canal but in the brain; the breathlessness also is a medullary effect, but it at least has a beneficent aspect, for the greater the quantity of air passed through the lungs (other things being equal) the higher the oxygen pressure in the air-cells, and therefore the less the tendency to mountain sickness.

We may conclude with a few sentences on the subject of acclimatisation. In an article in *NATURE* on the return of the Cerro de Pasco Expedition nearly two years ago (vol. 110, p. 152, July 29, 1922), I have already discussed acclimatisation in some detail. So far as the observers on that expedition could judge, the factors in acclimatisation were, as had been found by previous workers, of two categories, those which tended to increase the pressure of oxygen in the arterial blood, and those which tended to increase the quantity of oxygen which each cubic centimetre of blood carried at any specified pressure. In the latter category are (1) the increase in the number of corpuscles in each cubic centimetre of blood coupled with a corresponding increase in the hæmoglobin; (2) an increase in the affinity of the

hæmoglobin for oxygen, which is probably caused by a greater alkalinity of the interior of the red corpuscle.

Among the factors which tend to increase the pressure of oxygen in the alveoli of the lung, and so of the arterial blood, is the increase in the volume of air passed through the lungs. Probably the peculiar size and shape of the chest of the native inhabitants of the Peruvian Andes tends in the same direction. A native whose height is sixty-one inches has a chest of about the same size as a European of seventy inches in stature. No account of the factors concerned in acclimatisation can be complete without reference to a possible one, namely, a more copious blood supply to the medulla. Stress has already been laid upon the fact that symptoms of mountain sickness are medullary, and more accurate knowledge is desirable of the factors which govern the blood supply of this part of the brain. Since our return from Peru, however, the work of Roberts has shown that the medullary blood supply is not simply the toy of circumstances, but is under the control of the brain itself.

Insects and Flowers.

By Dr. E. J. SALISBURY.

THE more definite relationships which subsist between organism and organism, whether it be between the algal and fungal partners of the lichen complex; between the forest tree, the orchid, or the gentian and their respective mycorrhiza; or between the Planarian worm *Convoluta Roscoffensis* and the alga *Carteria*, all alike bring home to one the delicacy of biotic relationships and the efficiency of whatever be the *modus operandi* of the evolutionary process. The relation between entomophilous flowers and the insects through the agency of which their pollination is effected constitutes no less remarkable an example of mutual specialisation than those already cited. It is scarcely surprising that the subject has attracted the attention of a considerable number of investigators from the observational period rendered notable by the publications of Koelreuter (1761), Delpino (1867), Mueller (1883), Darwin (1876), Kerner (1876), and Knuth (1898), to the experimental period of modern times initiated by the extensive researches of Plateau (1877-1910), and so ably followed by Lubbock (1882), Frisch (1913-19), Knoll (1919-22), and the work of Clements and Long, which has prompted and is the basis of the present article.¹

The problems involved, though they admit of approach from either the botanical or the entomological point of view, can only be appreciated adequately if the interaction and interdependence of plant and animal be constantly before the investigator's mind. On the other hand, the earlier writers often obscured important issues by too teleological an attitude, as in the assumption that nectaries had been developed as organs of attraction for insects, whereas it is probable that, as the writer suggested fifteen years ago, all nectaries, both floral and extrafloral, originated as osmotic hydathodes and have secondarily acquired biological significance in relation to pollination. Occasionally extrafloral nectaries may themselves be important sources of

honey supply, as has recently been noted for the partridge pea, *Cassia chamaecrista* (Dixie Beekeeper, 1922).

Every one recognises that insects, and especially bees, visit flowers for either honey or pollen, and that the process of pollination is incidental thereto. That this result ensues is the outcome of two factors, namely, the efficiency of the flower and the efficiency of the insect. With respect to floral structure, it is significant that, when closely related actinomorphic and zygomorphic types are compared, the latter are usually found to exhibit a reduction in the number of stamens and not infrequently in the ovary also; a reduction that could scarcely have come about without detriment to the race, but for the increased precision of the pollination mechanism which the zygomorphic form ensures.

It is, however, too often forgotten that pollen wastage would be enormous and insect agency almost as precarious as anemophily, were it not for the habit which bees in particular exhibit, of restricting their attentions, on a given flight, to a particular species of flower. Aristotle commented on this disposition, but the evidence respecting the degree of constancy seems to be somewhat conflicting, largely perhaps owing to lack of discrimination between the behaviour of the individual and the behaviour of the species. The observations of Clements and Long, for example, showed that the bumble bee, *Bombus justus*, visits at least twenty-seven species of flowers belonging to as many as twenty-two genera, and including such varied and specialised types of floral mechanism as *Aconitum*, *Monarda*, *Thermopsis*, and *Gentiana*. But when attention is confined to single individuals of this same species, the apparent fickleness of behaviour is seen to be illusory. This is sufficiently shown by the examinations of the pollen loads of twenty-five individuals of *Bombus justus* carried out by these investigators. Of these loads, nineteen consisted of one type of pollen only, whilst the remaining six were mixed pollen. Similar examinations of thirty-one honey-bees yielded

¹ "Experimental Pollination: an Outline of the Ecology of Flowers and Insects." By F. E. Clements and F. L. Long. Pp. vii. + 274, with 17 Plates. Carnegie Institution, Washington. 4.00 dollars.

twenty-eight pure loads and three mixed loads. This high degree of constancy is not, however, always maintained with respect to the collection of nectar. The male bees, which in common with the Lepidoptera visit flowers mainly for nectar, may visit a variety of flowers even in a single flight, though constancy to one species is the general rule.

Numerous experiments in which flowers were placed in competition with one another as attractions to bees seem to show that these insects are remarkably constant to particular flowers, and that this is largely a matter of habit which tends to be perpetuated and developed owing to the increased dexterity resulting from practice. Mueller (1881) believed that the behaviour of bees indicated a psychological differentiation between the sexes, the males visiting the most accessible and fragrant flowers, whilst the thrifty females visit those which give the greatest yield of honey.

Admitting then the fact of constancy (oligotropism), it remains to inquire how the bee is attracted to the flower from a distance and on what features its taxonomic discrimination depends. The extensive experiments of Plateau, in which he employed artificial flowers of extreme perfection, showed that such are usually completely ignored, even though placed amongst their natural prototypes. The conclusion seems warranted that the perception of form and texture by bees is extremely acute. Experiments performed by Allard with the flowers of the cotton plant showed that *Melissodes* also has considerable discrimination with respect to structural detail. The story, recorded by F. P. Bedford, of the cabbage white butterfly which followed the artificial lilies of the valley on a lady's hat down a London street is scarcely less remarkable than that of the bee which flew to a coloured botanical wall-chart! The implied compliments in such occurrences are, however, more imaginary than real and bear testimony rather to the importance of colour and conspicuity as attractive devices than to the verisimilitude of the artifacts employed.

The experiments performed by Lubbock, in which he employed glass slips bearing honey and resting on variously coloured papers, indicated not only a preference of bees for blue, but also their colour-memory. Mueller and Lovell both obtained similar results, whilst the recent comprehensive study of Frisch (*Ver. Deut. Zoo. Ges.*, 1914), in which the range of colours was supplemented by numerous shades of grey, fully confirmed Lubbock's conclusion that bees recognise colour as such, and showed further that though distinguishing nuances of colour, there is a certain confusion similar to that of human beings colour blind to red and green.

Several investigators have shown that bees can be trained to visit a certain colour and exhibit association of impressions in a marked degree. Turner's experiments (1911) with diverse colour patterns demonstrated that amongst a mixed assemblage of these, bees usually return to the pattern to which they had become habituated. It is significant that the failures which have been experienced in the training of bees were associated with attempts to train for pure red and blue-green, unpleasant odours and geometrical patterns; that is, in respect to characteristics seldom if ever encountered by the bee under natural conditions.

It would seem to be fairly well established that

colour and conspicuity are important agents of attraction up to a distance of ten metres, whilst the memory of a particular form and the less powerful odours, or their associations, serve as guides over smaller ranges of distance.

When several colour varieties of a given species are grown in proximity to one another, bees appear to visit them indifferently, which shows that form-association may predominate over colour-association. But the case of *Pulmonaria* shows that when colour differences are important, they are as much regarded as form. Bees visit the pink flowers of this plant freely, whereas when the corolla has turned blue, at which stage the flow of nectar has practically ceased, the flowers are neglected.

Clements and Long employed natural flowers of a variety of species, which they painted with water-colours and observed 420 visits to them as against 845 visits to the unpainted flowers. When artificial flowers were used, however, the number of visits was only about 12 per cent. of those to natural flowers, and in no case was a honey-bee deceived in this way. But, whilst this attests to the delicate perception of form, the frequent inspections made of the artificial flowers show that minute differences of structure are only detected at close range.

That vision plays an important part in influencing the flight of bees is shown by the tests on the so-called "homing" instinct. These experiments, and others using isolated plants and flowers, also show the pronounced place-memory which bees possess, despite which, however, their radius of action is usually short (about a mile from the hive).

Attraction for considerable distances may evidently be effected by strongly scented flowers, but our ignorance respecting such phenomena as the "assembling" of moths sufficiently indicates how much is still to be learnt regarding long-distance perception of stimuli. An increased number of visitors was noted by Clements and Long to flowers from which all the conspicuous parts had been removed, a result which was attributed to the greater accessibility of the nectar. In this connexion, one may recall that quite inconspicuous flowers with little or no scent but containing honey are freely visited. The odour of honey itself has been suggested as the effective agent of attraction in these cases, but the addition of honey to artificial flowers has little effect in increasing the number of visitors to them. On *a priori* grounds it would seem not unlikely that the range of light and scent perception in bees should be different from our own, but there appears to be little experimental evidence to support such a view. Various attempts have been made with mutilated insects to determine the seat of sense perception, but with regard to most of these, whatever view may be held as to the humanity of their conception, there can be little doubt as to their lack of scientific value.

There are but few observations and still fewer experiments which give any indication as to the importance of competition between flowers for the visits of insects. Robertson (1914) held that the flora is the limiting factor to the size of the bee population, whereas Lovell (1914) held that bees only collect a portion of the available pollen and nectar. The latter is probably the more correct view, and cases have been recorded

from gardens of species which are normally visited being entirely neglected for more attractive types. Upon the acuteness of this competition depends the importance to be attached to the sequence of flowering periods. Clements and Long, using the method of reciprocal bouquets, came to the conclusion that habit was the most important factor in determining preference, but that abundance of nectar or ease of access might overcome the effect of custom.

The marked capacity for memorisation by bees which training experiments reveal show that features of floral

construction, of an apparently trivial character, may be of real importance in facilitating recognition. Moreover, the readiness with which bees discriminate the most profitable and easily worked flowers gives added significance to the minutiae of floral architecture.

Further progress in the study of insect behaviour in relation to flowers would appear to demand the use of marked individuals of freshly hatched insects which have not acquired the habits that so largely determine their actions when adult.

X-ray Studies on the Crystal Structure of Iron and Steel.

AT the recent meeting of the Iron and Steel Institute Messrs. A. Westgren and G. Phragmen presented a continuation of work published by them two years ago at the same Institute. The present paper deals with the crystal structure of δ iron, the crystal shape of Cementite, and the structure of Austenite. In their previous paper a series of powder photograms of α , β , γ and δ forms of iron was reproduced. At that time all attempts to get a photogram of δ iron (stable only above 1400°C .) in the pure state had failed. Its interference lines were mingled with those originating from γ iron. By improved heating arrangements it has been possible to obtain a more uniform temperature, and the new photograms are quite free from γ interferences and confirm the conclusion previously drawn, namely, that δ iron has the same lattice structure as α and β iron.

The question as to how the atoms are grouped in Cementite (Fe_3C) has even now not been solved. The powder photogram contains a very large number of lines, some of which flow into one another. As many of the interferences of this orthorhombic substance practically coincide it could not be settled definitely, without a more thorough experimental investigation, to which of the net planes the lines of the powder photogram correspond. To decide this question so-called "complete photograms" or "rotation photograms" have been taken of a Cementite crystal obtained from the blow-hole of a spiegel melt. The only developed faces (001) were finely striated parallel to [010]. The precision camera designed for this purpose was described by the authors in NATURE of January 26, p. 122. The theory of the photograms obtained has been given by Schiebold and Polanyi. A special camera was constructed for establishing the lattice dimensions and the authors showed photograms thus obtained. The edges of the elementary parallelepiped are $4.518\text{\AA}$, $5.069\text{\AA}$, and $6.736\text{\AA}$. This corresponds with an axial ratio of $0.671:0.753:1$. Laue photograms taken parallel with the three axes have given an axial ratio in perfect accordance with the above. If it is assumed that the elementary parallelepiped contains four molecules of Fe_3C the density of Cementite must be 7.68. Values hitherto available range from 7.74 obtained by Benedicks to 7.59 by Levin and Dornhecker.

The discrepancy which has hitherto existed with regard to the crystal structure of Cohenite—the iron carbide present in meteorites—has been cleared up. Weinschenk, who first investigated this mineral, found that its composition corresponds to Fe_3C , but concluded

that it probably belonged to the regular system. Goniometric measurements were afterwards carried out by Hussak on a Cohenite crystal obtained from a Brazilian meteorite. In spite of the small size of the crystal, the fact that its faces were frequently curved, and that most of them gave very poor reflections, Hussak concluded that Cohenite belonged to the regular holohedral system. Even so, some of his angles differed 2° or more from the values characteristic of the cubic crystal. The authors show powder photograms of cementite and Cohenite which are practically identical. These two substances are therefore orthorhombic.

The authors have also used their precision camera to investigate the structure of Austenites obtained in various ways, both pure and intermixed with Martensite. They conclude that carbon dissolved in γ iron has an enlarging influence on the lattice dimensions, and that the lattice parameter changes from $3.606\text{\AA}$ in the case of Austenite containing 0.9 per cent. of carbon, to $3.629\text{\AA}$ in the case of the saturated solution containing 1.7 per cent. The Martensite lines, however, are too cloudy and broad to enable conclusions to be drawn concerning the lattice dimensions of the α iron in quenched steels. The authors reason that if carbon atoms replace iron atoms in the γ iron lattice the dimensions should decrease with rising carbon content, since the carbon atoms are much smaller than those of iron. Since, however, the opposite is the case, it seems probable that Austenite is not formed by simple substitution, but represents an addition product with the carbon atoms in the interstices between the metal atoms.

Precision photograms of a manganese Austenitic steel, having a lattice parameter of $3.624\text{\AA}$, show that in all probability this is the case. The density of the steel can be calculated either on the assumption that the iron and carbon atoms replace each other in one and the same lattice, or that the mass of the carbon atoms is uniformly distributed among the metal atoms which occupy the points of the face-centred cubic lattice. In the former case the density is 7.36, in the latter 7.83. The experimental value found was 7.83. The second assumption therefore is correct, and this Austenite is not formed by simple substitution but is an addition product. The real nature of the addition of carbon atoms cannot be decided on the basis of the results so far obtained. The authors suggest that it may be a substitution of the atoms of the γ iron lattice by complexes consisting of an iron atom combined with one or more carbon atoms.

H. C. H. C.