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MORPHOLOGY AND ECOLOGY OF THE CENTRIC DIATOM *TERPSIONE MUSICA* EHRENBERG, BASED ON MATERIAL COLLECTED FROM CAIRO, EGYPT.

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Abstract

Specimens of the centric benthic diatom *Terpsione musica* Ehrenberg species belonging to family Biddulphiaceae, collected from different aquatic habitats in Cairo, Egypt were examined using LM and SEM in order to reveal more details about frustule structure and to reconfirm its identification. Ecology of this taxon aimed to be studied. Examination of *T. musica* revealed that the most characteristic features of this species are the presence of pseudosepta, which appear in girdle view as musical notation (from which the species derives its name) in addition to the presence of rimportula. Reconfirmation of the identification of *T. musica* was carried out to remove the confusion between this species and the related one; *T. americana*. Ecological studies of this species indicated that; although this species was recorded in many localities in The Greater Cairo; its maximum flourishment was observed in the ground seepages of Kobri El-Kobba (i.e. *T. musica* is a monomorphic specialist species), which characterized by slightly alkaline, brackish hard water with relatively high electrical conductivity and moderately high temperatures.

Introduction

Terpsione musica Ehrenberg (1841) is one of the most characteristic centric diatom species, belonging to family Biddulphiaceae. Many contradictions about morphology, taxonomy, and ecology of this taxon have been noticed in literature. Concerning the contradictions about ecology, *T. musica* has been recorded in many localities all over the world with a wide range of ecological differences. Van Heurck (1899) regarded this organism as tropical marine organism. Hustedt (1927 - 1966) considered it as euryhaline organism and stated that it occurs in fresh and brackish water, but also in marine littoral. Inland reports of *T. musica* considered it as euryhaline species lives in hard water springs of subtropical regions and has a wide range in its ecology (St. Clair and Rushforth, 1977; Whitford and Peterson, 1981; Wujek and Welling, 1981; Luttenton *et al*., 1986 and Sterrenburg, 1994).

The main contradictions about the morphology and taxonomy of *T. musica* mentioned in literature are; the identity of musical notations (Sterrenburg, 1994); misidentification and confusion between the two species *T. musica* and *T. americana* (Jouse *et al*., 1949-a and Hamed, 1995) and finally, scarcity of information about plastids (Round *et al*., 1990).

The objective of this work has been intended to study the morphology and ecology of this taxon based on materials collected from The Greater Cairo using LM and SEM in order to reveal more details about frustule structure and to

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reconfirm its identification. Furthermore, ecology of this taxon aimed to be studied.

Material and Methods

Materials

Specimens of *T. musica* were collected from many localities in The Greater Cairo, during the period from April 2000 to February 2001; these localities were Kobri El-Kobba (seasonal collections) and El-Katamia (Cairo governrate), Tall El-Yahodea (El-Qaleobiyah governrate) and El-Baragel, Kombora and Bartus Villages (Giza governrate). These materials were found as aerial, epilithic, epipelic greenish brown and brown masses and as epiphytes on *Phragmites* sp., *Ceratophyllum* sp., *Lemna gibba* and *Eichhornia crassipes* and on certain mosses such as *Funaria* sp. and *Bryum* sp.

Methods

Water samples were taken from the groundwater seepages at Kobri El-Kobba station to analyze and determine the concentrations of some chemical parameters. These parameters include field measurements of water temperature, pH, dissolved oxygen (DO) and some chemical parameters. Laboratory chemical analysis of major cations and anions was carried out according to Jackson (1958).

The collected samples were prepared for LM and SEM investigation by cleaning frustules using the method described by Jouse *et al*., (1949-b). For LM study, the material was mounted according to the method described by Proschkina-Lavernko *et al*., (1974). The technique used to prepare diatoms for SEM is that adopted by Hasle and Fryxell (1970).

The terminology of the ultrastructure of diatoms follows the suggested by Ananymous (1975), Ross *et al*., (1979) and Round *et al*., (1990).

Observations

Ecology and Distribution

T. musica is remarkably represented in the groundwater seepages at Kobri El-Kobba which characterized by brackish, very hard water with high ionic content (Table 1). It was observed in about 82% of the total collected samples within this locality. *T. musica* was found in aerial, submerged, epilithic, epipelic and epipsammic habitats. The submerged samples of *T. musica* were observed as densely hairy tufts of brown filamentous colonies submerged in water enclosed between the rails (Plate I, Fig.1). These filaments were also observed as a brown masses attached to the cemented side walls surrounding the metro open tunnel at Kobri El-Kobba. Many other samples were found associated with certain other algae, mosses, *Adiantum* sp. and attached as epiphytes to *Phragmites* sp. The seasonal fluctuation of growth revealed that *T. musica* reached its maximum flourishment during winter and it was also well represented throughout the other seasons.

The abundance of *T. musica* in the other localities (fresh water habitats) varies greatly from that in the groundwater seepages of Kobri El-Kobba. In these fresh water habitats this species just recorded but with no significant abundance (just as noted species). In Tall El-Yahodea it was found as epiphyte on *Phragmites* sp. and as scum in a noted frequency. From El-Baragel Village samples, *T. musica* was identified from scum and epilithic samples in a noted frequency. It was recorded in Kombora Village as epiphyte on *Lemna gibba* and *Eichhornia crassipes* in rare and noted occurrence, respectively. At Bartus Village, *T. musica* was observed in the scum material in noted form. Finally, at El-Katamia, it is represented in a noted frequency in epilithic samples.

Table (1): Seasonal variations of physico-chemical characteristics of Kobri El Kobba during 2000.

Season / Parameter	Winter	Spring	Summer	Autumn	Average
Temperature ($^{\circ}C$)	21	27	29	25	25.5
pH	7.2	7.7	7.3	7.4	7.4
EC ds/m	7.03	8.35	8.58	6.67	7.7
DO (ppm)	9.2	8.2	10	11	9.6
Ca^{++} (ppm)	250.5	350.7	501	206.41	327.15
Mg^{++} (ppm)	121.65	152.07	243.31	285.89	200.73
Na^{+} (ppm)	1287.36	1448.28	914.94	824.37	1118.74
K^{+} (ppm)	8.59	6.25	32.43	4.69	13
HCO_3^{-} (ppm)	182.93	146.34	292.68	439.02	265.24
CO_3^{--} (ppm)	0.00	0.00	0.00	0.00	0.00
Cl^{-} (ppm)	2464.54	1957.45	2375.18	1628.72	2106.47
SO_4^{--} (ppm)	299.04	438.94	665.87	800.96	551.20
NO_3^{-} (ppm)	0.4	0.4	0.2	0.5	0.37
NO_2^{-} (ppm)	0.1	0.1	0.1	0.2	0.13
PO_4^{---} (ppm)	0.8	1	0.5	1	0.83
SiO_2 (ppm)	10	9.5	10	12	10.38
T.D.S. (ppm)	4499.2	5344	5491.2	4268.8	4900.8
Hardness (ppm)	1126.21	1501.62	2252.46	1692.13	1643.1

Description

A. Examination of the fresh material

Microscopic examination of the fresh material revealed that *Terpsione musica* naturally present in the form of long separable filaments. The cells of these filaments may connect laterally to form straight ribbons or joined diagonally by the mucilage pads to give a characteristic zigzag appearance (Plate I, Fig. 2). These mucilage pads secreted through pseudocelli located at the valve poles (Plate I, Fig. 3).

Each cell contains many small discoid plastids that distributed throughout the cell in a radial manner from the center to the periphery. The cell contains a large nucleus situated in the center (Plate I, Fig. 3). Some small-celled diatoms were observed as epiphytes attached to the broad girdle side of the cells (Pl. I, Fig. 4).

B. Description using Light (LM) and Scanning Electron Microscopy (SEM)

Examination of this species after cleaning from organic matters revealed that the frustule appears in girdle view as rectangular with two broad and two narrow sides (Plate II, Fig. 1).

The frustules in valve view are bipolar, triundulate with heavily silica deposition, elliptical to lanceolate, with slightly capitate to rounded apices ending with pseudocelli (Plate II, Figs. 2 and 3). From the girdle view (Plate II, Fig. 1), it can be noticed that frustules are connected together from the hypovalves of two daughter cells (known as sibling valves) formed within the girdle of a mother cell. Transapical pseudosepta are observed by light microscopy in girdle view ending with a thickened ridge that resembling musical notes. The pseudosepta vary in number from frustule to another according to the stage of cell division. In general, mature epivalve has six pseudosepta, while immature valve has from 3-4 pseudosepta. Length of the narrow girdle side varies from 64 to 105 µm. This is due to the varying numbers of girdle bands in the cingula. Shorter cells often have 3 bands, while longer cells have 4-5 bands (Plate III, Figs. 1 and 2). These bands are more or less equal in width (6 µm).

The first girdle band or volvocopula underlaps the mantle. The cingula have a complete closed undulate copulae with plain edges and conspicuous fimbriae on the advalvar margin which also underlapping proceeding copulae (Plate III, Figs. 1 – 3). All bands are with fine areolation. Areolae are 20-24 in 10 µm. Areolae are simple poroid arranged usually in more or less straight rows (Plate III, Fig. 3).

The bipolar triundulate valve has an apical axis up to three times long as the transapical axis, 111-140 µm long and 35-49 µm broad. The valve is separated by a number of transverse pseudosepta (Plate III, Figs. 2-4), which appear in the girdle view as musical notes (Plate II, Fig. 1). On the pervalvar axis, one conspicuous rimportula (labiate process) presents in an eccentric position on the central constriction. Rimportula is clearly obvious from the interior (Plate II, Figs. 2 and 4) and exterior valve faces (Plate IV, Fig. 1). This structure is considered as the main characteristic feature of this species as examined from the valve view.

Each valve usually ended with two pseudocelli, which extend partly on the valve face and partly on the valve mantle (Plate II, Fig. 3). Valve face and mantle are at right angle of 90º. There is no apparent structural difference between valve face and mantle. The mantle is about 12-17 µm deep, terminated with plain edge (Plate II, Fig. 3 and Plate III, Fig. 3).

The pseudosepta can be clearly seen from the external and the internal valve faces (Plate II, Figs. 3 and 4 and Plate IV, Figs. 2 and 3). These pseudosepta divide the valve transversely and extend across the transapical axis from the two inner surfaces of the walls. The pseudosepta project from the apex of the valve face and extend for about 80% of the mantle (Plate IV, Fig. 4). It is obvious that the thickness of psudoseptum increases from the center to the edge (Plate IV, Figs. 2 and 3). The immature pseudosepta situated near the pseudocellus are represented by hyaline elevations (Plate IV, Figs. 2 and 3). These immature pseudosepta will complete when silica deposition progresses by time (Plate IV, Fig. 6).

The heavily silicified surface leads to formation of coarse areolation on the valve view, while girdle with fine areolation (Plate II, Figs. 1 and 2). On the exterior valve face, areolae are poroid, irregular, perforated, with rough surface extending to the mantle with a similar manner of areolation (Plate II, Fig. 3 and Plate III, Figs. 1 and 2). Areolae are with a weakly raised rim from the surface. Number of these areolae is 12-14 in 10 µm near the center of the valve surface. Interior valve surface differs from the exterior one in areolation system; areolae on the former are simple poroid with smooth surface (Plate IV, Figs. 2 and 3). Number of these areolae ranged from 10-14 in 10 µm near the center of the valve surface. Near the pseudocelli, areolae are arranged in more or less parallel rows, 12-14 areolae in 10µm (Plate IV, Figs. 2 and 3 and Plate IV, Fig.6). The pores of the pseudocelli are very small in size (about 40 areolae in 10µm) and arranged irregularly (Plate II, Fig. 3 and Plate IV, Fig. 5).

The valve surface with double layer and has two kinds of poroids. The exterior pores vary in size and shape (circular, semicircular and oval) ranged from 12-14 µm in 10 µm. From each exterior pore a number of fine pores (1-3) are observed (Plate IV, Fig. 1). On the siliceous valve and between the poroid areolae a number of small granules can often be seen over the valve surface (Plate III, Fig. 3 and Plate IV, Fig. 1).

Discussion

T. musica has been recorded in many localities allover the world with a wide range of ecological differences. The results obtained in the present study indicated that the optimal growth of *T. musica* was recorded in the ground water seepages at Kobri El-Kobba where temperature readings ranged between 21ºc and 29ºc, pH values were in the slightly alkaline side ranged between 7.2 – 7.7, EC was relatively high (averaged 7.7 ds/m), T.D.S (averaged 4900.8 ppm), very hard water (hardness averaged 1643.1 ppm), Ca^{++} (averaged 327.15 ppm) and Mg^{++} (averaged 200.73 ppm). These results denoted that *T. musica* flourished in slightly alkaline, brackish hard water with relatively high electrical conductivity and moderately high temperatures.

Van Heurck (1899) regarded this organism as tropical marine species. Hustedt (1927-1966) considered it as euryhaline organism and stated that it occurs in fresh and brackish water, but also in marine littoral. Inland reports of *T. musica* considered it as euryhaline species lives in hard water springs of subtropical regions and has a wide range in its ecology. (St. Clair and Rushforth, 1977;

Whitford and Peterson, 1981; Wujek and Welling, 1981; Luttenton *et al*., 1986 and Sterrenburg, 1994).

According to Levins (1968) scheme of genera and species adaptation, *T. musica* is considered as a monomorphic specialist species, because it reached its maximum growth in one environment but poorly represented in the second. In this study *T. musica* reached its maximum growth at Kobri El-Kobba locality as submerged, epipelic and epilithic taxon, while grown poorly in the other studied localities (fresh water habitats). This species has been previously recorded in Egypt in El-Tor (Hume, 1906), Ain Helwan and Ain El Sokhna springs (Hamed, 1995) and in Lake Mariut (El-Awamri *et al.*, 2000). Unexpectedly, *T. musica* has not been previously recorded in the Egyptian marine water habitats.

Concerning the morphology and taxonomy of *T. musica* the most obvious distinguishing feature of *T. musica* when seen in girdle view is the musical notations from which the species derives its name. These notations are the pseudospeta of the valve view. Sterrenburg (1994) described *T. musica* which was collected from a freshwater source North of San Pedro Curacao, Netherlands Antilles. He described the pseudosepta as bars freely suspended between the opposite sides of the mantle. Depending on this observation, Sterrenburg considered the musical score to be spurious. Contrary to Sterrenburg's collection of *T. musica*, the Egyptian samples of this species that were collected from brackish water (at Kobri El-Kobba) and described in the present work were found without any doubt contain these musical notations. These musical notations represent the complete pseudosepta projecting from the apex of the valve face and joined to the inner sides of the mantle. This difference in the structure of pseudosepta between brackish water samples (Egyptian material) and freshwater samples (Netherlands material) may be due to the ecological differences between the collected samples.

T. musica and the related species *T. americana* vary greatly in their main characteristic features as described in standard reference works such as Van Heurck (1899), Hustdt (1927-1966) and Round *et al.* (1990). These variations are: the presence of rimportula in *T. musica* while this structure is absent in *T. americana*; number of pseudosepta (3-6) in *T. musica* and (2-4) in the second species; arrangement of areolae and range of dimensions. In spite of these differences, misidentification and confusion between *T. musica* and *T. americana* have been observed. Revision was done to *T. americana* which was recorded from Ain Helwan and Ain El-Sokhna (Hamed, 1995) and reidentified as *T. musica*. Jouse *et al.* (1949 a) confused between the two species of *Terpsinoe*. Their descriptions about *T. musica* and *T. americana* (pages 212 & 213 and plate 100, figs. 1 and 2) varied greatly in comparison with the descriptions in the above-mentioned standard reference works. Jouse *et al*. (1949 a) described *T. musica* as *T. americana* and vice versa.

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Plates

Terpsione musica Ehr.

Plate I

Figures. 1 – 4, (Photomicrographs of fresh materials).

Figure 1: Brown hairy tufts of *T. musica* grow submerged under the water enclosed between the rails at Kobri El-Kobba Metro Station.

Figure 2: Cells from girdle view connected together by mucilage pads to form straight ribbons and zigzag-shaped filaments. LM, x 200.

Figure 3: Girdle view of three diagonally connected cells (Zigzag appearance) showing mucilage pad (arrow) secreted through pseudocelli, radial arrangement of discoid plastids and the central position of nucleus. LM, x 370.

Figure 4: Magnified part of girdle showing fine areolation, discoid plastids and small-celled diatoms attached to the girdle surface. LM, x 2000.

Plate II

Figure 1: Girdle view of 2 inseparable daughter cells showing pseudosepta appear as musical notes (6 in epivalve and 4 in hypovalve) and fine areolation. LM, x 400.

Figure 2: Valve view showing rimportula, pseudosepta, pseudocelli and coarse areolation on valve face. LM, x 500.

Figure 3: Whole frustule (valve and girdle) showing epivalve, hypovalve, pseudosepta, pseudocelli, mantle with plain edge, fimbriae (f), number of girdle bands (3) and fine areolation on these bands. SEM, bar = 10 µm.

Figure 4: Internal view of valve showing pseudosepta and rimportula (r). SEM, bar = 10 µm.

Plate III

Figure 1: Girdle view showing mantle, 4 girdle bands and areolation on both of them. SEM, bar = 10 µm.

Figure 2: Girdle view showing the mantle overlapping the volvocopula (v), 4 girdle bands with fine areolation and plain edges as well as separated undulate girdle band. SEM, bar = 10µm.

Figure 3: Magnified part of frustule (valve and girdle) showing the small granules (g) between the areolae of external valve face, mantle, fimbriae (f), arrangement of girdle bands and fine areolation. SEM, bar = 10µm.

Figure 4: Internal view of valve showing rimportula (r) and pseudosepta (p). SEM, bar = 10 µm.

Plate IV

Figure 1: External view of valve showing rimportula (r), areolae with different shapes and sizes and small granules (g). SEM, bar = 1 µm.

Figure 2: Internal view of valve showing immature (ip) and mature pseudosepta (p) as well as arrangement of areolae. SEM, bar = 10 µm.

Figure 3: Internal view of valve showing arrangement of areolae, immature (ip) and mature pseudosepta (p). SEM, bar = 10 µm.

Figure 4: Broken narrow girdle side showing the projection of pseudoseptum (p) from the apex of valve face. SEM, bar = 10µm.

Figure 5: Internal view of valve showing immature pseudoseptum (ip), arrangement of areolae and areolae on the internal mantle edge. SEM, bar = 1 µm.

Figure 6: Internal view of valve showing immature (ip) and mature pseudosepta (p) and arrangement of areolae. SEM, bar = 1µm.

Plate I

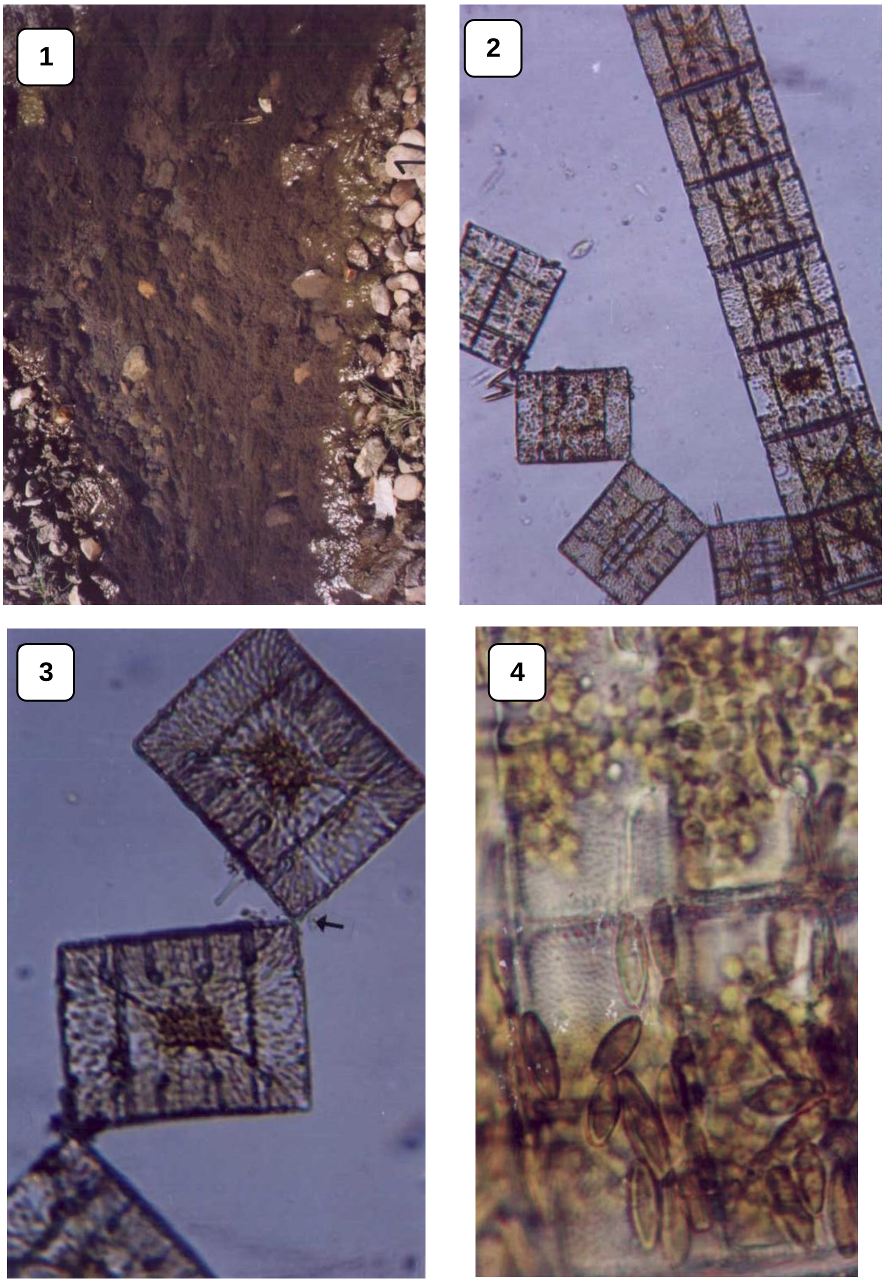


Plate II

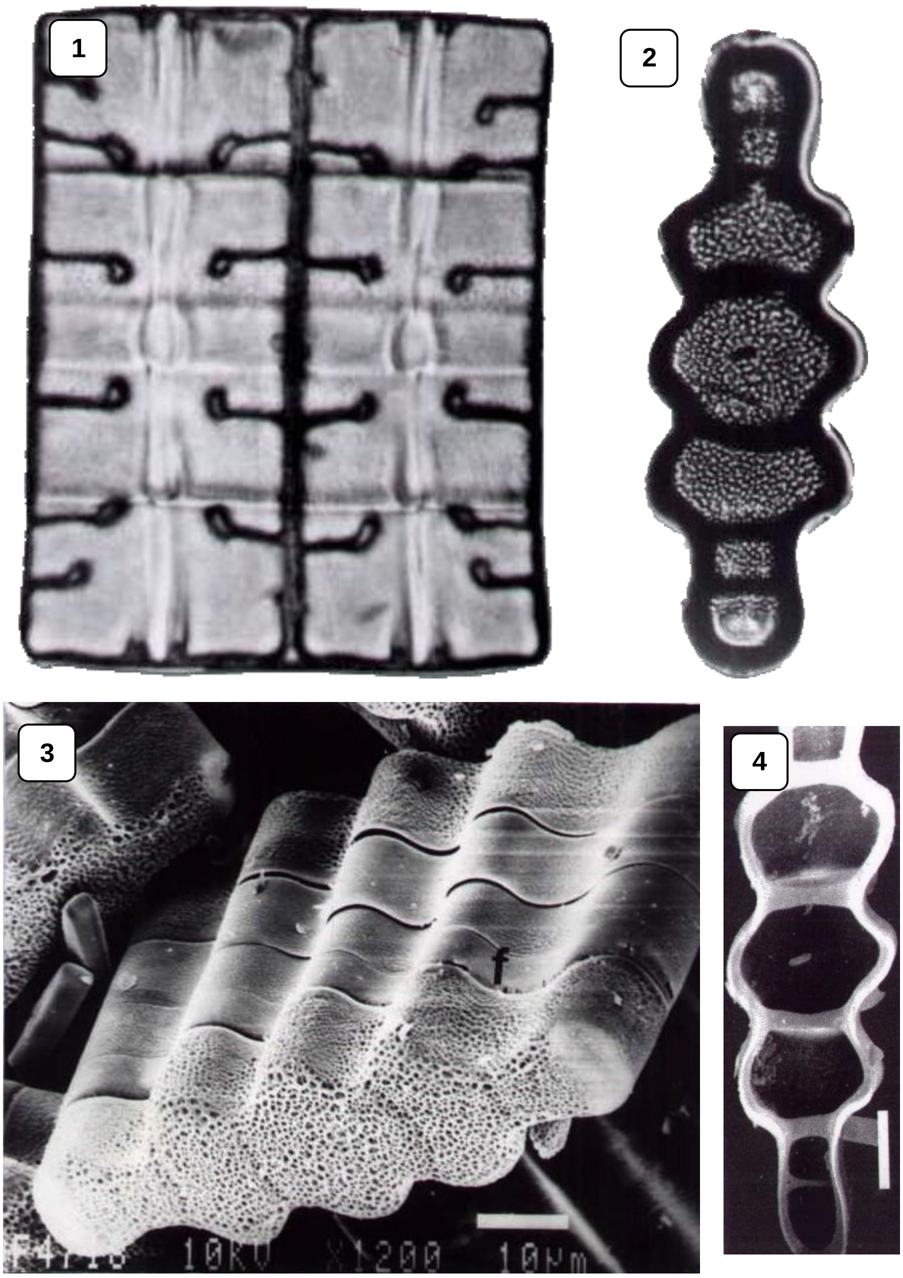


Plate III

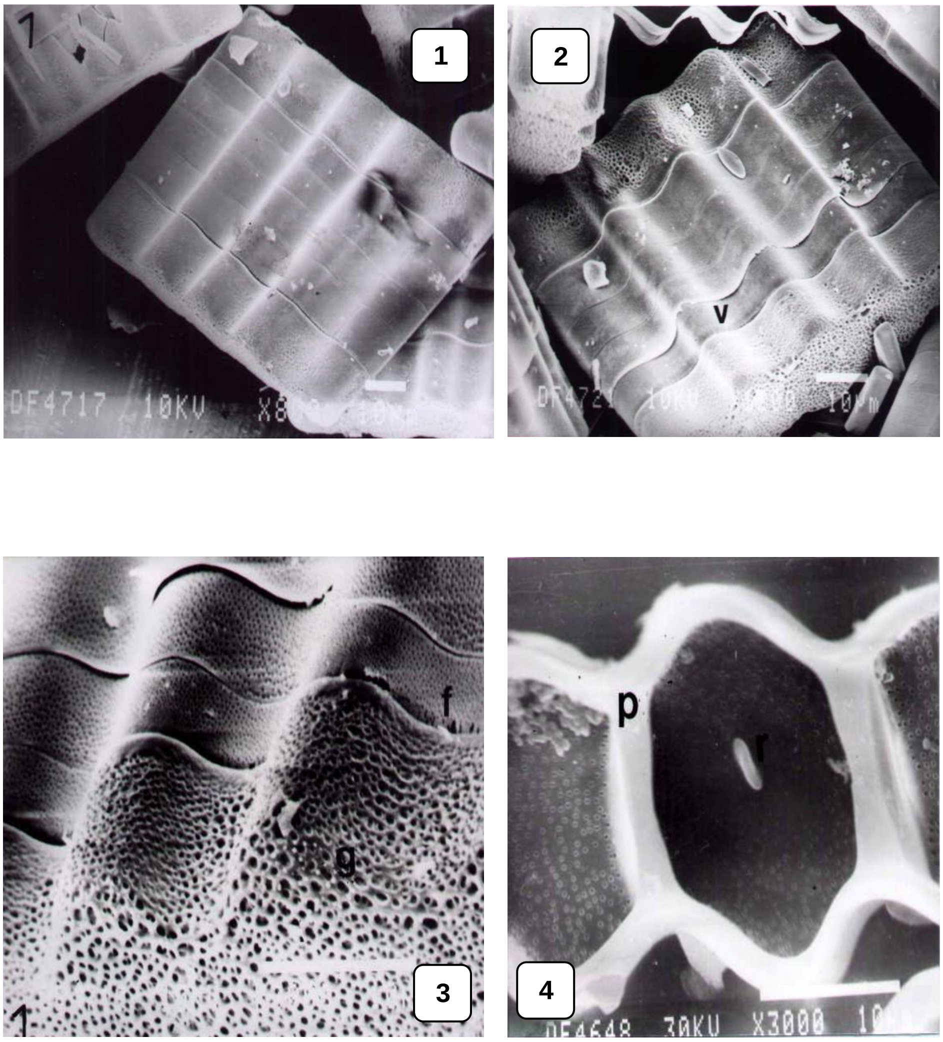
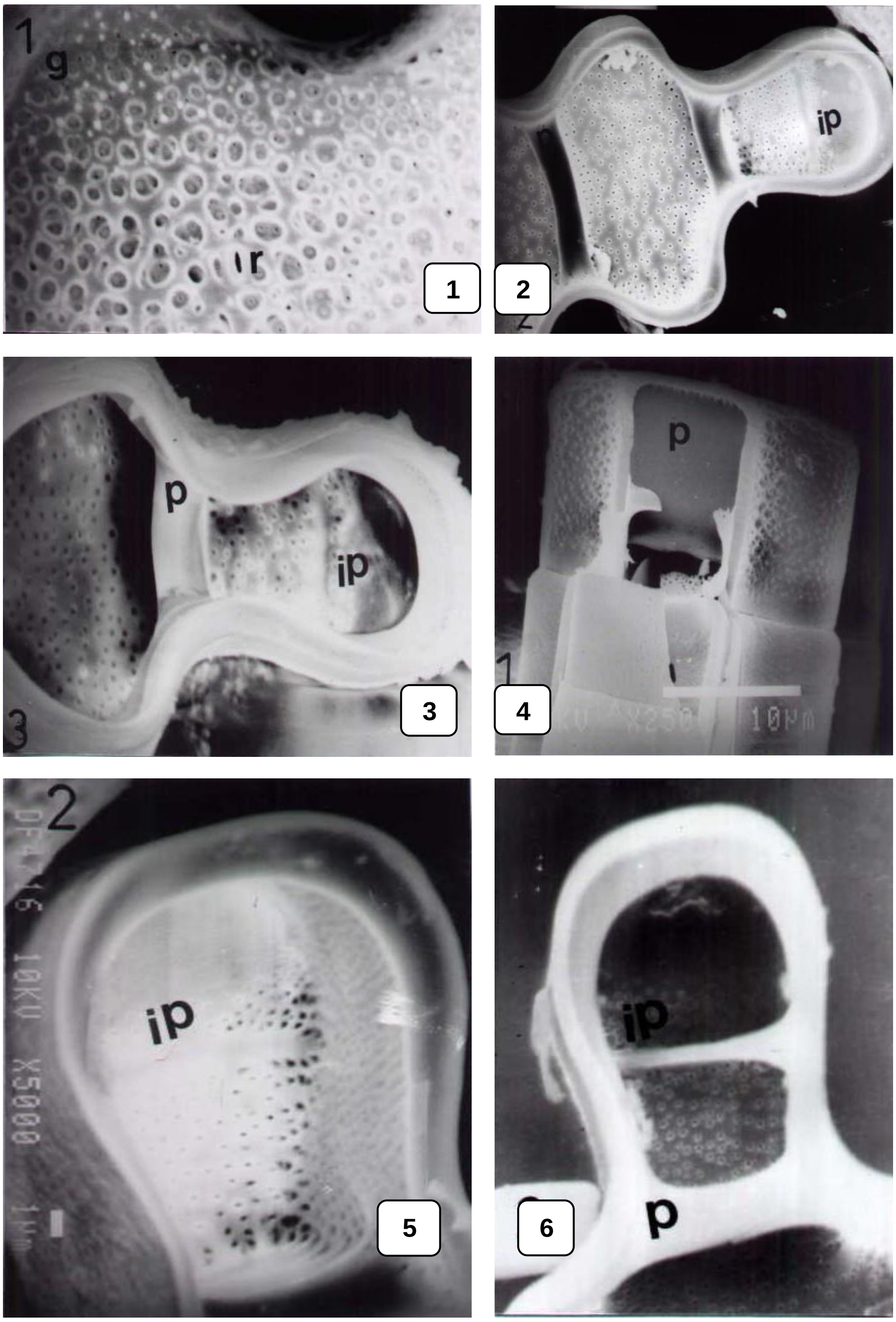


PLATE IV



دراسة الشكل الظاهري و بيئة الدياتوم المركزي*Terpsione musica* Ehr. المسجل في القاهرة ، مصر

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اشتمل البحث على دراسة الشكل الظاهري باستخدام المجهر الضوئي والمجهر الإلكتروني الماسح، كذلك دراسة بيئية على النوع *Terpsione musica* Ehr. لعينات تم تجميعها من بيئات مختلفة بالقاهرة (مصر)، و قد أوضحت نتائج الفحص المجهري لهذا النوع وجود كل من الزائدة الشفوية والحواجز الكاذبة و التي تظهر من ناحية الحزام كعلامات الموسيقي هي أهم الخصائص المورفولوجية لهذا الكائن.هذا وقد تم التأكد من تعريف هذا الكائن ومقارنته بـ *Terpsione americana* وعلي الرغم من تسجيل هذا النوع في مناطق عديدة في القاهرة الكبرى إلا أن أعلي انتشار و سيادة لهذا النوع لوحظت في المياه الجوفية المتسربة في منطقة كوبري القبة والتي تتميز بكونها ضعيفة القلوية ومتوسطة الملوحة و شديدة العسرة و محتواها الأيوني عالي.