BIOLOGICAL CONTROL OF INSECTS.

B. A. O'Connor, B.A., B.Sc.Ag., Assistant Entomologist.

One commonly hears allusion made to the phenomenon known as the "Balance of nature", the principle on which are based all attempts at biological control, that is, the control of one species of living thing by another. The phrase "Balance of nature" describes the state of equilibrium which occurs in any given locality between the native species of plants and animals. Any one species is prevented from multiplying to such an extent that it will jeopardize the welfare of the others, and each component of the native fauna and flora takes its part in confining the other components to a limited sphere. The principle is well illustrated by the predatory animals which keep down the numbers of other wild life.

Man, however, in his agricultural activities, interferes with natural conditions, and provides large areas of succulent food, on which various species of native insects thrive. Moreover, he frequently introduces, usually by accident, new kinds of insects from distant localities, often without the parasites which preyed upon them in their natural habitat. Hence the newly introduced insect, free from attack by its natural enemies, spreads with a rapidity which threatens serious damage to crops and stock, and it then has to be controlled artificially or biologically. Biological control consists of finding parasites of the injurious insect in the locality from which it was brought, and introducing them into the new area in the hope that they will adapt themselves to the new environment and reduce the numbers of the pest below the danger level. Obviously this method of controlling insects is ideal, for, once established, the parasite costs nothing, and in successful cases it keeps its host down to negligible proportions. But first the parasite must be found, and later successfully introduced into its new environment. The rewards of victory are so great, however, that many countries keep permanent staffs working on parasite introduction alone, the United States of America in particular spending huge sums on this work.

Though parasitism of insects by other insects has been known to observers since the beginning of the seventeenth century, it was not until 1889 that the first really great success was achieved by biological control methods. It was in this year that Koebele imported into California from Australia the lady-bird beetle *Vedalia cardinalis,* and thus saved the Californian citrus industry from the ruin which threatened it as a result of the ravages of the Cottony-Cushion Scale, *Icerya purchasi.* The story of this accomplishment, the first great landmark in the history of the biological control of insects, has often been told, but nevertheless it cannot be omitted from any discussion of the subject.

The Cottony-Cushion Scale had become firmly established in the citrus groves of California, and was the cause of immense loss to the growers, owing to the cost of controlling it by artificial methods. Riley, who was in charge of the entomological work of the United States Department of Agriculture, knew that the insect had been introduced from Australia or New Zealand, and by corresponding with entomologists in those two countries, he found that while the pest was abundant and injurious in New Zealand, it was not considered a pest in Australia. From these facts he concluded that Australia was the home of the insect, and that it was held in check there by natural enemies. In 1887, specimens of a parasite were sent to him from Australia, proving to be a remarkable new species of fly now known as *Cryptochaetum iceryae*. Riley was now eager to go to Australia to obtain supplies of this parasite, but was unable to do so. It happened, however, that in the following year an international exposition was to be held in Melbourne, and the United States of America intended sending a party of representatives. Riley arranged for one of his assistants, Albert Koebele, to be included in the party for the purpose of collecting parasites of the Cottony-Cushion Scale.

On his arrival in Australia, Koebele collected and sent back material containing *Cryptochaetum*, which, however, did not prove a success; but he found *Vedalia cardinalis*, the lady-bird beetle, feeding on the scale, and forwarded several colonies to Los Angeles, comprising 139 beetles in all. A few months later, the lady-birds were liberated in the field, and within twelve months the Cottony-Cushion Scale was practically wiped out in California. The growers and many of the leading men in the horticultural industry were wildly enthusiastic over this spectacular success, and were convinced that at last the panacea had been found for the control of all insect pests. As a matter of fact, Dr. Howard, of the United States of America Department of Agriculture, states that this achievement was by no means an unmixed blessing, as it set back control work against insects for many years, due to a lack of faith in artificial methods of control. *Vedalia cardinalis* was subsequently sent to many parts of the world where the scale was a pest, and everywhere it registered a complete and rapid victory.

The investigation of the reasons for the great success of *Vedalia cardinalis* is of particular importance to the student of biological control, as it sheds considerable light on the question of the qualities in a parasite or predator which should be looked for as desirable. The main factors in the success of the lady-bird may be tabulated as follows:—

1. It is largely independent of climatic conditions, flourishing in almost every locality where its host is found.

2. It is a "specific predator", that is its activities are confined to one insect species, instead of being dissipated on a number, and it devours large numbers of its host in all stages of its (the parasite's) life-history. (An insect which devours its host is usually referred to as a predator, the term "parasite" being commonly restricted to internal parasites, which develop within the body of their host. Predators usually are not specific, this characteristic being more often found among internal parasites.)

3. It is very active, and spreads rapidly, while its host is sedentary.

4. It has approximately three generations to the scale's one.

5. It is exceptionally free from natural enemies.

A great deal of work has also been carried out in California on the Black Scale, *Saissetia oleae*. Several parasites of this insect have been introduced, and the best of them is *Metaphycus lounsburyi*, brought from Australia in 1916. It is, however, by no means as effective as it should be, because it is attacked by a secondary parasite, *Quaylea whittieri*, which was introduced from Australia in 1901, and liberated under the mistaken idea that it was a parasite of the scale. It lived on another parasite of the scale until the introduction of *Metaphycus*, which was its preferred host, and to which it has now transferred the bulk of its attention.

The introduction of secondary parasites is a danger which nowadays is carefully guarded against by entomologists who attempt to import parasites, for once they are established in the field, they cannot be got rid of, and may cause, as in California, the annual loss of thousands of pounds. Two precautionary measures which definitely establish whether a parasite is primary or secondary are first the examination of the parasitized material from which the insect has emerged, to see if there are any remains of the larvae or pupae of primary parasites, and second a trial of whether the suspected parasite will breed in unparasitized specimens of the host insect. For instance, before *Dorinia leefmansi,* a primary parasite of *Sexava* eggs, was transferred from Lavongai to Manus, these tests were applied, revealing the fact that *D. leefmansi* was a primary parasite. Similar precautions were taken with *Leefmansia* before its introduction from Amboina as a parasite of *Sexava* eggs.

One of the most interesting phenomena met with in biological control work on insects is "multiple parasitism", that is, a simultaneous attack on a host insect by two or more species of parasites. The practical considerations arising out of this phenomenon are among the most important in the whole field of biological control, because they affect in the most decided fashion the policy to be pursued in the introduction of parasitic insects. Entomologists who have studied the subject have held radically different views on the question of whether it is better to introduce only one parasite of any given stage of an insect's life-history, choosing, of course, the most efficient, or to bring in as many different species of parasites as are available.

The point at issue is that if one parasite attacks say 80 per cent. of the hosts in its natural habitat, and the other only 40 per cent., would it not be better to introduce only the former, as it is the more efficient, rather than have the two competing with one another, possibly to the detriment of the better parasite. It oftens happens, too, that when two such parasites have both attacked the same host, the less efficient one proves more hardy, and survives while the other perishes. This subject has been extensively studied by Willard and Pemberton working on parasites of fruit fly in Hawaii. Several species of parasites have been introduced, and Willard and Pemberton came to the conclusion that it would have been better if only the most efficient of these had been utilized. This view was opposed, however, by Smith, a noted Californian expert on biological control methods, and his arguments are very convincing. In the work on local parasites of *Sexava,* Smith's ideas were followed, and an attempt was made to introduce several parasites from Lavongai to Manus, most important of them being *Dorinia leefmansi.* Unfortunately, however, these parasites, though doing excellent work in Lavongai, are by no means as robust as *Leefmansia bicolor,* the Amboina parasite, and their introduction to Manus has as yet shown no signs of success.

In no part of the world has biological control been more successful than in the Hawaiian Islands. In these islands an immense amount of work has been done by Muir, Perkins and others, employed by the Hawaiian Sugar Planters' Association. Muir, writing shortly before his death in 1931, ascribed the signal success obtained to two main factors, namely, the peculiar biological conditions existing in Hawaii, and the recognition of these factors by the entomologists resident there. The peculiar biological conditions alluded to are worthy of some discussion. The Hawaiian islands are the tops of a lofty chain of mountains which rises from the bottom of the sea, and extends from the north-west to the south-east. With the exception of a few deposits of mud and coral, the islands are composed entirely of volcanic rock. From this fact, and from the unique nature of the flora and fauna, we can conclude that the land is purely oceanic in origin. It rose slowly from the ocean, and was built up by outpourings of lava over a long period of time. The islands were never joined up to any large continental land mass, and this accounts for the peculiar nature of the flora and fauna. Only such plants and animals as could be borne by birds, or by the wind, or on floating logs and similar material could establish themselves. Muir claimed that even to-day it may truthfully be said that in a broad sense the native flora and fauna are composed almost entirely of types that arrived in this way, or their descendants.

Later on, primitive man arrived, bringing with him domestic plants and various insects attacking them, and by cultivating the food-plants of the insects, he provided them with plentiful sustenance, which, in conjunction with the suitable climate, provided ideal conditions for their rapid multiplication. However, many of these insects had parasites in the country of their origin, which, in the course of ages, had adapted themselves to the particular species concerned, or to closely allied species, and when they were introduced, they also found abundant food and suitable climate, and consequently, in many cases, proved very effective in controlling the injurious insects concerned.

So far, the discussion has been confined to the introduction of parasites from one faunal region to another, but there is a further aspect of the question which should be considered, namely, the breeding and dispersal of parasites already present in a region. At first sight this does not seem a very promising line of activity, because one would imagine that if the conditions were favorable for the spread of such an insect, it would spread without the aid of man, and that its failure to do so should be sufficient evidence that it could not be a success. Nevertheless, attempts in this direction have sometimes met with success, particularly when done on a large scale. One of the best examples is to be found in the annual breeding and distribution of the lady-bird beetle *Cryptolaemus montrouzieri*, an insect predaceous on the *citrophilous* mealy bug in California. The lady-bird is not a native of California, having been brought from Australia in 1892 as a parasite of the mealy bug. However, it did not come up to expectations, for though every now and then it succeeded in controlling an outbreak of the pest, its efforts were too spasmodic, and usually too late in the season to be of any real value. By the year 1916, however, it had firmly established itself in the fauna of California, so it can be taken as an example of an insect already existing in a faunal region.

The Californian entomologists concluded that the trouble with *Cryptolaemus* was that it destroyed an outbreak of mealy bug and was then starved out, as it confined its feeding strictly to the one insect. Thus, when a fresh outbreak of the pest occurred, the lady-bird took a long time to breed up again, with the result that its beneficial effects were spasmodic. They considered therefore, that if they could keep a constant large supply of *Cryptolaemus* on hand, they would be able to distribute the parasite whenever it was called for by an outbreak of mealy bug, and thus give it an opportunity to cope with its host. The chief difficulty in this scheme was to evolve a satisfactory technique for breeding the beetle throughout the year. At first, the food used was green citrus fruits, chiefly lemons. Unfortunately, however, the laboratory conditions suitable for the welfare of the host plant and for that of the mealy-bug were not compatible. Gas heat was necessary for the rapid development of the mealy bugs, but it had the effect of curing the fruit and toughening the skin in such a short time that the insects either died or migrated unsuccessfully in search of more suitable food. It was at this juncture that the use of potato sprouts was initiated, and it proved a great success. A little experience in the technique of this method led to the production of a continual supply of mealy bugs on which to feed the lady-birds, and so large numbers of *Cryptolaemus* were available for distribution when required. The work of breeding and distribution has been aided considerably by the erection of branch insectaries in various countries of California, together with private insectaries on the properties of some of the more important citrus growers.

Often, ignorance of a very small detail in the life-history of a parasite will hold up successful breeding, and as often as not it is by chance that a solution is arrived at. A good illustration of this is the case of the introduction of a wasp, *Meteorus versicolor,* from France to the United States of America, for use in the control of the Gipsy Moth. Almost all parasitic *Hymenoptera* (the order which includes ants, bees and wasps) deposit eggs whether fertilized by a male or not, the unfertilized eggs almost always producing only males. Hence it is important to see that mating takes place, in order that both sexes may be available for breeding. The imported Gipsy Moth parasites laid freely in the caterpillars of their host, and in due course cocoons were spun and wasps emerged. However, they proved to be all males, indicating that mating had not taken place in the first instance. Further attempts were equally unsuccessful, so that finally it was decided to liberate in the field a small colony of the parasites bred from imported material. This colony was put in a glass tube, and, in the course of its being carried to the woods, it was struck by the direct rays of the sun. Immediately mating took place. It was then recognized that sunlight was necessary to induce mating, and from that time onward no difficulty was experienced in breeding the wasp.

The foregoing remarks should serve to show what a fascinating pursuit the study of biological control can be, and also what wonderful successes it is capable of achieving. But it also gives some indications of the many disappointments that are met with, and the amount of thought and labour that may be expended before any tangible result is obtained. Nevertheless, every day the fund of knowledge regarding our insect friends is being augmented, and the time may come when most of the worst insect pests will be controlled by means of parasites.
