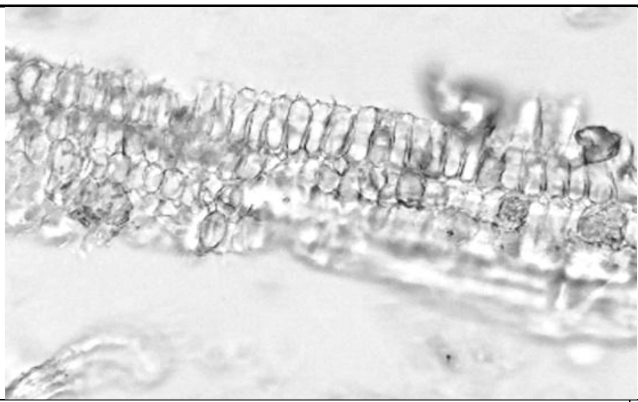

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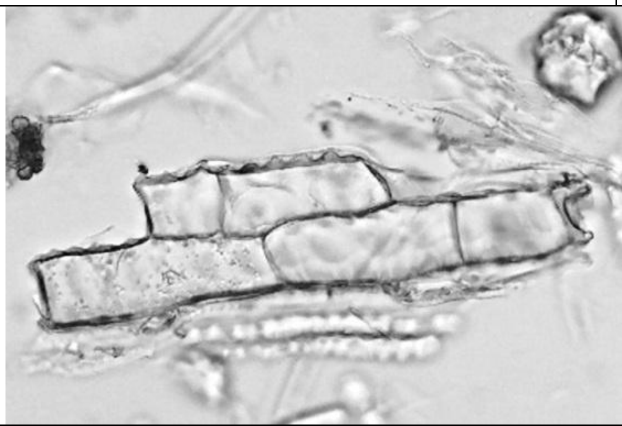

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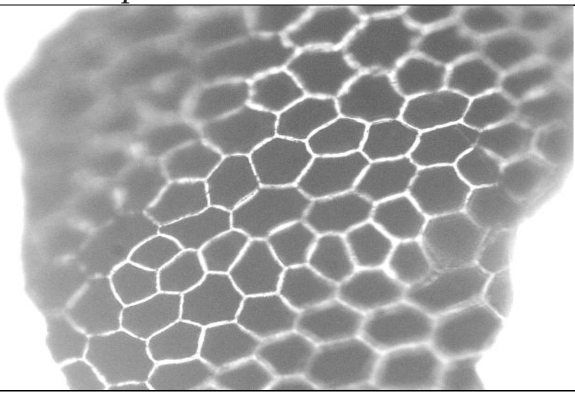

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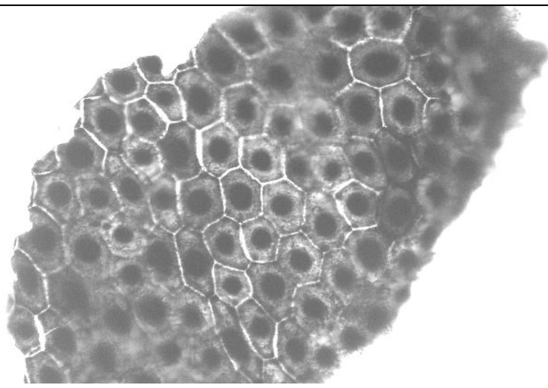

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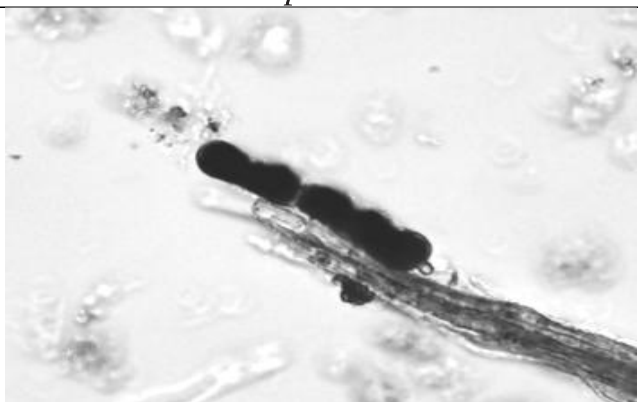
Kobresia stenocarpa



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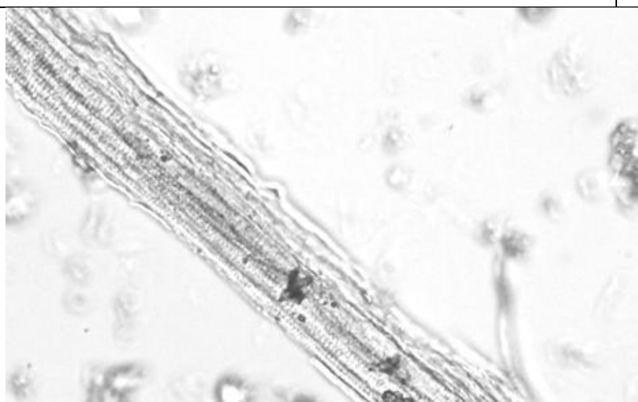

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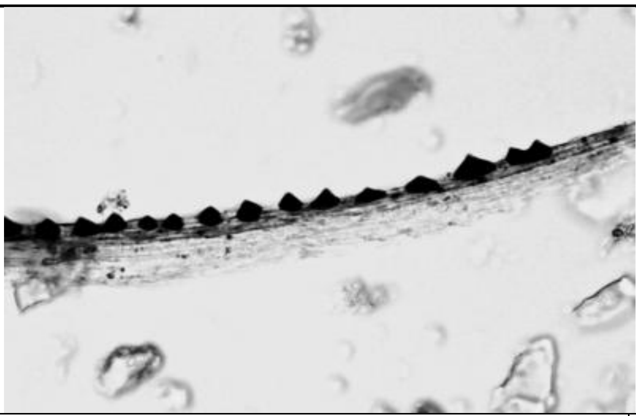


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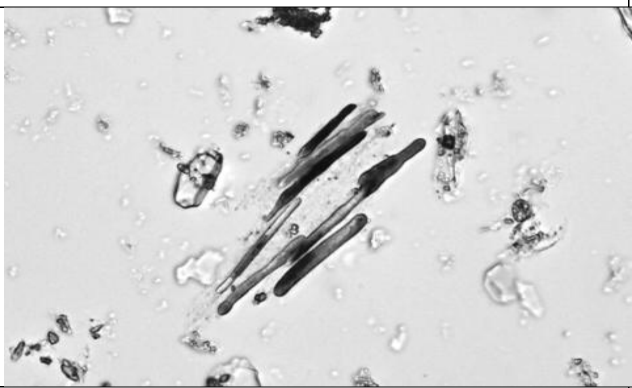
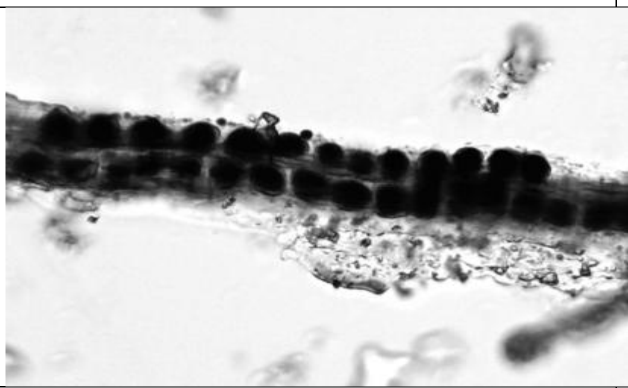

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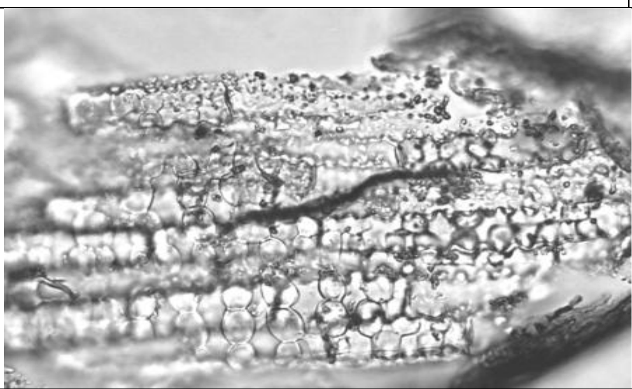
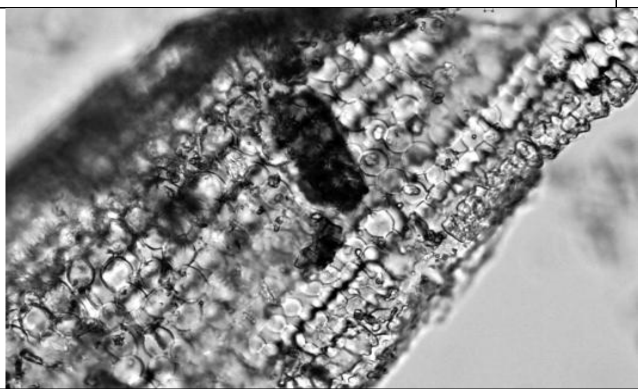

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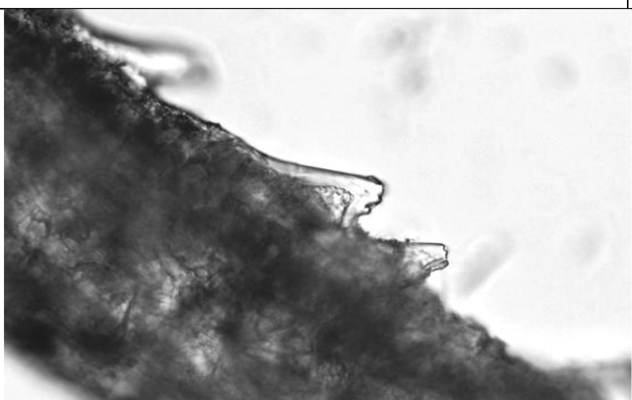
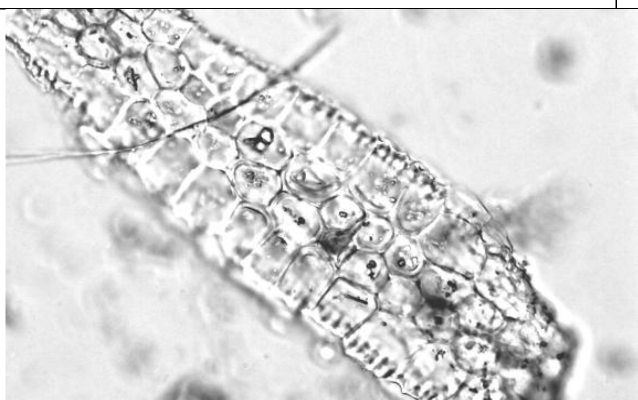

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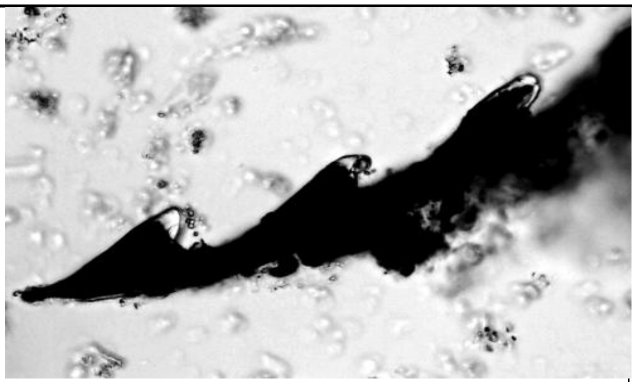	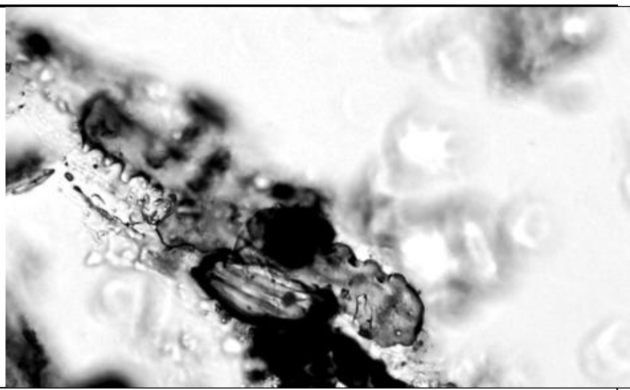
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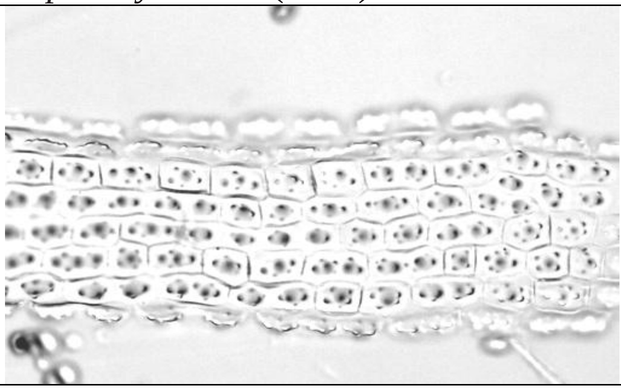
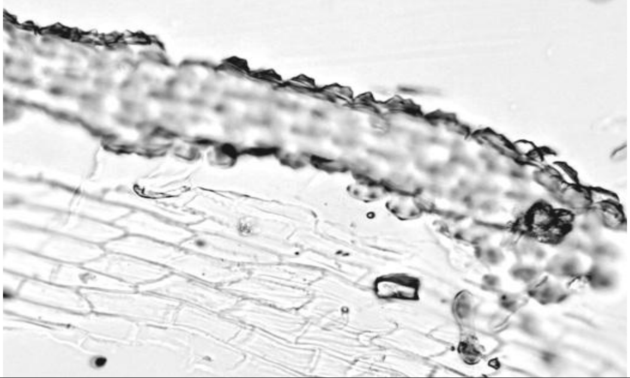
Sciprus sylvestris (culm)	
	
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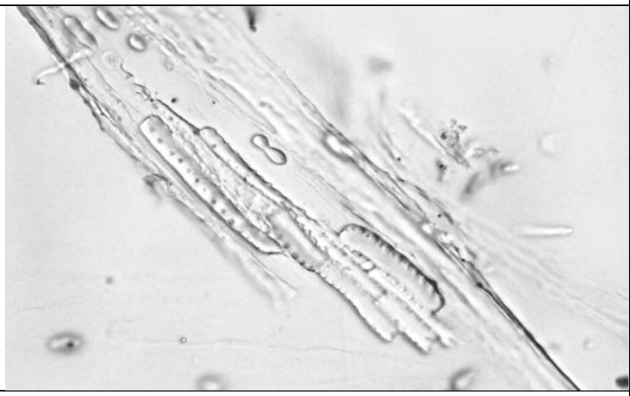	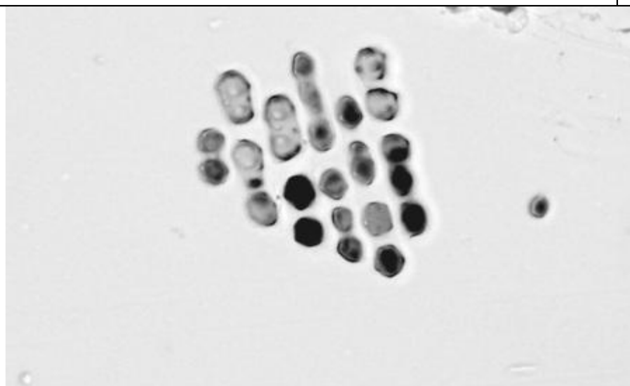
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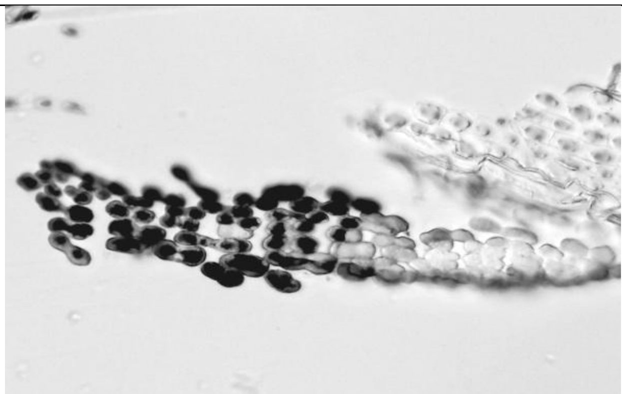	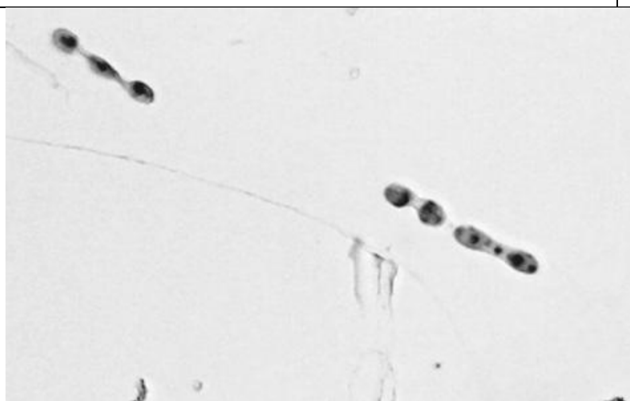
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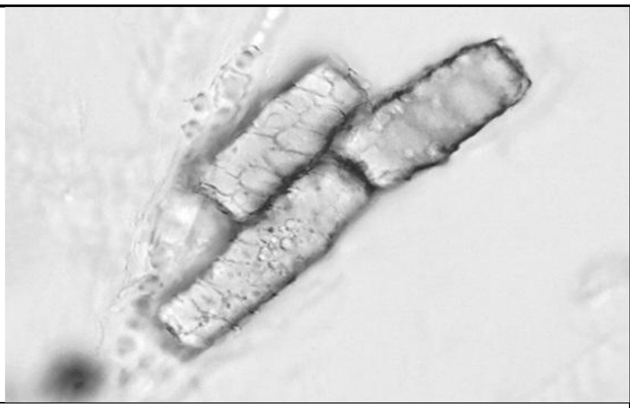
Sciprus sylvestris (leaves)	



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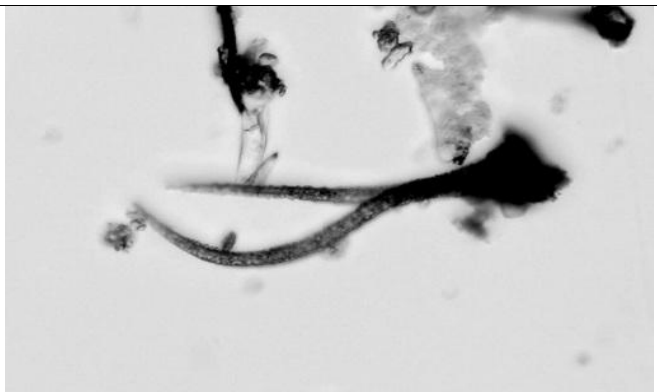
3

Cannabaceae

Cannabis sativa



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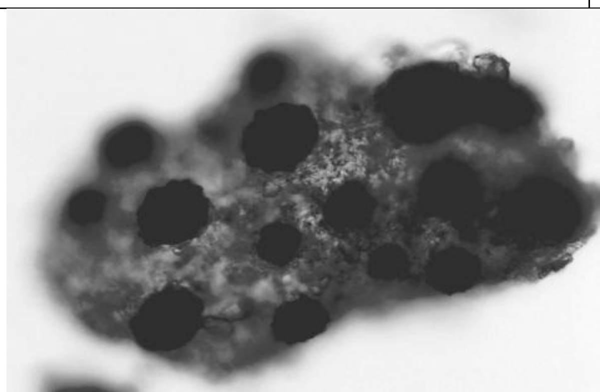

2

3

Agricultural plants	
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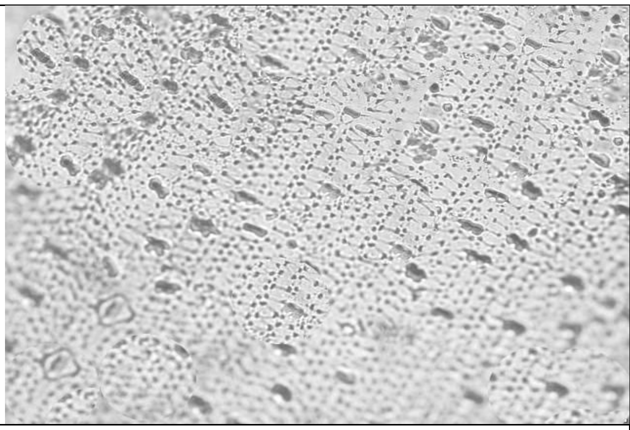	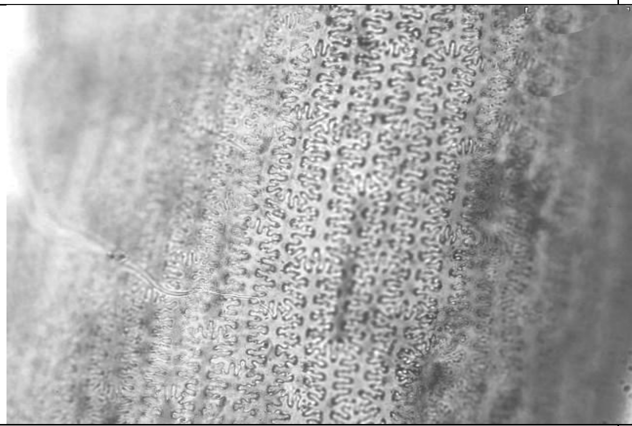
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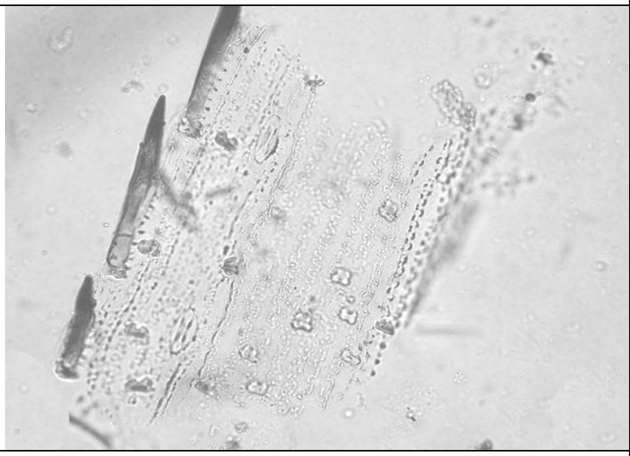	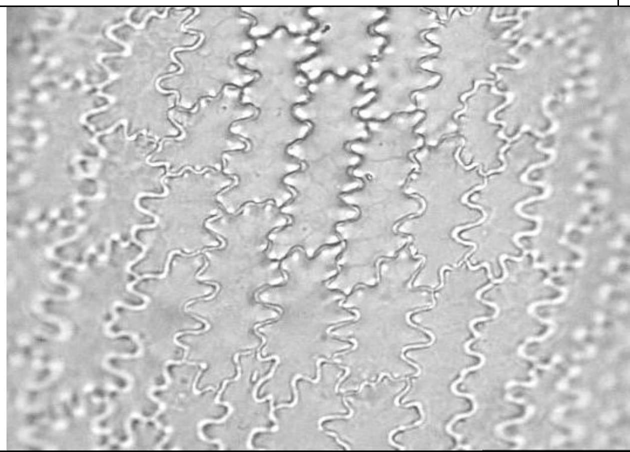
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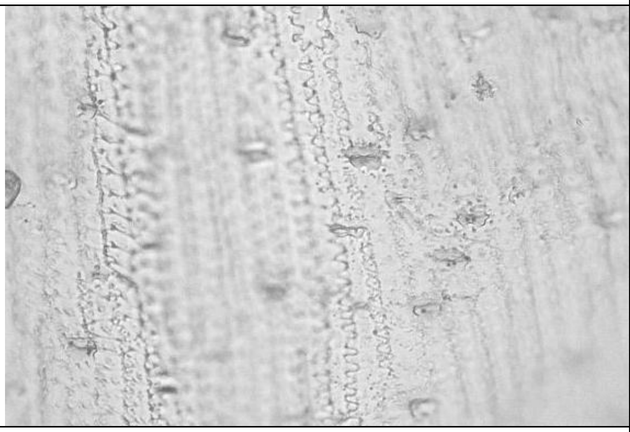	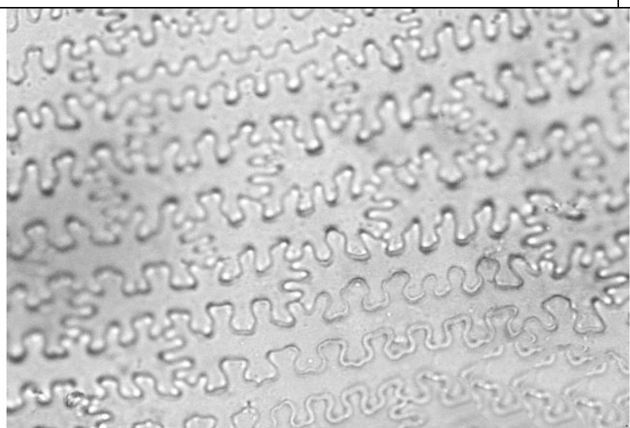
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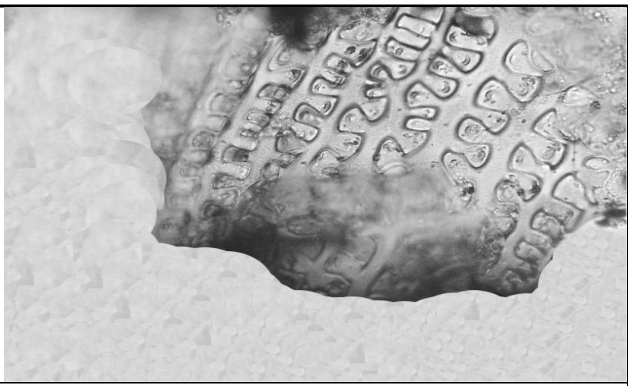
Triticum aestivum	



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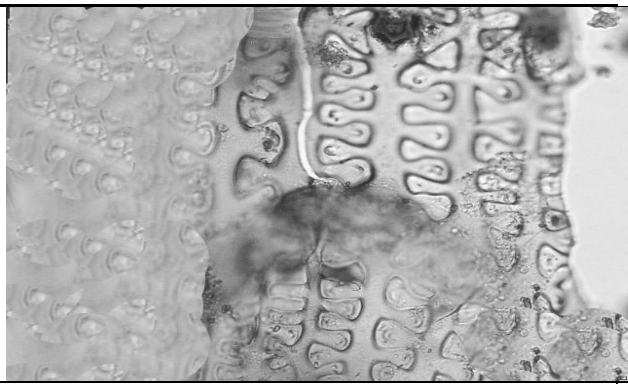

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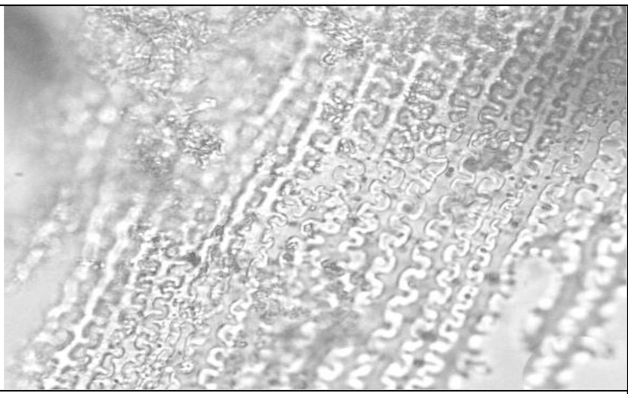
Secále cereále



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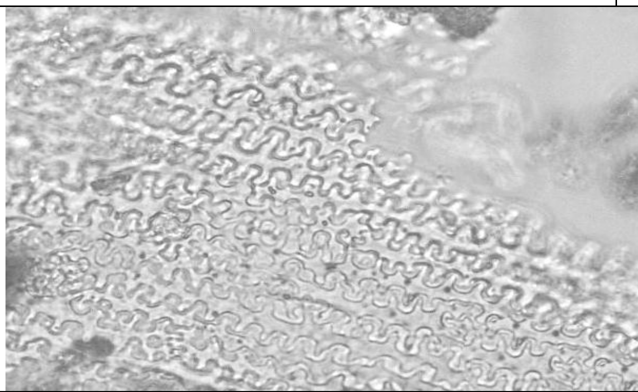

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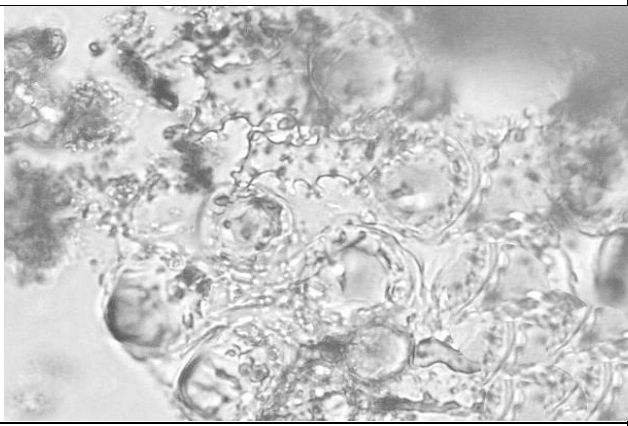

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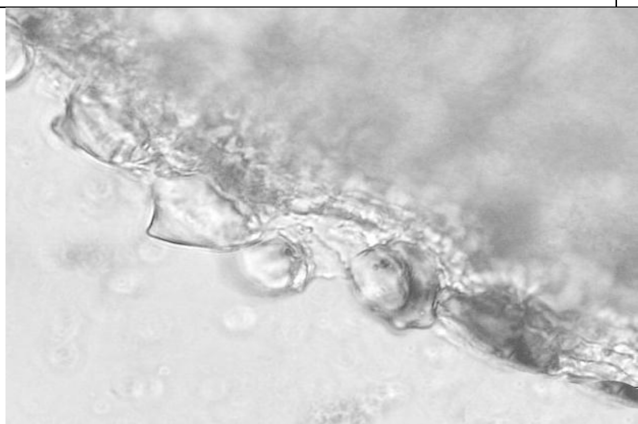

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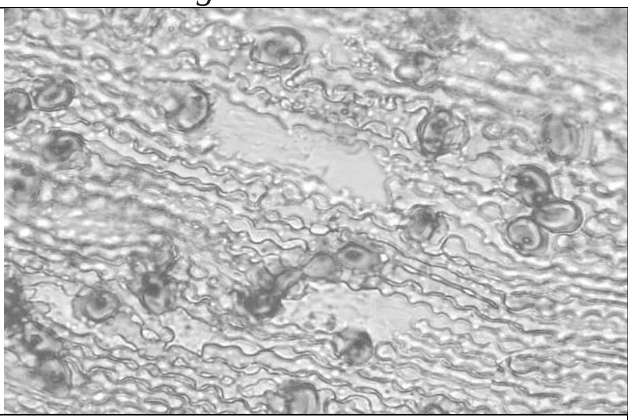
Hordeum vulgare



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	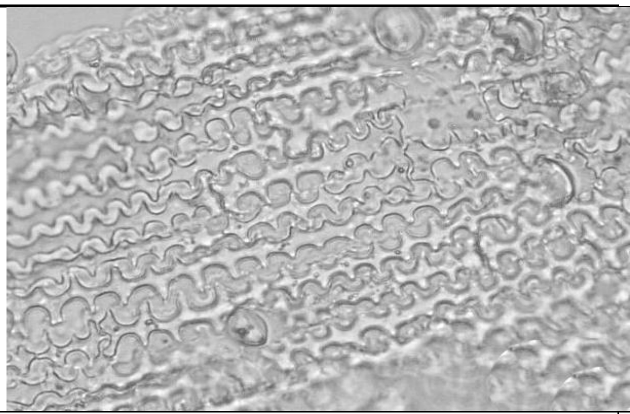
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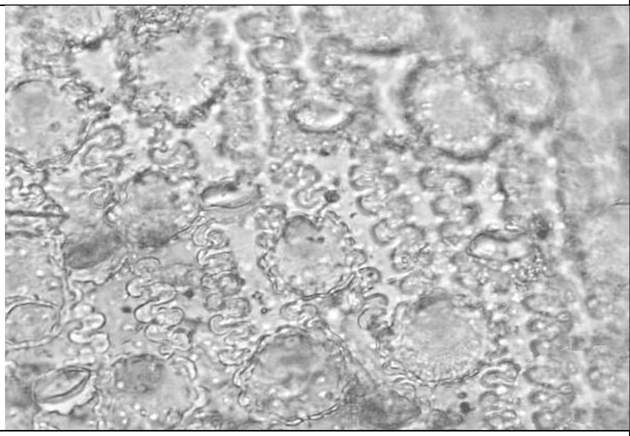
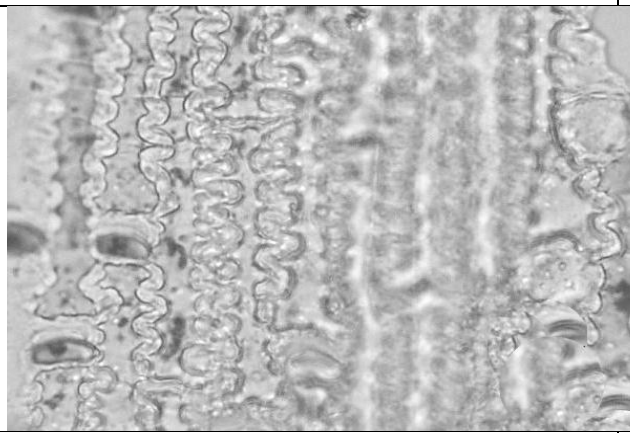
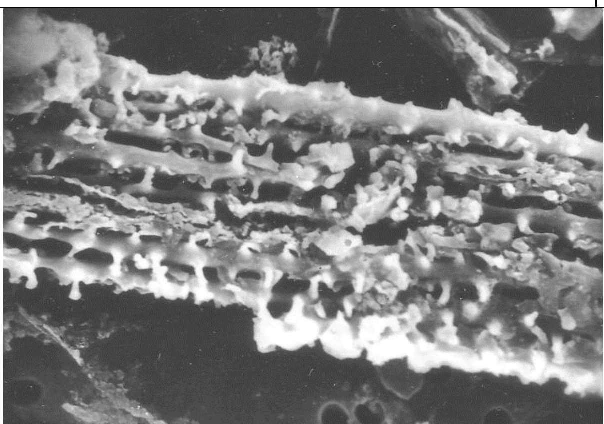
	
5	6

Results of phytolith analysis of plants examined using an electron scanning microscope

Poaceae:	
Aegilops cylindrica	
1	2
	
X500	X240
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	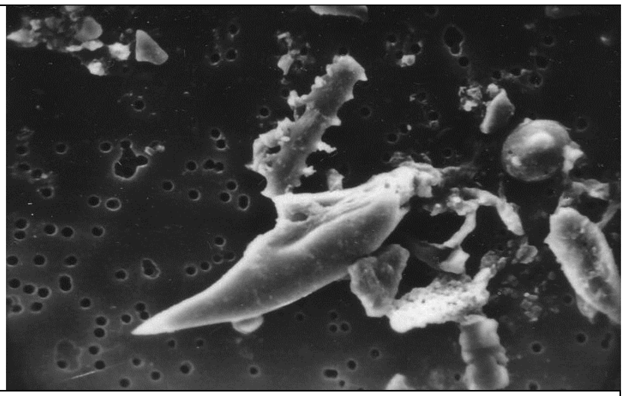
X150	X210
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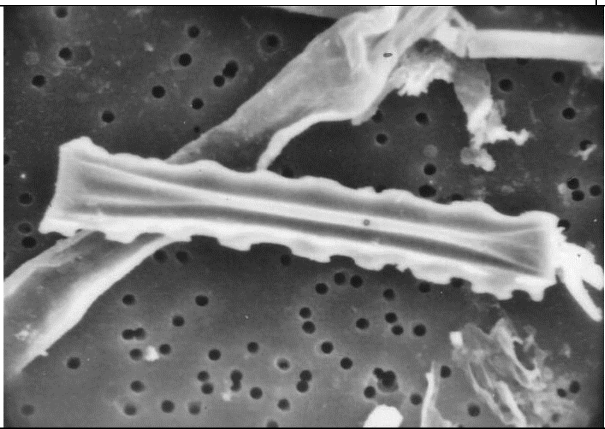	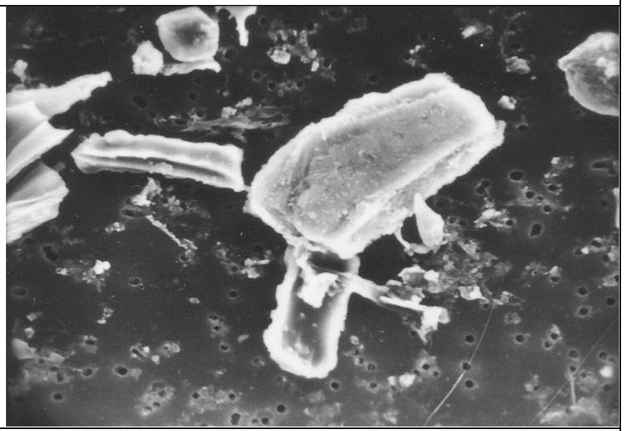
X270	X150
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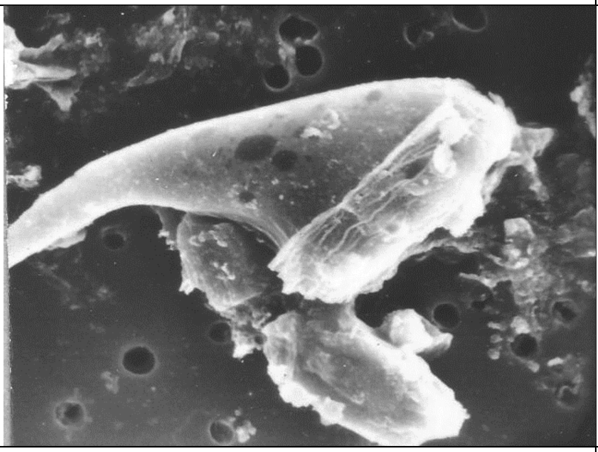
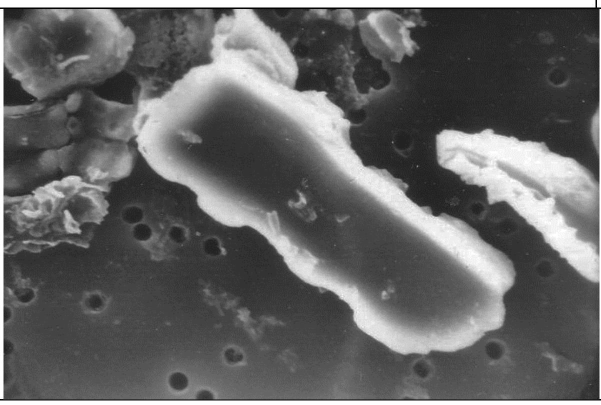
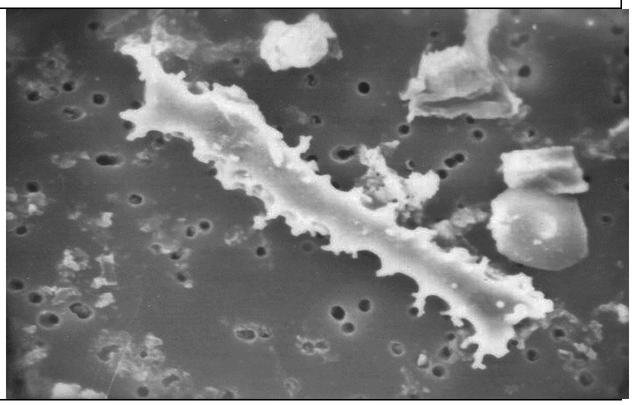
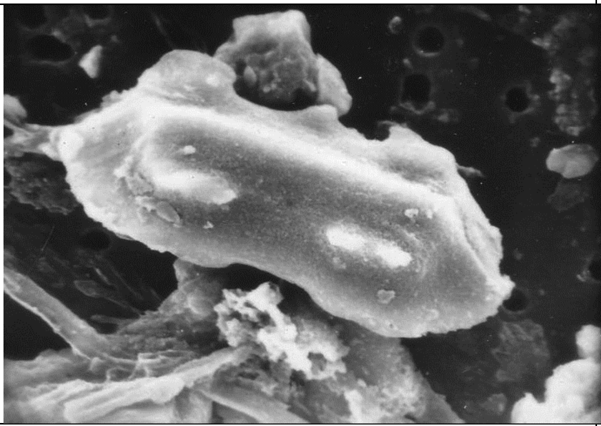
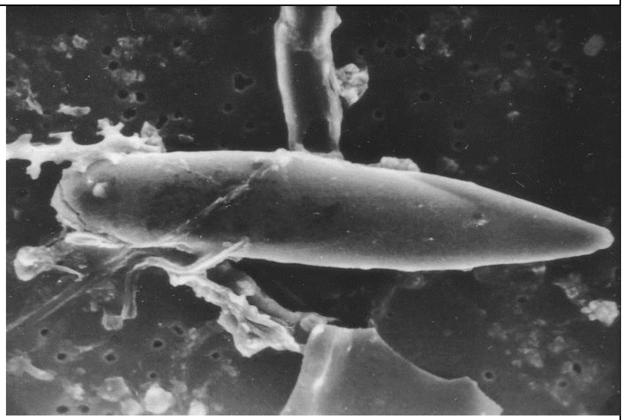
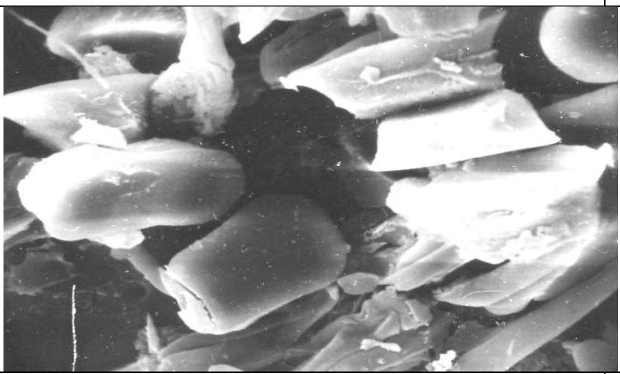
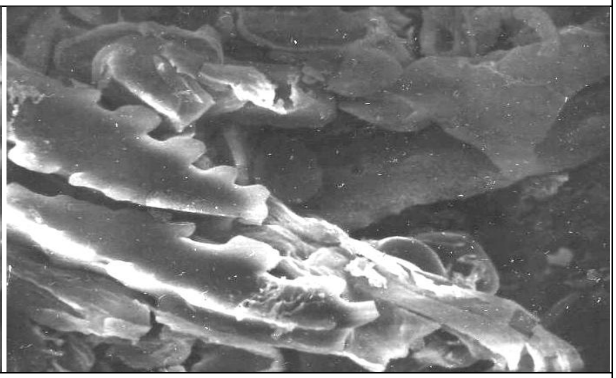
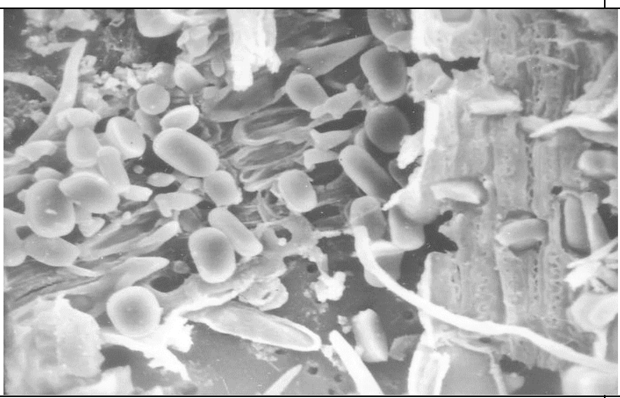
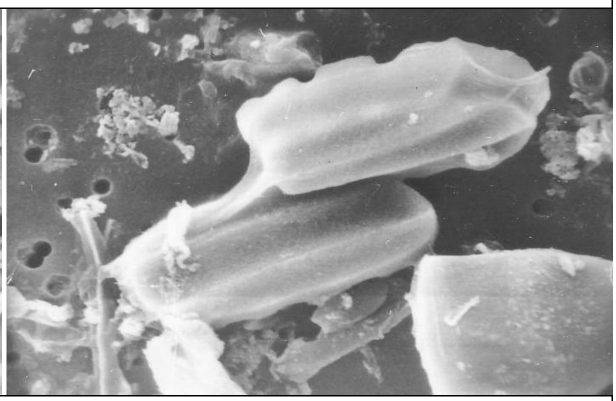
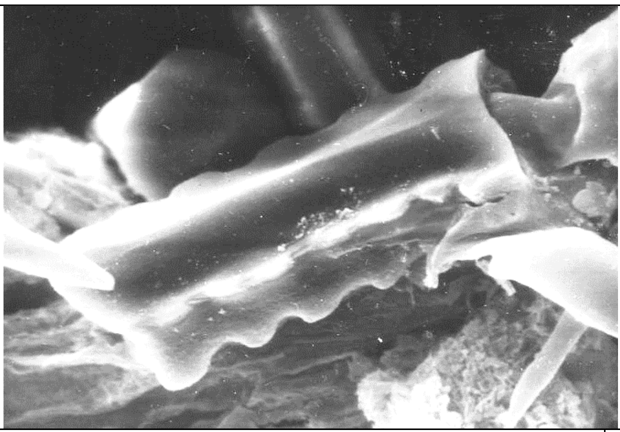
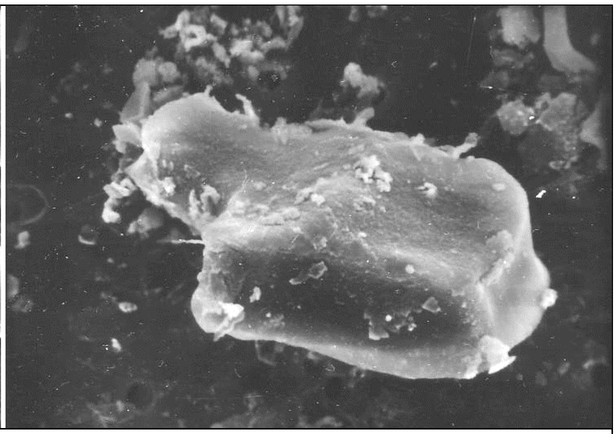
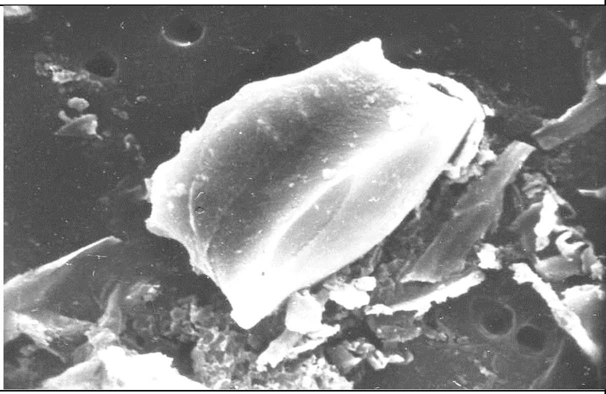
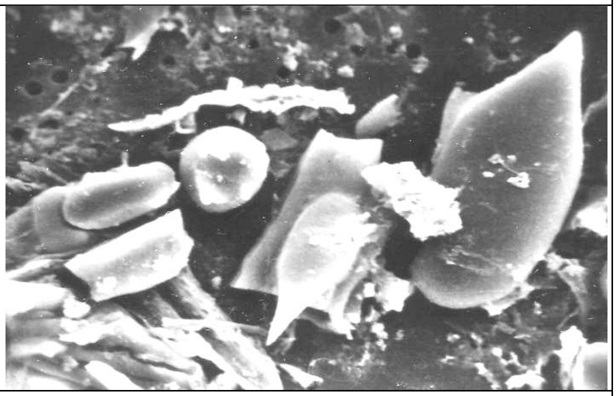
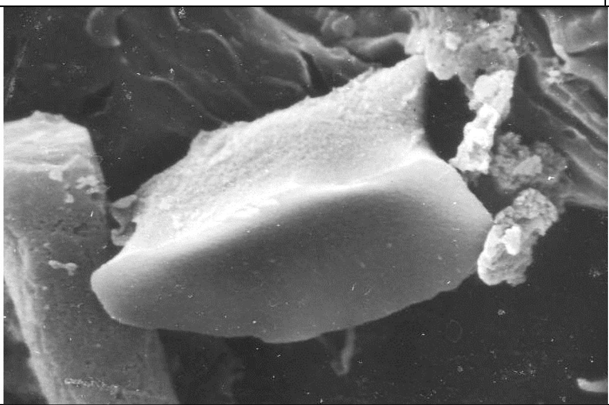
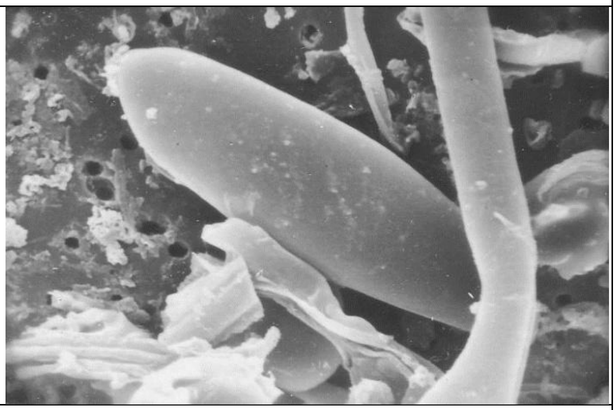
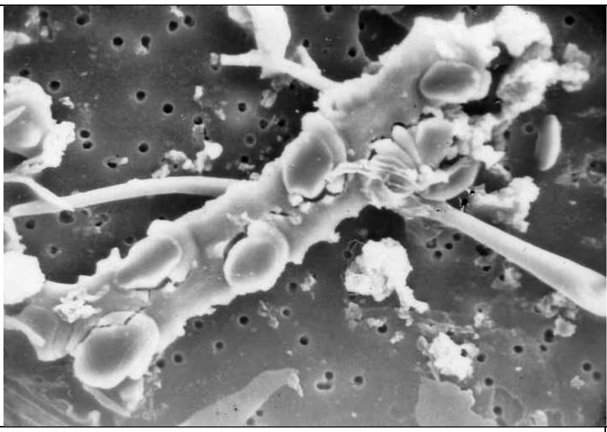
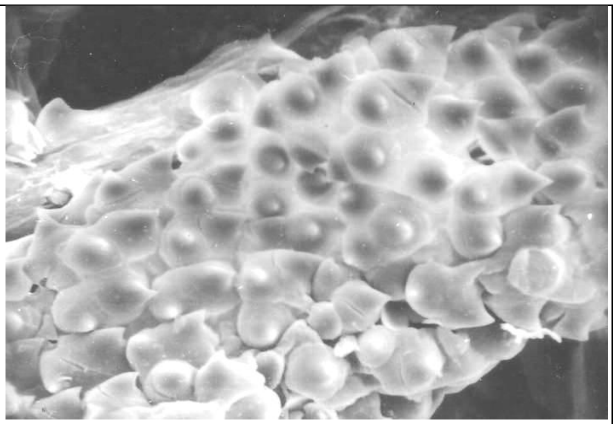
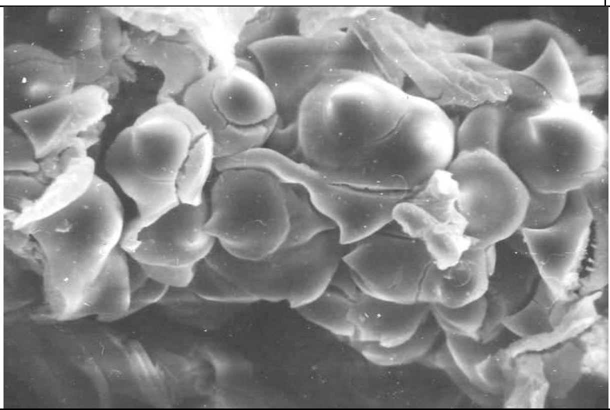
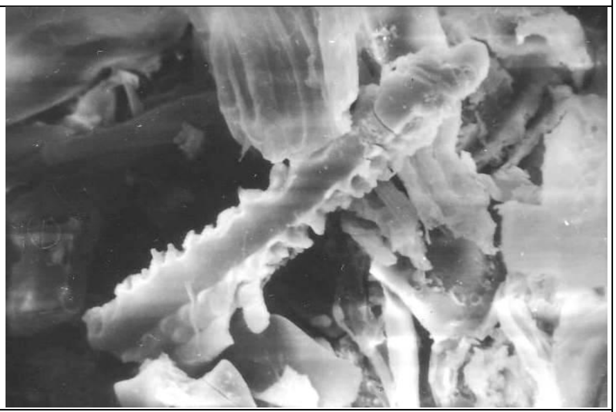
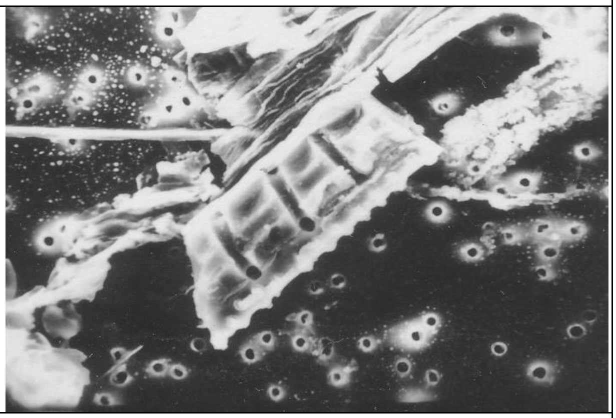
	
x600	X300
9	10
	

X300	X300
11	12
	
X300	X300
Agropyron cristatum	
1	2
	
X2100	X500
3	4
	
X1200	X400
5	6

	
X1000	x2000
7	8
	
X3000	X1000
9	10
	
X1000	X2000
Agropyron intermedium	
1	2

	
X600	X500
3	4
	
X300	X900
Alopecurus pratensis	
1	2
	
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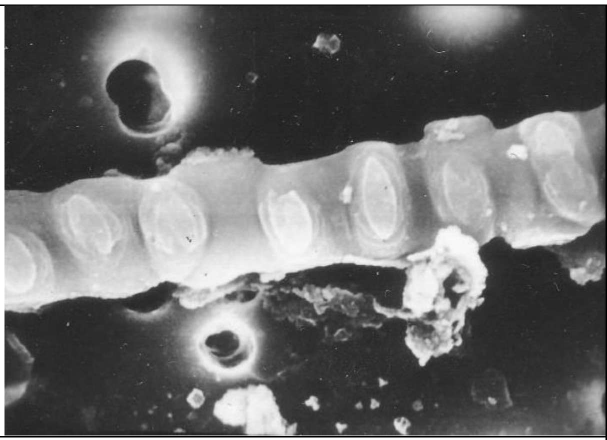
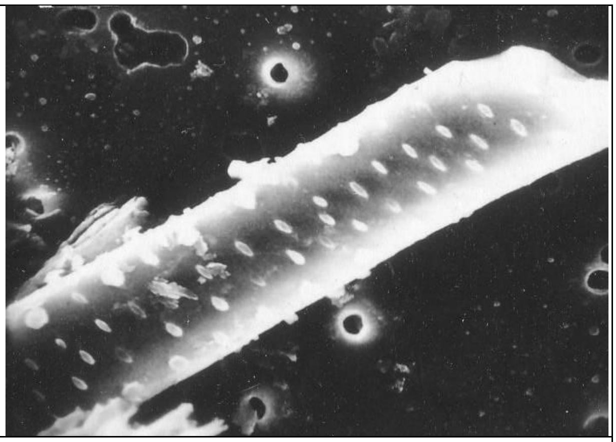
3	4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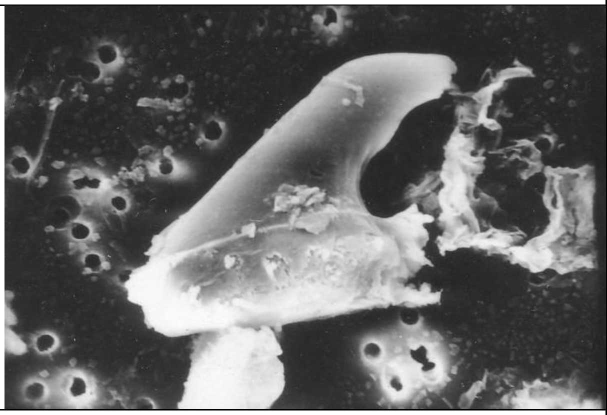	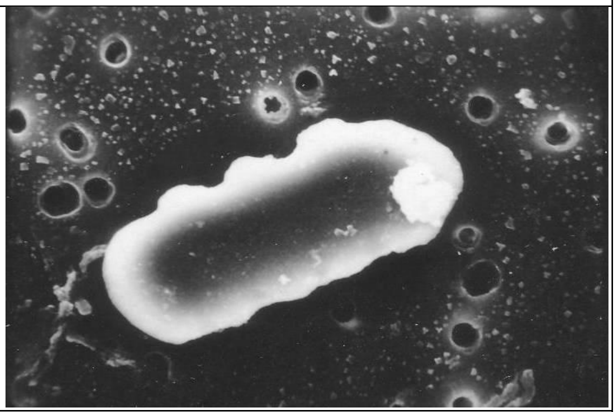
X1000	X1300
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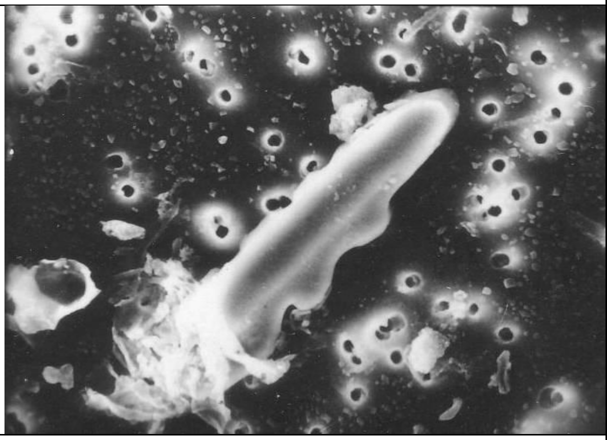
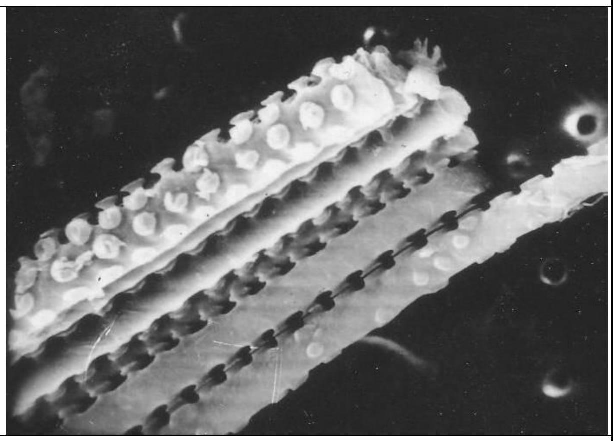
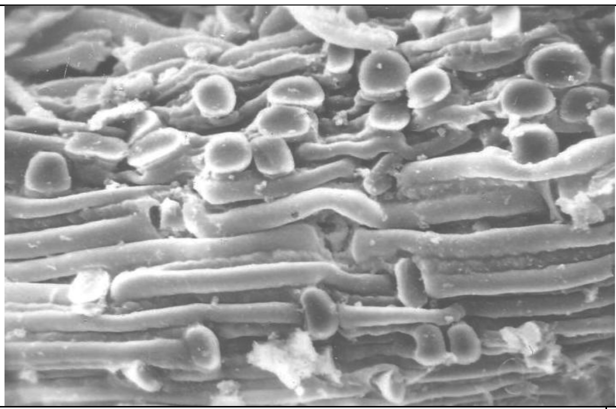
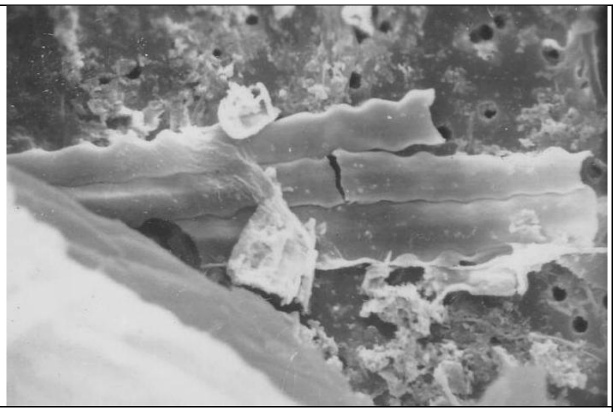
	
X1000	X1200
Arrhenatherum elatius	
1	2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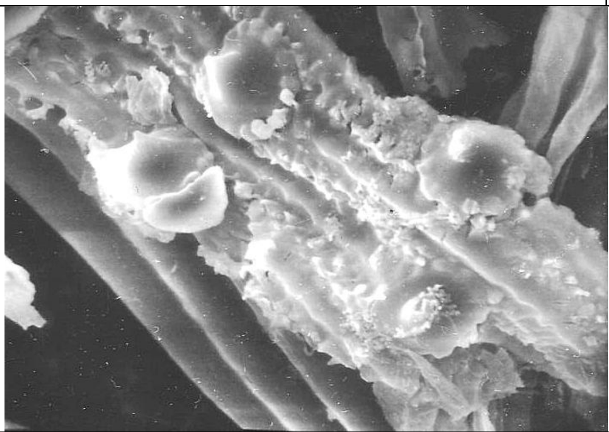
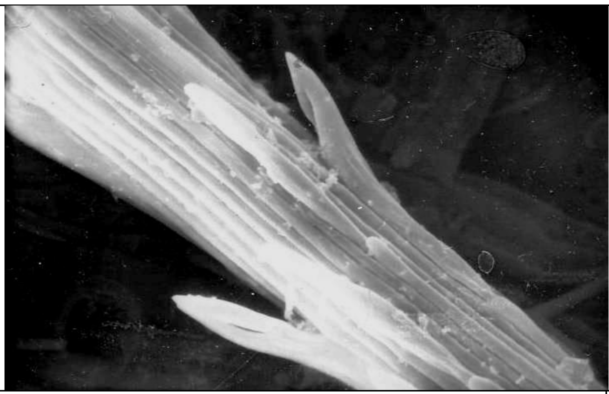
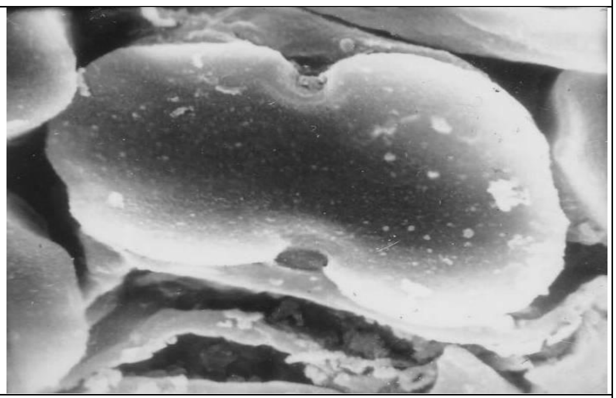
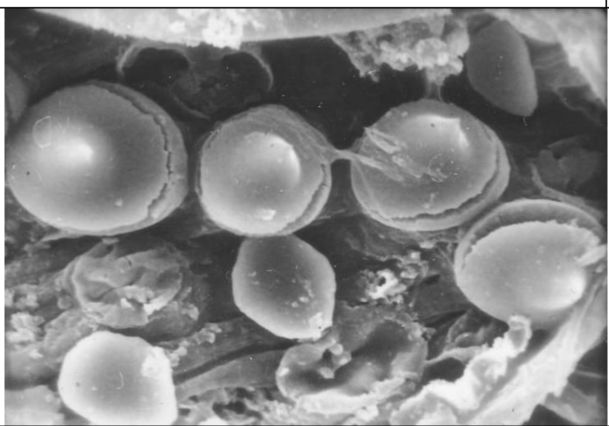
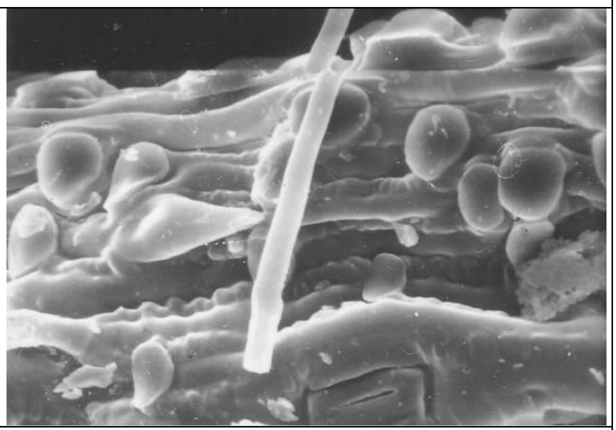
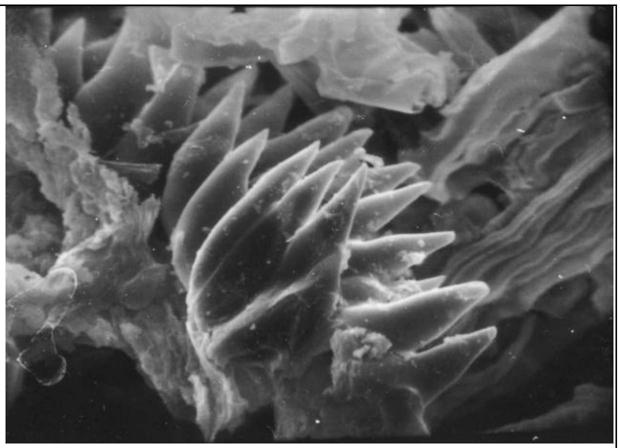
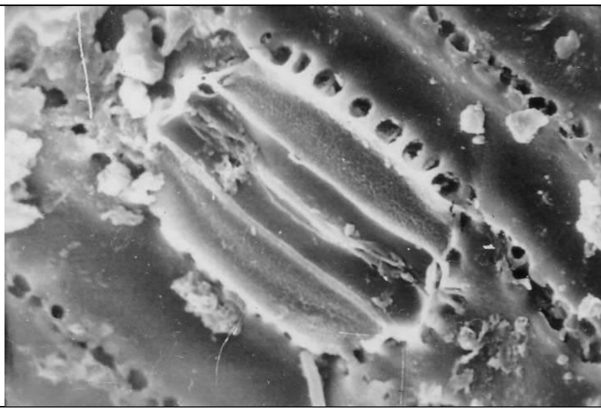
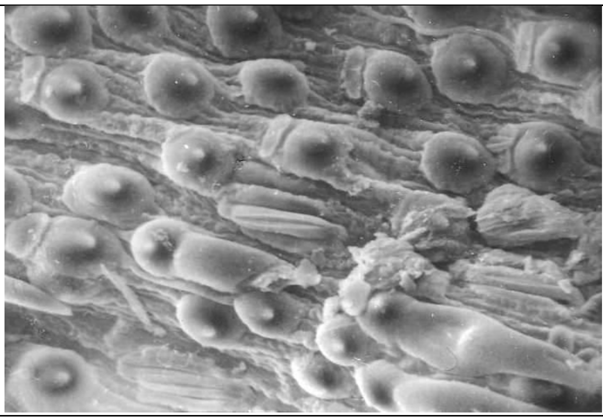
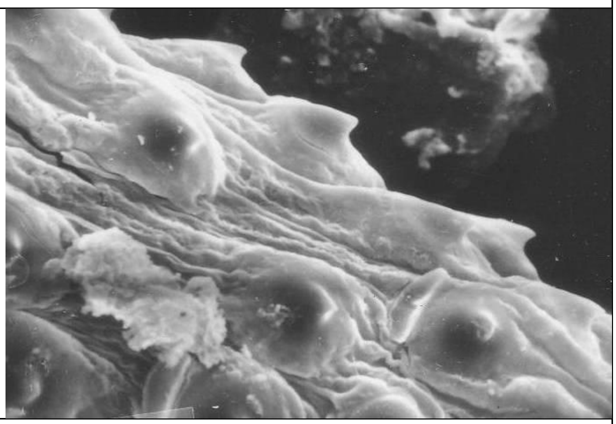
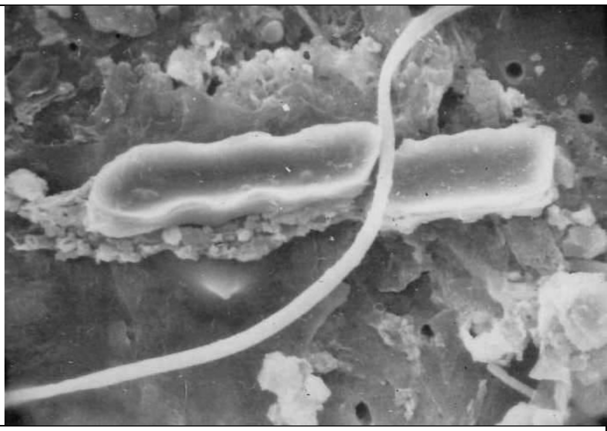
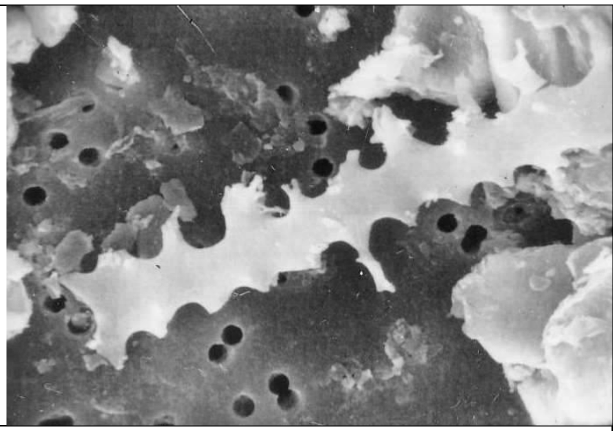
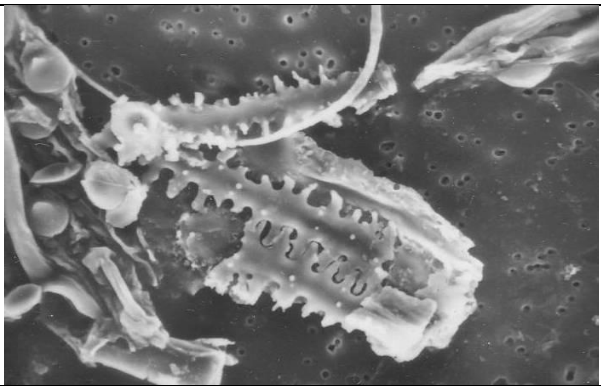
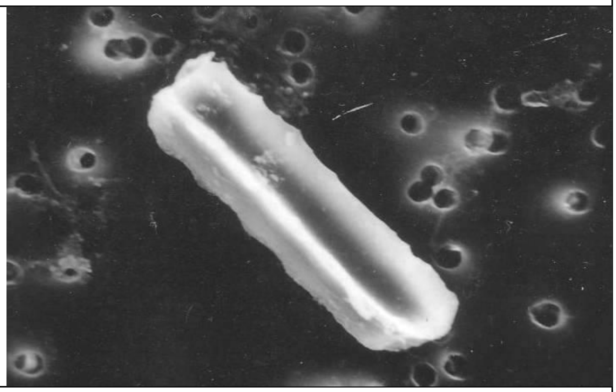
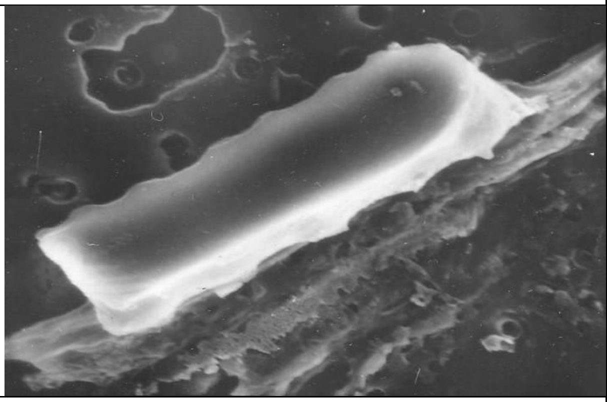
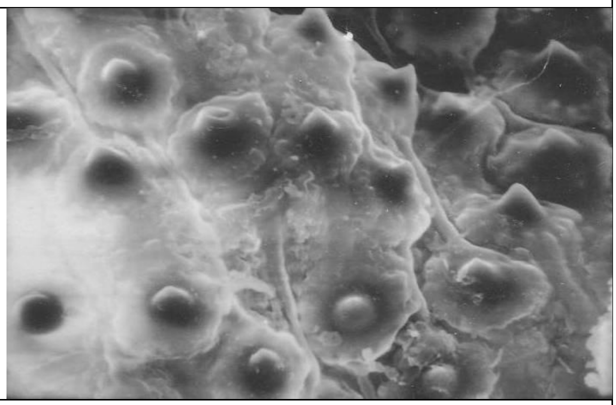
	
X1200	X1000
5	6
	
X600	X1500
Brachypodium rupestris	
1	2

	
X300	X1000
3	4
	
X4000	X3500
5	6
	
X3000	X1000
Briza australis	
1	2

	
X600	X600
Bromus arvensis	
1	
	
X1100	
Bromus commutatus	
1	2
	
X300	X600
3	4

	
X800	X1200
Bromus japonicas	
1	2
	
X1200	X1000
3	4
	
X1000	X1200
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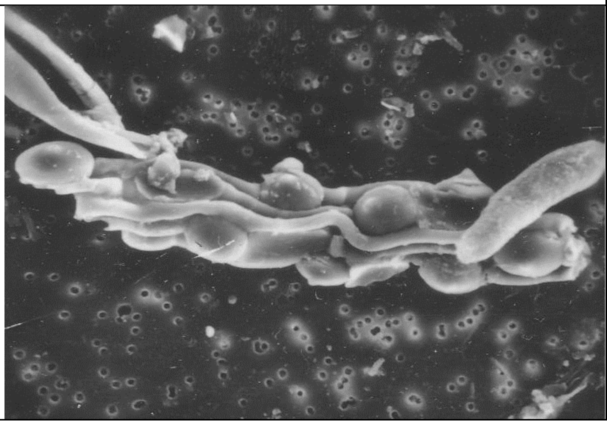
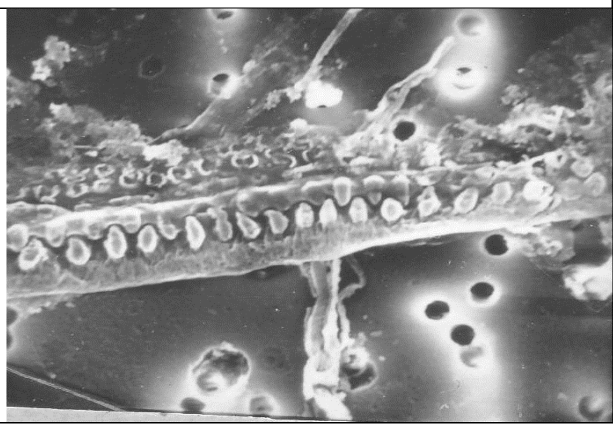
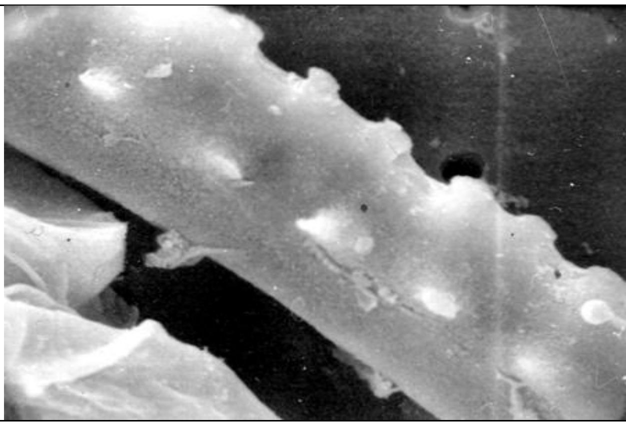
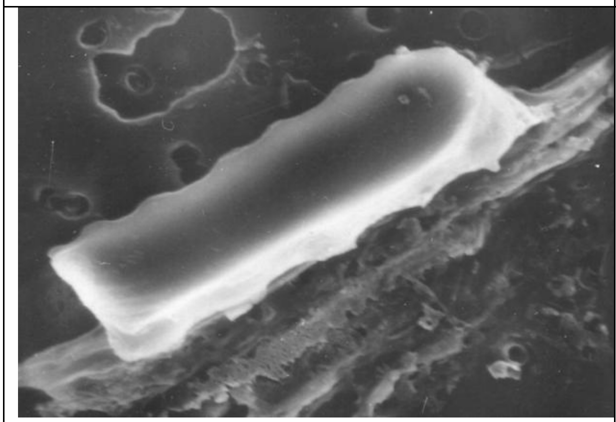
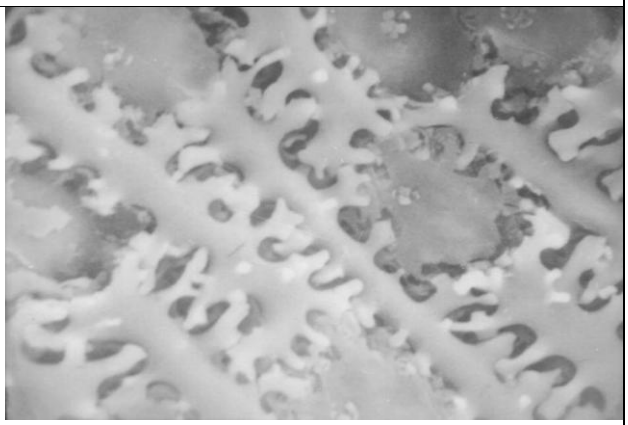
	

X1000	X300
Bromus riparius	
1	
	
X1700	
Bromus squarosus	
1	2
	
X1000	X633
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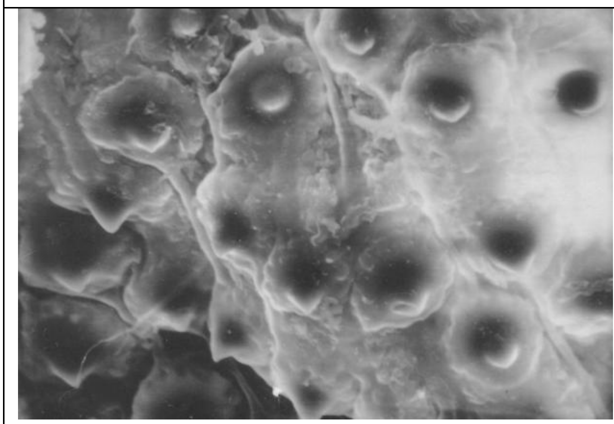
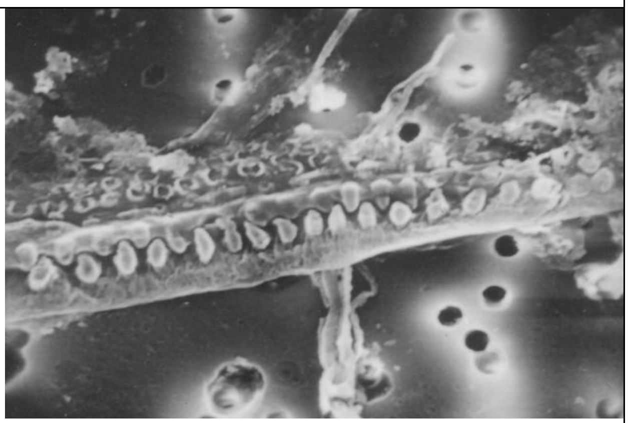
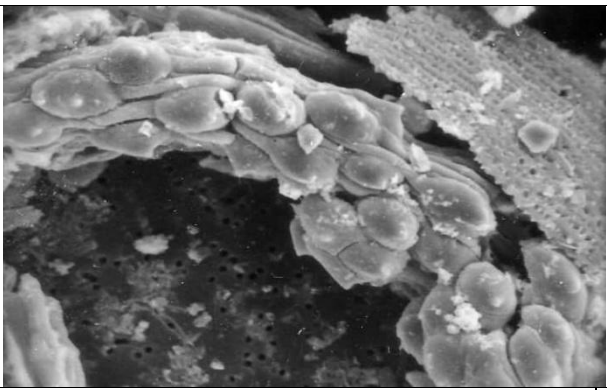
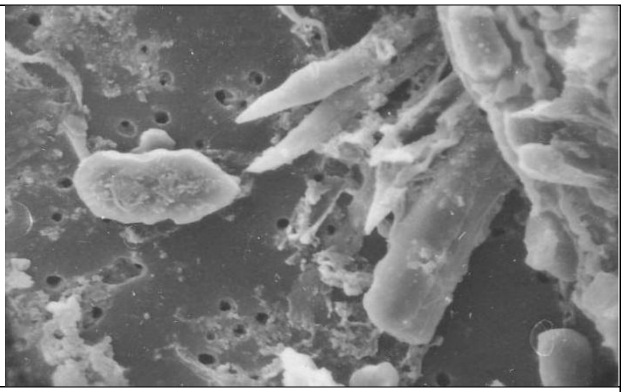
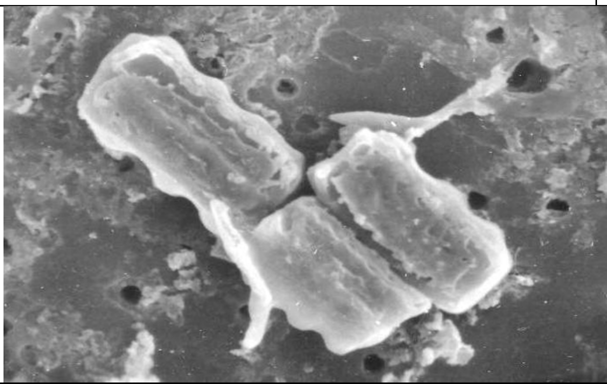
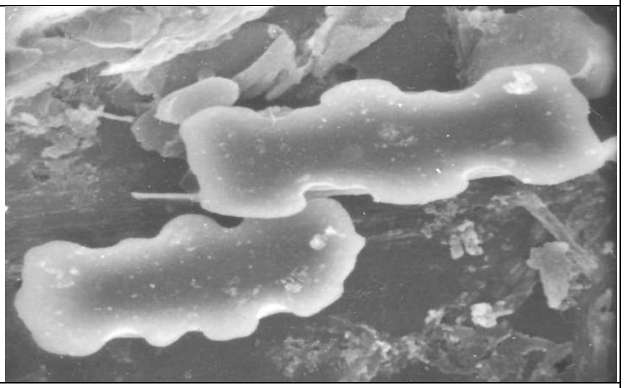
	
Bromus sterilis	
1	2

	
X300	X1200
3	4
	
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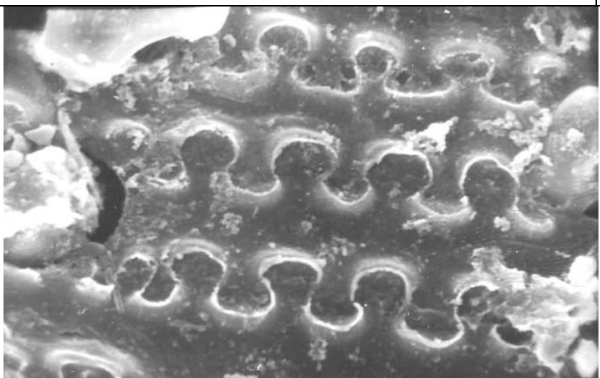	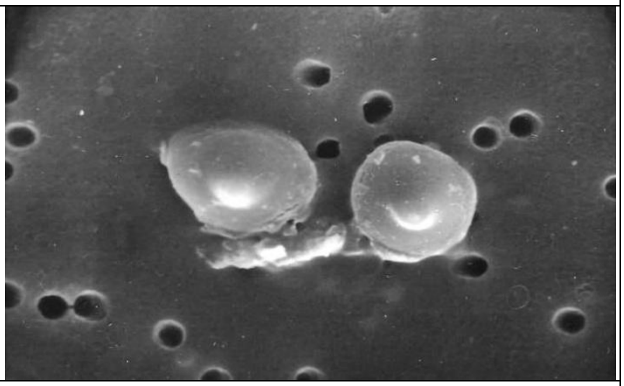
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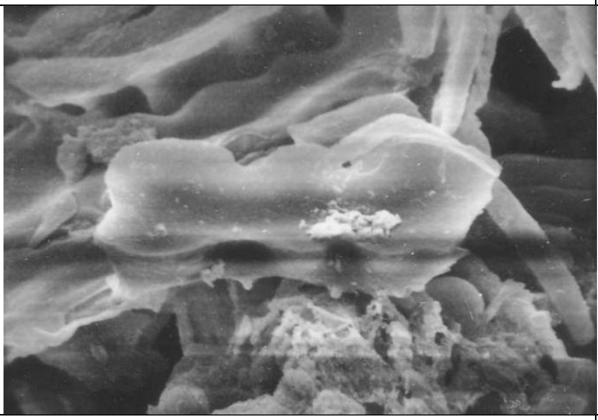
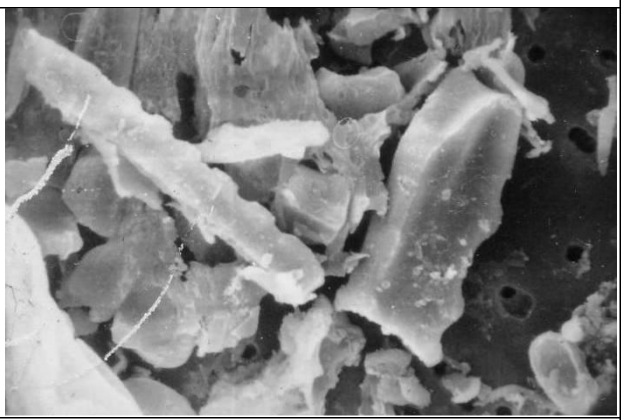
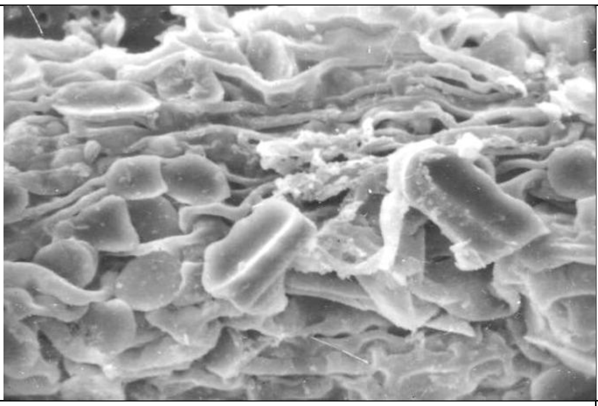
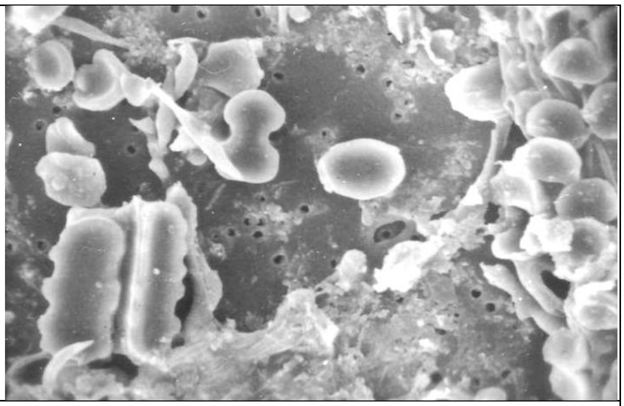
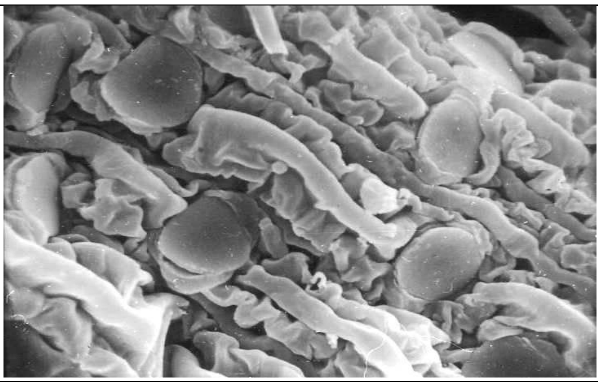
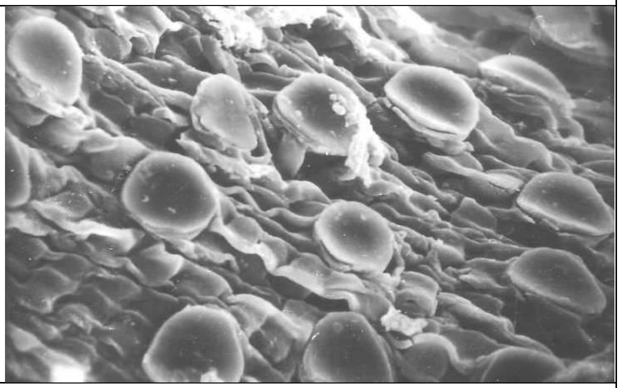
	
X1000	X1000
9	10

	
X630	X630
Bromus tectorum	
1	2
	
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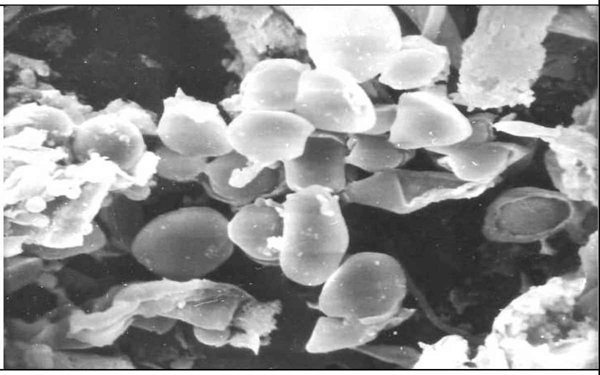	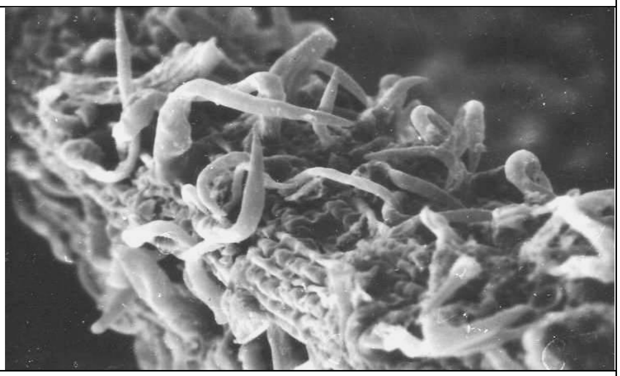
X400	X300
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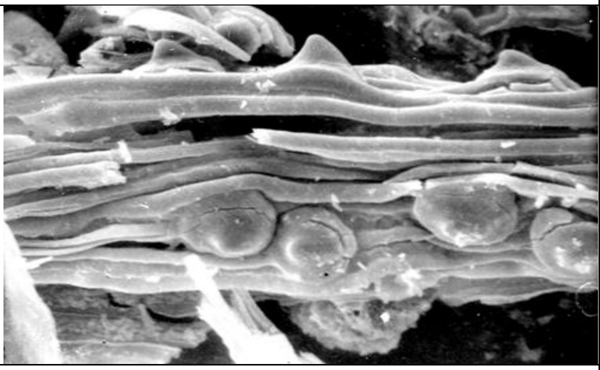	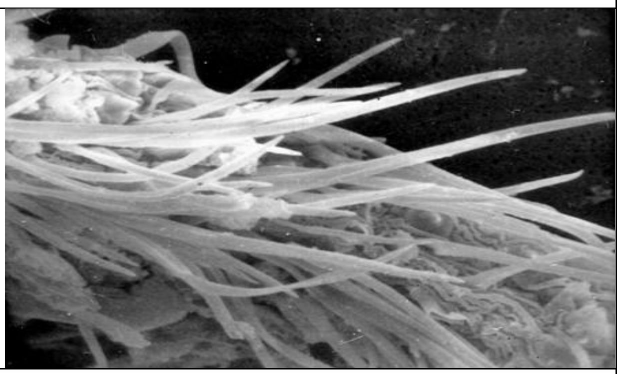
X400	X300
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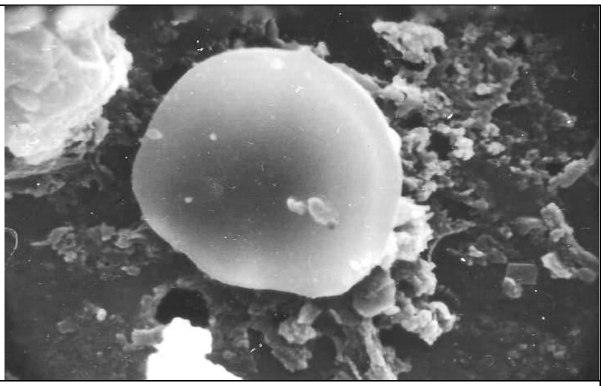
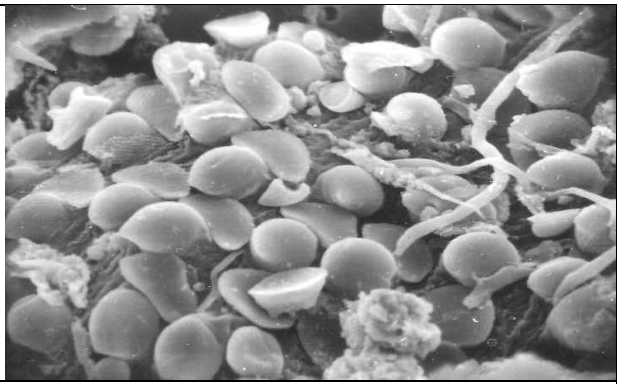
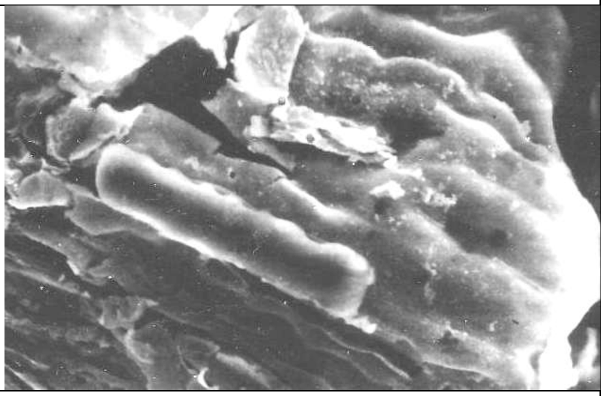
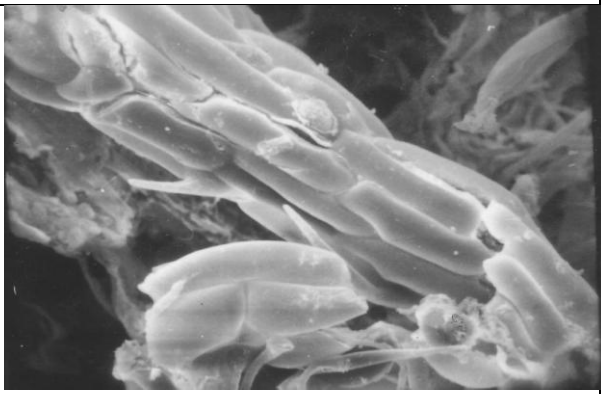
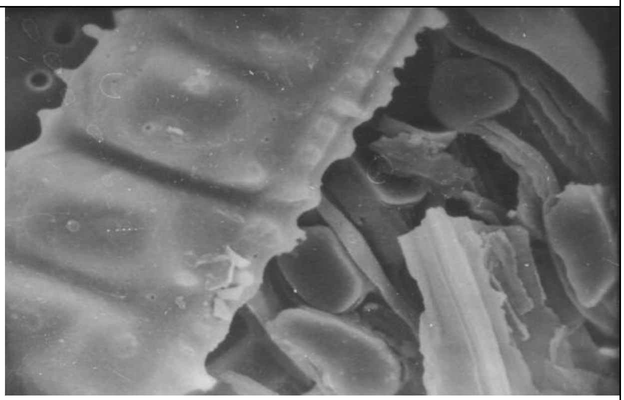
	
X1000	X100
Calamagrostis canescens	
1	2
	
X1000	X300
3	4
	
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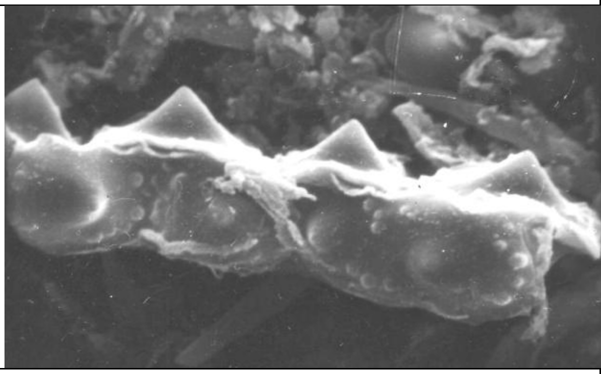
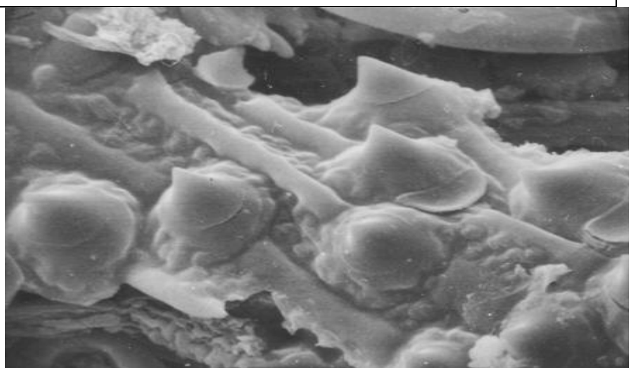
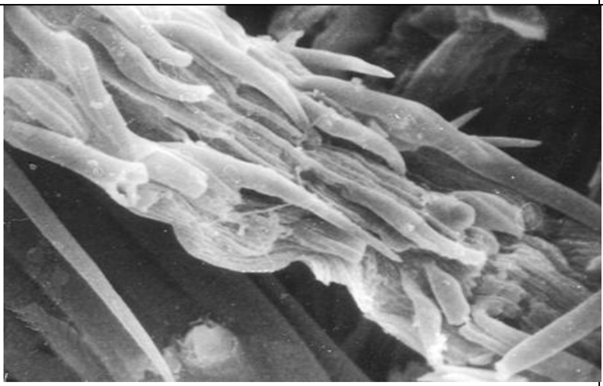
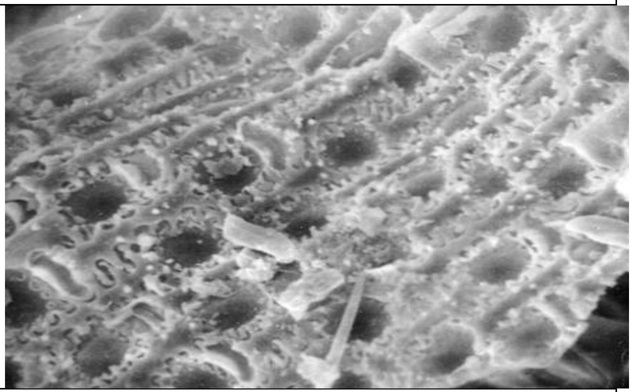
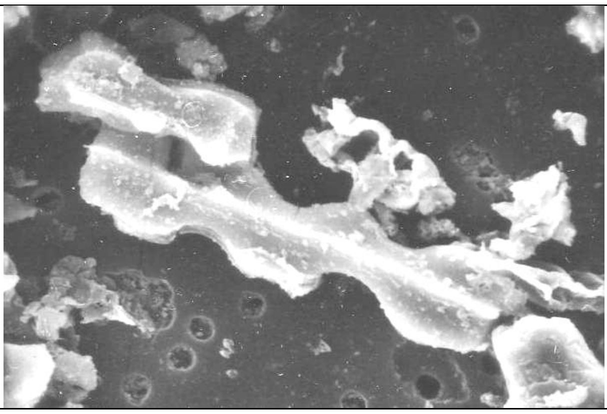
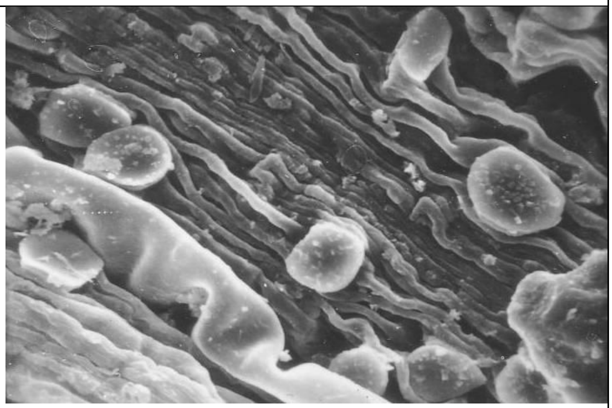
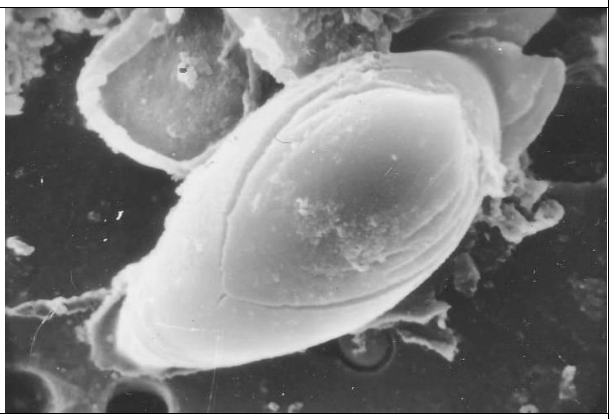
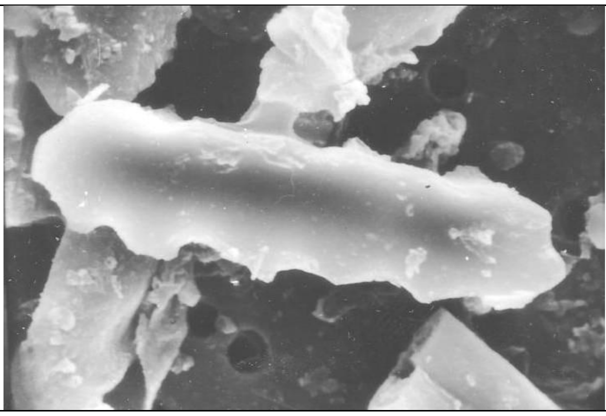
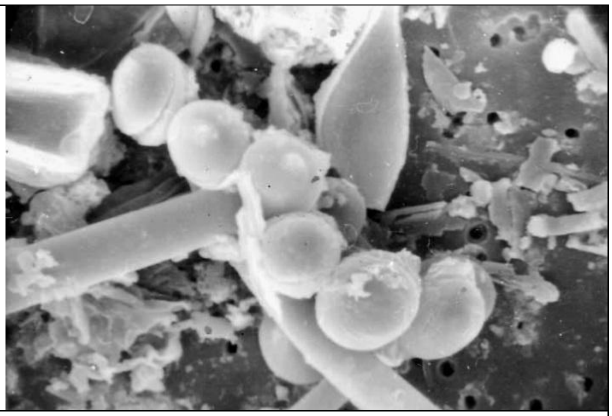
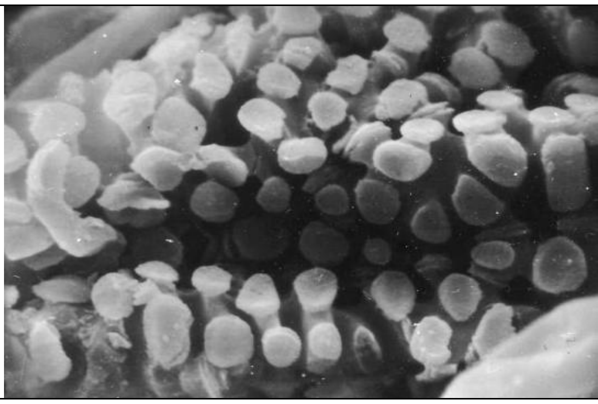
	
X1000	X1000

7	8
	
X100	X300
Élymus canínus	
1	2
	
X1000	X300
Elytrigia pseudocaesia	
1	2
	
X4000	X2100
3	4

	
X1200	X1200

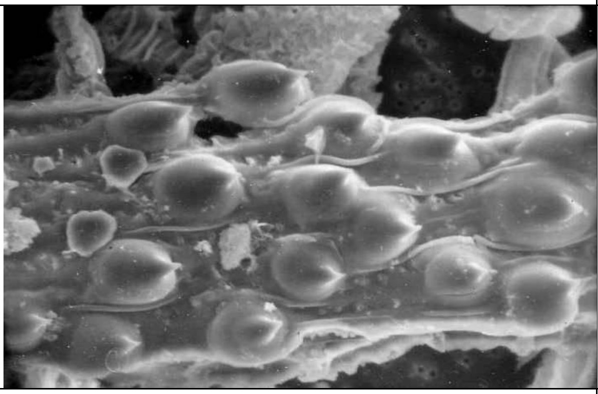
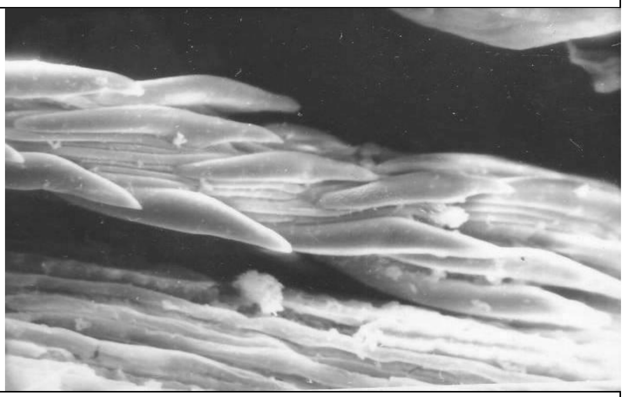
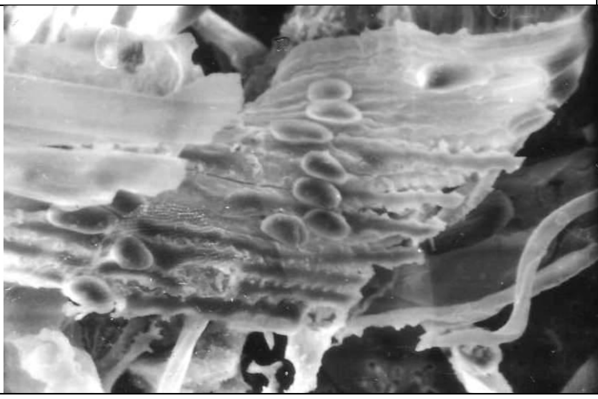
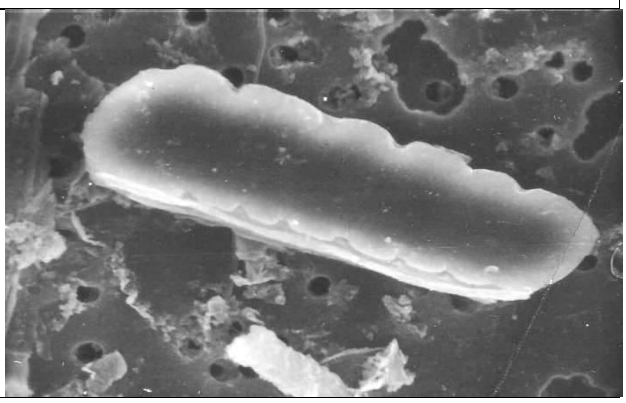
Festúca glauca

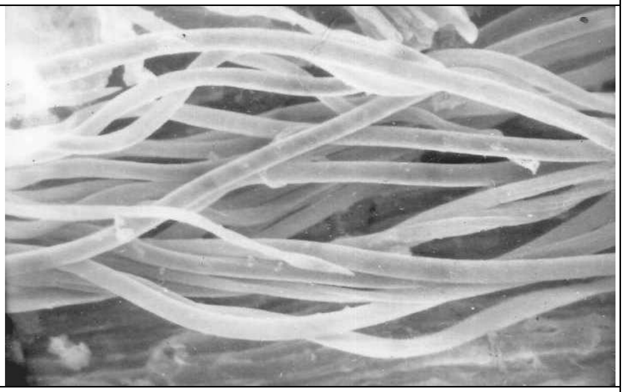
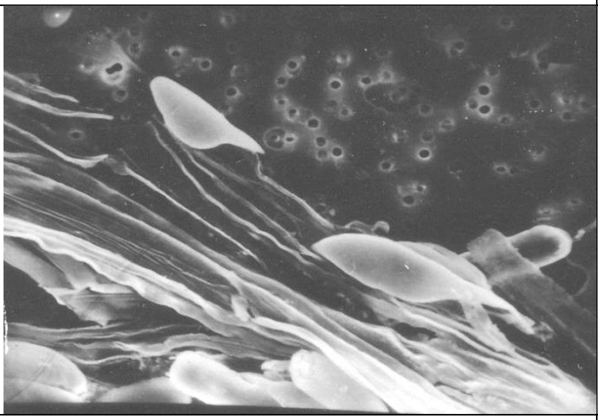
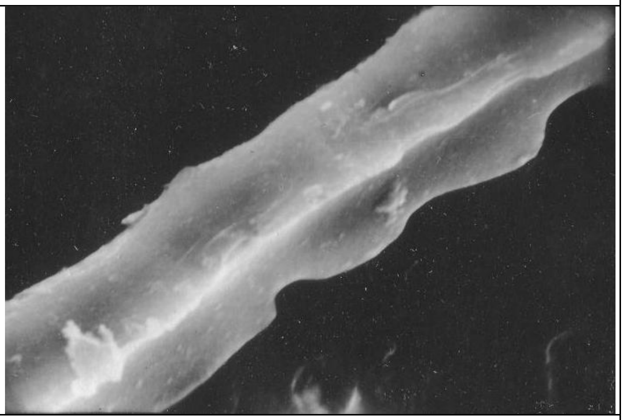
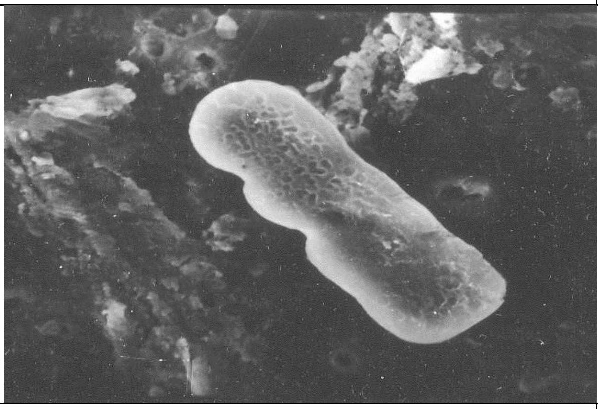
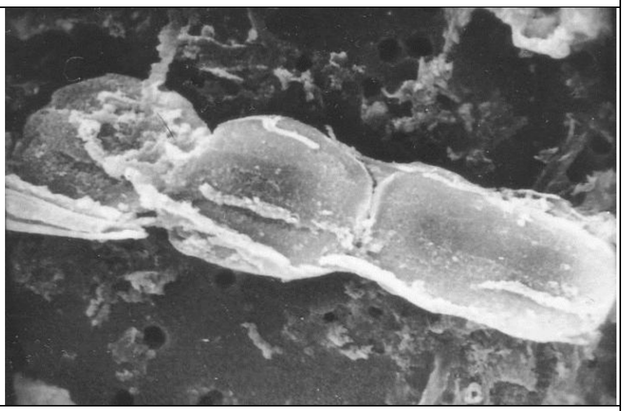
1

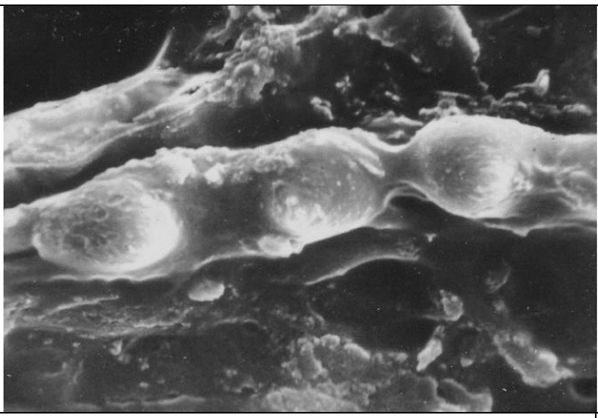
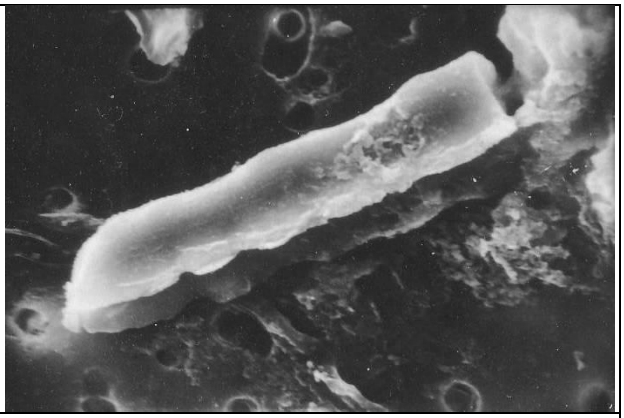
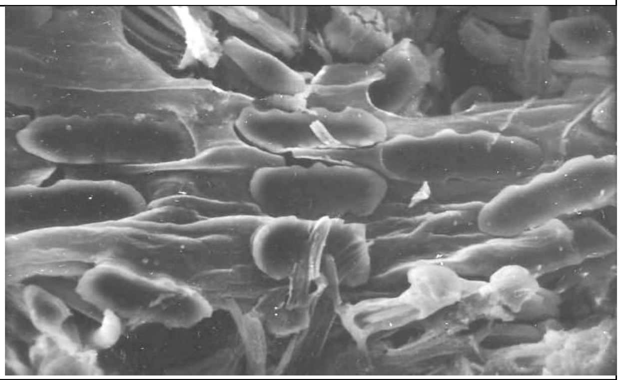
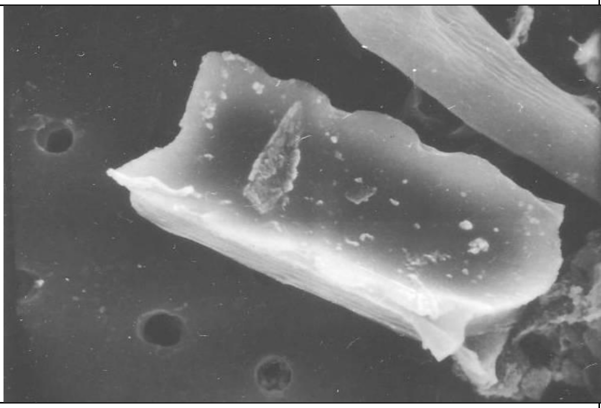
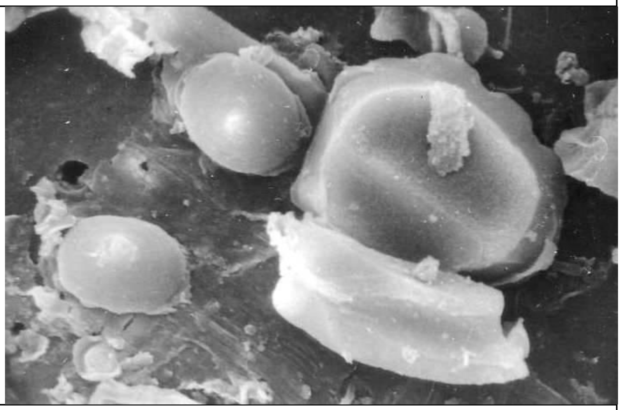


X1200

F. sulcata

1	2
	
X300	X300
3	4
	

X300	X1000
5	6
	
X300	X350
Hieróchloe repens	
1	2
	
X500	X3000
3	4
	
X1400	X1400
5	6

	
X1400	X2400
Hólcus lanátus	
1	2
	
X300	X1000
3	4
	
X2000	X600
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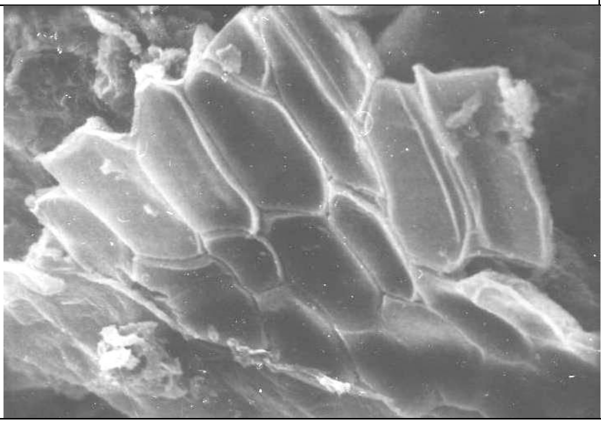
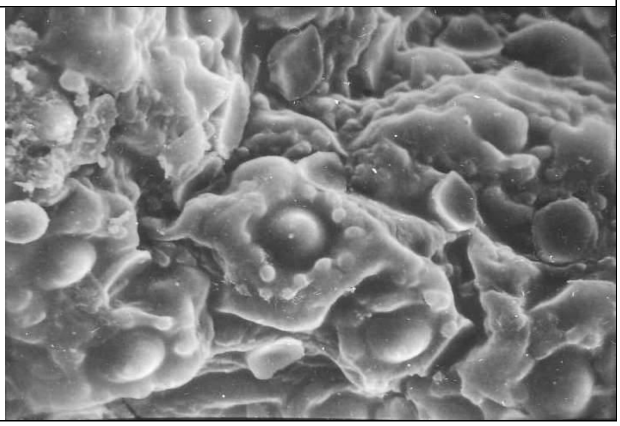
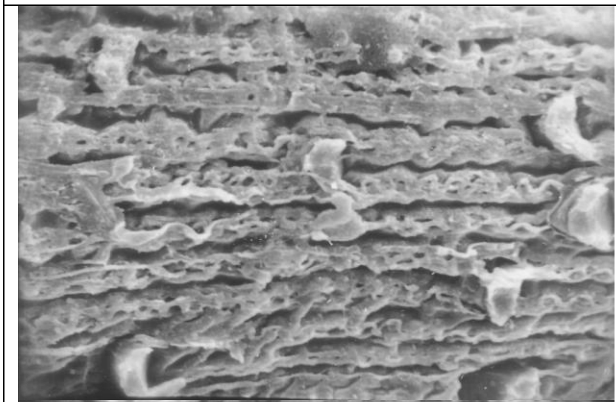
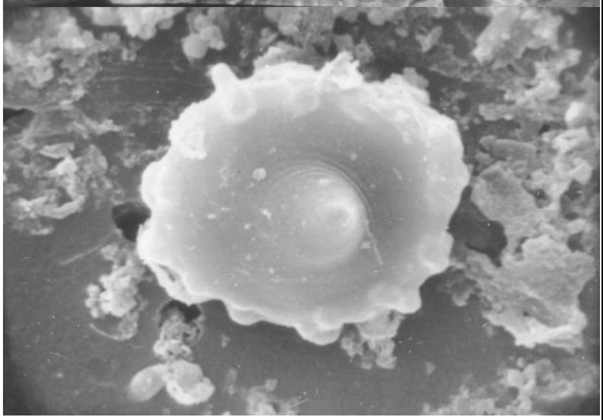
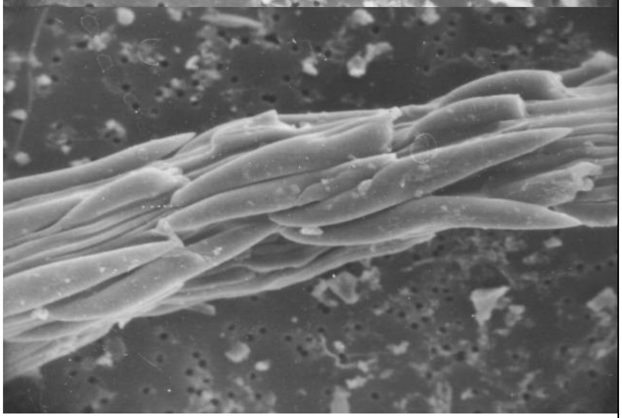
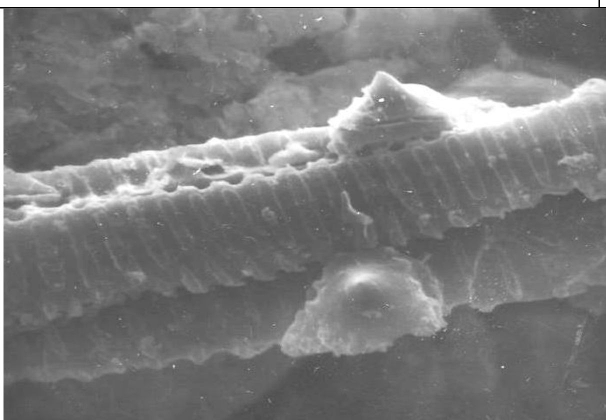
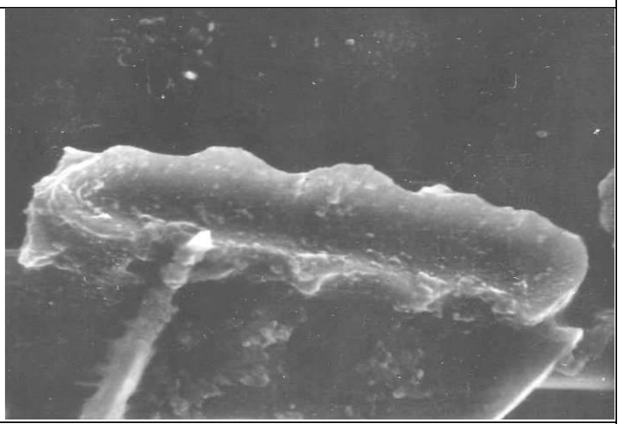
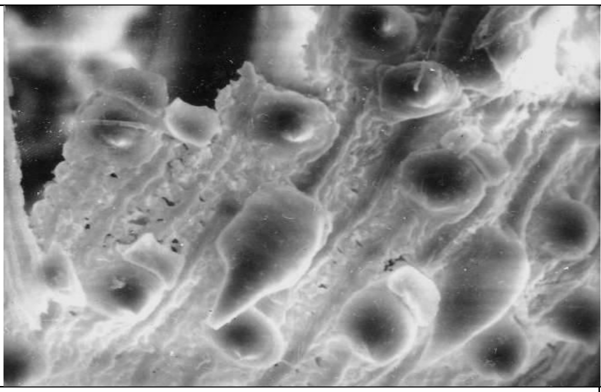
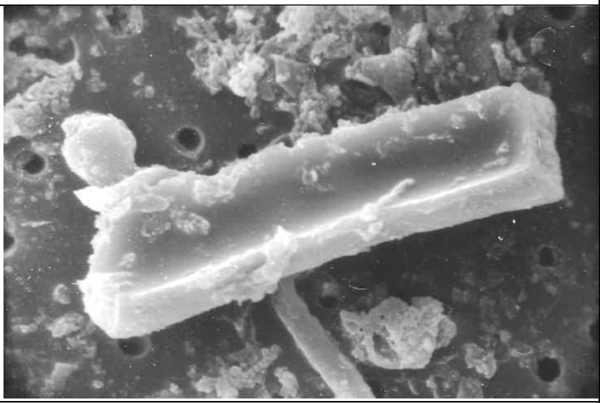
	

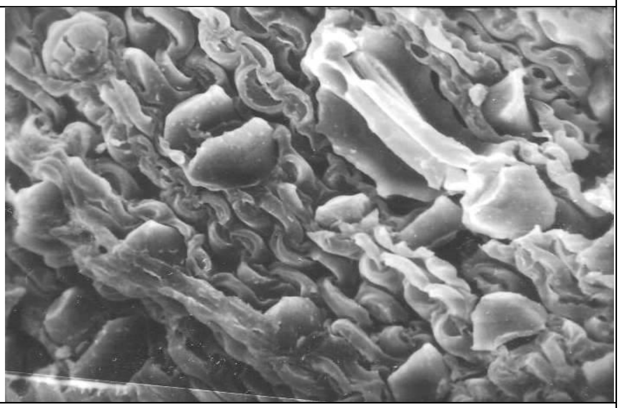
X1000	X1200
Hordeum murinum	
1	2
 	 
X3500	X300
3	4
Koelēria cristata	
1	2
	
X600	X2000
Koelēria glāuca	
1	2



X1000 X1200

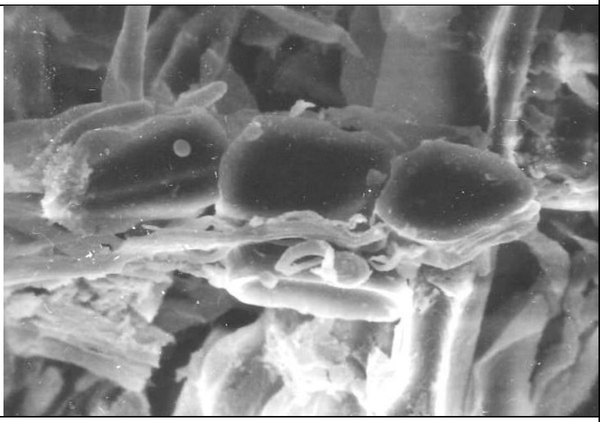
3 4

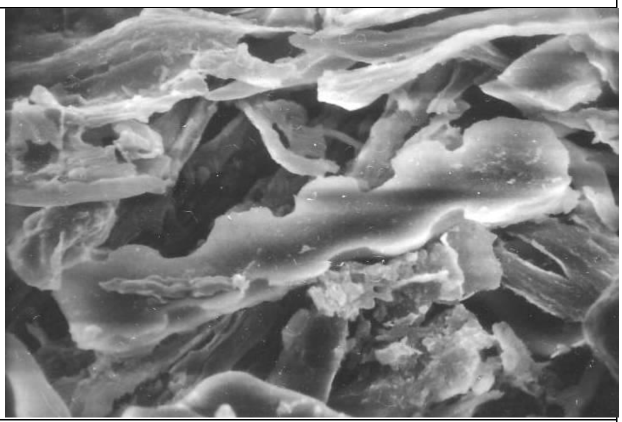




X1000 X1000

5 6

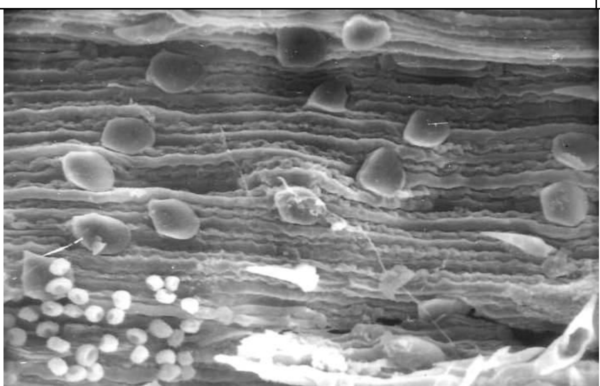


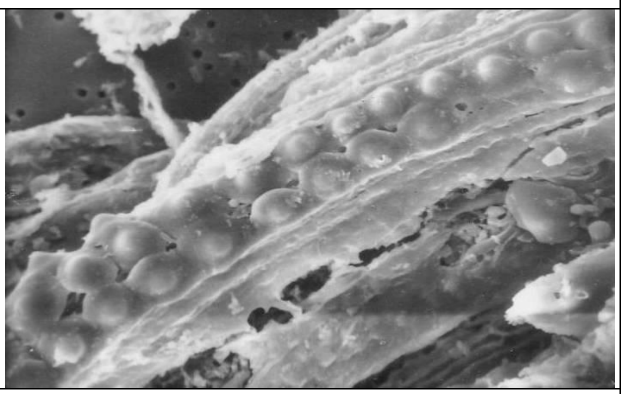


X1200 X1000

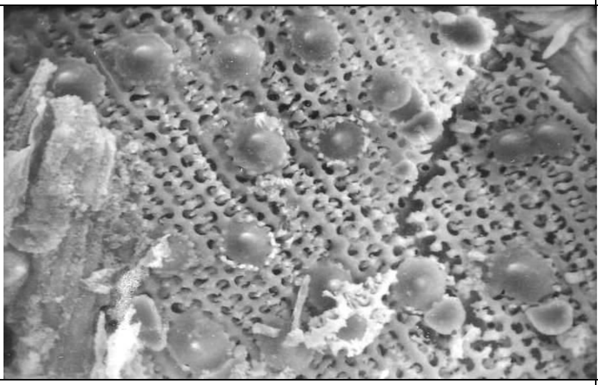
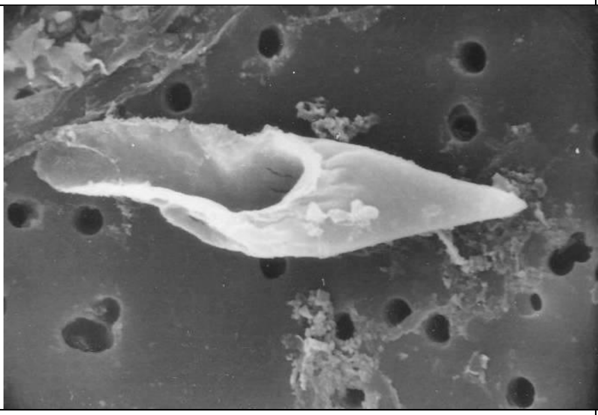
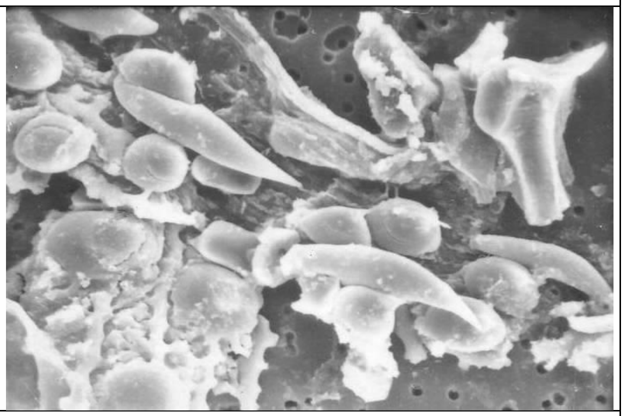
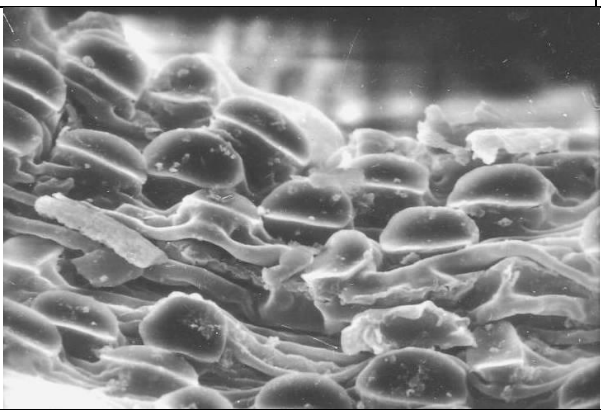
Phleum phleoides

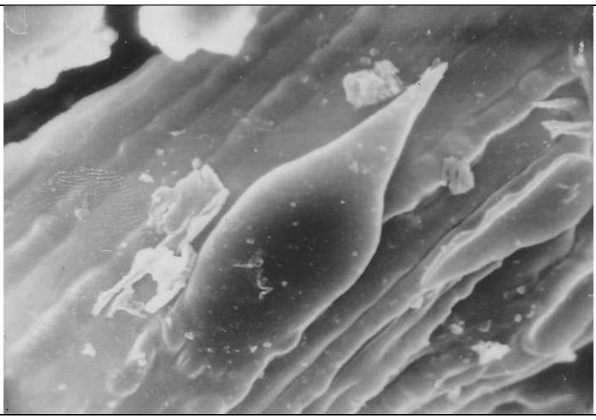
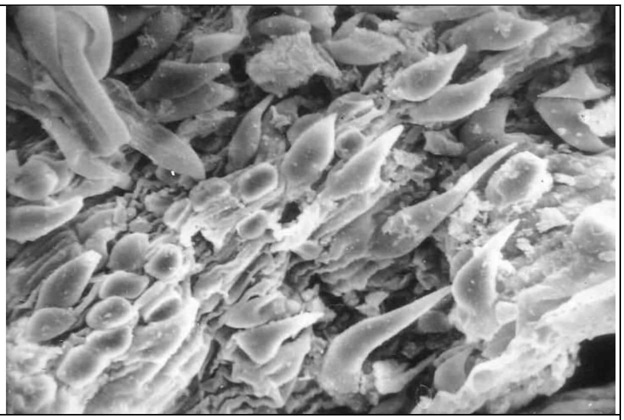
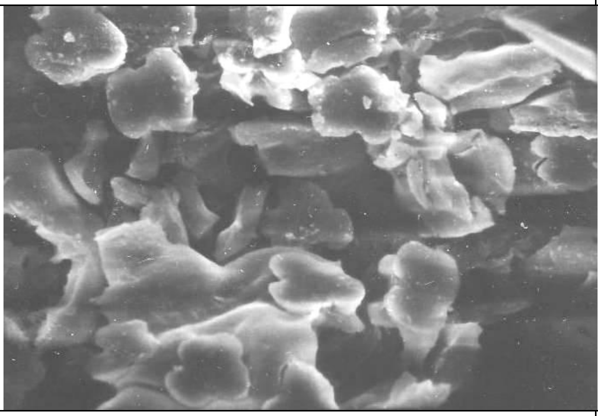
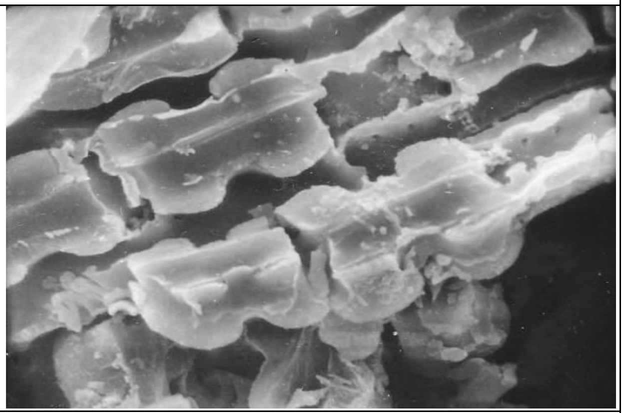
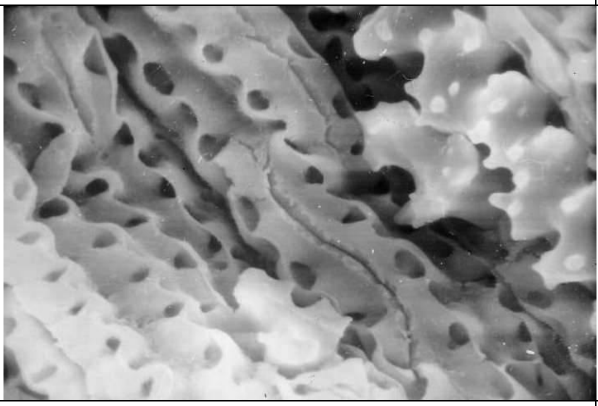
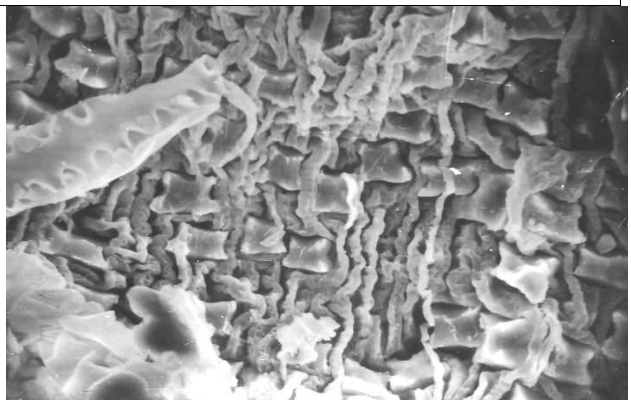
1 2

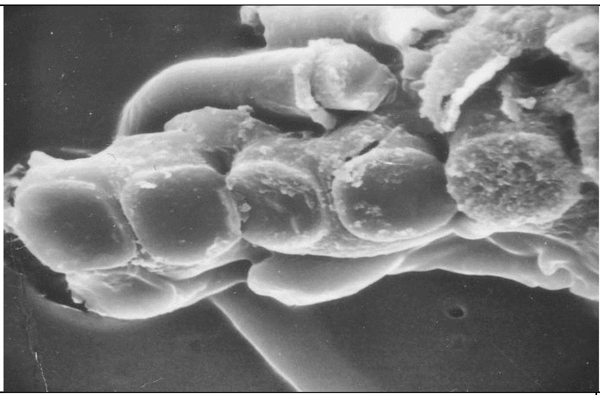
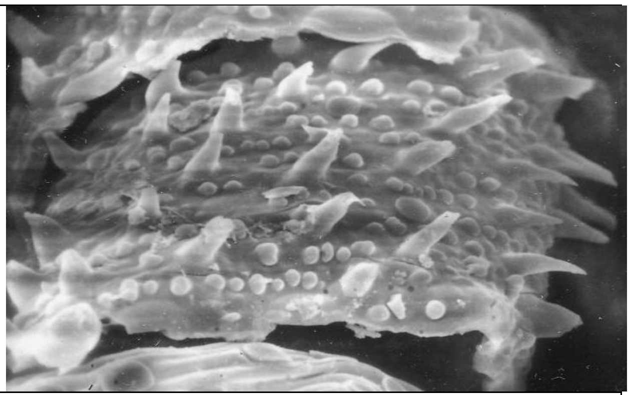
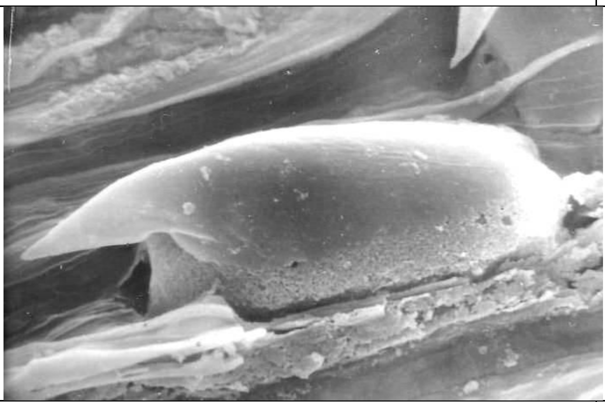
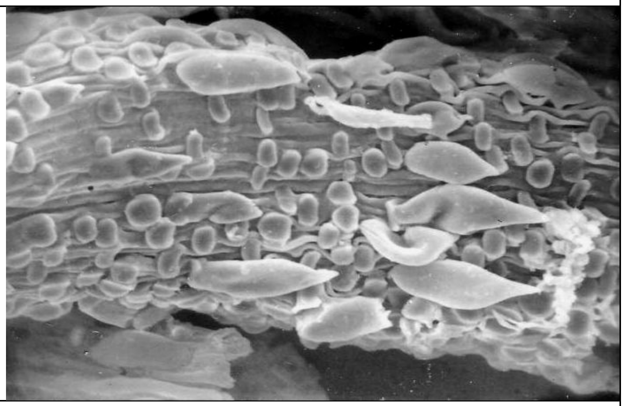
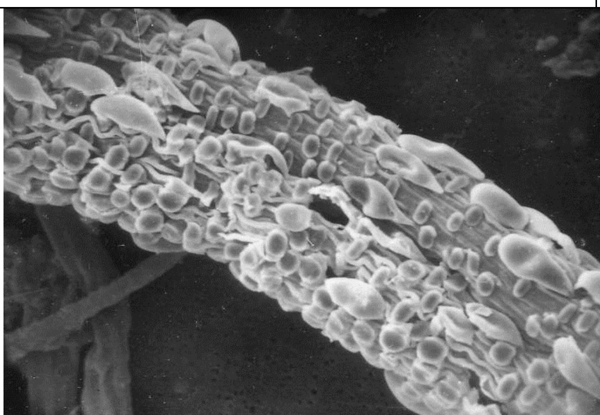
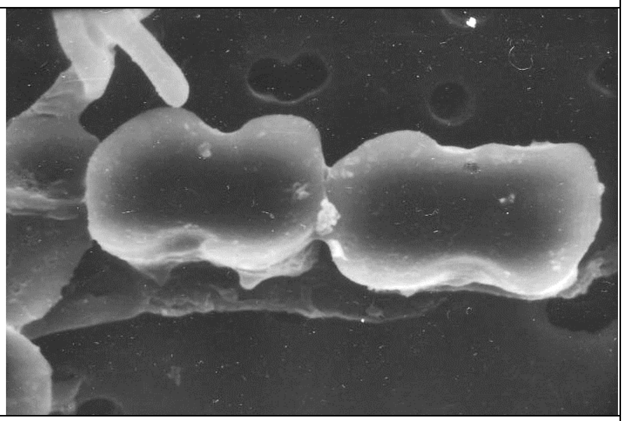
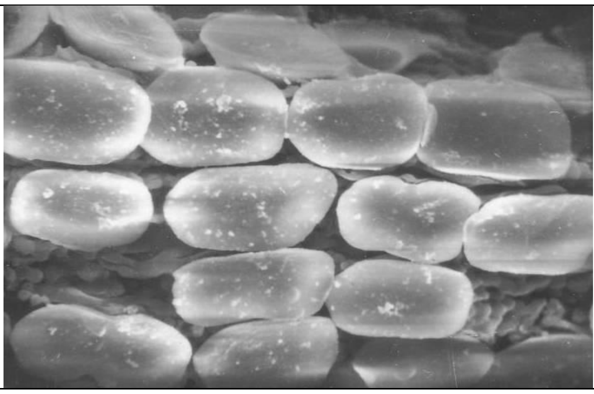
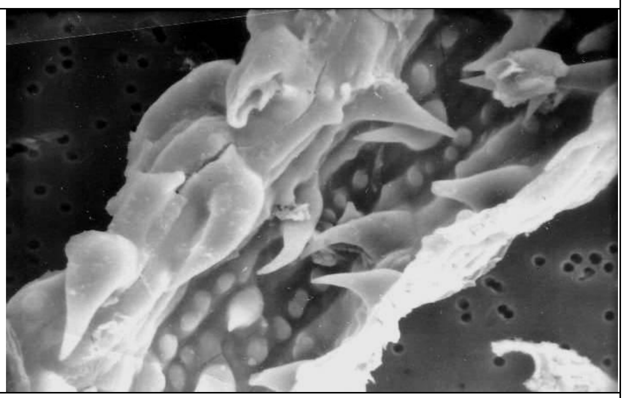


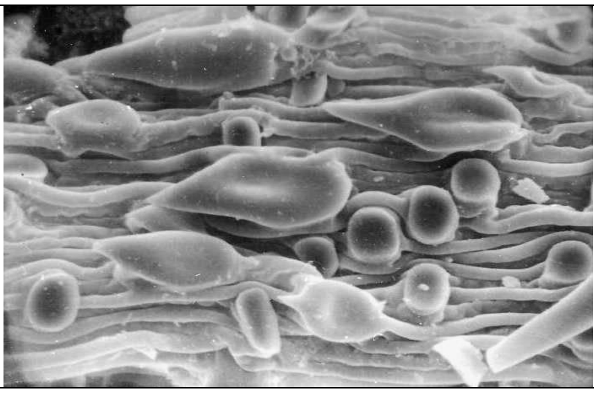
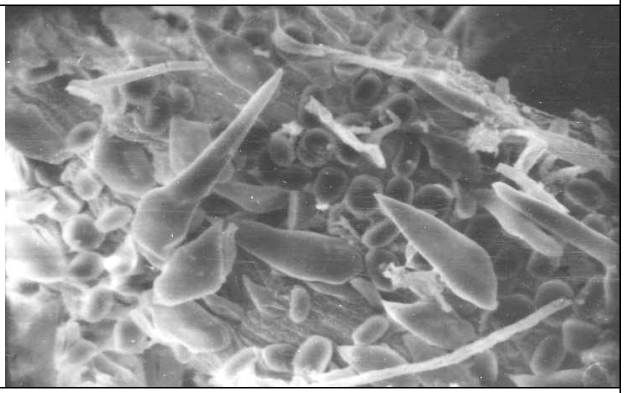
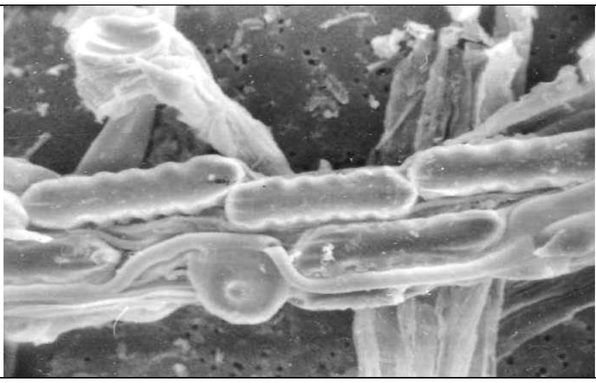
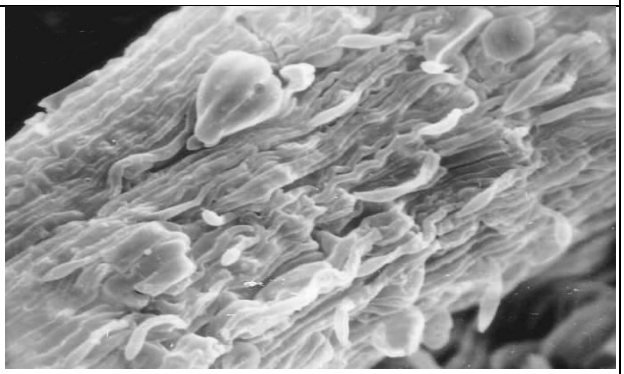


X2000 X300

3	4
	
X2000	X1000
5	6
	
X500	X300
Poa angustifolia	
1	2
	
X1000	X1000
3	4

	
X1000	X350
Sorgum halepense	
1	2
	
X630	X1200
3	4
	
X100	X400
Stipa capillata	
1	2

	
X500	X500
3	4
	
X1000	X500
5	6
	
X200	X2100
7	8
	
X500	X4200

Stipa dasyphilla	
1	2
	
X300	X300
Stipa lessingiana	
1	2
	
X650	X300
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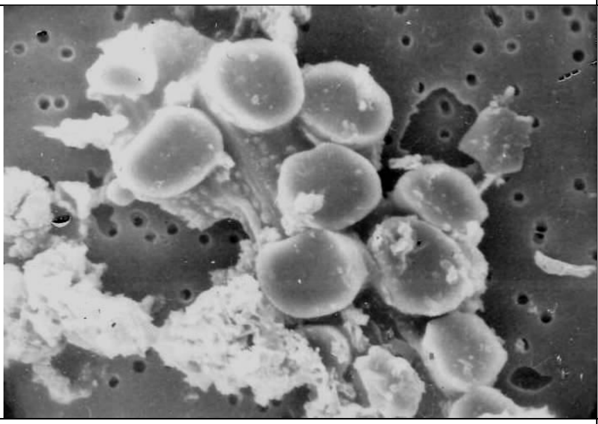	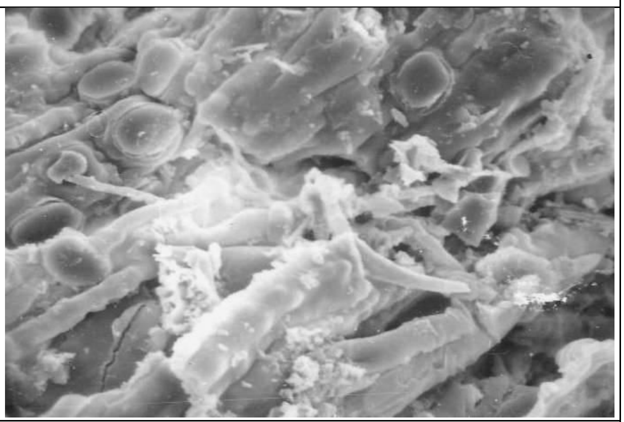
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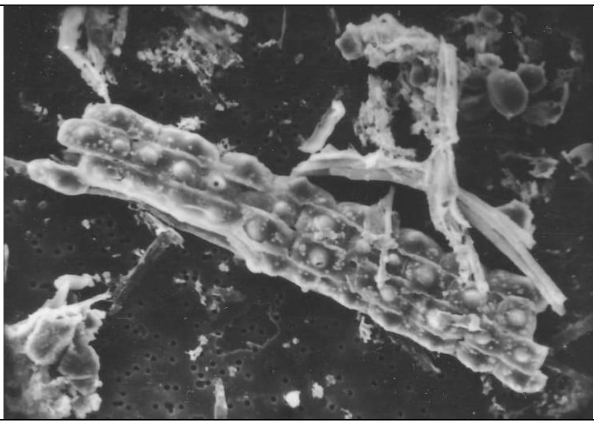
1	2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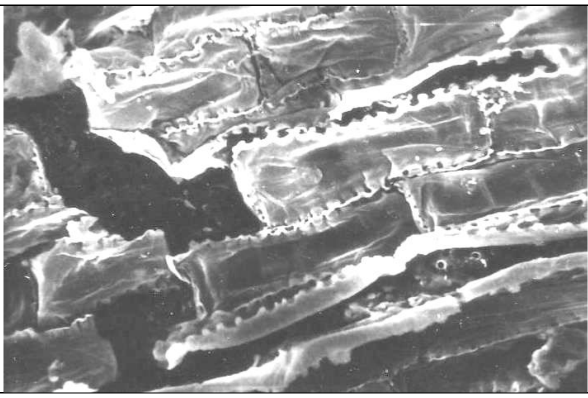	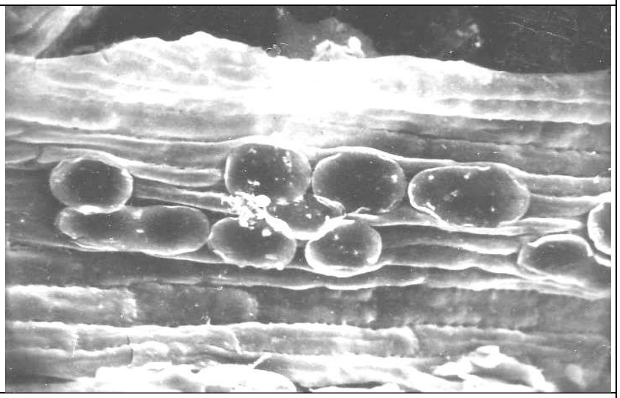
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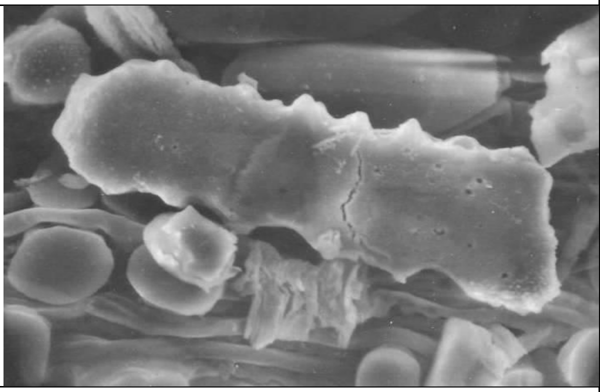
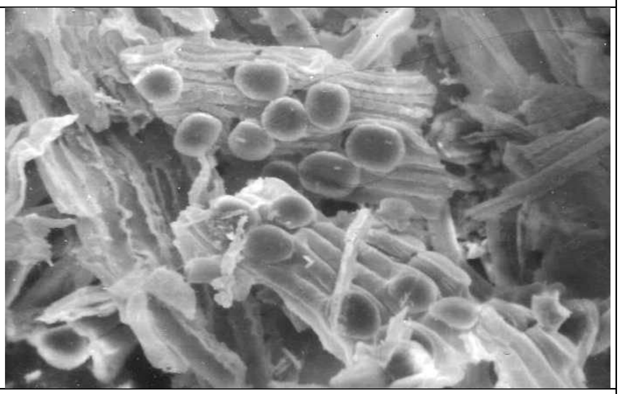
Stipa pennata	
1	2
	
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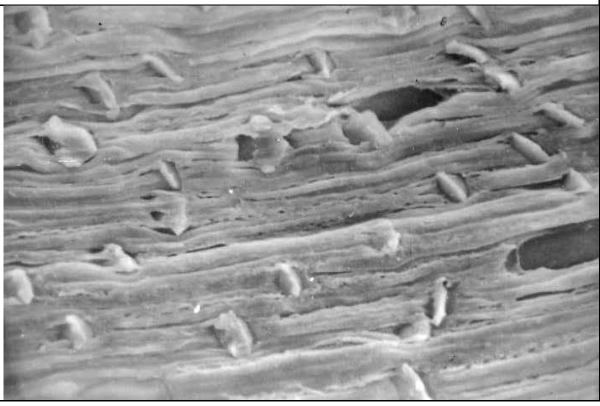
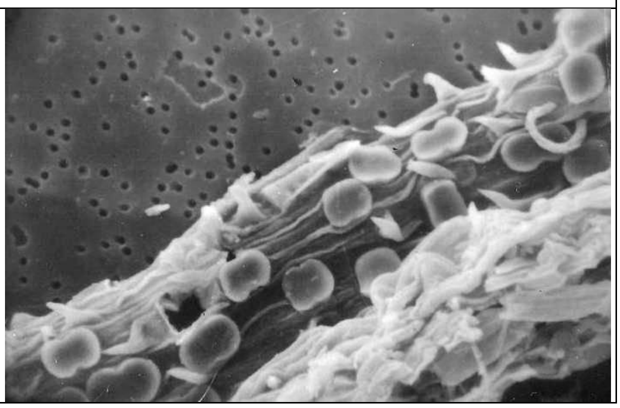
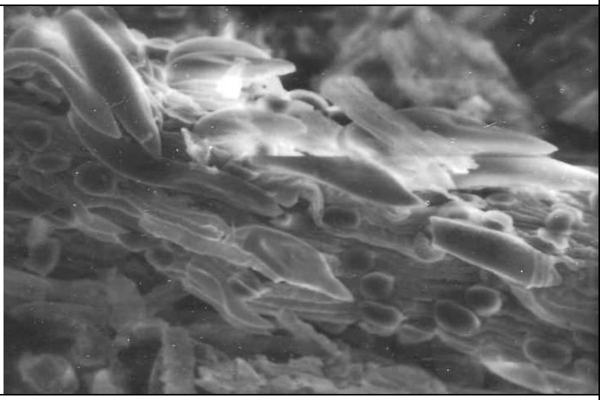
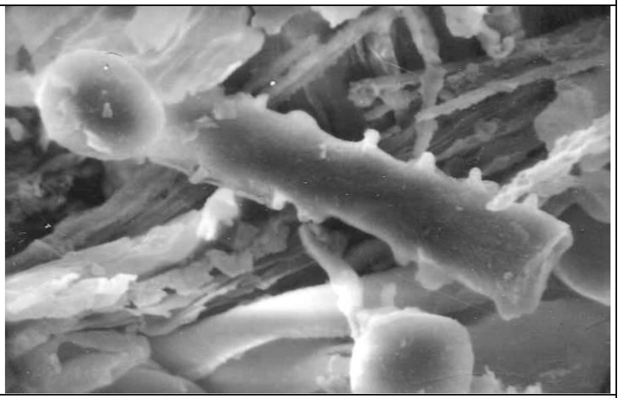
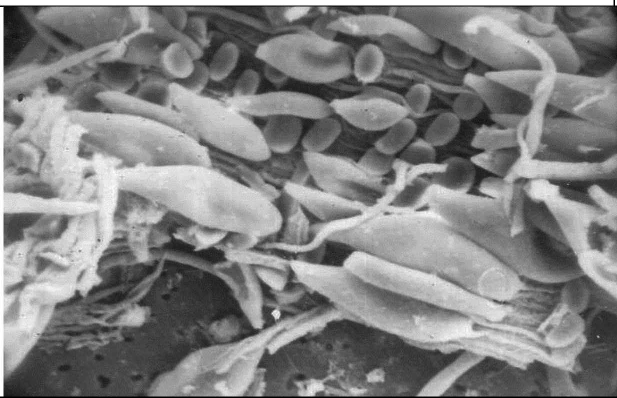
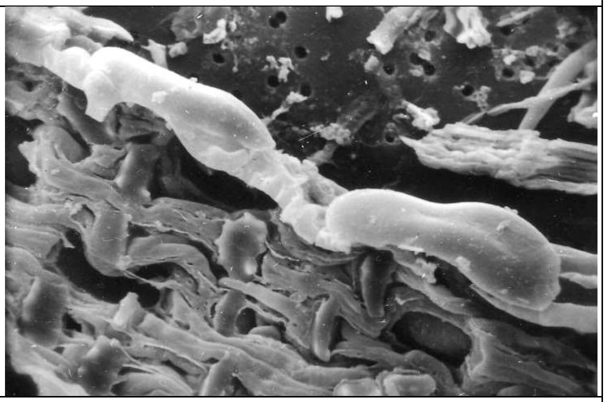
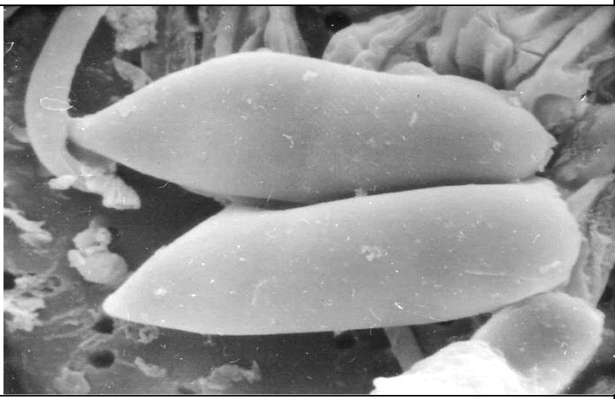
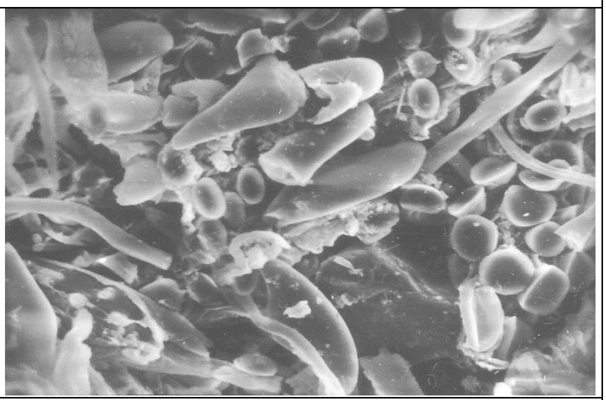
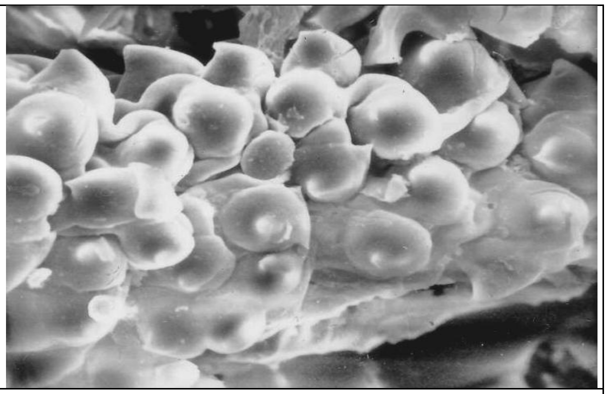
3	4
	

X300	X300
5	6
	
X1000	X1000
Stipa pulcherrima	
1	2
	
X1000	X1000
3	4
	
X300	X1200
5	6

	
X1200	X1000
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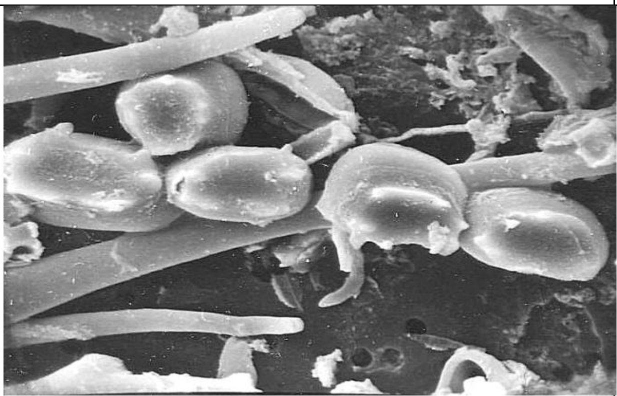
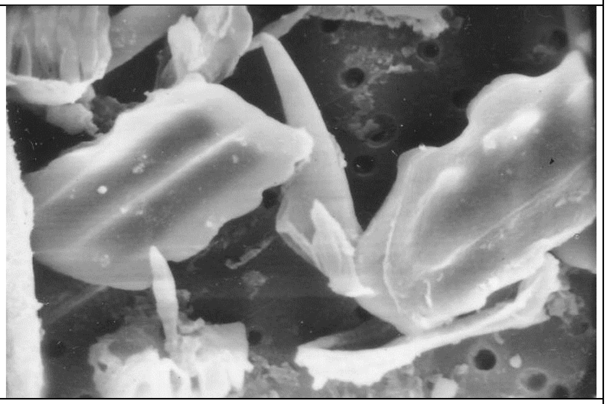
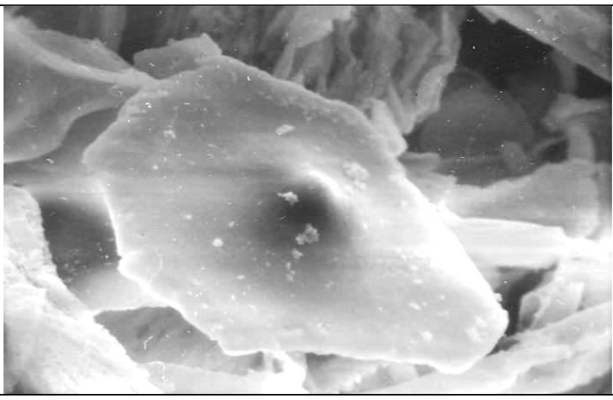
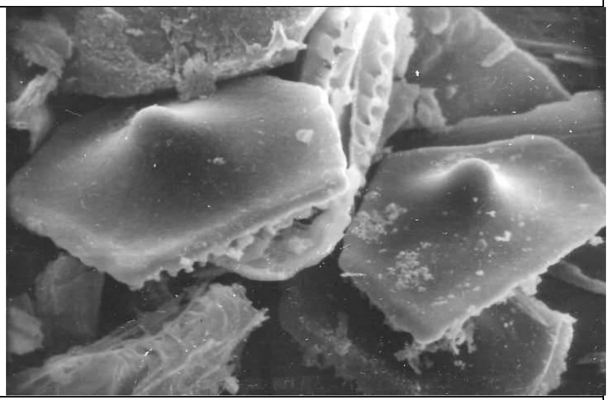
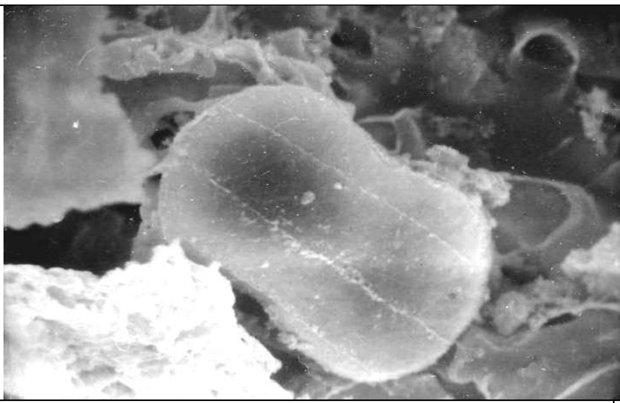
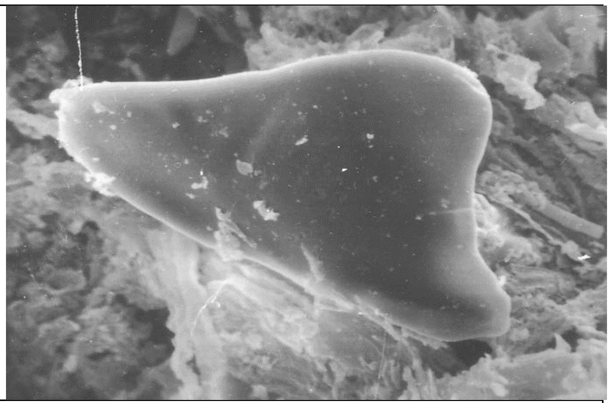
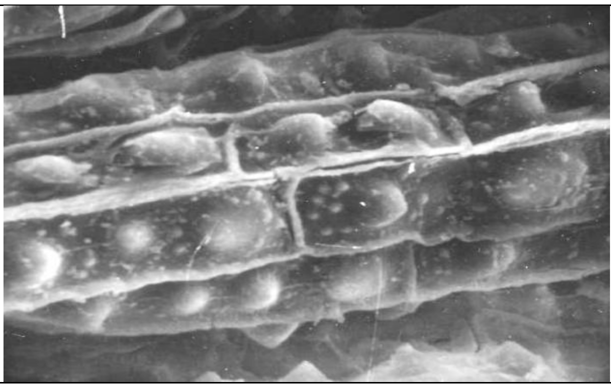
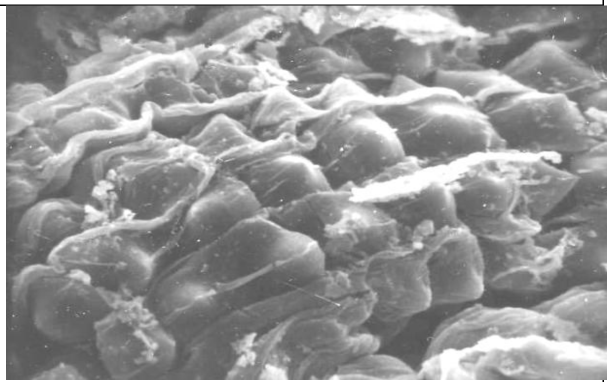
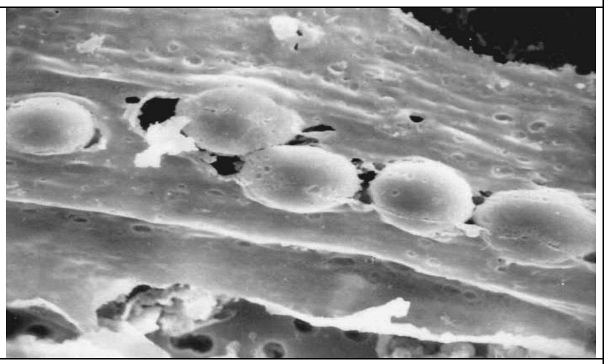
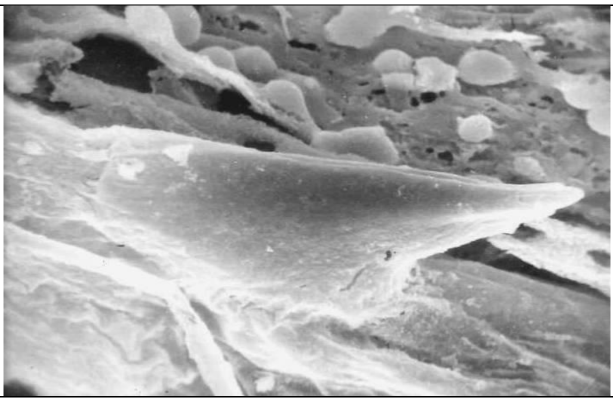
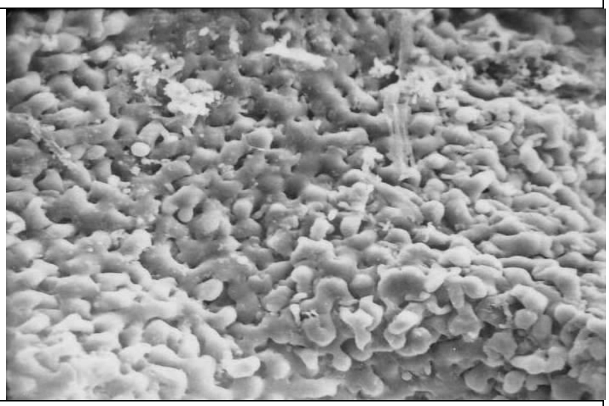
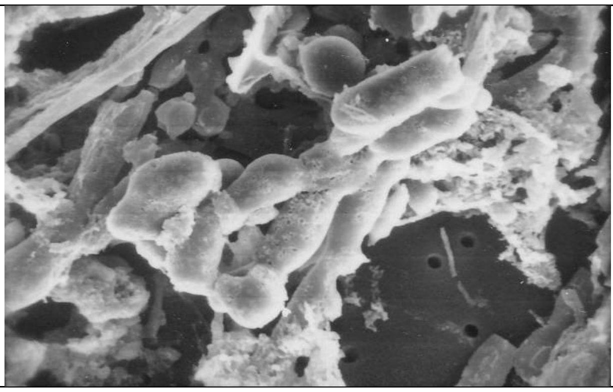
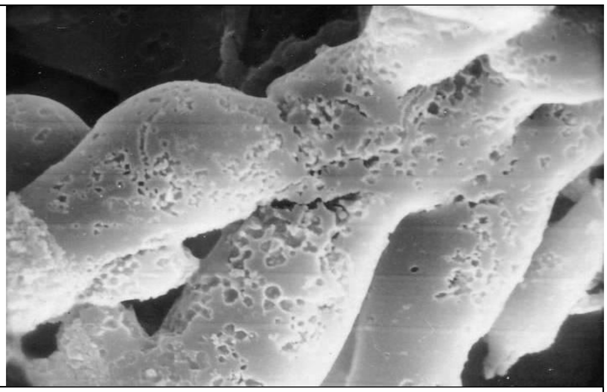
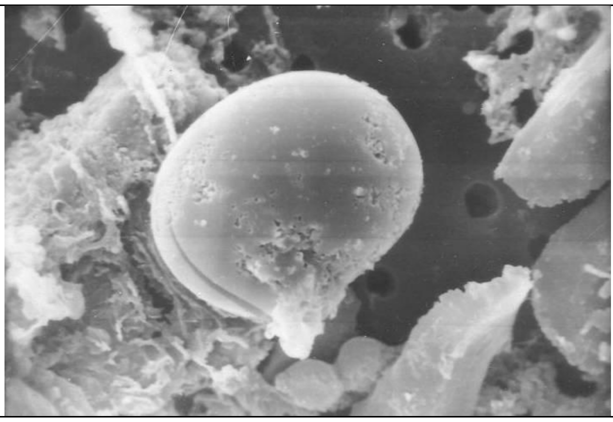
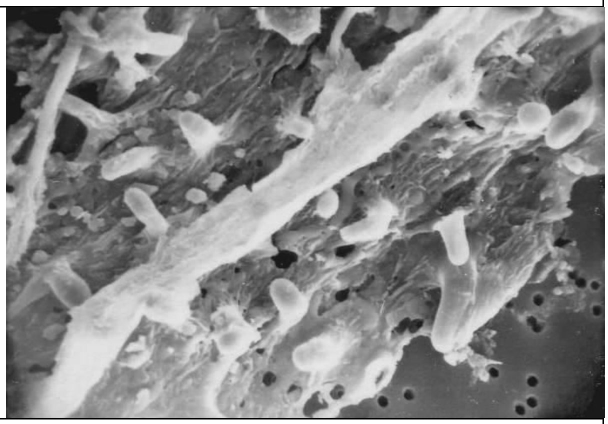
	
X630	X1500
Cyperaceae:	
Carex acutiformis	
1	2
	
X630	X630
Carex buekii	
1	2

	
x1000	x1000
3	4
	
X1000	X1000
Carex colchica	
1	2
	
X1000	X1200
3	4
	
X1200	X300
5	6

	
X2100	X2100
7	8
	
X1200	X1000
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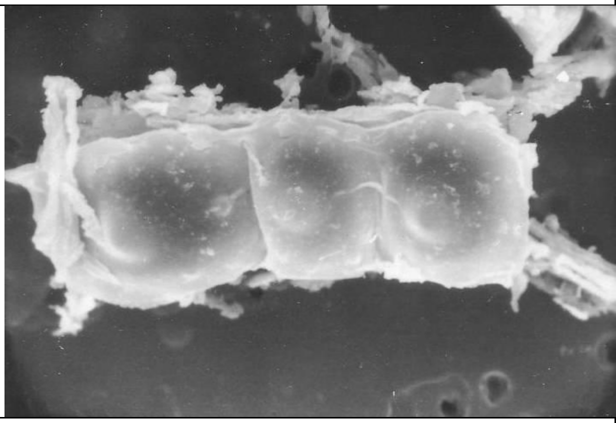
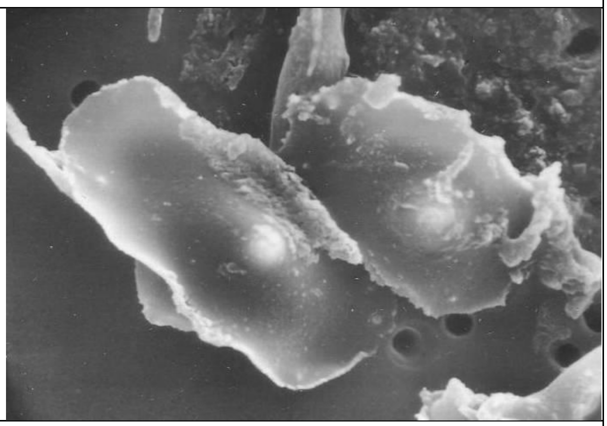
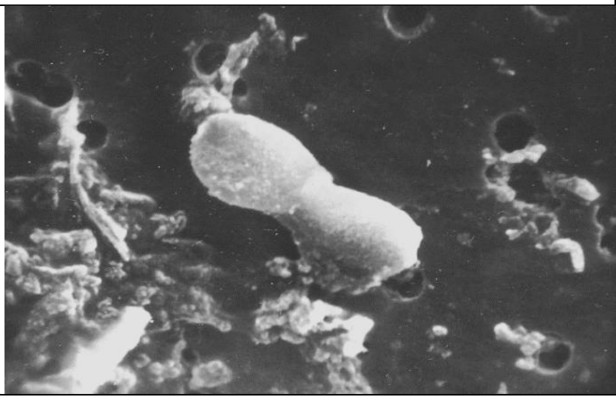
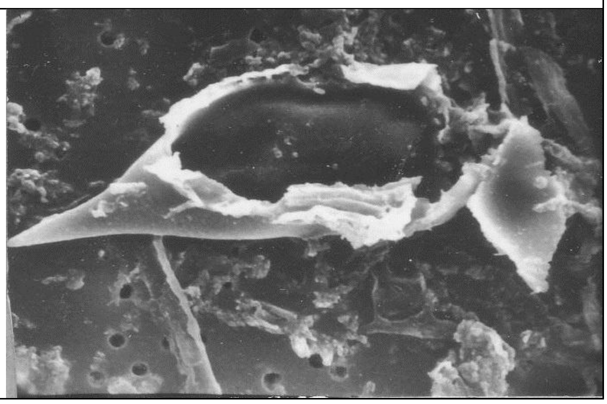
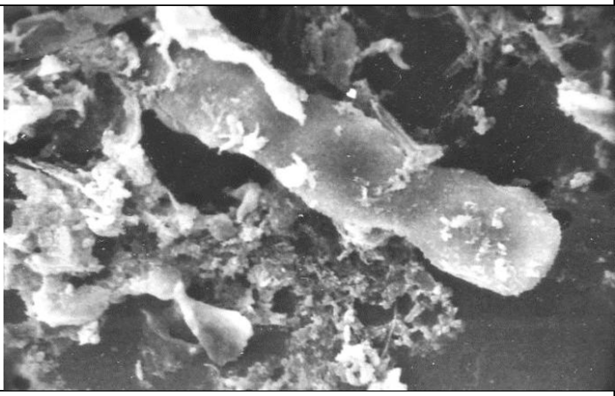
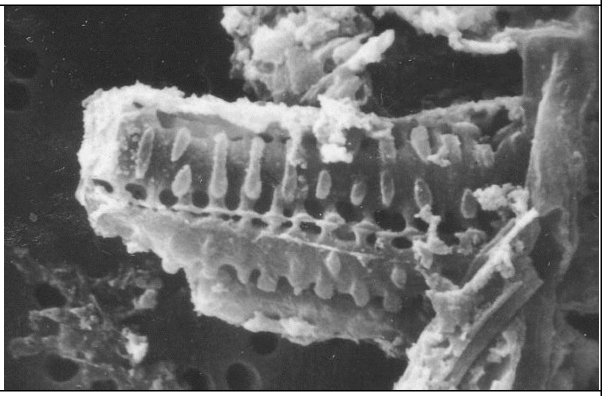
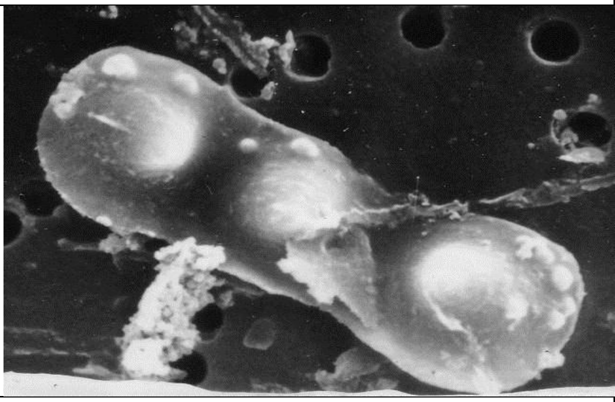
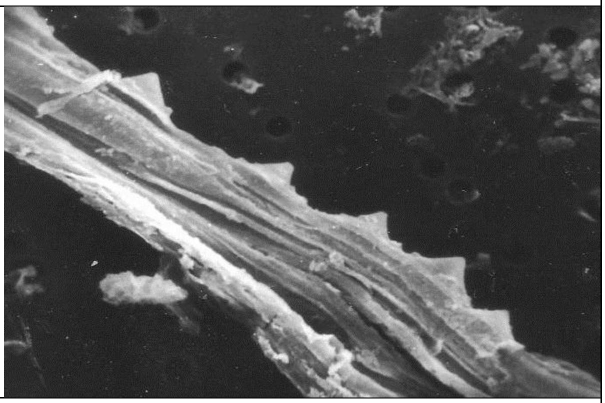
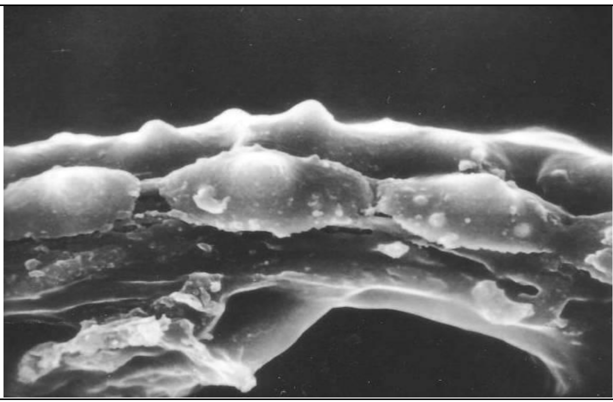
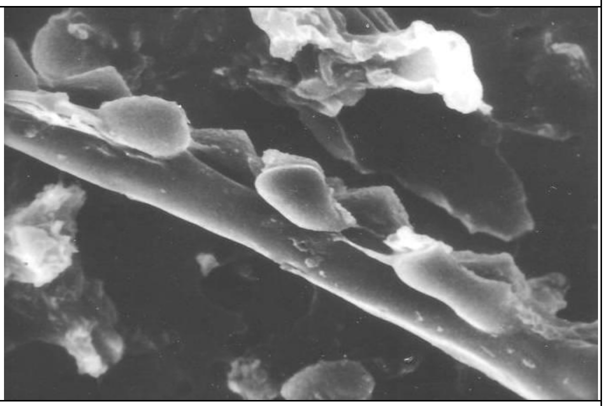
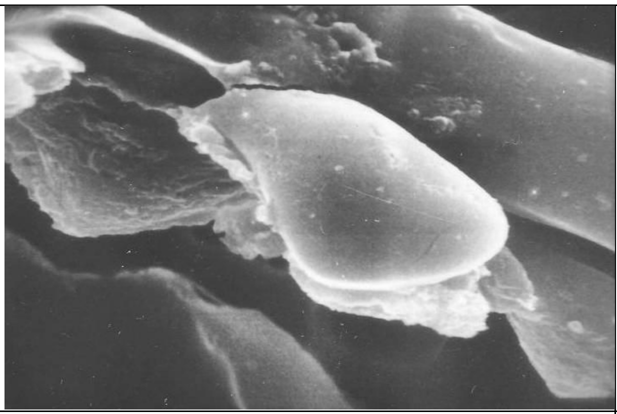
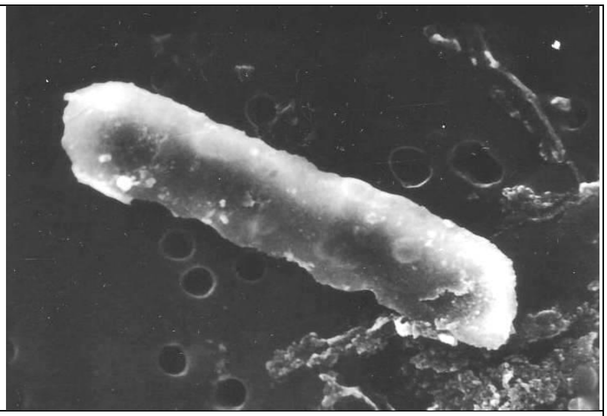
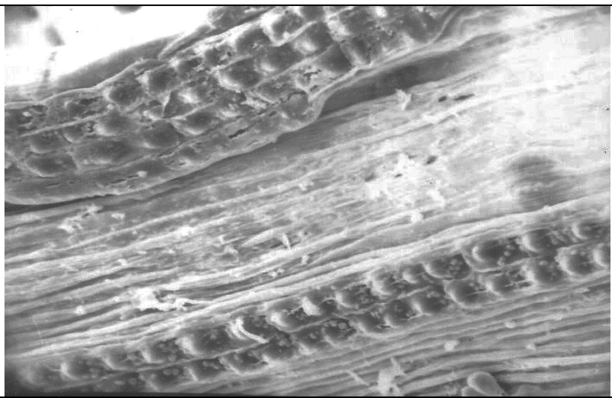
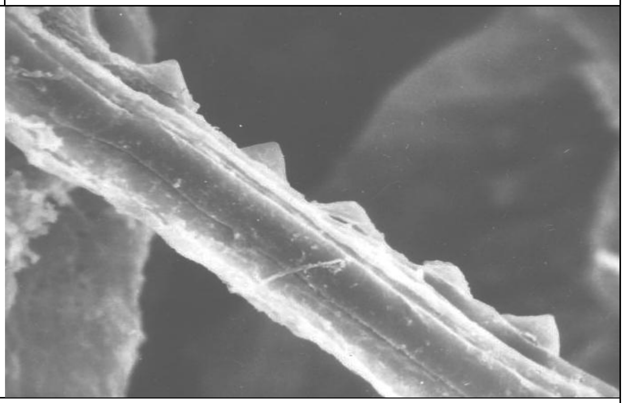
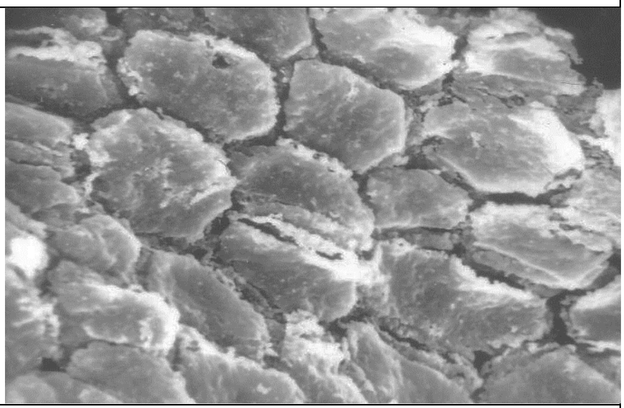
	
X1000	X1000
Carex cuspidata	
1	2
	

X2300	X1000
3	4
	
X1000	X1000
5	6
	
X2110	X2110
Carex depressa spp. *transsilvanica*	
1	2
	
X1000	X1000
3	4

	
X3150	X1800
Carex distans	
1	2
	
X300	X1000
3	4
	
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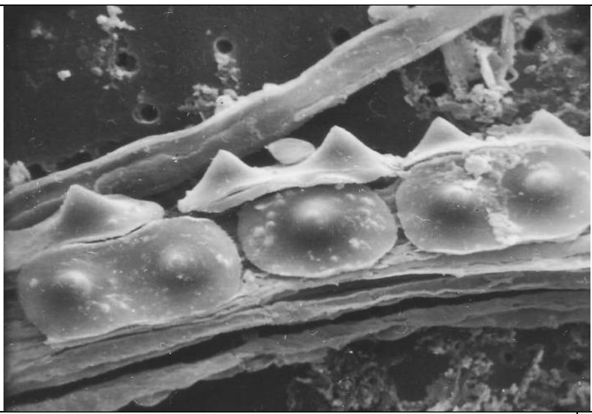
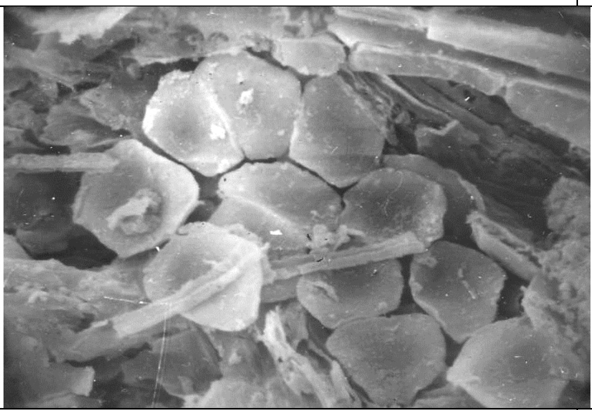
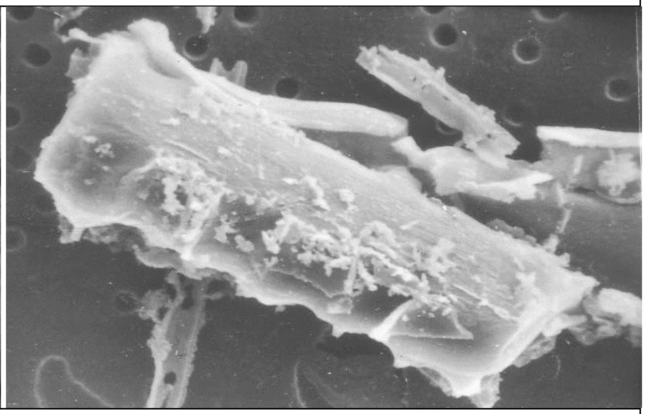
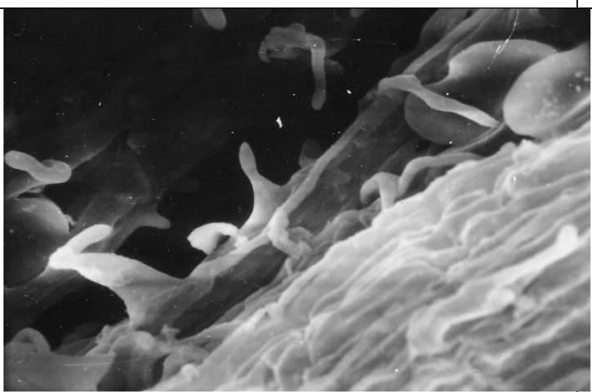
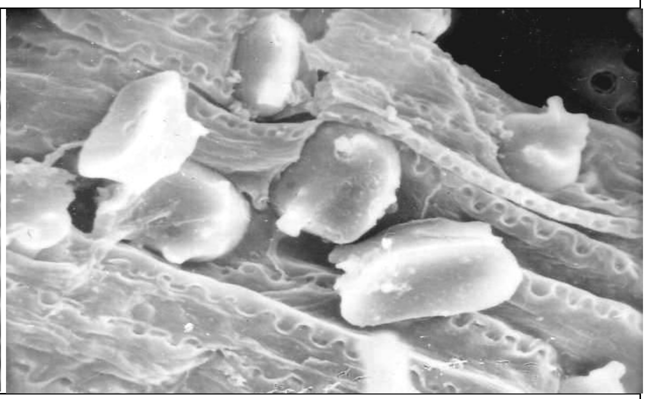
Carex divulsa	
1	2

	
X1200	X450
3	4
	
X700	X1200
Carex flava	
1	2
	
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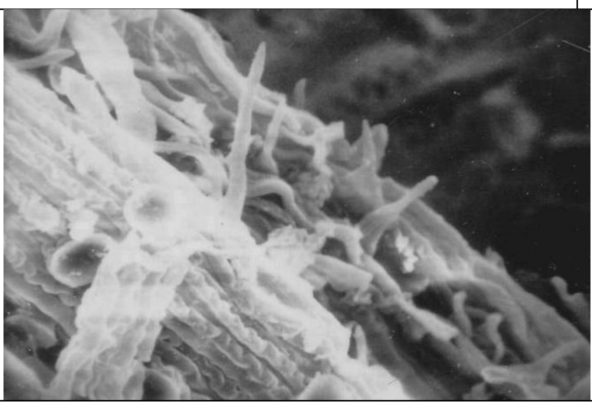
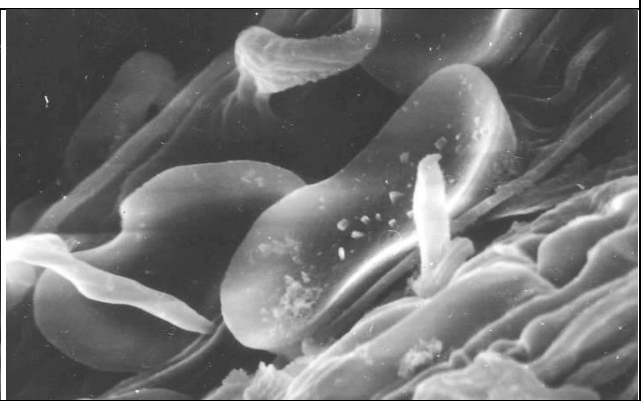
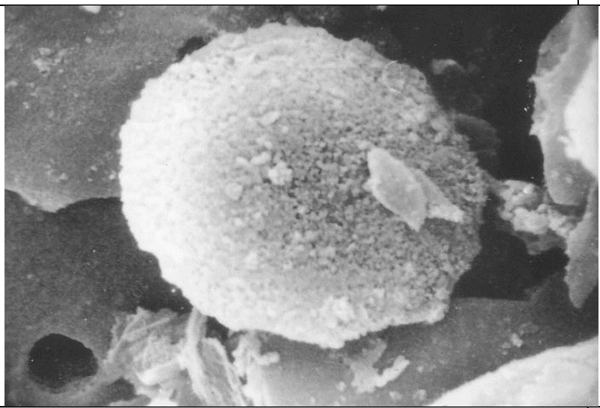
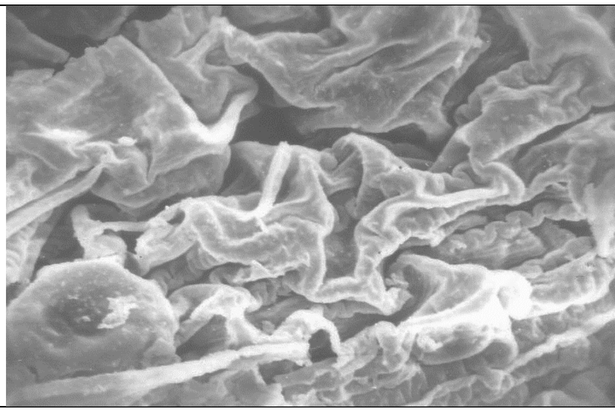
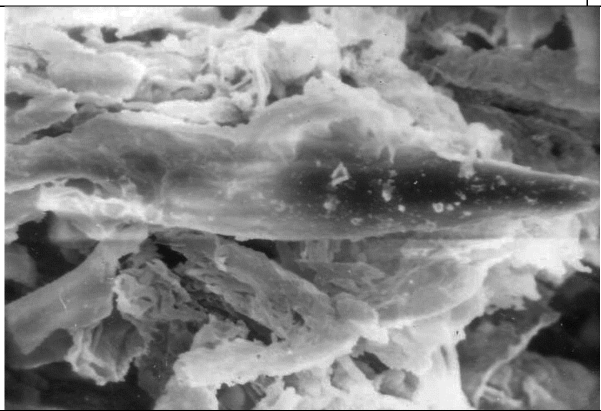
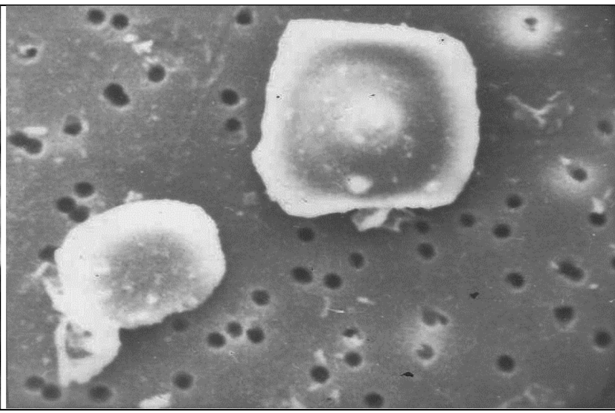
3	4
	

X1300	X1500
Carex hirta	
1	2
	
X3000	X300
3	4
	
X1000	X1200
Carex humilis	
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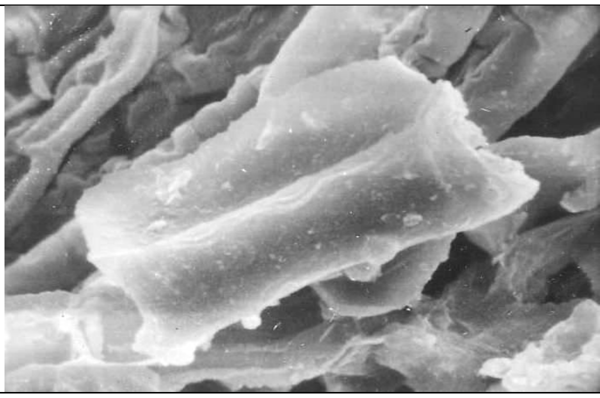
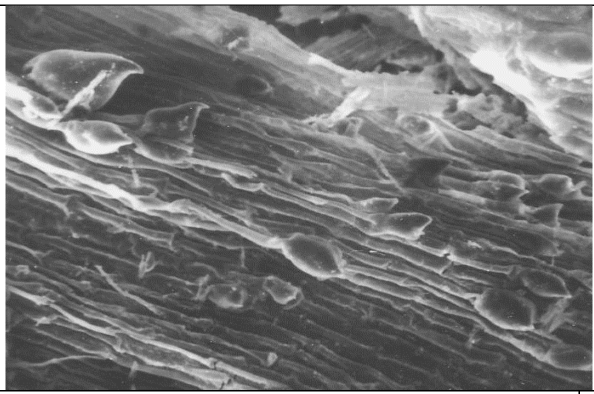
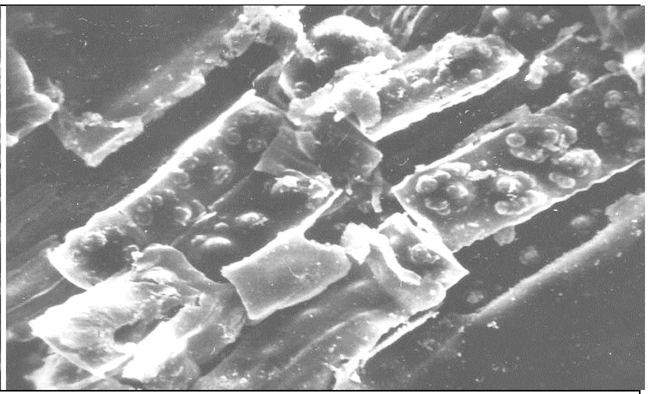
	
X2100	
Carex melanostachys	
1	2





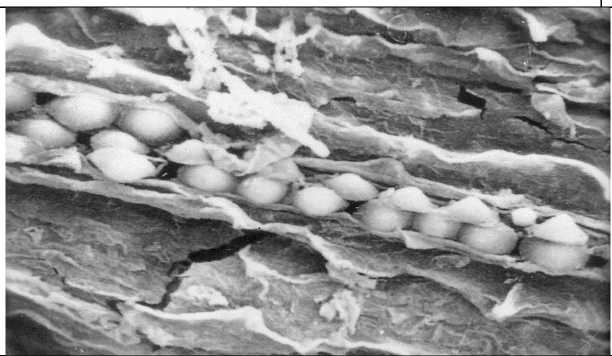
X1000	X1500

3

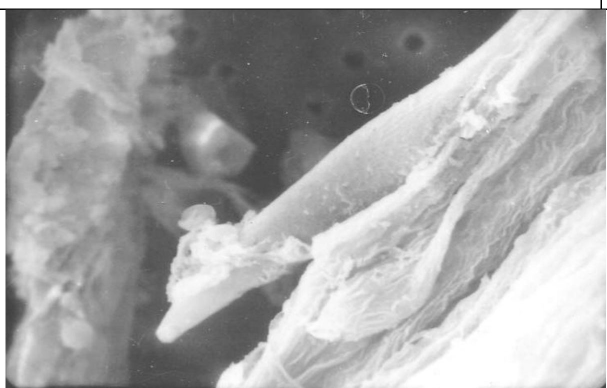
X1800

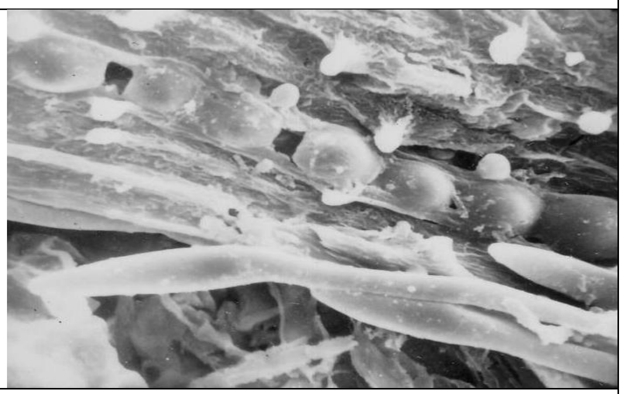
Carex montana

1	2



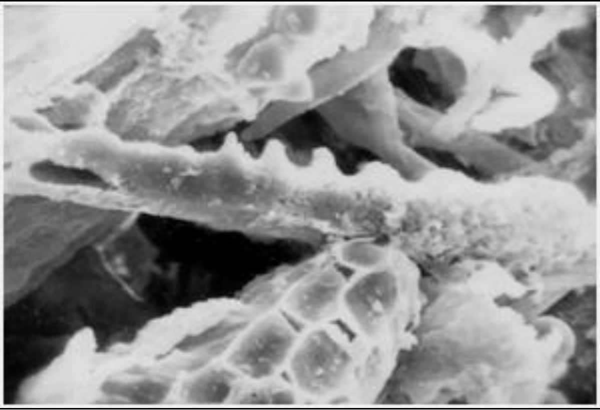
X1000	x1000
3	4





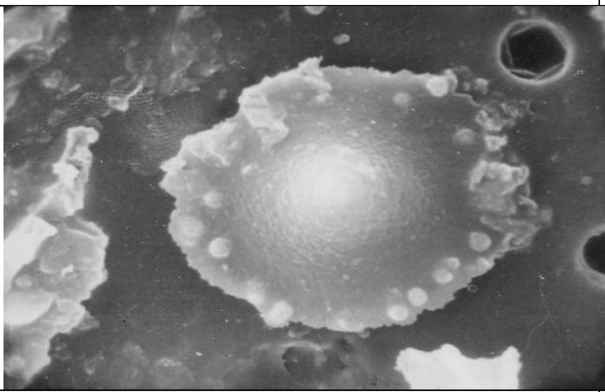
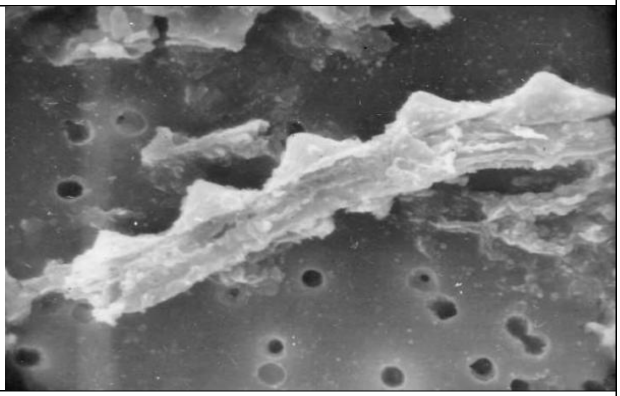
X3000	X1000

5

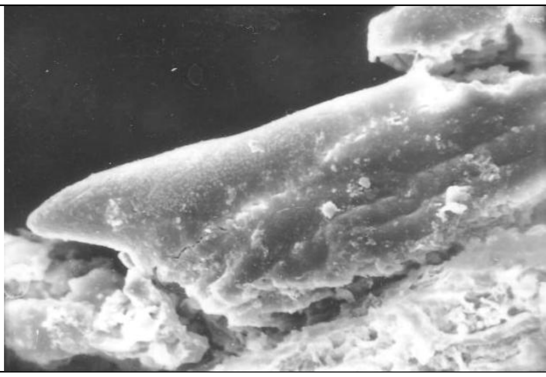


X1200

Carex otrubae

1	2
	
X4200	X1000

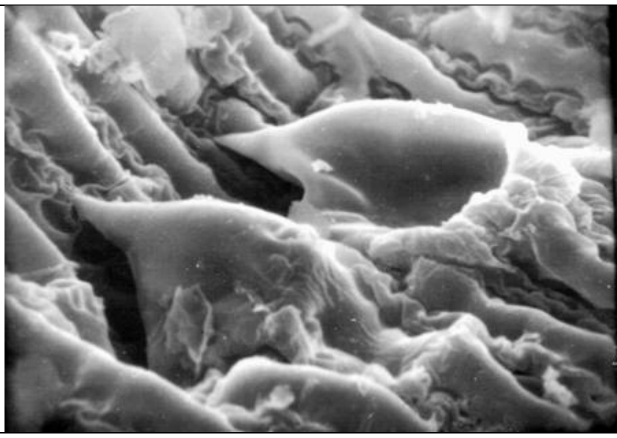
3



X630

Carex riparia

1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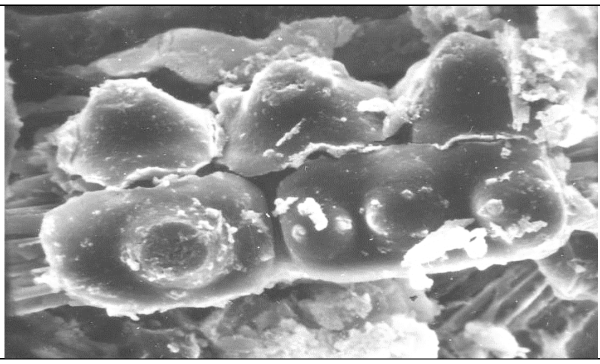	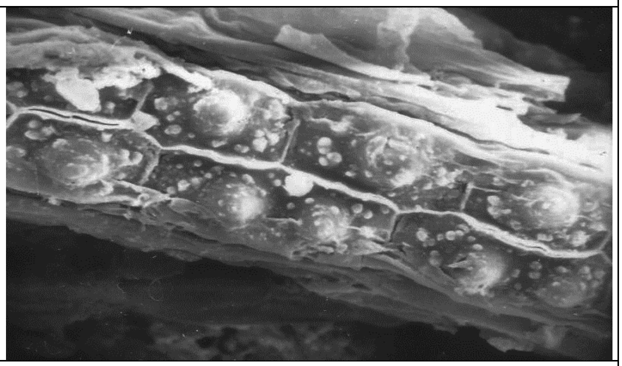
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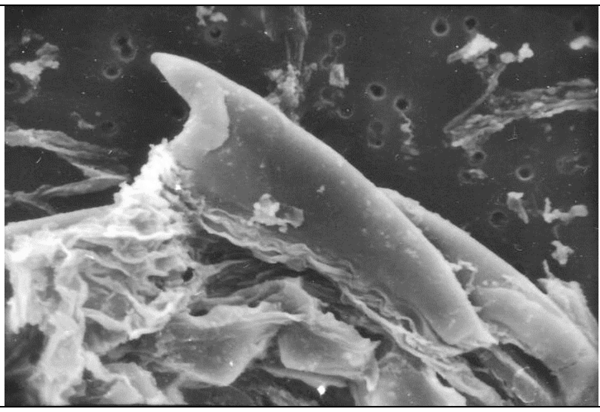	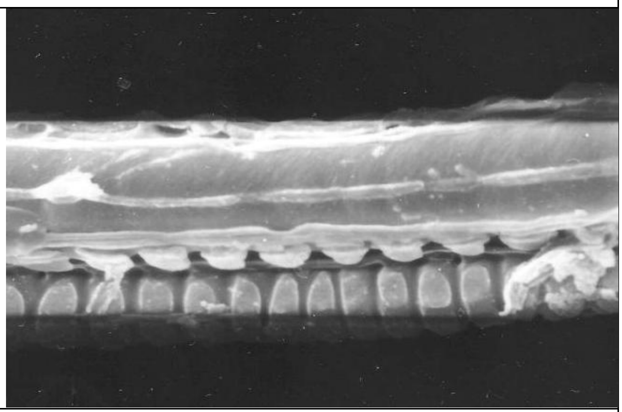
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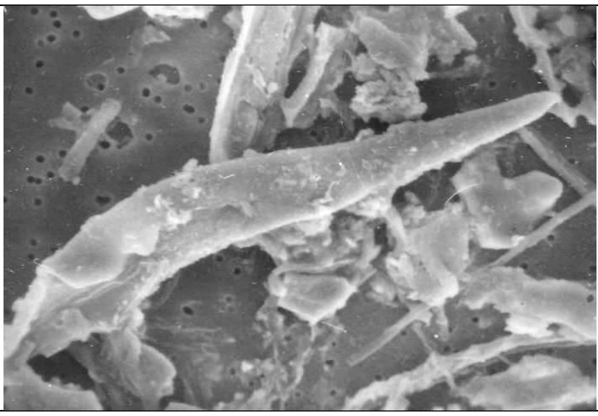	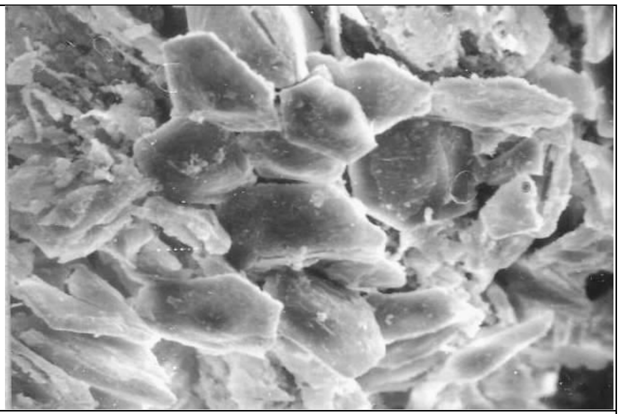
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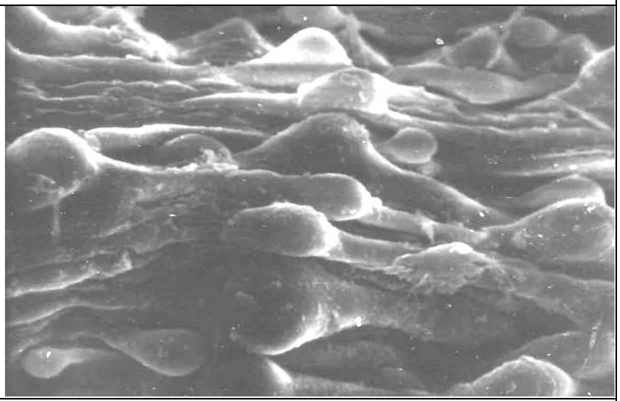
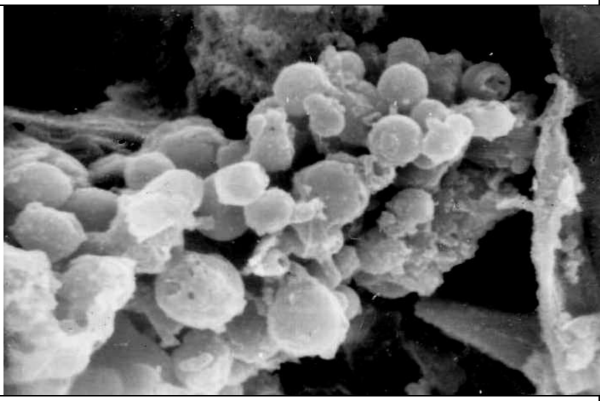
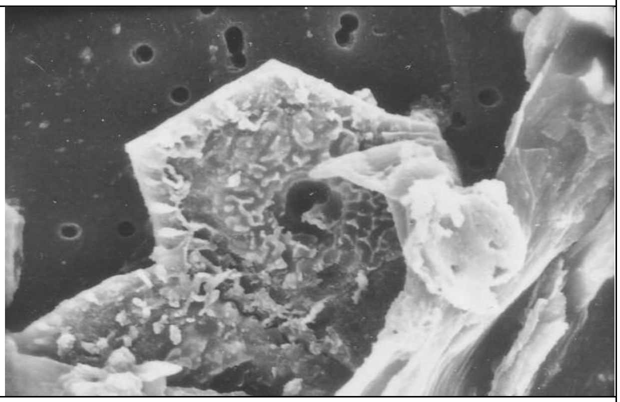
	
	X630
X630	
5	6
	
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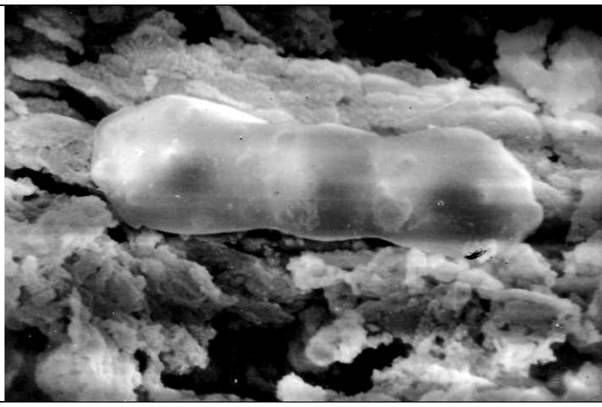	
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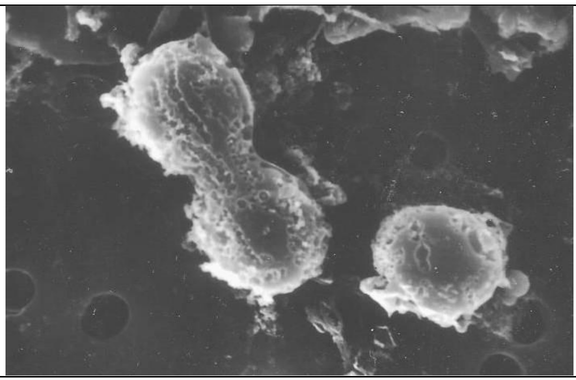
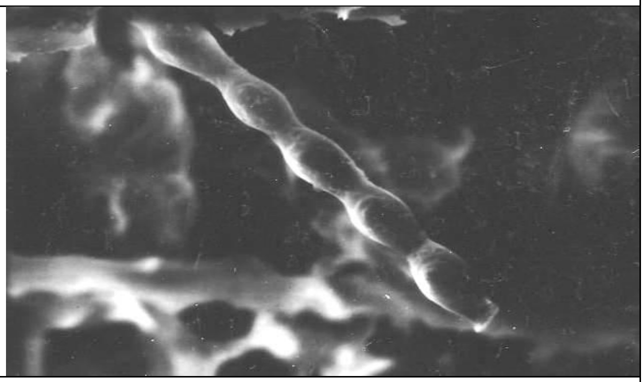
Schoenoplectus triqueter	
1	2
	
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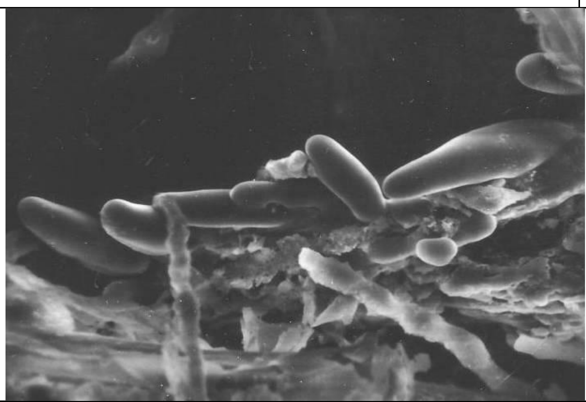	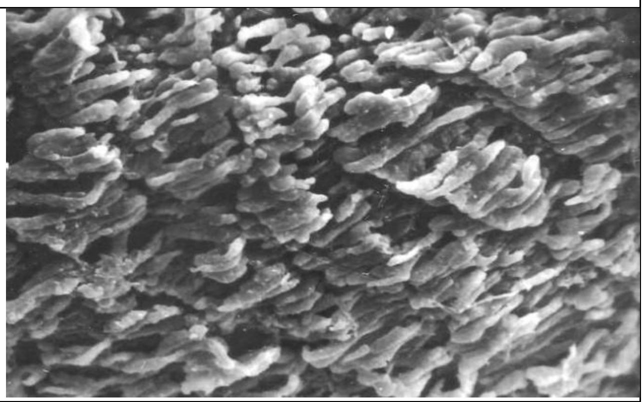
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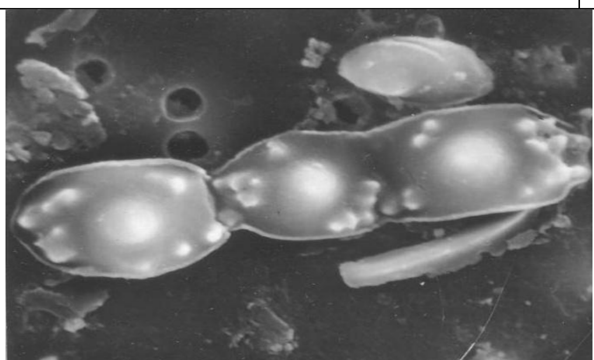
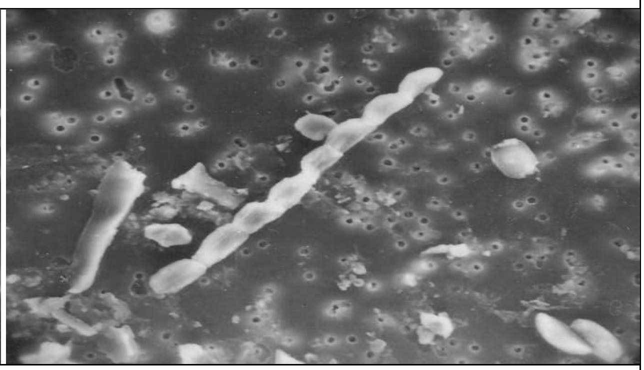
1	2
	
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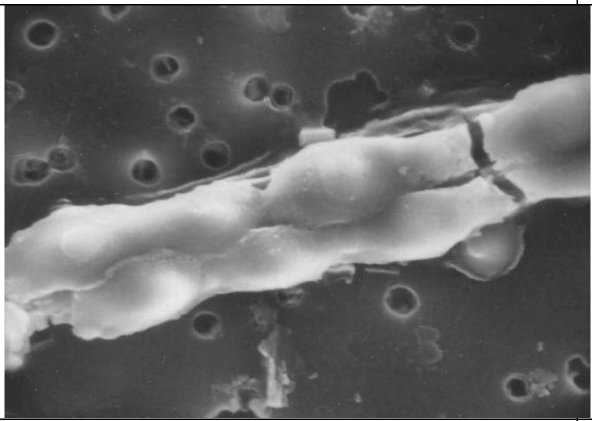	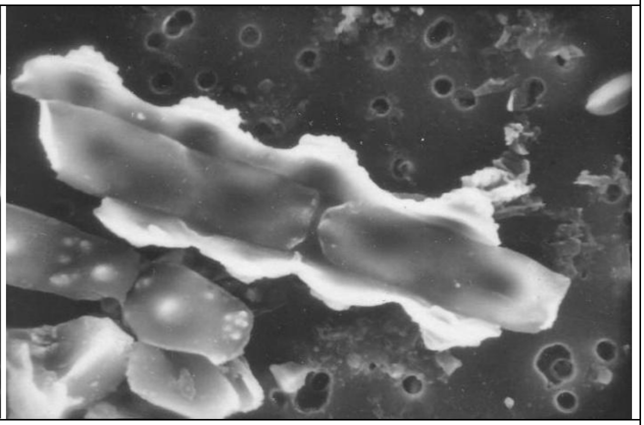
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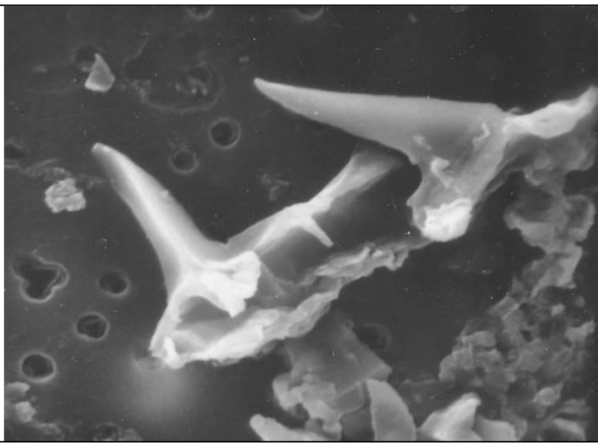
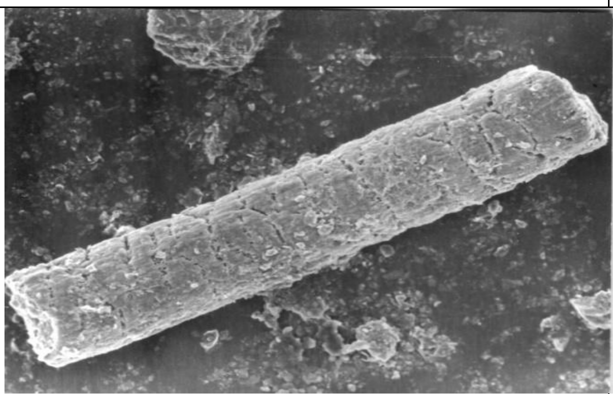
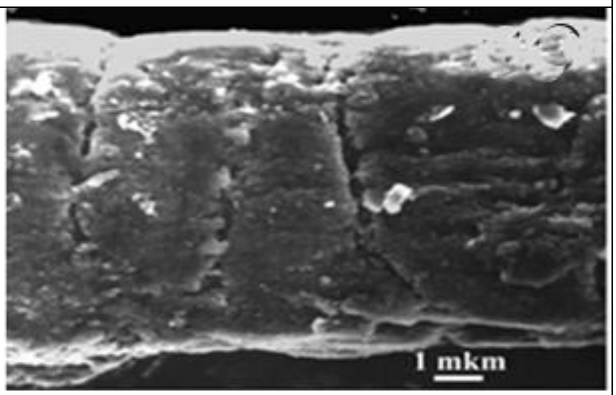
	
X1000	
Asteraceae:	
Artemisia lerchiana	
1	2
	
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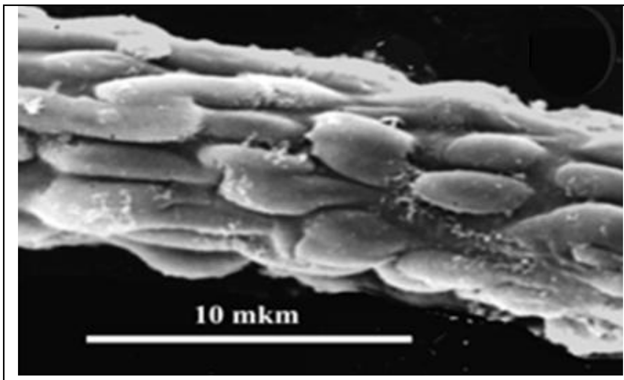
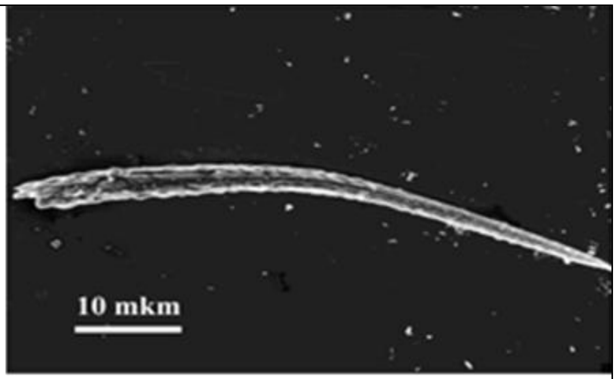
Cannabis sativa	
1	2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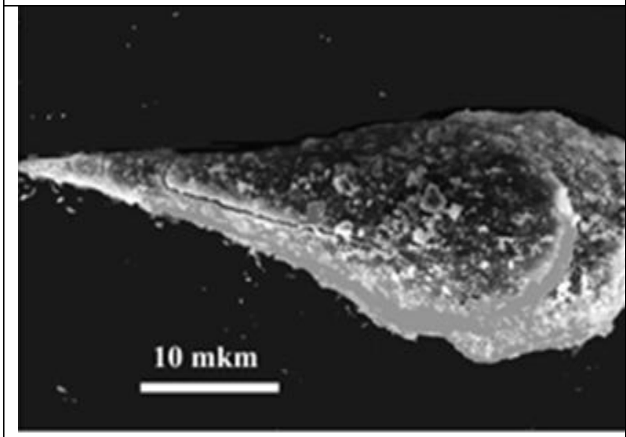	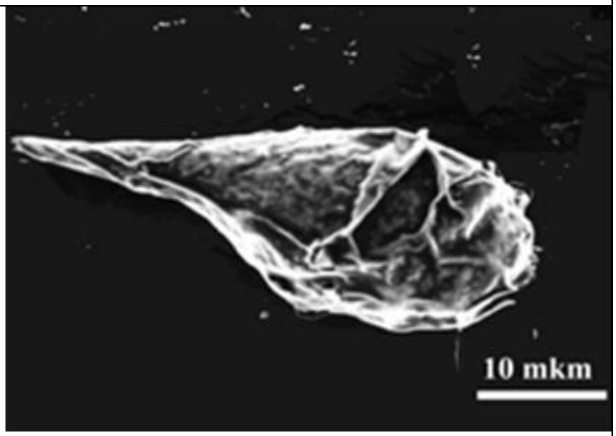

Conclusion

The author hopes that the proposed photographs will help archaeologists, paleoecologists, and paleosoil scientists find answers about the belonging of certain phytolith forms to certain plant taxa. This information helps to reconstruct and understand the climatic and ecological aspects of the past. Also important are studies in the field of plant evolution, their phylogenetic relationships, which is of great importance for plant taxonomy. Some of the results obtained can be used for the modern classification of phytolith forms.

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