

This article was downloaded by: [York University Libraries]
On: 01 January 2015, At: 16:48
Publisher: Taylor & Francis
Informa Ltd Registered in England and Wales Registered Number:
1072954 Registered office: Mortimer House, 37-41 Mortimer Street,
London W1T 3JH, UK



Transactions of the Botanical Society of Edinburgh

Publication details, including instructions for authors and subscription information:

<http://www.tandfonline.com/loi/tped18>

Some Observations on Spirogyra

Mr Gustav Mann

Published online: 01 Dec 2010.

To cite this article: Mr Gustav Mann (1891) Some Observations on Spirogyra , Transactions of the Botanical Society of Edinburgh, 18:1-4, 421-431, DOI: [10.1080/03746609109468076](https://doi.org/10.1080/03746609109468076)

To link to this article: <http://dx.doi.org/10.1080/03746609109468076>

PLEASE SCROLL DOWN FOR ARTICLE

Taylor & Francis makes every effort to ensure the accuracy of all the information (the "Content") contained in the publications on our platform. However, Taylor & Francis, our agents, and our licensors make no representations or warranties whatsoever as to the accuracy, completeness, or suitability for any purpose of the Content. Any opinions and views expressed in this publication are the opinions and views of the authors, and are not the views of or endorsed by Taylor & Francis. The accuracy of the Content should not be relied upon and should be independently verified with primary sources of information. Taylor and Francis shall not be liable for any losses, actions, claims, proceedings, demands, costs, expenses, damages, and other liabilities whatsoever or howsoever caused arising directly or indirectly in connection with, in relation to or arising out of the use of the Content.

This article may be used for research, teaching, and private study purposes. Any substantial or systematic reproduction, redistribution, reselling, loan, sub-licensing, systematic supply, or distribution in any form to anyone is expressly forbidden. Terms & Conditions of access and use can be found at <http://www.tandfonline.com/page/terms-and-conditions>

Some Observations on Spirogyra. By Mr GUSTAV MANN.

(With Figs. 1–8, PLATE II.)

(Read 10th April 1890.)

The fresh water alga *Spirogyra*, known to most people as it presents itself as smaller or larger patches floating on the surface of ponds and of slowly flowing waters, seems, however, when in this condition not to be growing normally. About two years ago, while I was fishing from a boat in Duddingston Loch, near Edinburgh, I accidentally came across large banks of this alga growing at a depth of from four to five feet; the species found were chiefly *S. nitida* and *S. jugalis*, in about equal proportion; the individual threads were from $2\frac{1}{2}$ to 3 feet long, not at all entangled, and in perfectly healthy condition. The bottom of the loch at places where this alga was growing was covered with a brownish-red material, which, on microscopic examination, proved to consist of dead *Spirogyra*-cells in which the chloroplasts had undergone a peculiar disintegration, giving rise to the formation of pink or reddish granules.

Each *Spirogyra*-thread is conveniently divided into an apical, a shaft, and a foot portion. I make this division because there are differences in the cells of these three regions.

The apical cell is slightly bulged out at its free end, the chlorophyll bands broaden out at the ends nearest the apex, and the cell as a whole seems to be the most vigorous in growth, as I conclude from the fact that I have seen twice division occurring in it, while, in one of these cases, the second cell only, and in the other case not a single cell of the thread—and I examined a piece at least 3 inches long—in either case, showed any indication of division.

The cells of the shaft are those usually described, and they normally divide. As we approach the lower end of a thread however, the cells appear to divide less regularly; *i.e.*, some may be far advanced in division, while neighbouring cells show no sign of it. The cells in the lower region of the shaft are slightly longer than those in the upper, but the difference is not so marked in cells formed during the

summer as compared to cells formed in the winter months. In fig. 1, Plate II., I have represented two cells of *S. nitida*; the shaded portion shows the increase in length that takes place during winter. The cells are drawn by aid of a Nachet's camera. The smaller cell represents the average length in the month of July, while the larger shows the average length of cells in February; but I shall refer to this fact again later on in my paper.

The cells at the very foot of each thread show signs of decay, for the chlorophyll bands tend to be irregularly disposed and to become vacuolated. As these cells decay they will not be able to support the weight of the whole thread, they will collapse therefore and form the already mentioned brownish material; but this change is so gradual that, under normal conditions, the foot will be strong enough to moor the whole thread to the bottom of the pond.

To estimate the amount of water, combustible and non-combustible solids, I proceeded thus: Healthy *Spirogyra* material (*S. nitida* and *S. jugalis* in about equal proportions) was repeatedly washed to remove all impurities, as bits of decayed matter, water insects, &c.; then the material was washed in distilled water to remove the salts which are in ordinary water, placed on muslin in a large filter and allowed to drain till it assumed a light green colour, showing that the water between the threads had run off. One kilogramme of this drained material was placed in a large shallow porcelain dish, the weight of which had been previously ascertained, and the dish exposed on a sand-bath to a temperature of 200° F. for 48 hours, then the temperature was raised to 230° degrees F. for 6 hours. The *Spirogyra* material had formed a hard crust in the dish, and as soon as the dish had cooled it was weighed; for if the weighing be delayed for several hours, the dried material will increase considerably in weight from condensation of the atmospheric moisture. The result of the weighing showed that of the original 1000 grms., 968 grms. had been evaporated, giving a percentage of 96·8 of water, and a residue of 32 grms. of solids. The residue was placed in a platinum vessel and burnt, to calculate the amount of pure ash; after burning, the amount of ash equalled 4·8 grm., the volatile substances therefore equalling 27·2 grm. for 1000

gram. The percentage of water, volatile and non-volatile constituents, in *Spirogyra* is therefore as follows :—

Water,	96·8	per cent.
Volatile constituents,	2·72	„
Non-volatile constituents,	0·48	„
	<hr/>	
	100	per cent.

This large amount of water led me to the following experiment, showing to what extent turgor stretches the elastic cell-wall. A slide is immersed in water in which are a few threads, preferably of *Spirogyra nitida* ; one end of a thread is fixed on the slide with the index finger and the slide gently withdrawn, when the thread will lie in a straight line. The slide and thread are arranged under a magnifying power sufficiently high to allow the individual cells being counted readily ; the ordinary eyepiece is then replaced by a micrometer-eyepiece, and the number of cells covered by the scale is counted and marked down ; then the same process is repeated with another part of the same thread, to see whether the number of cells counted the second time agrees approximately with the first number, and if the difference between the two numbers is only a slight one, *i.e.*, not more than half the length of one cell, the thread may be used for the experiment. We apply now a 75 per cent. solution of common salt, which will produce plasmolysis and cause the thread to become shorter. The thread is arranged again, and the number of cells covered by the scale on the eyepiece counted. The average shortening is close on 10 per cent. of the original length—*e.g.*, in one case I counted 20 cells, and after treatment with salt-solution 22 and part of a 23rd cell. We may therefore say that the cells owe one-tenth of their original size to turgescence.

As *Spirogyra* is a plant very suitable for many observations and experiments, it is convenient to have always a supply of fresh material at hand, and a few words on its cultivation may not be out of place. When a mass of *Spirogyra* material is placed in a vessel it will sink at first to the bottom, then the more vigorous threads begin to grow upwards towards the surface of the water, and in doing so ribbon-shaped masses or strands will be formed: this

vigorously growing material alone should be used for studies, and not the thread lying at the bottom of the vessel.

Strassburger's and Detmer's methods for cultivating *Spirogyra* answer both very well. Strassburger's method is shortly this. The material is placed in shallow vessels with opaque walls, to prevent unilateral light acting on the plant, but at the same time the vessel is placed in a light place, protected from the direct action of the sun, and a room towards the north is to be preferred. From time to time pieces of turf soaked in the following nutrient fluid :—

Water,	.	.	.	100	ccm.
Potassium nitrate,	.	.	.	1	gram.
Sodium chloride,	.	.	.	$\frac{1}{2}$	"
Calcium sulphate,	.	.	.	$\frac{1}{2}$	"
Magnesium sulphate,	.	.	.	$\frac{1}{2}$	"
Calcium phosphate,	.	.	.	$\frac{1}{2}$	"

are placed in the vessels containing river or spring water.

Detmer's formula for a nutritive solution is :—

1	gram.	Ca_2NO_3 ,	.	} in 1 litre of distilled water.
0.25	"	KCl,	.	
0.25	"	MgSO_4 ,	.	
0.25	"	KH_2PO_4 ,	.	
0.25	"		.	

I find that if $1\frac{1}{2}$ litre of distilled water instead of 1 litre be taken, that *Spirogyra* will grow more vigorously.

The vessel I like best for cultivating *Spirogyra* is one made of glass and covered with white tissue paper, about 18 inches deep by 18 inches broad (if broader ones are to be had they should be taken); it is filled with fresh spring water up to 3 inches from the top, then a current of carbon dioxide is passed through the water for five minutes, the material placed into the water and exposed to bright daylight. The carbon dioxide I prepare in the usual way with nitric acid and pieces of marble, and it is purified by being passed through a lye of caustic potash. The purified gas is conducted to the vessel with water by means of an india-rubber tube, into the end of which a glass tube is fitted, drawn out into a fine point. Whenever the gas begins to escape by the glass tube, the latter is pushed to the bottom of the vessel and moved about, to allow the gas bubbles to come in contact with as much water as possible.

After the *Spirogyra* has begun to grow in the vessel, which it will have done after 24 hours, we supply it daily early in the morning for two minutes with a stream of carbon dioxide bubbles, avoiding any undue commotion in the water, and thereby mixing of the healthy threads with the decaying ones lying at the bottom of the vessel. Every week the vigorous *Spirogyra* should be lifted out carefully and placed in another vessel, to allow removal of the débris lying at the bottom of the vessel.

What effect an extra supply of carbon dioxide has on carbon assimilation the following experiment shows clearly:—Take two glass jars, 4 inches broad by 2 feet high, fill them with ordinary water up to 6 inches from the top, pass through the water in vessel A a stream of carbon dioxide for five minutes, while the water in vessel B does not receive any CO₂ in addition to that already present in the water. Next take an equal quantity of vigorously-growing *Spirogyra* and push it to the bottom of vessels A and B, and expose these to bright daylight. After a varying time, according to the strength of the light, the material in vessel A will rise to the surface of the water a considerable time before the material in vessel B will do so, owing to the fact that assimilation, going on faster in vessel A (containing an extra amount of CO₂), a greater number of oxygen bubbles will be set free, which, acting as buoys, will carry the *Spirogyra* threads upwards.

By a process similar to the one just described the patches of *Spirogyra* that grow on the surface of ponds, &c., are brought about; for whenever the threads become entangled, and bubbles of oxygen that are given out during assimilation cannot escape through the entangled mass, the gas will gather till it is strong enough to overcome the resistance of the threads mooring the mass to the bottom of the pond, the foot-end of the threads will break, and, as already stated, a floating mass of *Spirogyra* will result.

The apices of threads grown in a glass jar have a nutative power, as will become evident from fig. 2, Plate II., which represents a mass of *Spirogyra* in the shape of a band, the broad side being directed towards the source of light. The band does not grow upwards, however, in a straight line, for at *a* and *b*/ the threads have grown towards the source of light, or rather, after cell division had taken place during the

preceding night, the threads exhibited during the day a heliotropic tendency, they approached the side of the vessel next the window only to grow away from that side during the night. I believe the nutation to be brought about in the following way:—As soon as the strong stimulus “light” has stopped acting on the cells, each cell, and thus the whole thread, will tend to procure for itself as large an area of water as possible, for the larger the area of water the more readily can respiration be carried out, and the more oxygen there is taken up by each cell the more energetic will be the metabolism of starch into directly available material.

This material will be consumed, firstly, by those elements of the cell which are essential for the maintenance of the life of the cell as an individual; any surplus of nourishment will be used for purposes of cell division or multiplication; or, to put it more clearly, it is of the highest importance to recognise that there are in each cell definite structures essential for division, *i.e.*, a reproduction of the cell, namely, the nucleolus with its contents; and other structures, which bring about this division by procuring and elaborating nutritive substances, namely, the nucleus proper, the cytoplasm, and the cell wall. Thus to distinguish in each cell between a reproducing and a vegetating element. The view just stated allows us to understand why, during the colder months of the year, cells of *Spirogyra* should attain a larger size than during the warmer months; for, during winter, each cell will have to combat low temperature, want of light, and similar conditions unfavourable for procuring and elaborating nutritive material, and hence the vegetating element of the cell will be specially developed to save at least the life of the individual cell.

It is only natural that under such conditions a cell should sometimes have enough energy to start division, without, however, being able to complete it, as is evident in those cases, not uncommon during winter, in which two nuclei are found in one large cell with either no indication of a new cell wall, or with only the rudiments of a cell plate attached to the inner aspect of the old wall (fig. 3, Plate II.). That in these cases we deal with cells which would not have formed a complete partition, had they not been disturbed in doing so by fixing the threads for micro-

scopical study, is proved by two facts: Firstly, the nuclei are fully formed, with no indication of a nuclear barrel; and, secondly, a line drawn between the two nuclei would not be at right angles to the plane of the rudimentary cell wall, and would not pass through the centre of this plane, as one of the nuclei is usually found close to the side of the mother cell, or even both nuclei may be on one side of the partition, the other half of the cell having no nucleus.

I shall conclude this paper by recording some miscellaneous observations made while studying the chlorophyll-bands, specially with regard to changes in the shape of the chlorophyll-bands, the form of the protein crystals, methods of staining nuclei and threads, &c., and ultimately I shall refer to the occurrence of crystals. The chlorophyll-bands represent on cross section usually a "Y" shape if examined during the day; but if material which has been kept in the dark for 48 hours is examined, the chlorophyll-bands show an oval or flattened outline (fig. 4). What the cause of this peculiar change is, I cannot state definitely, but one explanation may be this: the pyrenoids are placed in the centre of the chlorophyll-bands and sunk in the substance of the band, and as starch is gradually laid down in them, they will swell, and being pulled towards the nucleus by the threads joining them to it, they will alter the shape of the band, rendering the latter convex on the side next the nucleus, and concave next the cell wall. This view is strengthened by the fact that the more starch is laid down in the pyrenoids, the more marked is the ridge on the surface of the chloroplast next the nucleus. This change will also bring about less surface exposure of the band to light, and so diminish the elaboration of starch.

The threads joining the pyrenoids to the nucleus have a structure as first described by Pringsheim, namely, at the pyrenoidal end they form deeper or shallower cups, enclosing the starch-centres or protein crystals, as Strassburger terms them, while at the nuclear end the threads fuse, according to my observations, in two bags, in the shape of hemispheres, the margins of which are united together. The two bags are placed in the long axis of the cell, and are specially well seen in *Spirogyra jugalis*, if threads be treated first with absolute alcohol and then

with water, which causes the bags to expand and to form bladder-like structures, to which the threads are attached. In *S. nitida* the two bags are so dense that they won't swell up, and they seem to have fused completely to form only one circular bag. Fig. 5 represents a portion of the bag surrounding the nucleus with threads going to the pyrenoids, dissected out from a cell of *Spirogyra nitida*.

There seems to be considerable difference of opinion about the starch-centre or protein crystal, contained in the cup-like expansion of the threads. A. Meyer, in *Bot. Zeitung*, 1883, No. 30, describes the protein crystals as bodies with angular outline; Strassburger describes them similarly in his *Practical Botany*; Berthold denies the angular outline, and also the statement made by Schmitz that the protein crystal consists of a substance identical with the chromatin of the nucleus; A. Meyer and Schimper also deny the first-mentioned identity; Zacharias considers the nucleoli and pyrenoids to be similar, since both consist of digestible albuminoids. I myself hold that the protein crystals are either globular or angular, according to the amount of starch stored up in the pyrenoids. If a pyrenoid be examined in which there is no starch we see a central rounded body, the protein crystal surrounded by a pale ring, the cup-like expansion of the thread. As starch is being formed it is laid down outside the protein crystal round definite centres, and therefore we see, if a small quantity of starch is present in the pyrenoid, minute granules lying close to the protein crystal. As more and more starch is deposited, these small granules gradually increase in size, and assume a bi-convex shape; and whenever they have increased so much in size as to touch one another, the protein crystal assumes an angular shape. If assimilation has been going on very vigorously, so much starch may be deposited that it is no longer possible to make out the different starch granules, and they will appear to have fused to form a swollen ring-like mass round the protein crystal; and the latter will have, on focussing, a circular outline, as is best seen in *S. nitida*, if threads be examined towards the evening of a warm, sunny summer day. For explanation of the figures see page 431.

To study the relation of the starch granules to the protein crystals, the two best ways are these:—

1. Detmer's method—

Spirogyra (preferably *Sp. jugalis*) is placed in strong warm alcohol, which, in about ten minutes, will have extracted the whole of the chlorophyll. The bleached threads are laid either for a short time in hot, or for twenty hours in cold, not much concentrated caustic potash (a 5 per cent. solution I find best); next the threads are carefully washed out with distilled water, then treated with dilute acetic acid to neutralise the potash completely; again washed in water and placed in a solution of—

Iodine,	0.05	gram.
Potassium iodide,	0.2	„
Water,	15	„

2. Mann's method—

Treat the threads for two minutes with liquor chlori, and examine at once in liquor chlori.

Methods for demonstrating the nuclei and threads I may mention here also.

Nuclei show the endo-nucleoli beautifully if treated with a saturated solution of bichloride of mercury and picric acid in water or in absolute alcohol. Threads treated in this way show hardly any plasmolysis.

The threads joining the nucleus with the pyrenoids are stained most satisfactorily by placing some *Spirogyra* threads for three hours into a saturated watery solution of picric acid, to which nigrosine, readily soluble in water, has been added, till a layer, 1 inch thick, is of a deep olive-green colour. The *Spirogyra* is then washed thoroughly in distilled water to remove the picric acid. The threads and the nucleus will be stained a bluish black, and the nucleolus will be almost black.

Another equally good method for demonstrating the threads is this: place *Spirogyra* for twenty-four hours in a 1 per cent. gold chloride solution, and examine in this solution; the threads are not stained, but are well defined, having become very refractive. A saturated watery solution of picric acid renders the threads also very evident.

I may mention here that although, as a rule, the nucleus

is only indirectly in communication with the pyrenoids by means of the first-mentioned threads, that in a species which I found in February 1889 in the pond in the Royal Botanic Gardens, and the name of which I am unable to determine (*vide* fig. 7), the chlorophyll-bands touched the nucleus directly. Each cell contains three chlorophyll-bands, and as these approach the nucleus the spirals become steeper, the bands broaden out, and are closely applied to the surface of the nucleus, forming a complete bag, which seems to replace the threads. Remarkable is also the fact that the bag is packed with pyrenoids, which will act as a storehouse of nourishing material close to the nucleus. As I was not able to find this form of *Spirogyra* during last summer, it is possible that it may just be an ordinary species, which in this way has become modified to enable it to perform its functions during the cold spring months.

If *Spirogyra* material is placed in water to which a few drops of a 10 per cent. gold chloride solution have been added, the gold chloride will be reduced by the action of the threads joining the pyrenoids and the nuclei. I find, at least, the gold chloride deposited as small black granules along the course of the threads; but in addition to this, the gold chloride in the water is also reduced, imparting a beautiful violet colour to the water on transmitted light.

About ten years ago Dr Macfarlane observed crystals in *Spirogyra*, and according to a notice in *Nature* (1888), Strassburger has also observed them. My investigations, which were carried on mainly during the winter of 1889-90, enabled me, for this very reason, to pay special attention to these crystals, for during the colder months of the year, when the cells are merely vegetating and growing to exceptionally large sizes, the number of crystals in a cell may increase from two or three up to seventeen, this being the largest number of crystals I counted in one cell. The crystals are of common occurrence in *S. nitida* and *S. jugalis* growing in Duddingston Loch; they occur commonly in the form of a cross with slender pointed arms, as represented in fig. 8, *b*; by a fusion of a number of these crosses, forms, as represented in *d* and *f* are brought about. The crystals represented in figs. *g* and *h* I saw only once in a thread; the knobs were quite distinct, and had not the

appearance of crystals which are being dissolved. The composition of the crystals seems to be oxalate of calcium, as the crystals dissolve without evolution of gas in nitric acid, and as they are insoluble in acetic acid.

EXPLANATION OF PLATE II.

(Illustrating Mr Mann's papers on Chlorophyll and *Spirogyra*.)

ABSORPTION SPECTRA OF CHLOROPHYLL.

1. *Spirogyra*, living chlorophyll.
2. Moderately strong alcoholic extract from living material.
3. Strong solution alcoholic extract from living material.
4. Alcoholic extract evaporated and redissolved in benzole.
5. Alcoholic extract from boiled material.
6. Alcoholic extract from boiled material with ammonia added.
7. Alcoholic extract from boiled material with nitric acid added.
8. Extract made by triturating with benzole.
9. Extract made by triturating with xylol.
10. Extract made by triturating with petroleum ether.
11. Average spectrum given by living plants.

FIG. 1. *a*, Normal size of one cell of *Spirogyra nitida* during summer. *b*, Increase during winter.

FIG. 2. Jar cultivation of *Spirogyra*. *a*, Viewed laterally. *b*, Viewed from the front. *x*, Lower part with equal growth of *S. nitida* and *S. jugalis*. *y*, Middle part consisting largely of *S. nitida*. *z*, Upper part consisting entirely of *S. nitida*.

FIG. 3. *Spirogyra jugalis*. Cell with two nuclei and incomplete cell wall.

FIG. 4. Side view of cell showing change in outline of two chlorophyll-bands from deposition of starch.

FIG. 5. Bag formed by fusion of the nuclear ends of the supporting threads. The nucleus has been removed.

FIG. 6. Stages in starch formation. *a-f*, Surface view. *a'-f'*, Lateral view.

FIG. 7. *Spirogyra*, sp., showing chlorophyll-bands forming a bag round the nucleus.

FIG. 8. *a-h*, Crystals.

Fig. 1.

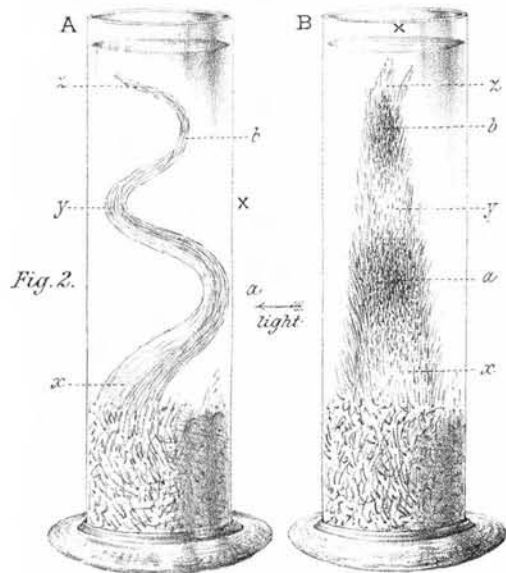


Fig. 4.



Fig. 5.

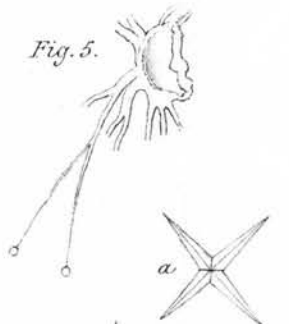


Fig. 3.

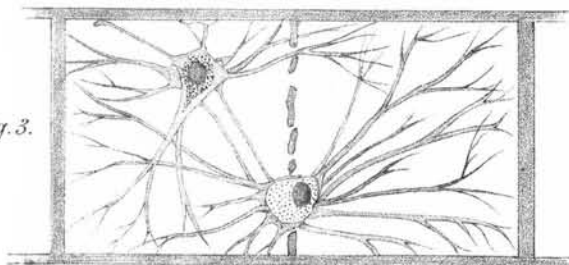


Fig. 6.

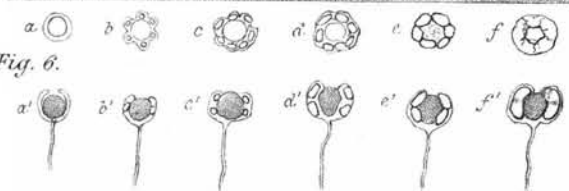
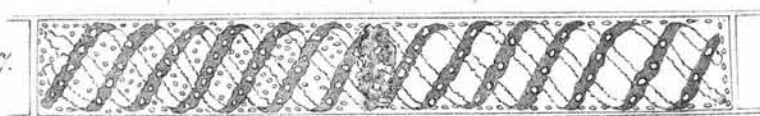
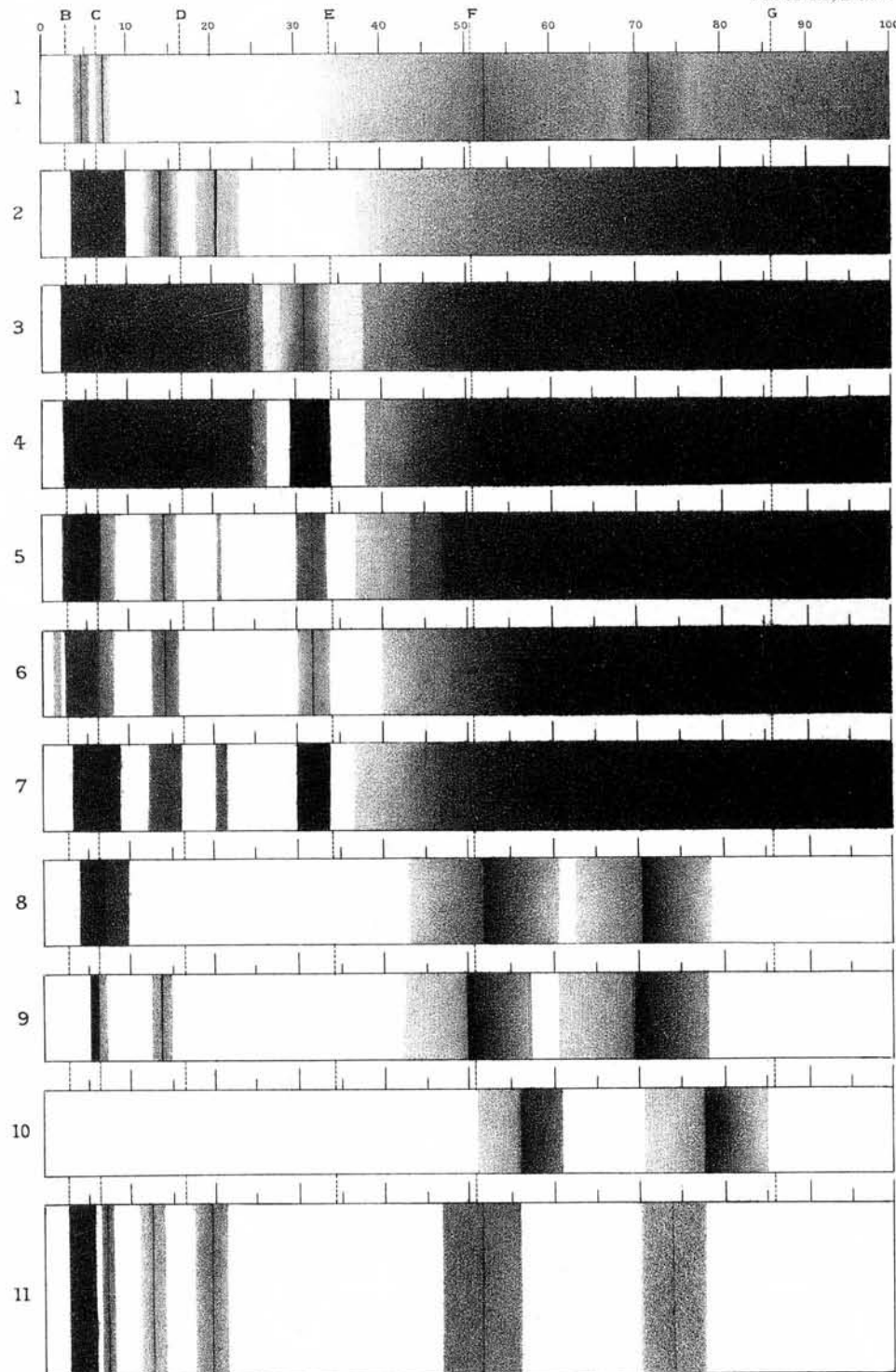


Fig. 7.



G. Mann del.

MANN.—ON CHLOROPHYLL.



F. Huth, Lith. Edin.