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Studies on the Luminous Fungus,

Pleurotus japonicus sp. nov.

By

Seiichi Kawamura, *Rigakushi.*

With 3 Plates.

I. Introduction.

In many parts of the upland regions of Japan there occurs in the autumn a luminous and very poisonous species of Hymenomycetes fungi, growing on dead trunks of the beech and commonly known under the name of "Tsukiyo-také," i.e., the "moon-night mushroom." It is a species apparently new to science, belonging as it does to the old genus *Pleurotus*, and shall be called by me *Pleurotus japonicus*. Although many unfortunate cases of poisoning by the fungus have been reported, yet it has hitherto attracted the attention of but a very few scientists.

In 1889, Inoko[1] published the result of his toxicological examination of the fungus in question. He proposed to call it *Pleurotus noctilucens*, without, however, giving a systematic description of the species. Moreover, that specific name is preoccupied,

1) Inoko, Y., Toxikologisches ueber einen japanischen Giftschwamm (Mitteilung der Med. Facultät der Kaiserlich-Japanischen Universität, Tokyo, Vol. I, 1889, No. 3, p. 210.)

having been given long ago by LÉVEILLE to anothor luminous fungus[1] of the same genus from Manila. So that, INOKO's designation can not be kept on. Hennings[2] in 1900, as he gave an enumeration of Japanese fungi, put forth the species under the name of *Pleurotus oleareus* D.C., which example was followed by some later authors. As a matter of fact, the identification with that common European species can not be supported, as will soon be pointed out.

Since September 1909, I have had frequent occasions to collect fresh specimens of the fungus in question, and thus to make studies on it, the results of which I propose to report in this paper. The large size of the species and the abundance of its occurrence have greatly facilitated my observations.

Before proceeding further, I take pleasure in acknowledging my deep obligations to Professor MIYOSHI, under whose direction the work was carried on. I wish also to express my thanks to Professor IJIMA for his aid in the preparation of this report.

II. Characters of Pleurotus japonicus sp. nov.

Diagnosis.—Pileo carnoso, molli, conchato, dimidiato, firmo, elastico, sursum incrassato, basi non-stigoso; lamellis breve decurrentibus, subdistantibus, albis; sporae globasae et magnae; ad truncos praecique Fagi; venenata. (Pls. I & II.) Nom. Jap.—Tsukiyo-také; Kuma-bera; Watari.[3]

Description (Pls. I & II.).—Pileus convex to expanded, more or less depressed at attachment to stem, the older ones with involute margin; the surface floccose at first, afterwards floccose-

1) *Pleurotus noctilucens* Lév., (Ann. d. Sc. Nat. Oct. 1844, p. 171.)

2) Hennings, P., Fleischige Pilze aus Japan, (Hedwigia, Vol. XXXIX, 1900, p. 156.)

3) This should be the local name of the fungus in the Province of Yamato, according to the old story book "Konjaku-monogatari."

scaly, breaking up into triangular scales which are distinct in the central parts and become smaller and less conspicuous towards the margin. The pileus is usually lateral in relation to the stem and half-moon-shaped or reniform except in very small specimens, in which it is roundish with the stem attached near the center. It easily splits in the margin on being handled. The color is a light brown tinted with yellowish or rosy; in old specimens it is a dark brown with purplish tint. Flesh white, thick, reaching 1·3–2·0 cm. in thickness near the stem in large specimens. Stem attached to pileus usually at the edge, short, 1·4–2·5 cm. long and 1·5–3·0 cm. (in largest specimens even 4 or 5 cm.) thick, firm, tough, fibrous, showing in sections a dark purplish central part. Gills white, acquiring a light yellowish tinge with age, 0·95–1·8 cm. broad, 0·6–1·5 mm. thick, straight, not branching throughout; shortly decurrent, all ending abruptly in a line at the remnant of the ring-like prominence in the upper part of stem. Spores spherical, 13–17μ in diameter, white when caught in a mass on paper, slightly tinged with lilac color.

The plants grow in clusters on decaying beech trunks in the mountainous parts of Japan during the autumn. They are luminous and very poisonous.

Remarks.—So far as external features go, the present species somewhat resembles *Pleurotus sapidus* Kalckbr. as well as *Pleurotus ostreatus* Jacq. However, the former has several pilei starting from a common stem and the gills running down deep over the stem. The latter species is more like the present one in habitus, but is characterized by having smaller spores of an elliptical outline. Moreover, both the species mentioned are non-luminous. *Pleurotus oleareus* 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 pileus, and further in having pileus meagre in flesh and of a bright yellow color.

Of the numerous species of *Pleurotus*, so far as I am aware, the following ten have hitherto been reported to be luminous:

Pleurotus Gardneri Berk.[1]

Pl. illuminans Müll. et Berk.[2]; Queensland, Australia.

Pl. facifer B. et C.[3]; Pennsylvania.

Pl. nidiformis Berk.[4]; Swan River, Australia.

Pl. Lampas Berk.[5]; Swan River, Australia.

Pl. noctilucens Lev.[6]; Manila, P. I.

Pl. oleareus D. C.[7]; Europe and America.

Pl. Prometheus B. et C.[8]; Hongkong.

Pl. candescens Müll. et Berk.[9]; Melbourne, Australia.

Pl. phosphorus Berk.[10]; Tasmania, Australia.

To the above list should now be added *Pleurotus japonicus* of Japan.

III. Habitat and Distribution.

Pleurotus japonicus seems to be widely distributed in Hondo, Shikoku and Kiushiu. It has been found in the Aomori Prefecture at the northern end of Hondo as well as in the Kagoshima Prefecture in the southern part of Kiushiu. From other islands of Japan it has not yet been reported. However, since Yezo is very rich in the beech tree (*Fagus sylvatica* L. var. *Sieboldi* Maxim.) on which it grows, it appears quite likely that the fungus occurs in that island also. So far as my experience reach, I should say

1) Hooker's Journal of Botany II, p. 426.—2) Berkeley, Australian Fungi n. 15, (Grevillea, VI, 1877.)—3) Berkeley et Curtis, Centuries of North American Fungi, (Ann. Nat. Hist. Dec. 1853.)—4) Berkeley, Dec. n. 1, Lond. Journ. III, 185.—5) Berkeley, Dec. n. 25, Lond. Journ. IV, p. 44.—6) Léveillé, Ann. d. Sc. Nat. Oct. 1844, p. 171.—7) De Candolle, Flore Française, VI, p. 44.—8) Berkeley et Curtis, Characters of Fungi collected on the North Pacific Exploring Expedition by Charles Wright, (Amer. Acad. Arts and Sci., Boston, IV, 1858.—9) Berkeley, Australian Fungi, n. 16.—10) Berkeley, Australian Fungi, n. 192.

that the host of the fungus is confined to the beech tree. Records are indeed not wanting that it was found growing on certain other trees, as f. i. *Castanea sativa* Mill. var. *pubinervis* (Hassk.) Makino, *Zelkowa serrata* (Thunb.) Makino, *Quercus serrata* Thunb., *Prunus Jamasakura* Sieb., etc.; but I think these have to be received with caution, since it is frequently no easy matter to precisely identify the dead trunks on which the fungus grows.

On Mt. Togakushi in Province Shinano, on which mountain I made extensive searches for the fungus, I have determined to my conviction that the fungus grow on dead trunks of the beech only, and not on any other broad-leafed trees found there. In this matter I have received emphatic endorsement from an old wood-feller of the locality.

The so-called beech zone in the middle parts of Hondo lies in regions higher than about 2000 feet above the sea level, while in Shikoku, Kiushu and the western parts of Hondo, it is restricted to summits of high mountains. On the other hand, the farther north we go in Hondo, the lower becomes the altitude of the zone as a general matter; and finally in the Aomori Prefecture at the northernmost end of Hondo, it extends down to open valleys and fields of the low plain. Accordingly, while in south-western Japan the fungus is limited in occurrence to mountain summits, in the northern parts it is often met with in the woods near villages.

The fungus is found generally from the middle of September to that of October, appearing a little later in southern, than in northern, districts. Possibly it grows in the spring also, as is the case with the edible mushroom *Cortinellus Shiitaké*, Tanaka, but I have no actual observation on this point.

The fungus commonly grows on standing trunks of dead beeches, generally at points higher than 4 m. from the ground. Less frequently it was discovered on fallen trunks rottening on the

ground. As the beech is not much used as timber in this country, the fuel collectors cut off the branches for their use but leave the trunks to decay as they stand, thus preparing an abundance of substratum which eventually may give growth to the fungus.

Usually the fungus is found growing numbers together in close clusters and situated one above another in an imbricate-like manner. This is well seen in the figure shown on Pl. II.

IV. Luminous parts of the fungus.

The following informations may be of use to mycologists interested in the luminosity of fungi. ALPINE[1] in his observations on *Pleurotus candescens* Müll. et Berk. of Australia reported that it kept its luminosity for a week at least after it began to be luminous. The gills were capable of emitting light during all that length of time, while the mycelium was found to be luminous only for the first two days. TULASNE[2] stated that *Pleurotus oleareus* D.C. is luminous not only in the hymenia, but occasionally also in the whole fruit-body. Experiment was made also on the same species by ARCANGELI[3], who likewise came to the conclusion that the luminosity was always located in the gills, but, without being restricted to these, may extend to other parts, as f. i. the surface of stem and the inner structures of pilei. BREFELD[4] reported that the mycelia of the fungus *Armillaria mellea* Vahl. showed luminosity in the culture medium. MOLISH[5] observed the same fungus in pure culture form some luminous rhizomorphs in the medium, MEYEN[6] observed in a forest that light was emitted at night by a

1) Alpine, D. Mc., Phosphoreszierende Pilze in Australien, (Proceeding of the Linnean Society of New-South Wales, XXV. 1900, p. 548-562.)—2) Tulasne, L. R., Sur la phosphorescence spontanée de l'Agaricus olearius D.C., du Rhizomorpha subterranea Pers. et les feuilles mortes du chêne, (Annal. d. Sc. nat. 3, sér. Botanique, IX, T. Paris, 1848. p. 338.). - 3) Arcangeli, G., Ricerche sulla fosforescenza del Pleurotus oleareus D.C., (Reale Accadémia dei Lincei, Anno CCLXXXVI, 1889.)—4) Brefeld, O., Botanische Untersuchungen über Schimmelpilze, Heft. III. Basidiomyceten, I. p. 136.—5) Molish, H., Leuchtenden Pflanzen, 1904, p. 36.—6) Meyen, F.J.F., Neues System der Pflanzenphysiologie, Bd. II, 1838, p. 195.

decaying mass of certain fungi, which luminous matter could be spread over a trunk of tree; but, as a matter of fact, its real nature has not been accurately determined. Several species of fungi other than those referred to above are believed to be of a luminous nature, but in most of these cases we have no trustworthy record of experimental researches. Apparently the luminous parts differ in different species of fungi; and even as regards the same species different observers have maintained different views on the point. In the new fungus studied by me the luminosity is restricted to the fruit-body. The mycelia found on and in the decayed beech trunk are never luminous. The light is uniformly emitted all over the region of the gills only. It never appeared spotwise except where the gills had been injured.

The fungus commences to emit light at a stage of its growth when the gills have become fully expanded. The light dies out gradually as the plant becomes old. The fading away takes place uniformly in all parts of the gills. The free edge of gills is very thin, while its base is massive and may well be compared to the back of a knife-blade. In relation with that fact, the light remains for a long time at the bases of gills after it has faded at the thin edge; and in old specimens of the fungus some non-luminous lines are seen radiating from the stem toward the circumference of pileus.

The next problem was to determine from what part or parts of the gills the light is emitted. DELILE[1] and some other authors have maintained that the luminosity originates in the hymenium. But there still remained undetermined the question, if it is the hymenium alone that emits light, and if the trama between hymenia does not participate in the emission. This uncertainty stands in relation to the feebleness of the light, on which account

1) Delile, Nouv. exam. de la phosph. de l'Ag. de l'Olivier.

the fungus light, when examined under the microscope, is absorbed in passing through the lenses of even a low power. Under the microscope of sufficiently strong power to resolve the exact configuration of the cells, the optical field is quite dark. Accordingly, I had to take recourse to the following method of observation. Selecting one of the largest specimens, the gills were cut in the thickest part parallel to the surface of pileus. The section was found to be uniformly luminous in all parts, verifying in a rough way the fact that both hymenium and trama are luminous. In large specimens the gills are very thick, measuring from 1·0 to 1·5 mm. across. Some of the thickest gills were cut into pieces about one cm. square, and these were sliced off on both sides with a sharp razor so as to leave the middle parts only. The pieces were still luminous. They were then chopped into smaller pieces, which on microscopical examination by the aid of lamp-light, proved to consist of trama cells, quite in exclusion of hymenium cells, such as basidia and spores.

Next, in order to ascertain whether the basidia and spores were luminous or not, the surface of gills was gently grazed with a razor. The small quantity of tissues thus collected on the razor edge appeared white in lamp-light and was luminous in the dark, presenting a thin line of feeble light along the edge. This lasted for a considerable length of time. In the scraping on the razor I have found under the microscope numerous separated basidia and spores. It was evident therefrom that not only the trama but also the hymenia have luminosity. It still remained not clear whether it was basidia or spores, or both, that emitted light, since both were found mixed together in the preparations. To obtain light on this point, a fresh fungus was placed upside down on a glass plate for several hours, till numberless spores have fallen and accumulated on the plate. The spores thus gathered

were always non-luminous as tested by repeated experiments.

The above series of experiments shows that all the cells in the hymenia, excepting the spores, are luminous. I have then experimented with the cells of subhymenium which exists between trama and hymenium. As it forms a thin zone, only one or two cells thick, it was quite impossible to isolate it completely from other tissues. However, since no dark stratum could ever be discerned underlying the hymenium in sections of the gill in full illumination, I am inclined to believe that the subhymenium also has luminosity.

Desirable as it was to ascertain whether or not old and new cells in each kind of the luminous tissues differed in the degree of luminosity, and also if the sterigma in basidia and the younger spores were luminous or not, the solution of these questions had to be suspended owing to the impracticability of examining individual cells microscopically in the dark. On one occasion I have wrapped a highly luminous gill in a piece of cloth and crushed it by pressing between fingers. The crumbled mass was still luminous, though the light was of a somewhat diminished intensity. Then, placing the mass under a stronger pressure, a small quantity of a milky juice was obtained which was not luminous at all, though the residue still retained its luminosity. On squeezing the mass much harder, or on crushing luminous gills by grinding, the luminosity was irrecoverably lost. It seemed the luminosity ceased as soon as the cell contents were freed by the bursting of the wall.

V. Effect of temperature on the fungus-light.

(**A**) Experiments in the air of different temperatures.

Method:—My first experiment was to ascertain in what

manner the fungus light is affected by a change in environmental temperature. A large test-tube, 80 cc. in capacity, was provided with a wooden stopper with two holes, one large and one small, the former for the insertion of the thermometer and the latter for the purpose of ventilation which seemed to be necessary in order to avoid the accumulation of carbon dioxide produced by respiration. Test-tubes were used for the experiments, as they offered facility in rapidly changing the temperature of the air within. The change of temperature was effected by dipping the test-tube into warm water or into a freezing mixture. A second thermometer was placed directly in the warming or the cooling medium for comparing the temperatures inside and outside of the test-tube. After the air in the tube has continued to maintain for some time a certain temperature, the mouth was opened and the luminous object—generally a piece of a gill—was quickly inserted. In numerous experiments made to observe the influence of temperature of water or of various gases on the fungus, nearly the same result was obtained in all cases of each sort, irrespective of whether a whole fungus or a few gills or mere fragments of a gill were used.

(a) **0°C.** This temperature was produced by the use of crushed ice. When a luminous gill was subjected to this temperature, the light commenced to fade after twenty seconds, and in two minutes' time it faded away very markedly, say by about two-thirds of the original intensity. After that the fading took place at a slower rate. In half an hour the change of light intensity became so slow that scarcely any difference could be detected at intervals of several minutes, untill after two hours from the beginning, the light became totally invisible to the eye. After the gill was kept one hour and a half longer in the cooled tube, it was taken out and placed in room temperature of 13°C. Ten minutes afterward,

it again showed a feeble light, and after half an hour, the original strength of luminosity was fully recovered.

(b) **-7°C.** At this temperature the light of the gill began to fade after fifteen seconds, and became invisible after twenty-five minutes. The gill was kept for an hour longer in the refrigerated air, and then taken out and placed in a temperature of 13°C. It began to emit a feeble light after twenty-five minutes, and recovered the original intensity after an hour. Another specimen which has been kept for seven hours in the refrigerated air never recovered the power of emitting light.

(c) **-10°C.** At -10°C. the light of the gill began to fade after ten second and became invisible twenty minutes after. An hour later the gill was removed into the air of 13°C. temperature. In half an hour it began to emit a feeble light, and after an hour the light recovered its original strength. Another piece of gill which has been kept for five hours in the refrigerated air, did not emit light again after removal from the refrigerator.

(d) **3-5°C.** The gill placed in the air of 3-5°C. temperature began to show light of diminished intensity after two minutes, but that was long before the light became finally invisible.

(e) **10-15°C.** The gill kept in a temperature of 10-15°C. for twenty-four hours, exhibited all the while no change in light intensity.

(f) **30-39°C.** At this temperature the light of the gill began to diminish intensity after one and a half minutes, but did not totally disappear even after four hours, Then the test-tube was taken out of the hot water; and two or three seconds after when the internal temperature became equal to the external, the fungus' light has recovered its original intensity.

(g) **50°C.** The gill in the air of 50°C. temperature began to show diminished light after one minute. A feeble light lingered

for about two minutes and became invisible after two and a half minutes more. Then the specimen was taken out into the external air, in which it was seen to commence emitting light after thirty seconds and to recover original light intensity after one minute. A gill which was kept in the temperature of 50°C. for twenty minutes never recovered its power of producing light.

(h) **60°C.** A gill in 60°C. temperature began to show diminished light after thirty seconds; after one minute only a feeble light remained; and after one minute and ten seconds, the light was invisible. The specimen was then taken out into the air of 19.3°C. Thereupon it became again luminous after fifteen seconds, and completely recovered the original strength of luminosity after thirty seconds. On the other hand, a gill taken out from the test-tube fifteen minutes after it ceased to be luminous, did not emit light again.

(**B**) Experiments in water of various temperatures.

My next attempt was to observe changes in luminosity in water of various temperatures. Crushed ice or water of different temperatures was put into a wide-mouthed bottle of 500 cc. capacity. Into this was thrown a piece of highly luminous gill, keeping up a constant temperature during the experiments.

(a) **0°C.** In crushed ice the light began to decline in intensity after five seconds and became invisible in half an hour. The gill was then quickly taken out, whereupon after one minute it began to emit a feeble light and recovered full luminosity in five minutes.

(b) **10.7°C.** In the water of 10.7°C. the light became feeble after ten minutes. As the water was stirred, the light temporarily revived, to begin again to fade on being kept still for five seconds. After half an hour from the beginning, the light was reduced, roughly speaking to about one third of the original strength.

Strong agitation of the water at that period caused a slight revival of the light. Also the diminished light could be brought to temporary revival by removing the specimen into new water of the same temperature. Two minutes after revival, the light again became feeble; and after three hours from the beginning, it became quite invisible. Five minutes after that, the specimen was taken out into the air, in which it began to emit light after two minutes and eventually recovered the original degree of luminosity.

A small specimen weighing 115 grammes was put into water of the same temperature as above. Its light commenced to fade after ten minutes. Taken out into the air immediately after complete loss of light, it took thirty seconds to begin to glow again and one minute to recover completely. Another specimen, which has been kept long in the water and has completely lost luminosity, took two minutes to recover its original light intensity.

(c) **30°C.** When a specimen was put into water of 30°C., the light began to fade away after twenty seconds and became invisible after five minutes. When the water was stirred, the light revived, and, when restored to the air, immediately recovered the original intensity. The specimen was again placed in the water, and when it was restored to the air after ten minutes, it began to emit light after one second and completely recovered the luminosity after five seconds.

(d) **35°C.** In the water of 35°C. the light began to fade in ten seconds, and became invisible after three minutes. On being taken out into the air, it immediately began to emit light. In ten seconds more, complete recovery of luminosity ensued.

(e) **40°C.** Five seconds after a specimen was placed in the water of 40°C., the light began to fade slowly and finally became invisible in one minute. The object was kept twelve minutes in the water and was then restored to the air. In half an hour, the

internal parts appeared luminous, but the surface had not recovered luminosity, on which account the entire object was but faintly luminous. It seemed that the surface which had been in direct contact with the warm water had permanently lost the luminosity.

(f) **47°C.** Placing the fungus in the water of 47°C., the light commenced to fade after two seconds and became invisible after ten seconds. The specimen was then restored to the air, but did not recover luminosity.

(g) **60°C.** As a specimen was thrown into the water of 60°C., the light immediately began to grow weaker, and became invisible after five seconds. Though it was then quickly taken out of the water and exposed to the air, the luminous power was irrecoverably lost.

TABLE OF THE RESULTS OF EXPERIMENTS WITH REGARD TO THE EFFECT OF DIFFERENT AIR TEMPERATURE ON THE LUMINOSITY.

Air temperature.	Duration from start of experiment to first indication of decline in luminosity.	Duration from start of experiment to extinction of luminosity.	Duration in which the object was allowed to remain in the same temperature after extinction of luminosity.	Duration from restoration of object into open air to first indication of luminosity revival.	Duration from restoration of object into open air to full revival of luminosity.	Remarks.
—10°C.	10 sec.	20 min.	1 hr.	30 min.	1 hr.	
—10°C.	10 sec.	20 min.	5 hr.	.....	.....	Luminosity not recovered.
—7°C.	15 sec.	25 min.	1 hr.	25 min.	1 hr.	
—7°C.	15 sec.	25 min.	7 hr.	.....	.....	Luminosity not recovered.
0°C.	20 sec.	2 hr.	1 hr. 30 min.	10 min.	30 min.	
3—5°C.	2 min.	.....	.....	.....	3 min.	
10—15°C.	.....	.....	.....	.....	.....	No effect upon luminosity.
30—39°C.	1 min. 30 sec.	.....	.....	.....	2 sec.	
50°C.	1 min.	2 min. 30 sec.	0	30 sec.	1 min.	
50°C.	1 min.	2 min. 30 sec.	20 min.	.....	.....	Luminosity not recovered.
60°C.	30 sec.	1 min. 10 sec.	0	15 sec.	30 sec.	
60°C.	30 sec.	1 min. 10 sec.	15 min.	.....	.....	Luminosity not recovered.

TABLE OF THE RESULTS OF EXPERIMENTS WITH REGARD TO THE EFFECT OF TEMPERATURE ON THE LUMINOSITY IN WATER.

Temperature of water.	Duration from start of experiment to first indication of decline in luminosity.	Duration from start of experiment to extinction of luminosity.	Duration in which the object was allowed to remain in the same temperature after extinction of luminosity.	Duration from restoration of object into open air to first indication of luminosity revival.	Duration from restoration of object into open air to full revival of luminosity.	Remarks.
0°C.	5 sec.	30 min.	0	1 min.	5 min.	
10.7°C.	10 min.	x	0	30 sec.	1 min.	
30°C.	20 sec.	5 min.	x	1 sec.	5 sec.	
35°C.	10 sec.	3 min.	0	0	10 sec.	
40°C.	5 sec.	1 min.	12 min.	30 min.	.....	Partial recovery of luminosity.
47°C.	2 sec.	10 sec.	0	.....	.....	Luminosity not recovered.
60°C.	0	5 sec.	0	.....	.....	„ „

To summarize the results of my experiment: The fungus-light in the air, when cooled to −10°C., became invisible after twenty minutes; on removal of the object to room-temperature after an hour and twenty minutes, the luminosity gradually recovered itself, but when allowed to remain in the same low temperature for five hours and twenty minutes, the recovery did not take place. In a temperature of 0—10°C., a considerable time was required for the setting in of the invisible state; and if the object was taken out within an hour, it always well recovered the luminosity, but if kept for a longer period in that temperature, the recovery did not take place. As may be gathered from the above experiments, both the rise of temperature to 30—60°C. and the fall to 5— −10°C. excercise decrescent effect upon the luminosity. In no

instance of the experiments was the increscence of luminosity brought about by changes of air temperature. The recovery of suppressed luminosity was speediest at a temperature of 10—15°C.

The changes of the fungus-light were more rapid and intense in water than in air at the same temperature. Water, being a better conductor of heat than air, transmits heat more rapidly to the plant. This fact, together with the limited supply of oxygen in water, goes to make the changes in that medium more rapid than in air. In water of 30—35°C. temperature, the fungus retains the power of recovering suppressed luminosity. In that of 40°C., the light loses itself in the superficial parts in direct comtact with the hot water and that permanently, though the internal parts continue to emit light for some time and may recover the power after temporary loss. So, 40°C. may be taken as the critical temperature, at and above which the fungus permanently loses its luminous power.

It scarcely needs to be pointed out that the results are greatly influenced by duration of exposures as also by certain other circumstances. The limited supply of oxygen in water has probably much to do with the relatively quick fading of the fungus light. As a general matter, the fungus dipped into water of 10—15°C. did not lose its luminosity for a period as long as an hour, while in water of −10—0°C. and of 50—60°C. it lost the luminosity within a few seconds or a few minutes at the longest.

DE VRIES[1] and others stated that the parenchyma of many phanerogams, mosses and algae is killed either by heating to 43—47°C. in water and to 51°C. in air or by cooling to −6—−9°C. in air. If that be so, it may be assumed that the fungus pieces used by me in the experiments were killed in those cases in which

1) De Vries, H., Matériaux pour la connaissance de l'influence de la température sur les plantes, 1870, p. 3 (reprint from Archives Néerlandaises &c., t. III.)

they were kept in the water of 40°C. for forty three minutes, in that of 47°C. for twelve seconds, and in the air of 50°C. for twenty-three minutes,—in all which cases the recovery of lost luminosity did not take place.

For the sake of comparision, I may now refer to the results of other author's experiments on luminous Hymenomycetes and Bacteria. As to Hymenomycetes, ARCANGELI[1] showed that *Pleurotus oleareus* D.C. lost its luminosity in half an hour when cooled to 0°C. After five hours he removed the specimen into the air of 14°C. and found that it could recover the lost luminosity. Another specimen dipped into the water of 40°C. soon lost its luminosity; but, as soon as it was taken out of that water, the luminosity was recovered; in the water of 50°C. the fungus light rapidly became invisible and did not revive on the fungus being taken out of that water. A still another specimen was dipped into the water of 14°C.; the light underwent no sudden change, but gradually diminished in intensity until it finally became invisible. Some specimens cooled down to 0°C. and then slowly warmed, commenced to emit light after from three to four hours and were most intense from eight to ten hours from the beginning.

EIJKMANN[2] observed *Pseudomonous javanicus* (Eijk.) Mig. in different temperatures ranging from −20 to 45°C. all the time the fungus-light was clearly visible, though it was exceedingly weak when the temperature fell below 10°C. or rose above 40°C. The optimum temperature for the luminosity was determined to extend from 25° to 33°C. According to BEIJERINK[3], *Photobacterium in-*

1) Arcangeli, G., Ricerche sulla Fosforescenza del Pleurotus olearius D.C., 1889.—2) Eijkmann, C., Lichtgebende Bacterien, (Jaarverslay von het Laboratorium voor pathologische Anatomie en Bacteriologie te Welteoreden over het Jaar. 1891). Overgedrukt uit het Geneeskundig Jijkschrift voor Nederlandsch-Indié. Deel XXXII. Aflevering 4 Batavia en Noordwijk, p. 109–115, 1892: An abstract in Zentralbl. f. Bakteriol., XII., 1892, p. 656–657.—3) Beijerink, M. W., Le Photobacterium luminosum, bacterie lumineuse de la Mer du Nord, (Archives Neérlandaises, &c. t. XXIII, p. 401-415, 1889).

dicum Beijer. shows its luminosity strongest in a temperature of 30—32°C., and *Photobacterium luminosum* Beijer. in that of 25—28°C. LEHMANN[1] reported that *Bacterium phosphorescens* Fischer kept at a temperature of 0.1°C. continued to emit feeble light for several days. FORSTER[2] observed a certain bacterium emit light in temperatures of 0—20°C. but lose the luminosity at 32°C. MOLISCH[3] reported for *Bacterium phosphoreum* (Chon) Molisch that its light was strongest at a temperature of 16—18°C., and that the minimum and maximum temperatures for its luminosity were respectively some degrees below 0°C. and above 28°C. An experiment by the same author on a luminous mycelium, called by him X mycelium for the sake of reference, showed that it could continue to be luminous in temperatures ranging from −1° to 34°C., being strongest at 15—25°C.

To tabulate the results obtained by different observers:

Name of fungus.	Observer.	Minimum temperature of luminosity.	Optimum temperature of luminosity.	Maximum temperature of luminosity.
Pleurotus japonicus Kawam.	Kawamura.	3—5°C.	10—15°C.	40°C.
Pleurotus olearius D.C.	Arcangeli.	3°C.	8—10°C.	40°C.
Pseudomonas javanicus (Eijk.) Mig.	Eijkmann.	-20°C.	25—35°C.	45°C.
Photobacterium indicum Beijer.	Beijerink.		30—32°C.	
Photobacterium luminosum Beijer.	Beijerink.		25—28°C.	
Bacterium phosphoreum (Cohn) Molisch.	Molisch.		16—18°C.	
X mycelium.	Molisch.	-1°C.	15—25°C.	34°C.

1) Lehmann, K. B., Studien über Bacterium phosphorescens, (Zentralbl. f. Bakteriol. etc. Bd. V, No. 24, 1889.)—2) Forster, J., Über einige Eigenschaften leuchtender Bakterien, (Zentralbl. f. Bakteriol. etc. Bd. II, 1887, p. 337.)—3) Molisch, H., Über das Leuchten des Fleisches insbesondere todter Schlachttiere, (Botan. Zeitg. 1903.)—6) Molisch, H., Leuchtende Pflanzen, p. 93, 1904.

VI. Reactions against gases.

In most of the following experiments, bottles of 500 cc. capacity were filled with various gases, and into these were put pieces of luminous gills weighing 50 grammes.

(a) With nitrogen gas, the fungus-light began to fade after ten seconds; it became very feeble after fifty seconds, barely recognizable after one minute and twenty seconds, and finally invisible after one minute and forty seconds from the beginning, upon that, the specimen was at once taken out into the air, where it recovered the light after twenty seconds.

(b) With hydrogen gas, the light began to fade after ten seconds, and after thirty minutes from the beginning it was invisible.

(c) 1 cc. of ether put in the bottle; this closed with a glass plate and kept quiet until the ether was vaporized. Then, a piece of gill weighing 50 grammes was placed in the battle, keeping it suspended by a thread. After one minute and fifty seconds, the light became invisible. Thereupon, the specimen was taken out into the air; thirty seconds after, the luminosity was recovered.

(d) Chloroform vaporized in a like manner caused the fungus-light to vanish in fifty-five seconds. The specimen was then promptly taken out into the air. The recovery of luminosity was found to take place much more slowly in this case than in that of ether. Specimens, which were left in the chloroform vapor for a short while after the loss of luminosity, failed to recover.

(e) Taking wide-mouthed bottles of 200 cc. capacity each, one was filled with chloroform vapor and the other with ether vapor. A piece of gill weighing 40 grammes was put into each bottle. After twenty-five minutes, the specimen in the chloroform still emitted a very feeble light, while that in the ether became non-luminous. Then, both specimens were simultaneously taken

out into the air. The specimen, which had been in the ether did not recover light at all; the other, which had been in the chloroform, did not revive in the least but passed over very slowly into non-luminous state. For the purpose of control, a similar-sized piece of gill cut from the same fungus was placed in a closed bottle of the same capacity but without any reagent or gas in it, It continued to emit light for at least three days. Similar experiments with similar result has already been reported by previous authors. According to MOLISCH[1] *Bacterium phosphoreum* placed in ether vapor should lose its luminosity in fifteen minutes. But it should be borne in mind that the length of time necessary for bringing fungus-light into invisibility largely depends upon the quantity of ether and the capacity of the bottle used. ARCANGELI[2] made similar experiments on *Pleurotus oleareus* D.C., using such gases as carbon-dioxide, carbon monooxide, nitrogen oxide, hydrogen, nitrogen, etc. In each case, the extinguished light could be brought into revival if the fungus was taken out of the gas not very long after the extinction, but not otherwise. On the whole, his results stand in agreement with my own.

(f) A piece of old gill with weakened power of luminosity, placed in the vapor of ether under the conditions befere mentioned, became highly luminous after five or six minutes. Chloroform vapor brightened the fungus-light a little after ten minutes. In either case, when the specimen was promptly taken out at that stage into the air, the light returned to its former weak state in a few minutes. On the other hand, when the specimens were allowed to remain in the gases, the temporarily brightened light began in a few minutes to weaken gradually until it became altogether invisible.

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1) Molisch, H., Leuchtende Pflanzen, p. 117, 1904.—2) Arcangeli, G., Ricerche sulla Fosforescenza del Pleurotus olearius D.C., 1889.

(g) To see what would happen by exhausting the air, the fungus was placed, luminous surface upward, in the bell-glass of air exhauster. Pumping the air out for one minute, when the atomospheric pressure within registered 0.17, the fungus-light began to weaken. As the pressure stood at 0·05 atmospheric pressure, the light was very weak, but still visible. As the exhausting could not be carried on any further, the air was let in, on which the dimly luminous fungus gradually resumed the original brightness.

(h) In oxygen the fungus-light showed no change whatever, but behaved exactly as in the air.

VII. Character of the Luminosity.

The manner in which the present fungus emits light seems to be much the same as that of other fungi and bacteria which are endowed with that power. The light is not intermittent, but maintains an almost steady continuance for a long time. As the fungus becomes decrepit, the light gradually weakens until it finally becomes invisible to the eye. Rainy weather shortens the period of luminosity by causing early decay of the fungus. Luminosity is strongest in fresh specimens in which the gills present a pure white color. It is distinctly much weaker in older specimens with gills which have turned somewhat yellowish in color and have begun to bear juicy exudation on the surface. Usually, the light becomes totally invisible to the eye three days after the setting in of the first sign of fading. Should the fungus rapidly become putrid, it retains a feeble light for a considerable time and that even after it has begun to give off offensive smell. The luminosity is always uniformly spread over the surface of gills; it never appears spotted or spotwise, unless the tissue is injured.

The fading of light takes place also uniformly over the gills; all the parts becoming non-luminous at the same time.

DELILE[1] observed that *Pleurotus oleareus* D. C. was luminous only at night. ARCANGELI[2] contradicted this statement, maintaining that the fungus is luminous in the day-time also. It was fitly remarked by him that, in order to ascertain that fact, the specimens should be observed in a dark room, the observer waiting from three to ten minutes until when the eye shall have sufficiently recovered the sensibility to recognize the fungus-light in the dark. The results of my repeated experiments on *Pleurotus japonicus* go to confirm ARCANGELI'S view in the main. I have found that the time required for bringing our eyes into proper accommodation to see the light in the dark varies considerably according to individuals and also to the state of weather. Whereas in rainy or cloudy day it may take, after entering the dark room, only a minute or thereabout to be able to recognize the luminous fungus placed in it, on bright sun-shiny days it may require from three to seven minutes to arrive at the same end. The reason is obvious. Further experiments have shown that, while some person could exactly tell the number and position of the fungi in one minute, others who have entered the dark room at the same time required three minutes to come to the recognition.

It might be asked if the fungus does not emit light in the day-light, but does so only on being placed in a dark room as on a dark night; in other words, if the presence or absence of sun-light have any direct influence on the luminosity of the fungus. To determine as far as possible the point in question, I have kept a specimen of the fungus in the dark room for a long time before I entered; it took several minutes before I could recognize the

1) Delile, Nouv. exam. de la phosph. de l'Ag. de l'Olivier.—2) Arcangeli, G., Ricerche sulla Fosforescenza del Pleurotus olearens D.C., 1889.

fungus-light. After that I continued to stay in the room for about ten minutes in order to thoroughly accustom my eyes to the light in the darkness. Then, I caused a fresh specimen of the fungus which has been in the day-light, to be quickly brought in. The light of this new fungus I was able to see from the very moment it was in the dark room. This seems to indicate that the intrinsic luminosity of the fungus is independent of the presence or absence of the sun-light.

VIII. Color of the Fungus-light.

The light emitted by bacteria has been called by many authors to be green, blue or yellow in color. MOLISCH[1] observed that the light of the luminous mycelium cultured by him and of *Armillaria mellea* Vahl., also contained shades of green, yellow and blue. The light of certain luminous bacteria, which I have had frequent occasion to observe in Japan, was likewise of a greenish blue color. On the other hand, the light of *Pleurotus japonicus* can scarcely be said to be of any particular color except whitish. The appearance is somewhat like that of a white paper in the moon light.

The fungus light was called blue by many, probably, only in illusionary comparison with light of petroleum lamp. One morning, early before dawn, I placed on the floor of my room several fungi, side by side with their luminous side turned upward. Covering these with a thin Japanese paper, I could at first dimly perceive their light through the paper, but not later as the dawn advanced. At a certain stage of the twilight, there was a period when the fungus-light could scarcely be distinguished from the appearance of a white paper placed near by.

1) Molisch, H., l.c. p. 122, 1904.

For the spectrum analysis, the fungus-light is so feeble that, when the slit of the spectroscope is made very narrow, it can not be perceived. I have therefore made use of the flashes of a dry-battery electric lamp, which was switched on and off, for showing the scale on the spectrum of the fungus-light. The latter occupied about the middle third of the solar-spectrum, i.e. the orange, the yellow and the green.

IX. Intensity of the Fungus-light.

The following account will give an idea of the intensity of the fungus light.

By the aid of light from a luminous piece of the fungus, about 100 sq. cm. in size and placed close by, I could well recognize with the naked eye complex Chinese characters of a size 1 cm. or more across and Roman alphabets about 0·8 cm. large. The letters were much more readily distinguishable when seen under a magnifying glass.

As to the determination of distance at which the naked eye can perceive the fungus-light, experiments were made in rooms which were made pitch dark. The fungi of different sizes could be easily recognized at a distance of thirty metres. They could be counted if placed 20—25 cm. apart from one another. When their positions were changed, the movement could be followed without difficulty. At a distance of thirty metres, however, the light from a piece 7 cm. in longest diameter could not be distinctly recognized. A larger piece 14 cm. in longest diameter could be recognized at a distance of thirty-two metres, but not at a greater distance. Although the luminous area of the latter piece was about six times as large as that of the former, yet the greatest distances at which they could be perceived differed only two metres.

X. The Fungus-light and Photography.

It has already been shown by the experiments of DUBOIS[1], BARNARD[2], and MOLISCH[3] that the light of luminous bacteria is sensible to photographic dry-plate. Moreover, MOLISCH[4] has taken photographs by the light of a luminous mycelium. Since the light emitted by luminous bacteria is in many respects similar to that of Hymenomycetes, the sensibility of the latter to photographic dry-plate could be taken in anticipation. At first, I have fixed the photographic apparatus in a dark room at night, using dry-plates of such brands as "Lion," "Ilford Alliance," &c., with the view of photographing the luminous side of *Pleurotus Japonicus*. Two dry-plates were exposed to the fungus-light for three and five hours respectively, without either of them receiving any impression as the result. When specimens of the fungus were placed, with their luminous side downward, directly upon dry-plates in the dark and left in that position for one hour, the plates received but a slight impression. Next. extremely sensitive plates of the brand "Ilford Alliance, fastest," were used in the following way: The dry-plate was placed on a table in the dark room, with the filmed surface upward; a fern was then put on it and covered with a clear glass-plate, upon which was placed a specimen of the fungus with the luminous side downward. After three hours' exposure under the above arrangement, the plate was developed. The result is shown in the figure 1. in Plate III. Replacing the fern-leaf with a red maple-leaf and by exposure of one hour and fifty minutes, the result was also successful, as attested by the figure 2 of the same plate.

1) Dubois, R., Das kalte Licht, (Umschau, 1901.)—2) Barnard, J. E., Luminous Bacteria, (Nature, 1902.)—3) Molisch, H., Bakterienlicht und photographische Platte, (Sitzber. d. Kais. Akad. zu Wien. Bd. CXII. Abt. I. 1903.)—4) Molisch, H., Leuchtende Pflanzen, p. 137, 1904.

In order to take a photograph of the luminous side of the fungus, a camera provided with dry-plate of the same sort as above was properly arranged in the dark room. The image obtained after an exposure of seven and a half hours, was a very weak and obscure one. Even twenty-four hours' exposure under the same procedure gave no better result. The obscurity of the image obtained may partly be due to the fact that the gills had moved, owing to growth during the long period of exposure. Nevertheless, it seems the light is scarcely strong enough for successful photographing with camera. MOLISCH's experiments[1] with *Bacterium phosphoreum* have shown that the light of that bacterium is sensible enough to dry-plates by one second's exposure, and that even its reflection can be caught by the dry-plate, so that the printed surface of a book could be clearly photographed by its shine after twelve hour's exposure. It is plain that the photo-sensible power of the light of *Bacterium phosphoreum* light is very much stronger than that of *Preurotus japonicus*.

XI. Summary.

The chief result of my observations on *Pleurotus japonicus* may be summarized as follows:

1. The fungus belongs to the genus *Pleurotus*, being characterized by the position of stem at one side of pileus, by the decurrent gills, by the spores presenting white color when caught in a mass, &c. It somewhat resembles *Pleurotus rapidus* Kalchbr. and *Pleurotus ostreatus* Jacq., but apparently represents a new and distinct species.

2. The fungus usually grows in clusters, overlapping one another, on the decayiug trunk of the beech (*Fagus sylvatica* L.

1) Molisch, H., Leuchtende Pflanzen, p. 136, 1904.

var. *Sieboldi* Maxim.), which is the only host as yet known. It is found in the Autumn.

3. The light is emitted by the gills only; all other parts of the fungus, including spores, are not luminous. The gills are uniformly luminous all over. Both hymenium and trama of gills are luminous. The juice squeezed out from the luminous gills are non-luminous.

4. The minimum and maximum temperatures in which the present fungus emits light are 3—5°C. and 40°C. respectively. The optimum temperature may be put down at 10—15°C.

5. In nitrogen gas, the luminosity begins to fade after ten seconds, becomes very feeble after fifty seconds, is scarcely recognizable after one minute and twenty seconds, and finally becomes completely invisible after one minute and forty seconds. In hydrogen gas, it begins to fade after ten seconds and becomes invisible in thirty minutes. In ether vapor, the light becomes invisible after one minute and fifty seconds, and if immediately after that, the object be taken out into the air, the luminosity returns after thirty seconds. In chloroform vapor, it vanishes in fifty-five seconds.

Exposure to oxygen gas causes no change in the luminosity. Gills with faded luminosity become temporarily highly luminous some minutes after being in gaseous ether or chloroform.

6. The fungus with luminous area of about 100 sq. cm. gives sufficient light for seeing Roman alphabets of about 8 mm. diameter in the dark. The luminosity can be fully perceived at a distance of thirty metres or more.

7. The light is white in color, not greenish, bluish or yellowish as in almost all other cases of luminous fungi. Photographic images of the luminous surface of the fungus taken in the dark room, by exposure of seven and half hours and also of twenty-

four hours, were all very faint. Good dark prints on white background were secured of the leaves placed between the luminous fungus surface and a photographic dry-plate, by an exposure of one hour and fifty minutes.

APPENDIX.

Poisoning Effect of the Present Fungus.

The present fungus resembles the edible species, *Pleurotus ostreatus* Jacq., in shape and habitat, a fact which has led to numerous cases of poisoning. Sometimes it has also been mistaken for the edible fungus, *Cortinelleus Shiitaké* Tanaka. Although cases of poisoning by the present fungus seem to be not very rare, yet details of the toxicological symptoms have hitherto not been given except mention of vomiting, diarrhœa, and pain in the abdomen. It may therefore be worth while to give an account of the following cases, informations about which were supplied me by the victims themselves.

(1) The first case concerned a farmer family which lived in the village of Okinajima, Yamagori, Fukushima Prefecture. The family consisted of five persons. *viz.* a grandfather (aged 86 years), a grandmother (80 years), a father (61 years), a mother (58 years) and a son (21 years). One day in the middle of October 1901, the son gathered fungi, which he took for the edible mushroom "Hirataké" (*Pleurotus ostreatus* Jacq.), from a dead beech and also from another tree (probably a chestnut tree) in the woods at the foot of Mt. Bandai. About ten of them, measuring from four to five inches in diameter were selected and cooked in an iron pan with rape-seed-oil and "miso" (a preparation of fermented and pounted beans). At about 7 P.M., the cooked fungi were taken at dinner, together with rice and pickles, by

all members of the family. The grandfather and the father alone helped themselves with about a pint of "sake" (Japanese wine). Nothing else was served at the meal. About an hour afterwards, all the five persons began to vomit and felt pain in the abdomen. They also had a severe attack of diarrhœa, accompanied with much rumbling in the bowels. They felt dizzy and everything around them appeared blue to their eyes. Moreover, they experienced a feeling as if a number of fire-flies were flying around them. The mother, who had delicate constitution, suffered most. She vomited and had to discharge diarrhœa more than a dozen times during the night. As all of the family suffered, no one could be sent for the doctor; and so they had to be content with taking some pills of a patent medicine. The son, being a young man, suffered least and was already convalescent on the following day. The others also got gradually and slowly better, and it took ten days before all had quite recovered from the effect of poisoning. On examing the fungus which remained uncooked, it was noticed that they emitted a pale light at the gills, revealing the fact that the fungus concerned was the "Tsukiyotaké," instead of the "Hirataké."

(2) People in north-eastern parts of Hondo are fond of a mushroom known to them by the name of "Tamogitaké" (=*Pleurotus ostreatus* Jacq.?). One day in August, 1907, some fishermen staying at Shimofuro in the Aomori Prefecture, gathered *Pleurotus japonicus*, evidently mistaking it for the edible "Tamogitaké," from a dead beech. Seven of them ate the fungi. After about an hour, all the men were attacked by symptoms of poisoning—vomiting, stomachache, diarrhœa, rumbling in the abdomen and dizziness of head. Fortunately all gradually recovered.

In the cases above mentioned, it seems the poisoning was comparatively light. In worse cases death not infrequently occurs. However, the poisoning effect of the present fungus is in general much weaker than that of *Amanitas*.

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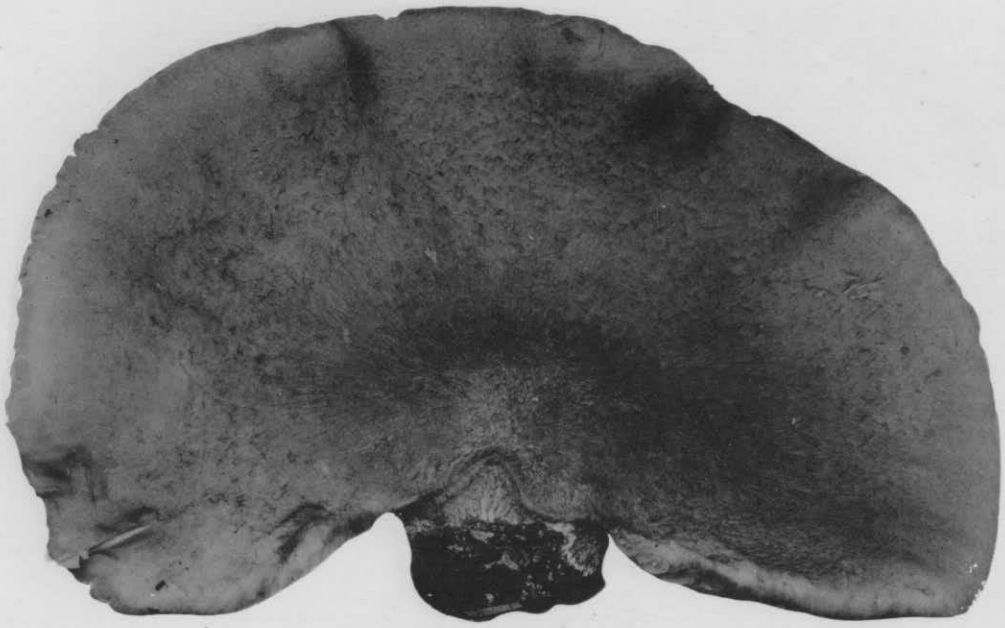
PLATE I.

PLATE I.

Fig. 1. *Pleurotus japonicus* Kawam. Upper surface, showing fibrous scales. $^2/_3$ natural size.

Fig. 2. Same. Lower surface, showing gills radiating from the stem which is attached at a point in the margin of pileus. $^2/_3$ natural size.

1



2

S. Kawamura : *Pleurotus japonicus* n. sp.

PLATE II.

PLATE II.

Pleurotus japonicus Kawam. Showing the imbricate-like growth on a rotten beech trunk. $^1/_6$ natural size.

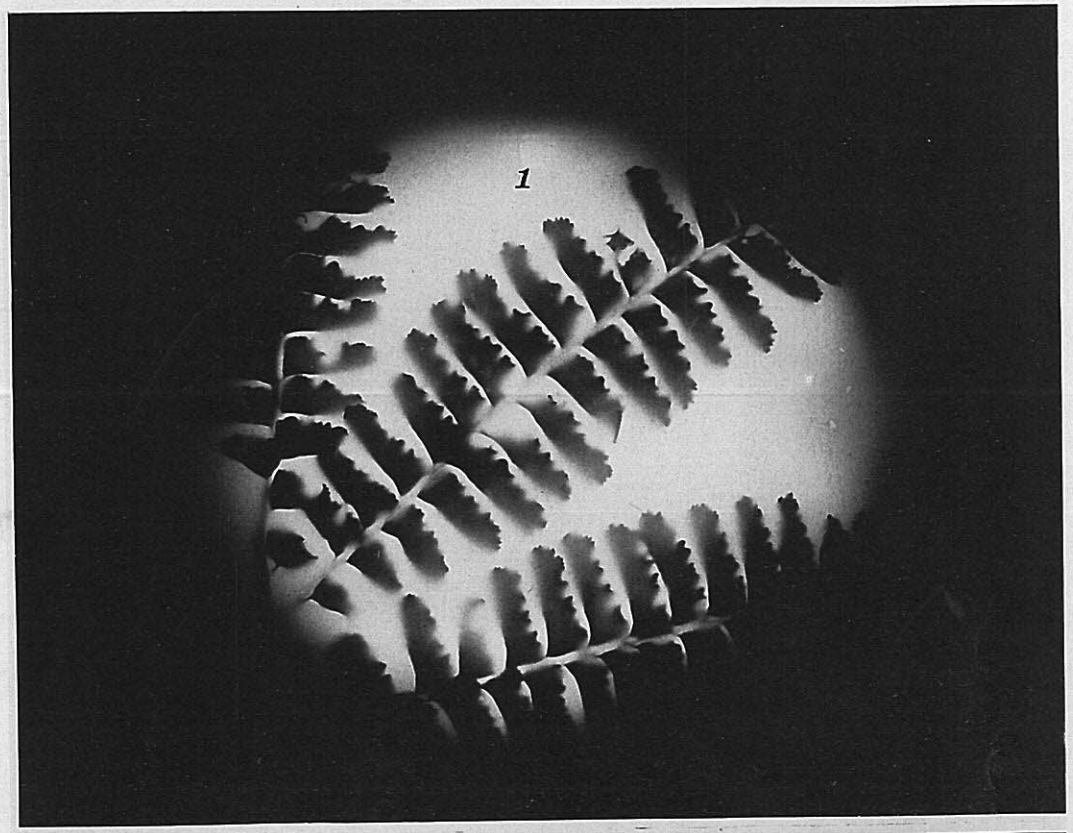
S. Kawamura : *Pleurotus japonicus* n. sp.

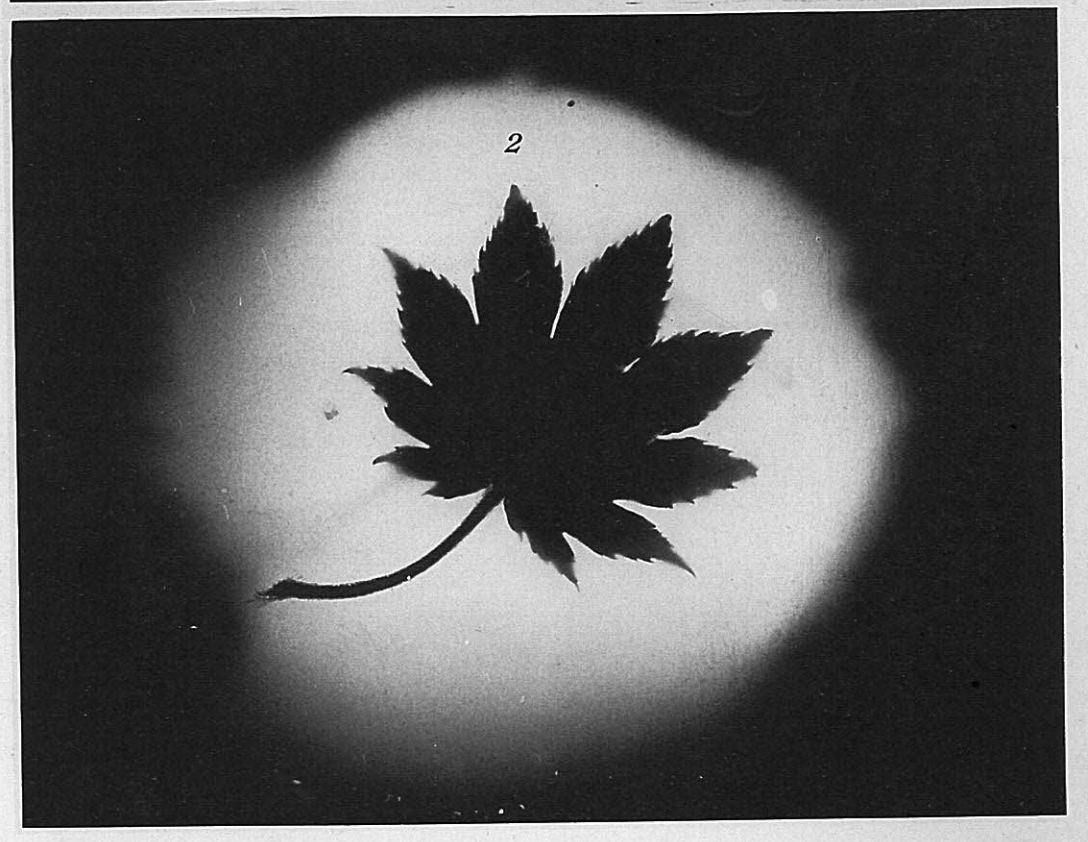
PLATE III.

PLATE III.

Fig. 1. Print by the fungus-light of a fern-frond on a photographic dry-plate. Exposure, three hours.

Fig. 2. Same of a maple leaf. Exposure, one hour and fifty minutes.





S. Kawamura : *Pleurotus japonicus* n. sp.