OBSERVATIONS ON THE LUMINESCENCE IN FUNGI, I, INCLUDING A CRITICAL REVIEW OF THE SPECIES MENTIONED AS LUMINESCENT IN LITERATURE

by

E. C. WASSINK [1])

(Utrecht - Delft Biophysical Research Group, under the Direction of A. J. Kluyver, Delft, and of J. M. W. Milatz, Utrecht).

With Tab. I and II.

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§ 1. INTRODUCTION.

Since 1935 the Utrecht - Delft Biophysical Research Group has devoted several studies to the problem of light emission in luminous bacteria (*cf.*, *e. g.* [1 - 8]). Various reasons had led to the special choice of these organisms for the study of the phenomenon of bioluminescence, one of the chief considerations being that they can readily be cultivated under standard laboratory conditions, in which they are preferent over most other types of luminous organisms.

In 1940, we incidentally were brought into contact with the luminescence of fungi (*cf.* § 2). Since a general analysis of bioluminescence will have to consider luminescent organisms other than bacteria as well, it was deemed useful to collect if possible additional experiences with fungi. Therefore, the present writer has spent some time on the cultivation of luminous fungi, and on some biological problems concerned with the luminescence of fungi.

In the present paper a survey is given of a preliminary study carried out in this field. We started with attempts to isolate the organisms responsible for luminescence of wood (§ 2). In all cases examined so far, a luminous fungus was found to be the cause of the luminescence.

Besides this, some attention was given to the occasional luminescence of decaying leaves, which subject will be discussed in § 3.

We then attempted to survey the occurrence of luminescence in fungi with a view to collect cultures of luminous species and to select those which might prove to possess a relatively strong luminescent power, and thus might be especially suitable for physiological work. It soon appeared that only a rather limited number of

1) Present address:
Laboratorium voor Plantenphysiologisch Onderzoek der Landbouwhogeschool, Wageningen, Netherlands.

species has been recorded as luminescent in literature. In order to obtain a clear survey of the actual distribution of luminescence in the fungi, a critical examination of the avaibable data was necessary, since on closer consideration many observations appeared to have been uncritically interpreted. Moreover, according to outstanding mycologists, a number of luminescent fungi, described as "new species", will have to be incorporated into earlier described species. A rather comprehensive discussion of these matters in combination with related personal observations has led to a new critical list of luminous fungi, as will be expounded in § 4.

Meanwhile, a number of species indicated as luminescent had been obtained in pure culture. As a rule, species of common occurrence in the Netherlands were cultivated from spores of fruit bodies collected in nature. I am indebted especially to Mr. E. T. NANNENGA, and to Dr. A. J. P. OORT, for their aid with the determinations, and also for the supply of material. From some exotic species pure cultures could be procured from the "Centraalbureau voor Schimmelcultures", at Baarn. Thanks to the kind cooperation of the director, Prof. Joha. WESTERDIJK, additional observations and informations were obtained. Chiefly because of the restrictions owing to the war, we have not yet been able to obtain cultures of all fungi which might be of interest from the viewpoint of luminescence. As far as our own observations have a bearing upon the distribution of luminescence in the fungi they will be mentioned along with the discussion in § 4. In § 5 we give an enumeration of the species we have got in culture so far, and we present some general observations concerning their luminescence. Based on these observations a few species were selected which seemed especially suitable for physiological work. With these species some preliminary investigations were made, in collaboration with Miss A. VAN DER BURG. These studies include the quantitative determination of the emission spectra, and some physiological experiments. The results will be communicated in a forthcoming paper.

§ 2. LUMINESCENT WOOD.

In June 1940, the following communication occurred in a newspaper. During a heavy thunderstorm in the evening, the lightning had struck the garden of an inhabitant of Krommenie, near Zaandam, Mr. M. SCHOTS, who, inspecting the damage done, had found nothing particular except that the stump of a dead shrub emitted a distinct and relatively intense light, a phenomenon which was brought into connection with the striking of the thunder. Since this explanation was not very likely, the light more probably resul-

ting from an organism present in the stump, and the appreciable intensity of the light might render a further investigation promising, a letter was written to Mr. SCHOTS, to ask for some pieces of the luminous wood. Mr. SCHOTS was so kind to send us a few samples, which, however, on receipt were only faintly luminescent. After splitting of the wood and preserving it in a moist atmosphere at about 23°, the luminescence increased again. Inoculations from the luminescent spots were made upon cherry-extract agar, luminescent pieces of wood taken from the interior of the small luminescent blocs being laid upon the agar. Initially, chiefly yeasts developed; some isolations, however, gave rise to the formation of a — still contaminated — luminescent mycelium. From the centre of the mycelium rhizomorphs grew out, from which the non-contaminated tips could be transferred to fresh cherry-agar in tubes. By its way of growing, especially by the formation of rhizomorphs, the fungus could be identified, at least with a high degree of probability, with *Armillaria mellea*, which thus may have caused the remarkable phenomenon in Mr. SCHOTS' garden.

Since that time, I have tried to obtain more pieces of luminescent wood and tried to cultivate the organism responsible for the luminescence. Various colleagues and friends [1]) were so kind to furnish pieces of luminescent wood, belonging to various trees, so that specimens originating from various places in the Netherlands, so from Apeldoorn, Baarn, Delft, Maarn, Utrecht, Wageningen, Warnsveld, and others, could be studied. Up to the end of 1944 isolations from ten pieces of luminescent wood have been made. In all cases *Armillaria mellea* — at least cultures which in all respects were similar to those obtained from spores or pieces of the pileus of *Armillaria mellea* — could be isolated from the luminescent wood. So we may well conclude that *Armillaria mellea* is by far the most common, if not the only cause of the luminescence of wood in the Netherlands. This is not very surprising in view of the high frequency of this wood-destroying fungus in all types of woods in this country, especially on poor, sandy, soils. In most cases the wood obtained was slightly rotten, whilst the centre still was solid; mostly the luminescence was still apparent by receipt or it revived in a moist atmosphere. In a few cases the luminescence was no more to be observed. Contrary to the first case, in which contaminations had caused considerable trouble (*cf.* above), in the following cases the isolation of *Ar-*

[1]) Among others the names of Miss Dr. SPIERENBURG, Miss Dr. KONING, Mr. FLORSCHÜTZ, Dr. v. ZINDEREN BAKKER, Mr. HOGEWEG, Mr. STEGEMAN, †Mr. E. J. WASSINK, Dr. MEEUSE may be mentioned in this connection.

millaria mellea succeeded very easily when I had learned not to take beautifully luminescent parts of the wood but solid pieces from the not yet obviously invaded part of the bloc, directly under the apparently decayed zone. The decayed parts were removed with a flamed knife; then, small rectangular blocs were cutted from the underlying hard wood. With a needle, these blocks were brought separately into culture tubes with an oblique layer of cherry-agar. The isolation directly into tubes appeared preferable over the use of PETRI-dishes, more commonly used for primary isolations. The tubes afford less space and condiserably less nutrient material, and offer less chance for contamination which was a special advantage in view of the slow growth of the Basidiomycetes.

Once a dead fir-tree was found, which showed a beautifully luminescent white mycelium between the bark and the wood, adhering to the inner side of the bark. A large piece of bark was removed, transported as aseptically as possible, and quadrangular pieces of the mycelium layer transferred to cherry-agar. Also in this case typical cultures of *Armillaria mellea* resulted.

It may be deemed superfluous to give a detailed description of the pure cultures of *Armillaria mellea*. Some remarks may be made. On cherry-agar (extract of 1 kg. ripe cherries in 1 L. water, diluted 1 : 2, with 2% agar) they grow well, but still much better on bread-agar (10% dried and crushed ordinary wheat bread, 1,8% agar). So far, I have not tried other media. Contrary to what is found in many other luminescent fungi, the luminescence of the *Armillaria mellea*-cultures is confined to a number of separate spots, corresponding with the growing white parts of the mycelium: its borders and the ends of the rhizomorphs. A continuous, white, luminescent mycelium develops in many cases between the glass and the somewhat dried agar.

In his well-known study, MOLISCH (9) has given a survey of previous observations on the luminescence of wood, and he has expressed as his opinion that in central Europe in most cases the luminescence of wood is due to *Armillaria mellea*. It is very probable that MOLISCH has isolated pure cultures of *A. mellea* from wood, though he only describes the cultivation of the fungus from spores.

In some cases MOLISCH isolated another luminous fungus from wood, which did not form sporophores, and so far, has never been identified; it is called "mycelium X" by MOLISCH. According to BOTHE (10), Mycelium X may belong to a *Mycena*.

COBLENZ and HUGHES (11) mention *Armillaria mellea* as the luminous fungus of decaying oak wood, and, according to BULLER (12) there can be no doubt that in Europe and North America the mycelium of the exceedingly common funtus *Armillaria mellea* is the chief cause of the production of luminous wood. Furthermore, MOLISCH (19) reports the occurrence of luminescent wood with *Armillaria mellea* in Japan.

Thus, we may well conclude that at least in the moderately temperated zone of the northern hemisphere *Armillaria mellea* is by far the most common cause of the luminescence of decaying wood.

On the contrary, in the older literature we find the opinion that various fungi may cause luminescence of wood. As such, *e.g.* LUDWIG (13) has quoted at the side of *Armillaria mellea* especially *Xylaria Hypoxylon*, *Trametes Pini* (less certain) and an unnamed rhizomorph-forming fungus, the „von EIDAM entdeckte Urheber der Blutfäule des Eschenahorns. . . ." (*l.c.* p. 529). MOLISCH tried to verify this statement (14, 9*a*) as far as *Xylaria Hypoxylon* and *Trametes Pini* are concerned, but he could discover neither rhizomorph-formation nor luminescence in pure cultures of these fungi. It must be admitted that the occurrence of sporophores, rhizomorphs, and luminescence in the same piece of wood is no sufficient guarantee that they are manifestations of the same fungus. It doesn't seem at all excluded that especially in the cases that rhizomorphs were found, *Armillaria mellea* was the actual cause of luminescence, notwithstanding the fact that sporophores of other fungi were present on the wood.

On the other hand, in later years we have got acquainted with the fact that in some species of fungi luminous and non-luminous strains exist at each other's side, sometimes differing in geographical distribution. A more detailed discussion of the various observations on fungus-luminescence is given in § 4 of the present paper.

Various investigators have drawn attention to the remarkable fact that in the fruit-body of *Armillaria mellea* as a rule no luminescence can be observed. In a few cases BULLER (12) noticed a weak light in the central tissue of the basal part of the stipe. The spores neither are luminescent; with spores, collected from a fruit body and brought in ranges upon cherry-agar at 24. 9. '40, and kept at about 23° C., germination was visible with the naked eye at 2. 10. '40, formation of rhizomorphs and luminescence were seen at 7. 10. '40. However, in order to denote the very first occurrence of luminescence, new observations must be made.

It is of considerable interest to know what conditions are responsible for the absence of luminescence in the fruit-body. So far this has never been investigated. We have observed that isolations originating from tissue of the pileus yield cultures which are quite similar to those obtained from luminescent wood or from spores, and exhibit luminescence as well. According to REITSMA (13) the formation of rhizomorphs and the luminescence in dependence upon cultural conditions, show parallelism.

§ 3. THE LUMINESCENCE OF DECAYING LEAVES.

This is, besides the occurrence of luminescent wood, the most important manifestation of fungus luminescence in nature. It was first observed by TULASNE in France in 1848, while MOLISCH (9) and BULLER (12) have devoted detailed considerations to it. It occurs chiefly in forests of broad-leaved trees, especially beech and oak,

where the leaves remain lying on the ground for more than one season, and thus form a thick layer. MOLISCH has remarked that under these conditions a considerable fraction af the leaves may show luminescence. On beech and oak leaves the luminescent parts in most cases are pale-coloured and thus sharply distinct from the remainder of the leaf. So far no one has succeeded in isolating the organism responsible for the luminescence, but it is generally believed that it is a fungus. BOTHE (10), the discoverer of luminescence in many common *Mycena* species that normally occur on leaves, ascribes to these fungi the formation of the luminescent leaf spots. BOTHE has cultivated various species of *Mycena* on sterilized leaves and obtained luminous mycelia. However, he states that the development of the mycelia was otherwise, and much more abundant than in the luminescent leaves, in which no appreciable development of mycelium is recognizible. In view of these results I am of opinion that probably the luminescent leaves are due to a special small species of *Mycena*, the mycelium of which is restricted to the luminescent spot. I once found an oak-leaf with a luminescent spot, bearing a number of tiny sporophores which apparently belonged to a small *Mycena* (*cf.* Pl. I, fig. 1). The determination conducted to *M. capillaris*, also the type of the cystides and the measureas of the spores agreed with those given by OORT (16). However, the sporophores were attached upon the leaf with a small disc, which is not found in *M. capillaris*. The specimen pictured in Pl. I, fig. 1, was collected at 30. 11. 1941, in a wood near Utrecht. Spores were collected upon cherry-agar, transferred to tubes with cherry-agar, and incubated at 23°. Unfortunately the spores did not germinate. Still later in the same winter sporophores of *M. capillaris* were found abundantly at another locality (at Warnsveld, near Zutphen) in which luminescent leaves also were frequent. In that case, however, a connection of the sporophores with luminescent spots could not be detected. This time spore-cultures on cherry-agar were obtained at room temperature, but not at 23°. Thus, the failure of the above mentioned trial may be due to the circumstance that the temperature was too high. The growth of the mycelia obtained is extremely slow at room temperature. They are charaterized by growing for a great part within the agar, which is also found in *Mycena epipterygoides*. On bread-agar *M. capillaris* grows better than on cherry-agar. So far the cultures were found to be non-luminescent. It thus seems probable that the luminescent leaf-spots are not due to *M. capillaris* but to another, probably closely related species. In our opinion there can be no doubt that indeed the small sporophores pictured in Pl. I, fig. 1 belonged to the fungus that was responsible for the luminescenı

spot. Later on it occurred to us that possibly this fungus might be an *Omphalia*, and not a *Mycena*, but as the material is no longer present we can not verify this supposition. We also made some attempts to isolate the fungus from leaves, but without success so far.

Luminescent leaf spots are found on decaying leaves both of beech and oak. Their general appearance is exactly the same in these cases, and it seems probable that they are due to the same fungus. According to KÜHNER (17) *Mycena capillaris* grows on beech-leaves, the related *M. smithiana* on oak leaves. *Mycena stylobates*, which was found luminescent by BOTHE, occurs on beech, oak, and many other substrates (KÜHNER, *l. c.*), but appears earlier in the season and usually seems to be larger. It seems probable that the fungus of the luminescent leaf spots doesn't regularly develop sporophores. Luminescent spots are very frequent on decaying leaves, but only once we found sporophores on them. The rare occurrence of these sporophores constitutes a considerable difficulty for the attemps to ascertain whether the luminous leaf spots are always due to the same species or whether various species may give rise to this phenomenon. For, the only way to settle this question conclusively seems to be found in a reliable identification of such sporophores, and the cultivation of luminous mycelia from their spores.

It is remarkable that luminescent leaves are found in the tropics as well as in the moderately temperated regions (*cf.* BULLER [12]). It may not be regarded as certain that under the various conditions they are caused by the same species of fungus. BULLER (18) mentions that luminescent leaves so far have been observed in France (TULASNE) Germany, Java (MOLISCH), England, Canada, U.S.A. (BULLER), Bengal (BOSE). Later, MOLISCH has reported their finding in Japan (19). As far as we know the occurrence in Holland has never been recorded in literature, but no doubt the observation has been made by various mycologists; luminescent leaves were demonstrated about 1934 to the author by Mr. E. T. NANNENGA, who, following the indications of MOLISCH, found them near Utrecht.

§ 4. THE DISTRIBUTION OF LUMINESCENCE IN THE FUNGI.

> ". . . . . the true investigator who wishes to learn the truth about a subject, has his work more than half finished when some one publishes a good index of the subject."
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> C.G. LLOYD, Myc. notes No. 29, 1908, p. 366.

Various authors have given enumerations of fungi which they considered to be luminous. Some more important specimens of such lists have been collected in Table I.

TABLE I

Some published lists of luminous fungi

M. J. BERKELEY, 1857, ([20], p. 265),
without giving a distinct enumeration makes mention of the following examples of fungus luminescence.
Ag. olearius (S. Europe), *Ag. Gardneri*, BERK. (Brazil), *Ag. lampas*, "and some others" (Australia), "in Amboyna, by RUMPH.," "dead leaves" (TULASNE), *Rhizomorphae* (*e.g.* in mines).

L. CRIÉ, 1882 (21).
Agaricus olearius DC. (southern Europe), *Ag. igneus* RUMPH. (Amboina) *Ag. noctilucens* LÉV. (Manila), *Ag. Gardneri* BERK. (Brazil), *Ag. lampas* BERK. "et plusieurs formes voisines d'Australie", *Auricularia phosphorea* SOW., *Polyporus citrinus* PERS., *Rhizomorpha fragilis:* "Appareil végétatif de l'*Ag. annularius* et de plusieurs autres champignons", *Rhizomorpha setiformis* ROTH., *Xylaria polymorpha* GREV.

W. PHILLIPS, 1888 (22).
Evidently luminescent: *Ag. olearius* D.C. (Europe), *Ag. igneus* RUMPH. (Amboina), *Ag. noctilucens* LÉV. (Manila), *Ag. Gardneri* BERK. (Brazil), *Ag. lampas* BERK. (Australia), *Ag. Emerici* BERK. (Andamanes), *Polyporus annosus* FR. (Europe), *P. sulphureus* FR. (Europe), *Didymium sp.?* (Jamaica), Doubtfully luminescent: *Ag. fascicularis* HUDS., *Corticium coeruleum* SCHRAD. [1]), *C. lacteum* FR. [00]), *Cladosporium umbrinum* L. [000]) (all Europe). [0]) = *Auricularia phosphorea* SOW., [00]) = *Himantia candida*, [000]) a parasitic lower fungus to the presence of which FRIES erroniously ascribed the luminosity of *Ag. olearius.*

G. v. LAGERHEIM, 1889 (23).
Tropics: *Pleurotus noctilucens* LÉV., *Ag. igneus* RUMPH., *A. Emerici* BERK. (Andamanes). *Pleurotus nidiformis* BERK. (Australia), *P. Lampas* BERK. (Australia), *P. Prometheus* B. & C. (Hongkong), *P. candescens* MÜLL. et B. (Australia), *P. phosphoreus* BERK. (Tasmania), *P. Gardneri* BERK. (Australia, Brazil), *P. illuminans* M. & B. (Australia), *Didymium sp.* (Jamaica), *Polyporus mycenoides* PATOUILLARD (New Caledonia).
Europe: *Armillaria mellea* VAHL., *Ag. fascicularis* HUDS. *A. socialis* FR. (?), *A. acerbus* FR. (?), *Collybia tuberosa* BULL., *Collybia cirrhata* SCHUM., *Pleurotus olearius* D.C. *Naucoria semiorbicularis* BULL., *Panus stipticus* FR., *Heterobasidion annosum* BREF., *Trametes Pini* FR., *Polyporus sulphureus* FR., *Corticium coeruleum* SCHRAD., *C. lacteum* FR., *Xylaria hypoxylon* GREV, "&c".
North-America: *Clitocybe illudens* SCHW., *Pleurotus facifer* B. & C. Described as new luminescent species: *Polyporus noctilucens* nov. spec. (Angola [W. Africa]).

ZOPF (1890) (24) (with references regarding observations of luminescence at nearly each species quoted).
Ag. (*Armillaria*) *melleus* VAHL (on wood and fruittrees), *Ag.* (*Pleurotus*) *olearius* DEC. (on olive and other trees, S, and S.E. Europe). *Ag.* (*Pleur.*) *phosphorus* BERK. (on roots of trees, Australia), *Ag.* (*Pleur.*) *Gardneri* BERK. (Australia, Brazil), *Ag. illuminans* MÜLL. et BERK. (on dead wood,

Australia), AG. (*Pleur.*) *facifer* B. et C. (N. America), *Ag.* (*Pleur.*) *Lampas* BERK (on plant stalks, Australia), *Ag.* (*Pleur.*) *noctilucens* LÉV. (on stems of trees, Manila), *Ag.* (*Pleur.*) *Prometheus* B. et C. (on dead wood, Hongkong), *Ag.* (*Pleur.*) *candescens* M.et B. (on dead wood, Australia), *Ag.* (*Pleur.*) *igneus* RUMPH. (Amboina), *Ag.* (*Collybia*) *longipes* BULL. (Germany), *Ag.* (*Coll.*) *tuberosus* BULL. (Germany), *Ag. Coll. cirrhatus* PERS. (Germany), *Polyporus Emerici* BERK. (Australia).
- *Xylaria Hypoxylon*, *X. polymorpha.*

LUDWIG (1892) (13) mentions the following species as luminescent in the text of his work:
Ag. (*Pleurotus*) *olearius* D.C., (S. Europe), *Ag. Gardneri* BERK. (Brazil), *Ag. igneus* RUMPH (Amboina), *Ag. noctilucens* LÉV. (Manila), *Ag. lampas* BERK. (indicated without place), *Ag. Emerici* BERK. (Andamanes), *Ag. candescens* MÜLL. (Australia), *Ag.* (*Clitocybe*) *illudens*, *Polyporus noctilucens* LAGERH. (Angola), *Ileodictyon cerebrum*, *Kalchbrennera coralloides*, *Agaricus socialis* FR., *Ag. acerbus* FR. (luminescent, due to luminous bacteria, according to PATOUILLARD).
Only mycelia luminous: especially species forming rhizomorphs or sklerotia, *e.g.*, *Ag. melleus* Fl. Dan., *Xylaria Hypoxylon* PERS., *Trametes Pini* FR.?, an unknown fungus causing "Blutfäule des Eschenahorns" (EIDAM), *Ag.* (*Collybia*) *tuberosus* BULL., *Ag.* (*Coll.*) *cirrhatus* SCHUM., *Ag.* (*Coll.*) *longipes* SCOP.
Luminescence not quite certain: *Polyporus sulfurius*, *Heterobasidium annosum*, *Corticium coeruleum* (SCHRAD.) FR. [0]), *Polyporus citrinus* (= *caudicinus*)[0]), *Xylaria polymorpha*[0]).
[0]) mentioned as luminous by CRIÉ.

P. HENNINGS (1893, 1903) (25, 25a).
Pleurotus olearius D.C. (S. Europe), *Collybia cirrhata* PERS., *C. tuberosa* BULL. (both Germany), *Pleurotus illuminans* M. et B., *Pl. Lampas* BERK., *Pl. nidiformis* BERK., *Pl. candescens* M. et B., *Pl. phosphorus* BERK. (all in Australia), *Pl. noctilucens* LÉV. (Manilla), *Pl. Prometheus* BERK. (Hongkong), *Omphalia Martensii* P. HENN. (Borneo), *Marasmius spec.*? (New Guinea, taxonomic data uncertain, luminescence reported by KÄRNBACH). (Added 1903): *Mycena illuminans* P. HENN. (Java), *Locellina illuminans* P. HENN. (Celebes), *L. noctilucens* P. HENN. (New Pommern), *Pleurotus Gardneri* BERK. (Brazil), *Clitocybe illudens* SCHWEIN. (N. America), *Polyporus noctilucens* LAGERH. (Angola).

R. DUBOIS (1898) (26).
Ag. olearius (France), *Ag. phosphoreus*, *candescens*, *lampas*, *illuminans* (Australia), *Ag. Gardneri* (Australia, Brazil), *Ag. Prometheus* (Hong-Kong), "un *Polypore* jaune"(Nw. Caledonia)), *Ag. igneus*, *Ag. tuberosus* (luminous sclerotia). "Les rhizomorphes photogènes les plus connus sont fournis par les *Agaricus melleus*, *Trametes pini*, *Polyporus igniarius*, *Lenzites betulina.*"
[1]) Obviously, *P. mycenoides* PAT..

Mc. ALPINE (1900) (27) (chiefly according to ZOPF, with the distribution of those found in Australia added).
Armillaria mellea VAHL (Europe, America, Australia; very common), *Pleurotus candescens* M. (Victoria, N.S. Wales, on dead wood), *P. facifer*

B. & C. (U.S.A.), *P. Gardneri* BERK. (Queensland, on half rotten fronds of Palm; Brazil), *P. igneus* RUMPH. (Amboyna), *P. illuminans* M. (N.S. Wales, Victoria, Queensland; on dead wood), *P. lampas* BERK. (Victoria, W. Australia, Tasmania; on languid but not dead stems of *Grevillea*), *P. nidiformis* BERK. (W. Australia; on the ground), *P. noctilucens* LÉV. (Manilla; on tree stems), *P. olearius* D.C. (S. and S.E. Europe; among roots of olive trees), *P. phosphoreus* BERK. (Tasmania, on roots of trees), *P. prometheus* B. &. C. (Hong Kong; on dead wood), *Collybia cirrhata* PERS. (Germany, Britain), *C. longipes* BULL. (Germany, Britain, Victoria, Queensland), *C. tuberosa* BULL. (Germany, Britain, Queensland), *Fomes annosus* FR. (Europe, America, Queensland), *Polyporus grammocephalus*, var. *emerici* (Queensland, on trunks; N. Guinea), *P. sulphureus* FR. (Europe, Asia, Africa, America, Queensland, Tasmania), *Corticium coeruleum* FR. (N.S. Wales, Queensland, Britain; said to be phosphorescent), *Xylaria hypoxylon* GREV. (Europe, Australia; common), *X. polymorpha* GREV. (Europe, Australia; common).

MOLISCH (1912) (9a).
Agaricus melleus VAHL (Europe) = *Armillaria mellea* QUÉL., *Ag. olearius* D.C. (S. Europe), *Ag. Gardneri* BERK. (Brazil), *Ag. igneus* RUMPH (Amboina), *Ag. noctilucens* LÉV. (Manila), *Ag. phosphorus* BERK. (Australia), *Ag. Prometheus* BERK. et C.N. (Hongkong), *Ag. lampas* BERK. (Australia), *Ag. illuminans* BERK. (Australia), *Ag. Ernerici* (read *Ag. Emerici*!) BERK. (Andamanes), *Ag. candescens* MÜLL. (Australia), *Ag. socialis* FR. = *Collybia tabescens* FR. (S. Europe), *Ag. acerbus* FR. = *Trichloma acerbum* BULL. (Europe), *Pleurotus candescens* MÜLL. (Australia) (obviously the same as the one quoted as *Ag. candescens*, *cf.* above!), *Pleurotus nidiformis*[0]) (Australia), *Panus incandescens*[0]) (Australia), *Mycena illuminans* HENN. (Java), *Clitocybe illudens* SCHWEIN. (N. America), *Polyporus noctilucens*[0]) (Angola), *Kalchbrennera coralloides* [0]) = *K. Tuckii* BERK. (Africa), *Omphalia Martensii* HENN. (Borneo), *Locellina illuminans* HENN. (Celebes), *L. noctilucens* HENN. (New Pommern), *Ileodictyon cibarium* TUL. (New Zealand), *Mycelium X* MOLISCH (Bohemen).
Further observations require: *Polyporus citrinus* (= *caudicinus*) (SCHAEFF.) SCHRÖT., *Polyporus igniarius*[0]), *Heterobasidium annosum*[0]), *Ag.* (*Collybia*) *longipes* SCOP., *Ag.* (*Coll.*) *tuberosus* BULL., *Corticium coeruleum* (SCHRAD.) FR. = *Auricularia phosphorea* SCH., *Panus stipticus* FR.
Non-luminescent: *Xylaria Hypoxylon* PERS., *X. Cookei*[0]), *Trametes pini* FR., *Polyporus sulfureus* FR., *Collybia cirrhata* PERS.
[0]) no authors' names given).

MURRILL (1915) (28). North American species reported as luminescent, either in the mycelium or the fruit body.
Armillaria mellea (VAHL) QUÉL., *Ceriomyces crassus* BATT., *Clitocybe illudens* (SCHW.) SACC., *Collybia longipes* (BULL.) QUÉL., *C. tuberosa* (BULL.) QUÉL.. *Corticium coeruleum* (SCHRAD.) FR., *Fomes annosus* (FR.) COOKE, *Laetiporus speciosus* (BATT.) MURRILL, *Panus stipticus* (BULL.) FR., *Polyporus caudicinus* (SCOP.) MURRILL, *Porodaedalea Pini* (THORE) MURRILL, *Xylaria Hypoxylon* PERS.

BULLER (1924) (12) (f = luminescent fruitbody, m = luminescent mycelium).
Clitocybe illudens SCHW. (f., m, N. America), *Panus incandescens* B. & BR. (f., Australia), *Panus stipticus* FR., physiol. form *luminescens* (f, m, N. America), *Pleurotus candescens* M. et B. (f, Victoria, N.S. Wales), *P.*

facifer B. & C. (f, Pennsylvania, U.S.A.), *P. Gardneri* BERK. (f, Brazil), *P. igneus* RUMPH. (f, Amboyna), *P. illuminans* M. et B. (f, Australia), *P. japonicus* KAWAM. (f, Japan) *P.Lampas* BERK. (f, Swan River,Australia) *P. nidiformis* BERK. (f, Swan River, Australia), *P. noctilucens* (LÉV. f, Manila), *P. olearius* D. C. (f, S. Europe), *P. phosphoreus* BERK. (f, Tasmania, Australia), *P. Prometheus* B. et C. (f., Hong Kong), *Armillaria mellea* VAHL (m, rhizomorphs, Europe, N. America), *Collybia tuberosa* BULL. (germin. sclerot., Europe, N. America), *C. cirrhata* PERS. (germin. sclerot., Europe, N. America).

BULLER mentions as doubtfully luminous: *Fomes annosus, Polyporus sulphureus, P. citrinus* (= *P. caudicinus*), *Trametes pini, Corticium coeruleum, Collybia longipes.*

KLEIN (1928) (29) (names and regions of distribution checked by E. JANCHEN and H. LOHWAG).

Polyporus noctilucens LAGERH. (Angola), *Panus incandescens* B. et BR. (Australia), *Locellina illuminans* P. HENN. (*Celebes*), *L. noctilucens* P. HENN. (New Pommern), *Pleurotus candescens* MÜLL. et BERK. (Australia), *P. facifer* B. et C. (Pennsylvania) *P. Gardneri* BERK. (Brazil), *P. illuminans* MÜLL. et BERK. (Australia), *P. japonicus* KAWAM. (Japan), *P. lampas* BERK. (Australia), P. *lux* HARIOT (Tahiti, Borabora), *P. nidiformis* BERK. (Australia), *P. noctilucens* LÉV. (Australia), *P. olearius* (D.C.) FR. (S. - Middle Europe), *P. phosphorus* BERK. (Australia), *P. Prometheus* B. & C. (Hong Kong), *Agaricus Emerici* BERK. (Andamanes), *Ag. igneus* (RUMPH.) P. HENN. (Amboina), *Omphalia Martensii* P. HENN. (Borneo), *Mycena illuminans* P. HENN. (Java), *Collybia tabescens* (SCOP.) FR. (S. Europe), *Clitocybe illudens* (SCHWEIN.) FR. (N. America,) *Trichcloma acerbum* (BULL.) FR. (Europe), *Armillaria mellea* (VAHL) FR. (Europe), *Ileodictyon cibarium* TUL. (Australia, New Zealand, S. America), *Kalchbrennera corallocephala* (WELW. et CURR.) ED. FISCH. (Africa), *Mycelium X* MOLISCH (Europe). Indicated as luminous, but in want of renewed investigation: *Fomes annosus* FR. (Europe, N. America), *F. igniarius* (L.) FR. (Europe, Asia, N.-, S. America, Australia), *Polyporus sulphureus* (BULL.) FR. (Europe, Asia, N. America, Cuba, Tasmania), *Panus stipticus* (BULL.) FR. (Europe, N. America), *Collybia longipes* (BULL.) FR. (Europe), *C. tuberosa* (BULL.) FR. (Europe).

BOTHE (1931) (10). Luminous fungi occurring in Germany.

On wood: *Armillaria mellea* VAHL, *Mycel. X* MOLISCH, *Mycena tintinnabulum* FR., *M. polygramma* BULL., *Clitocybe olearia* D.C.

On leaves or needles: *Mycena galopus* PERS., *M. sanguinolenta* ALB. et SCHWEIN., *M. epipterygia* SCOP., *M. dilatata* FR., *M. stylobates* PERS., *M. zephira* FR., *M. pura* (some fruitbodies with luminous gills), *M. parabolica* (from C.B.S., Baarn).

BULLER (1934) (18), mentions as luminescent, in addition to his list of 1924: *Omphalia flavida* MAUBL. et RANGEL (Trinidad, Porto Rico), *Omph. Martensii* HENN. (Borneo), *Mycena polygramma* BULL., *M. tintinnabulum* FR., *M. dilatata* FR., *M. epipterygia* SCOP., *M. galopus* PERS., *M. sanguinolenta* A. et S., *M. stylobates* PERS., *M. zephira* FR. (these species in Germany, according to BOTHE), *M. pura* (parts of gills luminescent according to BOTHE).

A perusal of Table I will show that the various lists have a considerable number of species in common. Some of the lists appear to be more critical than other ones, but practically none of them seems to be founded on a thorough evaluation of the original observations concerning each of the various species quoted. Indeed, such an evaluation presents considerable difficulties, since in many cases the belief that a species is phosphorescent appears to originate from an incidental note in an often difficultly accessible periodical.

On the other hand, an approach to such an evaluation seems of importance, even if the ultimate aim of tracing the informations back to their very source cannot be reached for all species. Too many species have been carried through the lists of "luminescent fungi" for too long a time without practically any discussion regarding the value of the quoted names having been attempted either from the viewpoint of bioluminescence or from that of fungus taxonomy. Nevertheless it seems clear that in order to bring the study of fungus luminescence on a scientific base, it will be necessary to start with a critical examination of the so far rather incidentally gathered knowledge. We cannot go on upon communications that one or the other fungus has been "believed" to be luminescent by a single observer 60 or 70 years ago. A study of the literature reveals that many of the informations are not much better founded. It will be evident that it is very difficult to deny definitely the reliability of communications regarding the luminosity of a certain fungus. Such negations have been attempted on various occasions by serious investigators who were unable to confirm earlier statements. But, especially in the later years we have learned that from certain fungi luminous and non-luminous forms may exist side by side, so that "negative" and "positive" statements as to luminescence may be equally true.

The only thing we can do to help to establish a starting point for a scientific discussion on the occurrence of luminescence in fungi is precisely to show the quality of the evidence on which the various statements rest, and to discuss the comments that may have been given on it by students of bioluminescence or fungus taxonomists.

A treatment of the mentioned type is attempted in the present section. It will be seen that a somewhat more close examination of the available data leads to rather considerable amendations also of the more recent enumerations of luminescent fungi.

The reader should be aware of the fact that the present writer is not a mycologist, so that, in questions of synonymic and nomenclature, he can only refer to the opinion of the mycologists. Nevertheless, for a correlative

discussion of the various data on fungus luminescence it seems indicated to make use of the knowledge mycologists independently gathered about the species concerned.

The outcome of our discussion will be summarized in Table III at the end of this section. Readers who want to have a glance only at the chief result of the discussion, can compare this Table with the lists of Table I. As a starting point we will take the list presented in Table II which has been composed from the enumerations of Table I.

TABLE II.

List of fungi quoted as luminous by various authors (compiled from Table I).

Agaricus (*Pleurotus, Clitocybe*) *olearius* D. C.
Ag. igneus RUMPH.
Ag. (*Pleurotus*) *noctilucens* LÉV.
Ag. (*Pleurotus*) *Gardneri* BERK.
Ag. (*Pleurotus*) *Lampas* BERK.
Ag. (*Pleurotus*) *Emerici* BERK.
Pleurotus nidiformis BERK.
P. Prometheus B. et C.
P. candescens M. et B.
P. phosphorus BERK.
P. illuminans M. et B.
P. facifer B. et C.
P. lux HARIOT
P. japonicus KAWAM.
Clitocybe illudens SCHW.
Ag. (*Armillaria*) *melleus* VAHL.
Collybia tabescens (SCOP.) FR.
C. cirrhata PERS.
C. tuberosa (BULL.) QUÉL.
Ag. (*C.*) *longipes* SCOP.
C. longipes (BULL.) FR.
Naucoria semiorbicularis FR.
Panus stipticus FR.
P. incandescens B. et BR.
Omphalia Martensii HENN.
O. flavida MAUBL. et RANGEL
Mycena illuminans HENN.
M. tintinnabulum FR.
M. polygramma BULL.
M. galopus PERS.
M. sanguinolenta ALB. et SCHWEIN.
M. epipterygia SCOP.
M. dilatata FR.
M. stylobates PERS.
M. zephira FR.
M. pura PERS.
M. parabolica FR.
Locellina illuminans HENN.
L. noctilucens HENN.
Ag. fascicularis HUDS.
Ag. (*Tricholoma*) *acerbus* FR.
Polyporus mycenoides PAT.
P. noctilucens LAGERH.
P. Emerici BERK. (*P. grammocephalus*, var. *Emerici* MC. ALPINE).
P. sulphureus FR.
P. caudicinus (SCOP.) MURRILL (= *P. citrinus*).
Laetiporus speciosus (BATT.) MURRILL
L. sulphureus MURR.
Polyporus (*Fomes, Heterobasidion*) *annosus* FR.
P. igniarius L.
Trametes Pini FR.
Lenzites betulina L.
Ceriomyces crassus BATT.
Corticium coeruleum SCHRAD. (= *Auricularia phosphorea* SOW.)
C. lacteum FR. (= *Himantia candida*)
Kalchbrennera corallocephala (WELW. et CURR.) KALCHBR. (= *K. Tuckii* (KALCHBR. et MC. OWAN) BERK.
Ileodictyon cibarium TUL.
Xylaria Hypoxylon PERS.
X. polymorpha GREV.
Didymium spec.

We start our remarks with the genus *Pleurotus*, from which many species have been indicated as luminescent in the literature. So far, we were not able to obtain pure cultures of these various exotic

species. The Centraalbureau possessed of these only *P. olearius* D.C., which we obtained from it in pure culture. In the Centraalbureau a number of other species of *Pleurotus* are present, namely *P.columbinus* QUÉL., *cornucopioides* PERS., *corticatus* (FR.) QUÉL., *eryngii* D.C. (= *fuscus* (BATT.) BRES.), *euosmus* (BERK.) CKE., *fuscus* (BATT.) BRES. var. *ferulae* LANZI, *griseus* PK, *lignatilis* FR., *mitis* (PERS.) FR., *mutilus* PERS., *ostreatus* (JACQ.) FR., *palmatus* (BULL.) QUÉL., *Passeckerianus* PILÁT, *petaloides* FR. ex BULL., *sapidus* SCHULZ., *serotinus* (SCHRAD.) FR., *ulmarius* BULL., coming from various parts of the world. Professor WESTERDIJK was so kind to inform us that she and her collaborators could not observe luminescence in any of the cultures of these species.

It further seems of importance that according to more recent mycological works (30, 31, 32, 33) the number of luminescent species in the genus *Pleurotus* will have to be considerably restricted. Many species, especially a number of those BERKELEY described about a century ago upon the study of specimens supplied by tropical collectors, are now considered to be identical with the south-european *Pleurotus olearius* D.C., while, furthermore, the same is claimed for *Clitocybe illudens* SCHW., from North America.

To his description of *Pleurotus olearius* D.C., BRESADOLA (30) adds the following observations. "Specimina mecum communicata ex Australia sub nomine *Pleurotus Lampas*, *Pleurotus candescens* nil aliud erant quam *Pleurotus olearius*, cui adscribendum puto etiam *Pleurotus illuminans* MÜLLER et *Pleurotus phosphoreus* BERK. Etiam ex America Boreali specimina *Agarici illudentis* SCHW. habui, quae omnino cum *Pleuroto oleario* D.C. concordant; sporae etiam in speciminibus americanis 6-7 × 5—6 μ." Some years before, BRESADOLA (35) has remarked concerning *Pleurotus illuminans* BERK. et MÜLLER: "= *Pleurotus olearius* DE C. lamellis crassis quia ab insectis deformatis."[1])

KONRAD & MAUBLANC range the species *olearia* in the genus *Clitocybe* (*Cl. olearia* [FRIES, ex DE CANDOLLE] R. MAIRE). As synonyms these authors present a.o. *Agar. olearius* D.C., *Pleurotus olearius* GILLET, *Agaricus illudens* SCHWEINITZ (syn. Fung. Carol. sup. no. 604 (1822)) *Clitocybe illudens* SACCARDO, *Polymyces phosphoreus* BATTARA.

KILLERMAN (32) who, according to the introduction to his survey, may be regarded to adhere closely to BRESADOLA's conceptions,

[1]) "BRESADOLA. . . . . est un homme d'esprit large en ce qui concerne la démarcation des espèces et il fut parmi les premiers à démontrer la distribution étendue d'une même espêce."
(C. G. LLOYD, Myc. Notes No 35, 1910, p.462).

mentions as synonyms of *Pleurotus olearius* DEC. *P. phosphorus* BERK., *Clit. illudens* SCHW., *P. illuminans* MÜLL, and some other names given to Australian specimens ("usw." [*l. c.*]).

PILÁT (33) gives a.o. the following synonyms which are of interest for us: *Pleurotus olearius* (D.C.) FR., *Agaricus olearius* D.C. *Pleurotus phosphoreus* (BATT.) GILLET, *Clitocybe phosphorea* (BATT.) MAIRE, *Clitocybe illudens* SCHWEINITZ (Carol. no. 604)., *Pleurotus Lampas* BERK., *Pleurotus phosphoreus* BERK., *Pleurotus illuminans* MÜLL. et BERK., *Pleurotus facifer* BERK. et CURT., ?*Pleurotus candescens* MÜLL. et BERK., ?[1]) *Pleurotus Gardneri* BERK. PILÁT remarks: "Des tropiques encore d'autres espèces phosphorescentes ont été décrites, qui peut-être sont différentes. Ainsi par ex. *Pleurotus noctilucens* LÉVEILLÉ, décrit de Manilla, et *Pleurotus Prometheus* B. et C., décrit de Hong-Kong, ayant d'après la description un chapeau blanc".

BRESADOLA (30) gives *Agaricus illudens* SCHW., Car. n. 604 as a synonym of *Pleurotus olearius* D.C. This is the same quotation as given by SACCARDO (34) at the top of his description of *Clitocybe illudens* SCHW. It may be remarked by the way that a reference to the same species of SCHWEINITZ occurs once more in SACCARDO's Sylloge, namely under *Panus illudens* (SCHWEIN.) FR. (Nov. symb. Myc. p. 39, *Ag. illudens* SCHW. Carol. n. 604), whereas in his description of *Pleurotus facifer* B. et C., SACCARDO alludes to obviously the same species as *Pleurotus illudens*.

A very brief, but excellent discussion on the taxonomic place of *C. illudens* was given by LLOYD as early as 1899 (34a). Notwithstanding LLOYD himself considers *C. illudens* to be "a peculiarly American plant", he mentions that FARLOW compared it to *Pleurotus olearius*, "and infers that it may be a *Pleurotus*, with which genus it would not be far out of place". Moreover we learn from LLOYD's discussion that FRIES, from dried specimens sent by CURTIS, concluded that it was a *Panus*, and LLOYD also mentions that SACCARDO compiles the species both under *Panus* and *Clitocybe*.

As for the probably also identical North-American *Pleurotus facifer*, BERKELEY and CURTIS (69) remark in the original description: „A highly curious species with the habit of *A. illudens*", and also mention its phosphorescence, whereas many further elements of their diagnosis also suggest the close similarity of both fungi.

[1]) In the list of synonyms given at the top of PILÁT's description of *Pleurotus olearius* this ? is placed at the end of *Agaricus superbiens*, in stead of before *Pl. Gardneri*. However, in the list of synonyms at the end of the genus, it is placed at *Pl. Gardneri* (p. 184) and not at *Ag. superbiens*. This, and also the way of placing of the ? at *Pl. candescens* suggest that between *Ag. superbiens* and *Pl. Gardneri* ? and — have to be interchanged, and that indeed the ? belongs to *Pl. Gardneri*.

Drawing a preliminary conclusion from the survey given so far, we may consider it very probable that the specimens described under the following species-names actually belong to the species *Pleurotus olearius* (D.C.) FR.: *Clitocybe illudens* SCHW., *Pleurotus phosphorus* BERK., *Pleurotus Lampas* BERK., *Pleurotus illuminans* MÜLL. et BERK., *Pleurotus facifer* BERK. et CURT. — *Pleurotus candescens* MÜLL. et BERK. may be *Pl. olearius* D.C. too; concerning *Pl. Gardneri* BERK. this seems to be somewhat more doubtful. *Pleurotus noctilucens* LÉVEILLÉ, and *Pl. Prometheus* B. et C. are perhaps different from *Pl. olearius* D.C. (33).

A number of additional remarks concerning some of the mentioned species, and on some related ones, may follow. For species which below have not been mentioned especially, the reader may be referred to the Appendix to this Section (p. 195) in which diagnoses of interesting species, and some additional remarks, have been collected.

According to HENNINGS (26), ATKINSON was the first who observed the luminescence of *Clitocybe illudens*. ATKINSON described his observation only in a short note (38). The luminescent specimens were found in Watauga county, N.C., and determined as *Clitocybe illudens* SCHW., by A.P. MORGAN. The luminescence was practically confined to the hymenium; no luminescence was observed in the stipe or in the fleshy part of the pileus.

A few illustrations of *C. illudens* are reproduced in Figs 10 and 11, Plate I.

MC. ALPINE (27) gave a detailed description of the appearence and the luminescence of *P. candescens* v. M. & BERK. He lays stress on the variability of this fungus, the colour *e.g.* varying from yellow to brown in specimens of the same size. The spores are white, elliptical, $7^1/_2 - 9^1/_2 \times 4^1/_2 - 5^1/_2\ \mu$. The illustrations given by MC. ALPINE are reproduced in Fig. 12, Plate I; the general similarity of the appearance with that of *P. olearius* D.C. is obvious, and none of MC. ALPINE's indications seem to give rise to a serious objection against BRESADOLA's proposal to identify also this species with *P. olearius* D.C.

Pleurotus nidiformis BERK. has been founded by BERKELEY upon a very large phosphorescent fungus, collected by DRUMMOND at the Swan River in Australia.

In a letter to the editor of the London J. of Bot. (36) which has a bearing upon this species, DRUMMOND tells to have seen 6-7 years earlier luminescent agaric fungi, "belonging to that division which has the stem at one side of the pileus. They grow parasitically on the stumps of trees, and possess nothing remarkable in their appearance by day, but by night they emit a most curious light..... The first species in which I observed this property was about

2 inches across and was growing in clusters on the stump of a *Banksia* tree. . . . A few weeks ago, and not till then, I discovered another instance of the same kind. . . . . I was struck with the beauty of a large fungus, of the same character as the former, but measuring 16 inches across, and about a foot from the root to the extremity of the pileus. The specimen which I carried home weighed about 5 pounds, was very smooth, yellowish brown above, and dirty-white upon the gills: it gradually became thinner towards the outer edge of the pileus, where it was waved and sinuated . . . . . in the dark I observed the fungus giving out a most remarkable light, similar to what I described above. . . . . "

SACCARDO[1]) has added to the description of *P. nidiformis*: "Affinis *P. ostreato*", and from *P. Lampas*, BERKELEY says: "Allied to *Ag. nidiformis* BERK." *Pleurotus Lampas* was founded by BERKELEY also upon a specimen sent by DRUMMOND from the Swan River (*cf.* 37), growing in groups upon the stems of sickly but living plants of *Grevillea Drummondii*. BERKELEY remarks that the list of Agarics would have been much larger, had not the notes belonging to many species been lost, and the specimens themselves much corroded by insects. Considering these various data, it seems not unlikely that also *P. nidiformis* BERK. will turn out to be identical with *P. olearius* D.C., in any case it is closely allied to it, as ensues from BERKELEY's own remark concerning *P. Lampas*, which species, according to BRESADOLA and to PILÁT is the same as *P. olearius* D. C.

Another species worth further investigation in this respect is *Panus incandescens* B. et BR., described upon a specimen sent by BAILEY from Brisbane, Queensland. It has been pictured in F. Brisb. II, t.X, f. 8-10, but I have not seen this figure. According to MOLISCH (9), LAUTERER has first drawn attention to the luminescence of this species. SACCARDO (34) ranges it in the immediate neighbourhood of *P. illudens* (SCHWEIN). FR. in the section characterised by "Pileo irregulari, stipite excentrico". As we have seen, *P. illudens* (SCHWEIN.) FR. is obviously the same as *Clitocybe illudens* SCHWEIN., and must thus be considered to be identical with *Pleurotus olearius* D.C. The question arises whether perhaps also *Panus incandescens* B. et BR. will turn out to be the same as *Pleurotus olearius* D.C. According to LAUTERER it grows in clusters around trees (*cf.* 9a), its colour is denoted as whitish. This case and also that of *P. nidiformis* BERK. would require a careful examination of the type specimens from modern mycological viewpoints.

Pleurotus Gardneri was described by GARDNER himself as *P. phosphoreus* GARDNER (39). But, BERKELEY, in an additional note (39), remarks that, since the property of emitting phosphorescence

[1]) Owing to the missing of a few pages in the available copy of the Lond. J. of Bot. we were not able to consult BERKELEY's original description of *P. nidiformis*.

was known already from *P. olearius*, it might be more suitable to give another name, and proposed *P. Gardneri* BERK., under which name the species has furtheron been quoted in literature. The remark is rather curious, especially since somewhat later, BERKELEY himself has given the name *P. phosphorus* to a specimen collected by GUNN in Tasmania (40). Notwithstanding BERKELEY's statement that *P. phosphorus* is "certainly distinct from the two phosphorescent Australian species, *A. nidiformis*, and *A. lampas*", BRESADOLA and also PILÁT consider it as well identical with *P. olearius* D.C., as was already mentioned above. (It may be observed by the way that both authors have quoted this species as *P. phosphoreus* BERK.).

GARDNER seems to have made a drawing of his fungus at the spot, which, according to himself is quite characteristic. In addition to the communication, the editor of the Journal proposed to give a picture of the new fungus, as soon as the specimens would arrive, making use also of GARDNER'S drawing. As far as I know, this picture has never appeared, I have nowhere found it quoted.

In 1869, COLLINGWOOD (41) drew attention to a luminous fungus from Borneo. From his interesting letter the following passages may be mentioned.

"The fungus grows in small clusters upon roots of trees. It is of a light cream colour, and possesses a strong fungoid, or, rather, *Agaric* odour. . . . The specimens gathered while in a state of luminosity had, the next morning, thrown out an abundance of whitish spores. . . . The luminosity did not impart itself to the hand, and did not appear to be affected by the separation from the root on which it grew, at least not for some hours. I think it probable that the mycelium of this fungus is also luminous; for turning up the ground in search of small luminous worms, minute spots of light were observed, which could not be referred to any particular object. . . . and were probably due to some minute portion of its mycelium. - Mr. Hugh Low. . . . saw the jungle all in a blaze of light. . . . some years ago. . .; this luminosity was produced by an *Agaric*".

To these communications the Secretary of the Linnean Society added, without further comment, the following remark: "The fungus mentioned in the above letter appeared to be identical with *Agaricus Gardneri* BERK., a Brazilian species."

A few luminescent species of *Pleurotus* still remain to be discussed, in the first place *P. Emerici* BERK., and *P. lux* HARIOT.

P. Emerici was described by BERKELEY in 1880 upon specimens received from the Andaman-Islands (49, 50), *Pleurotus lux* was collected at Tahiti and Borabora, and described 1892 by HARIOT (51). The luminosity of these two species seems to be without doubt. They appear to have some features in common: the small size (pileus about 1 cm across) and the short lateral stem. BERKELEY initially (44, 50) indicated that *P. Emerici* had no stem at all, but in a following communication after receipt of new material he remarked that

this fungus "occasionally has a very well marked stem" (52). Until these species are studied further, it doesn't seem possible to give any definite indication regarding their relation with other species. From the available information identity of both species doesn't seem to be excluded. Identity with *P. olearius* cannot be defended, nor wholly excluded. Especially the small measures of the specimens described speak against identification. For *P. lux* the spores are indicated to measure 4 across, which is not much different from the measures given for *P. olearius* (34, 33). HARIOT (*l.c.*) communicates the interesting observation that the native women especially of Borabora wear luminous artificial flowers in their hairs, made of a real flower in which a specimen of *P. lux* is attached. From these luminous "flowers", bouquets, crowns, &c. are made (*cf.* GARNIER's similar observation at New Caledonia (23, 53, this paper p. 182).

P. Emerici has been quoted as *P. Ernerici* in MOLISCH' list, which failure was corrected by KLEIN.

In 1915 KAWAMURA (48) described *Pleurotus japonicus* as a new luminescent species. According to KAWAMURA, INOKO has studied this species already in 1889. HENNINGS, in 1900, had mentioned this species under the name *P. olearius* D. C., but KAWAMURA makes objections against this, and, according to the description and figures, it seems indeed that this species actually differs markedly from *P. olearius* D. C. The following points may be mentioned.

1. The form of the pilei and the type of growth strongly remember that of *P. ostreatus* JACQ. It is practically exclusively found on standing dead beech truncks and it is especially interesting that it seldom occurs below 4 m. above the ground. On lying stems it is only rarely found. This does not agree with what is found for *P. olearius* D.C.
2. The gills are white, only slightly yellowish when getting old, they are only briefly decurrent, ending abruptly, apparently at a kind of annulus, whereas in *P. olearius* D. C. they are yellow, and longly decurrent.
3. The flesh is white; in *P. olearius* D. C. it is, according to PILÁT (33) at least partly yellow.
4. The spores of *P. japonicus* measure 13 — 17 μ in diameter, and thus are much larger than those of *P. olearius* D.C., which, according to PILÁT (33), measure 5 — 7 × 4, 5 — 6.5 μ.
5. It being confined to the beech, it is also confined to the beech-zone, which may well be considered to indicate a colder climate than that in which *Pl. olearius* D. C. preferently grows. Thus, according to KAWAMURA, only in the North of Japan it occurs in the plains, whereas in the southern parts it is restricted to the summits of the mountains.

From *P. ostreatus* JACQ. it differs by its luminescence, its being very poisonous, and also by the larger spherical spores. The light seems to be confined to the gills; according to KAWAMURA the mycelium in the beech-trunk is non-luminescent. The spores are, as so far observed in all luminescent fungi, non-luminescent. The

luminescence of the mycelium in pure culture seems not to have been studied and deserves attention, since, so far, no luminescent fungi are known in which part of the pileus is luminescent whereas the mycelium in pure culture is not, the reverse being observed in various cases (*cf.* below). So far there seems to be no reason to believe that *Pleurotus japonicus* KAWAM. is not a good species. For its separation from *P. olearius* D.C. the *ostreatus*-like shape is perhaps not a very strong argument: some of BERKELEY's *olearius*-like phosphorescent species apparently also remind of *P. ostreatus*. So, for *P. Lampas* the alliance with *P. nidiformis* is mentioned, whereas this species has an affinity to *P. ostreatus*. It was reported above that *P. Lampas* now is considered to belong to *P. olearius* D. C.

One of KAWAMURA's illustrations of *P. japonicus* has been reproduced in Fig. 7, Plate I.

In 1934, BOSE (54) gave a detailed description of a *Pleurotus* with luminous fruit bodies, originating from luminous wood found in South Burma. BOSE states that this fungus differs from the luminous species of *Pleurotus* enumerated by BULLER (12) in the fact that in his species also the mycelium is luminous whereas in the twelve species of BULLER only the fruit body was indicated as luminous. But, it must be kept in mind that in most of the cases quoted by BULLER no information regarding the luminosity of the mycelia exists.

BOSE states that his species does not exactly agree with the descriptions of the following ones from Australia, the Philippine Islands, Japan and America "*P. candescens* F. v. M., *P. Gardneri* BERK., *P. illuminans* F. v. M., *P. Lampas* BERK., *P. nidiformis* BERK., *P. phosphoreus* BERK. (= *P. olearius* D. C.), *P. japonicus* KAW., *P. facifer* B. & C., *P. igneus* RUMPH., *P. noctilucens*, LÉV., *P. Prometheus* B. & C.", and he gives a detailed description without proposing a name. The developed fructifications are small, about 1 cm^2 surface area, brownish yellow, with a lateral white stalk. The hymenial surface is white, the gills are decurrent. Spores white, oval, $2—3 \times 4—5\ \mu$. BOSE obtained pure cultures from spores; the mycelium is white, and luminous when young; in older stages it grows deep brown, and ceases to emit light.

Identity of BOSE's fungus with *P. olearius* D.C. neither seems to be fully certain, nor seems any of the mentioned characteristics apt to exclude it, except perhaps the small size and the predominant white colour of the under side, but both these features may well be connected with the not fully natural conditions under which the fruitbodies appeared. Thus, in any case, there seems to be a fair chance that the luminous *Pleurotus* from South Burma will, like so many others, turn out to belong to *P. olearius* D.C. too.

One of the oldest records of a tropical luminescent fungus is found in RUMPHIUS's Amboinian Herbal (45) where he has given a description and a picture of *Fungus igneus*.

A copy of this picture is given in Fig. 6, Plate I, of the present

paper. It appears to be a rather fragile fungus of a *Mycena*-like type, the gills don't seem to be decurrent.

According to RUMPHIUS' description (*l. c.*) this fungus is very poisonous, and it is very similar to and often mistaken for the "fourth edible species of Boletus". It is a small fungus, the pileus having initially only about 1,5 cm diameter, being like a "half-closed hat", above tuberculate, glabrous, viscous, with a very short stipe which then stretches to about 3 inches, whitish, inside hollow. Later on the pileus extends to about 2.5 cm diameter, above it is pale greyish, beneath full of folds, blackish grey, smooth, frail, with a disagreeable odour. At night they are luminescent like stars, with a blue fire, like a crushed milliped, though only as long as they are moist and viscous. At night they thus are easily distinguishable from the fourth species Coelat tana [1]), but by day hardly otherwise than by their disagreeable odour. They grow in the dark wood, where decayed twigs lay, but always out of the earth, they also grow in the neighbourhood of hedges from which the lower parts are decayed, both out of the earth and upon the decayed wood. The fungus is sometimes used by the inhabitants as a light in order not to loose each other at night, but they do not like doing so, since these little fires remember them of sorcerers who might lead them on wrong pades.

Notwithstanding this description given by the "blind seer of Amboina", is not much more incomplete than many of those given by nineteenth century's travellers, it has so far not been possible to range RUMPHIUS' luminescent fungus at its right place in the mycological system. FRIES (46) has mentioned it in a note at the end of the section *Psilocybe*, without however classifying it definitely there, and, according to MERRILL (47) "the description is not sufficiently definite to warrant even a guess as to the genus the plant pertains to, and the figure is very poor".

In more recent enumerations of luminescent fungi it has mostly been referred to as *Agaricus igneus* RUMPH. BULLER (12), however, apparently following ZOPF (24), has quoted it as *Pleurotus igneus* RUMPH. Definite reasons for ranging this fungus into the genus *Pleurotus* seem to be lacking, and, more especially, according to RUMPHIUS's picture and description there seems to be no reason to assume that this species might be identical with *Pleurotus olearius* D.C. It may be considered to be worth while to look for this fungus in the future.

Concluding, we can say that a relatively large number of tropical phosphorescent species, with which about a century ago especially BERKELEY and his collaborators enriched the genus *Pleurotus*, have not been able to stand a more critical discussion. A few still remaining ones in this and allied genera deserve a critical study, after which, no doubt, some of them will have to be dropped also. From the species, discussed so far, *Fungus igneus* RUMPH. may be consi-

[1]) Under this name RUMPHIUS describes „Boletus terrestris" and he means with it all kinds of pileus-forming fungi, growing on the earth (RUMPHIUS, *l. c.* p. 126).

dered as actually different from *P. olearius* D. C. *Pleurotus japonicus* KAWAM. probably is different from *P. olearius* too, and perhaps *P. Emerici* BERK., and *P. lux* HARIOT.

Besides the interest that the inclusion of various "species" into *P. olearius* deserves for mycological taxonomy, it is also important in some other respects.

In the first place the distribution of luminescence in fungi becomes restricted again to a smaller number of species, thus increasing its "particularity".

Secondly it throws a new light upon this special case of geographical distribution of a fungus species. If the synonymy as presented above will be maintained in the future, we may consider *Pleurotus olearius* D. C. as much more wide spread than has been assumed formerly. Besides its presence in Southern Europe which was known since long, it can now be considered to occur in North Africa (*cf.* PILÁT, *l.c.*), in South Africa (*cf.* PILÁT, *l.c.*), in North America (as *Clitocybe illudens* and *Pleurotus facifer*), presumably in South America (as *Pl. Gardneri*), in Australia (under various names, *cf.* above), and perhaps also in the East-Indies (*cf.* COLLINGWOOD *l.c.*) Besides this, KONRAD and MAUBLANC remark: "Considéré à tort comme purement méridional et lié à l'olivier, ce champignon a été longtemps méconnu plus au Nord et pris pour *Clitocybe aurantiaca* (chantarelle orangée) d'ou la nocivité attribuée certainement à tort à cette dernière espèce". Notwithstanding this statement, the northern limit of this species in Europa doesn't seem to extend very far beyond the warmer regions. Apart from a doubtful record from Sweden (*cf.* PILÁT), according to PILÁT it is rather rare in central Europe. "En Autriche il est encore assez fréquent, en Tschécoslovaquie et en Allemagne déjà fort rare et il ne s'y trouve que dans les régions les plus chaudes".

It does not occur in RICKEN's works (42, 43), and according to BOTHE (10) it appears in Germany only "als seltener Irrgast". In the Netherlands it seems to be at least extremely rare, only a few years ago it was reported for the first time from Wilp near Deventer, where it was found by REUVEKAMP; a description of this case was given by SWANENBURG DE VEYE (44).

In Fig. 9, Plate I, a figure of one of the Netherland's specimens has been reproduced; in Fig. 8, Plate I, a copy of BRESADOLA's plate is given.

It would be interesting to know whether in America *P. olearius* reaches farther to the north than in Europe. Its missing in the colder parts of Europe can mean that it cannot stand low temperatures, but it can also mean that it has not yet been able to occupy again its potential area since it was removed from it by the glacial periods. It is well-known that the conditions for south-north plant migration in America and in Europe are different. According to a friendly private communication of Mr. REUVEKAMP, at its locality near Deventer the fungus seems to have been severely damaged, if not totally abolished, after the exceptionally cold winters of the years 1939-1942. In 1940 only a few non-valid fruitbodies appeared, in the following years none were observed.

As to the phosphorescent fungi belonging to other genera we may first mention *Armillaria mellea*, the specific value and lumines-

cent property of which cannot be doubted, and thus it doesn't require further discussion here. The luminescence is confined to the mycelium and the rhizomorphs, the pileus and the spores are non-luminescent.

In connection with *Armillaria mellea* it is worth while to draw attention to the closely allied *Clitocybe tabescens* (FRIES ex SCOP.) BRES. which indeed has been indicated as luminescent (*cf.* Table I). Some mycologists consider this fungus only as a variety of *Arm. mellea*, chiefly different by the total absence of the annulus, but according to KONRAD and MAUBLANC (31), and to KÜHNER (55) it differs from *A. mellea* by a number of features, *e.g.* the absence of the annulus, the earlier appearance, and the possession of a membrane pigment in the surface tissue of the pileus, so that it should be considered as a related but distinct species.

Lists of synonyms have been given by KONRAD and MAUBLANC (*l.c.*), and by RHOADS (56). The last mentioned author devoted extensive studies to *Clitocybe tabescens* (56, 57, 58, 59, 60); in his paper (56) a very thorough and valuable discussion of the nomenclature is given. From the synonyms the following are of special interest to us: *Agaricus tabescens* SCOP., *Collybia tabescens* SACC., *Armillaria tabescens* EMEL, *A. mellea* var. *tabescens* REA, *Agaricus socialis* D.C., *Clitocybe socialis* BARLA. However, *Agaricus socialis* FRIES, pictured by COOKE (61, plate 134) is different.

Luminescence of *Clitocybe tabescens* was once described by ROUMEGUÈRE (62), who considered a luminous fungus, collected by DULAC on decaying roots of *Quercus robur* L. near Sauveterre in the Hautes Pyrenées to belong to this species. In ROUMEGUÈRE's paper the species is referred to as *Ag. socialis* D.C. (in a quotation from a letter of DULAC), and as *Ag.* (*Gymnopus*) *socialis* Fr.. ROUMEGUÈRE remarks: "FRIES (Hym. Europ. p. III)[1]) rapporte la forme décrite par l'auteur de la Flore française à l'*Ag.* (*Collybia*) *tabescens* SCOPOLI".

It is very probable that these observations of ROUMEGUÈRE and DULAC have lead to the appearance of *Clitocybe tabescens* in the lists of luminous fungi. It was mentioned by LAGERHEIM (as *Ag. socialis* FR.) as doubtfully luminescent, by MOLISCH (as *Ag. socialis* FR. = *Collybia tabescens* FR.), by KLEIN (as *Collybia tabescens* [SCOP.] FR.). It is apparent that a considerable confusion in the nomenclature exists, as was also pointed out by RHOADS (56), and thoroughly discussed. Obviously this confusion originated chiefly from two facts, namely the use of the name *tabescens* twice by FRIES, and

[1]) Obviously, III is a typographical error for 111 (one hundred and eleven).

the use of the name *socialis* by FRIES for a species different from *Ag. socialis* D. C. Especially RHOADS, and also KONRAD and MAUBLANC have much aided to clarify the situation by their extensive list of synonyms to which the reader is referred. Only a few remarks may be made, which have a special bearing to the quotations appearing in the enumerations of luminous fungi. *Ag. tabescens* SCOP. is quoted twice in FRIES (63), *viz.*, at p. 319, and at p. 111; at. p. 704 FRIES alludes to the difference of these two species. SACCARDO (34) has maintained both descriptions of FRIES side by side and referred to them as *Ag. tabescens* SCOP. (*l. c.* p. 1143) and *Collybia tabescens* SCOP. (*l.c.* p. 206). The latter is the one which, according to FRIES, is identical with *Ag. socialis* D.C. and very closely related to *Ag. contortus*. The latter remark was made also by ROUMEGUÈRE concerning his luminescent species, so that indeed there is little doubt he considered this fungus to belong to *Ag. socialis* D.C. Obviously, both RHOADS and KONRAD and MAUBLANC consider the two *Ag. tabescentes* of FRIES to be identical. Besides these, *Ag. socialis* Fr. is another species, described by FRIES (*l. c.*) on p. 83. According to KONRAD and MAUBLANC, the picture of COOKE's plate 134 (*l. c.*) refers to this species. Considering these facts, MOLISCH's quotation: *Ag. socialis* FR. = *Collybia tabescens* FR. doesn't seem to be correct for *C. tabescens* FR. is identical with *Ag. socialis* D. C., (non FR.!) which species must be considered to be the one to which ROUMEGUÈRE brought DULAC's luminescent mushrooms. The same remark holds good for ROUMEGUÈRE's quotation: *Ag. socialis* FR., instead of which, in view of ROUMEGUÈRE's further statements, obviously *Ag. socialis* D. C. is meant, and, finally this remark also applies to LAGERHEIM's quotation.

RHOADS (56) copied a plate of BOUDIER to illustrate this fungus. Part of his figure has been reproduced in Fig. 3, Plate II.

Coming now back to the bearing of *Collybia tabescens* to fungus luminescence, we find the following extremely interesting remark in ROUMEGUÈRE's paper:

> "La forme communiquée par M. l'abbé DULAC a la chair jaunâtre et point blanche, le stipe relativement plus court que celui de l'*Ag. socialis*. L'espèce est comestible, quoique de digestion difficile, parce qu'elle est coriace. La proprieté phosphorescente, si elle était constatée à nouveau devrait faire écarter les champignons qui l'offriraient d'une saine alimentation".

Obviously, the luminescent specimens differ rather markedly from the normal ones of *Ag. tabescens*, and it will occur to us that the yellow flesh, the short stipe, and the difficult digestion contain an indication that they actually may not have belonged to *Ag. tabescens* but to *Pleurotus olearius*! This suspicion even receives some

support from the fact that some years later DULAC (64) has mentioned his finding of *Ag. olearius* D.C. in the same region on the same substratum (*Quercus robur* L.) on which he found the specimens referred to by ROUMEGUÈRE. Also the mode of growth of the latter ("par véritables bancs sur les racines pourries. . . ." [62]) does not exclude *Pl. olearius*. DULAC, in the same communication (64) reports the occurrence of *Pl. olearius* in a grass field without visible connections to any tree, but only adhering to grass roots, so that, apparently, the species is not at all rare in the High-Pyrenees.

As far as I know luminescence of fruit bodies of *Clitocybe tabescens* has never since been reported, and the above suggested explanation for ROUMEGUÈRE's statements may thus be recommended.

It may be asked whether perhaps the mycelia of this fungus are luminescent in pure culture, which, in view of its close relation to *Armillaria mellea*, would not be very surprising.

RHOADS has made extensive comparisons between the cultures of *Armillaria mellea* and of *C. tabescens*, and he states that although both organisms develop very similar rhizomorphs, the characters of the mycelial growth are different, and moreover, while the cultures of *Armillaria mellea* (and of *A. fuscipes*) are generally phosphorescent in the dark, this feature is absent from the many cultures of *C. tabescens* examined (58). I had the opportunity to see cultures in the Centraalbureau, at Baarn, which had been obtained from RHOADS, who isolated them from various trees suffering from mushroom root rot. RHOADS' statement was fully confirmed: no luminescence could be observed in them. Also young vigorous cultures on malt-agar were, so far, not seen in a luminous state. It remains useful, perhaps, to make observations including various substrates, and cultures of european origin also, in order to establish whether actually luminescence is always lacking. Up to now it thus seems very doubtful that *C. tabescens* is a luminescent species. The ? LAGERHEIM put with this species in his list seems very reasonable, and it is not evident why MOLISCH and KLEIN have dropped it.

It may be mentioned in addition that DULAC once more sent a luminous fungus from the Hautes Pyrenées to ROUMEGUÈRE, which case was discussed by PATOUILLARD (65). According to PATOUILLARD this specimen belongs to the species *Agaricus acerbus* FR.

PATOUILLARD doesn't seem convinced that the fungus was actually luminescent itself, for he considers the luminescence, which still was observable, as „accidental", and ascribes it to „parasitism" of luminous bacteria. Notwithstanding that this explanation is not very likely, the observation as such doesn't seem sufficient to range *Agaricus* (*Tricholoma*) *acerbus* among the luminous fungi. *Tricholoma acerbum* is not a very rare fungus, and if its

fruitbodies would emit light, this would certainly have been reported again. The question arises whether also in this case a confusion with *Pleurotus olearius* might be suspected. The only argument in favour of this supposition is in fact the occurrence of a distinct luminescence in the fruit body. *Tricholoma acerbum* and *Pleurotus olearius* may show superficial similarities in colour and magnitude, but the differences in the gills, which are strongly decurrent in *P. olearius*, might furnish a sufficient guarantee against confusion by a trained mycologist.

LAGERHEIM (23) has, again, rightly expressed PATOUILLARD's doubt concerning the significance of the luminescence of *Tricholoma acerbum* by providing it with ? in his list; also in this case MOLISCH and KLEIN have dropped the question mark.

Besides pure cultures of *Clitocybe illudens*, and *C. olearia*, cultures of the following species of *Clitocybe* are present in the Centraalbureau, at Baarn.:
C. aurantiaca (WULF) STUDER, *clavipes* (PERS.) QUÉL., *cyathiformis* FR., *flaccida* SOW., *fragrans* SOW., *gallinacea* SCOP., *geotropa* BULL., *infundibuliformis* (SCHAEFF.) FR., *nebularis* (BATSCH) QUÉL., *rivulosa* (PERS.) FR., *robusta* PK., *suaveolens* (SCHUM.) FR., *tabescens* (SCOP.) BRES. In none of these species luminescence was observed so far.

Some words may be said regarding a few species of the related genus *Collybia* which have been mentioned as being luminescent. In the first place the sclerotia building species *C. tuberosa* BULL., and *C. cirrhata* PERS. For these species LUDWIG (66,67,13) observed phosphorescence in the sclerotia which had started formation of mycelia or fruit bodies. MOLISCH (14) tried to verify LUDWIG's observation for *C. cirrhata* PERS., but without success, so that he concluded that *C. cirrhata* is not a luminous fungus. As far as can be judged from LUDWIG's communication, however, there seems to be no plausible reason to doubt his statements so that these two fungi certainly deserve renewed attention with respect to luminescence.

An interesting case of nomenclatory confusion seems to be represented in the quotation of *Ag.* (*Collybia*) *longipes* under the luminous fungi. MOLISCH quoted it as *Ag.* (*Coll.*) *longipes* SCOP., whereas KLEIN, obviously alluding to the same species, quoted it as *Ag.* (*Coll.*) *longipes* (BULL.) FR. FRIES (63) has mentioned the latter species under No. 337, whereas he has alluded to the former at two different places, *viz.* under No. 336 (*Ag.* [*Coll.*] *radicatus*), where he remarks: "Alienus est *A. longipes* SCOP., albus, *in tenebris candelae instar lucens*,. . .", and under No. 974. *Ag. semiorbicularis*, where he remarks: "*A. longipes* SCOP. Carn. p. 466 hunc l. praecedd. spectat." According to KONRAD and MAUBLANC (102) *Naucoria semior-*

bicularis (FR. ex BULL.) QUÉL. 1872, and *Ag. longipes* SCOP. 1772, are synonyms. We thus kill several birds with one stone: In FRIES we find the indication of *Ag. longipes* SCOP. as a luminous fungus; KLEIN's quotation of "the other" *C. longipes* as luminous is obviously erroneous, and we understand LAGERHEIM's quotation of *Naucoria semiorbicularis* BULL. under the luminous fungi. LUDWIG (66, 13) has communicated that FRIES had informed him in a private letter that the luminescence of *C. longipes* SCOP. ("der Flora carniolica") was observed by RUMPHIUS. I have not yet been able to verify this statement of FRIES.

As far as I know luminescence of *Naucoria semiorbicularis* (FR. ex BULL.) QUÉL. has never since been reported; it seems worth while to recommend also this species to the attention of the students of fungus luminescence, in order to verify the reliability of the old statement.

Under the most doubtful records of luminescence in fungi may certainly be arranged that of *Hypholoma fasciculare*. It seems to have no better foundation, than that wood bearing fruitbodies of this fungus was seen in a luminous state. PHILLIPS (22) has stated that this species has to be excluded from the list of doubtfully luminescent fungi, but, at least from his paper in french (22) it cannot well be ascertained whether he considers luminescence in this species to be definitely established or to be absent.

The luminescence of *Panus stipticus* was first observed in 1885 by G. GENTRY, at the gills of specimens found in the neighbourhood of Philadelphia. Soon afterwards, ELLIS (68) saw the same at specimens from Newfield, and communicated GENTRY's observation too. According to ELLIS, the stipe and the surface of the pileus show no luminescence. ELLIS' statement that *Panus stipticus* was the first luminescent fungus known from North America is not quite correct, since in *Pleurotus facifer* luminescence was described earlier (69). MOLISCH failed to corroborate GENTRY's observation with european specimens and pure cultures of these. In this controversy a very interesting elucidation was presented by BULLER (12) who discovered that all specimens of this species, collected in North America, were luminescent, whereas those, collected in England were not. He concludes that, "of the species *Panus stipticus* there are evidently two forms, morphologically alike but physiologically different, occupying separate geographical areas and kept apart by the great barrier of the Atlantic Ocean" (*l.c.* p. 365). BULLER was able to endorse very strongly the opinion that the american and the european *Panus stipticus* indeed are closely related forms of the same species by demonstrating that they were capable of mutual hyphal fusions (*l. c.* p. 413). The light emission of *P. stipticus* is strongest in the gills; in the flesh of the pileus the luminescence

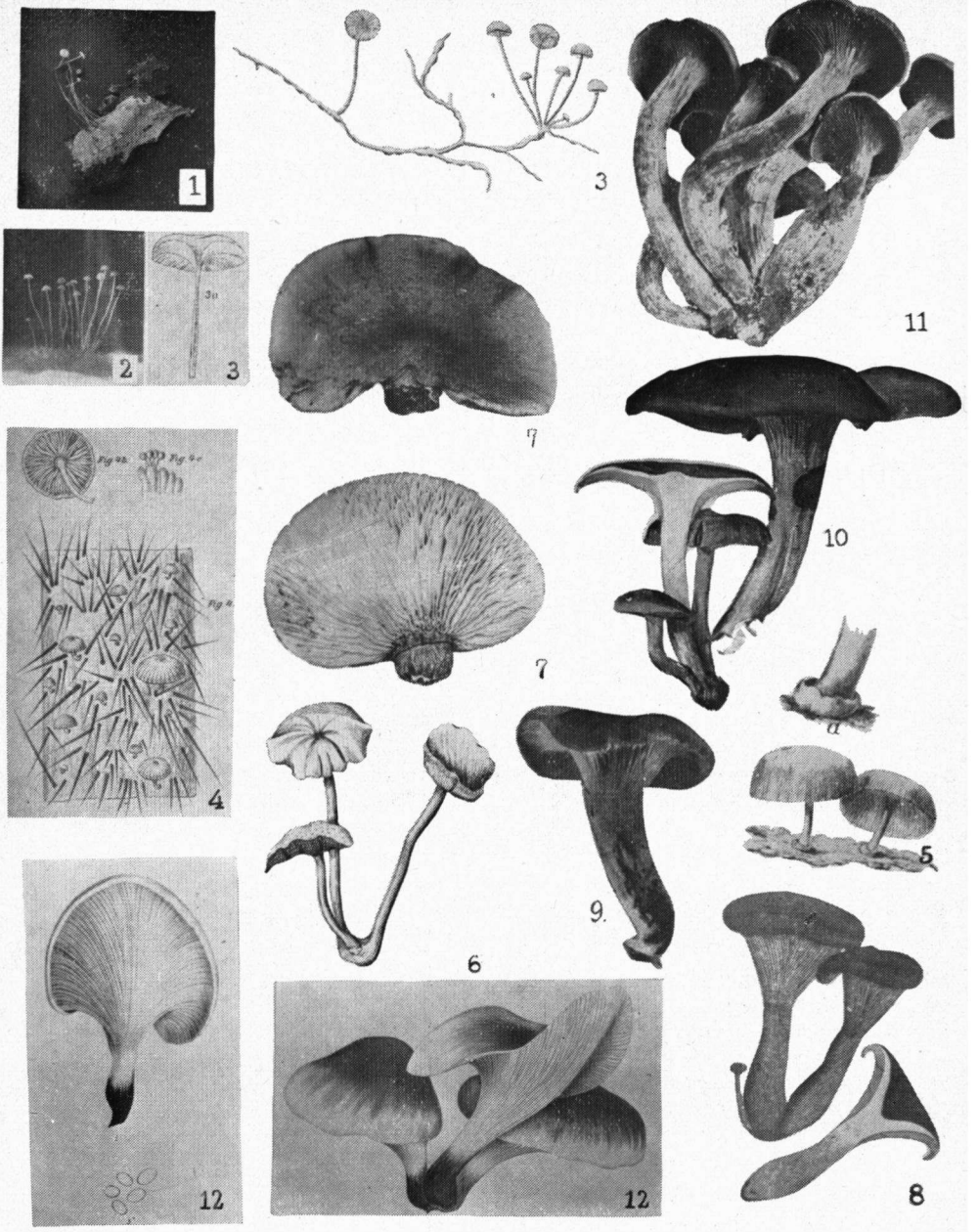

PLATE I. 1. *Mycena spec.* cf. *capillaris*. On yellow, luminescent spot on decaying oak leaf. Collected near Utrecht, 30-11-'41. About natural size. - 2. *Omphalia flavida* MAUBL. et RANGEL (from BULLER [18]), about 1.5×, *cf.* also plate II, fig. 1. - 3. *Omphalia Martensii* P. HENNINGS (from HENNINGS [25]), about natural size. - 4. *Mycena illuminans* P. HENNINGS (from HOLTERMANN (75]); a: about 2/3, b: about natural size, c: × 230. - 5. *Locellina illuminans* P. HENNINGS (from HENNINGS [73]), about 1.5 ×. - 6. *Fungus igneus* RUMPH. (from RUMPHIUS [45]). - 7. *Pleurotus japonicus* KAWAM. (from KAWAMURA [48]), about 0.5 ×. 8. *Pleurotus olearius* D.C. (from BRESADOLA [30]). - 9. *Pleurotus olearius* D.C., found in the Netherlands (photographed by REUVEKAMP, from SWANENBURG DE VEYE [44]). - 10. *Clitocybe illudens* (SCHW.) SACC. (from MURRILL [28]). - 11. *Clitocybe illudens* (SCHW.) SACC. (from BULLER [12]). Figs. 8 -11 illustrate the identity of these 2 species, and at the same time the variability of each of them. - 12. *Pleurotus candescens* F.v.M. (from Mc. ALPINE [27], reproduced at about $^1/_2$ of orig. size).

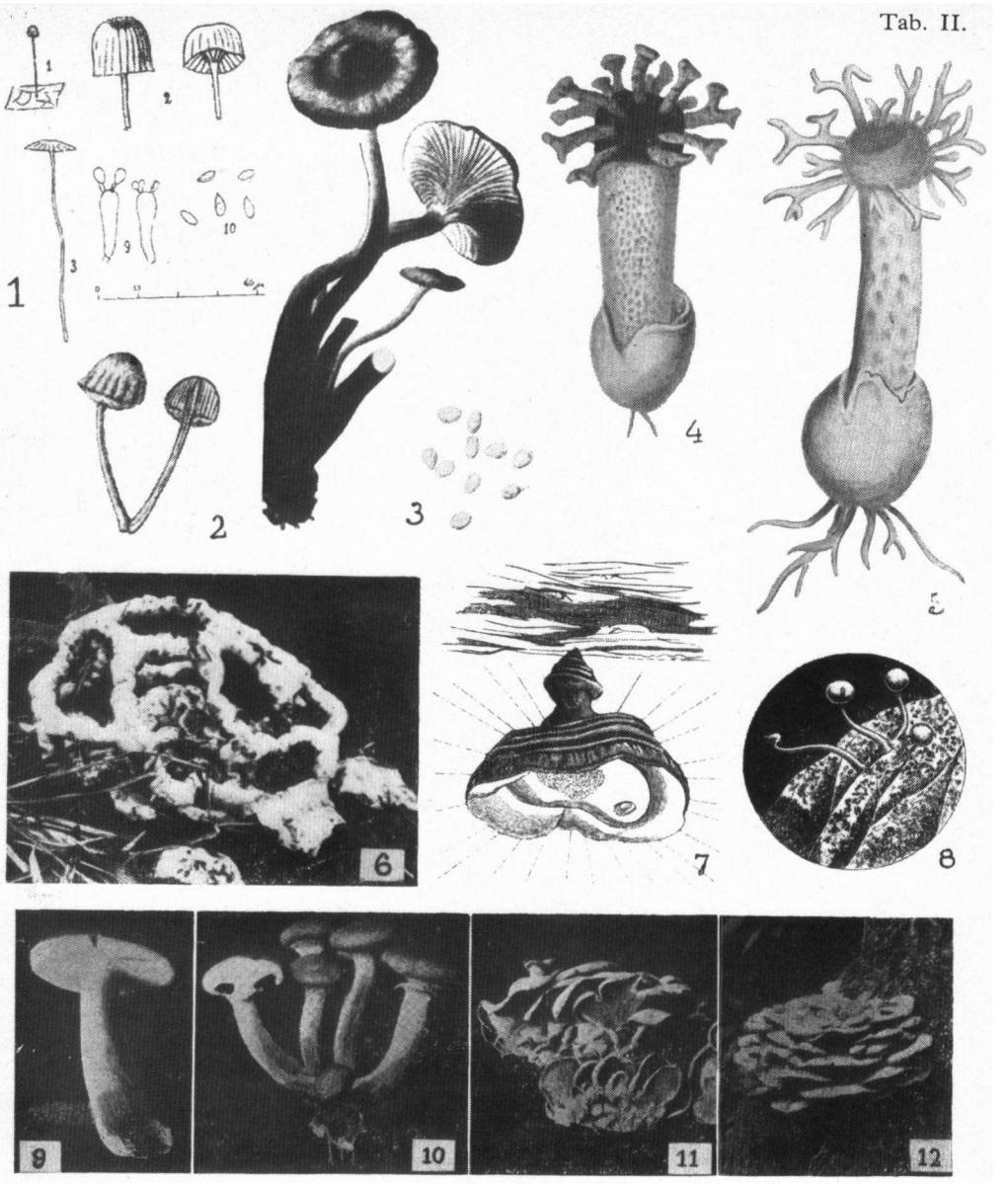

PLATE II. 1. *Omphalia flavida* MAUBL. et RANGEL. 1) Part of leaf of *Eriobotrya japonica* with a fruit body (somewhat enlarged), 2) young pilei, 3) full grown pileus,9) basidia, 10) basidiospores, scale 0 - 40 μ (from MAUBLANC et RANGEL [71a]) *cf.* also plate I, fig. 2. - 2. *Polyporus mycenoides* PATOUILLARD (from PATOUILLARD [85]), about 2 × enlarged. - 3. *Clitocybe tabescens* (FRIES ex SCOP.) BRES. (part of a cluster, pictured by BOUDIER, taken from RHOADS [56]), about 3/5 of the size of the original plate. - 4. *Kalchbrennera Tuckii* (K. et M.O.) BERKL. (from KALCHBRENNER [116]) somewhat reduced. - 5. *Kalchbrennera corallocephala* (WELW. et CURR.) K. (from KALCHBRENNER [116]) somewhat reduced. - 6. *Clathrus cibarius* (TUL.) ED. FISCHER (*Ileodictyon cibarium* TUL.) (part of Fig. 267, from LLOYD, Myc. Notes), about natural size. 7. "Luminous fungus (*Polyporus annosus*)" (from W.G. SMITH [90]). - 8. "Luminous fungus on leaf of *Spermacoce*" (illustration from Dr. HOOKER, identified by BERKELEY as *Didymium spec.*; from an anonymous communication in Gard. Chron., Jan 10, 1874 [121]). 9. "*Ceriomyces crassus*" - 10. "*Armillaria putrida*" - 11. "*Panellus stipticus*" - 12. "*Laetiporus sulphureus* on ash tree." Nos. 9—12 from MURRILL (91), constituing his "collection of fungi that give forth a luminescence that is truly startling" (!). — Only for Nos. 1, 2, 11, and the mycelia and rhizomorphs of 10, luminescence may be considered as definitely demonstrated. The identification of 8 is very probably erroneous. *Cf.* text, and Table III (p. 188—191).

is much feebler, and the stipe is non-luminous. Neither is any luminescence observable in the spores, whereas the mycelium in pure culture is luminescent. As far as we know, in Europe luminous specimens of *Panus stipticus* have never been observed; we have a culture of Siberian origin, obtained from the C.B.S., which does not show luminescence either.

It seems, therefore, that the distribution of the non-luminous form is Eurasian, as also would appear most probable, and was already suggested by BULLER: "Possibly its distribution is Eurasian in extent. It seems most likely that one of the two physiological forms arose from the other and that to-day they are separated geographically because the great barrier of the Atlantic Ocean prevents their intermingling" ([12], p. 416).

This extremely interesting case demonstrates that rather minute physiological differences may determine whether a species is luminescent or not. That these differences must be considered not to be very great is proved by BULLER's fusion-experiment. On the other hand, however, the change nevertheless must be of a rather definite and fundamental character, since, apparently, no ecological circumstances can make the non-luminescent form luminescent.

In later years MACRAE (70, 71) has carried out interesting crossing-experiments with luminescent and non-luminescent single-spore mycelia of *Panus stipticus*, and found the diploid mycelia to be luminescent in all cases, so that in the F_1 luminescence is dominant.

In 1925, BULLER (18) gave another important contribution to the knowledge of fungus luminescence in discovering the luminescence of *Omphalia flavida* (CKE.) MAUBL. et RANGEL, a fungus causing a coffee-leaf disease in America. The mycelium and the so called gemmifers, reproduction-organs carefully studied bij BULLER, emit light, the sporophores don't. Also the leaf spots are luminous which thus offers some analogy with the luminescent leafspots observable in decaying leaves, which were discussed in § 3 of this paper. We obtained a culture of *Omphalia flavida* from the C.B.S.; it belongs to our best luminescent species (*cf.* § 5).

In Fig. 2, Plate I, one of BULLER's figures is reproduced; in Fig. 1, Plate II, we present some figures from the paper by MAUBLANC and RANGEL (71a), the authors of *Omphalia flavida*, who recognized it as the complete form of *Stilbum flavidum* COOKE.

BULLER has drawn renewed attention to the fact that long ago another luminescent species of *Omphalia* has been described, namely *Omphalia Martensii* P. HENNINGS. It grows on roots on the earth in Borneo; in fig. 3, Plate I, we give a picture of it that was copied from the one in HENNINGS' paper (25).

HENNINGS described a number of other luminescent tropical fungi, which so far, have not been given much attention to in literature on bioluminescence. In the first place two species of the genus *Locellina* GILL. (72) namely *Locellina illuminans* from Celebes (73), and *L. noctilucens* from New Pommern (74).

Locellina illuminans P. HENNINGS is a small brownish Agaric with a campanulate pileus and a hollow stipe with a volvacious disc at its base. The lamellae are free, yellow-brownish, the spores also brownish, 8 - 9 × 6 - 7 μ. In fig. 5, Plate I, we give a picture copied from HENNINGS. The fungus was collected at Tomohon, Celebes, in 1894, by the brothers SARASIN who reported that the fungus, especially the gills emit a strong green light. Looking from above, one sees the stipe, which is non-luminescent, like a black disc in a luminescent field.

Locellina noctilucens P. HENN. was collected by DAHL, in 1897 at Ralum in New-Pommern, on a piece of wood at a house ("auf einem Holzstück am Hause"); according to DAHL it emits a greenish light. It seems to be very similar to *L. illuminans*, the chief differences apparently being the brighter colour ("albo subcinerascente"), the more rudimentary, only discoid volva, and the smaller spores ($4^1/_2$ - 5μ). The spores are pale brown.

KILLERMANN (32) denotes *Locellina* as an "uncertain genus", which, according to this author, is also the opinion of BRESADOLA, who never saw a specimen belonging to it; some species are probably identical with species of the genera *Pluteus* and *Volvaria*. It may be worth while to look for HENNINGS' luminescent *Locellina*'s again both from the viewpoint of fungus-taxonomy and from that of bioluminescence. It may be remarked that a few elements of the description remind of RUMPHIUS' *Fungus igneus*, so the hollow stipe in *L. illuminans*.

Furthermore, HENNINGS (25a, 25b), drew attention to a small, strongly luminescent terrestrial fungus, observed in New Guinea by KÄRNBACH, and which was supposed to be a small *Marasmius*. Identity with RUMPHIUS' *Fungus igneus* doesn't seem to be excluded. The generic name doesn't seem fully warranted, and renewed observations are wanted.

Another tropical luminescent fungus described by HENNINGS fortunately has not remained so mysterious, namely *Mycena illuminans* P. HENN. It was described in 1903 (25a), upon specimens collected 1902 by VOLKENS in the botanical Garden at Buitenzorg, on stems of *Calamus*.

Some particularities, obviously communicated by VOLKENS, appear doubtful, so especially: "Es ist besonders der klebige Schleim auf der Hutoberfläche, welcher leuchtet".

The fruit bodies are sitting in groups in the trees, up to very

high, at night they glow with a greenish light, so that the twigs look as if they were provided with candles. MOLISCH (9, p. 48) reports of a small white strongly luminescent *Agaric* he saw in 1897-'98 on a rattan-palm in the garden of Buitenzorg, and he adds that HOLTERMANN (75) has given a picture of this fungus. Later on MOLISCH (9a, 76) has reported the identity of this fungus with HENNINGS' *Mycena illuminans*. We have copied HOLTERMANN's figure of this species (fig. 4, Plate I).

HOLTERMANN's specimens also were collected in the garden of Buitenzorg, and were growing also on a rattan palm. HOLTERMANN obviously intended to study the species later on: "die ich in einer späteren Arbeit genau untersuchen werde.... Ueber die Ergebnisse der Culturen werde ich später berichten". As far as we know, these studies have never been published. HOLTERMANN also strongly emphasizes the brilliant luminescence of this fungus. "Er glich einem kleinen electrischen Glühlicht". Notwithstanding the fact that various botanists visiting the Hortus bogoriensis may have seen *Mycena illuminans*, it seems not yet to have been studied further, and I found nowhere any indication as to the existence of pure cultures. The species was mentioned furthermore in VAN OVEREEM- DE HAAS' list of malayan fungi (77) in which the original description is quoted, and, more recently, in a popular review of the Java fungus flora by BOEDIJN (78), in which attention has been drawn to its luminescence.

For many years *Mycena illuminans* P. HENN. was the only species of this genus which was known to be luminescent, till BOTHE (79) discovered that the mycelium of an european species occurring on wood, *M. tintinnabulum*, was luminescent. A few years later, BOTHE (10) considerably enlarged the list of luminescent european *Mycena*'s in observing luminescence in the mycelia of the following species: *M. galopus* PERS., *sanguinolenta* ALB. et SCHWEIN., *epipterygia* SCOP., *dilatata* FR., *stylobates* PERS., *zephira* FR., and, furthermore, in cultures of *M. polygramma* BULL. and of *M. parabolica* FR. We have been able to corroborate BOTHE's observations for a number of these species, as will be discussed below. Furthermore we observed luminescence in a culture of *M. galericulata* (SCOP.) FR., var. *calopus* FR., present in the Centraalbureau. According to OORT (16), this species is identical with *M. inclinata* FR., and according to this author this also is the opinion of RICKEN and of LANGE.

With RICKEN, however, matters seem a little different in so far that he indeed will not exclude identity of *M. inclinata* FR. and *M. calopus* FR., but he doesn't consider the latter one to belong to *galericulata* (42, p. 438). MAUBLANC (80) objects to identification of *M. inclinata* (FR.) QUÉLET with *M. galericulata*, var. *calopoda* FR. On the contrary KÜHNER (17, p. 340), like OORT, considers *inclinata* FR. and *galericulata*, var. *calopus* (FR.) and also *M. calopus* (FR.) sensu RICKEN to be identical. It may be mentioned that according

to BOTHE the type-species of *M. galericulata* (SCOP.) FR. is non luminescent. A culture of this species present in the C.B.S. didn't show luminescence. In the strain of *M. polygramma* of the C.B.S. no luminescence was observed upon cherry- and "x"-agar, whereas a strain we have isolated from a fruit body collected at Bunnik near Utrecht is very strongly luminescent. However, it shows the best luminescence on bread-agar and the Baarn strain has not yet been cultivated on this medium and has, in general, not yet been studied further.

BOTHE has reported highly important investigations (81) concerning *M. galopus* and *M. polygramma*. Single spore cultures of both species yielded luminescent and non-luminescent strains, which, furthermore, gave rise to luminescent or non-luminescent diploid mycelia. The inheritance of luminescence didn't appear to follow a simple scheme. In view of BOTHE's remark, that the non-luminescent strains "allerdings in Massenaussaat und auch wohl am natürlichen Standort von den leuchtenden Hyphen, mit denen sie verflochten sind, überdeckt werden und daher nicht zur Geltung kommen können", the occurrence of non-luminescent cultures arising from tissue-isolations or from spore-masses are of some interest. In 1945 we obtained cultures of *M. polygramma* from spore-masses of a pileus collected near Utrecht, that were non-luminescent both on cherry- and on bread-agar, whereas cultures obtained in the same way from other pilei were distinctly luminescent. Notwithstanding the fact that these cultures have not yet been followed for a very long time, it seems probable that of *M. polygramma* non-luminescent strains occur in nature also.

From the species so far reported by BOTHE as being luminescent the following, according to OORT (16) do not occur in the Netherlands: *M. dilatata*, *M. zephira*, *M. tintinnabulum*. We were able to obtain a culture of *M. tintinnabulum* from the C.B.S.; it was observed to be luminescent. BOTHE reports that he saw luminescence in the gills of *M. pura* PERS., but he could not get the spores germinated. In 1943 we received fruit bodies of *M. pura* from Dr. OORT, but we were not able to obtain cultures either. However, from spores of fruit bodies collected 1945 at Bilthoven, a few very slowly growing cultures were obtained. Observations concerning luminescence were not yet made. Luminescence of the fruit bodies of European *Mycena*-species was not known before BOTHE observed that occasionally a weak luminescence was emitted by the gills of some of the species, the mycelia of which are luminescent in culture. BOTHE, furthermore, mentioned a number of *Mycena*-species which, in pure culture, he found non-luminescent.

The luminescent fungi, discussed so far, all belong to the Agaricaceae, and the greater part of them, if not all, to the group with white spores. In 1942 Prof. WESTERDIJK, Director of the C.B.S., was so kind to inform us that she and her collaborators had observed that a strain of *Polyporus rhipidium* BERK., in the collection of the C.B.S. was luminescent. We have received a culture of it and have grown it upon cherry- and bread-agar, and have regularly observed the luminescence which was sometimes rather strong. The strain of *P. rhipidium* present in the C.B.S. is of Australian origin and has been sent to the C.B.S. by REFSHAUGE and PROCTOR (82). *Polyporus rhipidium* has been described by BERKELEY in 1847 (83) upon material collected by T.G. LEA on rotten trunks, in woods, at Waynesville, Ohio. To his description BERKELEY has added the following very interesting remark: "This curious species exactly resembles *Panus stipticus* with the exception of the hymenium. I know of no species to which it has a close affinity". It would of course be a very bold theory to denote *Polyporus rhipidium* as a form of *Panus stipticus* with pores instead of lamellae, but nevertheless there are a few facts that are worth mentioning in this connection. In the first place so far *Polyporus rhipidium* was the only luminescent species observed in the collection of *Polyporus*- and *Fomes*-cultures present in the C.B.S., which contains more than 200 species. (For the names of these species the reader is requested to consult the list of the C.B.S. (84)). In the second place it is remarkable that the Agaric mentioned as similar by BERKELEY is a species the American form of which is luminescent (*Panus stipticus luminescens* BULLER). In the third place the phenomenon that from Agaric fungi forms exist that develop pores instead of gills, seems actually to have been observed in other cases, *e.g.* with *Mycena*'s in the Dutch East Indies (*cf.* BOEDIJN (78)). We don't possess cultures of *Panus stipticus luminescens*, but we have a culture of the non-luminescent form of Siberian origin, obtained from the C.B.S. (*cf.* above). On cherry-agar and bread-agar this culture develops much more abundant mycelia than *Polyporus rhipidium* does, the former often tending to grow through the cotton-plug, which in *Pol. rhipidium* was never observed.

Polyporus rhipidium BERK. is not the only pore-forming fungus from which luminescence has been reported. The other records, however, are all of early date, and have not been verified in recent years. The most reliable ones are probably those concerning *Polyporus mycenoides* PATOUILLARD (85), (86): p. 163, and *P. noctilucens* LAGERHEIM (23), (86): p. 173.

PATOUILLARD's species was collected by BALANSA between 1868 and 1870 in New Caledonia. It looks like a small *Mycena* with a

half-globular thin-fleshy pileus, and pores instead of lamellae, *cf.* Fig. 2, Plate II. Perhaps it may indeed be considered as a pore-forming *Mycena.* (*cf.* [78]). In the original description it's luminescence was mentioned. LAGERHEIM has quoted it in his list, but it has been omitted in later enumerations of luminescent fungi. However, I have not been able to find a definite reason for these omissions. It is obviously to this species that DUBOIS (26) alluded:

"A la Nouvelle-Calédonie, surtout dans le sud, et en juillet, qui est la saison froide, on trouve, paraît-il, un *Polypore* jaune, émettant une lumière verdâtre très vive..... Il pousse dans les ravins humides sur des fragments de bois et ne vit que quatre jours....."

In connection with this New-Caledonian luminescent fungus, mention may be made of a very interesting communication by J. GARNIER (Voy. autour du Monde, Vol. 2, p. 140, 1871, quoted after [53] and [23]) that at a feast in the evening on New-Caledonia, young girls wore a kind of luminescent "flower" in their hairs, which GARNIER found out to be a small luminescent *Agaric.*

Polyporus noctilucens LAGERH. was collected 1857 in Angola by WELWITSCH, who added the diagnosis in the schedule, and remarked: "nocte eximie phosphorescens". It is a yellow-brownish, woody species. The diagnosis is very brief, so that a thorough idea about the species can hardly be obtained from it. As far as can be ascertained it is not unlike *P. sulphureus,* but without further investigation of the type specimen, nothing definite can be said about it.[1])

Like on many tropical luminescent *Agarics* renewed observations on these luminescent *Polyporaceae* don't seem to exist, and are urgently wanted.

ZOPF (24) didn't mention the luminescent *Polyporaceae* discussed so far, but indicated „*Polyporus Emerici* BERK". from Australia as luminescent which was followed by MC. ALPINE (27) who denoted the species as *P. grammocephalus,* var. *emerici,* without author's name. ZOPF quotes the description given by COOKE (87). In this description, however, we don't find any indications concerning the luminescence of the species, and I do not know of any further records hereof. Also SACCARDO (86) fails to give any indication concerning a possible luminosity of this species, so that at present I should like to doubt whether actually ZOPF's indication exists to rights. It doesn't seem quite excluded that *Polyporus Emerici* BERK. has been con-

[1]) I am very much obliged to Prof. F. RESENDE, and to Dr. C. N. TAVARES, of the Botan. Institute, Univ. of Lisboa, who recently kindly supplied me with very valuable material and informations concerning this interesting species, which matters I intend to discuss in a separate communication.

founded with *Pleurotus Emerici* BERK., the luminescent fungus from the Andamanes described by BERKELEY not so long before.

Various authors have attributed luminosity to *Polyporus sulphureus* (BULL.) FR. PAULET was said to report (88) about luminescent specimens of this species on an old oak in the Bois de Boulogne.[1] W.G. SMITH (89) also mentioned it among the species he saw luminescent himself: "I have also seen *P. sulfureus* FR. phosphorescent. . . " (89). . . . "seen in a luminous state *Polyporus sulfureus* FR.. . . . (90). LUDWIG (13) states: "Das Mycel des *P. sulfureus*, soll phosphoresciren" (*l. c.* p. 533). In more recent times *P. sulfureus* has been mentioned among the luminescent fungi by MURRILL. In 1915 (28) he quotes "*Laetiporus speciosus* (BATT.) MURRILL" as being luminescent, and in 1920, in a popular article (91), he has given a picture of "*Laetiporus sulphureus* on ash tree" as one of "a collection of fungi that give forth a luminescence that is truly startling" (!) The other members of this collection were: *Ceriomyces crassus*, a cluster of *Armillaria putrida*, and *Panellus stypticus* (*cf.* Fig. 9-12, Plate II).

It would be interesting to know whether MURRILL actually saw himself the fruit bodies of these fungi in a luminescent state. For *Armillaria putrida*, which no doubt is to be considered identical with *A. mellea* this seems to be excluded, and it is to be feared that those readers who MURRILL's paper had made eager to verify his interesting statements, will have been disappointed![2])

According to AINSWORTH and BISBY (92) the genus *Laetiporus* MURRILL is based on *Polyporus sulphureus* FR.; *Laetiporus speciosus* (BATT.) MURRILL is quoted by DONK (93) as a synonym of *P. sulphureus* FR.

Investigators who have studied *Polyporus sulphureus* more closely in view of its luminescence, have so far not been able to confirm its luminosity. BULLER (12) could not distinguish luminescence in the fruit body of *Pol. sulphureus* and neither could MOLISCH (14) in its mycelium. We have made several isolations upon cherry-agar, and transfers also on bread-agar, both from spores and from flesh of the pileus of *Polyporus sulphureus*, from various specimens

[1]) See, however, A d d e n d u m, p. 212.

[2]) Certainly, this is not the right way to popularize science! Another objection to MURRILL's mycological work has been founded upon his rather deviating conception of nomenclature, so that he "juggled" (LLOYD) the names of the majority of the species he handled, and created numerous new combinations (*cf.* C. G. LLOYD, Myc. notes 31, 1908 p. 410). The reader will have observed already that MURRILL's contributions to the study of fungus-luminescence also show this feature. It may, however, not be omitted that MURRILL's taxonomical rearrangements have found more approval by some other outstanding mycologists!

found in Utrecht, on *Robinia*, and from a specimen, collected at Vragender (Gld.). The cultures have a very curious appearance, they are orange-yellow and powdry, owing to the development of numerous conidia, a phenomenon also mentioned by MOLISCH (14). Similar conidia masses were described for the first time by DE SEYNES (94), who found them in a fruit body. Luminescence was never observed in our cultures. The cultures of *Pol. sulphureus* present in the collection of the C.B.S., neither showed luminescence. Nevertheless, as BULLER demonstrated so clearly in *Panus stipticus*, it cannot be excluded that luminescent and non-luminescent strains exist of other fungi also. It was already mentioned that we obtained indications herefor in the case of *Mycena polygramma*. Thus nowadays, if any one is unable to observe luminescence in fungus-species for which such has been claimed, he will not so easily follow MOLISCH example, who drew the conclusion that such species "sind aus der Liste der Leuchtpilze zu streichen"! (14).

It may be added here that, according to ROUMEGUÈRE (62), PLINIUS tells of an *Agaricus* that was collected at night because it was luminescent, "qu'on a cru, de nos jours, retrouver dans le *Polypore officinal*". According to COSTANTIN & DUFOUR (95), *P. officinalis* is only a variety of *P. sulphureus*, growing on *Larix*. On the other hand, in the extensive studies on *Polyporaceae* by DONK (93) and by PILAT (96), *P. officinalis* is not included in the list of synonyms of *P. sulphureus*, so that the identity seems at least doubtful. SCHERTEL, in his interesting paper (97) quotes PLINIUS' communication as follows:

"In Gallien bringen hauptsächlich die hartschalige Früchte tragenden Bäume den *Agaricus* hervor; es ist dies aber ein weisser, riechender Pilz..... Er wächst oben auf den Bäumen und leuchtet zur Nachtzeit".

SCHERTEL (*l. c.*, p. 141) comments this observation as follows:

„Nach den über diesen Schwamm von früherher vorhandenen Abbildungen (MATTHIOLUS' Kreuterbuch, 1640) dürfte mit jenem *Agaricus* eine *Polyporus*art gemeint sein, von welcher wir bereits gehört haben, dass Angehörige dieser Familie die Fähigkeit zu leuchten besitzen".

It may be deemed difficult to identify the species PLINIUS alluded to from these sources. One would be inclined to think first of *Pleurotus olearius*, but the addition "oben auf den Bäumen" seems to point against this.

CRIÉ, in 1882, has mentioned *Polyporus citrinus* PERS. among the luminescent fungi. He states (21):

"Récemment, en effet, j'ai vu, dans notre pays, l'*Auricularia phosphorea*" (see below) "et le *Polyporus citrinus* produire des radiations lumineuses. L'*Auricularia phosphorea* Sow. croît sur les arbres à demi pourris et

le *Polyporus citrinus* PERS. sur les troncs des saules, des chênes et des pommiers".

Equivalent statements are found in two other papers of the same author,which appeared at about the same time (98, 99). MOLISCH has quoted "*Polyporus citrinus* (= *caudicinus*) (SCHAEFF.) SCHRÖT." among the species requiring further observations, whereas MURRILL quoted *Polyporus caudicinus* (SCOP.) MURRILL as luminescent. From various mycologists we learn that both *P. citrinus* PERS., and *P. caudicinus* (SCHAEFF.) SCHRÖT. have to be considered as synonyms of *P. sulphureus* BULL. So, *e. g.*, HENNINGS (72) p. 167, and RICKEN (43) have mentioned as such *P. caudicinus* (SCHAEFF.) SCHRÖT., and LLOYD (100) has given *P. citrinus* PERS. ("*citrinus*— as PERSOON called the wellknown *sulphureus*").

From recent synonymics we may quote that of DONK (93) who mentions both *Polyporus citrinus* PLAU. ex PERS., and *P. caudicinus* (SCHAEFF. ex KARST.) KÖHL. as synonyms of *Polyporus sulphureus* BULL. ex FR., and that of PILÁT (96) who mentions *Polyporus caudicinus* (SCOP.) SCHRÖT., and *Boletus citrinus* PLAUER in this respect. We thus may well consider *P. citrinus* and *P. caudicinus* to be equivalent with *P. sulphureus* in the lists of luminous fungi.

MOLISCH (9a), apparently, was not aware of, or didn't agree with this synonymic, for he quotes *P. sulphureus* under the definitely non-luminous species, and "*P. citrinus* (= *caudicinus* SCHAEFF.) SCHRÖT." among those worth further observation. Neither did MURRILL (28), who quoted *Polyporus caudicinus* at the side of *Laetiporus speciosus* among the luminescent fungi.

Considering these various quotations, *Polyporus sulphureus* and its allied forms may be deemed to deserve further attention by the students of fungus luminescence.

We have to deal with some more pore-forming fungi which have been indicated as luminescent, *viz.*, *Polyporus annosus* FR. *P. igniarius*, *Trametes Pini*, *Ceriomyces crassus* BATT.

The luminescence of *Polyporus annosus* was presumably first reported by W.G. SMITH (89) to whom material was sent of luminescent fungi from coal mines. Among these were fruit bodies of *Polyporus annosus*, "and they could be seen in the dark at a distance of 20 yards". From a later communication by SMITH (90) it is apparent that he has not seen the luminescence of the fruit bodies himself:

". . . . . the phosphorescence had departed by the time the plants reached me, but according to the statements of the miners, both the plant itself and its ramifying mycelium is so phosphorescent as to be plainly seen 20 yards off. . ."

This fungus proved to be *Polyporus annosus*, and, apparently, SMITH trusted the statements so much that he gave a slightly phan-

tastic figure, picturing a fruit body of *Polyporus annosus* as a radiating lamp (*cf.* Fig. 7, Plate II), which may have much contributed to the repeated quotations of *P. annosus* as a luminous fungus.

MOLISCH (14, 9a) has studied this fungus (= *Trametes radiciperda*) in pure culture on bread and on wood during two years, and observed neither rhizomorph-formation nor luminescence. BULLER observed no luminescence in the fruit body.

LUDWIG had indicated *Trametes pini* as the presumable cause of luminescence in certain pieces of wood with rhizomorphs. Also in this case MOLISCH (14, 9a), using pure cultures, observed neither rhizomorphs nor luminescence.

Polyporus igniarius was mentioned by MOLISCH and by KLEIN as a species worth further investigation. LUDWIG (13) didn't give any indications as to a possible luminescence of this species, but DUBOIS (26) mentioned it among the species possessing luminous rhizomorphs (*l. c.* p. 49). Probably also here the evidence largely rests on the combined occurrence of luminous rhizomorphs and fruit bodies of the fungus in question without sufficient guarantee that both belong together, and the same may be supposed for *Lenzites betulina* which DUBOIS quoted in the same respect.

It was already mentioned that, except *Pol. rhipidium*, no other culture of *Polyporus*- and *Fomes*-species was found to be luminous in the extensive collection of the C.B.S. Among these were *Fomes annosus* FR., and various strains of *F. igniarius* (L.) FR. Although continued attention may be worth while, at present it doesn't seem very probable that after a more profound study these species would still turn out to be luminescent.

Ceriomyces crassus BATT. was indicated as luminescent by MURRILL (28), who in 1920 (91) pictured it in the "collection of luminescent fungi" mentioned already above (*cf.* Fig. 9, Plate II). No doubt this fungus is identical with *Boletus crassus* MASSEE (*cf.* AINSWORTH and BISBY (92)), which species, according to SACCARDO (101), is closely related to *B. impolitus* FR. KONRAD and MAUBLANC (102) consider *B. crassus* MASSEE as a synonym of *B. impolitus* FR. According to KONRAD and MAUBLANC it is rare and little known, and apparently more widespread in the mediterranean regions. It may be recommended in the attention of students of fungus-luminescence.

It seems doubtful whether luminous *Gasteromycetes* actually exist. Luminescence has been reported for three species, *viz.*, *Dictyophora phalloidea* DESVAUX, *Ileodictyon cibarium* TUL., and "*Kalchbrennera coralloides* = *K. Tuckii* BERK."

According to MOLISCH, FRANCÉ once mentioned the luminescence of *Dictyophora phalloidea*, but MÖLLER, who studied the plant in its native country, did not report the luminescence; on the contrary, being questioned by MOLISCH about this point, he informed MOLISCH that he never observed this species exhibiting luminescence. Thus, there seems to be little reason left to condider *Dictyophora phalloidea* as a luminous fungus.

MOLISCH (9a) found *Ileodictyon cibarium* TUL. indicated as luminescent in a paper of v. LENDENFELD (103) on the luminous organs of fishes. Indeed the species is mentioned in this paper as an example of luminescent fungi, but apparently quite incidentally, and without mentioning the source of information, even the name is not quoted correctly.

The relevant passage in v. LENDENFELD's paper runs as follows: "Unter allen Gruppen von Tieren kommen leuchtende Arten vor. Abgesehen von den phosphoreszierenden Bakterien [O. KATZ, Proc. Linn. Soc. N.S.W. 1887] und Pilzen (*Ileodiction cerebrum*), der *Noctiluca* und andere finden wir die einfachste Leuchtvorrichtung bei den Cölenteraten",

In the quoted volume of Proc. Linn. Soc. N.S.W., O. KATZ published a number of papers on luminous bacteria (104), but he didn't report anything about luminous fungi.

Since no other quotation is present, it appears impossible to trace v. LENDENFELD's source of information.

LUDWIG has quoted the luminescence of *Ileodiction cibarium* on two occasions (13, 105, see also below); probably he used the same source of information as v. LENDENFELD's, since he also speaks of *I.* "*cerebrum*".

It is remarkable, that, in the "Lehrbuch" (13) he quotes many luminous fungi with the names of their observers, whereas for the species we are now considering he only remarks: "Schliesslich werden aus den Tropen noch *Ileodictyon cerebrum* und *Kalchbrennera coralloides* als phosphorescirend beschrieben".

Probably these quotations originate from descriptions of tropical voyages, and I have not been able to trace them further. In the original description of *I. cibarium* (106) no indications concerning its luminescence are found, nor in that of the closely related or identical *I. gracile* BERK. (107), nor in SACCARDO's Sylloge (108), nor in FISCHER's (109, 110, 111), and LLOYD's (112, 113) communications. Recently, *Ileodictyon cibarium* and *Dictyophora phalloidea* were again quoted as "said to be luminous" by HARVEY in his comprehensive book on luminous organisms (114).

Concerning *Kalchbrennera corallocephala* matters don't stand much better. It was mentioned in MOLISCH's list of luminescent species (9a) without indication of the source of information. Neither seems further tracing possible from LUDWIG's communications (13, *cf.* above), and (105):

TABLE III

Distribution of luminescence in the fungi.

A. Species for which luminescence seems well established.

Indication	Name	Luminescent parts	Where *discovered* and found so far	Description and/or indications about luminescence
◙	*Armillaria mellea* VAHL	mycelium, rhizomorphs	Europe, Azia, N. America	(9), (9a), (11), (19)
◙	*Pleurotus olearius* D.C.	pileus, mycelium	S. Europe	(9), (9a), (33)
□	*Clitocybe illudens* SCHWEIN.	„ „	*N. America*	(12)
□	*Panus illudens* (SCHWEIN.) FR.	„ no observations concerning mycelium	*N. America*	(34)
□	*Pleurotus Lampas* BERK.	„ „	*Australia*	(37)
□	„ *phosphorus* BERK.	„ „	*Tasmania*	(40)
□	„ *illuminans* MÜLL. et BERK.	„ „	*Australia (Queensl.)*	(34)
□	„ *facifer* BERK et CURT.	„ „	*N. America*	(34), (69)
□	„ *candescens* MÜLL. et BERK.	„ „	*Australia*	(34), (27)
△	„ *Gardneri* BERK.	„ „	*Brazil*	(39), (34)
△	„ *nidiformis* BERK.	„ „	*Australia*	(37), (34)
△	„ *Prometheus* B. et C.	„ „	*Hong Kong*	(34)
△	„ *noctilucens* LÉVEILLÉ	„ „	*Manilla*	(34)
△	*Panus incandescens* B. et BR.	„ „	*Queensland*	(34)
∧	*Pleurotus Emerici* BERK.	„ „	*Andaman Islands*	(49), (50), (52)
△	„ *lux* HARIOT	„ „	*Tahiti, Bora Bora*	(51)
△	„ *spec.* [S. R. BOSE]	„ „	*S. Burma*	(54)
◙	„ *japonicus* KAWAM.	„ ?	*Japan*	(48)
◙	*Panus stipticus* FR. *f. luminescens* BULLER	„ mycelium	*N. America*	(18), (70), (71)

◙	*Omphalia flavida* (CKE) MAUBL. et RANGEL	gemmifers, mycelium	Trinidad, Porto Rico	(18)
△	„ *Martensii* P. HENNINGS	pileus, myc. no. obs.	*Borneo*	(25)
◙	*Mycena illuminans* P. HENNINGS	„ „	*Java*	(26), (75)
◙	„ *polygramma* BULL.	— mycelium	Europe	(10), (81)
◙	„ *tintinnabulum* FR.	— „	„	(79)
◙	„ *galopus* PERS.	— „	„	(10), (81)
◙	„ *epipterygia* SCOP.	— „	„	(10)
◙	„ *sanguinolenta* ALB. et SCHWEIN.	— „	„	(10)
◙	„ *dilatata* FR.	— „	„	(10)
◙	„ *stylobates* PERS.	— „	„	(10)
◙	„ *zephira* FR.	— „	„	(10)
◙	„ *parabolica* FR.	— „	„	(10)
◙	„ *galericulata* (SCOP.) FR. var. *calopus* FR.	— „	„	§ 4
□	„ *inclinata* FR.	— „	„	§ 4
△	„ *pura* PERS.	parts of pileus	„	(10)
△	„ *spec.* cf. *capillaris*	— mycelium in luminescent leaves	„	§ 3
△	*Locellina illuminans* P. HENNINGS	pileus, no observations concerning mycelium	*Celebes*	(73)
△	„ *noctilucens* P. HENNINGS	„ „	*New Pommern* (*New Britain*)	(74)
△	*Fungus igneus* RUMPH.	„ „	*Amboina*	(45)
◙	*Polyporus rhipidium* BERK.	? , mycelium	*N. America*, Australia	(83), (82); § 4
△	„ *mycenoides* PAT.	pileus, no observ. conc. mycelium	*New Caledonia*	(85), (86)
△	„ *noctilucens* LAGERH.	„ „	*Angola*	(23), (86)
△	*Didymium spec.* (?)	fruit bodies on leaves	*Jamaica*, St. Kitts	(121), (22), (23)

(continued on p. 190).

TABLE III (continued)

B. Species, luminescense of which is doubtful.

Indication	Name	Luminescent parts	Where *discovered* and found so far	Description and/or indications about luminescence	
				"pro"	"contra"
●	*Collybia cirrhata* PERS.	— germinating sclerotium	Europe	(67), (13)	(14)
●	„ *tuberosa* BULL.	— „	„	(66), (13)	(14)
●	„ *tabescens* (SCOP.) FR.	pileus	France	(62)	(58)
○	*Naucoria semiorbicularis* FR.	„	?	(66), (13)	
○	*Collybia longipes* SCOP.	„	—	(66), (13)	
○	*Ag.* (*Tricholoma*) *acerbum* FR.	„	France	(65)	(65)
○	*Ag. fascicularis* HUDS.	wood with mycelium	„	(22)	
●	*Ceriomyces crassus* BATT. (= *Boletus impolitus* FR.)	pileus	N. America	(90), (91)	(12), (14)
○	*Polyporus Emerici* BERK.	?	?	(24)	
●	„ *sulphureus* FR.	pileus	Europe, N. Amer.	(88), (89), (90), (91)	
○	„ *caudicinus* (SCOP.) MURR.		—	—	—
○	„ *citrinus* PERS.		—	—	—
○	*Laetiporus speciosus* (BATT.) MURR.		—	—	—
○	„ *sulphureus* MURR.		—	—	—

O	*Polyporus annosus* FR.	wood with rhzomorphs and fruitbodies	England	(89) (12), (14)
O	„ *igniarius*	?	?	(26)
O	*Trametes pini* FR.	wood with mycelium	Europe	(13) (14)
●	*Corticium coeruleum* SCHRAD. (= *Auricularia phosphorea* SOW.)	wood with fungus	„	(21),(89) (117),(118)
O	*Corticium lacteum* FR.	?	„	?
●	*Kalchbrennera corallocephala* WELW. & CURR.) KALCHBR.	fruitbody	?	cf. (103)—(116)
●	*Ileodictyon cibarium* TUL.	„	?	
●	*Xylaria Hypoxylon* PERS.	invaded wood, and mycelium in pure culture	France	(21),(98),(99) (13),(119),(120) (9), (9a)
●	„ *polymorpha* GRÉV.	fruit body	„	(21),(98),(99)

Legenda (see also text).

Non-circular marks: Luminescent species.

◙ Taxonomically well founded, luminescent species.

△ Luminescent species, requiring further investigation.

□ Names, very probably to be considered as synonyms of the ◙-species below which they are quoted.

Circular marks: Species of doubtful luminosity.

● Continued observation especially indicated.

O Luminosity very doubtful.

○ Synonyms.

Numbers between brackets in last column refer to list of references at the end of the paper.

For additional notes concerning luminescence in pure culture of various species quoted in this Table, *cf.* § 5 of the present paper.

"Ob mehreren derselben" [Australian Phalloids] "die Eigenschaft der afrikanischen *Kalchbrennera corallocephala*, im Dunkeln zu phosphoresciren[1]), zukommt, ist bisher nicht untersucht worden".—[1]) Footnote: "Auch *Ileodictyon cerebrum* wird als Leuchtpilz genannt".

FISCHER (109) remarks: "Soll phosphoreszieren", but in the 2nd edition of his review (109a) this remark is no more to be found. Neither in WELWITSCH and CURREY's original description of the species (115), nor in KALCHBRENNER's paper (116), nor in FISCHER's more special studies (110, 111) luminescence is mentioned. Before *Kalchbrennera corallocephala* (WELW. & CURR.) BERK. can be regarded definitely as a luminescent fungus, new records seem much required.

In Fig. 5, Plate II, an illustration of *Kalchbrennera corallocephala* (WELW. et CURR.) K. is reproduced; in Fig. 4, Plate II, one of *K. Tuckii* (K. et M.O.) BERKL., a species which may well be considered to be identical with the preceding one. In Fig. 6, Plate II, part of a figure given by LLOYD is reproduced to give an impression of *Ileodiction cibarium* TUL.

A few words still may be said concerning some Basidiomycetes that were already mentioned as luminous very early, viz., *Corticium coeruleum* FR. (= *Auricularia phosphorea* SOW. = *Telephora phosphorea* FR.), and *Corticium lacteum* FR., = *Himantia candida* PERS. According to COOKE and BERKELEY (117) the phosphorescence of *Corticium coeruleum* was mentioned by FRIES (63), that of *Himantia candida* once by LINK, but already TULASNE (118) doubted the reliability of these records. Especially *Cort. coeruleum* has been quoted now and then in more recent enumerations, but I found only one communication of a new observation, *viz*,. of CRIÉ (21, quoted above, p. 185) The guarantee that the material underlying this observation was sufficiently pure cannot be estimated, and CRIÉ's statement is in want of confirmation before *Corticium coeruleum* can definitely be considered as a luminous fungus.

The knowledge about luminescence in the Ascomycetes appears in much the same state as that concerning the Gasteromycetes. Luminescence has been claimed for *Xylaria Hypoxylon* (L.) GREV., and *X. polymorpha* (PERS.) GREV. BULLER (12) and GUÉGUEN (119) have given some historical notes. Herefrom we learn that LUDWIG was the first to report luminescence of wood invaded by *Xylaria Hypoxylon*. Of course this is no conclusive proof that *Xylaria Hypoxylon* is the cause of the luminescence. In a later work LUDWIG (120) reported new observations along the same line, he stresses the differences between the luminescence caused by *Armillaria mellea*, and by *Xylaria Hypoxylon* in wood and mentions also differences in the emission spectra. Meanwhile, CRIÉ (21, 98, 99) observed luminescent fruitbodies of *Xylaria polymorpha*. MOLISCH (9) studied *X. Hypoxylon* and *X. Cookei* in detail, but he was unable to detect any luminescence in his pure cultures. MOLISCH has investigated also the luminescence of wood with *Xylaria*. If such wood was luminescent, which it was indeed in a few cases, MOLISCH

could cultivate *Armillaria mellea* or *Mycelium X* from it which could be made responsible for the luminescence. MOLISCH's argumentation looks very convincing, and it is remarkable that GUÉGUEN (119), at about the same time, in an apparently also reliable study, makes renewed claims for the luminescence of *Xylaria Hypoxylon.* His observation that crude cultures show luminescence doesn't seem so important as his statement that also pure cultures may emit a, be it faint, blueish light. It was only observable when the mycelium was in full development. BULLER (12) sees two possible explanations for the discrepancy between the results of MOLISCH and of GUÉGUEN. They may have used different culture media — GUÉGUEN appears to have obtained the best development on carrot — or they may have been working with different physiological, luminous and non-luminous forms. BULLER rightly emphasizes that the question of the luminosity of the *Xylaria*-species can only be settled by growing a large variety of forms in pure culture. It will be suitable to consider in this respect especially GUÉGUEN's culture conditions, because he reported the luminescence. I have not yet studied the *Xylaria*'s in detail, but I did not observe any luminescence in the species of *Xylaria*, present in the C.B.S., among which there were also cultures of *X. Hypoxylon.*

We still wish to mention a curious figure, published in the Gardener's Chronicle of 1874 (121), and reproduced on plate II, (fig. 8). According to the accompanying, anonymous communication, the fifigure came from Dr. HOOKER, and represents fruit bodies of a luminous fungus on the leaves of a *Spermacoce* in the island of St. Kitts. BERKELEY, apparently from the illustration, considered the fungus to be a species of *Didymium.* Presumably, this may be regarded as the source for PHILLIPS' and LAGERHEIM's quotation of *Didymium spec.* among the luminous fungi (*cf.* Table I) notwithstanding the fact that these authors give Jamaica as the locality instead of St. Kitts (= St. Christopher, in the Leeward Islands). BERKELEY's identification doesn't look so very convincing, *Didymium* being a Myxomycete. In view of the more recent observations of BULLER on *Omphalia flavida* I should rather like to suppose that HOOKER's fungus was a small *Mycena* or *Omphalia. Omphalia flavida* itself seems to be excluded, since its sporophores are non-luminous. Scientists in the West-Indian islands may be recommended to look for this small luminescent leaf-fungus again.

We will conclude this review with a new critical list of the luminescent fungi so far known (Table III), and a few remarks. The composition of the list is as follows. Those species which are certain, both to their being luminescent and to their specific existence are provided

with ▣. Secondly, a number of species is indicated of which there seems no reason to doubt the luminosity, but which are still insufficiently studied, for the greater part especially as to their specific nature, and their relation with other luminescent species. As far as possible, they are put in the neighbourhood of the species with which they will possibly appear to be related; they are indicated with △. In the third place, a number of species is given which are described as being luminescent, but which at present are, according to outstanding mycologists, to be identified with ▣ species. They are quoted with □, directly under the ▣ species to which they are brought. Finally the list includes a number of species, the luminescence of which has been mentioned by some authors, but could not be confirmed by others. The explanation herefor may be in part that these species include luminescent and non-luminescent strains, and therefore some of them still deserve further study. Those species which are among the first ones for which renewed observations may be indicated, are marked with ●, those for which luminosity seems indeed very doubtful are indicated with ○, synonyms with ○. It may be emphasized that I don't mean to say that the ●-species presumably will turn out to be luminescent, the mark ● only means that among the records of luminescence there are such that cannot be denoted as erroneous unless numerous observations with various strains will have failed to confirm them. And even in that case we would still retain the awkward feeling that in this field one positive statement can hardly be invalidated by a hundred negative ones. But it is the only way to prove or disprove old observations which were published with too little details to judge directly their reliability.

This no doubt lays a serious responsibility upon those who in the future want to add a new name to the list of luminous fungi. They will have to give as full as possible details concerning their observation, and to present data from which the reliability of their determination may be judged!

A thorough perusal of especially the older mycological literature may perhaps bring forward still other luminescent species. We hope that those who know such cases will publish them or communicate them to us. Furthermore, it would be worth while if mycologists in various parts of the world, and especially in the tropics would be willing to look for luminous species. This may reveal new and interesting cases of fungus luminescence, and furthermore lead to a more profound knowledge especially of those species indicated with △ in Table III, and of their geographical distribution. In order to facilitate the work, in an appendix we give a list of diag-

noses of species which may especially be considered worth while further investigation, and some directions how to collect material, and how to obtain cultures in the most valuable and reliable way.

We shall be very glad to receive information, and if possible also material of especially tropic and subtropic luminescent fungi, and, if possible, cultures of them.

Subcultures will eventually be sent to the C.B.S. at Baarn. The best would be to try to get specimens comparatively studied by mycologists; in this way uncertainties regarding specific qualities might have the greatest chance to be removed, and the geographic distribution of the various luminescent species would be traced in the best way.

APPENDIX

I. *Diagnoses of some luminescent fungi.*

1) Species that are insufficiently known regarding their geographical distribution or their specific nature (△ in Table III).

Pleurotus Gardneri BERK. See: (39) (34).

Pileo carnoso-coriaceo, subinfundibuliformi, glabro, flavo; lamellis longe decurrentibus, pallidioribus; stipite brevi, coriaceo, glabro, cinerescente.

Hab. in petiolis v. nervis semiputridis frondium Palmae a Brasiliensibus Pindoba nuncupatae, Natividade et Motto Grosso Brasiliae (GARDNER) et in Queenslandia-Australiae. - Pileus 6 cm latus, margine undoso lobatoque subtenaci, citrino; stipes $2^1/_2$ cm longus, $1^1/_4$ cm crassus, excentricus solidus. Totus fungus lumen phosphoreum emittit subsimile illi lampyridis pallide viride. - Ab indigenis nomine *Flor de Coco* designatur. Auctor in opella Fungi Brasil. n. 33 hanc speciem ad *Omphaliam* retulit.

Pleurotus nidiformis BERK. See: (37); BERKELEY: Lond. Journ. Bot. 3, 185 (1844); (34).

Praegrandis; pileo carnoso, cupuliformi, glabro, rufo, margine lobato-fisso, tenui, acuto, stipite centrali brevi, compresso, irregulari, firmo, glabro; lamellis ad basim stipitis decurrentibus, latis, distantibus, hic illic ramosis, ochraceis; interstitiis levissimis vel reticulatis.

Hab. ad terram, Swan River Australiae (DRUMMOND). - Pileus 15 cm altus, 40 cm latus; stipes 4 cm longus et crassus basi glebis terreis obrutus; lamellae latissimae. Affinis *P. ostreato*. Phosphoreus.

Pleurotus Prometheus BERK. et C.N. See: Pac. exp. n. 30; (34).

Albus, phosphoreus; pileo tenui, flabelliformi, minutissime virgato-maculato, in stipitem brevissimum postice attenuato; lamellis crebris angustis.

Hab. in lignis emortuis. Hong-Kong. - Phosphoreus.

Pleurotus noctilucens LÉV. See: Voy. Bonite; Ann. d. Sc. Nat. Oct. 1844, p. 171; (34).

Caespitosus albus; pileo sessili vel substipitato, carnoso-membranaceo, lobato vel flabelliformi, nudo, glabro; lamellis distantibus, basi reticulato-connexis.

Hab. in truncis arborum, Manilla. - Phosphorescens.

Agaricus (*Pleurotus*) *Emerici* BERK. See: (49), (50).

Pileus at first spathulate, quite smooth, dark brown; at length suborbicular, soon changing to white, with a slight tinge of yellow; minutely virgate; stem obsolete; gills of the same colour as the pileus, narrow interstices smooth. Pileus about ⅓ inch across, attached behind without any stem[1]), either nearly flat or helmet-shaped, emitting a most brilliant light, the entire substance being luminous. . . . . .

[1]) In Gard. Chron. 14, 338 (1880) BERKELEY reports that this species "occasionally has a very well marked stem". Pileus when most highly developed, scarcely more than an inch across. (BERK. G. C. 14) - From the Andaman Islands.

- SACCARDO seems to have overlooked this species. A diagnosis in latin was not to be found.

Pleurotus lux HARIOT. See: (51), (101).

Pileo dimidiato, applanato, deorsum truncato, stipitato, fusco-cinereo, margine integro obtusiusculo, subrevoluto, basi incrassatulo, tenuiter furfuraceo-tomentoso; stipite canescente, lamellis crassiusculis, membranaceis, albido-griseis, opacis, integris, liberis, deorsum confluentibus; sporis rotundatis, hyalinis, levibus, 4 μ diam.

Hab. in Borabora et Tahiti insulis (BRUNAUD). - Pileus 1 cm diam.; stipes 2 mm long; species per nutem lucifera. — The above is SACCARDO's description which represents the original one in a somewhat abbreviated form.

Panus incandescens B. et BR. See: F. Brisb. II, p. 55, t. X. f. 8 - 10; (34).

Pileo umbilicato, quandoque infundibuliformi, glabro minute virgato, margine involuto; lamellis tenuibus. longissime descendentibus, stipite sursum incrassato, deorsum cylindrico, striato.

Hab. Brisbane, Queensland (BAILEY). - Pileus 7.5 cm latus, stipes 3.5 cm. longus, 0.7 - 0.5 cm crassus.

Omphalia Martensii P. HENNINGS. See: (25).

Pileo membranaceo, campanulato, centro umbilicato, radiatim striato, isabellino, 5 - 9 mm diametro; stipite gracili, fistuloso, ½ - 1 mm crasso; lamellis subtriangularibus, latis subdistantibus, pallidis, decurrentibus; sporis non visis.

Hab.: Borneo occid. prope Bengkajang ad radicis. E. v. MARTENS leg. Martio 1863. - "Die Hüte der vorliegenden *Omph. Martensii* sitzen einzeln oder zu mehreren einer Wurzel auf und brechen aus den knollig verdickten stellen dieser hervor".

Locellina illuminans P. HENNINGS. See: (73), taf. 1, fig. 8.

Pileo campanulato, convexo, radiato-striato, vertice subapplanato, farinoso,, 1 - 1 ½ cm. diametro, brunneolo; stipite cavo, substriatulo, curvato, concolori, 1 ½ cm longo, 1 mm lato, basi discoideo-volvaceo, volva 2 - 3 mm lato, subdisciformi; lamellis liberis, ventricosis, flavo-brunneolis; basidiis clavatis, sporis subglobosis vel late ellipsoideis, 1 grosse guttulatis, brunneolis 8 - 9 × 6 - 7 μ.

Celebes, Tomohon, auf altem Holze, 21 Juni 1894 (SARASIN).

Lamellae with intense green luminescence, stipe dark.

Locellina noctilucens P. HENNINGS. See: (74).

Pileo membranaceo-carnuloso, campanulato-convexo, vertice applanato-depresso glabro, radiato-sulcato, levi, albo subcinerascente, ca. 1,5 cm. diametro; stipite tereti curvulo, levi, glabro, albido-nitenti, 1 ½ cm longo

1 ½ mm lato, basi volvato, volva membranaceo, alba, annuliformi vel subdisciformi; lamellis liberis, subconfertis, ventricosis, pallidis; sporis subglobosis 1 guttulatis 4½ - 5 μ, episporis pallido subbrunescente.

"Neu-Pommern, Ralum, auf einem Holzstück am Hause (DAHL, 21 Jan. 1897)". - According to DAHL greenly phosphorescent.

Fungus igneus RUMPH. See: (45).

".... sunt vero pusilli fungi magnitudine biobuli, instar petasi semi clausi, superius tuberculosi, glabri, & viscosi, brevissimo insidentes pedunculo, qui sese dein ad altitudinem trium pollicum elevat, albicans, & interne concavus.

Pileolus sese explicat ad magnitudinem denarii, superne pallide cinereus, inferne plicis refertus, ex cinereo nigricans, mollis & fragilis substantiae, odoris ingrati. Nocte lucent instar stellae igne coerulescente, vel instar millipedis commoliti". ".... in densa & obscura crescunt silva, ubi putridi locantur ramuli, sed semper ex solo, item in areis circa plaustra, ubi ligna subposita putrida sunt, tam ex solo quam carioso ligno....".

Vernacular names, according to RUMPHIUS: Tsjendawan, Coelat api, Mote. - Poisonous.

Polyporus noctilucens LAGERH. See: (23); (86).

Lignosus, apus, ad marginem circularem truncorum destructorum pullulans, aureo-fulvus, exsiccatus flavus, nocte eximie phosphorescens (WELW. in Sched.).

Hab. in apricis silvaticis prope Condo et Candumba in Angola Africae, Mart. 1857 (WELWITSCH) - "An Fomes?"

Polyporus mycenoides PAT. See: (85), (86).

Pileo exacte semi-globoso, 5 - 6 mm alt., usque ad apicem plicato, margine ultra hymenium sub-producto, centro rugoso gibbosoque; contextu nullo, h.e. ad cuticulam pileo reducto; hymenio convexo; tubulis gracilibus; poris angulosis, nudo oculo vix perspicuis; stipite gracili, ruguloso-villoso, centrali, 1 - 1.5 cm alt., cavo; sporis ovoideis, hyalinis, 6 × 3 -4 μ.

Hab, ad terram? Bourail - N. Caledoniae (BALANSA), Fungus phosphorescens, in sicco ochraceo-brunneolus. - SACCARDO's diagnosis, translated from PATOUILLARD's one in french.

2) The following species are known better, but still further observations especially regarding their geographic distribution and also regarding the luminescence of their various stages of development are wanted:

Polyporus (Pleuropus) rhipidium BERK. See: (83).

Caespitoso-imbricatus pileo coriaceo reniformi concentrice sulcato aculaceo-albo cute in areolas furfuraceus secedente; stipite laterali brevi sursum dilatato pruinoso; poris parvis albidis angulatis denticulatis quandoque elongatis.

"On rotten trunks, in woods. Waynesville, Ohio, August 21, 1844. T. G. LEA Esq. - Pilei gregarious, caespitoso-imbricate, coriaceous, 3/4 of an inch long and broad, deeply sulcate, yellowish, cracked into minute fufuraceous areolae. Stem 1/4 of an inch high, lateral, dilatated above, pruinose, yellowish when dry. Pores small, 1/100 of an inch in diameter, dirty white, angular, often elongated; edge of dessipiments toothed and uneven. - This curious species exactly resembles *Panus stipticus* with the exception of the hymenium. I know of no species to which it has a close affinity" (83).

- T. G. LEA collected in Waynesville also some species of *Panus*, described as new by BERKELEY (*e.g.* Nos. 121, 122 of his Decades), and a few more *Polypori*.

Pleurotus japonicus KAWAM. See: (48), Pl. I, II.
Pileo carnoso, mollo, conchato, dimidiato, firmo, elastico, sursum incrassato, basi non-stigoso; lamellis breve decurrentibus, subdistantibus, albis; sporae globosae et magnae; ad truncos praecipue Fagi; venenata. - Nom. Jap.: Tsukiyo také; Kuma-bera; Watari. - Pileus usually lateral in relation to the stem, half-moon shaped or reniform, light brown with yellowish or rossy, in old specimens dark brown with purple. Flesh white. Stem 1.4 - 2.5 cm long 1.5 - 3.0 (- 4 à 5) cm thick, dark purple in centrum. Gills white to slightly yellowish, not branching, shortly decurrent, abruptly ending. Spores spherical, 13 - 17 μ in diam, white (slightly lilac in mass). In clusters on decaying beech trunks in mountainous regions, in the autumn, mostly at least 4 m high. - Luminous and very poisonous (Abreged indications from [48]. - "*Pleurotus olearius* D.C. with which HENNINGS confounded the present species, differs from this markedly in having comparatively slender stem which is from one to three times as long as the diameter of the pileus, and further in having pileus meagre in flesh and of a bright yellow color". (48).

Mycena illuminans P. HENNINGS. See: (25a).
Pileo tenui membranaceo, subcampanulato, dein convexo, pallido vel flavidulo, medio umbilicato depresso, viscido, obscuriori, radiatim striato plicatoque, 5 - 15 mm diam.; stipite fistuloso, tereti; curvato, pallido, leavi, glabro, 5 - 12 × 0.7 - 1 mm, basi bulbilloso subdiscoideo usque ad 2 mm incrassato; lamellis sinuoso-adnatis, subdistantibus, inaequilongis latisque medio usque ad 2 mm latis ventricosis, utrinque attenuatis, pallidis vel albis; basidiis clavatis ca 20 - 25 × 6 - 8 μ, sporis globosis, laevibus, 1 - guttulatis, hyalines, 6 - 8 μ.
- Java, Hort. Bogor., ad truncos Calami. VOLKENS. - According to VOLKENS intensely luminescent with green colour.

3) It was mentioned before that *Pleurotus olearius* D.C. is perhaps much more widely distributed, especially in the warmer regions than was formerly accepted, since, very probably, it has been described under various names. It may be worth while to look for this species also, in order to enlarge the knowledge regarding its geographical distribution. Since some of the species quoted under 1) in this Appendix may also turn out to belong to *P. olearius* D.C., it seems useful to quote the descriptions of *P. olearius* and its thus far recognised co-species as well.

Pleurotus olearius D.C. See: (34).
Caespitosus; pileo carnoso, subexcentrico, plano vel umbilicato, sicco, rubro-fulvo, tandem saturate brunneo; stipite solido, firmo, rharbarbarino-fusco; lamellis decurrentibus, confertis, angustis, luteis.
Hab. in Europa australi in *Olea* aliisque arboribus, nec non in Africa australi. - Lamellarum phosphorescentia maxime insignis. . . . - Sporae albae 5 × 4 μ.

Clitocybe illudens SCHWEIN. Car. No. 604, FR. Epicr. p. 66; see: (34).
Pileo carnoso, applanato, obscurius virgato, margine inflexo glabro; stipite tolido, longissimo, compresso, basi attenuato; lamellis decurrentibus, confersissimis, tenerrimis ramosis.

Hab. in America boreali. - Extus intusque unicolor, foetens, valde distincta.

Panus illudens (SCHWEIN). FR. . . . . SCHW. Carol. No 604. See: (34).
Croceus; pileo carnoso-lento, applanato-umbonato, inaequali, virgato; stipite lignoso, solido, elongato deorsum attenuato; lamellis subdecurrentibus, ramosis, pallidioribus.
Hab. Caespitosus ad basim truncorum Carolinae (CURTIS) -. . . . Proximus est *Ag. mauritiano* LÉVEILL.

Pleurotus Lampas BERK. See: (37).
Fascicularis; phosphoreus; pileo centrali lobato carnoso glabro fulvo-nigrescente, margine tenui involuto; stipite compresso sursum incrassato solido demum fisso glabro; lamellis angustis integerrimis longissime decurrentibus. DRUMM. n. 109.
Hab. On the stems of sickly but living plants of *Grevillea Drummondii* PREISS, near the roots. - Australia. - Pileus 4 inches across, tawny to dark brown, stem 2 inches high, ½ an inch or more thick, solid, smooth. - Gills narrow, yellow when dry, very decurrent . . . . . Spores white. - Allied to *Ag. nidiformis* BERK.

Pleurotus phosphorus BERK. See: (40).
Pileus infundibuliformibus, glabris pallidis dense caespitosis; stipitibus utplurimum centralibus deorsum attenuatis subsericeis, supra e lamellis latiusculis integris descendentibus lineatis. GUNN., No 1361.
Hab. On roots of trees, Oct. 1845, and abundant in the succeeding January and February. - Tasmania. - Pilei 3 - 5 inches across, pale, yellowish brown, stem 1 - 2 inches high. Gills rather broad above, attenuated and decurrent behind, forming lines on the stem. Spores broadly ovate, white, or when seen in a dense mass, tan-coloured. - Solitary individuals, or specimens in the midst of a tuft somewhat different, having a short obtuse stem and abruptly ending, though much attenuated gills. Strongly phosphorescent, according to GUNN. "Certainly different from the two phosphorescent Australian species *A. nidiformis*, and *A. lampas* . . . ."

Pleurotus illuminans MÜLL. et BERK. See: (34).
Phosphoreus; pileo glabro fulvo; stipite crasso; lamellis latis, crassis, decurrentibus.
Hab. in Australia (TALBOT) in ligno emortuo, Rochampton in Queensland (THOZET). - Pileus circiter 5 cm latus.
(= *P. olearius* D.C. lamellis crassis quia ab insectis deformatis (35)).

Pleurotus facifer BERK. et CURT. See: (34), (69).
Caespitosus, phosphoreus, fusco-flavus; pileo tenui, convexo, subumbilicato; stipite subcentrali, solido, fibroso, albido-pruinoso; lamellis angustis, compositis, decurrentibus.
Hab. in Pensylvania Amer. bor. (MICHENER, CURTIS) - Pileus 8 cm latus, stipes 13 cm vel ultra longus, 8 mm crassus, fibrosus, subtiliter pruinosus; lamellae compositae; sporae candidae. Species singularis habitu *P. illudentis*.

Pleurotus candescens MÜLL. et BERK. See (34), (27).
Pileo excentrico glabro, ex albo sordide fulvescente, margine inflexo; stipite sursum dilatato, glabro; lamellis tenuibus, longe decurrentibus, hic illic laceratis.
Hab. in ligno emortuo in solo sabuloso, Melbourne in Australia. - Pileus 4 - 5 cm latus, stipes 2½ cm. longus. Valde phosphorescens. Stricte affinis *P. Lampade* et *P. noctilucenti* sed lamellis tenuioribus.

4) It doesn't seem necessary to quote here descriptions and illustrations of the more common European species, since these may be found in easily available books on fungi. It will, however, be useful to look for the occurrence of these species in other parts of the world, especially in connexion with the luminescence of leaves.

Neither did it seem necessary to quote the descriptions of *Kalchbrennera corallocephala*, and of *Ileodictyon cibarium* TUL. These species are well known, pictures thereof are represented at our plate II. Notwithstanding their connections with fungus luminescence appear to be very doubtful (*cf.* p. 187), it may be worth while to give these species further attention in this respect.

II. *Some directions for collecting fungus material, and for obtaining cultures.*

Directions for collecting fungi, and the notes required for scientific purposes are to be found in various fungus-books. A brief recall of some principal points may be given here.

According to SPILGER (122), the specimens are to be wrapped in paper directly after being collected. Besides adult specimens one should collect also young ones. From each fund detailed notitions should be made as to the way of growing (alone or in clusters, in wide rings, &c), the locality (name!, type of soil and vegetation, inclination, illumination, on soil or on wood, in the latter case whether living or dead wood, species, &c): date, climatic conditions. A piece of the substratum should be collected too. Of special importance is to note the colour of the fresh fungi (pileus, stem, gills), the nature of the flesh (whether soft or hard &c, change of colour when broken, smell and taste), one should also note measures of specimens one doesn't collect, "sowie sonst alles, was uns bezüglich des Pilzes auffält und bemerkenswert erscheint".

In order to be preserved, the fungi can be thoroughly dried or kept in alcohol or formol, the colours then are lost,but the preservation of the material is important in view of the possibility of a postponed microscopical investigation. However, it appears useful, if possible, to examine microscopical features already at the fresh pilei: measures of spores, number of spores per basidium, measures of basidii, form and measure of cystides, &c. Besides this, a detailed macroscopical description should be made, in which especially form and position of gills are important (whether equally long, split, decurrent, &c). If possible one should make sketches of fresh pilei and of median sections, and make aquarells. The colour of the spores is best observed enabling a pileus to shed spores on paper in quiet air with a rather high degree of moisture, *e.g.* under a jar or tin.

In order to obtain cultures, we should like to devise the method described in the present paper (*cf.* p. 202): collecting spores from a small pileus or a part of a large pileus on sterile agar by laying the spore-shedding part on two parallel glass bars closely above the agar,in a PETRI-dish. We use cherry-agar for collecting spores and for the first tranfers, but probably any slightly acid fruit agar will be suited. Many Basidiomycetes, especially those occurring on stumps of trees, &c, appear to thrive well on sterilized twigs or blocks of wood, *e.g.* from *Acer*, on which substratum many cultures are kept in the C.B.S. at Baarn.

§ 5. SOME OBSERVATIONS ON PURE CULTURES OF LUMINESCENT FUNGI.

So far, we have cultivated the following luminescent fungi in order to compare the relative intensity of luminescence with a view to physiological work: 1) *Armillaria mellea* (QUÉL.) VAHL, various strains, obtained by making isolations from luminescent wood (*cf.* § 2) or from fruitbodies or from spores, 2) *Clitocybe olearia* D.C., obtained from the C.B.S., 3) *Clitocybe illudens* SCHWEIN., obtained from the C.B.S., 4) *Omphalia flavida* (CKE) MAUBL. & RANGEL, obtained from the C.B.S., 5) *Mycena galopus* PERS., various strains cultivated from spores of fruitbodies collected in the neighbourhood of Utrecht, 6) *Mycena epipterygia* SCOP., idem, 7) *Mycena polygramma* BULL., a strain cultivated from spores of a fruitbody collected near Utrecht, 8) *Mycena tintinnabulum* FR., obtained from the C.B.S., 9) *Mycena inclinata* FR., cultivated from spores of fruitbodies, collected in the neighbourhood of Wageningen, supplied by Dr. OORT, 10) *Mycena galericulata* SCOP. var. *calopus* (P) FR. — which, according to OORT (16) is identical with *M. inclinata* — obtained from the C.B.S., 11) *Mycena parabolica*, obtained from the C.B.S., 12) *Mycena sanguinolenta* ALB. & SCHWEIN., some strains cultivated from spores of fruitbodies in the neighbourhood of Wageningen, supplied by Dr. OORT, 13) *Polyporus rhipidium* BERK., obtained form the C.B.S.

Moreover, a number of other species was brought into pure culture, in view of their possible relation to fungus luminescence. In this respect we mention especially *Panus stipticus* FR.: a strain of Siberian origin, *Mycena epipterygoides* PEARS., *M. capillaris* SCHUM. *Collybia tuberosa* BULL., *C. cirrhata* PERS., *Clitocybe tabescens* (FRIES ex SCOP.) BRES., *Polyporus sulphureus* FR.

So far, in the cultures of these species no luminescence was observed, but the observations will have to be continued, since many of the species have not yet been sufficiently studied.

The cultures are kept in culture tubes on oblique agar-layers. So far, two different nutrient media have been tried, *viz.*, cherry-agar and bread-agar. They are prepared as follows:

Cherry-agar.

1 Kg ripe cherries, boiled in 1 l. water, the extract is poured off, the stones of the cherries are removed, and the flesh is rubbed through a metal sieve (pores of about 2 qmm), the material that passes the sieve is added to the extract. The nutrient agar has the following composition: Cherry extract as described: 1 part, tap water: 2 parts, agar: 2%.

Caution must be taken against too extensive heating; as a rule we have sterilized the cherry extract and an aliquote portion of agar-solution separately at 120° for 20 minutes, joint them immediately thereafter, and then pou-

red the ready medium into sterilized tubes. If sufficient care is taken for aseptic work, the filled tubes needn't to be heated anymore.

Bread-agar.

Instead of using bread-media as such, we found it to be advantageous to supply the bread also in an agar medium. We used the ordinary wheat bread; in the first time sometimes milk-bread was taken, mostly however water-bread. During the war the meal used for the bread varied many times in composition; the various portions were used mixed, and no definite influence of these variations upon the growth of the cultures was found. The bread was cut into slices, the crusts were removed, and the slices dried at low temperature. After the bread was dry, it was ground in a morter into fine crumb. The medium was composed as follows: Dried bread: 10%, agar: 1.8%, in tapwater. The ready medium was filled into sterilized culture tubes, and thereafter sterilized about 20 min. at 120°.

New isolations were always started upon cherry-agar; culture tubes were used from the beginning, no use being made of PETRI-dishes, except for collecting spores. Hereto a pileus of a fungus or a piece of a pileus or only a piece of a lamella was placed upon 2 flamed glass bars which were layed parallelly upon the layer of cherry-agar in a small PETRI-dish (about 4 cm diameter). The spores shed by the hymenium fell upon the agar between the two glass bars. After about 24 hours the spore-shedding part was carefully removed, and a piece of agar, covered with spores, was introduced into a culture-tube with cherry-agar.

Collecting the spores directly upon cherry-agar in this way, in some species germination was more easily obtained than when the spores were collected *e.g.* upon a glass plate, presumably because they didn't dry. The transfer of cultures to fresh tubes was achieved by transferring a small bloc of agar covered with the mycelium. A stiff steel needle with rectangularly bent point was used for the transfer. As a rule in the way described the cultures were pure from the beginning; for the first transfers cherry-agar was used; later on also bread-cultures were made. On bread-agar in most cases the development is much more abundant than on cherry-agar, and the luminescence as a rule is stronger too.

As to the appearance of the cultures, only a few remarks will be made. The type of development on both media is much the same, on bread, however, it is more abundant in most cases. *Armillaria mellea* develops the characteristic mycelia, white in the younger, brownish in the older parts, with rhizomorphs originating especially from the inoculation block, and penetrating the agar. The luminescence is very bright and regularly occurring, but mostly confined to rather small parts of the culture. Only at places where abundant, white mycelia develop, as sometimes occur between the agar and the glass-wall, extensive luminescent area's may be found. We observed no definite differences in the appearance of cultures of various origin, *viz.*, from luminescent wood, from spores, or from parts of a fruit body. Last winter, in some cultures small fruit bodies were formed. The cultures present under the names *Clitocybe olearia* D.C. and *Clitocybe illudens* SCHWEIN. are yellowish, slightly brown in the older parts; so far, their luminescence was found to be

rather faint and irregular in its occurrence, but if present it mostly extends over a large part of the culture. *Omphalia flavida* develops a thin, yellowish mycelium which as a rule is brightly luminescent. The luminescence of the various species of *Mycena* was carefully investigated by BOTHE (10). A few remarks, therefore, may be sufficient. Most species develop fairly abundant mycelia; in *Mycena epipterygia* and *M. inclinata* the mycelium is white; in *M. polygramma* and *M. tintinnabulum* it is white when young; growing old it becomes dark coloured, especially in the last mentioned species. Somewhat dirty or yellowish white is the mycelium of *M. parabolica*, of *M. galopus*, and of *M. sanguinolenta*. As for the luminescence, our strain of *M. polygramma* is very brightly luminescent, especially in young cultures. As a rule the luminescence extends over a large area of the culture. It was already remarked in § 4, that in a strain present in the C.B.S., so far no luminescence was observed, but we have not yet cultivated this strain. Moreover, we isolated a non-luminous strain from material collected in nature (*cf.* § 4). A fairly strong luminescence was often observed in *M. parabolica*, and, a few times also in *M. epipterygia*. In general the luminescence of these and the remaining species was less regular than that of our luminescent strain of *M. polygramma*. With *M. epipterygia* and *M. galopus* we sometimes observed that old cultures werd especially brightly luminescent, as has also been recorded by BOTHE (10), however young cultures were also found luminescent. According to BOTHE, *M. epipterygia* was not luminescent on bread; however, our cultures on bread-agar did show luminescence. *M. zephira* was found very brightly luminescent by BOTHE; so far, we had no occasion to study this species. *Polyporus rhipidium* was rather brightly and regularly luminescent; it develops a rather abundant, slightly yellowish white mycelium.

A few records of luminescence of our cultures are collected below. The cultures were selected under complete dark-adaptation of the observer, and, as much as possible, arranged in the order of brightness of luminescence. The names then were noted afterwards. The cultures were grown in a thermostate at 23° C, in the dark.

11-10-1943.

The following cultures werd found luminescent (arranged in order of brightness):

Mycena polygramma	on bread-agar,	inoculated	2-9-'43.
„ *tintinnabulum*	„ „	„	2-9-'-43.
„ *polygramma*	„ cherry-agar,	„	2-9-'43.

(continued p. 204)

(continued)

Omphalia flavida	on	cherry-agar,	inoculated	21-5-'43.
„ „	„	„	„	21-5-'43.
Mycena epipterygia	„	bread-agar,	„	2-9-'43.
Omhalia flavida	„	„	„	21-5-'43.
Polyporus rhipidium	„	„	„	2-9-'43.
Mycena tintinnabulum	„	cherry-agar,	„	2-9-'43.
Clitocybe illudens	„	bread-agar,	„	2-9-'43.
Mycena tintinnabulum	„	cherry-agar,	„	2-9-'43.
„ *galopus*	„	bread-agar,	„	2-9-'43.
Clitocybe illudens	„	„	„	1-7-'43.
„ *olearia*	„	cherry-agar,	„	2-9-'43.

Obviously, cultures of *Armillaria mellea* have not been included into this record.

1-3-1944.

Luminescence of cultures, arranged in order of brightness.

Omphalia flavida	on	cherry-agar,	inoculated	17- 1-'44.	
„	„	bread-agar,	„	17- 1-'44.	
Mycena parabolica	„	„	„	18- 1-'44.	
„ *polygramma*	„	„	„	17- 1-'44.	
„ *tintinnabulum*	„	cherry-agar,	„	17- 1-'44.	
Armillaria mellea	„	bread-agar,	„	18- 1-'44	with very brightly luminescent spots.
Mycena sanguinolenta	„	cherry-agar,	„	10-12-'43	
„ *polygramma*	„	„	„	17- 1-'44.	
„ „	„	„	„	17- 1-'44.	
„ *tintinnabulum*	„	bread-agar,	„	17- 1-'44.	
„ „	„	cherry-agar,	„	17- 1-'44.	
„ *galericulata*, var. *calopus*	„	cherry-agar,	„	18- 1-'44.	
„ *parabolica*	„	„	„	18- 1-'44.	
„ *galericulata*, var. *calopus*	„	bread-agar,	„	18- 1-'44.	
Polyporus rhipidium	„	„	„	17- 1-'44.	
Clitocybe olearia	„	„	„	17- 1-'44.	
Mycena parabolica	„	cherry-agar,	„	18- 1-'44.	
Armillaria mellea (from lum. wood),	„	„	„	7- 2-'44.	
Mycena epipterygia	„	bread-agar,	„	17- 1-'44.	
„ *galericulata*, var. *calopus*	„	cherry-agar,	„	18- 1-'44.	
Armillaria mellea (from spores)	„	„	„	18- 1-'44.	
Clitocybe olearia	„	„	„	17- 1-'44.	
Armillaria mellea (from lum. wood)		bread-agar,	„	18- 1-'44.	
Mycena parabolica	„	cherry-agar,	„	13-10-'43	(very faint).

Moreover still many other cultures of various strains of *Armillaria mellea* were found to be luminescent, as well as some older cultures of *Omphalia flavida* and *Mycena polygramma*.

21-7-1944.

Luminescence of cultures, arranged in order of brightness. All inoculated 21-6-'44.

Mycena polygramma	on	bread-agar.
Armillaria mellea (from lum. wood)	„	„
Omphalia flavida	„	„
„ „	„	cherry-agar.
Polyporus rhipidium	„	bread-agar.
Clitocybe olearia	„	„
„ „	„	cherry-agar.
Mycena tintinnabulum	„	bread-agar.
„ *epipterygia*	„	„
„ *polygramma*	„	cherry-agar.
„ *parabolica*	„	„
„ „	„	bread-agar.
Mycena tintinnabulum	„	cherry-agar.
Clitocybe illudens	„	bread-agar.
Mycena galopus	„	„
„ „ (other strain)	„	bread-agar.
Armillaria mellea (from spores)	„	„
Mycena galericulata, var. *calopus*	„	„
Armillaria mellea (from lum.wood)	„	cherry-agar.
„ (from spores)	„	bread-agar.
„ („ „)	„	„
Mycena galopus	„	cherry-agar.

A number of further tubes with *Armillaria mellea* practically all showed luminescence.

It is well-known that cultures of luminous fungi may preserve their luminescence during a considerable time. The following record may illustrate this.

11-3-1945.

Luminescence of cultures, arranged in order of brightness. Practically only bread-cultures examined. Cultures had been kept in an unheated room since 6-12-'44. Examined at about 20° C, at which temperature they were brought about 12 h. before examination.

Armillaria mellea (from lum. wood), on cherry-agar, inoculated 4-11-'44,
Armillaria mellea (from lum. wood), on cherry-agar, inoculated 6-10-'44; both with strongly luminescent border.

Omphalia flavida, on bread-agar, inoc. 17-11-'44, homogeneously luminescent.

Mycena galopus, on bread-agar, inoc. 17-11-'44, homogeneously luminescent, remarkably strong for this species, about equal to *Omph. flavida*.

Mycena polygramma, on bread-agar, inoc. 6-10-'44, homogeneously luminescent.

Armillaria mellea, *Mycena galericulata* var. *calopus*, *Mycena tintinnabulum*, on bread agar, inoc. 6-10-'44, about equally luminescent.

With locally strongly luminescent borders:

Clitocybe illudens, *Polyporus rhipidium*, *Armillaria mellea*, (on bread agar, inoc. 6-10-'44).

Armillaria mellea (on bread-agar, inoc. 17-11-'44).

With weakly luminescent border: *Mycena inclinata*, on bread-agar, inoc. 6-10-'44.

Finally we present a series of successive observations on cultures inoculated for the greater part on 10-8-'45 upon cherry-

agar, and on 15-8-'45 upon bread-agar. Records of luminescence are given again arranged according to brightness.

In order to abbreviate the list, in the first record a brief characterization of the various strains which in this series showed luminescence is given under the number under which they are present in our collection. The numbers refer to the strains, they were present on cherry-agar (ch) or bread-agar (br.) In the further records then only the numbers are quoted, with (ch) or (br), except in a few cases, in which in a later record luminescence was observed in a strain that did not show it in the first record.

I. Record of 5-9-'45. Arranged in order of brightness.

Strain No. Characterization

15. *Mycena polygramma*, from Bunnik near Utrecht, from spores, isol. 1940, br.
24. *Armillaria mellea*, from luminous wood, Zaandam (*cf.* §2), isol. 1940, br.
15. *cf.* above, ch.
25. *Armillaria mellea*, from luminous *Pinus* bark, Huis ter Heide near Utrecht, isol. 1940, br.
19. *Omphalia flavida*, from C.B.S., ch.
26. *Armillaria mellea*, from luminous wood, strain SP., br.
18. *Clitocybe olearia*, strain ZOBL, from C.B.S., ch.
28. *Armillaria mellea*, from luminous wood, Maarn near Utrecht, isol. 1941, br.
27. *Armillaria mellea*, from a fruit body, Warnsveld (Gld.), br.
18. *cf.* above, br.
30. *Armillaria mellea*, from luminous wood, Baarn, ch.
17. *Clitocybe illudens*, from C.B.S., br.
29. *Armillaria mellea*, from luminous wood, strain L, Utrecht, br.
32. *Armillaria mellea*, from luminous wood, strain H, Utrecht, ch.
16. *Mycena tintinnabulum*, from C.B.S., br.
32. *cf.* above, br.
16. *cf.* above, ch.
24. *cf.* above, ch.
20. *Polyporus rhipidium*, from C.B.S., br.
36. *Armillaria mellea*, from spores, de Bilt near Utrecht, isol. 1943, ch.
27. *cf.* above, ch.
33. *Armillaria mellea*, from spores, Rhijnauwen near Utrecht, isol. 1940, ch.
48. *Mycena galopus*, from spores, De Bilt near Utrecht, isol 1943, br.
19. *cf.* above, br.
17. *cf.* above, ch.
38. *Mycena parabolica*, from C.B.S., ch.
50. *Armillaria mellea*, from luminous wood, Warnsveld (Gld.), isol. 1944, br.
25. *cf.* above, ch.
26. *cf.* above, ch.
53. *Armillaria mellea*, from luminous wood, Delft, isol. 1944, br.
20. *cf.* above, ch.
39. *Mycena galericulata* (SCOP.) FR., var. *calopus* FR., from C.B.S., ch.
44. *Mycena inclinata*, from spores, Wageningen, isol. 1943, br.
50. *cf.* above, ch.
33. *cf.* above, br.
30. *cf.* above, br.

II. Record of 12-9-'45. Arranged in order of brightness:
15 br. - 24 br. - 19 ch. - 25 br. - 26 br. -18 br. - 19 br. - 15 ch. - 16 br.

48 br. - 50 br. - 27 br. - 38 ch. - 13 (*Mycena epipterygia*, from spores, strain N., isol. 1941) ch. - 29 br. - 32 ch. - 32 br. - 20 br. - 24 ch. - 27 ch. - 28 br. - 17 br. - 33 ch. - 17 ch. - 25 ch. - 53 br. - 16 ch. - 20 ch. - 50 ch. - 30 br. - 18 ch. - 26 ch. - 33 br. - 36 ch. - 39 ch., - 30 ch.; newly luminescent: 36 br.

The placing of the strains of *Armillaria mellea* between the other ones was not very definite since luminescence is confined in them to small, sometimes very bright spots, whereas the others show luminescence more equally expanded over the surface. Checking *Armillaria* and the others separately the mutual placing of the *Armillaria*'s was rather correct; in the other range, it seemed better to exchange the strains 20 ch. and 18 ch.

III. Record of 18-9-'45. Arranged in order of brigthness. This time, *Armillaria mellea*-strains were arranged separately.

15 br. - 19 ch. -19 br. - 15 ch. - 48 br. - 18 br. - 13 ch. - 38 ch. - 16 br. - 39 ch. - 20 br. - 48 ch. - 16 ch. - 17 ch. - 13 br. (newly luminous) - 9 (*Mycena galopus*, strain 2, from spores, Houdringen near Utrecht, isolated 1941) ch - 18 ch.; almost invisible: 17 br. - 44 br. ; no more luminous: 20 ch.

Strains of *Armillaria mellea*: 24 br. - 26 br. - 50 br. - 30 br. - 32 br. - 24 ch. - 27 ch. - 25 br. - 32 br. - 27 ch. - 29 br. - 34 br. - 53 ch. - 28 br. - 26 ch. - 25 ch. - 29 ch. - 53 br. - 33 ch. - 50 ch. - 36 ch. - 33 br. - 36 br.; no more luminous: 30 ch.

IV. Record of 26-9-'45. Arranged in order of brightness, *Armillaria mellea* separately.

15 ch. - 19 br. - 48 ch. - 19 ch. - 48 br. - 18 br. - 39 ch. - 13 ch. - 15 ch. - 13 br. - 38 ch. - 16 br. - 16 ch. - 20 br. - 44 br. - 9 ch. (the last four very weak); no more luminous: 18 ch. - 17 ch. - 17 br.

Armillaria mellea: 24 br. - 26 br. - 50 br. - 53 br. - 27 br. - 26 ch. - 32 br. - 30 br. - 25 br. - 32 ch. - 36 br. - 34 br. - 29 br. - 53 ch. - 24 ch. - 27 ch. - 31 br. - 36 ch. - 29 ch. - 33 br. - 28 br. - 50 ch, - 25 ch. (last 3 very weak); no more luminous: 33 ch.

V. Record of 19-10-'45. Arranged in order of brightness, *Armillaria mellea* separately.

19 br. - 38 br. (inoculated 3-9-'45) -39 br. (3-9-'45) - 39 br. - 8 (*Mycena galopus*, strain 1, from spores, Houdringen near Utrecht, isolated 1941) br. (3-9-'45) - 48 ch. - 19 ch. - 48 br. - 15 br. - 38 ch - 8 ch. - 13 br. - 13 ch. - 15 ch. - 34 br. - 16 br.; no more luminous: 16 ch. - 39 ch. - 18 br. - 20 br. - 9 ch.

Armillaria mellea: 26 br. - 53 br. - 27 br. - 26 ch. - 24 br. - 50 br. - 30 ch. - 25 br. - 33 br. - 32 ch. - 29 br. - 29 ch. - 31 br. - 36 ch.; no more luminous: 27 ch. - 28 br. - 25 ch. - 50 ch. - 34 br. - 36 br. - 32 br. - 53 ch. - 24 ch.

The various records reveal that in our collection the brightest luminescence was shown as a rule by our strain of *Mycena polygramma* (No 15), by various strains of *Armillaria mellea*, and by *Omphalia flavida*. Whereas the luminescence of *Mycena polygramma* and of *Omphalia flavida* was more or less regularly distributed over the whole surface of the culture, in *Armillaria mellea* it was confined

to small spots of young mycelium, tips of the rhizomorphs, etc.

From these three species emission spectra could be determined, whereas *Mycena polygramma* and *Omphalia flavida* appeared the best suited for physiological work. Some preliminary results of this work will be presented in a forthcoming paper (123).

Summary

Luminescent wood, collected at various localities in the Netherlands, always contained *Armillaria mellea* as the luminescent organism (§ 2).

Collecting luminescent leaves, we once found sporophores of a small *Mycena*, closely answering the diagnosis of *M. capillaris*, on the luminescent spot. Unfortunately, the spores have not germinated (at 23° C.). *M. capillaris* was cultivated later on from spores, applying lower temperatures: these cultures on cherry- and bread-agar were non-luminescent. Therefore, and for small morphological differences, some doubt exists as to the full identity of the fungus, causing the luminescent spots, with *M. capillaris*, but it may well be deemed very probable that the special, small *Mycena*, pictured in fig. 1 of Plate I, is the cause of the luminescent spots on beech- and oak-leaves (§ 3).

A detailed discussion is devoted to data found in the literature concerning the distribution of luminescence in fungi, and to the taxonomical value of the various luminescent species. The principal data, forming the basis of this discussion, have been collected in Tables I and II, the outcome of the discussion has been summarized in Table III (p. 188—191). In the latter Table a discrimination between the various species has been attempted, according to their taxonomical meaning, the reliability of the records of their luminescence, and the profoundness of the knowledge existing concerning them.

Indications as to species which specially deserve renewed attention, and a few directions for making observations along this line are given (§ 4). Sending of material and informations will be welcome.

In order to select luminescent fungi, suited for physiological work, as many species as possible were grown in pure culture on cherry- and on bread-agar. Some characteristics of the cultures are described (§ 5). As a rule the brightest luminescence was observed in *Armillaria mellea*, *Mycena polygramma*, and *Omphalia flavida*. Mostly, luminescence was stronger on bread-agar than on cherry-agar.

Utrecht, December 1946.

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ADDENDUM to p. 183.

Only recently I had the opportunity to consult PAULET's text (without the plates). At the place to which ROUMEGUÈRE (62) refers (88), PAULET describes the „*Agaric-flamme*", and he states: „Cette espèce,..... a été trouvée dans un vieux tronc de chêne, au bois de Boulogne: il ressembloit à des flammes de feu dans l'obscurité". Somewhat higher we read: "Ces agarics sont remarquables par leur couleur de feu ou aurore....." Taking this into consideration, I am not convinced that PAULET meant to say that his specimens were *luminous*. Since Paulet's *plates* were not at my disposal, I cannot judge whether ROUMEGUÈRE is right in identifying PAULET's species with *Polyporus sulphureus*. (Added in proof, 2. 1. '48).