emphasising the points on which they chiefly dwell. If we would know life we must learn it not from the stage-box or dress circle, but by mingling with mankind. If we would know what scientific work is, we must not be content with listening only to skilfully-told tales of scientific triumphs, but must penetrate into the observatory or laboratory, where the fear of failure, and the uncertainty of long watching and waiting, are at least as frequent visitors as the assured forecast of success.

To-day, therefore, I have dealt with problems which are still surrounded by doubt and difficulty, with questions which can only be answered by the combined work of many men, it may be of many generations. It is true that on some of these matters we are gradually acquiring definite knowledge. That earth-air currents, if they exist at all, are very minute in north-western Europe; that the diurnal variation on quiet days is not necessarily to be regarded as normal; that local magnetic disturbances are due to forces so wide in their range that it is worth while to study them; these are all facts about which we were in doubt a few years ago, and on which we are in doubt no longer. But greater questions which lie behind these are still unanswered, and if I have ventured to deal with difficulties as well as with certainties, it has been because I have wished to give you a correct idea of current scientific thought on the subject of terrestrial magnetism.

MR. MERRIFIELD'S EXPERIMENTS ON THE RELATION OF TEMPERATURE TO VARIATION.

FOR the last ten or eleven years Mr. Frederic Merrifield, of Brighton, has been conducting a most elaborate and extensive series of experiments in the rearing of lepidopterous insects under various conditions of temperature. The results obtained by him are of high interest, both in themselves and also in reference to similar experiments independently undertaken by Dorfmeister, Weismann, Standfuss and others, some of which have already been noticed in the pages of NATURE. It is proposed to give here a short general account of the chief of Mr. Merrifield's experiments, with figures of some of the main results obtained. For full details the reader is referred to the original accounts which have appeared from time to time in the *Transactions* of the Entomological Society of London.

Experiments in 1887.—The first experiments undertaken had the object of supplying data for an inquiry by Mr. Francis Galton on the subject of heredity. It was anticipated by Mr. Galton that "the experiments would elicit incidentally many interesting results, some perhaps quite disconnected with the objects immediately in view." This anticipation was fully borne out by the facts.

The first species taken for experiment were two geometer moths, *Selenia bilunaria*, Esp. (*illunaria*, Hb.), and *S. tetralunaria*, Hufn. (*illustraria*, Hb.), both normally double-brooded in this country. Larvæ of both species were reared from eggs laid by females of the spring emergence; some of the moths resulting from these were selected for pairing according to size, three classes being formed, of maximum, medium and minimum expanse of wing, and the rearing of fresh generations was continued. Some of both species were fed up in the open air; these showed nothing remarkable. Others (of *S. bilunaria*) were kept during all their stages at a temperature of about 80° F., which had the effect of considerably accelerating their development. Five generations of *S. bilunaria* (counting the moths of the spring emergence as the first generation) were thus produced in the course of the year. These bred moths were all of the summer or *juliaria* form, and the females were always larger than the males, which is in accordance with the rule for the natural summer brood. The pairs selected for maximum and minimum expanse of wing produced no fertile eggs after the third generation. The fourth generation consisted entirely of the offspring of one of the medium-sized pairs of the third, and from these a selection was again made as before. The resulting moths of the fifth generation emerged in December and January, showing signs of deterioration. Only one of this brood laid fertile eggs, and these failed to hatch. The average size of the moths increased continuously up to the fourth, but diminished in the fifth generation.

Experiments in 1888.—The summer of 1888 was cold and wet, and the moths of both the selected species reared from larvæ kept in the open air showed signs of degeneration. That this was not due to the domestication of their progenitors appeared from the fact that a wild strain of *S. tetralunaria* behaved in the same manner.

It was observed in the case of *S. bilunaria* that the specimens produced from larvæ and pupæ that had been kept at about 80° F. showed a warmer colouring and fewer spots than those reared throughout their stages at ordinary temperatures. The same was found to be true in a still more marked degree of another species of geometer moth, *Ennomos autumnaria*, Wernb., and also, though to a less extent, of *S. tetralunaria*.

Experiments on the pupæ of *S. tetralunaria* led to interesting results. It was found that moths derived from pupæ of the summer brood, first retarded in development by freezing, though ultimately forced for a few days, tended, especially in the females, to assume the appearance of the comparatively dark spring emergence. Some larvæ of the same summer brood and their resulting pupæ were forced from the beginning, with the result that the same batch split into two divisions, the first of these feeding up rapidly and emerging, during the same season, with the summer colouring; the second taking much longer, and attempting to lie over for the winter as pupæ. A continuance of the forcing process brought out some of the latter in November and December, with the summer colouring. Others were exposed out of doors from November 7 to January 1, when they were brought into the house and again forced. The moths from this latter group came out in January and February, and were all of the spring colouring. Inasmuch as the continuously forced batch gave the summer form as late as December, it would appear that retardation alone is not in all cases sufficient to determine the assumption of the spring coloration. On the other hand, some pupæ of *S. tetralunaria* reared by Mr. Jenner, which were similarly trying to lie over for the winter, produced under forcing a series of intermediate forms becoming on the whole more and more like the spring type with the length of time that elapsed before their emergence. Here there was no exposure to winter cold; but only retardation from constitutional causes.

Mr. Merrifield remarks that the case of *S. tetralunaria* shows that the alternate succession of the two forms is not a necessary accompaniment of seasonal dimorphism. The same appears from Weismann's earlier experiments, in which, under appropriate conditions of temperature, the summer form *Vanessa prorsa*, L., was found to give rise in the next generation to *V. prorsa* instead of to *V. levana*, L. (the spring form).

The different reaction of members of the same brood of *S. tetralunaria* to the same conditions of temperature is interesting as an example of what may perhaps be called "physiological dimorphism"—a principle which there is reason to think is widely prevalent in nature, and which probably favours the survival of those species that exhibit it.

Experiments in 1889.—These had two main objects, the first being to determine the amount of exposure to cold that could be borne in the different stages, the second to ascertain more definitely the effect upon the perfect insect of temperature conditions applied during the immature periods.

Under the first head it was found that the eggs of both species of *Selenia* were injured by protracted icing; a temperature of 80° to 90° F., on the other hand, did no harm and quickened their development. Some eggs of *S. tetralunaria* gave another good example of physiological dimorphism. Thirty eggs were iced for seventeen days. On their removal from the ice-box, two hatched at once; none of the rest yielded larvæ until from eleven to thirteen days afterwards, when nineteen of them also hatched.

Icing the larvæ of *S. tetralunaria* was found to be rapidly fatal, and cooling injurious. The older larvæ stood cold better than the young ones. Larvæ of *S. bilunaria*, *S. tetralunaria*, *E. autumnaria* and *E. alniaria*, L., all endured a continuous temperature of 80° F. or a little more without apparent injury; but one of 90° to 100° F. was very detrimental.

Further experiments showed that no harm resulted from icing for moderate periods the pupating larvæ and pupæ of *S. tetralunaria* and the pupæ of *E. alniaria*, nor from cooling to about 47° F. the pupating larvæ or pupæ of *E. autumnaria*.

Under the second head some interesting conclusions were arrived at with *E. autumnaria*, *E. alniaria* and *S. tetralunaria*. Eggs from a single pair of the first-named species were divided into batches, and larvæ and pupæ of each batch were brought up under carefully regulated conditions of temperature. The same general result was obtained as in the 1888 experiments, but the additional fact was established that "it was in the pupal state that the effect was in the main produced. The forced pupæ, whatever the treatment of the larvæ had been, invariably produced pale and comparatively spotless moths; the cooled or iced pupæ, whatever the treatment of the larvæ had been, invariably produced dark and much spotted moths." It was found that a temperature of 63° F., or even higher, was low enough to produce the darker form. The treatment of the larvæ, though of slight effect compared with that of the pupæ, did not seem to be entirely without influence on the perfect insect; *e.g* the specimens that had been forced only as pupæ were darker than those that had been forced all through. Some individual variation was noticed in all the groups. Similar experiments on *E. alniaria* gave results tending in the same direction, but less regular and striking.

The effects on *S. tetralunaria* were far more marked than in 1888. Pupæ of the summer brood were iced for periods successively increased by two weeks up to twenty weeks. These yielded moths becoming generally, but not regularly, more and more like those of the spring emergence, both in colour and pattern, as the period of icing was lengthened. The converse experiment of forcing pupæ of the autumn brood, which would naturally give rise to the spring form of the perfect insect, proved very injurious to the pupæ, the majority of which died even when the temperature was kept at 60° F. only. The moths that emerged were irregular in their time of appearing, and poor in condition. In colouring they were intermediate between the summer and spring forms, those that remained longest in the pupal stage being as a rule the darkest. This autumn-spring brood, like the corresponding brood in *V. levana*, is evidently far more resistent in its colouring to temperature conditions than the summer one.

In all three species it was found that the period of pupation was longer for males than for females: most so in *E. alniaria*, least in *S. tetralunaria*.

The broods of *S. tetralunaria* that had fallen off in 1888 showed still further deterioration, both as to health and size, in the spring emergence of 1889. But some eggs of the degenerate race that were sent to Wimbledon produced once more much larger, more numerous and more healthy moths. The cause of this was apparently the change of condition, and especially the substitution of cherry for birch as the food plant.

As a result of this year's experiments, Mr. Merrifield came to the conclusion that the predisposition to assume one or other form in a seasonally dimorphic species can in some cases be completely controlled by external influences applied to egg or larva before the end of its growth; but not, except partially, after larval growth is finished.

Experiments in 1890.—In the course of 1890 the new fact was established that different portions of the pupal period were of different importance for the changes induced by temperature, and that the pattern or outline of the markings could be made to vary independently of the general colouring. It was proved to be possible to obtain by difference of treatment, from the same brood of a seasonally dimorphic species, individuals showing (1) summer markings with summer colouring, (2) summer markings with an approach towards spring colouring, (3) spring markings with summer colouring and (4) spring markings with almost the spring colouring.

A brood of spring larvæ of the light-coloured strain of *S tetralunaria*, which would naturally have produced moths of the summer form, was forced as a whole; pupating in June. Some of the pupæ were kept at 80° F., these produced well-marked summer forms (Fig. 1). The rest were iced for about twelve weeks, and then either forced or put out of doors. Those that were forced after icing produced moths all of which had the summer colouring, and most of which showed the spring markings (Fig. 3). Some of these which were cooled at 43° F. after the colours of the wings had begun to appear under the forcing process, showed no difference from the rest. Those that were put out of doors after icing (temperature at 8 a.m. averaging about 57° F.) gave moths with the spring markings and a dark colour in some cases almost reaching that of the spring emergence (Fig. 4). Similar experiments on two other broods gave corresponding results, and showed that, in some instances, from two to three days forcing during the last part of the pupal stage might be enough to produce a very marked effect upon the colouring. Another brood, of the third generation, which fed up rapidly and pupated before the middle of August, gave rise at the ordinary temperature of the room (between 65° and 70° F.) to moths of the usual summer markings and colouring, but slightly darker than their forced parents. When twelve of these had emerged, the remaining pupæ were cooled at about 43° F. Those moths that emerged after twenty-six days cooling, while still showing the summer markings, presented an approach to the spring coloration (Fig. 2).

Some striking results were also obtained with *E. autumnaria*. Forcing the pupæ produced, as in 1889, pale and comparatively spotless moths (Fig. 5). When the pupæ were cooled for fourteen days or more before forcing, the ground colour became

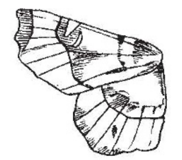

FIG. 1.—*Selenia tetralunaria*. Summer markings and colouring. (Forced.)

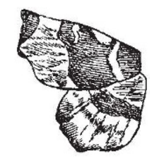

FIG. 2.—*Selenia tetralunaria*. Summer markings, spring colouring. (Cooled.)

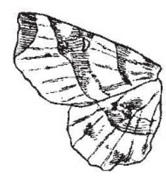

FIG. 3.—*Selenia tetralunaria*. Spring markings, summer colouring. (Iced, then forced.)

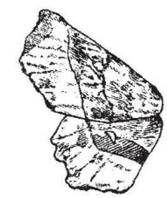

FIG. 4.—*Selenia tetralunaria*. Spring markings and colouring. (Iced.)

All the above were obtained from summer pupæ. Figs. 1, 3 and 4 are from the same parents. The difference should be noted in the shape of the inner area of the wings between Figs. 1 and 2 on the one hand, and Figs. 3 and 4 on the other.

dulled and the spotting blurred. Pupæ cooled for seven to twenty-eight days and then kept at the ordinary temperature of the room gave rise to moths as a rule very much darker than those finally forced; darker even than moths from pupæ that had been cooled for five or six weeks before forcing. The darkest moths of all were obtained from pupæ cooled for five or six weeks and then allowed to develop at the ordinary outdoor temperature, or this followed by cooling (Fig. 6). Even in these, forcing after eight days' exposure out of doors was found sufficient to counteract largely the tendency to darkening.

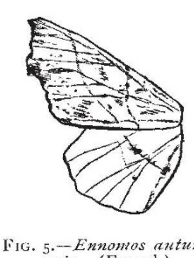

FIG. 5.—*Ennomos autumnaria*. (Forced.)

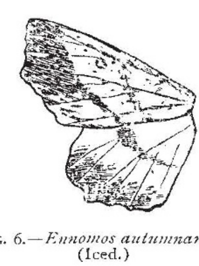

FIG. 6.—*Ennomos autumnaria*. (Iced.)

Both the above are from the same parents.

Experiments with *S. tetralunaria* and *E. autumnaria*, on the effect of moisture applied during the pupal stage in combination with various kinds of temperature, gave negative results.

A few trials of the effects of temperature on *Vanessa urticæ*, L. and *Lasiocampa quercus*, L., var. *callunæ*, were made this year, with the general result that cooling the pupa caused enlargement of the blue and dark marks in *V. urticæ*; while forcing the pupa caused increased paleness in *L. callunæ*, making it approach in aspect the ordinary *L. quercus*.

The suggestion was thrown out by Mr. Merrifield that the changes of pattern produced by temperature might assist investigators in tracing the evolution of the wing-markings in modern forms.

Experiments in 1891.—The first result established in 1891 was that the spring emergence of *S. tetralunaria* could be made by forcing during the penultimate pupal period to assume the colouring but not the markings of the summer form. In respect to the colouring it was found to be almost or quite as sensitive to temperature as the summer form, but in respect to markings it was completely resistent. The duration of the pupal period could in no case be shortened to that of the summer form; early and continued exposure of the winter pupa to a temperature of 80° F. or even of 60° F. generally proved fatal.

Experiments on the pupæ of both spring and summer broods of *S. lunaria*, Schiff., and *S. bilunaria*, and on the spring brood of *Falcaria falcataria*, L., gave the same general result of darkening in the cooled specimens and paling in the forced; and previous conclusions with regard to *S. tetralunaria* received confirmation.

In the case of *V. urticæ*, which was this year more completely investigated, it was found that a moderately low temperature generally deepened the colouring slightly, lowered the tone of the yellow patches, and spread the dark portions, especially the borders, enlarging also the marginal blue crescents.

Further experiments were also tried with *Lasiocampa quercus* and its variety *callunæ*. As in the former examples, exposure to a temperature of 80° F. was found to cause lightening, and to a temperature of 47° F. darkening, of the general ground colour. In *L. callunæ* the effect was most pronounced in the males. Some of the forced *callunæ* would, so far as regards colouring, be classed as *L. quercus*. *Arctia caja*, L., was found to be a species unusually intolerant of low temperatures, many pupæ dying when exposed to 50° or 60° F. In those that emerged there was a tendency for the dark spots on the hind-wings to spread and become confluent, and for the black transverse abdominal bars to increase in length and breadth. At 80° to 90° F. the brown of the fore-wings was paler than normal, and the red of the hind-wings took on a yellower shade.

The results obtained in this and former years seemed to Mr. Merrifield to afford evidence that besides the marking and coloration, the size and (less markedly) the shape of the wings might be affected by temperature. In most of the species tried the forced appeared to be smaller than the cooled specimens, and in the three species of *Selenia* a lengthening and increased angularity of the fore-wing seemed to result from a lowered temperature. In *V. urticæ* little difference was observed except in those from pupæ at 47° F., which were generally smaller than the others.

Temperature experiments on *Papilio machaon*, L., *P. podalirius*, L., (spring emergence), *Thais polyxena*, Schiff., *Argynnis paphia*, L., *Cerura vinula*, L., *Agrotis comes*, Hb., and *Attacus cynthia*, Drur. (all *winter* pupæ), gave negative results, as also did a careful trial of the possible effect of darkness and of different coloured light on *S. tetralunaria* and *A. cynthia*.

Experiments in 1892.—The experiments made this year were chiefly on butterflies; the first species taken being *Picris napi*, L. Pupæ of the summer brood were forced at 90° F. or kept at about 67° F. These yielded perfect insects of the ordinary summer form. Others of the same brood were iced for from three to four months; some were then exposed to an artificial "spring" temperature of 54° F., and the rest were forced at 80° F. Both of these two classes showed most of the characteristics of the usual spring form; *e.g.* on the upper surface greater suffusion and less intensity of dusky colouring; on the under surface faintness of the spots on the fore-wings and strongly marked nervures on all wings, with increased strength of the yellow parts. Those forced after freezing had the nervures more strongly marked than the rest, but in other respects partook less distinctly of the spring colouring. About one-fourth of the pupæ resisted attempts at forcing, and "went over" to the following spring, thus affording another instance of "physiological dimorphism."

A second species taken was *Vanessa atalanta*, L., which gave interesting results. About 100 pupæ were divided into six classes, and treated as under:—

(1) 80° to 90° F., emerging in 6 days.
(2) About 64° F., emerging in 18 or 19 days.
(3) About 56° F. (equable); emerging in about 34 days.
(4) 51° to 64° F. out of doors, averaging about 54°; emerging in 44 days.
(5) 45° to 58° F., averaging about 51°; emerging in about 40 to 50 days.
(6) 45° F. for from 32 to 47 days, then to various temperatures ranging from 90° F. (emerging in 6 days more) down to a mean of about 55° (emerging in from 19 to 34 days more).

Classes 2, 3 and 4 did not greatly differ among themselves or from the normal; their coloration, however, seemed on the whole to increase in intensity with the lowering of the temperature. In Class 1 the black ground-colour was slightly suffused with golden brown, the scarlet band was broadened, and its intensity of colour somewhat diminished. A new scarlet spot appeared on the under surface of the fore-wing (Fig. 9). In Class 5 the pale costal patch on the under surface of the hind-wing became more pronounced, and showed an increased tendency to spread along the costa. A light ochreous cloud about the middle of the hind margin of the same wing-surface, visible in normal specimens, became more strongly marked. In Class 6 the scarlet band was tinged with carmine, narrowed in area, and broken up by transverse bars of black. There was a tendency in the fore-wing to the diffusion of white and lavender scales over the black ground-colour, and round the edges of the

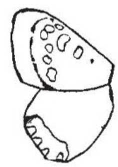

FIG. 7.—*Chrysophanus phlœas*. (Diagrammatic.) Forced; showing large size of black spots on fore-wing, and diminished breadth of copper border on hind-wing.

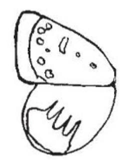

FIG. 8.—*Chrysophanus phlœas*. (Diagrammatic.) Iced; showing diminished size of black markings, and increased breadth of copper border. The latter has lost its external serrations, and shows prolongations passing inwards along the nervures.

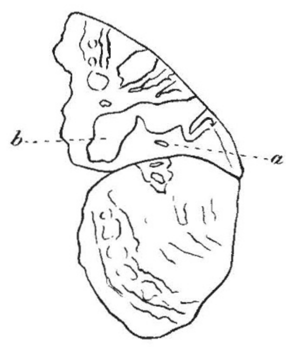

FIG. 9.—*Vanessa atalanta*, under side. (Diagrammatic.) Forced; shows appearance of new red spot (*a*) between scarlet band (*b*) and inner border of fore-wing.

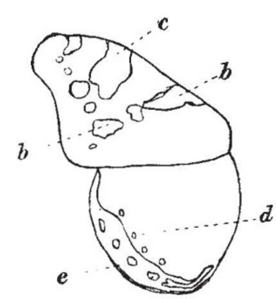

FIG. 10.—*Vanessa atalanta*, upper side. (Diagrammatic.) Cooled; shows scarlet band (*b*) broken up, enlargement of white costal mark (*c*), new row of minute blue spots (*d*). The submarginal spots of the hind-wing (*e*) are centred with lavender.

white spots. The submarginal black spots of the hind-wing were often centred with lavender, occasionally a row of minute blue spots appeared in the margin of the dark portion of the hind-wing, and another on the extreme border of the wing itself (Fig. 10). On the under side there was more diffusion and blurring of markings, with an increased tendency towards the multiplication and spreading of pale areas.

Chrysophanus phlœas, L., a species which had already been worked at by Weismann, was also made the subject of a series of temperature experiments. Well-marked differences were found to exist between the extreme forms produced under conditions of heat or of cold. The former caused enlarged size and diminished intensity of the black spots, a narrowing of the coppery band on the hind-wing, and a dusky suffusion of the fore-wings, especially towards the bases (Fig. 7). Under the latter, the black spots are much reduced in size, the coppery parts are lighter, and the coppery band on the hind-wing broadens, loses its posterior serrations, and often shows prolongations along the nervures towards the base (Fig. 8). These effects are noteworthy inasmuch as they differ considerably from the results of heating and cooling in other species. Their peculiar relation to the temperature conditions is also remarkable; thus, summer pupæ kept at 33° F. for ten weeks, if afterwards allowed to remain at 55° F., gave the cold form in its extreme development; but if forced at 90°, gave the heat form almost as perfectly as those kept at 80° to 90° all through. Another curious point is that whereas a temperature of 47° F. was very injurious to the pupæ, they bore icing at 33° F. for ten weeks without damage.

Leucophthalmia punctaria, L., which was also tried during this year, gave results in some respects like the above. Thus, though forcing at 90° F. or icing at 33° were borne without injury, exposure to 45° proved harmful. Again, as in *C. phlœas*, "a temperature of 33° F. seemed to suspend the physiological changes without much other effect," for the pupæ exposed to this temperature for over three months, and afterwards forced, gave the heat form in almost as complete a state of development as those forced from the beginning. Summer pupæ were used for the experiment, and the general effect of cooling was to cause "gradual disappearance of the submarginal blotches, increase of dark sprinkling, and intensification of the central line as the temperature was lowered."

To Mr. Merrifield's account of his experiments during this year a short paper was appended by the present writer, giving reasons for considering certain of the modifications produced in *V. atalanta* by both heat and cold to be ancestral in character.[1] Some of the new features produced by heat were considered to show an approach towards *V. callirrhoe*, Hb., and some of those produced by cold appeared to indicate reversion to a still older form of *Vanessa*.

Experiments in 1893.—A number of winter pupæ of *Picris napi*, L., were divided into groups, some being forced in February and March, others left to emerge out of doors, which they did in late April and early May. The two divisions showed the same kind of difference, though in less degree, as was apparent in the summer brood of 1892 between those forced throughout and those cooled for the greater portion of their pupal period.

Experiments on both summer and winter pupæ of *Pararge egeria*, L., showed that the general effect of forcing was to lighten the ground colour and cause the pale spots to become smaller and less well defined. In no case was any approach shown to the bright ochreous colouring of the South European form.

In *Hydriomena silaceata*, Hb., cooling the summer pupæ caused an approach towards the usual colouring of the spring emergence; while forcing, besides producing a more uniform appearance, generally diminished the size of the perfect insect.

A trial was also made of the summer pupæ of *Araschnia levana*. The results were in general accordance with those previously obtained by Weismann; the effect of a raised temperature being to produce the dark *prorsa* form, and that of low temperatures (from 48° F. downwards) being to cause the appearance of the pure *levana* type, a few of those only exposed to moderately low temperatures showing slight traces of the intermediate *porima* colouring.

Interesting experiments were made on four species of *Vanessa*—*V. polychloros*, L., *V. atalanta*, L., *V. c-album*, L., and *V. io*, L. Pupæ of *V. antiopa*, L., gave negative results, probably in consequence of being already too far advanced when their treatment began.

In *V. polychloros*, high temperatures caused a general lightening of the ground colour and the appearance of yellowish clouds and streaks; the ordinary black spots were sharply defined. It was found that yellowish marks made their appearance to a greater or less extent when a temperature of 80° or upwards was employed, even if the pupæ had previously been cooled or iced for some weeks. When exposed to low temperatures, the pupæ produced perfect insects with a deeper and duller ground colour and a spreading of the dark marks, especially of the submarginal band. The enlargement of this band was always observed in cooled or iced specimens, whether subsequently forced or not. The whole ground-area was generally dusted with black scales, which tended to form new spots, especially in a row parallel to the outer margin in both fore- and hind-wing (Fig. 13).

Fresh experiments on *V. atalanta* confirmed the previous year's results and added new ones. Forcing temperatures up to 100° F. were employed, with the result of killing many of the pupæ. Those specimens that emerged showed a scarlet cloudy patch in that portion of the fore-wing which corresponds to the centre of the ocellus in *V. io*; and some of them showed another new scarlet spot on the under side of the fore-wing, in addition to the new spot observed in 1892. One of the apical white spots tended to be loosely ringed with scarlet in the forced, and with white in the cooled specimens. The latter were generally undersized.

In *V. c-album* it was found that both the first and second brood, but especially the first, became darker if exposed to a moderately low temperature.

Forced specimens of *V. io* showed a tendency to the development of dark spots near the apices of the nervular interspaces. Cooled and iced specimens showed a tendency, increasing as the temperature was lowered, for the dark costal "claw-mark" of the fore-wing to lose its regular curve and become angulated, for the apical pale spots to separate themselves more distinctly from the remains of the dark submarginal band, and for the bluish constituents of the ocellus in the hind-wing to divide themselves into two parallel series, a marginal and a submarginal. The resolution of the ocellus in the fore-wing was in one specimen very complete (Fig. 11).

A paper by the present writer drew attention to the further reversionary features disclosed by the temperature modifications

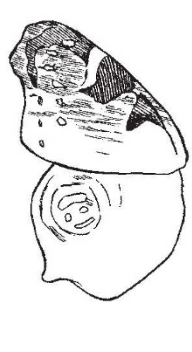

FIG. 11.—*Vanessa io.* (Diagrammatic.) Iced; showing resolution of ocellus.

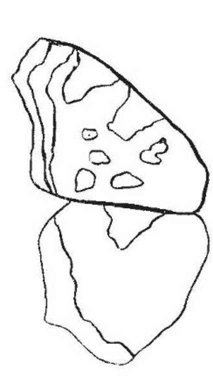

FIG. 12.—*Vanessa polychloros.* (Diagrammatic.) Forced; shows size of black marks somewhat reduced. The yellow markings are not represented.

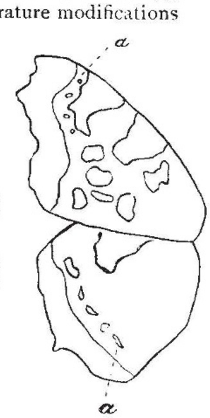

FIG. 13.—*Vanessa polychloros.* (Diagrammatic.) Iced shows tendency to formation of new submarginal row of black spots (*a*) in fore- and hind-wing.

above described, and commented on the significance of these phenomena with reference to the centripetal and centrifugal theories of heredity.

Experiments in 1894.—Pupæ of *Limenitis sibylla*, L., were found to be intolerant of heat. Those that survived a temperature of 85° to 90° F. gave rise to perfect insects with a slight increase of reddish scales near the apex of the fore-wings and the anal angle of the hind-wings. The orange-brown of the under surface was enlarged in area and paler in colouring. Exposure to a temperature of 48° F. for from three to five weeks caused a sprinkling of the white band with black scales, and on the under surface an increase in area and intensity of some of the darker parts with a tendency to suffusion and spreading of the white.

As a result of further experiments on *Vanessa c-album*, it was found that in certain of those exposed to low temperatures, which were not well borne by this species, there was an increase in the distinctness of the submarginal series of dark spots. Some of these were pupilled with bluish or lavender scales, as in the Chinese *V. c-aureum*, L., which appears to present an early form of the *Vanessa* pattern.

A few experiments were also made on *V. cardui*, L., giving results in accordance with those previously obtained by Standfuss in Zürich.

Experiments in 1895.—Both high and low temperatures (98° F. and 33° F.) were found to be well borne by pupæ of *Gonepteryx rhamni*, L. Little change was produced in the

[1] Weismann has expressed his general concurrence with these and subsequent conclusions of the present writer as to reversion (*Neue Versuche*, Jena, 1895, pp. 51, 72).

appearance of the imago, but the general effect of the low temperature was to reduce or abolish the orange discoidal spot on the fore-wing of both sexes, while under the high temperature the pale hue of the female appeared to assume a yellower tinge. In one instance this effect was well marked.

In *Vanessa atalanta* some further changes were observed as the result of high temperatures; the most remarkable of which were the appearance of a scarlet patch on the fore-wing between the red cross-band and the costa, and a long streak of grey-blue scales near the inner margin of the same wing. The most efficacious way of producing these modifications in this and other species of *Vanessa* appeared to be the use of a temperature of 95° F. to 102° F. for 12–14 hours at an early stage, afterwards gradually lowered, but still kept up to 85° F. or more till near emergence.

Some cooled specimens of *V. urticæ* bore great resemblance to the northern variety *polaris*. Heated specimens were like the southern form *ichnusa* in the shade and extent of the red ground colour, and also in the tendency towards disappearance of the isolated dark spots on the fore-wing. All three spots, however, were affected in these specimens, whereas in *ichnusa* the spot nearest the hind margin retains the normal appearance. Other changes were observed in the outer border, and in the shape of the fore-wing, the angulation being diminished.

Pupæ of *V. antiopa* at a low temperature gave similar results to those obtained with this species by Dr. Standfuss, but they were much less marked.

Experiments in 1896.—Pupæ of *P. daplidice*, L., from eggs laid in March, kept at a temperature of 70° F. to 80° F., gave the ordinary summer form. Some of the same batch, kept in the open air after five or six weeks' cooling at 52° F., emerged as the spring form *bellidice*. In *Melitæa didyma*, Esp., cooling at 51° F. was found to produce an extension of the black markings on the under side of the hind-wings. Of two specimens forced at 94° F., one was of an abnormally fiery tint.

Some specimens of *Saturnia pavonia*, L., from North Italy, forced in late winter and early spring, were much paler, ruddier and more uniformly coloured than those kept out of doors. This species is therefore not so resistent to temperature-conditions as many other winter pupæ.

Vanessa urticæ, var. *polaris*, from Lapland, was found to be sensitive to temperature, though less so than specimens from Central Europe.

Further experiments during the present year (1897) have shown that the tawny ground colour in *Argynnis paphia*, L., is brightened, and the size of the dark markings reduced by warmth, while the contrary effect follows exposure to cold. Also in *Aporia cratægi*, L., a low temperature causes much thickening and spreading of the black lines which mark the course of the nervures.

This ends the series of experiments so far undertaken and carried out by Mr. Merrifield. It is to be hoped that he will be able to continue and extend researches so interesting in themselves and so valuable to science. The present paper is concerned with facts only, not with their interpretation; but it must be obvious to any one who considers the remarkable results here briefly recorded, that they constitute an important contribution towards the better understanding of many disputed questions.

It may be well in conclusion to give Mr. Merrifield's own enumeration of the kinds of change observed. "The changes produced by temperature," he says, "are mainly of three kinds, viz. (1) general change, often striking, in the colouring, without material alteration in the pattern or form of the markings, but often with much enhancement or diminution in their intensity; (2) change caused by the substitution of scales of a different colour, either singly and generally distributed so as to be scattered, or so grouped as to cause a material change in pattern; (3) change in general appearance caused by imperfection in the development of scales or of their pigment. No. 1 seems a direct effect of temperature, not affecting vigorous development. Under No. 2 are to be ranged the most radical changes in pattern, as in the extreme case of *Araschnia levana-prorsa*, which have been explained on the theory of reversion to an earlier form. In No. 3 the wings are often somewhat reduced in size; the scales are scanty, irregularly placed, and often misshapen and deficient in pigment, the membrane of the wing showing between them. The three are more or less combined in many cases."

The figures which illustrate this paper were drawn from the plates which accompany Mr. Merrifield's papers in the Entomological Society of London's *Transactions*. F. A. Dixey.

UNIVERSITY AND EDUCATIONAL INTELLIGENCE.

Cambridge.—The Vice-Chancellor announces that he has opened a University Benefaction Fund, to which he has placed during the present term donations for various academic purposes amounting to nearly 3500*l.* This sum includes a gift of 1000*l.* from Dr. Peckover, Lord-Lieutenant of Cambridgeshire, and a grant of 1050*l.* from the Mercers' Company for the rebuilding of the medical schools. The family of the late Sir George M. Humphry, Professor of Surgery, have contributed 600*l.* towards the latter object, by way of a memorial gift; and Mr. H. Westwood Hoffman, 100*l.*

The Rede Lecturer for the ensuing year is Sir Henry Irving.

Prof. Ewing, F.R.S., has been appointed Chairman of Examiners for the Mechanical Sciences Tripos. Mr. A. F. Stabb has been appointed University Lecturer in Midwifery.

The examinations in Sanitary Science will begin respectively on April 19 and April 26, 1898, the incidence of Easter having rendered the advertised dates inconvenient.

A scheme of theoretical and practical training has been organised for members of the University who are intending to become masters in public schools. The scheme is under the direction of the Teachers' Training Syndicate, and will be carried out in connection with the existing Day Training College. Certificates of efficiency will be granted to candidates who have pursued the prescribed course and passed the examinations of the Syndicate.

The Council of the Institution of Civil Engineers have awarded a Salomons scholarship of 50*l.* to Mr. Edward Ernest Tasker, a student of the Technical College, Finsbury.

The University of Upsala has received from Mr. Franz Kempe the sum of 150,000 knonor (about 8333*l.*) for an associate professorship of plant biology. Dr. Lundström has been nominated to occupy the chair.

Since the beginning of the academical half-year (states the *Lancet*) all students attending the chemical and physical laboratories of the University of Heidelberg have been insured against accidents happening in the course of the lectures, of the laboratory work, and of scientific excursions. The insurance premium is paid by the treasury of the University, which has also made a new regulation in connection with the subject requiring the students to pay a small sum in addition to the class fees.

A Fellowship to be called the Geoffrey Fellowship, of the value of 100*l.* a year for three years, has been presented to Newnham College, Cambridge, and will be awarded in June 1898. The Geoffrey Fellow will be required to reside at Newnham College, and to pursue independent study in some department of learning, letters or science. Candidates must be women who have obtained honours in a Cambridge Tripos Examination or in the Oxford Final Schools. They should send in their names to Mrs. Verrall, President of the Associates of Newnham College, before May 1, 1898. Each application should be accompanied by a statement of qualifications, a scheme of the work which the candidate proposes to carry out, and, if possible, a dissertation or other evidence of work done. Further information respecting conditions of tenure, &c., may be obtained from Mrs. Verrall, Newnham College, Cambridge.

Speaking at Northampton a few days ago, Lord Spencer urged that great efforts should be made to improve secondary education in England. Much had been done for education in the Victorian age, but it was absolutely necessary to fill the gaps existing between primary education and University education. He trusted that the measure which the Government would introduce would be satisfactory to all educationists, and he knew if it was it would have the support of even the opponents of the Government. One of the great difficulties in the way of carrying out technical education was the want of good secondary education. No more useful measure had been passed during the reign of the Queen than that giving county councils and borough councils grants for technical education, for it had stimulated a desire for secondary education and technical education. What was now wanted was a measure which would put technical education on something of the same basis, though not perhaps under the same supervision, as primary education. More aid was wanted from public funds and from rates. When they had that they would have attained something of great benefit to the