II.—*Reproduction in the Mushroom Tribe.*

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(Coprinus radiatus, Fr.)

FOR the purposes of minute research into the vital phenomena of the Mushroom tribe, *Coprinus radiatus*, Fr., possesses many advantages over the other species of the large order to which it belongs. The first great advantage peculiar to *C. radiatus* is that it grows readily and abundantly on dungheaps from April to December, and it comes up equally well in town and country. The second point in its favour is that it is so small and transparent that every part can be quickly examined, and an entire plant kept under the covering glass of the microscope. The third advantage found in *C. radiatus* rests in the fact of its whole life being so exceedingly short, that its entire vital functions are performed in a few days. Having these points in view, I have, during the whole of the present summer and autumn, kept up a large bed of fresh horse-dung in my garden, and from this bed I have narrowly watched the growth of many generations of the plant I am about to describe.

A complaint is often made by persons unused to the microscope, and to the appearances of objects as seen by its aid, that it is impossible to see the real objects as they are represented in drawings. To a certain extent this is borne out by facts, for a drawing is never meant to represent what may be accidentally seen at one sitting, but is designed as a summing-up of all that has been seen during many hundreds of sittings. Anyone looking for the first time through a good telescope at Jupiter's moons, Saturn's ring, or the planet Mars, might be a little disappointed in the apparent smallness and lack of strongly marked outlines in the objects seen; but this does not detract from the correctness of astronomical diagrams, which are only matured after many patient observations. No one expects to see the solar system as shown in a model, or the country as seen on a map.

It may reasonably be premised that the facts observed in connection with the life history of *Coprinus radiatus* will more or less apply to all the other species belonging to the Mushroom tribe; but it would be impossible to make the observations here recorded on the more fleshy species, because, instead of days, these latter plants take months to mature. In *C. radiatus* generation after generation keeps springing up in almost daily succession, but in the more fleshy species, exclusive of *Coprinus* and *Bolbitius*, I am convinced there is, as a rule, but one generation in the year. The common Agarics of the autumn spring up from the mycelium formed during the fall of the previous year, and this mycelium has

rested in the ground for twelve months. In digging up old pasture ground, or the dead leaves of an autumn which has passed, mycelium in a resting state is invariably found. There is no such long rest with the mycelium of *Coprinus radiatus*, for so long as the weather is not too dry, too wet, or too cold, the fungus goes on perfecting itself day after day without ceasing. During hot, very wet, or frosty weather the spawn lies buried, and it rests in the warm, moist dung for short periods of time only.

Coprinus radiatus, Fr., is one of the dung-borne Agarics with a cap which measures from an eighth to one-quarter of an inch in diameter, and this filmy pileus is supported on a stem, which on an average measures from a quarter to three-eighths of an inch or more in height (Figs. 1 and 2, A). The whole cap is a mere transparent film, and the fragile stem is like an atom of gossamer thread. A breath will totally break down and collapse every part of the plant, whilst a heavy dew or slight shower of rain will destroy a whole colony. These minute Agarics can only be gathered with the aid of small forceps, for if they are taken in the fingers they at once collapse, become liquid and vanish. So little moisture does a single specimen contain that it is lost in the moment or two consumed in taking it for examination from the garden to the house. The young plants may generally be seen dotted over the dung, like in size to so many pins' heads (Fig. 1, B), and from this, the infant state, to maturity, the growth of the fungus is very rapid. At seven or eight in the evening nothing but immature plants can be seen (Fig. 1, C, D, enlarged 20 diameters); about eleven or twelve a rapid growth commences, and by two or three o'clock in the morning the full size is reached. If the morning is moist the plants will remain in perfection till nine or ten o'clock, but if it is dry they will not last after five or six. On shady roadsides or in dark places the time required for growth may probably be a little more or less, but the present observations apply to the plants as found growing on dung in a light and open place.

To get a good view of *C. radiatus* it is necessary to magnify it at least from 50 to 100 diameters; the nature of the stem and gills can then be made out, and all the individual component cells be clearly seen.

Mature plants are figured at E, F (Fig. 1), enlarged 10 and 20 diameters, the first showing the nature of the outer surface of pileus, with its furrows, and the other the lower or fruiting surface, with the nature of the gills, and the collar formed by them near the insertion of the stem. At G is shown the relative number of the basidia or privileged cells, which carry the naked spores, and at H the relative number and position of other privileged cells, termed cystidia. To these latter bodies I shall presently refer more fully, and they are merely adverted to here that some idea may be formed

of their great number. At I is shown a horizontal section through the cap of the fungus, a short time before expansion (when the

FIG. 1.*—*Coprinus radiatus*, Fr.
A, Natural size; E, Enlarged 10 diam.; other figures, 20 diam.

* The blocks have been kindly lent by the Editor of the 'Gardeners' Chronicle.'

umbrella-like top is down), to show that the hair-like stem is hollow, and that the plant in infancy is enveloped in a complete

FIG. 2.—*Coprinus radiatus*, Fr.
Enlarged 50 diam.

veil or bag, the presence of which is shown by the ring of cells and hairs which forms the circumference of the diagram.

For a proper comprehension, however, of this minute fungus much more than a superficial examination is necessary, and the first thing to be done in the way of dissection is to secure a good longitudinal section of the fungus from top to bottom, as shown in Fig. 2 (J); this enlarged 35 diameters, at once shows the immense number of cells which go to make up one of the fugitive little plants belonging to *Coprinus radiatus*. By reference to the figure it will be seen that the stratum of flesh which forms the pileus is only six or seven cells in thickness, and the external surface is covered with a few hairs of different sizes (the remnants of the universal veil or wrapper), some of the smaller hairs being tipped with a gland. Another good vertical segmental section across the cap and gills will show the appearance of the plicato-radiate outer surface of the pileus to be caused by a series of cracks which are brought about by the necessarily sudden expansion of the cap, which act of expansion tears (in these positions) the component cells of the pileus apart, Fig. 1, E, and Fig. 2, K. A transverse section through the fungus when in an infant state shows the commencement of these fissures, as at Fig. 1, I, and Fig. 2, L. The gills have no trace of a trama, the so-called trama being the cells which form the substance between the hymenium in the gills; if present this substance would be at M M, Fig. 2; but one of the characters of the genus *Coprinus* is that the gills have no distinct immediate substance in the gills. In the plant under examination the lamellæ or gills are free from, and form a collar round the stem (Fig. 2, N), and are only about seven cells in thickness.

Good sections down and across this stem when young will show it (gossamer-like as it is) to be piped or hollow from top to bottom (Fig. 2, O), and the hairs seen at the base (P P) are the torn remains of the veil or wrapper which once held the edge of the pileus (Q) down to the base of the stem. In this figure several spores may be seen at the base, carried up amongst the cells of the stem. On looking at an entire plant of *C. radiatus* in this way under a low power of the microscope it appears to be formed of a few thousands of cells only, but if these cells are now measured and counted, which is by no means a difficult matter, it will be found that instead of thousands it really requires millions of individual cells to build up one of these minute plants which a breath destroys. The smallness and lightness of one fungus is such that it requires 150 specimens to weigh a grain, or 72,000 to weigh an ounce troy. In the type specimen of *C. radiatus* now figured there were 22,560,000 cells in its structure irrespective of the spores, which numbered about 3,200,000 more. If all these cells and spores are only equivalent to the hundred-and-fiftieth part of a grain, it follows that in an ounce of fungus cells there must be no less than one billion six hundred and twenty-four thousand millions of these

bodies, exclusive of the spores. In a large Mushroom the cells would number hundreds of billions. Still more wonderful is the fact that each individual cell is furnished with a spark of life, contains water, protoplasm, and other material, and is capable of growth and assimilation.

The purpose of this essay is to demonstrate something of the life history of the minute but truly wonderful fungus now before us; and with this object in view it is not only necessary to use the higher powers of the microscope, but to patiently watch the fungus and its changes at every-hour (almost minute) of the night and day and for several days in succession.

In the vertical section of one of the minute gills, as shown in Fig. 3, magnified 150 diameters, the whole fruiting and reproductive surface of the fungus is seen at a glance. The nature of the furrows in the pileus (R) is now perfectly clear, every cell being seen in position, and the remnants of the universal veil or wrapper are seen on the surface of pileus at S. Studded amongst the cells of the upper stratum of cap may be seen various brilliant crystals which belong to the ammonio-phosphate of magnesia, and which crystals are taken up by the fungus from the manure on which it grows. Many dung-borne Agarics are covered with so-called micaceous particles, which, in many instances, doubtlessly arise from the manure which supports the fungus. It is a matter of considerable difficulty to get a section like this, for if attempted clumsily no result will follow beyond a slight discoloration of the edge of the lancet; it is necessary to take the slice at the exact moment of maturity, and even then it requires the perfection of dexterity to cut the fungus properly, as the plant is sticky in all its parts. A fragment of the fruiting surface of a gill is shown at T.

To understand the vital phenomena of *C. radiatus* it is necessary to comprehend the meaning of the bodies seen in Figs. 3 and 4. The whole fungus is built up of cells, which run parallel with each other (and at maturity are very long) in the stem (Fig. 2), and which spread laterally, and then become more or less spherical in the pileus. When these cells reach the gills or fruit-bearing surface (hymenium, U U), a certain differentiation takes place in their functions. The majority of the cells remain simple, but certain other cells which are spread over the gills with the greatest regularity assume a different nature, and produce spores. These cells are called basidia (meaning small pedestals, V V, Figs. 3 and 4), and the spores, or analogues of ovules or seeds, basidiospores, because they are carried on these little pedestals. The minute threads between the spores and their pedestals are termed spicules or sterigmata (literally props). Certain other privileged cells (W W, Fig. 3) are termed cystidia (bladders), and around these latter organs and their meaning the principal interest of the

subject in hand will now centre. But let it be borne in mind as a preliminary fact of the utmost importance that at first the fungus is composed wholly of simple cells which show no differentiation ;

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FIG. 3.—*Coprinus radiatus*, Fr.

Vertical section and surface of Gill, enlarged 150 diam. V, Basidia with spores ; W, Cystidia.

no differentiation in the cells is seen in infancy when the gills are first formed, but the privileged cells, known as basidia and cystidia, come only into existence and that simultaneously as the plants reach maturity. This differentiation I consider to be sexual, the

basidia being female, and the cystidia the male organs. When the contents of the basidia and cystidia are interchanged, the result is a

FIG. 4.—*Coprinus radiatus*, Fr.
V, Basidia bearing spores; W, Cystidia; X, Y, Spermatozoids.

return to another series of cells, which go to form a new plant. I am perfectly aware of the opinions which have been expressed by other botanists (and to which I shall return), but it is not so much

my aim to make my observations accord with what others have said, as to record what I have seen myself, and to give my own interpretation of the phenomena seen, irrespective of what has been said or done before.

The first sign of differentiation in the simple cells of the gills, when the basidia and cystidia are about to be produced, is in the privileged cells becoming glossy, crystalline, and translucent: they both appear to secrete a material which makes them conspicuously brilliant. Each basidium then throws out four slender branches, the tips of which gradually swell and form spores. The cystidia (W) are more sparingly produced (for their number in this species, see Fig. 1, H, and Fig. 2, Q), and at first cannot be distinguished from the basidia, though they are frequently larger in size; they are commonly granular within, and are in many species, as in the one before us, crowned with granules, W (Fig. 4, X), but sometimes they bear four spicules, and this latter condition has led some botanists to consider the cystidia to be barren basidia, but that they are really cystidia with spicules is proved by the following fact, which I believe to be somewhat new. In moisture, as supplied by the expressed juice of horse-dung (or even distilled water) these spicule-bearing cystidia germinate at the four points of the spicules, and produce long threads, which bear at their tips the granules so frequent in typical cystidia (Fig. 4, Y). The cystidia are moreover furnished with spicules in the subgenus *Pluteus*. The germinating cystidia are seen in several places at W, Figs. 3 and 4, and the granules at X, Y. On the top of Fig. 4 is seen a section of a gill with all the bodies in position enlarged 350 diameters, whilst on the lower part of the cut may be seen various germinating cystidia to the same scale as seen on the surface of a gill. The granules at Y, which are at first not capable of movement, are really spermatozoids possessed of a fecundative power, but to see this power brought into operation considerable care and patience and the higher powers of the microscope are requisite. In certain other of the *Agaricini*, the protoplasmic contents of the cystidia are at times discharged from one mouth only and that at the apex of the cystidium.

Before quitting Figs. 3 and 4, I may say that when a slice, as represented in Fig. 3, is placed under a covering glass in a drop of water, all the cells totally collapse and vanish, so that in three or four hours not a vestige remains, but the same drop of water which destroys the old cells instils life into the granules or spermatozoids, which after the lapse of a couple of hours begin to revolve, and ultimately swim about with great rapidity. These spermatozoids attach themselves to the spores, pierce the coat, and discharge their contents into the substance of the spore. From twenty-four to forty-eight hours after this the spore discharges a cell which soon becomes free, and this is the first cell of the pileus of a new plant

which rapidly produces others of a like nature (Z, Fig. 3). Now the same water which had the effect of immediately collapsing and destroying the old cells, has quite a different effect on the new cells as discharged from the fecundated spore, for the whole development of the new plant depends upon the constant presence of moisture, expressed juice of horse-dung being perhaps best. A spore unpierced by the spermatozoids is shown producing a mycelium peculiar to itself, at A, Fig. 3.

A spore is commonly considered to have some analogy with a seed, but according to my views its analogy is rather with an unfecundated naked ovule without an embryo, unless the nucleus within the spore may in some way represent the rudimentary fungus; when the spores are formed within sacs or asci, the ascus bears some analogy with the ovary. The cystidium, on the other hand, represents with its granules the anther and its pollen.

The six spores represented on the top of Fig. 5 are magnified 1000 diameters, and each viscid spore, which is furnished with a nucleus lighter in colour, but with a dark outline, has been pierced and fertilized by one or more spermatozoids, whilst the unfertilized spore at A has burst at both ends, and produced a mycelium of its own. At B may be seen three spermatozoids which have burst after twelve hours in expressed juice of horse-dung, and which have also produced branching threads peculiar to themselves, reminding one of a pollen tube. It is quite possible that these latter threads may help to produce a new plant if they come in contact with the spores. The large figure at C is similar in nature to the group at Z, Fig. 3, and represents three fertilized spores which have burst and produced the first minute knot or groups of cells of the cap of a new fungus. These eighteen cells took four days for their production, and the crystals belong to the expressed juice of the horse-dung in which they grew. The spermatozoids as here shown begin gradually to revolve after being kept in liquid for two hours, and the movements last for at least four days. At first these bodies are perfectly spherical, as at D, when they merely oscillate, then they revolve slowly, and as time goes on, a single turn of a spiral makes itself visible, and the bodies whirl round with great rapidity. At intervals the motion entirely ceases, and then, after a short lapse of time, the gyration is again continued.

Judging from the presence of the eddy round these bodies whilst whirling (E E, Fig. 5), they are possibly provided with cilia, but from the extreme minuteness of the bodies themselves I have not been able to satisfactorily demonstrate their presence. The whirling of the spermatozoids is sometimes so strong that when they attach themselves to the spores they twist them round after the manner of the revolving cosphere in *Fucus*.

When the cells of the old parent fungus collapse and disappear

in the water, their place is in less than two hours occupied by innumerable quantities of bacteria, vibriones and monads, which belong to the infusoria. In these two hours every cell of the pileus

FIG. 5.—*Coprinus radiatus*, Fr.
Spores, Infant plant C, and Infusoria, enlarged 1000 diam.; Spermatozooids at bottom further enlarged to 3000 diam.

has generally vanished. Where these infusoria come from, or how they so speedily come into being, is difficult to say. They may possibly be present in a latent state in the juices of the fungus, but I have invariably found, when a single specimen of *C. radiatus* has been placed on a slide under a covering glass with a drop of water, and this, again, under a propagating glass, that as the millions of fungus cells quickly disappear, so millions of simple infusoria just as quickly come into being. It seems almost reasonable to believe that the fungus cells themselves become suddenly transformed, and reappear as simple infusoria; the change would not be quicker or more remarkable than the rapid production of the purple-black spores from the crystalline and colourless basidia.

Be this as it may, I have here engraved the abundant infusoria to the same scale as the cells. The tailless monads at F have a rocking Brownian movement, whilst those with tails, G, propel themselves rapidly about after the manner of minute tadpoles. These monads are liable (without care) to be mistaken for the bodies I refer to spermatozoids, from which they are, however, very different. The bacteria are represented at H H, with their various movements (indicated by dotted lines), either straight, zigzag, or rapidly revolving on a central axis; when they so revolve they cause a miniature vortex amongst the monads and atoms. I have commonly seen one segment move from side to side, as at J, whilst the other segment remained quiescent. I have also seen them bud from the centre, and occasionally they occur with three limbs instead of two, radiating from the central axis. The vibriones are like vegetable screws, and are shown at K. The spores and infusoria neither collapse nor burst in boiling. As for the monads, vibriones, and bacteria, it can hardly be admitted that they are generated spontaneously from inorganic materials; my experiments rather point in the direction that they are only differentiated forms of already living cells. However this may be, my boiling has not destroyed either vitality or form, and those interested in the subject of spontaneous generation may possibly read the result of the following experiment with interest. A dozen semi-decayed specimens of *C. radiatus*, swarming with minute infusoria, were boiled in a test tube for five minutes and then hermetically sealed at the highest point of ebullition. At the end of a month the tube was opened and a drop of its liquid contents at once placed under a cover-glass of the microscope for examination. Spores, cells, monads, bacteria, and vibriones were all there, but the latter motionless and apparently dead. In fifteen minutes, however, they showed signs of life, and began to slightly move about; in thirty minutes the movements were decided in nearly every specimen seen; whilst in sixty minutes the infusoria darted about with almost the same energy as they did before they were boiled. For a better

appreciation of the exact form and gyrations of the spermatozoids they are shown again at the bottom of Fig. 5, enlarged 3000 diameters. At first it requires long and patient observation to make out the form of these bodies satisfactorily, but when the peculiar shape is once comprehended there is little difficulty in correctly seeing their characteristic form. The difficulty is something like that experienced by beginners in separating very small and close double stars with a telescope; at first and sometimes for a long period only one star can be seen, till quite suddenly the two are made out, and they are seen as two ever afterwards.

It is not uncommon to find the spores of other dung-borne fungi sticking to the specimens of *C. radiatus*, and it is quite frequent to find not only the spores but the perfect asci of certain species of *Ascobolus* sticking to the under surface, to which position they have been projected from the plants of *Ascobolus* growing on the dung. I have also seen the eggs of various mites, nematoid worms, &c., carried up amongst the cells, which quite accounts for larvæ being found within the substance of apparently sound fungi.

In the works I am acquainted with there is no mention of the cystidia falling bodily out of the hymenium on to the ground, yet this is the case in several *Agarics* I have examined, and is so with *C. radiatus*. The spores naturally fall to the earth, and with them the cystidia, and it is upon the moist earth that fertilization is generally carried out. All botanists will remember Hoffmann's observations, where he has indicated the passage of basidia into cystidia, and his remarks on the upper surface of the ring which grows round the middle of the stem in *Agaricus muscarius*. In this latter position Hoffmann found a quantity of gelatinous knots, from which projected one or more oscillating threads, terminated frequently with a little head, which occasionally becomes detached. My interpretation of these observations is, that Hoffmann lighted upon the fallen cystidia on the upper surface of the ring, where they were throwing out threads. Hedwig made somewhat similar observations on the ring in *Agaricus*.

From the condition of the infant plant, as figured on the hymenium, Fig. 3, Z, and Fig 5, C, it is easy to trace the young fungus through the various stages of its growth, as seen at Fig. 6, where the figures are all enlarged 500 diameters; the lower group of cells shows a plant of seven days' growth in the expressed juice of horse-dung. In all these figures it will be seen that crystals and spores are carried up by the cells, and the lower figure conclusively shows that the first cells of the new plant are the large ones which belong to the pileus; indeed the hairs of the pileus as here shown are amongst the earliest cells produced, these hairs and the threads of the mycelium (which is always highly granular near the plant) are almost one and the same in character. In Fig. 6 and

Fig. 7 the infant fungus resembles a Puff-ball, to which it indeed bears a certain natural relationship. The whole plant in infancy

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FIG. 6.—*Coprinus radiatus*, Fr.

Enlarged 500 diam., as grown from the spores, in expressed juice of horse-dung, under a covering glass of microscope.

is enveloped in a wrapper of cells, the fructification being entirely concealed within. In the lower figure on Fig. 6 may be seen two spermatozoids which have burst, and K K K shows the cells of straw.

When the fungus has made about the number of cells represented on the bottom of Fig. 6, the growth cannot be carried any

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FIG. 7.—*Coprinus radiatus*, Fr.
Enlarged 200 diam., and natural size at A A A.

further beneath a covering glass. Fig. 7 represents on one side the elevation, and on the other the section of the very smallest infant plant it is possible to see with a lens on the dung. The

fungus represented is magnified 200 diameters, and the original was about half the size of a pin's head (see A A A sketch in margin). The nature of the hairy coating, which forms the veil and the cells which are to form the future gills, are here clearly seen. This figure shows the fungus in its Puff-ball condition at the time when the cells are being actively produced. It contains only a small proportion of the actual cells which go to make up a perfect fungus, and represents probably a full week's growth from the spores. How it is that the cells have an inherent property of building themselves up into a particular design, no one knows any more than it is known how the fine spark of life is kept up in these cells from one generation to another.

The mycelium now grows in a radiate manner from the base of the young plant, just as a germinating seed throws up a plumule and throws down a radicle. This mycelium being the produce of fertilization is now capable, under certain conditions, of producing new plants on certain spots on the threads. Spores are now unnecessary, in the same way as fresh seeds are unnecessary where the creeping root-stock of Couch-grass is present. Or the mycelium may go to rest in the form of cords or thick threads, when it is termed Rhizomorpha, or in the form of the knots or bulblets known as Sclerotia. A similar state of things is common in many perennial flowering plants, as *Convolvulus sepium* and *Sagittaria sagittifolia*, and they both at first arise from a seed in the same way as a Mushroom arises from a spore. In Mushroom-spawn the grower gets a material similar in nature to the root-stock in Couch-grass.

Fig. 8 and last represents, enlarged 120 diameters, *C. radiatus* a few moments before expansion, when nearly all the cells are present. Most of the cells here shown are, however, only about one-half the size they reach at maturity, and they are not all and every one produced till the exact moment of complete expansion, as I have ascertained by counting the cells of many specimens. This is not to be wondered at, for if the 22,500,000 cells which go to make up one of these minute plants require fourteen days for their production, it follows as a necessity that the cells go on multiplying all the fortnight, night and day, at the rate of 1114 to the minute. It takes about five hours for the spores to be gradually produced all over the hymenium—say from 5 to 10 o'clock in the morning, and as there are upwards of 3,000,000 spores to each plant, they as a consequence gradually appear upon the basidia or spore-bearing spicules at the rate of 100,000 every minute.

No sooner has the plant arrived at perfection than that very moment it begins to perish. I have demonstrated that the cells of the pileus and the hairs which form the veil are the first to appear, and so they are the first to disappear. The fine matted hairs

which form the veil in Fig. 8, B B B, are all torn assunder during the few moments consumed in the expansion of the cap, and at the

FIG. 8.—*Coprinus radiatus*, Fr.
Enlarged 120 diam.

moment of maturity the hairs vanish and the pileus is naked, which nakedness is the first sign of its decay. When the fragile little

fungus has at length produced its fruit, and is prostrate and dying upon the matrix from which it sprang, then, as can be seen with patience under the microscope, the cystidia produce spermatozoids which are at first passive and then active; these pierce the spores and cause the discharge of the first living cell of the pileus of a new plant. It will be seen from these observations that *C. radiatus*, though one of the most minute and fugitive of all the Mushroom tribe, is yet as completely perfect in all its parts as any of the larger and higher species of *Agaricus*. It must not be supposed that these observations can be followed without close attention and the utmost patience. All the 3,000,000 spores of the fungus do not grow and make new plants, or the world would soon be covered with *C. radiatus*. For every spore that is fertilized and grows, there are millions which necessarily perish.

On a dunghheap which will produce *C. radiatus*, other species, as *C. nycthemerus*, &c., are sure to appear; and not only do allied species come up in company with *C. radiatus*, but every intermediate form between one and the other may be gathered any morning. These latter plants belong to no species described as such, but are natural hybrids, doubtlessly produced by the spermatozoids of one plant piercing the spores of another. Amongst the larger species of *Agaricus* similar forms are quite common, and they prove sore puzzles for those men who only want names for the fungi they find. I am convinced that at least three-fourths of the described species of the higher fungi have no claim to rank as true species, and that plants like *Agaricus procerus*, *A. rachodes*, *A. excoriatus*, *A. gracilentus*, with others, are mere forms of one and the same plant, and every intermediate form may be met with.

Van Tieghem has recently been working on this species, and he has arrived at the conclusion that the fungus produces spores of different sexes. But to me it is quite unreasonable to imagine seeds or spores to be of different sexes. Known facts point quite in the opposite direction; and if sex is once allowed in seeds and spores, then we must be prepared to allow sex in pollen and spermatozoids. A spore or ovule must be considered female, whilst unfecundated or still in the ovary, but when once fertilized it combines both sexes and cannot be other than hermaphrodite. A secondary colour, as orange (which combines the red and yellow primaries), can never be red or yellow. In dicecious plants the seeds are capable of producing either sex, and are not themselves male or female; and even the great fleshy root-stock of *Bryonia dioica* will be male in one place, and if removed to a different position be female. The Rev. M. J. Berkeley, writing of *Coprinus*,* says: "Late examinations of the spores of some *Coprinus* under germi-

* 'Gardeners' Chronicle,' April 17, 1875, p. 503.

nation seem to show that impregnation takes place at a very early period."

Now my observations show that this impregnation often actually takes place on the hymenium itself, the product being a single cell, which in the species now described rapidly develops into a new individual. The spore and spermatozoid may be considered as somewhat analogous with an ovule and a pollen grain, or with what is seen in *Chara*; or like the escaped oosphere and spermatozooids in *Fucus* amongst the Algæ.

I cannot attach much importance to CErsted's interesting paper on the fructification of the Agaricini. His notes are on *Agaricus variabilis*, a plant he gathered from a Mushroom bed. Now, as far as my experience goes, *A. variabilis* is peculiar to dead stems, sticks, and leaves, and does not grow upon dung. Moreover, CErsted experimented upon threads of mycelium taken from dung, and presumed only to belong to this *Agaricus*; but this mycelium was quite as likely, in my opinion, to have belonged to fifty other things. De Bary, speaking of CErsted's observations, says: "It is impossible not to perceive the similitude between the phenomena seen by M. CErsted and those I have described in *Peziza confuens*." It is quite doubtful whether or not CErsted had got the mycelium of some dung-borne *Peziza* for his experiments, as *P. vesiculosa*, which is always present on dungheaps.

In the observation of natural phenomena it is never well to follow, without thought and original observation, in the footsteps of others. In the case of *Peronospora infestans*, because De Bary said the resting spores were not likely to be found in the Potato plant, it was almost universally accepted as a fact that they never could be there found. Because conidia had not been described, it was commonly believed that no conidia existed. The mycelium of *Peronospora* has till lately been described as always destitute of suckers, but in some of the Chiswick plants the suckers were abundant. The same fungus is commonly described as having its threads without articulations or septa, but it is equally common to see the fungus and the figures of it too with septa in profusion.

Many botanists, as Corda, Bulliard, Klotzsch, and others, have considered the cystidium in *Agaricus* to correspond in some way with an antheridium; but as these views have not at present been favoured by Tulasne and De Bary, many botanists seem disposed to agree with De Bary in regarding the cystids as mere "pilose productions of a particular order," which is very indefinite, and the granules as mere conidia (Tulasne). Klotzsch and others have considered it possible that the spores are fecundated by a lubricating fluid given out by the cystidia. This fluid is evidently the same with the threads observed by me, and which at length gives birth to spermatozooids. I consider it quite possible that the mere contact

of the threads (or fluid) from the cystidia with the threads from the unpierced spores may be sufficient for the production of a new plant. But De Bary, in criticising Klotzsch, says an opinion of this nature is entirely gratuitous, and the contact and its result, if real, would represent nutrition rather than fecundation, and, as far as he knows, there exists, he says, no other observation on any female organ susceptible of fecundation by the cystidia. I cannot fall in with De Bary's views at all, especially after the analogy found in *Fucus* and in the confervoid pollen (which has no outer coat), and which exhibits rotation in the flowering plants found under *Zostera*, *Phucagrostes*, &c., and which are fecundated when in a state of immersion in water.

As regards the spores of woody species of fungi, they are probably fertilized on the parent plant, and are blown away by the wind in a condition suitable to at once form the first cells of a new plant on any proper habitat. If *Agarics* were perennial and persistent, instead of being annual and fugitive, we might expect to see a new hymenium produced each year upon the lower surface of the old one, and this state of things really does exist in many species belonging to the perennial and persistent woody fungi of trees, where a new stratum of tubes is every year produced underneath the old one, so that the age of the fungus in years may be correctly ascertained by merely counting the strata. As to the mycelium itself, and the possibility of its producing sexual organs in *Agaricus*, I have had the subject before me for many years, and have seen many germinating spores, but no trace of any sexual organ other than the spermatozoids as produced from the cystidia themselves, or from the protoplasmic filaments which they throw out. I am therefore disposed to believe that the absence of sexual organs on the mycelium is owing to the threads being the produce of fertilization.

As for the expressed juice of horse-dung, it abounds with nematoid worms, spores and infusoria of many kinds—no drop can be examined from a dungheap after a shower of rain without seeing large quantities of these organisms. Therefore, any uncertain thread taken for examination from dung is sure to lead to error. All my experiments were carried out in duplicate, one with expressed juice, and the other with distilled water, with very little difference in result, as the new plant seemed to live principally on the remains of the old parent.

As a proof of how much there is still to be learnt respecting the life history of *Agarics*, I may say that in Sach's recently published '*Text Book of Botany*,' one of the very best and most complete books of its class ever published, there is no mention whatever made of cystidia in the description of *Agaricus*, and in La Maout and Decaisne's '*Descriptive and Analytical Botany*,' under

fungi, it is stated that the male organs never produce antherozoids, and that the cystidia are always deprived of sterigmata or spicules.

To repeat and follow out these observations it is necessary to take the specimens for examination exactly at the proper period of growth, and to exercise the greatest care in securing a uniform moisture between the glasses. The life of the fungus is so short, and all the characters are so evanescent, that the points to be observed may be present one moment and all gone the next.

All the drawings have been made with a camera-lucida, and from different specimens, so where the dimensions of the parts slightly disagree, it is only such a disagreement (within defined limits) as is commonly found in Nature.—*Gardeners' Chronicle*, October 16 and 23.

III.—*Avoiding the Use of the Heliostat in Micro-photography.*

By G. M. GILES, M.M.M.S.

PLATE CXXVII.

SOME time ago I commenced to make some experiments in micro-photography. I did not wish to set aside a room to act as a camera, as in the method of Colonel Woodward, and did not like the form of instrument mentioned in the catalogues of the instrument makers, as in the first place it is very top-heavy, and in the second the disk produced, I found on inquiry, was no larger than a "five-franc piece." Above all things I wished to avoid the necessity of using a heliostat.

I was therefore constrained to contrive an apparatus to meet these requirements, which I have no doubt are those of a great many histologists. The image produced by an ordinary condenser of short focus is so small, that unless a heliostat be used, it is almost impossible to replace the focussing screen by the sensitized plate before, on account of the rotation of the earth, the image has passed across the field of the instrument and disappeared. Now the obvious

EXPLANATION OF PLATE CXXVII.

- Figs. 1 and 2, *a*.—Stand of camera.
 " " *b*.—Mirror.
 " " *c*.—Long-focussed condenser.
 " " *d*.—Microscope and its slider.
 " " *e*.—Grooved wheel at back.
 " " *f*.—Strings of horizontal movement.
 " " *g*.—Strings of vertical movement.

FIG. 3.—Section mode of connection of microscope with camera.

" 4.—Sectional view of "tramway."