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# THE DISTRIBUTION OF *EUGLENA MUTABILIS* IN SPHAGNA, WITH REFERENCE TO THE MALHAM TARN NORTH FEN

By ALLAN PENTECOST

*Department of Applied Biology, Chelsea College, University of London, Hortensia Road, London SW10 0QX*

ABSTRACT

*Euglena mutabilis* was found to be widely distributed in the surface layers of 5 species of *Sphagnum* in Malham Tarn North Fen. Numbers range from 50–70,000 cells $cm^{-2}$ ground surface. A positive correlation was found between cell numbers and the *Sphagnum* moisture content, but no correlation was found with pH, Eh and the total water hardness. Most of the algae were found in the top 2 cm of *Sphagnum* and numbers declined rapidly at depths greater than 4 cm. Other common algae were *Chlamydomonas acidophila, Mesotaenium endlichearum* and *Cylindrocystis brebissonii*. The distribution of these species and of *E.mutabilis* along a short transect into a bog-pool is described and the characters of the *Sphagnum* microenvironment are discussed.

## INTRODUCTION

LITTLE is known of the distribution and ecology of algae growing in bogs, marshes and fens (Round, 1965). This is probably due to the difficulties of quantitative sampling, species identification, (particularly in groups such as the desmids), and the heterogeneity of boggy sites in general. Such areas are usually densely vegetated and contain a great variety of microhabitats. Many bogs and fens are rich in bryophytes, particularly in species of *Sphagnum* which develop on nutrient-poor, ill-drained tracts of land throughout the cooler regions of the world. Many species of *Sphagnum* occur in well-defined wetland niches dependent upon the height of the water table, the degree of exposure to light and the groundwater chemistry. Most species are capable of absorbing in excess of ten times their own weight of water, owing to the peculiar anatomy of their leaves. Water expressed from a clump of *Sphagnum* is usually low in nutrients and slightly acidic. This is due primarily to cation exchanges between the plants and the water (Clymo, 1963). However, the water frequently contains a diverse and abundant flora and fauna of algae and protozoa.

Many algae, particularly desmids, have been described from areas dominated by *Sphagnum* but quantitative and seasonal studies of abundance have been few. One of the most recent and comprehensive studies is that of Duthie (1965) who monitored a desmid-dominated sub-alpine bog in Gwynedd, North Wales, over a two year period. Desmid numbers were found to vary considerably over distances of a few centimetres and seasonal fluctuations in numbers were not marked. This present study is not concerned directly with desmids, which play a minor role in the ecology of the area studied, but with *Euglena mutabilis* which dominates the algal flora of several hectares of *Sphagnum* in a North Yorkshire fen.

The euglenoids are a diverse group of algae inhabiting a great variety of places including ice fields, tree bark and swimming pools (Leedale, 1967). All of the green euglenoids (including *E. mutabilis*) so far investigated, appear to be photoauxotrophic (Leedale, 1967; Buetow, 1968) but in the absence of light, some species lose their chlorophyll and utilise alternative sources of energy. In *E. mutabilis* however, this has not yet been shown to occur.

The vast majority of euglenoids possess a long flagellum, about as long as the long axis of the cell, which enables the cells to swim through the water. In *E. mutabilis,* this long flagellum is much reduced so that swimming is impossible although the species retains some capacity for motility (see below). This species is best known, however, for its ability to thrive in highly acidic waters of pH 3 and below. In a survey of a large number of British streams with a pH of less than 3, Hargreaves *et al.* (1975) noted that this species was the most widespread and often the most abundant of the algae present. Most of the streams studied owed their acidity to the oxidation of sulphides present in the catchment of mining areas, and a tolerance to high levels of iron and other heavy metals by *Euglena* has also been noted (Say and Whitton, 1980). This association with heavy metal pollution and tolerance to acidity is likely to result in more extensive studies on *Euglena* in the future.

Bogs and fens dominated by *Sphagnum* do not possess such extremes of pH and heavy metal concentration as a rule, and the distribution and ecology of the algae within them has been a neglected field. The site for this study was chosen because it has already received considerable attention from biologists (Sinker, 1960; Proctor, 1974).

The North Fen, at the western edge of Malham Tarn, is a flat, wooded area (altitude 375 m) dominated by *Betula pubescens* and *Salix* species. There are also open areas with few trees and both regions were sampled. The flora of the fen has been described by Proctor (1974). The ground vegetation contains extensive areas of *Sphagnum,* particularly beneath the trees, where unbroken carpets of the moss may extend over several hectares. The most abundant species are *S. palustre, S. squarrosum, S. papillosum, S. fimbriatum, S. rubellum* and *S. cuspidatum.*

An attempt has been made to correlate the distribution pattern of *E. mutabilis* and the associated algae, with some environmental variables suspected of being important, e.g. water hardness, pH, moisture content and the species of *Sphagnum* inhabited.

## METHODS

Samples of *Sphagnum* were collected from twenty sites on Malham Tarn North Fen (Fig. 1) although only one site was sampled regularly (site 1). The sites were spread out to encompass most of the fen but a five metre transect, including seven sites (numbers 13–19) leading into a small permanent boggy pool, was included.

A 25 $cm^2$ sample of *Sphagnum* was removed carefully to a depth of 12 cm at each site and returned to the laboratory for examination. The algae were removed by squeezing the moss, which had been enclosed in a muslin bag and placed in a tray containing 200 ml water. It was found that a single squeeze of the water-saturated bag released few algae so an experiment was performed in order to determine how many squeezings would be required to remove most of the euglenoids. The results (Fig. 2) suggested that each sample should be squeezed, after taking up water, for a minimum of 200 times. This procedure was adopted for all of the samples.

A small, measured aliquot of the suspension resulting from the squeezing was transferred to an algal sedimentation tube containing a drop of Lugol's iodine. After sedimenting, the algae were counted under an inverted microscope. Where

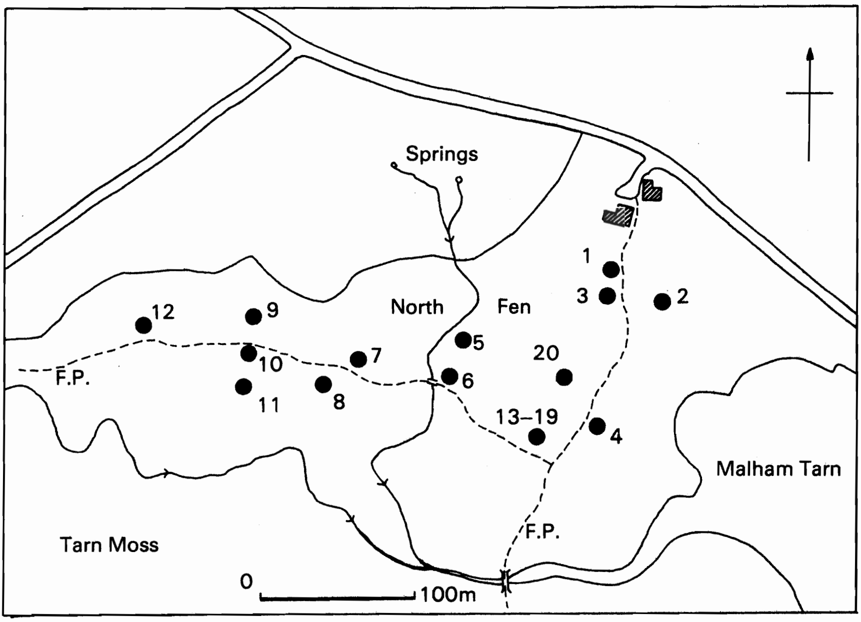



FIG. 1
Map of Malham Tarn North Fen showing the 20 sampling sites for algae.
F.P. = Footpath.

possible, a minimum of 100 cells was counted, which gave 95% confidence limits of ± 20% for the mean (assuming a Poisson distribution for the counts). In order to determine the distribution of the algae with depth, some *Sphagnum* samples were cut up into a series of strata 2 cm deep and these were squeezed independently. Cell numbers were expressed per $cm^2$ of *Sphagnum* carpet or per gram of *Sphagnum* dried to constant weight at 105 °C.

During 1980, samples were collected at monthly intervals from site 1. The ground

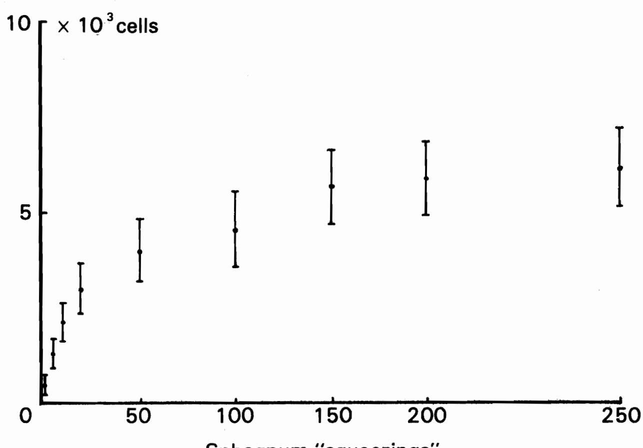



FIG. 2
Numbers of *Euglena mutabilis* expressed from *Sphagnum palustre* as a function of the number of squeezings.
95 per cent confidence limits are shown.

and air temperature, and rainfall were recorded during each sampling occasion. A survey of the twenty sites was made in October 1980. This involved the analysis of the water expressed from the samples. The Eh value of this water (a measure of the oxidation-reduction potential, measured in millivolts) was obtained with a Russell combined platinum-reference electrode fitted to a Pye Model 292 pH-mV meter. The electrode was cleaned with mild detergent and kieselguhr and washed thoroughly with distilled water before use and calibrated with Zobell's solution (Zobell, 1946). The electrode was dipped into the samples and the readings were taken after 2 minutes. These measurements were performed in the Field Centre laboratory close to the fen. The pH was determined colormetrically using Thymol blue indicator solutions and the calcium + magnesium concentration was found by titration with EDTA using Solochrome Black as indicator (Golterman and Clymo, 1969). The moisture content of the *Sphagnum* was determined by drying samples to constant weight at 105 °C. The species of *Sphagnum* was identified at each site.

Tests using three statistical methods were made. These were Pearson's correlation coefficient (parametric), the Mann-Whitney U-test and the Kruskall-Wallis one-way analysis of variance (non-parametric). The methods, together with the rationale for using them may be found in Siegel (1956) and Sokal and Rohlf (1969).

## RESULTS

a) *General description of* E. mutabilis.

*E. mutabilis* is readily distinguished from other euglenoids by its lack of a long flagellum, the scarcity of muciferous bodies (Leedale, 1967; Beutow, 1968) and, normally, the presence of two chloroplasts per cell (Fig. 3). The cells were extremely variable in shape and ranged from 40–100 μm long and 8–30 μm wide. They contained abundant food reserves in the form of paramylon granules measuring 2-3 x 1-2 μm. A conspicuous red stigma, which is believed to function as a photoreceptor, was present close to the canal at the anterior end of the cell. The species was usually motile under the microscope and an unusual mechanism involving the flow of cytoplasm within the elastic cell wall occurred. The movement was either erratic or, more frequently, a regular pulsation (Fig. 4). These pulses, were directed towards the anterior end of the cell, containing the canal, so that the cell moved in the same direction as it would if it had possessed a long flagellum, but the speed of movement was much slower, about 5 μm $sec^{-1}$ compared to 80–100 μm $sec^{-1}$ for

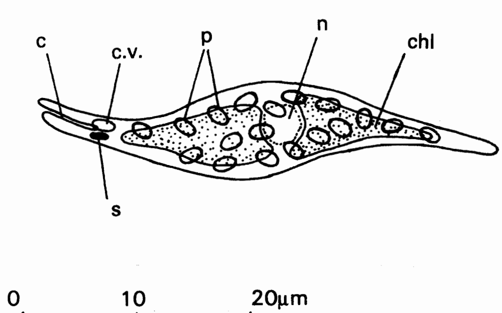



FIG. 3
*Euglens mutabilis* from the North Fen. *c.* canal, *chl* chloroplast, *c.v.* contractile vacuole, *s* stigma, *n* nucleus, *p* paramylon.

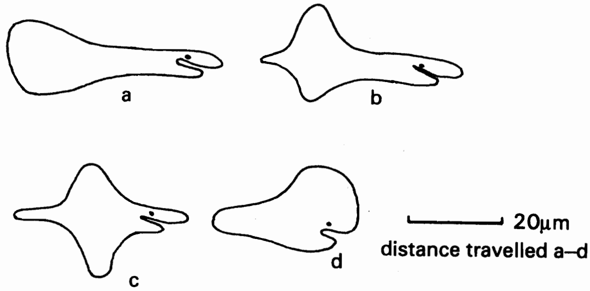



FIG. 4
The sequence of cell shape changes during the movement of *E. mutabilis* over a plane surface. The time lapses between a–d are approximately equal.

swimming euglenoids. The pulsations had a period of approximately 6 seconds. The alga could only move when in contact with a rigid surface such as a moss leaf or glass slide.

b) *Distribution of* E. mutabilis *with depth*

Cell numbers decreased in all cases with depth (Fig. 5). The top 4 cm of *Sphagnum* contained 50 per cent of the cells although the actual number of cells varied considerably over time and distance. No cells were observed at depths exceeding 8 cm. If cell numbers are plotted as a function of *Sphagnum* dry weight a different pattern emerges (Fig. 5h) with a maximum number of cells in the 2–4 cm layer. A steady decline in *Sphagnum* dry weight with depth is also apparent (Fig. 5g). The samples

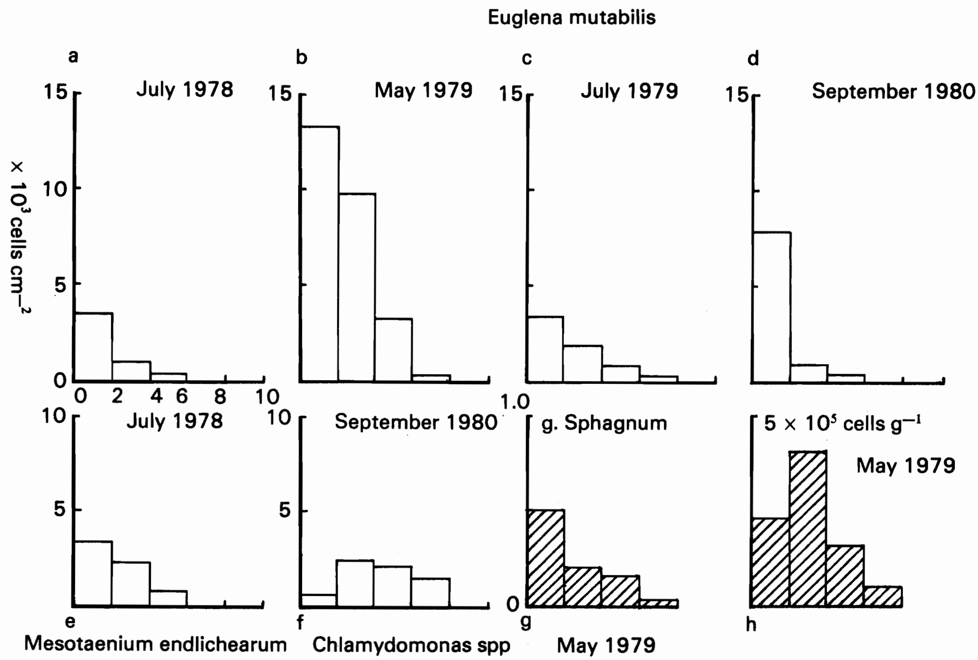



FIG. 5
The distribution of algae with depth in *Sphagnum palustre* (site 1). *a-d, E. mutabilis; e, Mesotaenium endlichearum; f, Chlamydomonas* spp.; *g, S. palustre* dry weight; *h E. mutabilis* replotted from *b* on a *Sphagnum* dry weight scale.

were collected about noon, but samples taken after dark from site 1 (not illustrated) indicated a similar distribution pattern which suggests that a diurnal migration of cells in response to changing light intensities does not occur on a large scale.

c) *Distribution of* E. mutabilis *across the fen.*

In order to assess the variation in *Euglena* numbers over various distances, a stepped transect was taken south from site 1 over a total distance of 40 m, through a homogeneous ground layer of *Sphagnum palustre*. This transect enabled variation over a series of distances to be compared. The results (Fig. 6a) indicated large differences in cell numbers along the length of the transect. For instance, a difference in numbers by a factor of 40 is apparent overall, whilst over 50 cm, the numbers only differed by 20 per cent. The seasonal variation in *E. mutabilis* numbers at site 1 is shown in Fig. 6b. Maximum numbers were recorded during the winter but they fell rapidly during spring to give minimum numbers in early summer. During late summer and autumn numbers increased to about 6,000 cells $cm^{-2}$. It is not possible to relate these changes in numbers to seasonal changes in the environment alone in view of the results obtained in the stepped transect. However, there is a clear relationship between the fall in *E. mutabilis* numbers and the 1980 spring drought illustrated in Fig. 7. Between 1 April and 20 May only 4.5 mm of rain was recorded at the nearby Field Centre, and this period corresponds closely to the fall in *Euglena* numbers. There appears to be no relationship between cell number and temperature (Fig. 7b). The maximum and minimum air temperature at the Field

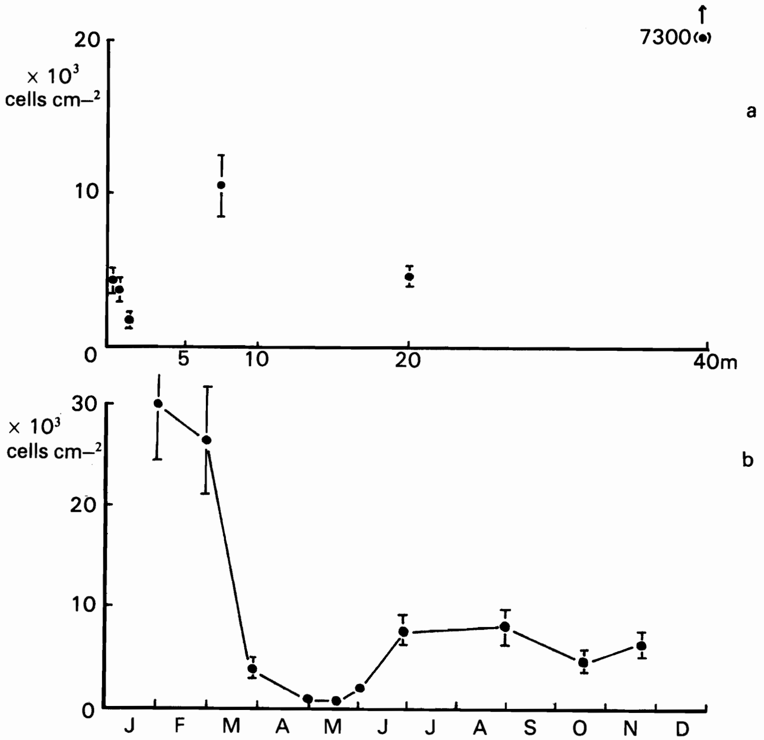



FIG. 6

*a)* Distribution of *Euglena* numbers along a 40 m stepped transect across level *Sphagnum palustre* south of site 1.
*b)* Seasonal variation in *Euglena* numbers at site 1. 95 per cent confidence limits are shown.

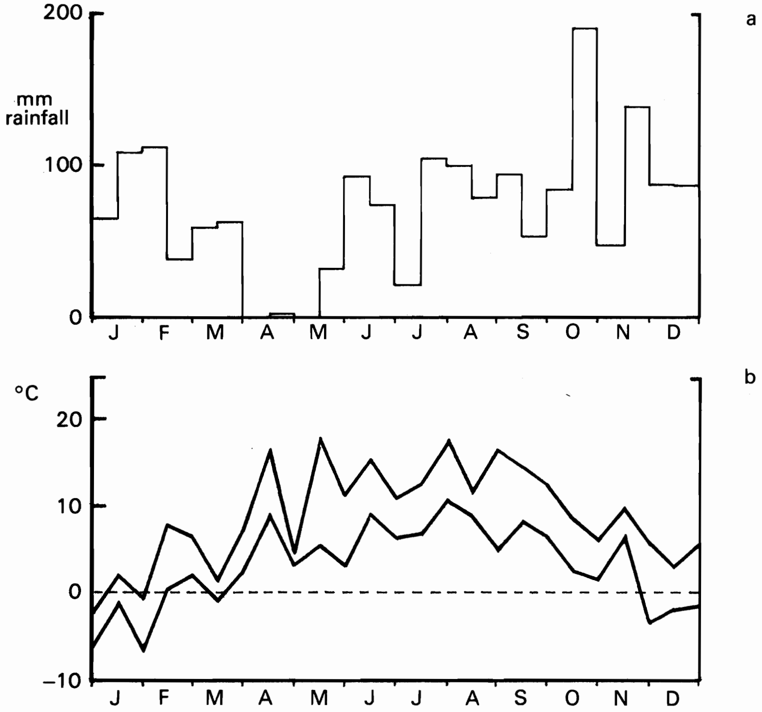



FIG. 7
*a)* Rainfall at Malham Tarn Field Centre during 1980 at two-weekly intervals.
*b)* Maximum and minimum air temperature at Malham Tarn Field Centre during 1980.

Centre ranged from 23–3 °C and 16–7 °C respectively. Air temperature fell below 0 °C on 81 days and only rose above 20 °C on six days. *Sphagnum* samples collected with their upper 2 cm frozen and covered in thin snow contained numerous actively motile *E. mutabilis* cells and there is little doubt that this species is a permanent inhabitant of the Tarn Moss.

The distribution of *E. mutabilis* within the North Fen (Fig. 8) suggests that the eastern part of the fen contains larger populations than the western area. Numbers ranged from 50–6,600 cells $cm^{-2}$ On 31 October 1980. The scatter diagrams shown in Fig. 9 suggest, and the values of Pearson's correlation coefficient confirm, the lack of statistically significant correlations between *E. mutabilis* and pH, Eh and water hardness. However, a weak positive correlation was found between this species and the *Sphagnum* moisture content ($r = +\ 0.44$, $p = 0.05$). The pH and Eh ranged from 3.3–4.0 and +515–+600 mV respectively and the waters were therefore of uniformly low pH and probably well oxygenated. The total hardness ranged from 3.9–37 mg $l^{-1}$ (mean: 13.4) with a calcium: magnesium ratio of 0.36–0.95:1.

The fen is partly covered by dense woodland and eight of the sites were overshadowed by trees. This could influence the algal flora and a statistically significant difference was obtained using the Mann–Whitney U-test. *E. mutabilis* was significantly more abundant in the open areas ($p = 0.05$). When the Kruskall–Wallis test was applied to these data a statistically significant difference was found between

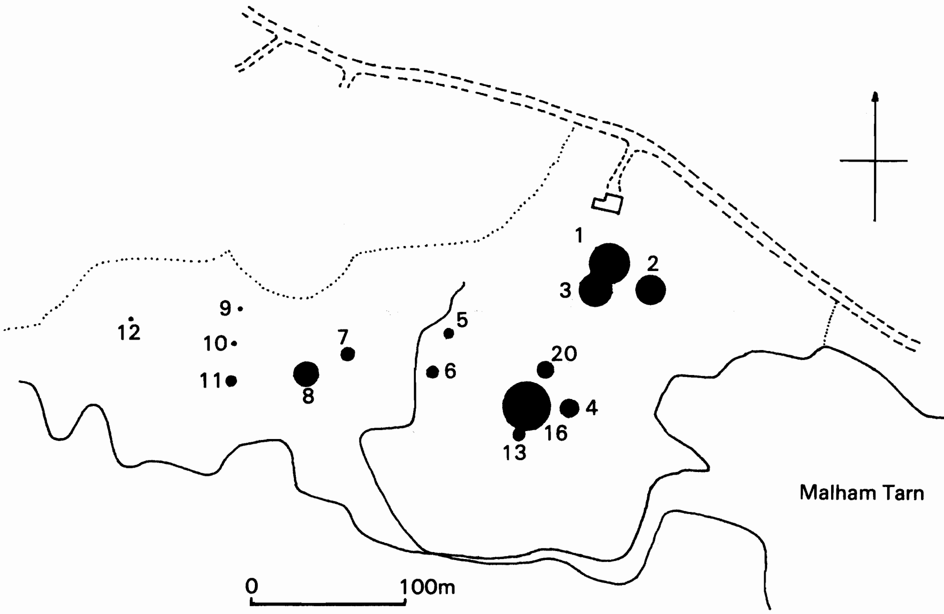



FIG. 8
Numbers of *Euglena mutabilis* cells in the sphagna of Malham Tarn North Fen on 21 October 1980. The circle areas are proportional to numbers per $cm^2$ surface.

the *Sphagnum* species. *S. papillosum* and *S. palustre* had larger populations of *E. mutabilis* than *S. squarrosum* and *S. recurvum*.

d) *Transect into a bog pool.*

This transect ran in a SE–NW direction for a distance of 5 m (Fig. 1, sites 13–19) from a raised peat surface dominated by *Sphagnum, Carex, Juncus* and *Calluna* into a permanent pool 10–50 cm deep. The transect was sampled on two occasions and the results, including a profile showing the distribution of the different *Sphagnum* species is shown in Fig. 11. There was a fall in height of 40 cm along the transect and the drained slopes supported *Sphagnum rubellum* whilst the permanently saturated pool edge contained *S. papillosum* and *S. cuspidatum.* The results for March (Fig. 11 b-g) show large numbers of *E. mutabilis* in the pool and around the edges, with few on the slopes, and a similar pattern was observed in October (Fig. 11h).

Species of *Chlamydomonas* and *Carteria* were often abundant throughout the fen and sometimes occurred in huge numbers. The commonest species was *Chlamydomonas acidophila* Negoro. The cells of this species were often packed full of dark, spherical bodies which obscured the chloroplast structure, and it was not possible to distinguish this species from the other chlamydomonads under the inverted microscope, hence their inclusion under *Chlamydomonas* spp. in the figures. There was no obvious gradient in pH, Eh and total hardness along the transect although there is a clear increase in the water content of the sphagna as the pool is approached (Fig. 11 l-o).

e) *Distribution of other algae.*

Although *E. mutabilis* was frequently the commonest alga in the fen sphagna, other species were often conspicuous in certain areas. *Chlamydomonas* spp. were wide-

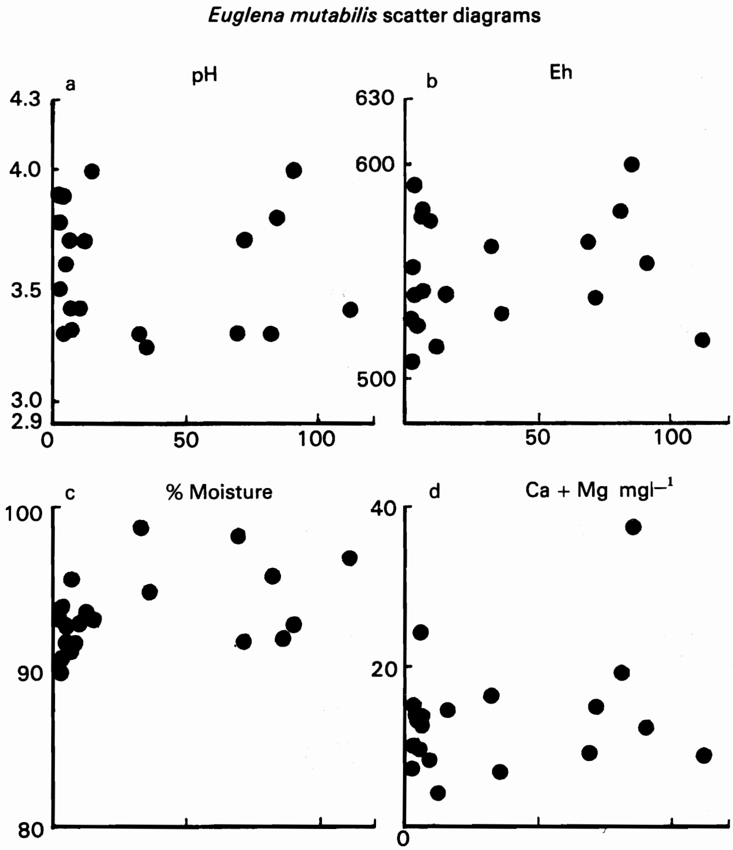



FIG. 9
Scatter diagrams showing the relationship between *Euglena* numbers and *a)* pH; *b)* Eh; *c)* per cent moisture in *Sphagnum* and *d)* Calcium and Magnesium ions.

spread and 50,000 cells $cm^{-2}$ were frequently recorded, but no statistically significant correlations were found between cell numbers and the variables previously mentioned (Fig. 10), although the largest numbers were recorded along the bog transect (Fig. 11 c, i). The distribution with depth in the *Sphagnum* carpet was similar to that of *E. mutabilis* (Fig. 5f) in terms of range, but the top 2 cm of moss did not contain the maximum number of cells. These algae were also common in the large cushions of *Acrocladium giganetum,* a moss in which *Euglena* was notably absent.

Two Saccoderm desmids, *Mesotaenium endlichearum* and *Cylindrocystis brebissonii* were common. The former, smaller, species was widespread and occurred in 14 of the 20 sites in numbers ranging from 300–230,000 cells $cm^{-2}$, with the largest numbers in permanently wet habitats among *Sphagnum palustre* and *S. papillosum.* (Fig. 11, e, j). *Cylindrocystis brebissonii* had a restricted distribution and also appeared to prefer permanently wet areas such as the edge of the bog pool, where it occurred in profusion (600–1500 cells $cm^{-2}$, Fig. 11 d, k). This site was also colonised by *Pinnularia* sp., *Cryptomonas* spp., *Eremosphaera viridis, Chroococcus turgidus* and *Palmella* sp. (Fig. 11, f, g).

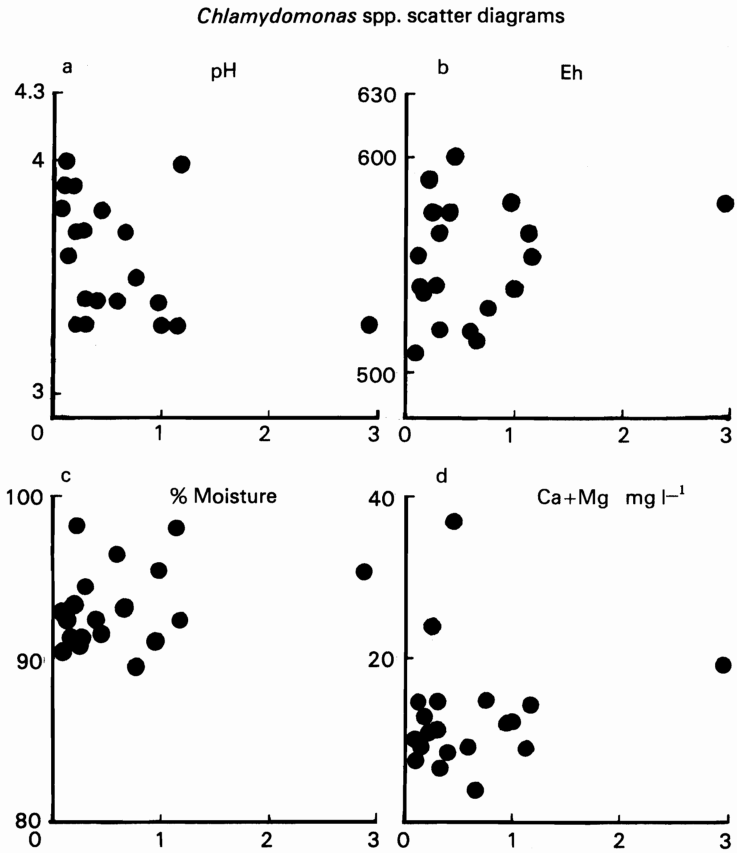



FIG. 8
Scatter diagrams showing the relationship between *Chlamydomonas* spp. numbers and *a)* pH; *b)* Eh; *c)* per cent moisture in *Sphagnum* and *d)* Calcium and Magnesium ions.

## DISCUSSION

*Sphagnum* communities often provide an environment which cannot be described satisfactorily as either terrestrial or aquatic. The water table fluctuates close to the moss surface and the ionic composition of the water is strongly influenced by *Sphagnum* and other bryophytes. *E. mutabilis* is not restricted to this habitat and its occurrence in acidic streams, particularly those associated with mine drainage, has been well documented (Dach, 1943; Hargreaves *et al.*, 1975; Hargreaves and Whitton, 1976). The species is widespread in Britain and the United States and it is one of the few algae capable of growth at pH values as low as 1.3 (Hargreaves and Whitton, 1976) although natural waters with this pH value are scarce and unknown in *Sphagnum* communities.

The *Sphagnum*-associated waters of the North Fen had pH values ranging from 3.2–4.5 although base-rich waters permeate the fens in certain areas (Proctor, 1974). Müller (1973) noted that the tips of *Sphagnum* spp. had a lower pH than other parts of the plant and that bog pools often had a higher pH than the surrounding *Sphagnum*. This was not evident in the North Fen and a pH probe through a bed of *S. palustre* gave a steady pH value to depths of 15 cm.

*E. mutabilis* has been observed from a variety of habitats and it may not be strictly acidophilic. The author has observed it on neutral soil in Surrey and it was found to be frequent on the damp sandrocks of the Weald. Furthermore, Lackey (1938) recorded the species from alkaline waters, iron seepages and salt water. It also appears to be tolerant to heavy metals other than iron (Whitton and Say, 1975; Hargreaves and Whitton, 1976; Say and Whitton, 1980). The Eh values obtained suggest a moderately oxidising environment and this is not surprising for a semi-terrestrial habitat and the lack of an obvious diffusion barrier to oxygen. Nevertheless, Müller (1938) noted that *Sphagnum*-associated waters were capable of reducing $Fe^{+++}$ to $Fe^{++}$ although no detailed study of this phenomenon has been made. In their review of recorded Eh values for the natural environment, Baas Becking *et al.* (1960) quoted a range of $-300$ to $\approx +700$ mV for peat bogs, the higher values being more characteristic of well drained sites. No measurements for living *Sphagnum* communities appear to have been made previously, but the Eh values recorded here fall within the above range. The potential of the platinum electrode is pH dependent and values corrected to pH 7 are sometimes published as $E_7$. For the North Fen, $E_7$ ranged from +315 to +410 mV. The interpretation of these potentials is a difficult matter, however, due to chemical reactions occurring at the platinum surface, particularly at low pH and high Eh (Whitfield, 1974).

*Chlamydomonas acidophila* is known from *Sphagnum* bogs and acidic streams (Fott and McCarthey, 1964; Hargreaves and Whitton, 1976) and Cassin (1974) found that the species grew in the pH range 2-6. The acidity of *Sphagnum* associated waters is known to result from the cation exchange activities of this moss (Clymo, 1963) and the release of organic acids from the associated flora. The hardness values obtained for the North Fen are considerably higher than those reported from fens elsewhere (Müller, 1973; Pakarinen and Tolonen, 1977) although they are similar to the values reported by Proctor (1974) for this fen. This anomaly may be related to the abundance of exposed limestone close to the fen, some of which could be transported as dust.

The penetration of light into *Sphagnum* communities has not been studied, but it is clear that light must be rapidly attenuated by the surface layers of the moss. The leaves of *Sphagnum,* when traced down from the surface, soon become bleached and a zone of decay is evident at a depth of 6–8 cm. The algal community is found almost exclusively in the upper zone among the green leaves and this probably represents the equivalent to the euphotic zone of lakes. Light appears to be essential to the existence of *E. mutabilis* in the fen, for if a patch of *Sphagnum* is covered with an opaque lid, the species disappears after a period of four weeks and the moss becomes bleached throughout. Re-exposure to light leads to a rapid recovery of the *Sphagnum* but only a slow recolonisation by *E. mutabilis* over a period of eight weeks. However, *Chlamydomonas acidophila* remains, in reduced numbers, throughout the dark period and this is one of the few chlamydomonads known to be heterotrophic (Cassin, 1974). Hargreaves and Whitton (1976) found that *E. mutabilis* avoided high light intensities, and *Sphagnum* might also provide an effective light shield for the community. Photophobotaxis was not observed in the field but it must be considered possible, despite the tortuous path the algae would need to take through the *Sphagnum* leaves. *S. palustre,* the commonest species on the fen has a recorded growth rate in Poland of 2–6 cm $a^{-1}$ (Sobotka, 1974) and Clymo (1973) observed that the surface structure of the communities was affected by the height of the water table. In

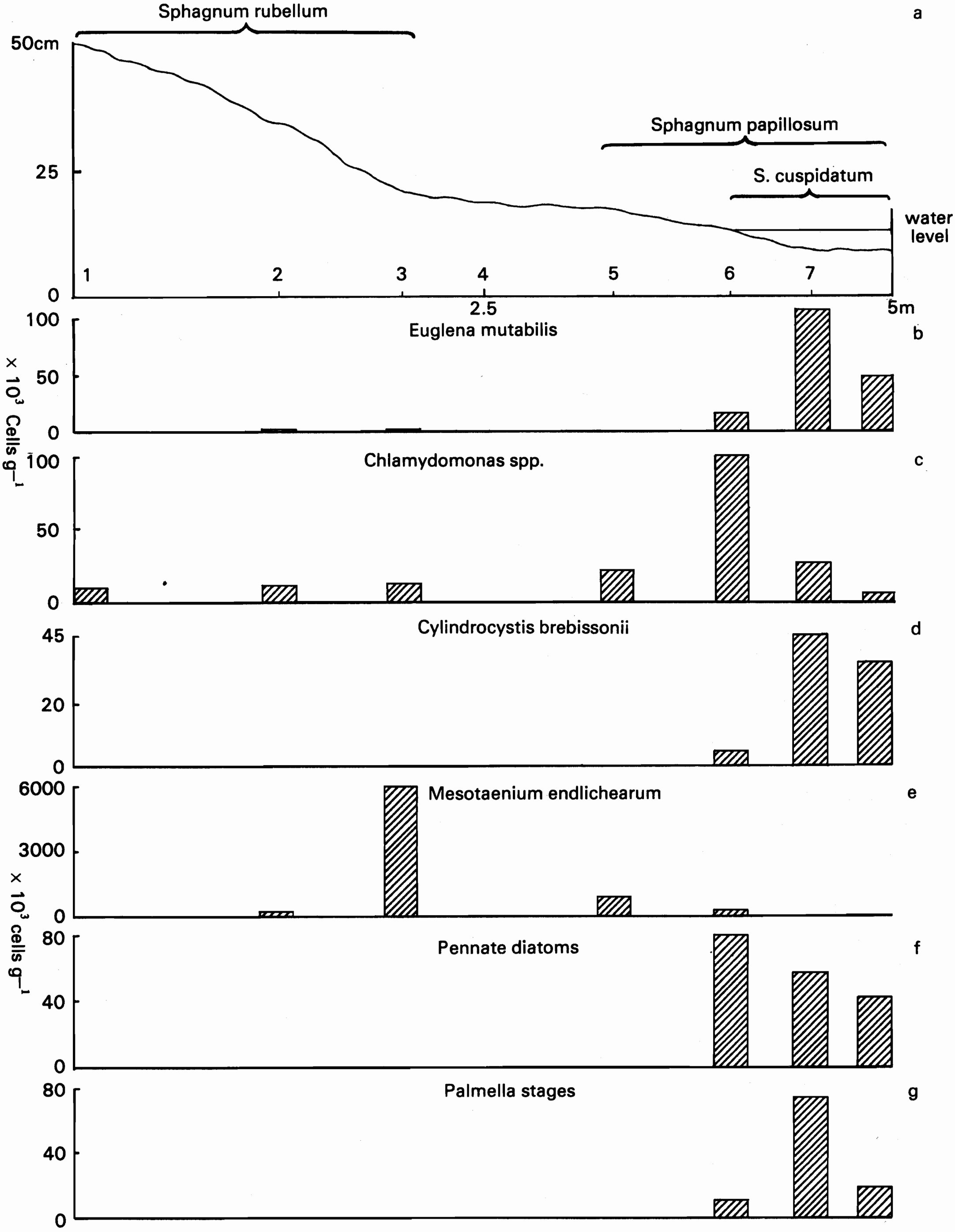
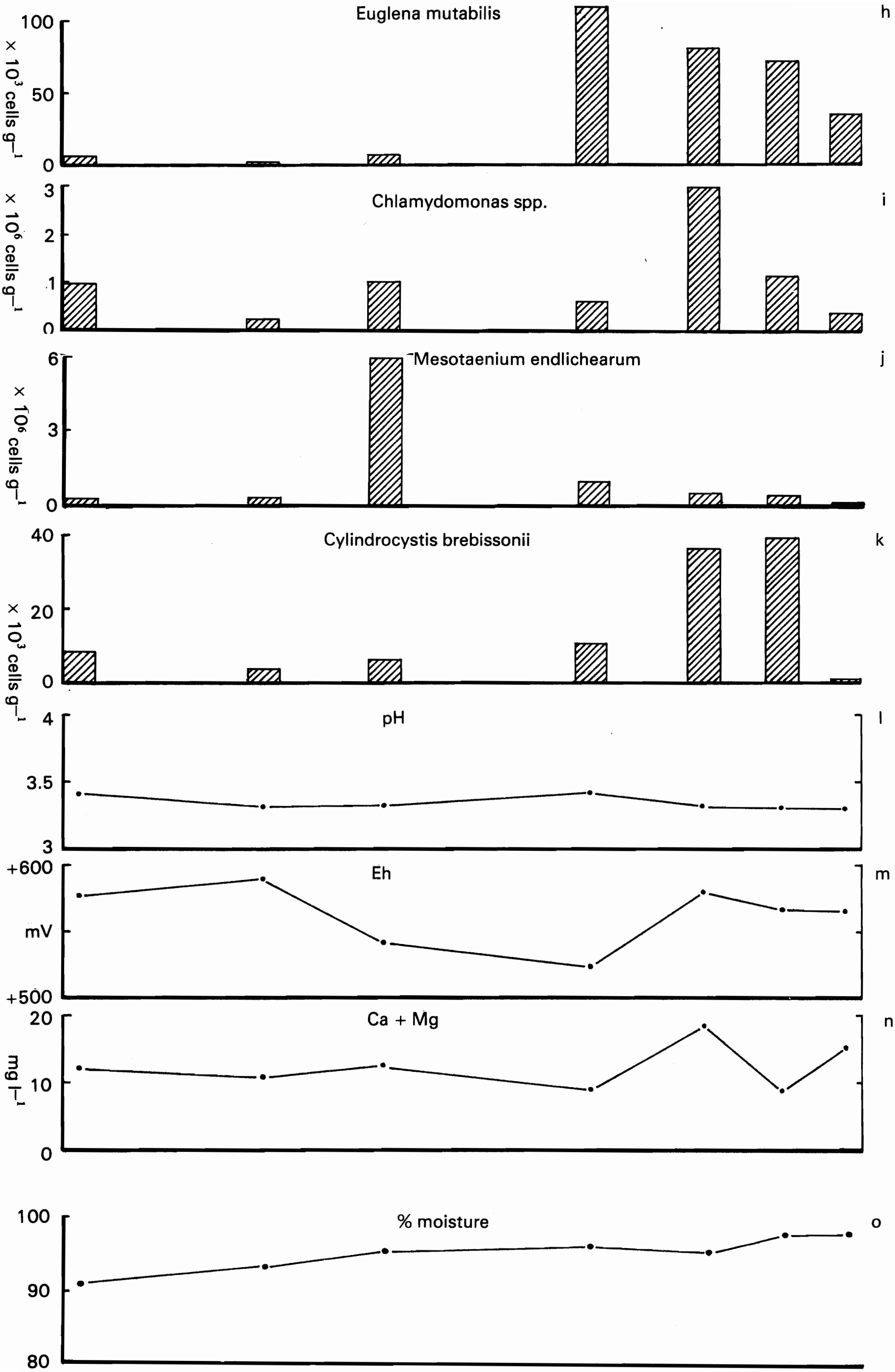



FIG. 11

Transect into a small bog pool on the North Fen.

*a)* Profile showing the distribution of *Sphagnum* species; *b-g)* Distribution of algae on 28 March 1980, *b) E mutabilis; c) Chlamydomonas* spp.; *d) Cylindrocystis brebissonii; e) Mesotaenium endlichearum; f)* diatoms, mostly *Pinnularia* sp. and *g) Palmella* stages *h-j)* Distribution of algae on 21 October 1980, *h) E. Mutabilis i) Chlamydomonas* spp.; *j) Mesotaenium endlichearum; k) Cylindrocystis brebissonii; l)* pH; *m)* Eh; *n)*Calcium and Magnesium ions; *o)* per cent moisture in *Sphagnum.*

The data for *l–o* were obtained on 21 October 1980.



Euglena mutabilis
h
× 10³ cells g⁻¹
100
50
0
Chlamydomonas spp.
i
× 10⁶ cells g⁻¹
3
2
1
0
Mesotaenium endlichearum
j
× 10⁶ cells g⁻¹
6
3
0
Cylindrocystis brebissonii
k
× 10³ cells g⁻¹
40
20
0
pH
l
4
3.5
3
Eh
m
+600
mV
+500
Ca + Mg
n
mg l⁻¹
20
10
0
% moisture
o
100
90
80

the North Fen, the *Sphagnum* surface consisted of a series of hummocks with local differences in elevation of several centimetres The growth of *Sphagnum* and its height above the water table would therefore give rise to small scale differences in the moisture content in the moss and this could help to explain the local variations in *E. mutabilis* numbers, which has been shown previously to be correlated to moisture content. The variation might also be a result of an unorthodox sampling method, although Duthie (1965) observed the same degree of variation over even smaller distances in a population of *Mesotaenium macrococcum* from a similar habitat.

The results of the Kruskall–Wallis test indicated that *S. papillosum* and *S. palustre* had higher numbers of *E. mutabilis* per unit surface area than the other species. This could be due to a number of reasons. For example, of the species sampled, only the above mentioned had broad and hooded branch leaves. The others had more narrow, unhooded leaves. Also, different species can tolerate different degrees of wetness. The above species prefer sheltered, permanently saturated conditions whilst *S. rubellum* prefers more exposed and well drained areas and *S. squarrosum* often occurs on the tops of small hummocks. However, *S. cuspidatum,* which prefers the wettest areas, did not, as might be expected, possess the largest *Euglena* populations, although the most diverse algal flora (and perhaps the largest in terms of biomass) was found among its leaves. The least diverse flora was found in *S. rubellum.* The relative surface areas of the different species almost certainly differ, although measurements were not made to test this. Nevertheless, it is clear that different species of *Sphagnum* do possess different microfloras although the water relations of these mosses probably play a large part in determining both the quantity and species of algae present. No relationship was found between *E. mutabilis* and water chemistry but Hargreaves and Whitton (1976) reported a positive correlation between this species and pH during late summer.

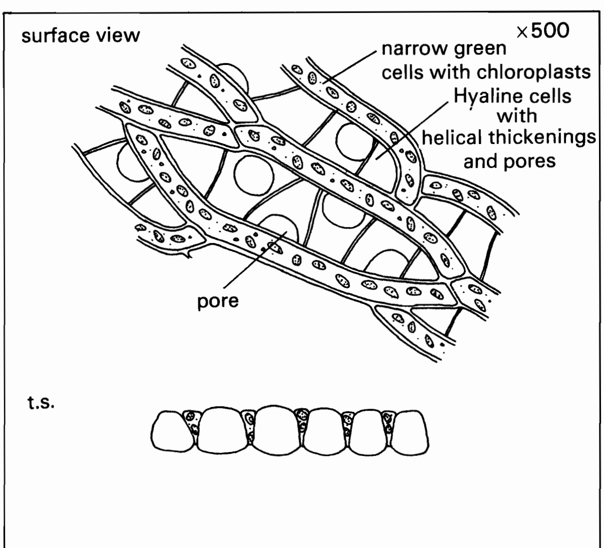



FIG. 12
Leaf anatomy of *Sphagnum palustre* showing a surface view of a part of the leaf and a transverse section across the leaf. The hyaline cells possess rib-like thickenings on the cell wall and pores which allow water, together with algae and protozoa to enter them. Other *Sphagnum* species have similar leaves.

Cell numbers in the North Fen ranged from $10^4$–$10^5$ $cm^{-2}$ at site 1 but it was difficult to locate *E. mutabilis* among the *Sphagnum* leaves and stems. This was probably due to the large surface area to volume ratio of *Sphagnum*. It was found that the surface area of *S. palustre* leaves and stems was 60–100 $cm^2$ per $cm^2$ ground surface (1,200–1,600 $cm^2$ $g^{-1}$ dry weight) and this excluded the interior surfaces of the hyaline cells.

*Sphagnum* possesses broadly lanceolate leaves composed of two kinds of cell producing a single layer of tissue (Fig. 12). The long and narrow green cells containing the chloroplasts are separated by larger dead cells without cytoplasm. These hyaline cells, as they are called, are strengthened with rib-like bands of cell wall material and the cells also contain circular openings or "pores" which permit water to enter and fill the cavity. The pores also allow small algae such as *E. mutabilis* to gain access to the cavities and this might afford some protection from herbivores. In fact, *Euglena* was frequently observed within these cavities and this helps to explain the difficulty experienced in extracting the cells for counting.

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