In Comets *b*, 1881, and *c*, 1882, the only lines recorded were magnesium *b*; but, as before, the apparent absence of other lines might be due to continuous spectrum.

Of the five bands shown in Huggins's photograph of the spectrum of Comet Wells, taken with a wide slit, no less than three agree fairly in position with three lines seen in the spectra of meteorites. The wave-lengths of these are 4253, 4412, and 4769, and it is interesting to note that, so far, the origin of these lines is undetermined. The two remaining bands are at wave-lengths 4507 and 4634.

It is seen, then, that the spectra of comets—when their internal motions are relatively either slow or fast, and when therefore the number of collisions, and with them the heat of the stones in collision, will vary extremely—resemble the spectra of meteorites seen in glow tubes.

(γ) "Stars" with flutings which have been observed in the laboratory and in luminous meteors and comets.

The most prominent bright flutings of carbon are not only observed in luminous meteors and comets, but in stars of Class III.*a*, and in some "Novas," notably Nova Orionis. So far, then, these bodies may in a certain measure be classed with luminous meteors and comets. But there is an important difference in the phenomena, for we have absorption as well as radiation. The discussion shows that the dark (or absorbing) flutings in these bodies are partly due to the absorption of light by the most prominent flutings of Mn and Zn, seen at low temperatures. This inquiry is being continued.

We have, then, in these bodies a spectrum integrating the *radiation* of carbon and the *absorption* of Mn and Zn vapour.

The law of parsimony compels us to ascribe the bright fluting of carbon in these stars to the same cause as that at work in comets, where we know it is produced by the vapours between the individual meteorites or repelled from them.

Hence we are led to conclude that the absorption phenomena are produced by the incandescent vapour surrounding the individual meteorites which have been rendered intensely hot by collisions.

These stars, therefore, are not masses of vapour like our sun, but clouds of incandescent stones.

We have here probably the first stage of meteoritic condensation.

J. NORMAN LOCKYER.

(*To be continued.*)

FAIRY-RINGS.

THE rains have come, and we have heard from all sides of the prolific crops of mushrooms and toadstools —paddock-stools, as they are termed in some northern districts—which have been springing up in the meadows and woods of England, Wales, and Scotland. Not only is surprise evinced at the marvellously rapid up-growth of these fungi, for the popular mind may well be amazed at that until a knowledge of the biology of these plants is more universal, but country people and dwellers in towns alike exclaim at certain other phenomena associated with their growth in the fields, and at none, perhaps, so much as what have been known from of old as "Fairy-rings" in England, *Hexenringe* and *Cercles de sorcières* on the Continent. Now fairy-rings, like very many other poetical objects, have of late years undergone the process of being explained away to an extent which, although it in no way removes the beauty from them, demands from us an admiration of a more stimulating and healthful character than the old awe which they inspired was capable of producing.

Disbelief prevails regarding Prospero and the beings that

"By moonshine do the green sour ringlets make,
Whereof the ewe not bites;"

and

"whose pastime
Is to make midnight mushrooms."

Fairy-rings are more or less regular and complete rings of grass, sharply distinguished from the ordinary grass surrounding them by means of their darker hue, more luxuriant growth, and other characters; in spring or autumn they are to be found with vigorous growths of mushrooms or toadstools springing from their outer margins, and the centre of the ring is often marked by a very poor crop of withered-looking herbage.

Before proceeding to give an account of the modern explanation of these remarkable objects, a few statements may be made as to their sizes, structure, and occurrence.

They are not always complete or regular rings, but may be parts of circles or ovals, or mere wavy strips. Nor are they always provided with the outer belt of fungi, though the rule is that a good season sees them so accompanied; if not, they do not remain long. In the typical cases, where the ring is annually provided with its fringe of fungi, it may go on increasing in size for years: records exist of rings which have been known to go on flourishing for forty or sixty years, and large rings on a hill-side could be seen from a considerable distance.

As to their sizes, they are known to commence as very small patches, but specimens have been measured as much as 60 feet and more in diameter. Indeed one observer refers to a fairy-ring which was nearly 100 feet across. While regarding these cases as rare extremes, it is well known that rings 12–20 feet in diameter have often been recorded, and, as we shall see, these must be several or many years old.

Although fairy-rings are usually noticed in meadows and on pasture lands, they are found on hills as well as in valleys, on dry soil as well as on wet, in woods and on heaths, and even in rocky places and situations near the sea. Perhaps the only generalization possible in this connexion is that they do not occur on highly-cultivated rich land.

On regarding carefully a typical fairy-ring, it may be found to present the following characters:—The central area, encompassed by the dark-green ring, consists of poor or even withered herbage—it may be of inferior grasses alone, or of these mixed with other plants. Then comes the band of luxuriant grass forming the ring proper: the grass composing this may be of more than one kind—*e.g. Lolium perenne* (the perennial rye-grass), *Dactylis glomerata* (the cock's-foot grass), and *Bromus mollis* (the soft brome) are common.

These grasses are rank, tall, and of a distinctly darker, bluer green hue than the rest; it is their coarseness, height, and especially the deeper colour, which render them so prominent. Fringing this ring, at the proper season, are found the spore-bearing heads of the Agarics *i.e.* the mushrooms or toadstools as the case may be; and if the observer digs carefully below the soil, he will find that these Agarics spring from a felted mass of root-like threads, the mycelium of the fungus. Then, outside all, comes the general herbage of the pasture, or whatever it may be: this is often scanty, indicating poor soil, and in any case is less luxuriant and lighter in colour than the rank herbage of the ring itself.

As with the herbage composing the rings, so the Agarics fringing them may be of different kinds. In the autumn the fairy-rings of this country and on the Continent commonly contain *Marasmius oreades*, Fr., a small pale mushroom with cream-coloured gills, and much esteemed as an esculent. It has a somewhat strong aromatic odour, and its mycelium is attached to the roots of the grasses among which it grows. It must not be confounded with certain acrid species allied to it.

The common mushroom (*Agaricus campestris*, L.) is also frequently found in large circles, fringing more or less complete fairy-rings. Among other forms may be mentioned the gray *Agaricus terreus*, Schoeff, not uncommon in beech- and fir-woods; the "parasol mushroom" (*Agaricus procerus*, Scop.), also not uncommon in fir-woods and pastures, and spoken of as one of the best of the esculent forms; also *Agaricus personatus*, Fr., with a lilac or purple stem. This is a late form, good to eat, and called the "Blewit." *Agaricus subpulverulentus*, Pers., is also not uncommon, and several others are known.

In the spring, fairy-rings have been found containing *Agaricus gambosus*, Fr., an edible mushroom known in England as the "St. George's mushroom," and much esteemed on the Continent.

There are also other forms, several of them poisonous, or at least inedible or dangerous; and even puff-balls are known to be associated with fairy-rings.

And now we come to the question, How do these fairy-rings arise and increase? It cannot be wondered at that the people of earlier days, wishing to explain a phenomenon which none could overlook, sought for satisfaction in their myths and folk-lore, and believed them to be "caused" by fairies and elves and other mystic beings of the woods and fields, dancing in circles beneath the moonlight, and enchanting the ground into a richness which it did not previously possess.

Then came the era of science, and people were dissatisfied with beliefs, and in course of time the followers of De Candolle at least tried to solve the problem according to what was known of Nature. It was at least necessary to explain (1) why the centre of the ring is so poor, (2) why the fungi are confined to the margin, and (3) why the ring goes on enlarging, as continued observation showed that it did.

The first theory of any merit was, that the "ring" takes its origin from a single mushroom, which sheds its spores from the gills down on to the ground around the thick stem: this necessarily produces a ring of spores, as the stem dies down in the centre. Now the physiologists of those days believed that a plant excretes into the soil at its base substances which are harmful to its further development, and so, they argued, the soil on the inside of the ring of spores is poisoned, as it were, and only the outer spores produce new plants. The new mushrooms come up in a ring, and in their turn shed spores in a ring of rings; but since the soil on the inside of all these rings is poisoned by the excreta, only the outer series can germinate and grow, and thus a new ring arises next season, and so on. But, it was thought, though the excreta are injurious to the growth of the same plant (the fungus in this case) in that particular soil, other plants can grow there (in the present instance, grasses), and so a ring of rank grass follows on, which in its turn spoils the soil for its own kind as it increases.

Now it has to be admitted that there was much ingenuity in this hypothesis, and it was maintained for some time; until, in fact, physiologists had to give up the excretion theory as not in accordance with observed facts.

Then followed the beginnings of the celebrated doctrine of the rotation of crops, and the facts accumulated about fairy-rings had to be looked at again. They had become too much for the excretion theory; how did they look when regarded from the new point of view? First, however, we may bear in mind the fact noticed by several observers. When two fairy-rings gradually extend so as to interfere, the green circles coalesce and form a single ring: evidently the conditions of the soil in the wake of the advancing ring are such that the grass of another advancing ring cannot go on luxuriating there. It is true this fact was as easily made use of by those who maintained the excretion theory as by those who advanced the theory we are now going to examine.

It gradually came to be recognized that the reason one species of plant cannot be continually grown on the same soil was not because the first crop poisons the soil by leaving injurious excreta behind it, but because it *takes away* certain mineral substances in such proportions that too little is left for the well-being of a second crop of the same species; in other words, it *exhausts* the soil of certain necessary ingredients. A crop of some other species may be raised on the partially exhausted soil, however, provided it is a plant which does not need the materials now deficient, in such large quantities as its predecessor. This is, roughly sketched, the *rationale* of the doctrine of the rotation of crops, and it was subsequently suggested that the "fairy-rings" we are considering are a natural illustration of this. The vegetable physiologists then came to the conclusion that the fungus causes the fairy-ring by exhausting the soil of certain substances which are necessary to its existence, and is only able to produce continued crops by extending centrifugally into soil which still yields these substances: the grass, however, does not need these substances in such large proportions, and so follows the fungus. But, as we have seen, the grass which immediately follows the fungus is particularly rank and luxuriant, and it was necessary to find an explanation for this fact. It was then suggested that the dying mycelium of the fungus acts as a manure for the grass to feed upon, and until this is exhausted the growth is peculiarly rich and rampant.

Before leaving this part of our subject, it should be pointed out that Dr. Wollaston, in an essay on fairy-rings published in the Philosophical Transactions of the Royal Society so long ago as 1809, ventured on the explanation that the fungi spread in rings, because the soil was, by their mycelium, progressively "exhausted of some peculiar pabulum necessary for their production. . . . An appearance of luxuriance of the grass would follow as a natural consequence, as the soil in the interior of a circle would always be enriched by the decayed roots of fungi of the preceding year's growth."

Meanwhile, the physiology of plants was passing into a more scientific phase of existence, and the beginnings of modern agricultural chemistry were made; and in 1846 an important contribution to our knowledge of fairy-rings was afforded by Way, who chemically analyzed the soil, the herbage, and the fungi of some of these curious formations. This chemist found that the fungi of his fairy-rings were remarkably rich in phosphoric acid and in potash; and that they also contained relatively large quantities of nitrogen. We know now that this is true of fungi generally, but these facts were by no means so well understood at that time. Way also analyzed the grasses composing the ring, and found that they also contained a larger proportion of phosphoric acid and potash than the herbage in the neighbourhood, but by no means so much as the fungi: the grass also contained considerable quantities of nitrogen.

The net result of these investigations was to explain fairy-rings as an illustration of the rotation of crops, but of course putting the explanation on much firmer grounds. Way also pointed out that as the rank green grass was cut or otherwise removed, valuable ingredients (phosphorus, potassium, alkalies, &c.), were removed with it, and so the crops of grass further inwards become poorer and poorer, accounting for the bare patches often found inside the dark ring.

Messrs. Lawes and Gilbert, whose magnificent experiments on the vegetation of agriculture will never be forgotten, supported the above view of the matter, and showed that the dark green colour of the rank grass is due to the relatively large quantities of nitrogen. It was at this time (about 1850) customary to suppose that plants obtained their nitrogen from the atmosphere, a view now known to be erroneous from the brilliant researches of Boussingault, and of Lawes and Gilbert themselves. On this supposition the extraordinary accumulation of nitrogen (in the fungus and rank grass) was thought probably due to a power on the part of the fungus of taking nitrogen from the air. Subsequently the whole matter was again taken in hand by Messrs. Lawes and Gilbert, and the results published in the Journal of the Chemical Society, 1883.

The chief additional facts may be summarized as follows:—The fungi remove large quantities of carbon, nitrogen, and especially phosphoric acid and potash, from the soil. The soil inside the ring contains less nitrogen than that under the ring, and this again less than the soil outside the ring; a gradual exhaustion of nitrogen, then, is taking place as the fungus and rank grass extend the ring centrifugally, and this is promoted by the removal of the grass.

These observers also demonstrated the spread of the mycelium: it is in greatest abundance just below the outer edge of the ring. They conclude that the fungus has powers of obtaining nitrogen from compounds in the soil which are not available to the roots of the green herbage, but after the decay of the fungus mycelium the grasses can avail themselves of part of the nitrogen. The grasses—being plants containing chlorophyll—of course obtain their carbon from the carbon dioxide of the atmosphere; but the fungus—equally of course, in the light of physiology—obtains its carbon from some organic substances in the soil. The accumulation of phosphoric acid and potash has already been accounted for.

We may now sum up, then, the rational explanation of these curious fairy-rings as follows.

A mushroom spore may be supposed to start its growth in or beneath the dung of cattle, or a bird, on poor soil; the first crop of mushrooms, produced from the mycelium to which the spore gave rise, exhausts the soil of available carbon, nitrogen, phosphorus, potash, and other substances, storing all it can get in its own substance. The mycelium extends centrifugally "into fresh fields and pastures new," and the next crop of mushrooms arises at a distance from the centre; and so the growth proceeds. The grasses, among the roots of which this extension is going on, now avail themselves of the rich manure afforded by the decomposition of the older mycelium, and a struggle for existence is set up which results in the victory of the coarsest and rankest-growing species. These in their turn exhaust the available supply, and if cut it is removed in their substance: no wonder, then, that the inner parts of the area are poor, and support little or no herbage.

Messrs. Lawes and Gilbert's researches also showed that if the growth of the herbage is promoted by means of manures containing much available nitrogen the fungi are found to suffer, and the "fairy-ring" may be brought to an end. Again, unfavourable seasons of drought may cause the death of the mycelium, and rings which have flourished for years be thus destroyed.

We have attempted in this article to give a complete explanation of the rise and progress of "fairy-rings," as afforded by modern science. That much is clear which was previously obscure will have to be conceded; but are all the facts covered by the explanation? There are some inquiring spirits who are never satisfied with an explanation, and we run the risk of being classed among these malcontents, but there are one or two curious little points which still obtrude themselves upon our attention.

There is, in the first place, some difficulty in realizing how the fungi manage to obtain their large supplies of carbon and nitrogen and other elements from poor shallow soil, in the absence of larger quantities of organic matter than may occur: there is, in fact, considerable difficulty about the whole question of the nutrition of the fungus. A second point is that we find the ultimate filaments into which the mycelium of the fungus breaks up becoming lost among the roots of the grasses; and if the latter are carefully washed and examined with the microscope, their fibrils and root-hairs can be seen to be infolded by delicate hyphæ, and in some cases the root-hairs are pierced by them. We do not know that this has been demonstrated before, but we find it the rule with *Marasmius*, and have already succeeded in detecting something of the kind in other forms.

Now this looks very like parasitism; and we are tempted to pause before accepting the last explanation of fairy-rings as conclusive, or covering all the facts. It may be, in fact, that the hyphæ of the fungus stimulate the roots of the grasses to increased activity: this would account for the rampant growth and the result of the struggle for existence. Subsequently the hyphæ kill the grass-roots—or at any rate those of some species—which accounts for the bare patches in some rings. It also easily explains the sources of the carbon and nitrogen, if the hyphæ absorb nutritive materials from the hard-working grass-roots. This being the case, fairy-rings become still more interesting, since they afford an illustration of symbiosis of a peculiar kind, at any rate during part of the time that the grass and the fungus are in contact; and it seems not improbable that the theory of the formation of fairy-rings will have to be modified somewhat as follows.

A fungus-spore starts its mycelium among the roots of the grasses, and the hyphæ obtain a hold on some root-hairs and fibrils; the mycelium thus parasitic on the roots reacts in a stimulating manner on the latter, and we have a symbiotic relationship established between the fungus and the host. The consequence is that both flourish, and become rampant. It may be that only some grasses are thus stimulated, or even attacked, and this will affect their struggle for existence, and result in the selection of a few coarse forms. In time the hyphæ or the roots get the upper hand, and this is expressed in the survival of the grass, or its decay; in some cases it is clear that hyphæ are living at the expense of dead and dying roots.

However, until the results of investigations at present going on are set forth more at length, it is impossible to say which of the above explanations is the true one; in any case, the attachment of fungus hyphæ to the living grass-roots needs explanation, and it must also be allowed that at present we have no satisfactory theory to account for the nutrition of these rampant mycelia. But this is not the place to do more than point out how interesting the subject is, and how promising a field for further research it offers.

NOTES.

MR. W. BATESON, Fellow of St. John's College, Cambridge, who has just returned from a zoological expedition to Central Asia, and is well known for his researches on *Balanoglossus*, has been awarded the Balfour Memorial Studentship in Animal Morphology.

THE second meeting of the newly-formed Anatomical Society of Great Britain and Ireland will be held on Tuesday, November 22, at University College, Gower Street, at 5 p.m. The following papers will be read:—Prof. Sir William Turner, F.R.S., (1) "Variations in the Hippocampus Major and Eminentia Collateralis," by Robert Howden, and (2) "A Metallic Body in the Spinal Canal," by David Hepburn; (3) "Minute Anatomy of Clarke's Column in Spinal Cord of Man, the Monkey, and the Dog," by Dr. Mott; (4) "The Arteries at the Base of the Brain," by Prof. Bertram C. A. Windle; (5) "Note on the Functions of the Sinuses of Valsalva and Auricular Appendices, with some Remarks on the Mechanism of the Heart and Pulse," by Mayo Collier. A number of interesting exhibits are also announced.

ON Tuesday evening the second part of an important paper upon the causes of accidents in mines and the development of measures and applications for combating or avoiding them was read by Sir Frederick Abel at the Institution of Civil Engineers. The first part of the paper was read in May last, at the close of the session. Sir Frederick's ideas will be discussed at the meeting of the Institution next Tuesday.