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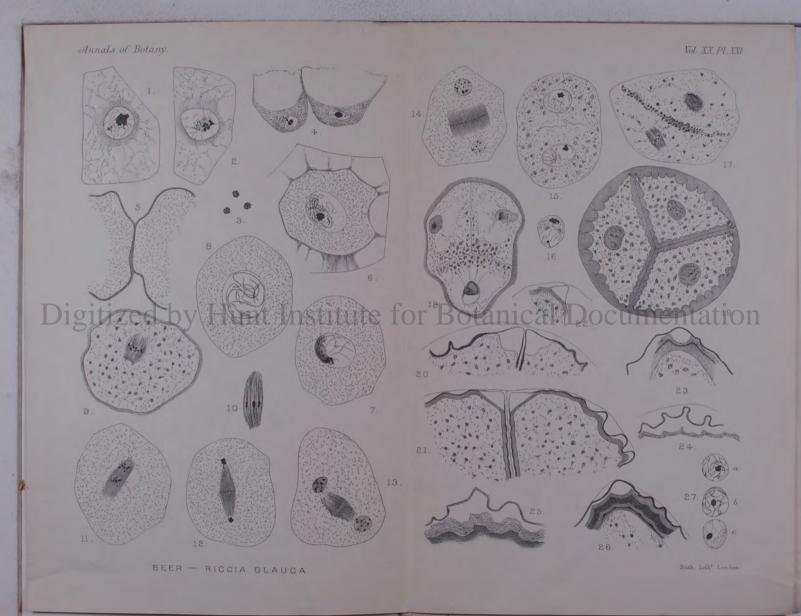
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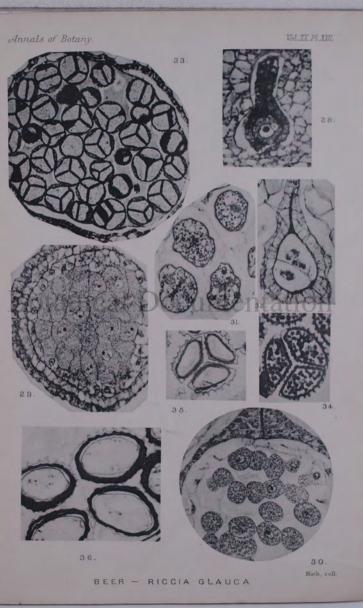
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RUDOLF BEER, F.L.S.

With Plates XXI and XXII.

THE principal facts in the development of the spores of *Riccia* have already been described by Leitgeb¹ and Strasburger². In the seventeen years which have elapsed since Strasburger's paper was written botanical microtechnique has, however, made such immense progress that it was thought desirable to subject these spores to a renewed investigation. Quite recently Garber³ has dealt with the life-history of *Riccia carpus natans*, and Lewis⁴ with the embryology and development of *Riccia lutescens* and *R. crystallina*, but neither of these authors has described the spore or the development of its membranes. Lewis's observations show that *Riccia lutescens* is merely a terrestrial form of *Ricciacarpus natans*, and he believes that the differences which exist in the structure of the thallus and the arrangement of the sexual organs are not sufficiently marked to justify the genetic separation of *Ricciocarpus* from *Riccia*. He accordingly drops the genus *Ricciocarpus*

The material for the present study was fixed in strong and medium chrom-acetic mixtures (Chamberlain's formulae), strong Flemming's solution and in alcohol and acetic acid mixture. Of these the stronger chrom-acetic fluid proved the most satisfactory, but excellent results were also obtained with the alcohol and acetic mixture.

altogether and includes Ricciocarpus natans among the Ricciae.

I will begin my account with the fertilization of the egg-cell. The general character of this process is shown in Pl. XXII, Fig. 28, from which it will be seen that it closely resembles the fertilization of *Riccia (Ricciocarfus)* natans as described by Garber. My photograph also shows that the shrinkage

¹ Leitgeb, Ueber Bau und Entwicklung der Sporenhäute. Graz, 1884, pp. 39-49.

² Strasburger, Ueber das Wachsthum vegetabilischer Zellhäute. Histologische Beiträge, Heft 2, 1889, pp. 104-11.

⁸ Garber, The Life-history of *Ricciocarpus natans*. Bot. Gazette, vol. xxxvii, 1904, pp. 161-77. ⁴ Lewis, The Embryology and Development of *Riccia Intescens* and *Riccia crystallina*. Bot. Gazette, vol. xii, 1906, pp. 169-38.

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of the egg-cell is far less than is usually figured, and in this point I am again in agreement with Garber's statements. The first division of the fertilized egg-cell is usually obliquely transverse (Fig. 32). The succeeding divisions have been so frequently described that I need not recapitulate them here. They result in a mass of sporogenous tissue surrounded by a single layer of sterile wall-cells, the whole being enclosed within a two-layered calyptra. The young spore-mother-cells are at first separated from one another by extremely delicate membranes (Fig. 29). These stain, often deeply, with bismarck brown, but I am unable to get a decided reaction in them with ruthenium red, whilst with calcium-chloride-iodine and chlor-zinc-iodine they colour yellow but show no signs of containing cellulose.

The cell contains a quantity of starch which is especially abundant round the nucleus. Upon the primary walls which separate the sporemother-cells from one another a secondary and, later, a tertiary thickening layer is deposited (Pl. XXI, Fig. 5). Both layers give the reaction of cellulose as well as those of pectose, but the tertiary thickening layer (viz. the one in immediate juxtaposition with the protoplast) stains the more deeply with pectic reagents.

The protoplast surrounded by the tertiary thickening laver now rounds itself off and becomes separated from the primary mother-cell membrane. The secondary thickening layer, which has become more or less mucilaginous in consistency, sometimes separates completely from the primary walls and then forms a well defined layer surrounding the protoplast (Figs. 5, 9, 31). At other times, on the contrary, it remains partly adherent to the primary wall and in that case it becomes drawn out into a number of strands bridging over the gap between the rounded protoplast and the primary wall. The latter condition is represented in Fig. 6, and it will be observed that my drawing closely resembles Leitgeb's Fig. 3, Taf. II. Leitgeb, however, believed that the space between the primary wall and the protoplast was occupied by a homogeneous mucilage, and that the strands of material which both he and I have figured are composed of food-materials diffusing in from the outside. In my preparations it is quite certain that no homogeneous mucilage occupies the space between protoplast and primary wall; moreover the strands of material stretching across this space give cellulose and pectose reactions exactly corresponding with those obtained in the secondary thickening layer (e.g. of Fig. 5 where the cells are still partly united).

It should be mentioned that the condition represented in Fig. 6 is no doubt somewhat exaggerated by the reagents used. The measurement of the spore-mother-cells shown in Figs. 30 and 9 gave an average diameter of about 46μ , whilst that of the cells in the sporangia from which Fig. 6 was drawn was only 40μ . I believe, therefore, that the effect is somewhat heightened by the reagents employed, but I see no reason to conclude that

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the condition is entirely due to them. During the isolation of the sporemother-cells from one another the sporangial cavity enlarged considerably. Taking the measurements from the periphery of the outer of the two layers of the archegonial wall the diameter of the cavity at such a stage as that shown in Fig. 20 is about $240 \,\mu$, whilst when the mother-cells are rounding off (as in Fig. 30) it has increased to about 300 or $345 \,\mu$.

Garber and Lewis have both described a large amount of nutritive material which fills the space between the mother-cells and which is secreted by the surrounding cells. In my preparation of *Riccia glauca* I have seen nothing of this material¹.

The rounded mother-cells now proceed to divide. The following description is based upon the study of preparations which have been stained with Heidenhain's haematoxylin, either alone or with a light counter stain with bismarck brown. The large nucleus of the spore-mother-cell just before the commencement of division contains a conspicuous, deep-staining nucleolus and a number of delicate linin fibres which have little affinity for dyes (Figs. 1 and 2). In these features the resting nucleus of the sporogenous cells of Riccia glauca differs from the description given by Lewis for the two species which he has studied. He found the nuclear cavity to be occupied by a linin network upon which the scanty chromatin is irregularly scattered ; moreover he states that no nucleolus was to be seen. I have examined a large series of sections of sporangia containing mothercells at all stages up to their majotic division, but I have never observed a nucleus which contained a reticulum such as Lewis figures, nor one which was without a nucleolus. In the case of Riccia glauca, therefore, we can be certain that no such non-nucleolated, reticular resting stage occurs.

 It may also be added that the resting condition of the vegetative nuclei of the thallus of *Riccia glauca* agrees essentially with what I have described above in the case of the sporogenous cells.

The nucleolus in nearly all cases has a lobular outline (Fig. 1) and I believe that this is due to the fact that the nucleolus is not a homogeneous body, but is composed of a number of small chromatic masses or granules held together by a common matrix. These granules are usually so closely crowded together in the nuclei of the sporogenous cells that it is not easy to see their separate individuality. In a few cases, however, the nucleolus was actually seen to be composed of distinct granule-like bodies which had become rather more widely separated from one another than usual by the action of the reagents employed or through the pressure of the microtome knife (Fig. 2) $^{\circ}$. In the vegetative nuclei at the growing apex of the thallus the constitution of the nucleolus can be much more readily determined when

³ See Garber, I. c., Plate X, Fig. 37.

⁹ Compare also Fig. 16, in which the separate chromatin granules of the earlier stages of division are massing together to form one body.

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differentiation with the iron-alum has been carried to the right point. It can then be seen that these nucleoli consist of a faintly stained matrix in which are embedded a number of intensely black bodies (Fig. 3).

Compound nucleoli of a similar character occur in the nuclei of the Musci. In the spermatogenous cells of *Atrichum undulatum* the nucleoli can be quite clearly seen to consist of a lightly coloured matrix containing a number of chromatic particles ¹.

In several sporangia I have found that the linin threads tend to become more or less massed towards one side of the nuclear cavity (Fig. 7). This may correspond to a synapsis stage, although I am not prepared to say how far reagents are responsible for its production in the present case.

Following this condition we find that a much more deeply staining and thicker thread has been developed, which traverses the nuclear cavity in a number of coils or loops (Fig. 8). This is unquestionably the spirem-thread, and it differs radically from the short thread described by Lewis in *Riccia crystallina*². The thread can often be followed continuously for a considerable distance, and I believe that it forms an unbroken filament.

In well stained preparations the spirem-thread shows very beautifully an alternation of deeply coloured bodies (chromomeres) with lighter areas (Fig. 8).

It is very probable that the increased amount of chromatic material which the thread contains at the spirem stage has been derived from the nucleolus and most likely at the expense of the chromatic granules which this body encloses. I have unfortunately been unable to find the stages in the division of the sporogenous cells which lie between the establishment of the spirem and the arrangement of the chromosomes at the equator of the spindle (Fig. 10). In the spermatogenous cells of the antheridium, however, in which a spirem is also developed, the actual segmentation of this thread into the chromosomes could be followed, and it was clearly seen that during this process the nucleolus became more and more inconspicuous. By the time the chromosomes are fully established the nucleolus has been lost sight of altogether.

Both Garber and Lewis have recorded four chromosomes in *Riccia* (*Ricciocarpus*) natans, and Lewis found the same number in *Riccia crystallina*. In *Riccia glauca* the number of chromosomes is higher than this, and I have been able to determine with certainty that the reduced number is either seven or eight (Figs. 9 and 11). The distribution of the chromosomes to

¹ I should like to take this opportunity of correcting an error which I made in a previous note upon 'The chromosomes of *Finarria hygrometrica*' (New, Flyt., vol. ii, 1903, p. 166). If there stated that the number of chromosomes which appeared in the first division of the spore-mother-cells was four. Since this was written I have examined properly fixed material of several mosses (*Finarria hygrometrica, Atrikhum unduldum, Muium hermun, Polytrichum juniferum*) and I have found that in all cases the number of chromosomes is far higher than I formerly supposed.

² Compare Lewis's Plate VII, Fig. 35, with my drawing of this stage.

the daughter-nuclei is shown in Fig. 11. On first reaching the apex of the spindle the chromosomes are crowded closely together (Fig. 12). Soon, however, a nuclear membrane is formed and the chromosomes proceed to open out.

During the earlier stages of the telophase a number of chromatic bodies can be seen distributed upon the linin, and these bodies are no doubt the derivatives of the chromosomes (Figs. 13 and 14). At a later stage that scattered chromatin bodies have come together to form a single lobular nucleolus, whilst linin fibres, containing little or no stainable material, extend through the nuclear cavity (Figs. 15 and 16). The spindle during the metaphase and anaphase of the division is a comparatively narrow structure. A conspicuous cell-plate is developed at the equator of the spindle (Fig. 12), During the telophase of division the spindle shortens and broadens out very considerably and the cell-plate becomes correspondingly broader (Fig. 14).

A membrane is developed at the equator of the spindle, no doubt between the split halves of the cell-plate, although the splitting of the plate could not be followed here on account of its great delicacy. This membrane, which stains rather deeply with bismarck-brown, does not at first reach right across the cell (Fig. 15), but by the time that the nuclei are again dividing it has almost or quite reached the periphery of the cell (Fig. 37). After a short interval of rest the nuclei center upon the second matoric division. At the conclusion of this division cell-membranes are formed which

ormplete the division of this utbrish certainenbranes are formed when complete the division of the mother-cell into the four daughter-cells, which are conveniently, if incorrectly¹, called the special-mother-cells. These membranes, separating the special-mother-cells from one another, give both cellulose and pectose reactions, as do the secondary and tertiary thickening layers of the mother-cell which still form the peripheral envelope of the tetrad group.

It may be mentioned here that during the development of these septa a large proportion of the starch of the cell is seen to be aggregated in their neighbourhood (Figs. 17 and 18).

The special-mother-cell walls do not long remain in this condition, but secondary thickening layers are soon deposited upon the inner surfaces of the thin pectose-cellulose membranes (Fig. 19).

These thickening layers have an uneven outline, forming the papillate projections into the interior of the cell, which previous writers have fully described. Their reactions show that they consist of callose apparently unaccompanied by any other substance. They colour deeply in corallinsoda, in aniline-blue, in congo-red and in naphthol-black². On the other

⁸ I have elsewhere dealt with the specific staining properties of naphthol-black (see Beihefte zum Bot, Centralblatt, Bd. XIN, Abt. I, Heft 2, 1905, p. 289).

¹ Miss Benson, New Phytologist, vol. iv, 1905, p. 96.

hand, calcium-chloride-iodine and chlor-zinc-iodine do not stain these layers. In ruthenium-red and bismarck-brown they assume a faint colour, but I do not think that this is sufficiently marked to indicate the presence of pectose in these layers.

The membranes which first limited the cells of the tetrad from one another before the thickening layers were deposited can now be seen as middle lamellae running through the midst of the callose layers, and as a peripheral covering to the entire tetrad. These primary membranes continue to colour distinctly pink-violet with calcium-chloride-iodine solution and deeply red with ruthenium-red, whilst callose reagents leave them unstained. They still possess, therefore, the unchanged pectose-cellulose constitution which they had in the first place.

It may be mentioned here that Leitgeb¹ reached very different results on these points. During the earlier stages following the thickening of the special-mother-cell walls he could distinguish no middle lamella, and only after the first spore-wall has made its appearance 'differenzirt sich in den Scheidewänden die Mittellamelle.' This is certainly incorrect, for the middle lamellae are nothing but the original pectose-cellulose septa of the unthickened special-mother-cell wall which maintain their individuality throughout.

Leitzeh further states, on the same page, that in aniline-blue an outer layer of the special-mother-cell wall colours deep blue whilst the inner parts, corresponding to our secondary thickening layers, only assume a yellowish tinge in this solution. If this were the case we should have to conclude that the composition of the special-mother-cell wall is very different from that which I have described above, but I have so repeatedly assured myself that the behaviour of this wall towards aniline-blue is precisely the opposite to what Leitgeb found and, moreover, this has been so thoroughly supported by the reactions of the wall with other reagents, that there cannot be the slightest doubt of the correctness of my conclusions.

The occurrence of callose in the special-mother-cell walls of one of the Hepaticae is of interest since in no other member of the Archegoniate series which I have examined is that substance to be found in this position; and it is only when we reach the Gymnosperms and Angiosperms that callose can again be seen surrounding the pollen-tetrads².

It is very probable that callose occurs constantly in the special-mothercell walls of the liverworts since some observations which I am making upon the spore-development of *Anthoceros laevis* have shown that callose is also present in the tetrad walls of this plant.

In the Musci the special-mother-cell walls contain pectose and cellulose,

1 Leitgeb, 1. c., p. 43.

² In all Gymnosperms and Angiosperms which I have examined callose formed the only demonstrable constituent of the special-mother-cell wall.

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whilst in the leptosporangiate ferns, the Ophioglossaceae and in the ligulate and eligulate Lycopodiums these walls contain either cellulose and pectose or pectose alone, but no trace of callose¹. On another occasion² I have referred to the manner of origin of callose in the special-mother-cell walls of *Ocnothera*, and the same remarks apply with equal force to the callose of *Riccia*. In the present case it is impossible to suppose that the callose can have arisen from the transformation of cellulose, since none of this substance precedes the callose nor can any cellulose be seen to disappear from other neighbouring membranes. We must conclude, therefore, that the callose in the tetrad walls of *Riccia* is formed directly as such by the protoplast.

The tetrad-group grows in size from about $6o\mu$ to about 75 to 85μ in diameter and then the first spore-wall ³ is formed round each of the four cells. The question of the origin of this layer constitutes one of the chief points of difference between the accounts of Leitgeb and Strasburger. The former writer was convinced that this wall is a transformation product of the innermost layers of the special-mother-cell wall, whilst Strasburger is equally positive that it is a new formation of the protoplast which has no relation to the special-mother-cell wall.

I have spent no little time upon this question and the only conclusion which I am able to reach is a negative one. After carefully considering the grounds upon which Latgeb and Strasburger based their respective views I am forced to conclude that these were insufficient to prove the case efflier one way or the other. Leitgeb lays the greatest weight upon the firm adhesion which exists between the special-mother-cell wall and the first spore-wall. After treating the spores with various reagents (chlor-zinciodine or a not too strong mixture of chromic and sulphuric acids) he found that the first spore-wall remained firmly fixed to the special-mother-cell wall, although this was greatly swollen.

An argument based upon the adhesion of two layers to one another cannot, however, be accepted as proof of their common origin. Cases are known in which two layers are firmly united but which have unquestionably been separately deposited by the protoplast. Thus Fitting ⁴ has referred to the special-mother-cell wall and the secondary thickening layer of the spore-mother-cell wall of *Isoetes* which adhere closely together but which are independently developed. The special-mother-cell wall and the very young pollen-wall of the Phanerogams furnish another example of two layers which

¹ I have, unfortunately, had no opportunity of examining the special-mother-cell walls of *Equivitum* as yet.

² Beer, l. c., p. 290.

³ In the following account I have avoided the terms exospore or perispore and speak only of first and second spore-membranes. Since, however, the innermost layer of the spore is certainly homologous with the endospore of other plants I have used that name for it.

* Fitting, H., Bot. Zeit., Bd. 58, 1900, p. 126.

are often at first inseparably united, but which nevertheless have a distinct origin. In his examination of *Riccia* Strasburger found that by bursting the special-mother-cell wall by means of pressure he was able to separate the spore-protoplast, surrounded by the first spore-wall, from the specialmother-cell wall. Moreover, he states that the folds of the first spore-wall never quite reach to the summits of the indentations in the special-mothercell wall ¹. If this were actually the case it would, as Strasburger clearly saw, form strong evidence in favour of the independent origin of the two layers. My own preparations, however, do not confirm Strasburger in this respect. Wherever the section is accurately longitudinal (as regards the fold of membrane and the indentation) it can be distinctly seen that the first spore-wall lines the indentation in the special-mother-cell wall to its very apex. Where, however, the section has cut the fold of the first sporewall somewhat obliquely the true relations of this fold to the indentation are not always at once clear.

From what has been said above it will be seen that the evidence which we possess is entirely inconclusive and that neither Leitgeb nor Strasburger were justified by the facts in assuming a definite position.

A study of the microchemical reactions of this wall furnishes no assistance in deciding this question. The whole behaviour of the wall indicates that it is enticularized from a very early period; whether there is a basis of cellulose, earlose, or pectose preceding or underlying the cuticularization was not apparent from any of my experiments.

It may be mentioned here that after treating sections of older spores with a mixture of chromic and sulphuric acids and then (after washing) adding chlor-zinc-iodine it can be seen that the first spore-wall has a rather densely laminated structure (Figs. 24 and 25).

Not long after the first spore-wall has been formed a deposit of mucilaginous substance can be seen at the equatorial rim² of the spore (Fig. 20). As Leitgeb correctly stated, this mucilage has the same chemical and physical properties as the secondary thickening layers of the special-mother-cell wall; that is to say it is composed of callose. Leitgeb further supposed that this mucilage was derived from the special-mother-cell wall, a portion of which wandered through the first spore-wall at the equatorial region. The first spore-wall is, however, always continuous and never interrupted at any spot, as Leitgeb thought was sometimes the case (Figs. 20, 21). Strasburger considered the mucilage to be a part of the first spore-wall; his chief reason for doing so was that he found that this wall and the mucilage ware not sharply marked off from one another at the equatorial rim. I find that the mucilage is formed later than the first spore-wall, that the callose

¹ Strasburger, I. c., p. 109.

⁹ Leitgeb called this equatorial rim a 'Saum,' whilst Strasburger wrote of 'einem äquatorialen Flügel, das heisst einem an der Grenze von Rücken- und Bauchfläche verlaufenden Saum.'

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mucilage is always sharply defined from the delicate spore-wall which has quite different staining properties, and that it is not difficult to separate the one from the other by means of reagents. I regard the mucilage, therefore, as a new formation which has no relation either to the special-mother-cell wall or to the first spore-wall.

The older writers believed that this mucilage formed a continuous layer over the inner face of the first spore-wall. I do not find this to be the case.

Over the ventral surfaces of older spores, in which the second sporewall has been developed, it can be seen that the two membranes lie closely against one another without any mucilage between them (Fig. 21). Over the dorsal surface of the spore the two layers of the wall are indeed frequently separated from one another and then the space between them appears to be, at least partly, occupied by a mucilage. How far this separation between the two walls of the spore over the dorsal surface is a normal feature of their structure is, however, difficult to say. In older spores the mucilage at the equatorial rim has again become absorbed and can no longer be seen.

At first this mucilage is limited internally only by the plasma membrane of the protoplast, which is pushed inwards at the equatorial seam by the plug of mucilage (Fig. 20). Before long, however, the spore-protoplast develops a new wall within the first one, and this them forms a flattened internal boundary to the mucilage at the rim of the spore (Fig. 21). This second spore-wall is a cuticularized structure almost from the commencement. At the very first, however, it is probably composed of uncuticularized pectose-cellulose, for when it is just discernible it stains more deeply with bismarck-brown than is usual with cuticularized membranes, and, moreover, the lamellae which are subsequently added to its thickness unquestionably have, at first, a pectose-cellulose constitution.

During the earliest stages of its existence the second spore-wall appears, even under high magnifications, as a perfectly homogeneous layer, but in spores which are a little older it has become considerably thicker and then a dark line can be seen traversing the middle of this wall and dividing it into an inner and an outer part (Figs. 22, 35). This dark line grows in thickness with the age of the spore until it not infrequently becomes a thick layer which stains intensely black with Heidenhain's haematoxylin and forms the most conspicuous feature in the spore-wall (Fig. 26). It is not casy to assure oneself of the real nature of this dark layer, but after comparing together a large number of spores I am led to the conclusion that this layer most probably only represents a gap which is formed between two sets of lamellae and which becomes occupied by some dark-coloured, stainable material. This view seems to me to be supported by the fact that the dark layer varies in the time and in the position of its appearance. Some-

times it is discernible at a very early stage in the history of the second spore-wall. Sometimes the spore has become much older and the second spore-wall has become quite a thick structure before any signs of this layer can be seen ¹. Again its appearance is sometimes nearer, sometimes further away from the outer periphery of the spore-wall. In preparations which have been treated with a mixture of chromic and sulphuric acids a separation of two sets of lamellae can often be seen in the second spore-wall with an evident gap between them. Further evidence is given by a study of older spores in which a similar but much narrower black band can usually be seen between the inner boundary of the second spore-wall and the endospore (Fig. 26). What the nature and origin of the substance which occupies this space may be is quite unknown. It does not seem unlikely, however, although I can bring forward no proof for the view, that the dark substance which collects in the gap of the spore-wall is the material which colours brown the older spore-walls throughout their thickness.

Most instructive preparations of the spore-wall at the middle periods of development may be obtained by treating sections with a mixture of chromic and sulphuric acids, washing and then examining them in chlorzinc-iodine or calcium-chloride-iodine. The first spore-wall is coloured vellow and shows a densely laminated structure. Within this wall lies the second spore-wall. The outer portion of this wall is seen to be composed of loosely arranged lamellae which sometimes lie closely against the first spore-wall but which have usually become separated from it by the action of the reagent (Figs. 24, 25). The inner portion of the wall, which is generally separated from the loose lamellae by a gap, has a homogeneous appearance and no lamellae can be distinguished in it. If the action of the acids has been carried to the right point it can be seen that the inner part of this internal layer of the second spore-wall gives beautiful cellulose reactions with the iodine reagents. The band of cellulose is considerably thicker on the dorsal surface of the spore, whilst cuticularization had become more complete over the ventral surfaces. Congo-red in dilute solution also colours the cellulose areas a deep red.

Although the inner portion of the second spore-wall has a homogeneous appearance, even after the action of reagents, it is nevertheless really built up of successive lamellae.

During the development of the spore this inner region of the second spore-wall grows very considerably in thickness, and the sections show with unmistakable clearness that this growth is due to the deposition of a series of lamellae upon one another. The newest lamella is formed by the protoplast of the spore in the most intimate attachment with the plasmatic membrane. By plasmolysing the protoplast this lamella is usually at the same time separated from the walls of the spore and the contracted proto-

¹ The late appearance of this dark layer is shown in Fig. 23.

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plast can then be seen to be surrounded by a thin layer which gives cellulose-pectose reactions (Fig. 36). It may be said, therefore, that in the formation of the second spore-wall the first lamellae which are deposited are comparatively loosely arranged together (outer region of second sporewall), whilst the later ones become so firmly united that the lamellose nature of this portion of the wall becomes obscured (inner region of second spore-wall). It is these two regions of the wall—the loosely and the densely laminated areas respectively—which become more or less separated from one another by the interpolation of the dark material which was mentioned above.

The endospore is formed comparatively late in the development of the spore. It gives the reactions of cellulose and pectose, and it is usually separated from the second spore-wall by a narrow space occupied by date material similar to that which occurs in the more conspicuous gap between the two layers of the second spore-wall (Fig. 26). In spores which are nearly or quite mature the walls are deeply coloured brown and have become much denser and in consequence thinner. The lamellated structure of the wall is now obscured. Heated to redness on platinum foil with a drop of concentrated sulphuric acid the entire spore dissolves without leaving a silica skeleton behind.

Nothing has been said above of the nutrition of the spore or of the sources of the material for the growth of its membranes, so that a few words upon this subject must be added here. That the protoplast of the spore is itself actively concerned in the growth of the membranes which surround it can scarcely be doubted. The new lamellae which are added to the second spore-wall are formed, as we have seen, in the most intimate union with the plasmatic membrane; the nucleus of the spore also presents an appearance which strongly suggests that it is participating in metabolic activities.

Unlike the usual resting nucleus of *Riccia glauca*, to which I have already referred, the chromatin is not confined to the nucleolus, but is also distributed along a rather thick filament which strongly recalls the spirem-thread of the dividing nucleus (Fig. 27 a, 27 b). It is difficult to decide whether this thread forms one continuous structure or not.

As the spore grows older and its walls become thickened we find that, although the thread long maintains its spirem-like arrangement, it gradually stains less and less deeply with the haematoxylin (Fig. 27 c). Somewhat similar spirem-nuclei have been described in various animal cells. Thus the well-known case of the salivary glands of *Chironomus* larvae, studied by Balbiani, may be recalled, or the ovarian eggs of *Triton Laematus*, in which Born found a spirem-stage to precede a more diffuse arrangement of the chromatin. In most of the cases already known in which the chromatin is distributed through the nucleus in this manner, we are dealing with cells

which exhibit considerable metabolic activity, and we may probably infer that some relation exists between the spirem-arrangement and the cell activity. A similar relation between the peculiar nuclear structure and cell-metabolism no doubt also occurs in the developing spores of *Riccia* glauca. The actual material which is used by the protoplast in forming and adding to the spore-walls must be derived from without the spore. The reserve material and cytaplasm of the spore suffer very little diminution during development, and if these are drawn upon to furnish material for the growth of the membranes, this loss is at once fully compensated by the arrival of new material from without. The starch-contents of a spore at about the middle period of its development is shown in Fig. 34, and almost precisely the same appearance is presented by the spore-protoplast in the preceding and succeeding stages.

Both the sterile parietal layers of the sporangium and the inner layer of the calyptra¹ degenerate and yield some material which is no doubt employed in the growth of the spore-walls. Neither of these layers is, however, rich in substance (see Figs. 4, 29), and I scarcely think it is possible that their degeneration can furnish all the material required for the very considerable growth undergone by the membranes. Most probably this source is supplemented by material which is assimilated by the vegetative cells of the thallus, and which diffuses into the sporophyte in a state of solution. After the first spore-wall has been formed, and during all the earlier periods of the growth of the second spore-wall, a mucilage is constantly present in the sporangium between the sporetetrads (Fig. 33). The origin and significance of this mucilage are, however, somewhat obscure. It is certainly not the material secreted by the surrounding cells of the thallus, since not a trace of mucilage can be detected in any of these. The callose special-mother-cell walls, which for some time continue to surround the spore-tetrads, gradually disappear, but there is no evidence to show that their substance makes any contribution to the sporangial mucilage which, moreover, gives none of the reactions of callose. Two sources remain, both or either of which may be responsible for the sporangial mucilage. In the first place the degeneration of the parietal cells of the sporangium and of the inner archegonial layer may contribute to the formation of the mucilage. In that case it still remains to be explained how it is that the parietal cells have degenerated some time before the mucilage can be seen, whilst some remains of the inner archegonial cells can frequently still be detected after the mucilage has again become absorbed. Secondly, the degeneration of the primary mother-cell walls and of their thickening lavers, which are both lost sight of about this time, may give rise to part or all of the sporangial mucilage. A difficulty in the way of at once accepting this view of the origin of the

¹ The outer layer of the calyptra persists to a very late stage.

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mucilage lies in the fact that whilst the secondary thickening layer of the mother-cell walls gives both cellulose and pectose reactions, I have been unable to demonstrate the presence of cellulose in the mucilage.

It must, therefore, remain uncertain for the present to what extent the mucilage in the sporangium possesses a nutritive value.

By the time that the second spore-wall has become differentiated into the two sets of lamellae (with the dark layer separating them from one another) the mucilage has become very scanty, and soon after it entirely disappears.

SUMMARY.

1. Fertilization of the egg-cell of *Riccia glauca* corresponds essentially with Garber's description of this process in *Riccia (Ricciocarpus) natans*.

2. The spore-mother-cells are at first separated from one another by extremely delicate membranes, which stain deeply with bismarck-brown but in which no cellulose could be demonstrated.

3. Upon these primary spore-mother-cell walls secondary and, later, tertiary thickening layers are deposited. Both these layers give pectose-cellulose reactions.

4. The protoplast, surrounded by the tertiary thickening layer, now rounds itself off. The secondary thickening layer, which becomes more or less mucilaginous, sometimes separates completely from the primary walland then forms an external envelope to the mother-cell, whilst at other times it still remains partly adherent to the primary wall, and in that case it becomes drawn out into strands of mucilage bridging over the space between primary wall and tertiary thickening layer. The latter condition corresponds to Leitgeb's description of this stage, but he erroneously interpreted the mucilage-strands as nutritive material passing into the mother-cell.

5. In *Riccia glauca* no demonstrable nutritive material was found between the isolated mother-cells such as Garber and Lewis have described in the case of *Riccia (Ricciocarpus) natans.*

6. The resting nucleus of the spore-mother-cell contains a large, deepstaining nucleolus and a number of delicate linin fibres. No non-nucleolated, reticular resting nucleus, as described by Lewis in *Riccia (Ricciocarpus) natans* and *R. crystallina*, was found in *Riccia glauca*.

7. The nucleolus of the nucleus of *Riccia glauca* appears to be a compound structure consisting of a number of deeply chromatic masses or granules embedded in a matrix which stains only faintly.

8. A long and well-marked spirem-thread occurs in the prophase of the division of the spore-mother-cell. This differs radically from the short thread described and figured by Lewis in *Riccia crystallina*.

9. The reduced number of chromosomes in *Riccia glanca* is either seven or eight, but it could not be decided with certainty between these two numbers.

It will be noted that this number is considerably higher than that (four) recorded by Garber and Lewis in *Riccia (Ricciocarpus) natans* and *R. crystallina*.

10. In the telophase of the division a number of chromatic bodies, which are no doubt derivatives of the chromosomes, are distributed upon the linin fibres. Subsequently these scattered bodies aggregate together to form the lobular nucleolus of the resting nucleus.

11. The membrane, which is formed between the daughter-cells resulting from the first division of the mother-cell, does not at first extend to the periphery of the cell.

12. At the conclusion of the second maiotic division the specialmother-cells are separated from one another by delicate membranes which have a pectose-cellulose composition.

13. Upon these primary special-mother-cell walls secondary thickening layers are deposited which give the reactions of callose. This callose is directly deposited as such by the protoplast, and is not a transformation product of cellulose.

14. The first spore-wall is a cuticularized structure from a very early period. No decisive data could be found to determine whether this wall is derived from the transformation of the innermost lamellae of the specialmother-cell wall or whether it is a new formation directly due to the sceretory activity of the protoplast. It was shown that the arguments brought forward by previous writers are insufficient to prove the case either one way or the other.

15. Within the first spore-wall at the equatorial rim a plug of mucilage is deposited. This mucilage, which gives the reactions of callose, has no direct relation either to the thickening layers of the special-mother-cell wall (as Leitgeb supposed) or to the first spore-wall (as Strasburger supposed). It is a new and independent formation.

16. The second spore-wall is next formed within the first wall. It is cuticularized from a very early time, but there is reason to believe that previous to its cuticularization it reacts as a pectose-cellulose membrane.

17. At first the second spore-wall appears to be quite homogeneous, but subsequently it can be seen to be composed of three parts :---

(i) an external loosely laminated region;

(ii) a layer of darle coloured material; and

(iii) an internal densely laminated region.

The dark-coloured material appears to have been interpolated into a space which forms between the two laminated regions of the wall.

18. The endospore, which is formed late in the development of the

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spore, gives the reactions of pectose and cellulose. It is often separated from the second spore-wall by a very thin band of dark-coloured material similar to that which occurs in the gap between the two regions of the second spore-wall.

19. No silica could be detected in the spore-membranes.

20. The protoplast of the spore is actively concerned in the growth of the membranes which surround it. The intimate union which exists between each new lamella, which is being added to the wall, and the protoplast in itself indicates this fact, whilst the curious spirem-like structure of the spore-nucleus, resembling that of certain animal cells, also suggests the occurrence of active metabolic processes in the cell.

21. The actual material necessary for the growth of the spore-walls is partly derived from the breaking down of the parietal cells of the sporangium and of the inner layer of the calyptra. This source is most probably supplemented by material which is assimilated by the vegetative cells of the thallus, and which diffuses into the sporophyte in a state of solution.

22. After the first spore-wall has been formed, and during all the earlier periods of the growth of the second spore-wall, a quantity of mucilage is constantly present in the sporangium between the spore-tetrads. The origin and significance of this mucilage are, however, still somewhat obscure. The various possibilities of the case are discussed in the body of the paper. In conclusion I should like to express my thanks to Professor J. B. Farmer, F.R.S., for kindly examining my sections and for offering several valuable suggestions.

EXPLANATION OF FIGURES IN PLATES XXI AND XXII.

Illustrating Mr. Beer's paper on the Spores of Riccia.

All Figures refer to Riccia glauca.

PLATE XXI.

A. DRAWINGS.

Fig. 1. Spore-mother-cell. Resting nucleus showing lobular nucleolus.

Fig. 2. Spore-mother-cell. Nucleolus of resting nucleus broken up into distinct granules.

Fig. 3. Nucleoli of nuclei from the apex of the thallus showing chromatic granules embedded in a matrix.

Fig. 4. Sterile parietal cells of sporangium in which the mother-cells were becoming rounded off. Fig. 5. Spore-mother-cells which are separating from one another. Where they are still attached

Fig. 5. Spore-momenteers watch are separating transfer and the separation of a middle lamella (the primary wall) and secondary and tertiary thickening layers can be recognized, x about 1100.

Fig. 6. Spore-mother-cell which is becoming rounded off. Secondary thickening layer forms strands between primary wall and tertiary thickening layer. x about 1100.

Fig. 7. Spore-mother-cell. Synapsis (?).

Fig. 8. Spirem-stage of the first division of the spore-mother-cell. x about 1100.

Fig. 9. Chromosomes at equator of spindle. Secondary and tertiary thickening layers of the wall surround the spore-mother-cell.

Fig. to. Chromosomes at the equator of the spindle in first division of the spore-mother-cell. x about 1100.

Fig. 11. Anaphase of first division of the spore-mother-cell. x about 1100.

Fig. 12. Chromosomes crowded together at the poles of the spindle. x about 1100.

Fig. 13. Telophase of first division of the spore-mother-cell. x about 1100.

Fig. 14. Later stage of telophase.

Fig. 15. Daughter-nuclei in resting condition before commencement of second division. Septum between cells not yet complete.

Fig. 16. Daughter-nucleus from similar cell as in Fig. 14. Chromatin granules are aggregating together to form the compound nucleolus.

Fig. 17. Second division of the spore-mother-cells. The septum between the cells now nearly or quite reaches the periphery. x about 1100.

Fig. 18. Young tetrad with delicate septa between the cells and the periphery still clothed with secondary and tertiary thickening layers of mother-cell-wall.

Fig. 19. Special-mother-cells. Examined in glycerine and congo-red. Thickening layers red ; middle lamellae and periphery colourless.

Fig. 20. Spore with first spore-wall (drawn black) at the equatorial rim of the spore. Examined in glycerine and congo-red. Secondary thickening layers of special-mother-cell and mucilage at the rim of spores (both left white in the figure) stained red; spore-wall yellowish. Equatorial mucilage limited internally by the plasma membrane alone. x about roo,

Fig. 21. Spore with first and second spore-walls in the neighbourhood of the equatorial rim. The second spore-wall still appears homogeneous. Examined in glycerine containing a very little furthing fig. 22. Spore at the equatorial rim. Early stage in the differentiation of the second spore-wall.

Fig. 23. Older spore. Examined in calcium-chloride iodine. Second spore-wall differentiated into an outer distinctly laminated region and an inner apparently homogeneous region. In the present case the darkly coloured layer is only just appearing between the two regions at this comparatively late stage.

Fig. 24. Portion of spore-wall after warming in a mixture of chromic and sulphurie acids, washing and examining in calcium-chloride-iodime solution. Laminated structure of first spore-wall and outer region of second spore-wall is well shown. Intimate union exists between remains of thickening layers of special-mother-cell walls and first spore-wall. Both first and second spore-walls colour yellow. x about 1100.

Fig. 25. Somewhat older spore treated similarly to the one drawn in Fig. 24. All the membranes colour yellow. \times about 1100,

Fig. 26. Older spore from microtome section stained with Heidenhain's haematoxylin and bismarck-brown. Dark-coloured layer between inner and outer regions of the second spore-wall is very conspicuous. A similar, but narrow, dark layer lies between the second spore-wall and the endospore. x about 1100.

Fig. 27. Nuclei from developing spores :

(a) from spore with first spore-wall only;

(b) from spore with two spore-walls but second wall still homogeneous;

(c) from older spore with thick, differentiated second spore-wall.

PLATE XXII.

B. PHOTOGRAPHS.

Fig. 28. Archegonium showing fertilization of the egg-cell.

Fig. 29. Sporangium containing spore-mother-cells; calyptra two-layered.

Fig. 30. Spore-mother-cells becoming rounded off and separated from one another.

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Fig. 31. Second division of the mother-cells and young tetrad. Secondary and tertiary thickening layers of the mother-cell wall still surround the periphery of the cells.

Fig. 32. First division of the egg-cell.

Fig. 33. Sporangium containing spores with two-layered coats. Note mucilage between the spore-tetrads.

Fig. 34. Spore at about middle period of its development treated with iodine solution to show distribution of starch.

Fig. 35. Section of spore showing layers of its wall. Darkly coloured layer is particularly noticeable.

Fig. 36. Section of spores to show the new lamellae which are to be added to the thickness of the second spore-wall plasmolysed away from that wall together with the protoplast to which they are firmly fixed. These lamellae gave cellulose-pectors reactions.

Botanical Documentation

On the development of the Spores of Riccia glanca The principal & facts in the development of the spores of Riccia have already been described by Leitgeb & Stresburger? In the seventeen years which have Elapsed since Strasburger's paper was written botenical microtechnique has beton Such immense studes forward that it was thought desirable to to subject these spores to a renewed investigation. Hore recently Garber has dealt with the life - history of Riccio carpus natans + & Lewis with the Subry alagy + development Dapikeed lutes in stille crystalling cabilocidither tof theme authors have dealt with the Spore or the development of its membranes (1) Leitgeb Ueber Bau und Entwicklung der Sporenhäute. Grag, 1884 pp. 39-49. (*) Strasburger " Ulber des Wachsthum Vegetabilischer Zallhäute" Histologische Beiträge Heft 2.1889. pp. 104 - 111. (3) Garber The & Life History of Riccio carpus natans" Bot. Sazette Vol XXXVII. 1904. p.p. 161-177. (4) Jewis " The Imbryology & Development of Riccia lutescens & Reccia crystallina Bot. Gazette Val XLI. 1906 . p.p. 109-138

Levis' observations show that Riccia lutescens is surely a terrestrial form of Ricciocarpus natens I he believes that the differences which snest i to Structure of the thellers & the arrangement of the Seand organs are not sufficiently marked to justify the genetic separation of Ricciocarpus from Riccia. He accordingly drops the genus Receiverpus setagether + includes Receiverpus nateurs among the Reciae. Digthe enatorial for the upresent study besuperiation Strong & medium chrom - acetic mextures (Chemberlains formulae), Strong Flemming's Solution + in alcohol + acetic and minture. of these the Stronger chrom. acetic fluid proved the most Satisfactory but in whent results were also obtained with the alcohol & acutic misture

2

I will be gin any account with the fertilization of the 288-cell. The general character of this process is shown in 7, 528. from which it will he acon that it closely resembles the fertilisation of the (Riccio carpus) nations as described by garber " . My photograph also shows that the Shrinkage of the egg-call is far less than is usually figured & in this point Reside of in agreement with Garber's Statements. regarding Ricciocarpus. The first division of Digitzedfortitiset Inssignitutor Botanially Doobligudytion transverse (Fig 32). The Succeeding divisions here been so frequently described that I need not recapitulate them here. They result in a mass of Sporogenous tessae surrounded by a sigh lager of sterile wall-cells, the whole being Enclosed within a two legered calyptra.

(1) Harber "The Life History of Ricciocarpus notens" Bot & dgette March 1904 Vol XXVI PAULIX

The young spore - matter - cells are separated from one another by Satremely delicate membranes (Fig 29) These stain, often deeply with besmarch brown but I was unable to get a decided reaction in them with ruthencum red soon did they whilst with Calcum - chloride - codine + chlor-zini - codine they colour yellow but gain hor of the collar reactions - Show no Signs of containing cellulose. Sopon The cell contains a quantity of stand Digitized by Hunt institute for Botanical Documentation Upor the primary wells which reparate the Spore-matter - alls from one another a Secondary & later a tertiary thickening layer is deposited (Fig. 5) Both leyers give the reactions of cellulose as well as of pectore but the tertierny thickening layer (ving the one in immediate fustaposition with the protoplast) stams, more deeply with pectre reagents. The protoplast surrounded by the terteary

tuckening layer now rounds strelf aff + - all membrane. The secondary thickening, layer which has become more or less mucilagenous in consistency, sometimes Separates completely from the primary walls + then forms a well defined layer surrounding the protoplast (Figs 5, 9, 31). what at atter times, it becomes drawn out partly address remains partly adherent to the primary walk & Digitize that Institutentes Batanical Decumentation sumber of strands bridging over the Sap between the rounded protoplast + the primary wall. The latter condition of things is represented ~ Fig 6 . Fit will be observed that my drewing closely resembles Deitgebs. Fig 3 Tef.II Deetgeb, however, believed that the Space between the primary wall of the protoplast was occupied by a homogeneous muculage + that the strends of material mending which bath

he & I have figured are really composed of food-materials diffusing in from the outside In my preparations it is quite cortain leal no homogenous muchage occupies the space between proloplast & prinery wall, moreown the strends of material stretching across the Space que cellulore + pectore reactions Exactly corresponding with those obtained in the Secondary thekening layor (2.8 of Fig 5 3) Digitte der Edund Institute fore Betwicater Ochretestation represented in Fig 6 is no doubt Somewhat Sx afferated by the reagents used. The measurgment of the spore-matter-cells show in Figs30x 9 & gave an avorage deameter of about 46 pe whilst that of the cells in the Sporangia I befine the Fig 6 was drawn was only 40 pi I befine the effect is Somewhat heightened & the reagents suployed but I see no reason to the the condition the entirely caused by the due to them.

Suring the coolation of the Spore - matter - cells prom one another the Sporengial centy two enlarges considerably in size. Taking the measurements for the onter periphory of the onter of the two layers of the archegonical wall the deameter, at such a stage as shut shown i Fig 29 . is about 240 je whilet when the matter-cells are rounding aff (as in Fig. 30) that deenster as about Toghly believen 300 + 345 pm. but Boundentar large amount of metritive material which fills the space between the matter-cells & which is Secreted by the Surrounding cells. In my preparations of Riccia glauca I have Seen nothing of this material. " The rounded mother - cells now proceed to divide. The following description is based upon the study of preparations which that been stained with Heidenhain's haemalorghin, rether alone or with a (1) See Garber R. c. Plate X Fig. 37

light counter Stain wilt besmarch brown. The large nucleus of the Spore - mother - cell just before the commencement of division contains a conspections, deep-staining nucleolus + a humber of delecate linin febres which have little affinity for dyes , In there features the resting nucleus of the Sporagenous cells of Recien glanca differ from the description given ly Lewis for for the case of the two species which he studied for He found the Digitized by Hunt Institute for Botanical Documentation network upon which the Scenty chrometin two is irregularly Scattered; wholes no nucleolus was seen. I have a large series of Sections of Sporangia tothe matter-cells at all stages up to their division but I have neur observed a hundlens which contained a reteculum duch as Lewis figures hor one alich was without a nuclealus. In the case of Riccia glance, therefore, hu can be certain

that no such non-nucleolated, reticular resting Stage occurs. It may also be added that the resting condition of the Vegetative nuclei of the thallas of K. Slance agrees as Essentially an structure with what I have described above in the case of the sporagenous cells. The nucleolus in nearly all cases has a lobular outline of I believe that this is due to the fact that the nucleolus is not a top Dightand gentainst Institute tor to stanisal phoceing neation number of Swall masses or granules held dogetter by a common matrixe. These granules are usually so closely crowded together in the nuclei of the sporogenous cells that it is not Easy to see they separate individuality. In a few cases however, the nucleolus was actually Seen to be composed of destinct granule. like bodies which had become rather more widely separated from one another then repuel

leg the action of the reagents suployed or through the pressure of the incorotome knife (Figd) In the Vegetative nuclei at the growing apex of the thelles the constitution of the undeolus can be much more readely determined when differentiation with the from- alum has been carried to the right (1) compare also Fig 16 in which the chromatin granules are of the carlier stages of division are massing trather to form one body.

12 11 point. It can then he seen that there undedi consist of a faintly stained matrice in which are embedded apartonself black a number of intensely black bodies (7.8 3) Compound nucleole of a Semilar character occur in the nuclei of the Musei. In the Spormatigenous cells of thickum undulation the nucleoli can he quite clearly seen to consist of a lightly coloured matrix containing a member of chromatic particles " Dig stinged lide to take Inthis topportoning Best converting to Smare which on made in a previous note upon the " The chromosomes of Funeria ty grometrica (New Plugt. Vol II 1903 p. 166.) I those stated that the number of doron romes which appeared in the first devision of the spore - mother - cells was four. Since this was written I have seemined properly fined material of Several masses (Funeria by growetrica, atrichum unsulatur, muum hornen, Poly trichum juniperum) + I have found that in all cases the aunher of chromosomes is for higher than I formerly supposed. I have not get succeed in counting the number of chromomes with accuracy in any species but

12 In several sporengia I have found the linin Threads tend to become more or less medaed towards one side of the nuclear cavity (7:87) This Bolely corresponds to a Synapsis Stage although I am not prepared to say two far reagents are responsible for ets production in the present case . Following this condition we find that a much more deeply Staining & tucker thread has been developed which trenerses the nuclear cevity Digitized by Hunt Institute for Retarical Resummentation This is unquestimally the Spirim - thread + it differs radically from the short thread described by Tewis in Reccia crystallina !! The thread can after be followed continuously for a considerable distance & I believe that it forms an unbroken filement. In well stained preparations the Sperem - thread Shows Vory beautifully an alternation of (1) compare Lewis' Plate VII Fig 35 with my drawing of this stage

(chromomeres). deeply coloured bodies with lighter areas (7; 8) It megle hone on It is very probable that the increased amount of chromatic material which the of thread Established has been distributed Thes been derived from the nucleolus + most lekely at the expense of the chromatic grandes Which this body Incloaes. I have unfortunetely been able to find the stages in the division of Digitile of por opentolis stredes to role dan her Holten retation Sotablichment of the Sporem & the arrangement of the chromosomes at the Equator of the Spindlen I the spermatogenous cells of the antherideum, trovener, i which a spirem is also developed, the actual sequentation offer this Stread backard Sequented into the chronosmes the followed & it was dearly seen with the chronosmes ~ the during this process the nucleolous became more + more inconspicuous. By the time the chromosomes are istablished the hadeolas the leen lost sight of altogetter .

14 The chromo and are rether you & in hundrer. The chronos are little seven or eight in member Both Garber & Jewis have Recorded four chromosomes in Ruccia (Riciscerpes nations & Lewis found the Same number in R. crystallina . & Reccia glanca the number of chromosomes is certainly higher them this + I have been able to determine with certainty that the reduced number is rither seven or eight (Figs 9 + 11) Digit Hed by the the decayater hacement sign in Figs 11 . On first reaching the aper of the Spindle the chromosomes are crowded closely together (7+5 12). doon, however, a nuclear membrane is formed & the chromosomes proceed to open out. During the earlier stages of the telaphase a number of chromatic bodies can be seen distributed upon the lenen & these bodies are the no doubt the derivatives of the

Chromosomes (Figs 13+14) At a later Stage the Scattered Chromatin bodies have come together to form a bob single lobular nucleolus intigon whilst livin fibres, containing little or no Stainable material, Estend through the nuclear cerity (7:50 15+16) The spendle during the metaphase & anaphase of the division is a comparatively harrow Structure. A conspicuous cell-plate is developed at the Equator of the Spindle (Fig12 Digitized by thent telephone or aforanical 20 au spinke Shortens + broadens out very considerably + the cell plate becomes correspondingly broader (Frs 14)

15

16 a perfecte very conspicuous cell- plate is developed at the Equator of the Spindle.) During the telaphase of division the spindle Shoftens + - broadens very confiderably (7:5) + the cele-plate becomes correspondingly broader. The specting of the cell- Acate could not be observed on a stin frombrande is tracloped account of the small size of the structure. A membrene is developed at the 2quator of the spindle, presumably between the Digitispere the last of stante cell Balance Caladaniga entertion splitting of the plate could not be followed on account of its small great delicary. This membrane, which stains deeply with bismarck brown does not at first reach right across the cell to but by the time that (tu nuclei are again dividing it has almost (7/2/2)) or quite reached the periphery of the celliption I have been able to make only very few observations upon the second division of the after a short interval of rest the nuclei anter upon lendingo the second maistre devision.

mother - all + I will only mention here that the class again handor &: at the conclusion of this devision cell-membranes are formed which devision of the molter. cell into the four daughter cells which are conveniently if incorrectly, called the Special - mother - cells These membranes, separating the formaling the Special-mother - cells give both cellulose + pectore reactions like the sundary tertiany theckening layers of the matter - cell which still Digitizforder Hant Herikharabr Suvelakeral of Guirkedradion group It may be mentioned here that in the development of these young septa best at the conclusion a large proportion of the starch is seen to be aggregated in their neeghbourhood (Figs 17+18) The opened - mother - cell walls do not long remain in this condition but de condary (1) "mins Benson New Phytologist Vol IV 1905 p 96

theckening layers are Soon deposited upon the enner Surfaces of the then pectore - cellalore membranes. (Fig 19) These theckening layers have an uneven ontline, forming the papellate projections into the interior of the cell which previous writers have fully desired Their reactions show that they consist up callose apparently unaccompanied by any other Substance. They could colour deeply in corallin - Soda, in aniline - blue, in congo - red Digitized by a plital nother ad for Briattical the unadation Calcuim - chloride - codine & chlor - Zinc - iodine do not stain these lagers. In ratheneim. red + bismarch-brown they assume a faint colour but I do not think that this is Sufficiently marked to indicate the presence of pectore in these layers.

18

Retenium ned bigminch brom + similar dy es ton to with first failer solar in the solar and the solar The membranes which first limited the cells of the tetrad from one another before the theckening layers lare deposited can now be seen as middle lamellae running through the undst of the callon legers & as a periphiral covering to the Entire tetrad. These primary membranes continue to colour distinctly penk - Violet with calcium. - Chloride - corre Solution & deeply red with ruthencum red this showing chilat cellore reagents leave them unstained. ipzed by Hunt Arriver to Botanical Domehenson ation they still constitution while constitution while cellulore while they possered had in the first place . It may be mentioned here that Leitgeb reached Very different results on theme points. Turing a the earlier stages often the thickering layers bad been special matter - tell bills ing of the special - matter - cell walls thickering to toalls be could diatinguish no middle lamella + tuly after the forat "Leitgeb l. c. p.43

20 Mg Spore- wall her made its appearance " differenjort Sech in den Scheide wänden die Mittellamelle" This is certainly incorrect for the original Septa of the spread-matter all can be the middle lamellae are nothing but the original pectre - cellalore repta of the centreckened Special - mother - cell walk which maintain their individuality throughout ." Teetgeb further states on the Same page that in anchine - blue an outer lager of the ispected therefore to a for the and a society of the tion whilst the uner parts, corresponding to our the Second any thickening layers, only addune a yellowich tinge in this Solution that If this were the case the composition of the Special - mother - cell well too the the very differents pro doe which all described above but Than So repeatedly assured my self that the bedencon of this well towards at aniline-- blue is precessly the opposite to what

aug 21 Seitgeb found & this has been so thoroughly supported by the reactions of the wall with other reagents that I there not the Slighteat doubt con remain of the correctness of my conclusions. The occurrence of callon in the special-sustan - cell walls of the Hepaticae is ap sustan - cell walls of the Hepaticae is ap sinterest since in no alter member of the Arche goniate Series have I found which I have reasoning is that Substance tized by Hunt Institutes Propering ical Documentation when we reach the Symmosporus + Ungeosperms that the pollen teledone have to be sworounded by callose wells. cellore can again be seen surroundig the pollen - tetrads ." It is very probable that callose occurs constantly in the Speciel - matter - cells of wells of the leverworts since some observations which I an making upon the Spore-development (1) & all Gymnospyringen + Angior pyrus which I have Examined collose the former the special-matter-cell wall. (The may demonstrable constituent of

46 alightesent in the tetrade valles up and In the musi the special - matter - cell walls Contain my pectore & cellulore ohilst in the leptosporangealt forms, the Ophioglossacce I in the legulate & Eligulate Ly copodiums these walls contain retter cellulore & pectose or pectore alone but no trace of callore. On another occasion I have referred to the manner of origen of callore in the special-gitized by Hunt Institute for Boranical Documentation Same remarks apply with Equal force to the calloar of Riccia. In the present case it is impossible to Suppose that the callore can have arean from the transformation of presenting cellectore since none of the Substance precedes the callose to can the seen to disappear from other neighbouring membranes. We must conclude, therefore, that callose in (1) Spear l. c. p. 290

23 14 the tetrad walls of Riccia is formed directly as Such by the protoplast. The tetred - group grows in Size from about 60 p in diameter to " 35 to 85 p , the the former wer is formed round sach of the four cells to the question of the origin of this layer formed one of the chief points of difference between the accounts of Steitgeb + Strasburger. The former, was convinced that this well is a trensformation Digprother Hupitastanter Botarlager Doquete napide. . mother - ciel wall which Stresburger is Equally positive that it is a new formation of the protoplast which has no relation to the special - matter - cell well . I have spent no little teme to trouble upon this question + the only conclusion which I am able to reach is a negative one. after carefully considering the grounds upon which Leitgeb & Strasburger based their (1) I the following account I have avoided the terms savepore or perispose + speak only of & first & second spore membranes. Since, how to and the inserved layte of the spore is certainly thoulagons will the sudospore of other pearts I have used that & name for it.

24 Mg respective Views I am forced to conclude that these wore insufficient to prove the case rither , way or theather. Deitgeby lays the greatest weight upon the firm adhesim which sacots between the special-matter- all ball + the first spore-wall but crees a and interfacte comfor between flagters of and known i which there leyers certainly had a deflerent origen. after treating the spores with Various reagents (chlor - Sine - iodine tized by Hunt Institute for Botanical Documentation or a not too strong to be measure of chromes of Sulphuric acids) he formed that the prathe Supelier special mother sell well Jointy free the pour protoprate stice first spore wall state firmly fixed to the greatly swollow special-matter - cell walk, separated for the protoptant although this was greatly swallen. On argument based upon the adhesion of

25 19 two layers to one another cannot be accepted as proof of their common oregen. Cases are known to in which two layers are formly united but which have unquestionably been deparately deposited by the proloplast. This felling? has referred to the matance of the Special matter - cell wall + the secondary tuckening layer of the "matter - cell wall of Isocle send can which adhere closely together but which are independently for developed. Digithed the tradit-Institute-fails atallical A classification ball of Phenorogenes the Phenerogams furnistis another and scample of two membras legers which at first see inseparably united but blief and here a distinct origen. I his securination of the spores Stresburger found that les bursting the spiceal-mother cell wall through the application of pressure he was able to separate the spore-production (1) Fitting H Bat. Zeit. B& 58 1900 p. 126

, surrounded by the first spore-wall, from the Special - mother - cell well. Moreover he states that the folds of the first Spore-wall never quite reach to the Summits of the indentations in the Special mother - cell well ." If this were actually the case it would, as Strasburger clearly saw, form strong evidence in favour of the independent origin of the two layers. My own preparations, hovener, do not confirm Strasburger in this respect. Wherever the Section is a curately longitudinal (as regards the Dighte of byen hindrenstilline independence I BEcomentation distinctly seen that the first spore well leves the indentation in the Special - mother - cell wall to its Very apex. Where, however, the Section has cut the fold of the forst spore-wall somewhat obliguely the true relations of this fold to the indentation are not always at once clear.

R. c. p.109

28 formed a deposit of mucelagenons Substance can be seen spicely at the Equatorial rem of the spore (Fig. 20). as Leitzeb correctly Stated the muchage has the same chemical o physical properties as the thecken cullecter Secondary theckening layers of the Special- mother all well; that is to day it is composed of cellose. Teilgeb further Dupposed that this mucclage was derived from the Special - mother - all well, a portion of which Digitized hydrolyskitute for Boran pak-Deeliment thion Equatorial region. The first Spore wall is, however, always continuous & never interrupted at the any spot as Leitgeb throught we considered Sometimes the case (Figs 20,21). Strasburger rickow the mucilage to part of the first spore well this chief reason for doing so was that he distinction the two the found that this ball & the huncelege were not (1) Leitzeb called this Equatorial rim a " Saum" whilat Streaburger wrote of "Einem agent äquatorialen "Hügel das Keisst einem an der Greuze von Rücken - und Bauchfläche Verleufender

29 sharply marked off from one another at the equatorial rim . I find the the minichage is formed separately that apartely for the forst spore wall, that the calloace mucclage is always sharply defend from the delecate sporewall which has quete different Staening properties I that it is not defficalt to reparate the one from the other by means of I regard the muchage, therefore, as a new formation which - has no relation selter to the Special - mother Digitized by Funt Institute for Botanical Locumentation I have been able to trace the minulage, as a very deficite layer, for son distance bed beyond the squatorial rim & in older spores, in a muilage, apprently spore toale that been formed, over the dorsal dagae of the spore but kenertiglers den for an le no means dure Atal eties quickage adre della forms a continuents lager lining the totale uner

30 manting) The older writers believed that this unuclage formed a continuous layer over the uner face of the first spore- wall I do not find this to be the case . however . own the Ventral Surfaces of older spores, in which the Second Spore - well has been developed, it can he seen that the two membranes lie closely against one another without any mucilage between them (Fig 21) Over the dorsal Surface of the Spore the two legers of the wall are prequently separated from one another + then the Space between them appears to be at least partly is Hyntalnatituilager Botattoral for the separaten helicen the two walls of the Spore over the dorsal Surface is a texormal feature of their Structure theter the mudage is a difficult to day " Even of it naturally occurs it is by no means certain that the mulage which me find the is the older spores the uncelage at the Equatorial rim has again become absorbed + can no longer he seen (1) The second sport-fuell Requis, hongin, not to reach the aper of the folds of the first spore-wall our the dorsal surface , of the spore such in that preparations which mere best showed the heat fination a here was probably one millage really occurs.

31 84 Lace of the first spore-wall . On the Ventral Surfaces of the older spores the first & Second Spore-sells, suen under high magnifications, appear to be unmediatly agagust one another It is possible, towever, that from at this comparatively sarly stage the mucilage may already have become absorbed to the two spore-walls he thus brought together. At first this mucchage is limited enternally only by the plasma membrane of the protoplast an Digithick by Hpurchastinutar Ds Batenica Deguatoristertion Seam by the plug of mucilage . (7; 20) Before long, thomener, the Spore-protoplast developes a new well within the first ones this then forms a flattened enternal boundary to the mucilage at the rem of the Spore (Fig 21 Dect get believed that the second spore well This - well is a cuticalarised Structure from a commencement. When it is just discomable it stains rather deeply

32 is may let the Very forst, however, it, probably concerts ellulose for them it is just discornable it Stains deeply with bismarch brown that is usual with cuticularised membranes to the lamellae which are Dabaequently added to its tuckness unquestionably have, at first, a pectore -Suring the Earliest stages of its suistance. At final the Second Spore - Wall appears, Inen under hogh magnifications, as a perfectly Dighoragenrolsintleysintite boo Bistaspork Dochierention little older it has become considerably thekor + then a dark line can be seen traversing the meddle of this wall + dividing

it into an enner + an outer part (7igs22,35) This dark line grows in thechners with the age of the spore until it not infrequently forms a trick layer which stams intensely black with Heidenhains haematrylin + forms the most conspicuous feature in the spore wally It is not easy to absure oneself of the real nature of thes dork layer but after company a large number of spores only toget which the comparing together formed between two sets of landlace + which becomes accupied by some dark coloured, stainable materiel . This view deems to me to be supported by the fact that the dark layer Varios in the time + in the position of its appearence. Sometimes it is discernable at a very say Early stage in the history of the Second Spore - Wall & Sometimes the spore has become much older & the Second Spore -

34 22 without wall has become quite a third Structure before any signs of this layer complex seen ". again its souther would appears appearance is Sometimes nearer, Sometimes forther away from the onter perphery of the second spore - wall. I preparations which have been breated with a meature of Chromic & Sulphanic acids a Separation of two sets of lamellae can be seen in the second spore - wall with an evident Sap between them. Further evidence Digitized by Hunt Institute of dearanged Documentation Similar but much nerrower black band can smally be seen between the einer boundary of the Second Spore- wall & the endospore A What the nature + oregen of the Substance which occupies the space may be is quite inknown. It does not seen imeipely hour, although I can bring forward no proof of for the view, that the dark material in the Saps of the Spore- wall are end is the (1) The late appearance of this dark layer is show - Fig 23.

35 28 brown Substance when colours, the older spore-walls throughout their theckness. Those instructive preparations of the spore-wall an able of the middle periods of development may be obtained by treating sections with a mixture of chromic + Sulphuric aads, westing + then Scanning them in chlor-Zene-Lodine or calcum - chloride - codine. The first spore. wall is coloured yellow & shows a densely lamineted structure. Wattien this wall lies the Digitisectly Hant-Institute for Botatical partition wall is seen to be composed of loosely arranged lamellae which sometimes lie closely against the show first spore - wall but which have usually become separated from it by the action of the reagent . (Figs24, 25) The inner portion of the wall that we which is sometime reported fin the loose lamellae by a gap, and has appearance & in which ho lemellae can be distinguished in it. It's most

36 24 If the action of the auds has been carried to the right point it can be seen that the uner to after not infrequently almost the of the second spore- wall gives beautiful cellular reactions with the codine reagents. The band of cellulore the considerably thicker and the dorsal surface of the spore whilst cuticula cuticularisation had be come more complete over the Ventral Surfaces. Congo-red in Digitizedeby Hent Institute for Betaniaal Reacumentation areas a deep red. although the enner portion of the decond Spore-wall has a homogeneous appearance, menerthelen relege fast built up af successive lanellae. Apon the fine of the first oppearance of the wall this inner region groups very considerably of thickness of it for not deficult & obtain preparations / which

34 Faring the development of the spore this enner region of the Second spore-wall grows Very Considerably in the chness I the Section's Show with unmistakable clearness that this growth is due to the deposition of a series of lamellae upon one another. The newest lamella is formed by the protoplase of the Spore in the most internate attachment with the plasmatic membrane. By plasmoly sing the protoplast this lamella is at the same time separated from the walls of the spore & the contracted protoplast can then be seen to be surrounded by a thin layer Washigues beendent pertoute for any might Documentation therefore, that in the formation of the Second Spore-wall the first lemellae which are deposited are comparatively lossely arranged together (onter region of second spore well) whilst the later ones become So formly united that the lamellose nature of this portion of the wall be comes abs cured (uner region of Second spore wall). It is these two & regions of the wall - the loosely + the densely laminated areas respectively - which become more or less separated from one

38 another by the interpolation of the dark material which was mentioned above The endospore is formed comparatively late in the development of the spore. It gives the reactions of cellulore + pectore + is fee usually repareted from the Second spore- wall by a nerrow ge Space occupied by the a similar dark material Similar to that which occurs in the more conspicious Sap between first + sound spore the two layers of the second spore-hall (Fig 26). Digitizeprey blickt anstituter to ro Baitanical attacuate nation are deeply coloured & these become much denser + in consequence thenner. The lamellated Structure of the wall is now obscured. Heated to redness on platenum foil with a drop of concentrated Sulphuric acide the entire Spore dissolues without leaving a Silica Skeleton behind. In the foregoing description of the spore membranes I have represent from using the terms nemes

39 hotting has been Said above of the nutrition of the spore or of the Sources of the material for the growth of the membranes So that a few words upon this subject must be added here. That the protoplast of the Spore is stall actually Concerned in the growth of the membranes which Surround it can scarcely be doubted. The new lanellee which are added to the second spore- wall are formed, in the most internate union with the plasmatic membrane; Digitte couleget ing liter toportor also an predents com appearde which - strongly daggestine duggests that it is participating in metabolic activities. Unlike the usual resting success of Reccia glauca to which I have abready referred to the chromatin is not confined to the nucleolas but is also distributed along a rather thick filment which Strongly recalls the strongly recalls thread of the spor sporem - thread of the deviding nucleurs (Fig27a, 6, 6). It is difficult

to decide whether this thread forms one continuous Structure or not. attract is the spore grows alder I its wells become thechened we find that although the thread long maintains its spirem - like arrangement it gradually stains less + less deeply with the harmatoxylin (7ig 27 a c) Somewhat Similar sporem - muclie have been described in Various animal cells. Thus tu well known case of the Salivary glands of cheronomus - Parvae for Betanical Decimentation chironomus - Parvae , may be recalled or the ovarian 2885 of Treton taeniatus in which Born found a spiren - stage to precede a more diffuse arrangement of the chromatin . In most of abready known which the chromatin is destribuled through the uncleas in this manner we are dealing with cells which Takebit Considerable metabolic activity & we may probably infer that andemiles some relation

Excepts between the spirem - arrangement + the cell activity . a similar relation between the peculiar nuclear structure + cell-metabolism no doubt also secures in the developing spores of Reccia glanca. The actual material which is used by the protoplast in forming + adding to the spore - walls must be derived from without the spore. The reserve material I cytaplasm of the Spore Suffer very little diminution during development & if there are drawn upon to furnish Digatized b for alter Sissificity file Browning Die ukpostatiets once fully compensated by the arrival of new material from without. The starch-contents of a Spore at about the suddle period of its development is shown in Fig 34 & almost precisely the Same appearance is presented by the spore - protoplast in the precedeng & Succeeding Stages. Both the sterile parietal layers of the sporengum t the unner layer of the calyptra degenerate & yield Some material which is no doubt suployed in the The orter say layer of the calyptra personals to a very late stage.

glowet og ter Spore - menderane. Neither og ture lagere an, honenor, rich in Substance + Scercely think it is possible that this degeneration can furnish soffward material & for the very considerable growth undergone by membranes. Hong thost probably this Source is Supplemented by the material which is assimilated by the Vegetative cells of the Stallers + which deffuses into the sporphyte sporophyte in a state of solution. lefter the first spore- wall that been formed & during Digall atu yearlein perister ay the groat of the estation Spore-wall a muchage is constantly present between the in the Sporangeum between the spore - tetrads (Fig 33) The oregen & Seguepeance of this uncerlage are however, Somewhat obscare. It is certainly not the materiet by the Surrounding cells of the thalles Since not a trace of huncelege can be detected in any of these. The callone special - moltin- cell walls, which for some time continue to surround an Spore-tetrades, gradually desappear but there

is no sudence to show that their Substance makes any contribution to the sporangeal numilage which, moreover, seves none of the reactions of callore There are two Sources remain, both or Either of which may be responsible for the Sporengial muilage. In the first place the degeneration of the parietal & inner as chegonial layers men contribute to the formation of the unalage. In that case it still remains to be ig seplained a how it is that the paretal cells Digit there degenerated ensistence ter Botapical to cuincitage on can be seen whilst remains of the inner archegonial cells can prequently still they detected after the huncilage has again become absorbed. Secondly the degeneration of the primary moltur - cell balls & of their Theckening layers, which are lost Sight of about this time, may give rive to part or all of the Sporengial musilage . View of the

44 muilage is that whilst the secondary thickening layer of the mother - cell wells quies bath cellabore & pretone reactions I have been unable to demonstrate the presence of cellalore in the mucilage . It must remain uncertain for the present whether the the mulage in au Sporenquin possesses a mutriture Value. or no. By the time that the Second Spore - wall has become differentiated into the two sets of lamellac (with the Digitarit lay en unde pareting thim Balania enothing the on mucilege has become very scenty + soon after it In conclusion I must sapres my thinks to Professor J. B. Farmer F. R.S. for kindly Examining my Sections I for affiring Several Valuable Suggestions.

all figures refer to Riccia glanca , I Explanation of the Figures. 12 A. Drawings Spore - mother - cell . Resting nucleus Fig 1. Showing lobular nucleolus 7.5 2 Spore - matter - cell . Nucleolus of resting nucleus broken up into distinct granules 75 3 Nucleoli of segal nuclei from the apea of the thellus showing chrometic granule's Embedded in a matrix. 7:54. Sterile parietal cells of sporangeum i by Mucht the statute for elestanical becoming mounds Fig S. Spore-mother-cells which are separating from one another. Where they are still altached a middle lamella (the primary wall) secondary + tertiary thekening layers can he recognised. X about 1100 Fig 6 Ipore-molter- cell which is becoming rounded off. Decondery theckening layer forms Strands between primary wall & tertiary thechening layer . X about 1100

46 73.8 Spore - molter-cell: Synapsis (?). Sporem - Stage of the division first division af the spore - matter-cell X about 1100 Fig 9. Chromosomes at Equator of Spindle. Runary Secondary + & terteary thickening layors of the wall surround the spore--moltur - cell. 715 10 Chromosomes at the Equator of the Spindle in forst devision of Spore-maltur-cell × about 1100 Quapheseity for Botabisca apoensportatio Dig#jZ91 molter cell X about 1100 7,5 12 Chromosomes crowded together at the poles of the Spindle X about 1100 71513 Telophase of first devision of the Spore-malter-cell × about 1100 713 14 Later spage stage of telophase Daughter-nuclei in resting condition before Fig 15. commencement of Second division. Septem between cells not yet complete Daughter - nucleus from Similar cell as in Fig14 chrometin granules are aggregating together to form the compound nucleolus. Fig 16.

47 Fig 17 Second division of the Spore- matter - cells. The septem between the cells now nearly or quite reaches the periphery × about 1100. Young letrad with delicate princing thether the cells & the Septa & cell periphery still clothed in 713 18. with secondary + terteary thekening legers of matter - cell - wall. 715 19 Special - mother - cells . Isemened in congo red Stycerine & congo-red. Thickening layers Spore with first for Bodrain a black for sentation D7:5120 in glycenie + congosted at the 2quatorial Turn of the spore. Tramined in Sycerime + Congo-red . Apecal mother cell Secondary thekening layers of Special - motion - cell + nucclage at the rim of spores (both left white in the figure) Stained red, spore - well yellowish . Equatorial much mucilage limited internally by the plasma membrane alone. X about 1100

(inter recishborhood of the squatories rin Spore with first + Second Spore - wells The talter Still appears homogeneons. Examined in gly cerine & the a very little 7; 21. fuchsin Spore at the Equatorial rim. Early 715 22 stage in the differentiation of the Second Spore-wall. 78 23. Older spore examined in Calcium chloride - codine . First Spore - wall stand yellow . Second Spore - wall Digitized by Hupt Institute for Batanical Dostingentation lemenated region + on inner apparently homogeneous region. In they case the darkly colored layer we only just appearing at between the two regions at this comparaturely late Stage . 7824 Portion of spore- wall after warning in a meseture of chromic + Sulphurie acids washing + Saamening in Calcium - Chloride - codine solution. L'aminated Structure of first spore wall & outer region of Second Spore wall is well shown. Intimate

49 union excepts between remains of thedening layers ay Special - mother - cell walls & forat spore - wall serat Both first & Second Spore-wells colon yellow. X about 1100 Fig 25. Somewhat older spore breated with Similarly to the one drawn in Fig 24. all the membranes colowr yellow X about 1100. ×4 g 26. Older spore from section succrotome section Stained with Heidenhains heematory his + besmarck brown. Dark coloured layer Digitized by the Institute for the tanigat Dogume station Spore wall is very & conspicuous. a Semilar, but narrow, dark layer lies between the Second Spore - wall & the endoepore X about 1100. Fig 27. Nuclei from developing spores. (a) from spore with first spore-well only (b) from spore with two spore-walls but Second wall still homogeneous (c) from older Spore with thick, differentiated Second spore-well.

50 B. Photographs Archegonium Showing fertilisation of the Fiz: 28 lgg - cell Fig 29 Sporangium containing spore- mather - cells. Calyptra two-layered. 75 30 Spore - matter - cells becoming rounded off + separated from one another. 75 31. Second division of the mother-cells + young tetrad. Decondary + terteary thickening layers of the mother - se cell well Still Historio and tector periphisal of the needs allon 7; 32 . First division of the egg-cell. Sporangum containing spores with 75 33 . two-layered coats. Note mucilage between the Spore - tetrads. 75 34 Spore at about middle period of its development treated with Russon I odine Solution to Show distribution of Harch Spore Showing layers of its wall 7835. Are arotomen S.

48 35. Section of spore showing layers of its wall. Darkly colonned layer is particularly noticeable Space Section of spores to show the 75 36. new lamellae , which are to be added to the tuckness of the Second Spore - well, pleomoly sed away from that wall together with the protoplast to which they are firmly fixed. These lamellae gave cellulore - pectore reactions.

(1) Fertilisation of the ess-cell is mentially Similar corresponds to the description of this process in Ricia (Ricciocarpus) volans. The sandy devisions of the fortilized 288- will an wow found to (2) The Spore - matter-cells are at forat separated from one another & salvemel delicate membranes which fine forme of the pictic reactions (squite bismarch brown but which is which is Digitized by Hunt Institute for Botovecal Documentation (3) Upon these primary Spore-watter - all walls A & contag + later, & terliary Thickening layers and deposited. Both the layers Sur both pictore + cellulore reactions. The protoplast, sworounded by an lertiary tuckening (4) layer now round tralt affin The Seconday thickening by or he comes minelagina & Sonatines superates completes from the primary wall & the forms an setemal Sucelope to the mother all whild at other times it shell

partly adheres to the primary walk as in that care it the appears as strend of miniclage bridging over the space between primary hall & mother cell. The latter condition I corresponds & Teitgel's description of this stage but he interpreted the mulage as nutritine material parsing into the molter cell. (5) L Riccia glanca no mutriline materiale and i condito could be demonstrated with the Stand found believe any ofthe Un isolated Digitized by thint Interistute for Botanical population such as Garber + Lewis have described -Riccia (Reciscarps) relans (6) The Resting unclean of the spore - halter cell Contains a comp large , dup- staining uncholmen + a under of delicate limitifiere. to mon-undestated, returnly resting inclus, in as to and described à & Tenis y Brain lateran + R. 104 st Ricci (Receips an pars makans) + R. cy stallina, bes found in Reacia glanta

The nucleolus of the huder of Ricia N Server appears to be a compoind Structure Consisting of a number of deeps chromatic masses or granula substitud in a matrix which has one fainted in dyes a long & warked spire stops occurs in the (0) metosis of the spon - matter . all. what This differs sutirely from the short thread describer & figured & Tewis is Recie Diggizethey Hunter of the Spore - make als of Diggizethey Hunter of the bora Botanical Rocementation from to be sitter Seven or Sight but but these members was that it could not be decided with containty which of these two members is the correctione, this are been the present plant differs in the sucches of its chroman for Reccia (Ricco carpo) nalem + K. crystalling in the maistic divisions J which I ander + Levis have recorded one of four cheomones. (Rie-up) nature + R. crysenther .

In the telaphese of the division a number of chrometic (10) hodis, and duck which are no doubt derivation of the chronis mes, are destributed upon the linen. Inlessquently these scattered bodies aggregate together to for the lobular nucleolus (11) The membrane which is formed helines the daughter-eello resulting from an first division of the mattin cell does not at first reach this perphy of the cell. Digitize at you which clusticity the Botani can aloca maintation the special - matter rells are deparated for me another & delicate menteran which gow the [13] Upon the primary Special matter - cell walls Secontar tuckening layers an deposited which give in reactions of calloce. This (tas callone is certainly a here formation of directly deposited as and I the protoplant + cannot be a bansforder product of cellular.

The first spore- wall is a cuticalaries structure (14) for a very Early period. It could not be deceded whilthe it was derived for the transford of the unormat levelac of the apecial mate all walk or whether it is a new formation donated domains to the Secretary acting of the particular the arguments proceeds brought formand & preasions writers are manphicant to prome the case Either one way or the other. (15) With the first spore well at the Equatorial Digitized by Hunt Iperioute for Ballingical Dodepositation This mucilege , which gens the reading of Collor has no direct relation retter to the thickoring legies of the special - mother - cell - mall on to the first Spore wall. (16) The second from well is next formed with the first ball. This is cuticularised for almost very rack time from the comment but there is reason to believe that the cuticularisation is preseded of it reacts as a pector - cellulore mentione.

(14) at forat the hall the Second sport wall in apparents homogeneon but subsequely it can be seen to consist of three parts viz. an ultimal & Internet (1) a. External loosel laminated region (2) a lager of dark - coloured realernal (3) an internal densel lameneted Region. The derk - coloured material appears to be subsequently interpolated into a space which forms between the two leminated regions of the Digitized bee Hunt Institute for Botanical Documentation (18) The Entraport is a formed late in the development of the Spore and give the reactions of pictor & cellulone. It is often Separatio for the Second I pour ball & a notion band of the deck - coloured material Similar to that which secures in the Sap between the Two regions of the second spore well .