of object. These strange and, at present, unaccountable resemblances will probably be developed and possibly be interpreted by future investigations.

A. M. CLERKE.

TIMBER, AND SOME OF ITS DISEASES.[1]

XI.

It may possibly be objected that the subject of the present paper cannot properly be brought under the title of these articles, since the disease to be discussed is not a disease of timber *in esse* but only of timber *in posse*; nevertheless, while acknowledging the validity of the objection, I submit that in view of the fact that the malady to be described effects such important damage to the young plants of several of our timber-trees, and that it is a type of a somewhat large class of diseases, the slight impropriety in the wording of the general title may be overlooked.

It has long been known to forest nursery-men that, when the seedling beeches first appear above the ground, large numbers of them die off in a peculiar manner—they are frequently said to "damp off" or to "rot off." A large class of diseases of this kind is only too familiar, in its effects, to cultivators in all parts of the world. Every gardener, probably, knows how crowded seedlings suffer, especially if kept a trifle too damp or too shaded, and I have a distinct recollection of the havoc caused by the "damping off" of young and valuable Cinchona seedlings in Ceylon.

In the vast majority of the cases examined, the "damping off" of seedlings is due to the ravages of fungi belonging to several genera of the same family as the one (*Phytophthora infestans*) which causes the dreaded potato disease—*i.e.* to the family of the Peronosporeæ—and since the particular species (*Phytophthora omnivora*) which causes the wholesale destruction of the seedlings of the beech is widely distributed, and brings disaster to many other plants; and since, moreover, it has been thoroughly examined by various observers, including De Bary, Hartig, Cohn, and others, I propose to describe it as a type of the similar forms scattered all over the world.

It should be premised that, when speaking of this disease, it is not intended to include those cases of literal damping off caused by stagnant water in ill-drained seed-beds, or those cases where insufficient light causes the long-drawn, pale seedlings to perish from want of those nutrient substances which it can only obtain, after a certain stage of germination, by means of the normal activity of its own green cotyledons or leaves, properly exposed to light, air, &c. At the same time, it is not to be forgotten that, *as conditions which favour the spread of the disease to be described*, the above factors and others of equal moment have to be taken into account; which is indeed merely part of a more general statement, viz. that, to understand the cause and progress of a disease, we must learn all we can about the conditions to which the organisms are exposed, as well as the structure, &c., of the organisms themselves.

First, a few words as to the general symptoms of the disease in question. In the seed-beds, it is often first noticeable in that patches of seedlings here and there begin to fall over, as if they had been bitten or cut where the young stem and root join, at the surface of the ground: on pulling up one of the injured seedlings, the "collar," or region common to stem and root, will be found to be blackened, and either rotten or shrivelled, according to the dampness or dryness of the surface of the soil. Sometimes the whole of the young root will be rotting off before the first true leaves have emerged from between the cotyledons; in other cases, the "collar" only is rotten, or shrivelled, and the weight of the parts above ground causes them to fall prostrate on the surface of the soil; in yet others, the lower parts of the stem of the older seedling may be blackened, and dark flecks appear on the cotyledons and young leaves, which may also be turning brown and shrivelling up (Fig. 36).

If the weather is moist—*e.g.* during a rainy May or June—the disease may be observed spreading rapidly from a given centre or centres, in ever-widening circles. It has also been noticed that if a moving body passes across a diseased patch into the neighbouring healthy seedlings, the disease in a few hours is observed spreading in its track. It has also been found that if seeds are again sown in the following season in a seed-bed which had previously contained many of the above diseased seedlings, the new seedlings will inevitably be killed by this "damping off." As we shall see shortly, this is because the resting spores of the fungus remain dormant in the soil after the death of the seedlings.

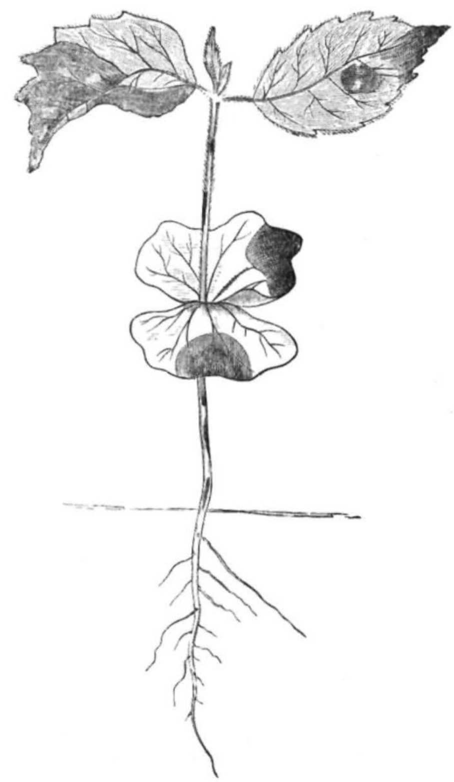

FIG. 36.—A young beech-seedling attacked by *Phytophthora omnivora*: the moribund tissues in the brown and black patches on the young stem, cotyledons, and leaves. are a prey to the fungus, the mycelium of which is spreading from the different centres. The horizontal line denotes the surface of the soil.

In other words, the disease is infectious, and spreads centrifugally from one diseased seedling to another, or from one crop to another: if the weather is moist and warm—"muggy," as it is often termed—such as often occurs in the cloudy days of a wet May or June, the spread of the disease may be so rapid that every plant in the bed is infected in the course of two or three days, and the whole sowing reduced to a putrid mass; in drier seasons and soils, the spread of the infection may be slower, and only a patch here and there die off, the diseased parts shrivelling up rather than rotting.

If a diseased beech seedling is lifted, and thin sections of the injured spots placed under the microscope, it will be found that numerous slender colourless fungus-filaments are running between the cells of the tissues, branching and twisting in all directions. Each of these fungus-fila-

[1] Continued from p. 293.

ments is termed a hypha, and it consists of a sort of fine cylindrical pipe with very thin membranous walls, and filled with watery protoplasm. These hyphæ possess the power of boring their way in and between the cell-walls of the young beech seedling, and of absorbing from the latter certain of the contents of the cells. This is accomplished by the hyphæ putting forth a number of minute organs like suckers into the cells of the seedling, and these suckers take up substances from the latter: this exhaustion process leads to the death of the cells, and it is easy to see how the destruction of the seedling results when thousands of these hyphæ are at work.

At the outer parts of the diseased spots on the cotyledons or leaves of the seedling, the above-named hyphæ are seen to pass to the epidermis, and make their way to the exterior: this they do either by passing out through the openings of the stomata, or by simply boring through the cell-walls (Fig. 37). This process of boring through the cell-walls is due to the action of a solvent substance excreted by the growing tip of the hypha: the

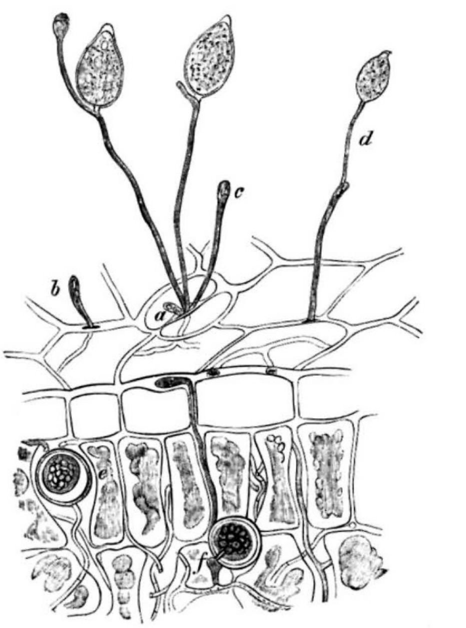

FIG. 37.—Portion of a cotyledon of the beech, infested with *Phytophthora omnivora*: the piece is shown partly in vertical section. The mycelium, spreading between the cells, puts forth aërial hyphæ, which bore between the cells of the epidermis, *b* and *d*, or emerge from the stomata, *a*, and form conidia at their apices: the various stages of development are shown. On other hyphæ, between the cells of the interior, the oospores are formed in oogonia, *c* and *f*. (Highly magnified.)

protoplasm secretes a ferment, which passes out, and enables the tip to corrode or dissolve away the substance of the cell-walls. It is also characteristic of these hyphæ that they make their way in the substance of the cell-walls, in what is known as the "middle lamella": in this, and in what follows, they present many points of resemblance to the potato-disease fungus, which is closely allied to *Phytophthora omnivora*.

The hyphæ which project from the epidermis into the damp air proceed to develop certain spores, known as the *conidia*, which are capable of at once germinating and spreading the disease. These conidia are essentially nothing but the swollen ends of branches of these free hyphæ: the ends swell up and large quantities of protoplasm pass into them, and when they have attained a certain size, the pear-shaped bodies fall off, or are blown or knocked off.

Now the points to be emphasized here are, not so much the details of the spore-formation, as the facts that (1) many thousands of these spores may be formed in the course of a day or two in warm, damp weather; and (2) any spore which is carried by wind, rain, or a passing object to a healthy seedling may infect it (in the way to be described) within a few hours, because the spore is capable of beginning to germinate at once in a drop of rain or dew. A little reflection will show that this explains how it is that the disease is spread in patches from centres, and also why the spread is so rapid in close, damp weather.

When a conidium germinates in a drop of dew for instance, the normal process is as follows. The protoplasm in the interior of the pear-shaped conidium becomes divided up into about twenty or thirty little rounded naked masses, each of which is capable of very rapid swimming movements; then the apex of the conidium bursts, and lets these minute motile zoospores, as they are called, escape (Fig. 38, *a*).

Each zoospore then swims about for from half an hour to several hours in the film of water on the surface of the epidermis, and at length comes to rest somewhere. Let us suppose this to be on a cotyledon, or on the stem or root. In a short time, perhaps half an hour, the little

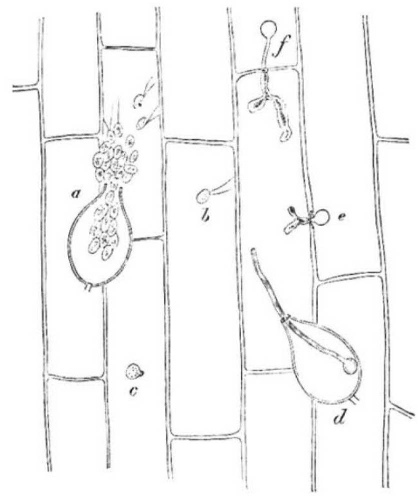

FIG. 38.—Portion of epidermis of a beech-seedling, on which the conidia of the *Phytophthora* have fallen and burst, *a* and *d*, emitting the motile zoospores, *b*, which soon come to rest and germinate, *c*, by putting forth a minute germinal hypha, *c*, *e*, which penetrates between the cells of the epidermis, *e* and *f*, and forms the mycelium in the tissues beneath. At *d* a zoospore has germinated, without escaping from the conidium. (Highly magnified: partly after De Bary and Hartig.)

zoospore begins to grow out at one point—or even at more than one—and the protuberance which grows out simply bores its way directly through the cell-wall of the seedling, and forms a cylindrical hypha inside (Fig. 38, *b*, *c*, *e*, *f*): this hypha then branches, and soon proceeds to destroy the cells and tissues of this seedling. The whole process of germination, and the entrance of the fungus into the tissues, up to the time when it in its turn puts out spore-bearing hyphæ again, only occupies about four days during the moist warm weather in May, June, and early in July.

We are now in a position to make a few remarks which will enable practical people to draw helpful conclusions from what has been stated. Let us suppose a seed-bed several feet long and about three feet wide, and containing some thousands of young beech seedlings: then suppose—by any means whatever—that a single conidium of *Phytophthora omnivora* is carried on to a cotyledon of one of the seedlings. Let us further assume that this occurs one warm evening in May or June. During the night, as the air cools, the cotyledon will be covered with a film or drops of water, and the conidium will germinate, and allow, say, thirty zoospores to escape. Now, the average size of a conidium is about 1/400 of an inch long by about 1/700 of an inch broad, and we may take the zoospore as about 1/2000 of an inch in diameter; thus it is easy to see that the film of moisture on the cotyledon is to a zoospore like a large pond or lake to a minnow, and the tiny zoospores, after flitting about in all directions, come to rest at so many distant points on the cotyledon—or some of them may have travelled abroad along the moist stem, or along a contiguous leaf, &c. Before daylight, each of these thirty zoospores may have put forth a filament which bores between the cells of the cotyledon, and begins to grow and branch in the tissues, destroying those cell-contents which it does not directly absorb, and so producing the discoloured disease-patches referred to. Supposing the weather to remain damp and warm, some of the hyphæ may begin to emerge again from the diseased and dying seedling on the fourth day after infection—or at any rate within the week—and this may go on hour after hour and day after day for several weeks, each hypha producing two or more conidia within a few hours of its emergence; hence hundreds of thousands of conidia may be formed in the course of a few days, and if we reflect how light the conidia are, and how their zoospores can flit about to considerable distances, it is not surprising that many of them are shed on to the surrounding seedlings, to repeat the story. If we further bear in mind that not only every puff of wind, but every drop of rain, every beetle, or fly, or mouse, &c., which shakes the diseased seedling may either shake conidia on to the next nearest

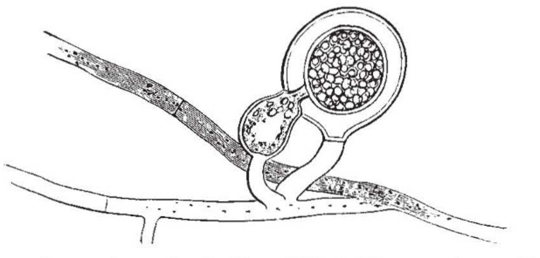

FIG. 39.—An oogonium and antheridium of *Phytophthora omnivora*. The oogonium is the larger rounded body, borne on a branch of the mycelium: it contains an oosphere, in process of being fertilized by the protoplasm of the antheridium (the smaller body applied to the side of the oogonium). The antheridium has pierced the wall of the oogonium, by means of a fertilizing tube, through which the contents pass into the oosphere, converting the latter into an oospore. (Very highly magnified: after De Bary.)

seedlings or even carry them further, it is clearly intelligible how the infection is brought about, and spreads through the seed-bed, gathering strength, as it were, hour by hour.

But, although we have explained the rapid infection from plant to plant, it still remains to see how it is that if we sow the seeds in this bed next year, the seedlings are almost certain to be generally and badly attacked with the disease at a very early stage.

When the fungus-mycelium in the cotyledons and other parts of the diseased seedlings has become fully developed, and has given off thousands of the conidia above described, many of the branches in the dying tissues commence to form another kind of spore altogether, and known as an oospore, or egg-like spore. This spore differs from the conidium in size shape, and position, as well as in its mode of development and further behaviour, and if it were not that several observers have seen its formation on the same hyphæ as those which give rise to the conidia, it might be doubted by a beginner whether it really belongs to our fungus at all. As it is absolutely certain, however, that the oospore on germination gives rise to the fungus we are considering, the reader may rest satisfied on that point.

The spore in question is formed in a swelling of the free end of a branch of the hypha as follows. The protoplasm in the rounded end of the hypha becomes collected into a ball (the egg cell or *oosphere*) and then a smaller branch with a distinct origin applies itself to the outside of this rounded swelling and pierces its wall by means of a narrow tube: protoplasm from the smaller branch (*antheridium*) is then poured through the tube into the "egg-cell," which thus becomes a fertilized "egg-spore" or *oospore*. This *oospore* then acquires a very hard coating, and possesses the remarkable peculiarity that it may be kept in a dormant state for months and even a year or more before it need germinate: for this reason it is often called a resting spore. It has been found that about 700,000 oospores may be formed in one cotyledon, and a handful of the infected soil sufficed to kill 8000 seedlings.

Now, when we know this, and reflect that thousands of these *oospores* are formed in the rotting seedlings and are washed into the soil of the seed-bed by the rain, it is intelligible why this seed bed is infected. If seeds are sown there the next spring, the young seedlings are attacked as soon as they come up. These *oospores* are, in fact, produced in order that the fungus shall not die out as soon as it has exhausted the current year's supply of seedlings; whereas the *conidia*, which soon lose their power of germinating, are the means by which the parasite rapidly extends itself when the conditions are most favourable for its development and well-being.

It has already been mentioned that other plants besides the beech are destroyed by the ravages of this fungus. Not only has it been found to grow on herbaceous plants, such as *Sempervivum*, *Clarkia*, and many others, but it habitually attacks the seedlings of many timber-trees, such as, for instance, those of the spruce and silver firs, the Scotch pine, the Austrian and Weymouth pines, the larch, the maples, and particularly those of the beech.

It is obvious that this makes the question of combating this disease a difficult one, and the matter is by no means simplified when we learn that the fungus can live for a long time in the soil as a saprophyte, and apart from the seedlings. In view of all the facts, let us see, however, if anything can be devised of the nature of precautionary measures. It must at least be conceded that we gain a good deal by knowing so much as we do of the habits of this foe.

In the first place, it will occur to everybody never to use the same seed-bed twice; but it may be added that this precaution need not be taken as applying to anything but seeds and seedlings. Young plants, after the first or second year, are not attacked by the fungus—or rather are attacked in vain, if at all—and so the old beds may be employed for planting purposes. In the event of a patch of diseased seedlings being found in the seed-bed, as in our illustration quoted above, the procedure is as follows: cover the whole patch with soil as quietly and quickly as possible, for obviously this will be safer than lifting and shaking the spore-laden plantlets. If, however, the sharp eye of an intelligent gardener or forester detects one or two isolated seedlings showing the early stages of the disease, it is possible to remove the single specimens and burn them, care being taken that the fingers, &c., do not rub off spores on to other seedlings.

In the last event, the beds must be looked to every day to see that the disease is not spreading. All undue shading must be removed, and light and air allowed free play during part of the day at least; by such precautions, carefully practised in view of the above facts and their consequences, it is quite feasible to eradicate the disease in cases where ignorant or stupid mismanagement would result in the loss of valuable plants and time. In the case of other seedlings also, much may be done by intelligently applying our knowledge of the disease and its cause. It is not our purpose at present to deal with the diseases of garden-plants, &c., but it may be remarked in passing that in the large majority of cases the "damping off" of seedlings is due to the triumphant development of fungi belonging to the same genus as the one we have been considering, or else to the closely allied genus *Pythium*. In illustration of this I will mention one case only.

It is always possible to obtain well-grown specimens of the fungus *Pythium* by sowing cress seed fairly thick, and *keeping the soil well watered and sheltered*. Now what does this mean? Nobody imagines that the fungus arises spontaneously, or is produced in any miraculous manner; and in fact we need not speculate on the matter, for the fact is that by keeping the crowded cress seedlings moist and warm we favour the development of the *Pythium* (spores of which are always there) in somewhat greater proportion than we do the development of the cress. In other words, when the cress is growing normally and happily under proper conditions, it is not because the *Pythium* is absent, but because (under the particular conditions which favour the normal development of healthy cress) it grows and develops spores relatively so slowly that the young cress seedlings have time to grow up out of its reach. The recognition of this struggle for existence on the part of seedlings is of the utmost importance to all who are concerned with the raising of plants.

H. MARSHALL WARD.

NATURAL SELECTION AND ELIMINATION.[1]

MR. DARWIN'S phrase, "natural selection," is applied to such processes, other than those involving the agency of man, as result under Nature in the survival of the fittest. These processes fall under two heads, which have not, I think, been sufficiently distinguished. For the first of these I here retain the word *selection;* for the other I suggest the term *elimination*.

In natural selection the favourable varieties are chosen out for survival: in natural elimination the failures or comparative failures are weeded out. In the one, Nature is employing conscious agents upon the upper or superior end of the scale: in the other, Nature is, through conscious or unconscious agencies, at work on the lower or inferior end of the scale.

Variation is constantly taking place; and the variations may be favourable or unfavourable or neutral. Under selection the favourable variations will be chosen out; the unfavourable and the neutral may go. Under elimination the unfavourable disappear; the favourable *and the neutral* remain. By how much the favourable variations are in excess, by so much will the race tend to advance. I see no reason why neutral variations should be eliminated, except in so far as—in the keen struggle for existence—they become relatively unfavourable.

In the valuable and suggestive paper in which Mr. G. J. Romanes dealt with physiological isolation, he brought forward the inutility of specific characters as one of the three cardinal difficulties in the way of natural selection considered as a theory of the origin of species. So long as we consider selection proper, this objection is valid. But under elimination (by far the more potent of the two) there is no reason why specific features without utilitarian significance should be weeded out. Undoubtedly, in the long run, useful variations will tend more and more to preponderate, since, the longer and keener the struggle, the greater the tendency for neutral variations to become relatively unfavourable. And this conclusion is in harmony with the teachings of biology. For, as Mr. Romanes remarks, "it is not until we advance to the more important distinctions between genera, families, and orders that we begin to find, on any large or general scale, unmistakable evidence of utilitarian meaning."

Natural elimination is intimately associated with the struggle for existence, which may indeed be regarded as the reaction of the organic world called forth by the action of natural elimination. The struggle for existence is the result of a threefold process of elimination (cf. "Origin of Species," chap. iii.). First, elimination by the direct action of surrounding conditions; secondly, elimination by enemies (including parasites); and, thirdly, elimination by competition.

[1] Abstract of a Paper read before the Bristol Naturalists' Society.

Natural selection (in the narrower sense suggested) is a much rarer process, and one that only comes into play when intelligence, or (since it may be objected that selection is in some cases instinctive) when the mind-element comes definitely upon the scene of life. Perhaps one of the best examples is the selection of flowers and fruits by insects and fruit-eating animals. But even here (at least in the case of flowers) the process of elimination also comes into play: for the visitation of flowers by insects involves cross-fertilization, the advantages of which Mr. Darwin so exquisitely proved. So that we have here the double process at work, the fairest flowers being selected by insects, and those plants which failed to produce such flowers being eliminated as the relatively unfit.

If we turn to the phenomena of what Mr. Darwin termed "sexual selection," we find both selection and elimination brought into play. By the law of battle the weaker and less courageous males are eliminated, so far as the continuation of their kind is concerned. By the individual choice of the females, the finer, bolder, handsomer, and more tuneful wooers are selected.

When we have to consider the evolution of human folk, the principle of elimination is profoundly modified by the principle of selection. Not only are the weaker eliminated by the inexorable pressure of competition, but we select the more fortunate individuals and heap upon them our favours. This enables us also to soften the rigour of the blinder law; to let the full stress of competitive elimination fall upon the worthless, the idle, the profligate, and the vicious; but to lighten its incidence on the deserving but unfortunate.

It is my belief that our views of evolution gain in clearness by the separation of these two processes by which the survival of the fit is brought about. Whether the use of the term "natural elimination" alongside of and in subservience to "natural selection" would be of service to those who are students and teachers of evolution doctrines, I must leave others to judge.

C. LLOYD MORGAN.

THE FAUNA AND FLORA OF THE LESSER ANTILLES.

ALTHOUGH much has been done of late years, both in the United States and in Europe, towards the investigation of the fauna and flora of the smaller West Indian Islands, or Lesser Antilles, as it is better to call them, much remains to be effected before we can be deemed to have an accurate knowledge of the natural products of these islands. And it is most important that steps should be taken to remedy this deficiency without further delay. As the tide of civilization advances—more slowly, perhaps, it is true, over these islands than in many other parts of the world's surface—the special peculiarities which each individual island possesses among its animal and vegetable indigens are fast becoming overwhelmed by the more powerful animals and plants that accompany the inroads of civilized man upon the wilderness of Nature. As in other places, where settlers from Europe arrive, rats and mice eat out the indigenous animals, and exotic weeds starve out the native plants. It is therefore most desirable that, while there is yet time, exact information should be obtained of the flora and fauna of these islands, every one of which seems to exhibit features more or less peculiar to itself.

This subject having been brought before the Committee of Section D at the Manchester meeting of the British Association by Mr. Sclater, a grant of £100 was made for