"The general purpose of the instruction given was stated to be not to prove or disprove any particular theory or doctrine, but to enable the student to know and to understand facts and conditions; to fit him to solve for himself the problems of government and of society, rather than to send him forth with a solution for all the problems that he may encounter.

"The Board of Visitors finds that the instruction given in the university, including that given by Professor Ross, is such as to strengthen, not to weaken, respect for government and the institutions of existing society.

Evidently the Board of Regents takes a more serious view of the case than the Board of Visitors but they agree that Professor Ross has been indiscreet. So does Professor Ross, for in a letter to President Van Hise he frankly acknowledges that he should not have alluded to Miss Goldman's lecture in his classes and promises not to commit that sort of a mistake again. We hope, therefore, that he will not feel that the censure of the regents makes it incumbent upon him to resign, and we hope that the regents will not feel it necessary to impose any further restrictions on freedom of expression by members of the faculty.—*The Independent.*

SCIENTIFIC BOOKS

Researches on Fungi. An account of the production, liberation and dispersion of the spores of Hymenomycetes treated botanically and physically. Also some observations upon the discharge and dispersion of the spores of Ascomycetes and of Pilobolus. By A. H. Reginald Buller. London, New York, Bombay and Calcutta. Longmans, Green & Co. 1909.

For several years Dr. Buller has been engaged in studying the biology of certain species of Hymenomycetes with special relation to their response to external natural stimuli, to the mechanism of spore discharge, the velocity of spore fall, the adaptation of the spores for wind dispersal, and the correlation of the structure and development of the fruit bodies, with their adjustments, for the production and dissemination of spores. A few papers have already been published in the *Annals of Botany* and the *Journal of Economic Biology,* dealing with the biology and adjustments of *Polyporus squamosus* and *Lentinus squamosus* (*L. lepideus*), but the larger body of interesting results are here published for the first time. It constitutes a notable contribution to the biology of the fungi, especially in regard to the question of spore discharge and spore fall in the Hymenomycetes, and the remarkable adjustments of the plants which assure the dissemination of myriads of these minute reproductive bodies.

Under the influence of gravity the geotropic curvature of the stem of certain agarics has been shown by Dr. Buller to exhibit the same phenomenon of geotropic swinging or swaying which occurs in the shoots of seed plants. He first observed this in *Coprinus plicatilis* where there was an overtilting or supracurvature four times before it came to rest in the perpendicular position. *Coprinus plicatiloides* Buller, a very minute species growing on horse dung, is remarkably sensitive, one plant curving through 90° in 17.5 minutes. This species also shows geotropic swinging, the successive supracurvatures of the individuals mentioned being 28°, 8°, 1°, 0°.

It has long been known that gravity influences the direction of growth of the stem of many agarics, the stems being negatively geotropic, and the horizontal development of the pileus of many woody or corky species of the Polyporaceæ, the fruit bodies of these plants being diageotropic. These adjustments under the influence of gravity have been recognized as of the greatest importance in permitting the fall of the spores from between the closely approximated gills of most agarics and from the long narrow tubes of most polypores. Dr. Buller has now placed the interpretation of some of these phenomena on a sound experimental basis and has shown also the variations and limitations of the influence of gravity in relation to the adjustment of position of the different parts of the fruit body in some half a dozen species. *A. campestris* responds in two ways to the influence of gravity —(1) the adjustment of the pileus in a horizontal position by the negatively geotropic stem, and (2) the finer adjustment of the gills by their positive geotropism. These two adjustments he speaks of as the coarse and fine adjustments, the positive geotropism of the gills placing them in a perpendicular position with reference to the earth in case the pileus should be slightly tilted from the horizontal.

Polyporus squamosus responds in four ways to the influence of gravity—(1) the negative geotropism of the stem after the initiation of the fruit body under the morphogenic influence of light, (2) growth of the pileus parallel to the earth's surface, (3) growth of the pileus with a symmetry suited to the position of the stipe, (4) growth of the hymenial tubes downward. *Agaricus campestris* is indifferent to light, while the fruit body of *Polyporus squamosus* is only initiated under the influence of light. The difference between the two species in the number of responses made to external stimuli, the author says, is correlated with the fact that one fungus grows on a tree and the other on the ground. While this correlation does exist it does not wholly explain the fundamental difference in behavior. One must take into consideration the difference in the origin of the plant parts, as well as the necessity of a permanent position of the stratum of tubes compared with the change in an agaric, provided the pileus has a general horizontal position, since the gills may descend or ascend from the stipe as the margin of the pileus is elevated and yet spore fall may not be interfered with.

The number of spores produced by a single fruit body was estimated in several species and the enormous number probably far exceeds the estimates and shows how prolific these plants are. An individual of *Agaricus campestris* produces about 2,000,000,000 spores, *Corpinus comatus* about 5,000,000,000, *Polyporus squamosus* about 11,000,000,000, and an individual of *Lycoperdon giganteum*, 40 × 28 cm. (16 × 11 inches) about 7,000,000,000,000. Single fruit bodies of some plants shed spores at the rate of 1,000,000 a minute, and this may be kept up for several days. Notwithstanding this enormous prolificness the waste is enormous because of the small chance of a spore being able to produce a new plant. He estimates that in *Polyporus squamosus*, considering also the perennial character of the mycelium, about one spore in 1,000,000,000,000 has a chance of starting a new successful cycle. The spores are sometimes shed in such vast numbers that they can be seen in clouds floating away from the plant. A species of *Polyporus squamosus* which was growing in a greenhouse shed such vast numbers that, when one entered in the morning and at other times, the air was so filled with spores it appeared as if some one had been smoking there. This continued for thirteen days and the plant continued to shed spores for three weeks. The spore-fall period varies in different individuals of a species. It was determined for several species, and the following examples are given: For *Coprinus plicatilis* a few hours, *Agaricus campestris* two to three days, *Polystictus hirsutus* five days, *Lenzites betulina* ten days, *Polystictus versicolor* sixteen days, *Schizophyllum commune* sixteen days, *Polyporus squamosus* three weeks.

One of the remarkable discoveries is the fact that many xerophytic fungi which have been preserved dry for several months or years may be revived by moistening, when spore fall will be resumed and continue for several days or weeks, even after the plants have been dried and revived several times in succession. Thus *Corticium læve* revived after one year shed spores, *Phlebia pileata* (*Phlebia strigosozonta*) after two years and eight months, *Polystictus versicolor* two years, *P. hirsutus* three years, *Schizophyllum commune* two years, *Trogia crispa* four months, *Lenzites betulina* three years, *Marasmius oreades* six weeks, *Collybia dryophila* one week. Spores of *Daedalea unicolor* and *Schizophyllum commune*, after the fruit bodies had been kept dry for three years, shed spores which were capable of germination as determined by test. This demonstrates that the shedding is an active process and that the plants were still alive. These two species are the only ones so far tested by the author for germination after such a long period of drying.

The spores are forcibly ejaculated from the sterigmata and fall down from between the gills or from the tubes. Thus spores of *Amanita vaginata* are shot outward with an initial velocity of 400 mm. per second to a distance of about 0.2 mm. The terminal vertical velocity of falling is about 5 mm. per second, while the spore is moist, but it soon becomes about 3 mm. as it dries. For most other species with smaller spores the spores are shot out for 0.5–0.1 mm. and the terminal vertical velocity is about 1–2 mm. per second. The horizontal discharge is so rapid that it can not be seen even with the aid of the microscope.

The terminal vertical velocity is reached in about one four-hundredth of a second. In actual observation and experience, however, the terminal velocity of fall is reached later, owing to the fact that the spores lose water rapidly by evaporation so that the velocity becomes reduced to one half in some and one third in others, the loss of water occuring even in a small compressor cell which contained wet blotting-paper and a drop of water, owing to the relatively high vapor pressure in the small spores whereby moisture passed over by distillation to the large drop of water. The more rapid fall, however, takes place while the spore is passing from between the gills or from the tubes, in consequence of which there is less danger of convection currents carrying them to the wall where they would adhere.

The mechanism of spore discharge in the Hymenomycetes receives special consideration. Several previous investigators have stated that the spores are squirted from the ends of the sterigmata by the bursting of the latter under hydrostatic pressure. Dr. Buller shows very conclusively that in the species studied by him and probably in all the Hymenomycetes this method of spore discharge is impossible. His reasons are as follows: (1) The successive, not simultaneous, discharge of the spores from a basidium. If the spores were squirted off, the basidium would lose its turgor after the discharge of the first one and the others would remain attached, (2) the absence of drops of liquid on the ends of the sterigmata, (3) the apparent closed condition of the sterigmata after discharge, (4) non-collapse of sterigmata and basidia as the spores disappear. While he is not able to state definitely the mechanism of discharge, owing to the very minute size of the point of the sterigma, he arrives at a very reasonable conclusion as to the mechanism. It is that of the existence of a double wall at the junction of the sterigma and the spore so that endosmotic pressure in the basidium and spore causes the rupture of the lateral wall connecting the edges of this double wall. This probably occurs somewhat in the same manner as the sudden breaking of threads of *Spirogyra* in consequence of the high endosmatic pressure of adjacent cells after the middle lamella of the wall has disappeared.

The trajectory described by the spore from the time it leaves the sterigma and follows its vertical path of fall is called the "*sporabola*." It was impossible to observe any portion of the sporabola except the path of vertical fall, since the velocity of discharge is so great, the initial velocity of a spore on leaving the sterigma being 40 cm. per second. The initial velocity is determined from mathematical formula, since the maximal horizontal distance of projection and the terminal vertical velocity of fall are determined by actual observation. These being known by mathematical formula, the sporabola can be plotted. The sporabola is remarkable in that the horizontal part passes with a very sharp curve into the vertical part, and the total declination on the horizontal path is approximately equal to the diameter of the spore. The very rapid slowing down of the horizontal velocity is due, of course, to the enormous friction which the relatively large surface of the minute spore offers to the air, and for the same reason the vertical velocity is very slow. Here is shown a very beautiful instance of correlation to structure and means for distribution. The gills of most agarics are very close together, from two millimeters to several millimeters apart. If the spores were not shot for some distance from the surface of the gill of the agaric, or tube of the polypore, they would fall upon the surface of the hymenium, and because of their adhesiveness could not escape. If they were shot too far they would strike the hymenium opposite and adhere. In *Agaricus campestris* they are thrust horizontally for about 0.1 mm. and in *Amanitopsis vaginata* about 0.2 mm. They then fall very slowly, and after passing below the gills are easily wafted away by even slight air currents.

The deliquescing Coprini represent another type of fruit body from that of other Hymenomycetes in the very high specialization which has taken place in the adaptations for spore dispersal. *Coprinus comatus,* the shaggy mane mushroom, will illustrate this type. The pileus is large and cylindrical, so that the broad, long gills stand vertically between it and the stem. The gills are very close together. At their edges are numerous projecting large cystidia which are connected with those of adjacent gills. If the basidia and spores matured simultaneously over the entire surface of the gills, or over any considerable portion, as in other agarics, very few of them would ever reach the outer air, since they would lodge on the surface of the gills or upon the numerous large cystidia on the sides of the gills. The basidia and spores are matured, first over a narrow zone occupying the edge at the lower end of the gills. The cystidia on the edges of the gills are dissolved by autodigestion. When these spores are shot off they readily reach the air below by falling. This now sterile part of the gill, by autodigestion, is reduced to a liquid condition. It is blackened probably by an oxydase which unites with certain substances. It is covered by a thin film and by evaporation becomes thinner, so that the spores from a narrow zone next above can readily fall down in the wider spaces thus formed, and so on. At the same time the pileus begins to expand more rapidly at the margin so that by the time the ink drops begin to fall they are out of reach of the falling spores. In contradistinction to the belief held by some that the spores of the Coprini are mixed with the inky fluid and that they are then disseminated by insects,[1] the author believes that under normal conditions very few if any spores are caught in the liquid, and that the spores are anemophilous.

The adjustments of the fruit body of *Coprinus comatus* are as follows: (1) A large number of gills with a very great spore-bearing surface, (2) a thin pileus, thus economizing energy in its development, but incapable of expanding and lifting the weight of the gills, (3) the spacing of the basidia by paraphyses assuring the free projection of the spores, (4) the nearly simultaneous expulsion of the spores from all of the basidia of a narrow zone at the lower edge, (5) the autodigestion of this zone to provide space for the fall of the spores shot from the basidia of an adjacent higher zone, and so on, (6) the gradual expansion of the pileus from its margin inward after autodigestion of the sterile parts of the gills removing the fluid parts from interference with the fall of spores from the successive zones of spore ejection, (7) the continued elongation of the stipe lifting the gills higher so that the spores are more easily caught by air currents.

These adjustments the author believes indicate a higher degree of specialization on the part of the Coprini and that, instead of being a primitive group as suggested by Massee[2] (p. 130), they represent the highest development and specialization of the Agaricini.

In many of the Ascomycetes, as has been long known, the spores are squirted out from the ascus. In *Peziza repanda,* with narrow cylindrical asci, the spores are shot out in a chain along with some of the liquid. The difference in momentum given the successive spores of the chain, together with the spontaneous segmentation of the liquid cylinder in which they are imbedded according to a well-known physical law, separates the spores in the air so that they are wafted away by the

[1] See Fulton, *Ann. Bot.*, III., 215, 1889.

[2] Massee, Geo., "A Revision of the Genus *Coprinus*," *Ann. Bot.*, X., 125–184, pl. 10, 11, 1896.

wind. This represents a type of the Ascomycetes adapted to wind dissemination of the spores. Another type is represented by *Ascobolus immersus* with broad elliptical asci, and large spores which are held together by a broad gelatinous investment so that they remain in a group as a single projectile as they are shot from the ascus to a distance of 20–35 cm. This mass, which is 2,000 times the volume of a basidiospore, is too heavy for wind dispersal. It falls on the surrounding herbage where the spores may be devoured by herbivorous animals and gain dispersal after passing through their digestive tract.

The rate of fall of the spores of the Hymenomycetes was used to test the theory known as Stokes's law relating to the fall of microscopic spheres in air, and it was confirmed to within 46 per cent. For determining the velocity of spore fall under direct observation through the microscope the author employed an ingenious device of an automatic electric recorder, the position of a spore, as it successively passed by spaced horizontal threads in a Ramsden ocular, being registered by a tapping key controlled with the left hand.

The illustrations and press work of this book are good, and besides the very interesting and important discoveries, it is full of stimulating suggestions and possibilities for further investigation.

Geo. F. Atkinson

Charles Darwin and the Origin of Species. Addresses, etc., in America and England in the year of the two anniversaries. By Edward Bagnall Poulton. New York, Longmans Green and Co.

It is fitting that upon November 14, 1909, the anniversary of the publication of the "Origin of Species," there should be published this memorial volume; fitting also that it should be written by a friend and advocate of Darwin's views in their entirety. Besides the addresses the volume contains some unpublished letters of Darwin and also a preface in which the author takes occasion to express his attitude toward the modern contributions to the study of evolution.

Nothing is more evident than that the younger generation of scientists has departed somewhat from the Darwinism of a generation ago. That fifty years' study of Darwin's great theories, by both friends and enemies, has established the general theories of which he was the most notable advocate upon an unshakable basis is very clear. But equally clear is it that this same half century has raised difficulties as to Darwin's special explanation of the method of evolution; difficulties so great that most of the younger generation of scientists are unable to accept Darwinism in its entirety as an all-sufficient theory. These difficulties have arisen not simply in the minds of Darwin's enemies, but in those of his friends also. That some solution of these difficulties is to be found is the belief of every admirer of Darwin, and moreover every admirer of Darwin must feel that this great master so fully exhausted the study of his great law of natural selection that little can be hoped for further study along the same lines. It is difficult to resist the belief that the removal of the difficulties that have arisen must come along new lines of study and not by the further exploitation of the old ones.

Poulton, however, apparently thinks otherwise and conveys the impression of holding that of the modern theories, that which is new is not true and that which is true is not new. The only real contribution to the discussion since Darwin that Poulton admits is Weismannism, and this he admits, seemingly, simply because it places the great theory of Darwin in a position "far higher than that ever assigned to it by Darwin himself." Of the mutation theory, which most thinkers to-day recognize as at all events decidedly stimulating, Poulton can only speak with a sneer, both at the theory and at its chief exponent. Some of Darwin's friends have been pleased to feel that Darwin really recognized mutations under the phrase "evolution per saltum" as a part of his theory. But Poulton is at pains to repudiate this idea entirely and to insist that Darwinism is a theory of evolution by minute steps and one of which any conception of mutation forms no part.