XVII. *On the Temperature of Insects, and its connexion with the Functions of Respiration and Circulation in this Class of Invertebrated Animals.* By George Newport, *Esq., Member of the Royal College of Surgeons, and of the Entomological Society of London. Communicated by* P. M. Roget, *M.D. Sec. R.S.*

Received June 5,—Read June 15, 1837.

Every naturalist is aware that many species of insects, particularly of hymenopterous insects, which live in society, maintain a degree of heat in their dwellings considerably above that of the external atmosphere, but no one, I believe, has hitherto demonstrated the interesting facts that every individual insect when in a state of activity maintains a separate temperature of body considerably above that of the surrounding atmosphere, or medium in which it is living, and that the amount of temperature varies in different species of insects, and in the different states of those species. Previously, therefore, to considering the connection which subsists between the evolution of animal heat and the functions of respiration and circulation in insects, I shall endeavour to prove that every species maintains a distinct temperature of body, the amount of which differs in the different states of the insect.

I was first led to the particular consideration of the subject of temperature in insects by some observations on the temperature of wild bees in their natural haunts, which were made by myself at Richborough, near Sandwich in Kent, in the autumn of 1832, at the suggestion of Dr. Marshall Hall, for the purpose,—similar to that of my observations on respiration, as noticed on a former occasion*,—of ascertaining what relation, if any, subsists between the natural heat of these insects in their hybernating condition and the irritability of their muscular fibre. The results of these observations on the temperature of Bees are shown on Table III., Nos. 1 to 14, and together with many other facts connected with the physiology of insects were communicated to Dr. Hall a short time afterwards†. These observations were

* Philosophical Transactions, Part II. 1836, p. 551.

† In submitting these observations on the Temperature of Insects to the consideration of the Royal Society, I have felt myself imperatively called upon to make the above remark, in explanation of the nature of my supposed obligations to Dr. Marshall Hall, with regard to this and other subjects connected with the Physiology of Insects, in consequence of certain misrepresentations which were made on a recent occasion respecting my communications with that gentleman; and I beg further to state, that many of the views here advanced respecting the temperature of insects, and also most of the subjoined Tables, particularly those on the temperature of the Hive Bee, from the commencement of my observations to the month of May 1836, were communicated by myself to Dr. Marshall Hall, at his own particular request, in the beginning of July 1836, in the presence of my intelligent friend, and late pupil, Mr. John Osborn, who assisted me in making the observations, and unto whom I am indebted for much valuable assistance during my investigations.

made in the usual manner, by placing a considerable number of insects of the same species together, and then introducing the thermometer among them. But it was a few days previously to making these observations that I first noticed the interesting fact, that each individual insect maintains its own temperature, which is perceptible externally by the thermometer, and that the amount of this varies in the different conditions of the same insect. The observation was first made on the larva of *Sphinx Atropos*, LINN., and on that of *Pygæra bucephala*, STEPH., as will presently be shown.

During the time I have been engaged in preparing the present communication I have become acquainted, through the kindness of Dr. FORBES of Chichester, with the recently published views of Dr. BERTHOLD, of Gottingen, who has made a series of observations on the temperature of cold-blooded animals*, and among them several on insects, somewhat similar to those which I now have the honour of submitting to the Society. But excellent as are the views of that gentleman, he does not appear to have paid sufficient attention to the conditions of activity or rest in the insects at the time of making his experiments, and consequently has omitted to observe the important fact of the existence of a distinct temperature of body in individual insects†, and also those circumstances which augment or lessen its amount, and has estimated the temperature by placing many individuals together, which, as will presently be seen, is open to several objections. Dr. BERTHOLD has, however, anticipated me in the expression of one opinion, unto which we have mutually been led by our observations, viz. that at all events the higher classes of invertebrated animals ought not to be considered as *cold-blooded*, since it is found that under certain conditions they have a temperature of body higher than that of the surrounding medium. HAUSMANN‡ made an observation as long ago as the year 1803, which ought to have led to a proper understanding of the nature of the temperature of insects. He placed a perfect specimen of *Sphinx Convulvuli*, LINN. in a small glass phial when the temperature of the atmosphere was 17° REAUM. (70°·25 FAHR.), together with a small thermometer, and at the expiration of half an hour the temperature of the phial was 19° REAUM. (74°·75 FAHR.), but soon afterwards he found that the temperature of the phial had sunk again to the previous standard 17° REAUM. He then repeated the observation with six specimens of *Carabus hortensis*, LINN. with similar results. From what will subsequently be shown respecting the temperature of *Carabi*, which do not develop so large a quantity of heat, it is very probable, as suggested by Dr. BERTHOLD §, that the results obtained by HAUSMANN arose from the bottle which contained the insects being touched by the hand of the operator. Dr. BERTHOLD has observed this in his experiments, and I have constantly remarked the same thing myself when proper care was not

* New Experiments on the Temperature of Cold-Blooded Animals, by A. H. BERTHOLD, M.D., Gottingen, 1835.

† *Ibid.* p. 36. Experiment 59.

‡ De Animalium exsanguinum Respiratione. Götting. 1803. p. 68.

§ Neue Versuche, &c., p. 11.

taken to guard against its occurrence. RENGGER* observed a distinct temperature in *Melolonthæ* when many of them were collected together in an earthen vessel, but could not detect a distinct temperature in water-insects, or in Caterpillars. JUCH† likewise made observations on the temperature of the bee-hive, the ant-hill, and on the common Blister-flies. In a vessel containing a large quantity of the latter insects, the *Lyttæ*, he found the thermometer rise several degrees above the temperature of the atmosphere. Dr. DAVY, according to BERTHOLD‡, in making observations on several species of insects, *Scarabæus pilularis, Lampyris, Blatta, Gryllus,* and *Apis,* found only a slight difference, except in the *Gryllus,* in which the difference amounted to five or six degrees, while in the Scorpion and Centipede he found a temperature lower than that of the atmosphere. Dr. BURMEISTER, in his Manual, recently translated by Mr. SHUCKARD, has spoken of the temperature of insects, but only of insects in society, and has referred to the observations of JUCH, REAUMUR, &c., and although he believes in the existence of individual temperature in insects, has given no observation of his own to prove the fact, while Dr. BERTHOLD, in the work just noticed, (experiment 59,) made on a single insect, could not detect it, nor could he do so in every species when the observation was made on a number of individuals collected together. It is evident, therefore, that although the existence of individual temperature is inferred from experiments on insects collected together, it yet remains to be proved that every individual insect in a state of activity invariably maintains a certain amount of temperature, which is readily appreciable by the instruments we are enabled to employ.

Before detailing the results of my observations it is necessary to explain the manner in which the observations themselves have been made, and to point out those circumstances which seem to have been overlooked by other inquirers in their experiments on the temperature of insects. It is only by a careful attention to those circumstances that we are enabled to detect the existence of temperature in single insects, and to understand the causes of its variations at different periods.

The thermometers employed by me on every occasion are of the smallest possible calibre, with cylindrical bulbs about half an inch in length, and scarcely larger than crow-quills, and are similar to those employed by Professor DANIEL for the purpose of ascertaining the dew point. They were made by Mr. NEWMAN of Regent Street, and are graduated from zero, or from a few degrees below freezing to about 110° or 120°. Whenever great delicacy of observation is required, in order to observe the varying temperature of an insect during a state of partial rest, it is necessary to use the same instrument for ascertaining the temperature of the atmosphere as for that of the insect, otherwise a great difficulty will arise, from the well known circumstance that two thermometers, be they ever so delicately constructed, and carefully compared

* Physiologische Untersuchungen über die thierische Haushaltung der Insecten. Tübingen, 1817, p. 39.

† Ideen zu einer Zoochemie, Bd. 1. 1800, p. 92.

‡ Neue Versuche, &c. p. 12, 13.

with each other, will seldom if ever both indicate precisely the same amount of temperature in exactly the same space of time. The mode of taking the temperature is either by allowing the insect to remain with the soft ventral surface of its abdomen pressing against the bulb of the thermometer when in a state of rest, or by pressing the thermometer firmly against its body when in a state of excitement, the insect being held during the time between a pair of forceps covered with woollen, in order that the contact of the fingers of the operator may not interfere with the correctness of the observation by unnaturally increasing the temperature of the insect. It is also further necessary to guard the hand with a glove, or non-conducting substance, to prevent the thermometer itself from becoming affected by it during the experiment. Much caution also is necessary when the same thermometer is employed to ascertain the temperature both of the atmosphere and of the excited insect, to guard against one very material source of error. It is necessary *first* to ascertain the temperature of the atmosphere, and *then* that of the insect, because if this be not attended to, and the experiment be made by taking the temperature of the insect *before* observing that of the atmosphere, the moisture on the bulb of the instrument occasioned by the condensation of the *cutaneous perspiration* from the body of the animal will occasion during its drying or evaporation, while taking the temperature of the atmosphere, an indication of a lower amount of atmospheric temperature than what really exists, and consequently the apparent difference between the temperature of the insect, previously taken, and that of the atmosphere, will be much too great, and thereby appear to indicate a higher temperature than what the body of the insect really possesses. When the temperature is taken during a state of rest, the thermometer is placed beneath, and as completely covered by the abdomen of the insect as possible, while a second thermometer, which has been very carefully compared with the first, is placed on the same level with and at a short distance from it to indicate the temperature of the atmosphere. When the temperature of active volant insects is to be taken, it is preferable to inclose them singly in a small phial, introducing them with the forceps as before, and being particularly careful not to touch the phial with the fingers. The degree of activity or quiescence of the insect must always be particularly noticed, and also the number of inspirations. By attending to these facts we acquire a knowledge of the amount of respiration compared with the quantity of heat evolved, as indicated by the thermometer. The temperature of the insect taken on the exterior of the body is always a little lower than that of the interior; but the difference is not so great as might at first be imagined, so that I have generally preferred taking the exterior temperature, because the observations are then less complicated by unnatural causes. The interior temperature is seldom if ever more than a degree and a half, or at most two degrees above the exterior, and often not even half a degree, when the insect is in a state of perfect rest. Perhaps it may be urged as an objection, that when the bulb of the thermometer is applied to the exterior of the body, it can seldom be so completely covered as to indicate the whole amount of

heat developed. But this objection, although at first plausible, must be considered valid only when the observations are made very quickly. But even were the objection substantiated it would be of but little consequence, because it is only the relative amount of heat developed by one insect as compared with that of another, when the observations on both are conducted in a similar manner, which is ultimately sought for, it being almost impossible to ascertain the exact amount evolved by any single insect. It may also be urged as an objection to this mode of taking the temperature of insects in a state of excitement, that when an insect is respiring very rapidly, the friction of the segments of its body against the bulb of the thermometer may evolve a certain amount of heat independent of the natural heat of the insect, and thereby indicate a higher temperature in the insect than that which really exists. In order to meet this objection, I made a number of trials with my thermometers, by using, as nearly as could be ascertained, about the same amount of attrition against the bulb of the instruments as that which is exerted by the segments of the excited insect during its laboured respiration and efforts to escape, and found that so small a quantity of heat is evolved that it is not in the slightest degree indicated on the scale of the thermometer. Hence I have not in general found it necessary to take the temperature of the interior of the body, although I have done so in a few instances, because there are also other circumstances which interfere with the correctness of the observation. The first of these is the large size of the instrument employed compared with that of the body of the insect into which it is inserted, and the consequent necessary loss of a certain amount of caloric, which becomes latent in the thermometer, before there is any indication of increased temperature on the scale, and because also of the unavoidable escape of a large amount of caloric into the surrounding atmosphere, and because still further it is only at the very instant after the introduction of the thermometer into the body of the insect that the real perceptible amount of temperature is indicated, while the insect under observation is every moment losing the power of generating and of maintaining its temperature, owing to the injury that has been inflicted upon it. These objections do not occur when the observations are made on the exterior of the insect, which from its being uninjured, continues to possess its power of generating heat unaffected by those circumstances which tend very materially to interfere with or destroy it, while a sufficient length of time is afforded for the production of its full amount of heat after a certain quantity has become latent in the thermometer, before the observation of the amount is taken.

These are the principal circumstances to be attended to in ascertaining the temperature of insects, and which have directed me in my observations.

I. *Temperature of the different States of Insects.*

1. *The Larva.*

The temperature of the larva is always lower than that of the perfect insect of the same species, provided both individuals be in a similar state of activity relative to their usual condition. This circumstance must never be neglected when making comparative observations on the different states of the same insect. Thus the larva of the more perfect hymenopterous insects, the common Humble Bees, *Bombi*, *Anthophoræ*, *Euceræ*, &c., which in all their stages have a temperature higher than perhaps any other insects, in their active larva state vary from about 2° to 4° FAHR. above the temperature of the surrounding medium, while the same individuals in their perfect state, when moderately active, have a temperature of from 3° to 8° or 10° FAHR. higher than that medium; but when the same insect is very greatly excited the amount of difference is raised to a much greater extent. There is a similar difference between the temperature of the larva of the common Flesh Fly, *Musca vomitoria*, LINN. and that of its perfect insect, only that the amount is not so great as in the hymenopterous insects. In the Musca the amount of temperature in the larva state seldom exceeds 1°·5, and in the perfect perhaps not more than 2°·5, above that of the surrounding medium. It is probable that this estimate of the difference between the larva and perfect state of dipterous insects may be rather too little, owing to the difficulty of making observations on these insects individually, their small size rendering precision in the experiment almost impossible. But the fact is sufficiently clear that they have not so high a temperature as hymenopterous insects. The same difficulty does not exist in making observations on large insects, particularly on the large soft-bodied larvæ of the Sphinges, and accordingly it is found that in these lepidopterous insects we are better enabled to ascertain the maximum amount of heat evolved by the larva, and the difference which exists between its powers of generating heat and that of its perfect insect. This difference is greater in lepidopterous insects than in dipterous, and approaches nearer to the hymenopterous. It was in the larvæ of lepidopterous insects that I first observed the existence, and the varying amount of temperature in individual insects. These observations were commenced in September 1832. At $2\frac{1}{2}$ P.M. September 14, the temperature of the atmosphere being 62°·5 FAHR., the bulb of a thermometer was applied to the under surface of the body of a full-grown larva of *Sphinx Atropos*, LINN., which had discontinued feeding preparatory to undergoing its transformation. The insect then weighed $365\frac{1}{2}$ grains. Previously to the observation it had been for a considerable time in a state of violent excitement, and was moving about with great rapidity. Its temperature, as indicated by the thermometer, was then 70° FAHR., or 7°·5 higher than that of the atmosphere. This, however, was much higher than its real temperature, which is probably not more than 3°, and was occasioned, as I subsequently had reason to believe, by

holding the insect in my hand while making the observation. At 12½ midnight, atmosphere 60°·5, the larva perfectly at rest had a temperature of only 61° FAHR.; and at 7 o'clock on the following morning, September 15, having remained perfectly quiet and apparently asleep since the last observation, the temperature of the atmosphere continuing at 60°·5 FAHR., when the bulb of the thermometer was gently pressed against its side without disturbing it, and allowed to remain there for a quarter of an hour, the mercury was not perceptibly affected, the temperature of the larva, now in a complete state of rest, being exactly that of the surrounding atmosphere. Observations in every respect similar to these were also made at the same time on the larva of the Bull-headed Moth, *Pygæra bucephala*, STEPH. At midnight the temperature of the atmosphere, as before stated, being 60°·5, the thermometer was applied to the under surface of a larva that had been lying perfectly at rest for several hours, and although it now became slightly aroused its temperature was only 61° FAHR. At 7 on the morning of the 15th, the larva still perfectly quiet, and the thermometer placed in contact with it, and, as with the *Sphinx Atropos*, allowed to remain for a quarter of an hour, there was no indication of any increase of temperature, the temperature of the insect being exactly that of the atmosphere; but a few hours afterwards, when the thermometer was again applied to the same insect, which had become slightly active, the mercury rose to 60°·5, the temperature of the atmosphere being then 60° FAHR. At 6½ on the morning of the 17th the observations on this species were repeated. The temperature of the atmosphere was then 62° FAHR.; and when the bulb of the thermometer was applied to a full-grown larva, which had been remaining several hours at rest, the mercury rose very nearly to 63° FAHR. The observation was then repeated on several other individuals of the same species, which had been lying at rest, and with precisely similar results. The bulb of the thermometer was then placed in a box which was filled with these larvæ, and being completely covered with them was suffered to remain for ten minutes, during which time they were in a state of great activity, and the mercury rose to 63°·3 FAHR., a difference of 1°·3 FAHR. Subsequent observations on the temperature of other species of lepidopterous insects confirmed these observations; and it was remarkable that the amount of temperature in the larvæ of different tribes of this order is pretty nearly the same. On the 26th of June 1834 I examined the full-grown larva of *Pavonia minor*, which like the preceding species had been at rest for several hours, and found that the temperature of the atmosphere being 68°, the temperature of the insect was only 68°·3. The insect then became a little excited, and the mercury rose to 68°·7; and when still further excited to 68°·9, and ultimately to 69°·3, being a difference of 1°·3 above that of the atmosphere, thus proving that the temperature of an insect increases immediately it becomes active, and that the increase is in proportion to the degree of activity, and probably also to the quantity of respiration of the insect. From these facts it is sufficiently clear that individual insects possess a temperature of body above that of the surrounding medium, and that the amount is not constant

in the same insect, but varies according to certain conditions of the insect. These views were still further confirmed and extended by observations on the *Sphinx ligustri*, *S. populi*, *S. ocellata*, LINN., and *Cerura vinula*, STEPH. The first and last of these insects, from their large size and frequency of occurrence, afford us the means of ascertaining all the facts connected with the temperature of larvæ, and are those on which most of my subsequent observations have been made. It is at about the fifth or sixth day after the larva of *Sphinx ligustri* has assumed its last skin, that it evolves the greatest quantity of heat. It then feeds most voraciously, and usually weighs about 80 grains. Its greatest temperature is then 1°·3 above the temperature of the atmosphere. I have seldom or ever found it higher, while on the eighth or ninth day it seldom exceeds nine tenths, and a little while before its change into the pupa state perhaps not more than five tenths. Its quantity of respiration at that time is diminished, and its temperature is reduced by copious cutaneous perspiration, which becomes very apparent when the insect is much excited. The difference which exists in the maximum amount of heat generated by the larvæ of different species of the same class of insects, appears to have some reference to the habits of those species. The greatest amount, so far as I have yet ascertained, excepting only the *Sphinx Atropos* before noticed, appears to be generated by the larva of the Puss Moth, *Cerura vinula*, STEPH., which usually lives on the boughs of trees, and subsequently undergoes its changes on the trunk or limbs of the tree a few feet from the ground, has a higher temperature of body, and a quicker circulation of its fluids than the larva of the Sphinx, which undergoes its changes in the earth. The larva of the *Cerura* in its most active condition sometimes has a temperature of 1°·8, or nearly half a degree higher than the Sphinx; but I have not observed the same difference between the temperatures of the perfect insects of these species, both of which constantly reside in the open air. The amount of difference between the perfect insect and larva in these species, like that of the hymenopterous insects, is very great. A perfectly healthy specimen of *Sphinx ligustri* in its perfect condition after violent exertion, has sometimes a temperature of nearly 8° above that of its larva. The usual difference is about 5°, and the same is the case with the *Cerura*.

When the *internal* temperature of a larva of the Sphinx or *Cerura* is taken, it is found to vary from ·5 of a degree to 1° above that of the external. But all observations on the internal temperature of larvæ, more particularly of soft-bodied larvæ, are necessarily uncertain, on account of the reasons before stated. Still it is sometimes desirable to ascertain its amount, particularly when the specimens have been kept in a steady medium. When the internal temperature of the larva of *Anthophora retusa*, STEPH. is taken with the necessary care, it is found to be nearly or quite a degree above that of the exterior; but the difficulty in making correct observations on these larvæ is exceedingly great, owing to the rapidity with which they part with their natural heat when exposed to a varying medium. Hence when the observations are attempted to be made, even with regard to external temperature, in the natural

haunts of these insects, they seldom afford very satisfactory results. In order therefore to ascertain the real temperature of these larvæ I collected a number of separate nidi, each of which inclosed a larva, and placed them for a few days in a room, the temperature of which varied but very slightly. Each larva was then submitted to observation immediately it was removed from its cell. The temperature of the room in which the nidi were kept was 57° Fahr. The first specimen examined had been lying partly exposed for a short time, and the larva perhaps had thereby had its temperature diminished. When the bulb of the thermometer was inserted into its abdomen the mercury rose only to 57°·8, while its external temperature was scarcely above that of the atmosphere. The second specimen had been better preserved from exposure, but the mercury rose again only to 57°·8. In a third, and apparently very healthy specimen, it rose to 58°. In a fourth, in every respect healthy, to 60° for about a moment, but rapidly sunk again to a little more than 59°; in a fifth it rose also to 60°; in a sixth to 59°·5 ; and in a seventh and eighth to 60°. On another occasion, when the medium in which the larvæ were kept was 57°·3, the temperature of the under surface of a larva was 60°, but when the bulb of a thermometer was carefully passed into its abdomen the mercury rose to 61° Fahr. In the larvæ of *Musca vomitoria*, Linn., treated in a similar manner, the temperature of the atmosphere being then 56°·8, the mercury rose to 57°·8, but was maintained at that height only for a few seconds, owing to causes before noticed.

I have not yet had an opportunity of examining the larvæ of coleopterous insects, which judging from their similarity to those of the hymenopterous and dipterous classes, it is fair to infer evolve a similar amount of heat. Neither have I been able to examine the orthopterous and hemipterous larvæ, which, from their approaching very near to the condition of the perfect insect, probably differ but little in their production of heat and the quantity of respiration.

2. *The Pupa.*

The pupa state being in all insects which undergo a complete metamorphosis a condition of absolute rest, the temperature of the individual is in general lower than at any previous or subsequent period of its existence, and is only equal to, or at most but very little above that of the surrounding medium. But in those insects which do not undergo a complete metamorphosis, the temperature probably is intermediate between that of the larva and perfect condition. In those species the individuals continue active during their whole life. These exceptions include most of the hemipterous, orthopterous, and a few coleopterous insects, and cannot properly be included under the designation of pupa, the term being here intended to apply strictly to the lepidopterous, dipterous, hymenopterous, and a few coleopterous insects.

The only periods during which the temperature of a pupa is higher than that of the surrounding medium, are, first at the period of, or within a short time after its change from the larva state, while it is still active, and respiring very freely, and be-

fore it has completely subsided into a state of rest. At that time, when the whole of its energies are called into activity in effecting its transformation, the temperature of the pupa may be considerably higher than that of the surrounding medium. Thus I have found it in the Sphinx, immediately after changing, equal to that of the active larva. When the temperature of its cell in the earth was 68°·3, the temperature of the newly-changed pupa within it was 69°·5, a difference of 1°·2; but within a single hour afterwards, while the body of the pupa was yet soft, the difference was scarcely more than three tenths of a degree. So likewise when a pupa is very much disturbed for the purpose of experiment, its temperature becomes considerably increased. Also when the medium in which the pupa is living is suddenly diminished, or when the pupa is removed from a warmer to a colder medium; and lastly, when the pupa, aroused by the stimulus of gradually increasing external temperature, begins again to respire freely, during a short time before it is developed into the perfect insect. In each of these cases its temperature may be more or less high, according, in the first place, to the rapidity with which the temperature of the surrounding medium has been diminished, and in the second according to its quantity of respiration in a given time. The increased temperature of a lepidopterous pupa arising, as it appears to do, with increased respiration, is coincident with the power which the insect gradually acquires before it is able to fissure its prison-house and liberate itself from the puparium; while the hymenopterous insect, which lives in society, and remains during its nymph or pupa state inclosed in an almost impervious cocoon, has its temperature artificially increased by the incubation of insects already developed.

It is very shortly after an insect has entered the pupa state that its respiration is diminished, and its temperature sinks down very nearly to that of the surrounding medium. At 8 A.M., November 10, two pupæ of *Sphinx ligustri*, which had remained during several weeks with other specimens entirely undisturbed, were carefully removed with the forceps into glass-stoppered phials, the temperature of which was exactly that of the room in which the pupa had previously been kept. They were examined during three succeeding days, the temperature of the atmosphere being also very carefully noted. The temperature of the phials varied a little, but there was not the slightest difference between the temperature of the atmosphere of the phials and of their respective pupæ, even when the thermometer was allowed to remain in contact with the pupæ for several minutes. The variations in the temperature of the phials are shown in the following Table.

TABLE I. Temperature of Pupæ.

Period of observation.	Atmosphere.	Phials.	Diff.	Remarks.
Nov. 10, 1834. A.M. 8	53°·4	No. 1. 53·4 No. 2. 53·4		
P.M. 1½	54·5	No. 1. 54·7 No. 2. 54·5	·2	Pupa had been a little excited.
11 P.M. 1	51·5	No. 1. 51·6 No. 2. 51·6	·1 ·1	Atmospheric temperature sinking.
12 A.M. 9	51·9	No. 1. 51·8 No. 2. 51·9		Atmospheric temperature rising.
13 A.M. 9½	50·9	No. 1. 51 No. 2. 51·1	·1 ·2	Atmospheric temperature sinking.

From these observations it is seen that when the pupa was disturbed there was a slight evolution of heat; the amount of this was greatest when the temperature of the atmosphere was subsiding. But as it appears reasonable to infer, *à priori*, that the internal temperature of the pupa may be higher than that of the surrounding atmosphere, although the thermometer be not perceptibly affected when applied to the thick exterior of the puparium, another specimen of the same insect was subjected to examination. This specimen had been lying for several weeks on the surface of the ground, in the shade, exposed to all the variations of the atmosphere. During that period the temperature of the air had seldom been more than a few degrees above freezing, while on the three nights immediately preceding the making of this observation, on the morning of the 23rd of March, the temperature of the atmosphere had ranged from 2° to 4° FAHR. below 32° FAHR. On the night of the 22nd it was from 3° to 4° below that standard. Under these circumstances there appeared to be a favourable opportunity of ascertaining the real internal temperature of the pupa. Accordingly at $7\frac{1}{2}$ A.M., atmosphere perfectly calm, and its temperature 32°·6 FAHR., and gradually but very slowly rising, an incision was made quickly with a pair of scissors through the posterior part of the pupa, which was held for the moment between a pair of forceps that had previously been cooled down to the temperature of the atmosphere. The fluids of the insect instantly gushed out, and the entire cylindrical bulb of a small thermometer was immediately passed into the body of the pupa. It was the same thermometer which only a moment before had been used to ascertain the temperature of the atmosphere. The mercury in the scale immediately sunk to 32°·3 FAHR., or three tenths below that of the atmosphere, and it was maintained at that standard for fifteen minutes, while the temperature of the atmosphere was still slowly rising. At the expiration of that time the pupa was slightly compressed with the forceps, and its temperature rose slowly to 32°·7, that of the atmosphere being 32°·8. In this observation there was not the objection of part of the bulb of the thermometer being exposed, nor of evaporation taking place from the surface of the wetted bulb. Hence it is fair to conclude that the internal temperature of a pupa, perfectly at rest, is scarcely above that of the surrounding medium, when the temperature of that medium is stationary. We have still further evidence that this is really the case, when instead of a single specimen a considerable number of pupæ are employed. When the bulb of a thermometer was completely covered with the pupæ of the Flesh Fly, *Musca vomitoria*, LINN., the temperature of the atmosphere being 56°·5 FAHR., the mercury was not in the slightest affected, but continued exactly at the same standard. But when the more delicate pupæ, or nymphs, are employed, as those of Bees, the temperature of a number of them which have been somewhat disturbed is generally a little above that of the surrounding medium; and this is also the case when a single specimen is employed, if its temperature be taken during the summer, when the nymph is active and preparing to pass into the perfect state, as shown in Table III., No. 39. But this difference very soon becomes reduced

by the greater rapidity with which insects in the condition of nymphs part with their natural heat than even the larva; and this apparently is the reason why most hymenopterous insects select those situations for their young which are found to be the worst conductors of heat. This evidently is why the *Anthophora* incloses its larvæ in cells constructed in the vertical sections of banks of earth which are exposed to the morning sun, and why the Hive and Humble Bees crowd over those cells which are about to produce the perfect insect, when the inclosed nymphs are most in need of increased temperature to invigorate them for the change they are about to undergo.

3. *The Imago, or Perfect State.*

When an insect has assumed its last or perfect condition it has a higher temperature of body than at any other period of its life, and when in a state of activity is not so much influenced by sudden changes of atmospheric temperature as in its earlier states of existence as larva or pupa; and it has also a greater power of generating as well as of maintaining its temperature. But it is not until some time after an insect has assumed its perfect form that it is able to support its full temperature. This period is longer or shorter, according to the habits of the species. When a lepidopterous insect leave its puparium with its whole body soft and delicate, and its wings undeveloped and hanging uselessly like little buds from the sides of its thorax, it so rapidly parts with its temperature that it appears to have a lower degree of heat than at the time when it was about to pass from the larva to the pupa state, and it immediately seeks a retired situation, where it may suspend itself vertically at rest, and complete the development of what are now to become its most important organs of locomotion. In effecting this development it is well known that the insect first begins to breathe very deeply, and it continues to do so for a considerable time. The inspired air passes from the large air-sacs in the abdomen of the insect into the base of the wings, with which the air-sacs have a direct communication*; and while the ramified tracheæ in the wings are becoming elongated and distended, and the wings in consequence developed, the temperature of the insect again begins to increase. But it is not until the wings have become firm and fitted for flight that the insect is enabled to generate its full amount of temperature. Thus in the Puss Moth, *Cerura vinula*, Steph. half an hour after coming from the pupa the temperature of the insect was only ·2 of a degree above that of the atmosphere; at an hour afterwards ·3; at an hour and a half ·6. During this period the insect was only in a moderate state of activity. But at two hours and a half, and when a little more active, its temperature amounted to one degree and two tenths; and on the following day, when perfectly strong and excited as during rapid flight, it amounted to nearly 7° above that of the atmosphere (Table V. Nos. 25 to 35.).

This is exactly the same with the *Sphinx ligustri*, Linn. An individual which had

* Mr. Goadby, Medical Gazette, April 2, 1836.

only left the pupa state about an hour and a quarter had a temperature of only ·4 of a degree above the atmosphere; but at the expiration of two hours and a quarter, when it had become strong and had just taken its first flight, it had a temperature of 5°·2 (Table V. No. 7.); while another specimen, which had been longer exerting itself in rapid flight, had a temperature of 9° above that of the atmosphere (Table V. No. 12.). Now these very species in their larva state, as we have before seen, have not more than 1°·3 and 1°·8 above that of the atmosphere. The circumstances connected with the power of generating heat are nearly the same in the development of hymenopterous as in lepidopterous insects, the only difference being that those hymenopterous insects which live in society have their heat augmented artificially before leaving the cocoon or pupa case. But when the young bee comes forth it parts with its temperature most rapidly, unless it be immediately protected by warmth afforded to it by the bodies of other individuals. But when the same insect a few hours afterwards has become fully able to perform all the duties of its existence, it sometimes has a temperature of perhaps 20° FAHR. above that of the surrounding medium, while the temperature of its larva is scarcely more than 3° or 4° FAHR.

During the whole of my observations I have not met with a single instance in which I was unable to detect a certain amount of external temperature in perfect insects in a state of activity, and it may therefore be regarded as proved that the whole class develop a certain amount of external heat. This uniformity of results, however, has not been observed in the experiments by Dr. BERTHOLD*, before alluded to, and I can only attribute the discrepancy which exists between his observations and my own, to the circumstance of his omitting to attend particularly to the degree of activity or rest in the insects on which he experimented. I am the more inclined to attribute it to this omission, because in his 58th experiment, page 36, he says that in "twenty chamber flies there was no development of heat or external temperature," the observation being made in a steady atmospheric temperature of 17 REAUMUR (70°·25 FAHR.). In my own observations upon insects of this order, as in an experiment with about the same number of specimens of *Musca vomitoria*, LINN. in their perfect state, the atmosphere being about 52° FAHR., the insects in a state of activity evolved from 1° to 1°·9 FAHR. of external heat, while in the same individuals in a state of partial rest the amount of heat did not exceed ·6 of a degree. Again, in Dr. BERTHOLD's 59th experiment, which evidently was made in order to ascertain whether single insects evolve any appreciable heat, the bulb of a thermometer was passed into the body of a "single chaffer," through an opening under the wing-covers, and examined half-hourly for about two or three hours, but no heat was detected. In several experiments made by myself in a similar manner to this by Dr. BERTHOLD, particularly on the *Melolontha vulgaris*, STEPH. (Table VI. Nos. 45 to 52), the amount of heat developed varied from 2° to 9° above that of the atmosphere, and was always in proportion to the activity of the insect.

* Neue Versuche, &c., p. 36.

These facts are sufficient to prove that insects have a high temperature of body, and that it is higher in their perfect than in their larva or infant condition. They also beautifully accord with the facts ascertained, and the views deduced from them by Dr. EDWARDS, respecting the difference between the temperature of the young mammiferous animals and their perfect adults.

II. *Temperature of Insects as influenced by various conditions.*

Abstinence, Inactivity, Sleep, Hybernation and inordinate Excitement.

1. *Abstinence.*

Having shown the difference between the temperature of the larva and perfect insect in a state of activity, we come next to the consideration of certain conditions under which the temperature both of the perfect insect and of the larva will sometimes subside, almost to that of the surrounding medium. When an insect, whether it be in its earlier or later condition, has been long deprived of food, its power of generating and of maintaining its natural heat is diminished. But this diminution of power does not keep pace with the length of time it has been fasting, but is only in an inverse degree. In the larva of *Sphinx ligustri*, Table XII., and in *Acrida viridissima*, Table VI. Nos. 9 to 16, the amount of heat is much below the usual quantity evolved when the insect is not deprived of food, and in a state of activity. When the proper quantity of food is again supplied to these insects, their respiration is restored to its original condition, and they again evolve a full amount of heat. When a larva that has been deprived of food, or has been fed sparingly, is preparing for transformation, its natural temperature is reduced to within two or three tenths of a degree of that of the surrounding medium. This was the case with the larva of *Cerura vinula*, STEPH. (Table X. No. 30, B.), which although actively employed spinning its cocoon, had, at one time, a temperature of only two tenths of a degree above that of the atmosphere; while the other specimen, No. 1. A, which had been supplied with its full amount of food of proper quality, had a temperature under similar circumstances, and almost at the same hour, of ·7 tenths above that of the atmosphere. In another larva of *Sphinx ligustri*, which having been inadequately supplied with food soon after it had assumed its last skin, and thereby retarded three or four days beyond the usual period before it began to prepare for transformation, the temperature of its body, while in the state of the greatest muscular excitement in attempting to rupture and cast off its exuviæ, was only ·3 tenths of a degree above that of the atmosphere.

2. *Inactivity.*

Another source of diminished temperature in insects is *inactivity*. In this condition, as in a state of abstinence, the quantity of respiration is also diminished. When an insect becomes quiet, after having continued for some time in a state of moderate

activity, its temperature gradually subsides, and continues to be diminished in proportion to the length of time it remains inactive, until it has approached very near to the temperature of the atmosphere. Thus many of those insects which have a comparatively high temperature when in a state of active exertion in the early part of the summer, have their temperature greatly reduced when they become inactive at the end of autumn; and when an insect passes from a state of inactivity into that of natural sleep, its temperature subsides even during summer, very nearly to that of the surrounding medium. This was the case with the larvæ of *Sphinx Atropos* and *Bombyx bucephala*, as shown in the observations on larvæ.

3. *Sleep.*

All insects enjoy a periodical state of repose, or natural sleep. They are endowed with this privilege of life for the renovation of their voluntary energies in common with other animals. It is at this period that the involuntary functions of the body, which, together with the voluntary, are exercised to their utmost amount during the willing activity of the individual, begin steadily to subside, in order to restore the equilibrium which ought to exist between the healthy capability of the organs employed and the amount of energy expended. Respiration, circulation, digestion, and the evolution of animal heat are all diminished, until a fresh amount of voluntary power is again generated, and the animal is aroused to the enjoyment of it either by its superabundance, or through the agency of external stimuli. It is no small amount of this privilege that is enjoyed by insects. I have witnessed sleeping in almost every order of insects, and am satisfied that they enjoy as great a proportion of rest as any other animals. Many insects will remain in a state of rest during ten, twelve, or twenty hours at a time, even in their seasons of activity, influenced as they are by external stimuli. Every one is aware that the common May Chaffer, *Melolontha vulgaris*, will often continue sleeping on the leaves of the lime tree throughout the whole of a fine summer's day, and not become active until near sunset. The case is the same with nearly the whole tribe of Sphinges and Moths, while many Butterflies which are active during sunshine, will often remain for two or three days, when the weather is gloomy, affixed to the very same spot. The common Honey Bee, *Apis mellifica*, LINN., notwithstanding the bustle and activity of the hive, enjoys its share of repose as well as other insects, even amidst the apparent commotion of its own dwelling. HUBER observed that his bees often inserted their heads and part of their bodies into the empty combs, and remained there for a considerable time. They were then quietly sleeping in the cells. At other times they appear to sleep for short intervals on the surface of the combs. I have seen them towards the latter end of summer sleeping in the cells in great numbers for many hours together. It is there also where many of them pass a portion of their winter, doubtless in a state of hybernation, or most profound sleep; and it is an interesting fact, that this inactivity of the inhabitants of the hive during winter, is accompanied by a diminution of heat in

their dwelling, as I shall presently have an opportunity of proving. The common Humble Bee, *Bombus terrestris*, even in the month of April, will continue in a state of rest* approaching to the condition of hybernation for at least twenty hours, while its temperature becomes diminished in proportion to the diminution of its quantity of respiration, which also is diminished in proportion to the length of time it remains in a state of rest. This is always the case with insects when the temperature of the surrounding atmosphere is stationary. But if the temperature of the atmosphere is gradually increasing when an insect is passing into a state of repose, the temperature of the insect will continue to rise also, accompanying that of the atmosphere, but not so rapidly as it would have done were the insect in a state of activity, so that the temperature of the air and of the insect will at length arrive at exactly the same level; and if, when this is the case, the temperature of the atmosphere continues rising, that of the insect will also accompany it for a certain time; but if the increase of atmospheric temperature be very rapid, the temperature of the insect will at length be found to be one or two tenths of a degree below that of the atmosphere. When this has happened the insect generally becomes slightly aroused, fetches one or two deep inspirations, and its temperature very quickly rises to that of the atmosphere, while the insect relapses again into its previous slumber. On the other hand, if the temperature of the atmosphere be gradually diminishing, that of the insect will also continue to be diminished, but will remain for a longer period higher than that of the atmosphere when the atmosphere is rising, or is remaining stationary, since the insect during sleep can neither acquire nor part with its heat so rapidly as the atmosphere around it. But if the temperature of the atmosphere continues to subside rapidly, the temperature of the insect during the whole period of its most profound sleep may continue considerably higher than that of the surrounding medium. These facts may be readily demonstrated by careful observations on the smooth-bodied larvæ of Lepidoptera, the best of which for this purpose are the larvæ of the Sphinges, in which besides the varying amount of temperature, the correspondent rate of pulsation may also be observed with great accuracy. The larva of *Sphinx ligustri* upon which the observations detailed in Table No. II. were made, had arrived at the seventh day of its age after assuming its last skin, or at about the thirtieth day after coming from the egg, and consequently was nearly full grown, and beginning to feed rather less voraciously than on the two preceding days. At the time my observations were commenced it had been lying at rest about an hour, having fed plentifully in the morning. The whole period of observation, throughout which it was sleeping almost uninterruptedly, was about nine hours. During this period the thermometer was allowed to remain entirely undisturbed on a table in close contact with the ventral surface of the insect, while a second thermometer, with which the one employed to take the temperature of the insect had been carefully compared, was used to take the temperature of the atmosphere, which throughout the obser-

* Philosophical Transactions, 1836, Part II., p. 555, Table I., No. 27.

vations was perfectly calm. Thrice during this period of repose the insect became slightly aroused, and each time, as shown on the Table, the number of its pulsations and its temperature slightly increased, but subsided again as the insect relapsed into its previous condition. Once also it was disturbed by the passing of excrement, immediately after which there was a slight increase of its temperature, and of the pulsation of its dorsal vessel, and the insect continued awake for a few minutes, but having relapsed into its former sleep its temperature and pulsation again subsided.

Table II.

Exhibiting the diminished temperature of body during sleep, and also a coincident diminution in the rate of pulsation of the dorsal vessel in different conditions of the insect during the last three days of the larva state of the *Sphinx Ligustri*, Linn.

No.	Species.	Period of Observation.	Atmosphere.	Insect.	Difference.	Pulsation.	Weight.	Fæces.	Loss.	Age.	Remarks.
		1834. ′ ″	°	°	°		grs.	grs.	grs.		
1	Sphinx ligustri, larva...	Aug. 29. A.M. 11 15	66·8	67·3	·5	27	....	......	......	7th day.	After last change of skin, sleeping.
2	Sphinx ligustri, larva...	A.M. 11 30	67·6	68·0	·4	27	....	......	......	....	Sleeping.
3	Sphinx ligustri, larva...	A.M. 11 40	67·8	68·1	·3	28	....	......	......	....	Sleeping.
4	Sphinx ligustri, larva...	A.M. 11 45	68·0	68·2	·2	29	....	......	......	....	Sleeping.
5	Sphinx ligustri, larva...	A.M. 11 50	68·4	68·6	·2	30	....	......	......	....	Sleeping.
6	Sphinx ligustri, larva...	A.M. 12 0	68·5	68·6	·1	30	....	......	......	....	Sleeping.
7	Sphinx ligustri, larva...	A.M. 12 8	68·8	68·9	·1	31	....	......	......	....	Sleeping.
8	Sphinx ligustri, larva...	A.M. 12 15	69·1	69·1	·0	32	....	......	......	....	Sleeping.
9	Sphinx ligustri, larva...	A.M. 12 23	69·2	69·2	·0	31	....	......	......	....	Sleeping.
10	Sphinx ligustri, larva...	A.M. 12 30	69·3	69·4	·1	33	....	......	......	....	Sleeping, but slightly aroused.
11	Sphinx ligustri, larva...	P.M. 12 38	69·5	69·5	·0	31	....	......	......	....	Sleeping.
12	Sphinx ligustri, larva...	P.M. 12 45	69·6	69·6	·0	32	....	......	......	....	Sleeping.
13	Sphinx ligustri, larva...	P.M. 12 50	69·7	69·7	·0	32	....	......	......	....	Sleeping.
14	Sphinx ligustri, larva...	P.M. 1 0	69·7	69·7	·0	32	....	......	......	....	Sleeping.
15	Sphinx ligustri, larva...	P.M. 1 8	69·8	69·8	·0	32	....	......	......	....	Sleeping.
16	Sphinx ligustri, larva...	P.M. 1 15	69·9	69·9	·0	32	....	......	......	....	Sleeping.
17	Sphinx ligustri, larva...	P.M. 2 0	69·7	69·8	·1	31	....	......	......	....	Sleeping.
18	Sphinx ligustri, larva...	P.M. 2 45	69·6	69·7	·1	31	....	......	......	....	Sleeping.
19	Sphinx ligustri, larva...	P.M. 3 15	69·2	69·6	·4	30	....	......	......	....	Sleeping.
20	Sphinx ligustri, larva...	P.M. 3 30	69·3	69·6	·3	30	....	......	......	....	Sleeping.
21	Sphinx ligustri, larva...	P.M. 4 0	69·3	69·8	·5	30	....	......	......	....	Sleeping.
22	Sphinx ligustri, larva...	P.M. 4 15	69·4	69·9	·5	30	....	......	......	....	Sleeping.
23	Sphinx ligustri, larva...	P.M. 5 0	69·4	69·8	·4	29	....	6·1	......	....	Sleeping.
24	Sphinx ligustri, larva...	P.M. 5 15	69·4	69·9	·5	31	....	......	......	....	Arousing, changing colour for transformation.
25	Sphinx ligustri, larva...	P.M. 5 30	69·4	69·9	·5	30	....	......	......	....	Sleeping.
26	Sphinx ligustri, larva...	P.M. 6 0	69·1	69·7	·6	29	....	......	......	....	Sleeping.
27	Sphinx ligustri, larva...	P.M. 6 30	68·8	69·3	·5	29	....	......	......	....	Sleeping.
28	Sphinx ligustri, larva...	P.M. 7 0	68·7	69·6	·9	36	141·4	......	......	....	Aroused and active.
29	Sphinx ligustri, larva...	Aug. 30. A.M. 6 0	65·0	65·4	·4	25	....	......	......	8th day.	Sleeping.
30	Sphinx ligustri, larva...	A.M. 7 0	65·5	65·8	·3	25	136·6	3·5	......	....	Sleeping.
31	Sphinx ligustri, larva ..	A.M. 8 0	66·0	66·3	·3	24	....	......	......	....	Sleeping, much discoloured.
32	Sphinx ligustri, larva...	A.M. 9 0	67·4	......	......	26	....	......	......	....	Aroused, very active.
33	Sphinx ligustri, larva...	Aug. 31. A.M. 11 0	66·6	67·0	·4	18	110·4	......	......	9th day.	Just entered the earth, very active.
34	Sphinx ligustri, pupa...	Sept. 4. A.M. 10 0	66·1	66·4	·3	12	79·4	Skin. 3·8	27·2	13th day.	Pupa within one hour after changing, has been much disturbed.

4. *Hybernation.*

From a state of profound sleep we pass to that of hybernation, which, as shown in the hybernating Mammalia*, appears to be almost identical with the natural repose of all animals. In insects, however, hybernation seems to differ from natural rest in some of its exciting causes. Thus there are reasons for believing that this disposition to pass into a profound sleep, bears some relation to the changes which take

* Dr. M. Hall, Philosophical Transactions, 1832, Part I.

place at certain periods in the capacity of the respiratory organs, which seem to become oppressed, and their full expansion prevented by the remarkable accumulations of fat which always exist in the bodies of insects before passing into the true hybernating condition. Thus before the larva assumes the condition of pupa it feeds most voraciously, and an immense quantity of fat is collected within it, and if it has been properly supplied with food, it acquires its utmost size and weight many hours before it changes to a pupa. During the interval which elapses between its full development as a larva and its change into the pupa state it is often much less active, and has the appearance of an animal suffering from repletion: it ceases to eat, it is more sluggish in its movements, often sleeps a great deal, and perspires copiously; its average temperature is lower than it had been a day or two previously, and its quantity of respiration is also diminished. These appear to be conditions which induce the phenomena of its transformation, because I have repeatedly found that if a larva be deprived of its proper quantity of food, its change into the pupa state does not take place so early, but is retarded for two or three days. On the other hand if the insect be supplied to repletion, its change will be slightly hastened. Thus if several specimens of the larva of the Sphinx be hatched at about the same time but supplied with different kinds of food, those which are fed upon one kind of plant will often arrive at maturity and undergo their changes before those which are fed upon another. In these cases it is inferred that a plethoric condition, which is supposed always to precede the change to the pupa state, occasioned by the accumulated fat within the body compressing the respiratory organs, and thereby preventing the full aeration of the circulatory fluids, is induced in the one instance earlier than in the other, owing to the more nutritious quality of the food supplied to the insect during the first few days after it has left the egg. There is also another strong reason for believing that this condition of body is closely connected with the phænomena of transformation, in the circumstance that, although for many hours immediately preceding the change, the quantity of respiration, relatively to the size of the insect, becomes diminished, yet within one hour of the actual period of rupturing and throwing off its skin, the insect makes several very powerful and laboured inspirations; and it is then probably that those tracheæ which seem to have become compressed and diminished in calibre during the plethoric state, begin again to be distended, previously to their subsequent development into the large respiratory sacs of the perfect insect. This enlargement of the sacs is slowly progressive during the earlier, but most rapidly so during the latter period of the pupa state, while particularly in the Sphinx, it is almost suspended in the middle, or intervening period of this state, the period when the insect is in its most complete state of hybernation. The enlargement, as suggested on a former occasion*, seems to keep pace with the gradually diminishing size of the alimentary canal, and with the absorption of the accumulated fat, and since it is well known that a higher or lower degree of atmospheric temperature will either accelerate or retard the completion of these changes in the pupa, it may not be unreason-

* Philosophical Transactions, 1836, Part II. p. 534.

able to infer that the subsequent arousing of the insect from this hybernating condition arises, in addition to the stimulus of increased temperature in the surrounding medium, partly also from the stimulus of a more perfect aeration of its fluids, through means of the greater quantity of air which necessarily enters its enlarging respiratory organs. These opinions are supported by the facts that some insects pass into the pupa state at two different periods of the year, and that their subsequent development into the perfect state depends upon the period at which they enter into the pupa. Thus the common Cabbage Butterflies, *Papilio brassicæ*, LINN., and *P. Napi*, LINN., when changed from larvæ to pupæ in the middle of summer, become perfect insects within a fortnight; but when the change into the pupa state takes place at the end of summer, the perfect insects are not developed until the following spring, unless, as shown long ago by REAUMUR, they are placed in a warm atmosphere, when they may at any time be developed within a few days, even in the months of December and January. Besides these facts, and a variety of others which are equally well known, every one is aware that the hybernation of many insects occurs at comparatively high degrees of temperature. The facts connected with the presumed plethoric condition of insects before hybernating are equally referable to those perfect insects which pass the winter months in hybernacula as to larvæ which are about to pass into the pupa state, since it is found that they always have a much larger accumulation of fat in the autumn than at other seasons of the year. This is the case in the bodies of *Vanessa Atalanta*, STEPH., *V. Io*, STEPH., *V. urticæ*, and in the Cabbage Butterflies just noticed; and it is well known to the cottager that when the flowers have not yielded an abundance of honey in the latter part of the summer, the bees in his hives will have less chance of existing through the winter than when the production of honey has been plentiful. This latter circumstance may, perhaps, be said to arise from a deficiency in the quantity of honey stored up by the bees, but I have strong reasons for believing that it arises chiefly from the bees being in a worse bodily condition, and having but a small quantity of nutriment stored up within their own systems, which alone enables them to pass some portion of the winter in a state of repose. If the female of the common Humble Bee, *Bombus terrestris*, STEPH., which sleeps through the winter and appears early in the following spring, be examined about the end of September, its abdomen is found to be supplied with large bags of fat. At that period the insect is less active, and evolves a smaller quantity of heat than in the spring when there is a much lower temperature of the atmosphere. And if at that period the insect be deprived of food it will continue to live, very much longer than it would have lived, under similar circumstances, and exactly at the same temperature of the atmosphere in the month of April. About the end of September I confined two large females, *Bombus terrestris* and *B. lapidarius*, STEPH., in the same box without food, and placed them in my sitting room, the temperature of which was seldom lower than 60° FAHR. and often 65°, during the whole time of their confinement. When first confined they were both very active. *B. terrestris* died on the 27th of October, and *B. lapidarius* on the 5th of November, having each of them been confined about a month or five weeks. Now the very same species when confined in

the early part of the spring and summer, at a temperature of at least 10° lower than the present, would have perished within forty-eight hours. Hence it is not diminished temperature alone that induces a state of hybernation. Now during the confinement of these individuals I examined other specimens of the same species, and found the abdomen in each of them well filled with fat, while the respiratory organs appeared to be diminished in calibre, and somewhat compressed by its accumulation. This was particularly the case with one specimen which I examined, and the circumstance became the more interesting to me from a knowledge of the fact that both the amount of respiration and the quantity of heat evolved by the insect are at this period diminished. But without going further with the causes of hybernation of insects, and which do not directly belong to this subject, it may be inquired how it happens that if the sleep of the hybernating insect be induced by a plethoric condition of body, that there are certain species, as, for instance, the *Anthophora retusa*, STEPH., which assume the perfect form and begin to hybernate during the summer, even at the end of August, but do not leave their abodes until April or May in the following spring, although the morning sun shines brightly on their dwellings, and sometimes raises the exterior surface of the bank in which they are deposited to a temperature of 80° FAHR. or upwards? Unto this it may be replied that the bodies of those insects, having so recently changed from the larva to the perfect state, are still provided with a full supply of nourishment; that the soil in which they are nidificating has not its temperature increased to a sufficient depth to arouse them into activity, and that even if its temperature be sufficiently increased for a day or two, it does not continue at the same standard, but gradually declines with the approach of autumn; while on the other hand, on the approach of spring the mean temperature of the atmosphere is daily augmented, and the insect becomes aroused from its long slumbers by the steadily increasing warmth of its dwelling; its respiration is then excited, its fluids circulate more quickly, and the nutriment stored up within its body when it entered its sleeping condition having become exhausted, it is soon stimulated by the calls of hunger*, which the more perfect aeration of its fluids and the activity of all its functions induce within it; it makes a powerful effort to escape from its prison house, and pioneers its way through the soil to a new life, a life of activity,—directed in its proper course by the less consolidated state of the earth, in the passage to its abode, with which, many months before, the careful parent bee had securely closed the entrance, to protect her delicate offspring from the intrusion of enemies. I have seen this insect at the moment of its first leaving its abode. It always takes several very deep and powerful inspirations before it first takes wing, and its temperature is then scarcely more than a degree or two above that of the nidus it has just left. The comparative amount of the temperature of this insect in its different states during the period of hybernation, as compared with the temperature of the soil in which it is living and with its temperature in the perfect and active period, is very interesting, and will best be shown in the accompanying Table.

* Dr. M. HALL on Hybernation, Philosophical Transactions, 1832, Part I. p. 22.

Table III.

Showing the temperature of the Wild Bee, *Anthophora retusa*, Steph., in its larva, nymph, and perfect state, as compared with the temperature of the atmosphere and of its nidus during the period of hybernation, and also with that of the same insect in a state of activity.

No. of Obs.	Period of Observation.	Wind.	No. of Specimens.	Duration of Experiment.	Atmosphere. Sun.	Atmosphere. Shade.	Soil or Nidus. Empty.	Soil or Nidus. With Honey.	Larva.	Nymph.	Perfect.	Remarks.	
				m	°	°	°	°	°	°	°		
1	Sept. 17, 1832. P.M. 3	.....	14	10	.....	64	65·7	.....	.....	.....	65·7	These observations were made in the open air at the natural haunts of the insects, when the temperature of the atmosphere was gradually subsiding, and at a season of the year when the perfect insect, which had never yet been exposed to the open atmosphere, was in a state of hybernation.	
2	P.M. 3½	.....	24	5	.....	64·5	65·7	.....	.....	64·5	.....		
3	P.M. 4	.....	24	5	.....	64	.....	.....	.....	64	.....		
4	P.M. 4½	.....	14	5	.....	63·5	.....	.....	65·5	.....	.....		
5	P.M. 4½	.....	14	5	.....	63·5	.....	.....	63·5	.....	.....		
6	P.M. 4½	.....	14	5	.....	63	.....	.....	63	.....	.....		
7	P.M. 4¾	.....	14	5	.....	62	.....	.....	.....	.....	62·3		
8	P.M. 5	.....	8	5	.....	60	63·5	.....	62	.....	.....		
9	P.M. 5¼	.....	.....	.....	.....	60	63	.....	62·3	60·7	.....		
10	P.M. 6½	.....	.....	.....	.....	59·5	.....	.....	62·3	60·5	.....		
11	P.M. 6½	.....	.....	.....	.....	58·5	.....	.....	63	.....	.....		
12	21 P.M. 3	.....	30	5	.....	64	66·3	.....	68·7	.....	.....		
13	P.M. 3½	.....	30	25	.....	63·7	.....	.....	67·3	.....	.....		
14	P.M. 3¾	.....	.....	.....	.....	63·5	66	.....	.....	67	66		
15	April 6, 1834. A.M. 12½	Brisk E.	.....	.....	60	54	56	.....	59·5	.....	59	Nidi with larva and perfect insect 1½ inch deep in soil, *dry sand* ...	Richborough bank, all these cells one inch and a half from the surface; *soil, dry sand.*
16	A.M. 12½	.....	.....	.....	60 to 81	54	55·7	.....	59·5	.....	59·7		
17	A.M. 12½	.....	.....	.....	60 to 81	54	55·7	.....	59·5	.....	58·5	Bank, but a little exposed to sun	
18	June 10, 1834. A.M. 10	Brisk S.E.	.....	.....	67·7 to 73	67·5	.....	84·4	.....	.....	84	Nidus open, without larva	
19	A.M. 10	.....	.....	.....	.....	67·5	.....	80	.....	.....	.....	Nidus closed, with larva	
20	A.M. 10	.....	.....	.....	.....	67·5	.....	79·8	.....	.....	.....	Nidus closed, with larva	
21	A.M. 10	.....	.....	.....	.....	67·5	.....	78	.....	.....	.....	Nidus closed, with larva	
22	A.M. 10	.....	.....	.....	.....	67·5	.....	78	.....	.....	.....	Nidus closed, with larva	
23	A.M. 10	.....	.....	.....	.....	67·5	.....	77·7	.....	.....	.....	Nidus closed, with larva	
24	A.M. 10	.....	.....	.....	.....	67·5	.....	82·5	.....	.....	84	Nidus open, perfect female very active	
25	June 17, 1834. A.M. 10	Brisk S.W.	.....	.....	63	62·5	63·8	63·8	.....	.....	.....	Nidus open	
26	A.M. 10	.....	.....	.....	.....	62·5	.....	69	.....	.....	.....	Nidus closed	
27	A.M. 10	.....	.....	.....	.....	62·5	.....	69	.....	.....	.....	Nidus closed	
28	A.M. 10	.....	.....	.....	.....	62·5	.....	69	.....	.....	.....	Nidus closed	
29	A.M. 10	.....	.....	.....	.....	62·5	.....	68·5	.....	.....	.....	Nidus closed	
30	A.M. 10	.....	.....	.....	.....	62·5	.....	67·4	.....	.....	.....	Nidus closed } 2½ inches deep	Richborough bank, exposed to sun; *soil, dry clay.*
31	A.M. 10	.....	.....	.....	.....	62·5	.....	67	.....	.....	.....	Nidus closed }	
32	A.M. 10	.....	.....	.....	.....	62·5	.....	66·4	.....	.....	.....	Nidus closed, 3 inches deep	
33	A.M. 11	.....	.....	.....	72	66·4	.....	75·7	.....	.....	.....	Nidus closed, 1¼ inch deep	
34	A.M. 11	.....	.....	.....	72	66·4	.....	74·3	.....	.....	.....	Nidus closed, 1¾ inch deep	
35	A.M. 11	.....	.....	.....	72	66·4	.....	78·7	.....	.....	80·7	Nidus open, 2 inches deep, female just returned from flight in cell...	
36	A.M. 11	.....	.....	.....	72	66·4	.....	68	.....	.....	.....	Nidus closed, 3 inches deep	
37	June 19, 1833. A.M. 8½	.....	1	.....	84·5	62·5	71	71	73·5	.....	82	Larva in its cell, female just returned from flight, (near Canterbury.)	
38	June 20, 1833. P.M. 1	.....	1	.....	.....	66	67	68	68·5	.....	72·7	Female in her cell, inactive	Richborough.
39	P.M. 1	.....	30	5	.....	66	67	68	71	.....	.....		
40	Aug. 21, 1834. P.M. 1	.....	1	.....	.....	70·5	76·2	74	.....	74·7	.....	Very few nymphs have yet become perfect	

From this Table it is seen that in the autumn, while the larva of the Anthophora continues active in its cell, its temperature is higher than that of either nymph or perfect insect, while the nymph, which has in reality a lower temperature than either the larva or perfect insect, being at that time in a state of activity, or degree of excitement inferior to that of the larva, and superior to that of the perfect insect, has a temperature in its cell intermediate between that of these two conditions. It was evident to me while making these observations that these apparently contradictory facts arose only from the circumstance of the perfect insect being then in a state of far more complete hybernation than the nymph, which, as well as the larva, was less able to maintain its temperature when raised to a certain amount than the perfect insect. But when the season of hybernation is over, and the swarthy female bee is roving abroad in the sunshine of the months of May and June, she has a temperature, as shown at Nos. 18, 24, 35, 37, and 38, very far above her temperature in the states of larva and nymph, or than what is possessed by her only a short time before she quits her cell in the months of March and April, when her temperature is scarcely higher than that of the larva, as shown in Nos. 15, 16, and 17. But if the perfect bee be taken from her cell either at the end of March or at the commencement of her hybernation in September, her temperature of body after a few inspirations will be raised to two or three degrees above that of the atmosphere, but if undisturbed the insect always endeavours to sink again into a state of repose, and the temperature of her body becomes that of the surrounding medium. The soil in which the hybernacula of these insects are formed being of sand or clay, which are bad conductors of heat, always continues of a more uniform temperature than the open atmosphere, and is less subject to variations through the alternating and often suddenly changed temperatures of day and night, so that the insects are neither exposed on the one hand to the chilling hoar frosts of midnight, nor to the scorching sun of noon, which even in April, as shown on the Table, Nos. 16 and 17, may raise the thermometer to 81° FAHR. on the surface of the bank, while the insects in their nidi at only $1\frac{1}{2}$ inch or 2 inches deep are preserved in an almost uniform temperature of 56° FAHR.; and when the perfect insects have left their dwellings and are again filling the bank with cells and storing them with ova and with honey-paste for the support of the future young, the temperature of the same cells may be raised to 80° or upwards, a temperature which perhaps is then necessary for hatching the ova, and rearing the larvæ in their earliest condition.

5. *Inordinate Excitement.*

The great rapidity with which, as we have just seen, the temperature of an insect is raised from being almost on a level with that of the surrounding medium to several degrees above it, would naturally lead us to conclude that a much larger amount of heat is in reality generated than what is indicated by the thermometer, and that since the heat evolved within the body of the insect becomes perceptible through means of

the thermometer so very rapidly, it is fair to suppose that the insect parts with it with nearly equal facility, and that a very large proportion evolved passes off to the surrounding atmosphere or medium in which the insect is inclosed, and that when such medium is of given small extent its temperature becomes raised as well as that of the insect, and is appreciable by the thermometer. This is in reality the case; and Dr. BURMEISTER* has already imagined it to be so, but he does not appear to have made any observations of his own in order to prove it, but refers to the observations before noticed by HAUSMANN†. I remarked the fact during my earlier observations on the temperature of insects in 1834, when endeavouring to ascertain the actual amount of temperature in the common Humble Bee in a state of rest and in a state of great excitement, and when endeavouring also to ascertain whether the amount of temperature in a single insect is equal to that of an indefinite number of individuals. I had long suspected that this could not be the case, and that, for instance, the temperature of a hive of bees in winter, stated by HUBER to be equal to 80° FAHR., could not be equal to that of a single individual at the same period. Previous observations had induced me to believe that the temperature of a single insect is only a few degrees above that of the medium in which it is living, and that the actual heat of the insect is increased in proportion to the amount of its respiration; that when an insect is at rest its temperature is comparatively low, and that it becomes greatly increased during violent activity; and further, that a number of individuals confined in a given space can raise the temperature of that space to a great amount. With these views I inclosed a single female of *Bombus terrestris* in a glass-stoppered phial of three cubic inches capacity, having first noted the temperature of the atmosphere within the phial, and of that of the external atmosphere immediately around it, both of which stood at 66°·9 FAHR. The bee was allowed to remain about five minutes in the phial in a state of great activity, and its temperature was then taken by pressing the bulb of a thermometer against its abdomen. The mercury rose to 73°·4 FAHR., or 6°·5 above the temperature of the atmosphere, while the temperature of the atmosphere of the phial was raised to 68°·2 FAHR., or 2°·3 above that of its original temperature. Three other individuals of the same species were then added, and the whole four continued in a state of excitement until the mercury rose to 74°·5. It was thus proved that a single individual when excited raises the temperature of the surrounding medium, and that several individuals collectively will increase the temperature of that medium beyond what it could possibly be increased by only one.

In the next experiment, the atmosphere being 69°·4 FAHR., five individuals of the same species were confined in the same sized phial as the one just employed, and after remaining in a state of great excitement raised the temperature of the phial to 72°·5, a difference of 3°·1, while the temperature of the five excited bees was 76°·3. In another experiment, when a single bee was allowed to remain at rest with the thermo-

* Manual of Entomology, p. 403. Translated by W. E. SHUCKARD, Esq. M.E.S. 1836.

† De Anim. Ex. Respirat. p. 68.

meter pressed against its abdomen until it had become perfectly quiet, the mercury rose only to about one degree above that of the surrounding medium. These experiments appeared to indicate that the quantity of heat evolved is in the ratio of the degree and activity of respiration.

On the 9th of June 1834 three female specimens of *Bombus terrestris*, *B. lapidarius*, and *B. muscorum*, all of which had been captured about three hours previously, were submitted to experiment, great caution being taken to prevent anything from interfering with the correctness of the observations. The temperature of the atmosphere and of the phials employed on this occasion was 68° Fahr., and the time occupied in each observation was five minutes. *Bombus terrestris* raised the temperature of the phial to 72° Fahr., and maintained it at that height during the whole of the experiment, while the temperature of its own body was 77° Fahr. That of *B. lapidarius* at the end of the observations was 71°·5, and of *B. muscorum* 72°·2 Fahr. In the first of these observations the temperature of *B. terrestris* was gradually raised from the temperature of rest, or only two or three degrees above that of the atmosphere, 68° Fahr., to 77°. During the whole five minutes the insect continued in violent motion, and maintained the temperature of the stoppered phial at 72°, or 4° above the temperature of the phial at the commencement of the observation, while that of the insect itself was raised to 9°, or 5°·5 above that of the medium around it, which it had itself raised 4°.

At that time I imagined that this great amount of temperature, nearly 10° Fahr., was very nearly or quite the maximum amount of temperature that a single insect can generate, since a little more exertion, or longer continuance of excitement, would have made the insect perspire copiously. The occurrence of this phenomenon in insects, as in vertebrated animals, must be looked upon as the natural cooling process, and beyond which the temperature of the animal cannot be raised in a state of health. The second specimen, *B. lapidarius*, was feeble, and only in a moderate state of activity, and consequently did not raise the temperature of its body above the usual standard. The third specimen, *B. muscorum*, was very much excited, and its temperature rose to 72°·2, or 4° above that of the atmosphere. On the 9th of July 1834, atmosphere 69°·8 Fahr., I placed a single specimen of *B. Jonella* immediately after it was captured in the stoppered phial employed in the previous experiments. The phial was closed, and the insect continued in a highly excited state for six or eight minutes. When it had become quiet a thermometer was very carefully introduced to the bottom of the phial without touching the insect, and the mercury rose to, and was maintained at 74°·7, or 5°·8 above that of the atmosphere and of the phial at the commencement of the observations. The insect then became excited, and the thermometer was held near enough to touch the tips of its wings. The temperature of the air in the phial immediately sunk to 72°·5, being a diminution of 2°·2. This observation was several times repeated with the same results, so that while confirming the previous conclusion respecting the evolution of heat, it shows also another interesting fact, viz. that the vibration of the wings tends to cool the body of the insect during

flight, and moderate its temperature. But the power of radiating from its body into the surrounding atmosphere is not confined to the insect in its perfect state only, but exists also in the larva, as I have had opportunities of observing in the larvæ of the Sphinges, Puss Moth, &c. From these observations it is clear that a very large proportion of the heat evolved by insects in all their states passes off into the surrounding medium, and that the amount of heat evolved is in proportion to the degree of excitement and consequent quantity of respiration.

III. *Temperature of different Tribes of Insects.*

Having found that every insect maintains its own temperature of body, and that the amount of this temperature differs in the different states of each insect, it yet remains to be seen which are the families that generate the greatest amount, and what relation that amount in the different families bears to the habits and localities of the species. Our previous observations lead us to anticipate the fact that the volant insects in their perfect state have the highest temperature, while on pursuing the inquiry it is found that those species which have the lowest temperature are constantly located on the earth. Among the volant insects, those hymenopterous and lepidopterous species have the highest temperature which pass nearly the whole of their active condition on the wing in the open atmosphere, either busily engaged in the face of day despoiling the blossoms of their honied treasures, or flitting wantonly from flower to flower and breathing the largest amount of atmospheric influence. Of these it may be almost superfluous to remark, the Hive Bee and its long train of near and distant affinities, and the elegant and sportive Butterflies have the highest. Next to these probably are their predatory enemies the Hornets and Wasps, and others of the same order; and lastly, a tribe of insects which have always attracted attention, and in general are located on the ground, but sometimes enjoy the volant condition, —the Ants, the temperature of whose dwellings has been found to be considerably above that of the atmosphere: according to JUCH the temperature of an ant-hill was 17° REAUM. (70°·25 FAHR.), while that of the atmosphere was 10° REAUM. (54°·5 FAHR.). Next below the diurnal insects are the crepuscular, the highest of which are the Sphinges and Moths, and almost equal with these are the *Melolonthæ*. But the following experiments with the different tribes, while they still further illustrate the causes of the variability of temperature in insects, will also show the relative amount of heat evolved by different species.

Melolontha vulgaris, STEPH.

May 20, 1835, 7 A.M.—Having captured many individuals of this species of Chaffer Beetle on the preceding evening, I now found them perfectly quiet. The temperature of the external atmosphere was 60° FAHR., and that of the interior of the box in which they had been confined during the night was 61°·3, while on carefully introducing the bulb of the thermometer among the beetles, without disturbing them, the mercury

rose to 61°·5 F. I then took a single beetle which had been remaining quiet, and having secured him with the forceps, opened the abdomen quickly with a pair of scissors, and introduced the bulb of a fine thermometer. The mercury immediately rose to 63°·3 FAHR., a difference of 2° above the temperature of the box, and 3°·3 above that of the atmosphere, and it was maintained at that height more than ten minutes, after which it sunk two or three tenths of a degree, as the energies of the insect became impaired. Half an hour after the above observations the temperature of the box had risen to 63° FAHR., and the insects were in motion; and when the bulb of the thermometer was merely allowed to rest upon the backs of several specimens, the mercury rose immediately to 65°·3 FAHR. When the beetles were again examined on the 23rd of May, at 7 A.M., they were perfectly quiet, having fasted since the last observation, being now a space of eighty-two hours since they were captured and had taken food. Atmosphere 60°·5 FAHR., of the box with the beetles 61°·3, thermometer introduced carefully among the beetles 61°·5, but when introduced as above into the body of a single beetle it rose to 63°·3 FAHR. One hour after this, at 8 A.M., atmosphere 64°, the temperature of the box was 66°, and the temperature of the interior of the body of a quiet beetle was 69°·2. At $8\frac{1}{2}$ A.M., atmosphere 64°·5, thermometer applied to the exterior of the body of a female beetle that had been respiring very rapidly and preparing for flight, the mercury rose to 69°·3, and continued to rise in proportion to the degree of respiration of the insect. At $8\frac{3}{4}$ A.M. the insect just employed was placed on its back for half an hour, during which time it was respiring very rapidly, and endeavouring to escape, and its temperature had risen at the expiration of this period to 74°·5, while that of the atmosphere was 65°·5, a difference of 9°, so that although this insect had now been entirely without food for nearly eighty-four hours, its long abstinence had very little diminished its power of generating heat. A male specimen was then placed under almost precisely similar circumstances, and its temperature rose to 74°. At 6 P.M., atmosphere 64°·1, the same female specimen which had been employed in the morning, but which subsequently had been lying at rest for several hours, and was still reposing, had a temperature of 66°·3, a difference of only 2°·2, while the same male specimen that had been employed in the morning and had since been at rest, but was now respiring again very freely, and attempting to escape, had a temperature of 69°·1, a difference of 5° above that of the atmosphere, thus fairly leading to the inference that the amount of temperature is in proportion to the quantity of respiration.

At 7 P.M. May 24.—The temperature of a female specimen which had been at rest since the morning in its natural haunts clinging to the leaves of a lime tree was very carefully taken without disturbing it, by applying the thermometer to its abdomen, and was found to be only 62°·6, or one tenth of a degree only above that of the atmosphere; so that, like the temperature of the hybernating Mammalia, it had sunk down during its rest almost to a level with that of the surrounding atmosphere.

Melolontha solstitialis, STEPH.

June 26, 1834, A.M.—The specimens employed on the present occasion were captured on the evening of the 25th, the temperature of the atmosphere being $70^{\circ}\cdot 5$; a single specimen, which had been lying for some time at rest, had a temperature only of $70^{\circ}\cdot 8$. Five specimens which had previously been very active, and were now perspiring profusely, raised the temperature of a phial, whose cubic bulk was about two inches, from $70^{\circ}\cdot 5$ to $71^{\circ}\cdot 4$. Nine insects in a similar-sized phial raised the temperature in four minutes from $70^{\circ}\cdot 5$ to $72^{\circ}\cdot 2$, and a few minutes afterwards to $73^{\circ}\cdot 2$. During this time the insects were in a state of the greatest excitement. The bulb of the thermometer was not brought into contact with the bodies of the insects. When the thermometer was placed among the beetles, and in contact with their bodies, the mercury rose to $74^{\circ}\cdot 5$, a difference of at least 4° above the original temperature of the bottle; but this was far from being the full amount of the heat of these insects. During these observations I found that a large amount of heat generated by the insects confined in the phial becomes latent, and also that much caloric is radiated from the exterior of the phial, which becomes heated by the beetles and warm air within, as is proved by the fact that when the thermometer is held very close to the side of the phial without touching it, the mercury is considerably affected, and when the bulb of the thermometer is held in contact with the phial the mercury ascends the scale. In the present experiment it rose more than a degree when the bulb of the thermometer touched the side of the phial. It must not be forgotten that besides this difficulty in our observations on the temperature of insects, there is another which prevents us from knowing the exact amount of heat generated by the insect under examination. It is seen in these observations on the *Melolonthæ*, as before shown in the *Bombi*, that a large amount of the heat generated by the body of an insect quickly passes off into the surrounding medium. But if the excited state of the insect be excessive, and the consequent evolution of heat greatly exceed its usual amount, nature has resorted to another expedient for cooling down the animal body, through means of a profuse perspiration, which is carried on in insects perhaps to a greater extent than in other animals. Thence the amount of heat believed to be generated under certain conditions is only comparative; but when, as in experiments made on many specimens collected together, a profuse perspiration breaks out among the insects, the amount of temperature indicated by the thermometer introduced among them is much lower than the real amount that has been produced. This was the case in the present instance: the specimens were in a state of profuse perspiration, besides which they had fasted about eighteen hours. These facts were further illustrated by a subsequent experiment, in which eighteen specimens were employed in the same sized phial; they were crowded together, and allowed to remain about a quarter of an hour in a state of great activity, until they became gradually weakened, were bathed with perspiration, and were becoming quiet and asphyxiated with the carbonic acid

gas produced during their confined respiration. The temperature of the atmosphere of the phial at the commencement of the observation was 71°·3, at the termination 73°·2, a difference of only 1°·9.

Lucanus cervus, LINN.

July 9, 1834, 9 A.M.—The temperature of the atmosphere being 67°, that of a male specimen of this insect, the great Stag Beetle, which had been fasting about two days, was very carefully taken while the insect was lying at rest, by placing the bulb of the thermometer for several minutes against the surface of its abdomen. The mercury rose to 67°·3, a difference of only ·3 of a degree of external temperature. At 9¼ A.M. I inclosed the insect in a stoppered phial of about three cubic inches capacity. The temperature of the atmosphere and of the phial was 66°·9. The insect remained perfectly at rest for a quarter of an hour, at the expiration of which the atmosphere of the phial was 67°·1. At the expiration of half an hour it was 67°·2, and the external temperature of the insect itself was 67°·4. During this period the insect had remained perfectly quiet, but at the expiration of an hour it began to find itself uneasy, and became slightly active, probably from the presence of carbonic acid gas in the phial, which had been generated during respiration. At 10½ the atmosphere of the phial was raised to 68°·5, or 1°·5 higher than at the commencement of the observation. The temperature of the atmosphere was now 66°·6. The insect was then removed from the phial, and the bulb of a delicate thermometer passed beneath its elytra, and the mercury rose to 68°·2. The insect was then placed on its back upon a smooth table, which occasioned it to exert itself greatly in order to recover its proper position. The bulb of the thermometer was applied as before, and the mercury rose to 69°·2, or 2°·6 above that of the atmosphere. At 4 P.M., atmosphere 71°, temperature of the insect beneath the elytra as before, was 71°·5.

Coccinella septempunctata, LINN.

It is almost impossible to ascertain with any precision the temperature of these interesting little insects, the Lady Cows, but I have sufficient reason for believing that it is very considerable, and corresponds with the views which ought to place them in the class of volant diurnal insects of high temperature. Had a larger number of specimens been employed, I have no doubt that the amount of heat evolved would have corresponded with the very high degree of respiration which they are found to possess. July, 9 A.M., atmosphere 67°·1, eight specimens were confined in a cubic inch phial, the temperature of which was 68°·2 , and when four of them were clinging to the bulb of the thermometer the mercury immediately rose, and was maintained at 68°·5, and after a short interval, when the insects had been moderately active, the thermometer stood at 69°, a difference of nearly one degree.

Meloe proscarabœus and *M. violaceus*, LINN.

These insects (the Oil Beetles), like their congeners the Blister Beetles (*Lyttæ*), have a temperature corresponding to their natural habits. The temperature of a number of *Lyttæ vesicatoriæ* was found by JUCH to be several degrees above that of the atmosphere. This, to a certain extent, is the case with the Meloes, which love to bask in the heat of the sun, and respire a large quantity of atmospheric air. On the 1st of May I examined the temperature of a female *Meloe proscarabœus* soon after it was captured, and found its temperature amounted to very nearly 3° above that of the atmosphere when the insect was a little excited; but half an hour afterwards, when the insect had become more calm, it had subsided to 1°·5. I have in general found that the temperature of a single Meloe varies from one to two degrees above that of the atmosphere when not excited, and it seldom sinks down to the temperature of the atmosphere, because during the season in which the perfect Meloe is found it is almost always active. But when the newly developed Meloe first leaves its nidus in the earth in the beginning of March or end of February, I have seldom been able to detect more than one, or at most two tenths of a degree, in those of one species which I have had opportunities of examining, *Meloe cicatricosus*; and the same is the case with the nymph of the same species found in the month of August.

Gryllus viridissimus, LINN.

All the Grylli or locust tribes have comparatively a high temperature, and exist but a short time when the atmosphere around them becomes vitiated. This accords with their usual habits. We find them in the most sunny places, basking in the hottest rays, or chirping among the bushes at some distance from the ground. Hence we should conclude, *à priori*, that they have a high temperature. In a female specimen of *G. viridissimus*, captured on the 14th of July, when confined for a short time, atmosphere 73°·7, the temperature of the air of the phial had risen to 74°·7, and that of the insect at rest to 75°·4, but when excited 75°·8, a difference of 2°·1. When the insect had been confined in a phial about an hour it respired at the rate of 37 irregular and forcible contractions per minute. It was then becoming affected by the carbonic acid in the phial, the atmosphere of which had been raised to 74°·9, while the insect was perfectly at rest. In a subsequent experiment the temperature of the insect was 76°, that of the atmosphere continuing at 73°·7. When the observations were repeated at 7 o'clock on the morning of the 15th, atmosphere 63°·3, the temperature of the phial was soon raised to 67°·4, while that of the insect not excited was 68°, a difference of 4°·7. At 11 A.M., atmosphere 71°·6, insect 73°·6, phial 72°·7, and on the morning of the 16th at 7, the insect having fasted for thirty-six hours, atmosphere 69°·1, phial 70°, insect 70°·5, but when excited 70°·8, thus proving that a great diminution of its power of generating heat had taken place during its abstinence.

Staphylinus olens, and *S. erythropterus,* LINN.

Both these species of Rove Beetles have a comparatively low temperature, and it is often difficult even to detect the existence of distinct temperature in these insects, unless the individuals have become considerably excited. I have never yet examined *S. Olens* in the autumn before it retires to its hybernaculum, but in a specimen found in April, the temperature of the atmosphere being 60°·2, that of the insect was 61°·2. I could seldom find it rise higher, and it was often difficult to detect its existence at all. In *S. Erythropterus* I have seldom found the temperature higher than about ·5 above the atmosphere. It must thus be seen that there is a marked difference between the power which these insects possess of generating heat, and those which are more constantly in the open air; and when we examine the *Carabi* and *Tenebriones,* this difference of power is still more remarkable.

Carabus monilis, C. violaceus, and *C. nemoralis,* LINN.

June 18, 1834.—A specimen of the Ground Beetle, *Carabus monilis,* without being touched with the fingers, was carefully placed in a stoppered phial, the temperature of which, as well as of the atmosphere, was 67°·4. When the bulb of the thermometer was pressed against the under surface of the insect the mercury was not perceptibly affected, nor was there any change in the temperature of the closed phial during five minutes, all which time the insect was in a state of great excitement. This observation being made precisely as in the cases with the hymenopterous insects, the temperature of the *Carabus,* consequently, is exceedingly low. It ought to be remarked, however, that this insect had fasted during eighteen hours, and of course could not be expected to generate so great an amount of heat as the recently fed specimens. A second specimen, which had been recently captured, was then placed with the first in the same phial, and within a few minutes the atmosphere of the phial was raised to 67°·6, or ·2 of a degree above the previous temperature. A specimen of *Carabus violaceus* was then added to the number, and the three insects continued in a state of great excitement for several minutes, when the inside of the phial was found to be 67°·7, or ·3 of a degree above its original standard; but only a very slight additional effect was produced on the thermometer when applied to the body of the insects.

April 11, 1836, 3½ P.M.—I examined a single female specimen of *Carabus nemoralis* which had recently been captured. The insect was lying quiet when I made the first observation, by applying the thermometer to the under surface of its abdomen. The temperature of the atmosphere was then 61°·6, and that of the insect 61°·8. The insect then became active, and at the expiration of half an hour was 62°·8, that of the atmosphere having risen to 62°·5, while in ten minutes after this observation, the atmosphere being 63°, that of the insect was 63°·4. The difference, therefore, in this specimen in a state of great excitement, was only ·4 of a degree, while, as we have

before seen, the difference in a Hymenopterous or Lepidopterous insect, in the perfect state, and under precisely similar circumstances, would have amounted to at least eight or ten degrees. From these observations it is evident that the natural heat of the *Carabi* is exceedingly low, and that their external temperature is scarcely more than ·2 or ·3 of a degree above that of the medium in which they are living; and although the respiration of these insects is higher than might at first be supposed from the small amount of their external temperature, yet they have the power of bearing the privation of oxygen for a very long time, and also of supporting the presence of some noxious gases; while they often reside in the coldest, dampest, and most unaerated situations. It was a specimen of this species that I once kept for several hours in hydrogen, and at the end of the observation found that it had expired a considerable quantity of carbonic acid gas during its confinement.

Blaps Mortisaga, LINN.

June 26, 1834.—The temperature of this species (which is truly a nocturnal one,) appears to be lower even than that of the *Carabus*. I placed two specimens in a phial, the temperature of which, and of the surrounding atmosphere, was 71°; but the thermometer was raised only ·1 of a degree, even after the insects had been for a considerable time in a state of activity. Two more specimens were then added, and the four insects were in a state of great activity for five minutes, when the temperature of the phial was only 71°·1, that of the insects themselves 71°·4, a difference of only ·4 of a degree above the medium in which they were confined. Thus the amount of power of developing heat in the *Blaps*, as in the *Carabus*, corresponds with the capability of supporting existence in a noxious medium, and also with its power of sustaining life during long abstinence. The *Blaps* will live for several minutes in a mixture of the most noxious gases, carbonic and even nitrous acid gas. I have confined one of this species in nitrous acid gas for three minutes, and it recovered in a quarter of an hour after being again exposed to the atmosphere. Another specimen was confined in nitrous acid gas for fifteen or sixteen minutes, and although it did not give any indications of recovering after being again exposed to the atmosphere for more than an hour, yet on my beginning to dissect the specimen, and after I had removed the whole under surface of the abdomen it began to recover, and in less than four minutes was so completely restored as to be able to walk about with nearly its usual speed. I have also confined other specimens in hydrogen for several hours, during which time they evolved a considerable quantity of carbonic acid gas, and did not appear to be at all inconvenienced by the medium in which they were placed. The low amount of heat in the species corresponds also with its power of going without food. One of this species is stated to have lived three years in confinement without food, and I have myself kept several individuals of this species about nine months fasting; it must be remarked, however, that this was during the winter months, from the latter part of autumn to the following spring, and may derive some

explanation from what is now known with regard to the condition of insects during the season of hybernation. Yet I have also kept this insect nearly three months without food during the summer, the season of activity, but it has generally died at the expiration of that period.

These observations on different species will sufficiently show the great difference which exists between volant and creeping insects, in the power which they possess of generating heat, while, comparing all the physiological conditions of the species with each other, they seem to point to the source or cause of the development of heat. Thus the amount of heat is found to approach very nearly in volant Coleoptera to the amount in Hymenoptera. In both these tribes of insects the organs of respiration are of large extent, and the quantity and activity of respiration in both are great, while the quantity of heat developed appears to be in proportion to the quantity of respiration. Further, these observations lead to the conclusion that some of the volant Coleoptera (*Melolonthæ*) have a higher temperature, even in a quiescent state, than some of the terrestrial Coleoptera in a state of moderate activity, while the amount is increased in a much greater degree in volant insects in a state of activity, than in those Coleoptera which live entirely on the ground. It also appears that the temperature of *Crepuscular* insects, *Melolonthæ*, *Sphinges*, &c. is lower than that of the diurnal Hymenoptera, and this we might naturally expect would be the case, *Crepuscular* insects having, compared with their size, a lower degree of respiration than Hymenopterous insects, nearly all of which are diurnal species, and bear the privation of atmospheric air with greater difficulty than any other tribes.

Table IV.

A Table exhibiting the Temperature of Insects of different Species under various circumstances, and in their different states, compared with the Temperature of the Atmosphere at the time of making the observation.

Division 1. Volant Insects. (*a.*) Diurnal Species.

No. of Exp.	Order.	Species and state.	Period of observation.	No. of Specimens.	Atmosphere.	Insect.	Difference.	Remarks.
1	Hymenoptera, 1834.	Bombus terrestris, perfect.	June 7. A.M.	1	66·9°	73·4°	6·5°	In each of these observations, which were all made within two or three hours of the insects being captured, the individuals were in a state of great excitement, excepting only *Bombus lapidarius*, which is a species that appears to be less readily excited than the others.
2	Hymenoptera, 1834.	Bombus terrestris, perfect.	A.M.	5	66·9	76·2	9·3	
3	Hymenoptera, 1834.	Bombus terrestris, perfect.	A.M.	1	66·9	73·4	6·5	
4	Hymenoptera, 1834.	Bombus terrestris, perfect.	A.M.	5	69·4	76·2	6·8	
5	Hymenoptera, 1834.	Bombus terrestris, perfect.	9. A.M. 12	1	68	77·5	9·5	
6	Hymenoptera, 1834.	Bombus lapidarius, perfect.	A.M. 12	1	68	71·5	3·5	
7	Hymenoptera, 1834.	Bombus muscorum, perfect.	A.M. 12	1	68	72·2	4·2	
8	Hymenoptera, 1834.	Bombus Jonella, perfect.	P.M. 6	1	68·9	74·7	5·8	
9	Hymenoptera, 1834.	Bombus Jonella, perfect.	P.M. 6	1	68·9	74·7	5·8	
10	Hymenoptera, 1834.	Bombus Jonella, perfect.	P.M. 6	1	69	75·4	6·4	
11	Hymenoptera, 1834.	Bombus Jonella, perfect.	P.M. 8½	1	68·2	71·3	3·1	
12	Hymenoptera, 1834.	Bombus terrestris, perfect.	29. P.M. 5	1	59	67·5	8·5	After great excitement.
13	Hymenoptera, 1834.	Bombus terrestris, perfect.	July 10. A.M. 12	......	70·5	77	6·5	Temperature of a nest of this species containing about thirty individuals and brood comb. The nest was contained in a box about seven inches square, and closed at night with a lid. Insects excited, but not in contact with the thermometer.
14	Hymenoptera, 1834.	Bombus terrestris, perfect.	P.M. 1½	......	70	80·2	10·2	
15	Hymenoptera, 1834.	Bombus terrestris, perfect.	P.M. 2½	......	70·5	80·4	9·9	
16	Hymenoptera, 1834.	Bombus terrestris, perfect.	Midnight 12½	......	68·5	80·3	11·8	
17	Hymenoptera, 1834.	Bombus terrestris, perfect.	July 11. A.M. 6	......	67	77·3	10·3	
18	Hymenoptera, 1834.	Bombus terrestris, perfect.	Midnight 12	......	67·5	78	10·5	
19	Hymenoptera, 1834.	Bombus terrestris, perfect.	July 12. A.M. 7	......	68·7	76·5	7·8	
20	Hymenoptera, 1834.	Bombus terrestris, perfect.	13. A.M. 8	1	71·8	84·1	12·3	Nurse Bees moderately excited. Nursing on a single cell, which contained a nymph that was developed from it about eight hours afterwards; during this incubating the Nurse Bee respired at the rate of 120 per minute.
21	Hymenoptera, 1834.	Bombus terrestris, perfect.	A.M. 8½	4	72·5	89·2	16·7	
22	Hymenoptera, 1834.	Bombus terrestris, perfect.	A.M. 8¾	7	72·5	90·2	17·7	
23	Hymenoptera, 1834.	Bombus terrestris, perfect.	A.M. 9	7	72·5	92·3	19·8	
24	Hymenoptera, 1834.	Bombus terrestris, perfect.	A.M. 9	1	72·5	91·5	19	
25	Hymenoptera, 1834.	Bombus terrestris, perfect.	A.M. 9½	7	72·7	91	18·3	
26	Hymenoptera, 1834.	Bombus terrestris, perfect.	A.M. 12	7	70·2	92·5	22·3	
27	Hymenoptera, 1834.	Bombus terrestris, perfect.	P.M. 1	7	72·2	85	12·8	
28	Hymenoptera, 1834.	Bombus terrestris, perfect.	P.M. 2½	4	72·5	94·1	21·6	
29	Hymenoptera, 1834.	Bombus terrestris, perfect.	P.M. 4	1	73·5	92	19·5	These observations show the great power which the Nurse Bees have of producing heat at will during the period of developing the nymphs. This evolution of heat is never produced when the insect is remaining perfectly quiet, but always occurs when the individual is much excited and respiring very rapidly. In those cases in the Table where a small degree of heat is indicated the insect was comparatively but little excited.
30	Hymenoptera, 1834.	Bombus terrestris, perfect.	P.M. 10	1	69	73·5	4·5	
31	Hymenoptera, 1834.	Bombus terrestris, perfect.	Midnight 12	1	68	83·2	15·2	
32	Hymenoptera, 1834.	Bombus terrestris, perfect.	14. P.M. 1½	1	69·5	89·4	19·9	
33	Hymenoptera, 1834.	Bombus terrestris, perfect.	P.M. 2	1	69·5	92·2	22·7	
34	Hymenoptera, 1834.	Bombus terrestris, perfect.	P.M. 3	1	69·5	91	21·5	
35	Hymenoptera, 1834.	Bombus terrestris, perfect.	P.M. 5	4	73·4	94·2	20·8	
36	Hymenoptera, 1834.	Bombus terrestris, perfect.	P.M. 11	1	68	83	15	
37	Hymenoptera, 1834.	Bombus terrestris, perfect.	15. A.M. 8½	1	68·2	88·2	20	
38	Hymenoptera, 1834.	Bombus terrestris, perfect.	A.M. 9½	1	71	91	20	
39	Hymenoptera, 1834.	Bombus terrestris, perfect.	A.M. 10½	1	72	93·2	21·2	
40	Hymenoptera, 1834.	Bombus terrestris, perfect.	P.M. 10	1	72·2	91·9	18·7	
41	Hymenoptera, 1834.	Bombus terrestris, perfect.	P.M. 11	1	71·6	85	13·4	

TABLE V.—A Table exhibiting the Temperature of Insects of different Species under various circumstances, and in their different states, compared with the Temperature of the Atmosphere.

Division 1. VOLANT INSECTS. (*b.*) Crepuscular Species.

No. of Exp.	Species.	Period of observation.	Bulk in cubic in.	Weight in grs.	Atmosphere.	Insect.	Diff.	Respirations.	Pulse.	Remarks.
1	Sphinx ligustri, A. (perfect male)	May 25. P.M. 2		34·2	64·6°	65°	·4°			At rest, but not sleeping.
2	Sphinx ligustri, A. (perfect male)	P.M. $2\frac{1}{4}$		34	64·6	65·2	·6			At rest for a quarter of an hour.
3	Sphinx ligustri, A. (perfect male)	P.M. $2\frac{1}{2}$			64·4	64·7	·3			Still at rest.
4	Sphinx ligustri, A. (perfect male)	P.M. $2\frac{3}{4}$		34	64·3	65	·7			A little disturbed.
5	Sphinx ligustri, A. (perfect male)	P.M. 3		34	64·2	65·4	1·2			Has been aroused, but is again at rest.
6	Sphinx ligustri, A. (perfect male)	P.M. 3			64·2	69	4·8			Violently vibrating its wings as in rapid flight.
7	Sphinx ligustri, A. (perfect male)	P.M. $3\frac{1}{4}$			64·2	69·4	5·2			Just taken its first flight since leaving the pupa state.
8	Sphinx ligustri, A. (perfect male)	P.M. $3\frac{1}{2}$			64·2	65·2	1			Has been sleeping since last observation.
9	Sphinx ligustri, A. (perfect male)	P.M. $3\frac{3}{4}$			64·3	64·7	·4			Still sleeping.
10	Sphinx ligustri, A. (perfect male)	P.M. $5\frac{1}{4}$			63·3	63·5	·2			Still sleeping.
11	Sphinx ligustri, A. (perfect male)	P.M. 6			63·4	63·7	·3			Still sleeping.
12	Sphinx ligustri, B. (perfect male)	31. A.M. 11			70	79	9		127	Has been in rapid flight around my room.
13	Sphinx ligustri, B. (perfect male)	June 1. A.M. $12\frac{1}{2}$			68	70	2		60	Active, but not excited.
14	Sphinx ligustri, B. (perfect male)	P.M. 1			68	72·6	4·6		151	Violently excited, as in rapid flight.
15	Sphinx ligustri, B. (perfect male)	P.M. 1′ 6″			68	72·3	4·3		110	At rest since the last observation.
16	Sphinx ligustri, B. (perfect male)	P.M. $1\frac{1}{2}$			68	70·6	2·6		50	Perfectly quiet.
17	Sphinx ligustri, B. (perfect male)	P.M. $1\frac{3}{4}$			68	69·8	1·8		45	Still at rest.
18	Sphinx ligustri, B. (perfect male)	P.M. $1\frac{3}{4}$			67·8	69·4	1·6		41	Still at rest.
19	Sphinx ligustri, B. (perfect male)	P.M. $2\frac{1}{4}$			67·6	69·6	2·0		53	A little aroused.
20	Sphinx ligustri, B. (perfect male)	P.M. $2\frac{3}{4}$			68·8	70	1·2		41	At rest.
21	Sphinx ligustri, B. (perfect male)	P.M. 3			69·5	75	5·5	42	139	Greatly excited in flight for a long time.
22	Sphinx ligustri, B. (perfect male)	P.M. $3\frac{1}{2}$			68·8	69·3	·5	18	49	Has been at rest since last observation.
23	Sphinx ligustri, B. (perfect male)	P.M. $4\frac{1}{4}$	·18	22·4	68·8	69	·2	15	42	Perfectly quiet.
24	Sphinx ligustri, C. (perfect female)	2. P.M. 6		39	67·5	73	5·5			Excited, three hours after coming from the pupa state.
25	Cerura vinula, D. (perfect)	Apr. 22. P.M. 4		24·6	63·7	63·9	·2			Half an hour after coming from the pupa state.
26	Cerura vinula, D. (perfect)	P.M. $4\frac{1}{2}$			63·5	63·8	·3			A little active.
27	Cerura vinula, D. (perfect)	P.M. $5\frac{1}{2}$		22·6	61·4	62	·6			Slightly disturbed.
28	Cerura vinula, D. (perfect)	P.M. $6\frac{1}{2}$		22·6	61·2	62·4	1·2			A little more excited.
29	Cerura vinula, D. (perfect)	23. A.M. $7\frac{1}{2}$			59·1	60·1	1			Quiet for several hours, but is now moving.
30	Cerura vinula, D. (perfect)	A.M. $7\frac{3}{4}$			59·1	61·6	2·5			Is becoming excited.
31	Cerura vinula, D. (perfect)	A.M. 8			59	62·7	3·7			Considerably excited.
32	Cerura vinula, D. (perfect)	A.M. 10			58	60·2	2·2			Has been quiet for two hours, is now excited.
33	Cerura vinula, D. (perfect)	P.M. $2\frac{1}{4}$			65·3	66·4	1·1			Quiet for some hours.
34	Cerura vinula, D. (perfect)	P.M. 2′ 20″			65·3	70·3	5			Very much excited.
35	Cerura vinula, D. (perfect)	P.M. $2\frac{1}{2}$			65·3	72·9	6·6			Violently excited as in rapid flight.
36	Cerura vinula, E.	P.M. $2\frac{1}{2}$			65·3	65·6	·3			Sleeping many hours in the same box with No. 29 (D).
37	Cerura vinula, D.	P.M. $3\frac{1}{4}$			64·5	65	·5			Has been resting with its abdomen on the thermometer since last observation.
38	Cerura vinula, D.	P.M. 5			61	62·4	1·4			Has been disturbed, but is now quiet.
39	Cerura vinula, D.	P.M. $5\frac{1}{4}$			60·4	61·9	1·5			Quite at rest, temperature of the atmosphere sinking.
40	Cerura vinula, D.	P.M. $5\frac{1}{2}$			60·3	61·9	1·6			Slightly disturbed.
41	Cerura vinula, D.	P.M. $5\frac{3}{4}$			60·3	61·8	1·5			A little disturbed.
42	Cerura vinula, D.	P.M. 6			60·3	61·8	1·5			A little disturbed.
43	Cerura vinula, D.	P.M. $6\frac{1}{4}$		19·9	60·1	61·6	1·5			At rest.
44	Cerura vinula, D.	P.M. $6\frac{1}{2}$		19·9	59·4	65·3	5·9			Violently excited as in rapid flight.

Table VI.

A Table exhibiting the Temperature of Insects of different Species under various circumstances compared with the Temperature of the Atmosphere.

Division 1. Volant Insects. (*b.*) Crepuscular Species.

No. of Exp.	Order.	Species.	Period of Observation.	No. of Specimens.	Bulk in cubic ins.	Weight in grains.	Atmosphere.	Insect.	Difference.	Remarks.
			1835.				°	°	°	
45	Coleoptera.	Melolontha vulgaris, perf.	May 23 A.M. 7	1	......	......	61·3	63·3	2·	Male, quiet; internal temperature of body.
46	Coleoptera.	Melolontha vulgaris, perf.	A.M. 7½	6	......	......	61·3	61·5	·2	All the specimens perfectly quiet.
47	Coleoptera.	Melolontha vulgaris, perf.	A.M. 8	1	......	......	66	69·2	3·2	Quiet; internal temperature of body.
48	Coleoptera.	Melolontha vulgaris, perf.	No. 1. A.M. 8¼	1	......	......	64·5	69·3	4·8	Respiring quick, preparing for flight.
49	Coleoptera.	Melolontha vulgaris, perf.	1. A.M. 8¾	1	......	......	65·5	74·5	9·	Female. Respiration violent and long continued.
50	Coleoptera.	Melolontha vulgaris, perf.	No. 2. A.M. 9	1	......	......	65·5	74	8·5	Male. Under similar circumstances.
51	Coleoptera.	Melolontha vulgaris, perf.	No. 1. P.M. 6	1	......	......	64·1	66·3	2·2	Female; has been long at rest.
52	Coleoptera.	Melolontha vulgaris, perf.	No. 2. P.M. 6	1	......	......	64·1	69·1	5·	Male; respiring rapidly and trying to escape.
53	Coleoptera.	Melolontha vulgaris, perf.	No. 3. P.M. 7	1	......	......	62·5	62·6	·1	Female just taken from her natural haunts, in the open air in a state of perfect rest.
54	Coleoptera.	Mel. solstitialis, perf.......	June 27 A.M.	1	......	......	70·5	70·9	·4	Quiet.
55	Coleoptera.	Mel. solstitialis, perf.......	A.M.	5	......	......	70·5	71·9	1·4	Very active and perspiring profusely.
56	Coleoptera.	Mel. solstitialis, perf.......	A.M.	9	......	......	70·5	72·3	1·8	Very active.
57	Coleoptera.	Mel. solstitialis, perf.......	A.M.	9	......	......	71·3	74·5	3·2	Very much excited.
58	Coleoptera.	Mel. solstitialis, perf.......	A.M.	18	......	......	71·3	73·6	2·3	Quiet, becoming asphyxiated.
59	Coleoptera.	Coccinella 7-punctata......	July 9 A.M.	8	......	......	68·2	68·5	·3	The insect had been moderately active.
60	Coleoptera.	Coccinella 7-punctata......	A.M.	8	......	......	68·2	69	·8	Very active; had raised the atmosphere of the phial to 68°·5.
61	Coleoptera.	Lucanus cervus	A.M.	1	......	......	67	67·3	·3	Insect had been lying perfectly quiet.
62	Coleoptera.	Lucanus cervus	A.M. 9¼	1	......	......	66·9	67·4	·5	Perfectly quiet, but raised the temperature of the phial in ½ an hour to 67°·2.
63	Coleoptera.	Lucanus cervus	A.M. 10½	1	......	......	66·6	68·6	2·	A little active; temperature of the phial at 1¼ raised to 68°·5.
64	Coleoptera.	Lucanus cervus	A.M. 10¾	1	......	......	66·6	69·2	2·6	After great exertion.
65	Coleoptera.	Lucanus cervus	P.M. 4	1	......	......	71	71·5	·5	Insect has been lying quiet.

Division 2. Terrestrial Insects. (*a.*) Diurnal Species.

No. of Exp.	Order.	Species.	Period of Observation.	No. of Specimens.	Bulk in cubic ins.	Weight in grains.	Atmosphere.	Insect.	Difference.	Remarks.
1	Coleoptera.	Proscarabæus violaceus...	April 11 P.M. 3½	1	·04*	11	62·4	63	·6	A very small female, somewhat excited.
2	Coleoptera.	Proscarabæus violaceus...	P.M. 3¾	1	·04	11	64·3	65	·7	Still excited; has been fasting.
3	Coleoptera.	Proscarabæus violaceus...	22 P.M. 6	1	·04	10·8	61·2	62·3	1·1	Active; has been feeding in warmer atmosphere.
4	Coleoptera.	Proscarabæus violaceus...	P.M. 6¼	1	·04	10·8	60·4	61·7	1·3	Has been active.
5	Coleoptera.	Proscarabæus violaceus...	P.M. 6½	1	·04	10·8	60	61·2	1·2	A little excited.
6	Coleoptera.	Proscarabæus violaceus...	23 P.M. 7	1	·05	12·7	58·2	59·3	1·1	A little excited.
7	Coleoptera.	Proscarabæus vulgaris ...	May 1 P.M. 3	1	·09	21·5	60·2	62·9	2·7	Just after being captured; excited.
8	Coleoptera.	Proscarabæus vulgaris ...	P.M. 3½	1	·09	21·5	63·1	64·6	1·5	Is now more quiet.
9	Orthoptera.	Acrida viridissima	July 14 P.M. 3¼	1	......	......	74·7	75·4	·7	Female quiet, fasting for 2 days.
10	Orthoptera.	Acrida viridissima	P.M. 3½	1	......	......	74·7	75·8	1·1	A little excited.
11	Orthoptera.	Acrida viridissima	P.M. 3½	1	......	......	73	74·1	1·1	Insect confined one hour; quiet, but respiring irregularly and forcibly at 37 per minute: during this violent respiration at rest.
12	Orthoptera.	Acrida viridissima	P.M. 3½	1	......	......	74·9	76	1·1	
13	Orthoptera.	Acrida viridissima	15 A.M. 7	1	......	......	67·4	68	·6	Insect quiet.
14	Orthoptera.	Acrida viridissima	A.M. 11	1	......	......	72·7	73·6	·9	Insect a little active.
15	Orthoptera.	Acrida viridissima	16 A.M. 7	1	......	......	70	70·5	·5	A little excited; } has fasted for the last 48 hours.
16	Orthoptera.	Acrida viridissima	A.M. 7	1	......	......	70	70·8	·8	Very much excited; }
17	Coleoptera.	Staphylinus olens	April 23 P.M. 7	1	......	3·8	60·2	61·2	1·	Active.
18	Coleoptera.	S. erythropterus	18 P.M. ½	1	......	......	64·5	65·1	·6	Male specimen; active.
19	Coleoptera.	S. erythropterus	P.M. ½	1	......	......	65	65·6	·6	Male specimen; active.

(*b.*) Crepuscular Species.

No. of Exp.	Order.	Species.	Period of Observation.	No. of Specimens.	Bulk in cubic ins.	Weight in grains.	Atmosphere.	Insect.	Difference.	Remarks.
20	Coleoptera.	Carabus nemoralis	April 11 P.M. 3¼	1	·05	12·5	61·6	61·8	·2	Female; quiet.
21	Coleoptera.	Carabus nemoralis	P.M. 3¼	1	·05	12·5	62·5	62·8	·3	A little active.
22	Coleoptera.	Carabus nemoralis	P.M. 3¾	1	·05	12·5	63	63·4	·4	Very much excited.
23	Coleoptera.	Carabus monilis	June 18 A.M.	1	......	......	67·4	67·4	......	Insect was excited, but did not evolve perceptible heat; had fasted for 18 hours.
24	Coleoptera.	Carabus monilis	A.M.	2	......	......	67·4	67·6	·2	Active.
25	Coleoptera.	Carabus violaceus	A.M.	3	......	......	67·4	67·7	·3	In a state of great excitement.
26	Coleoptera.	Blaps Mortisaga	26 A.M.	2	......	......	71	71·1	·1	Very active.
27	Coleoptera.	Blaps Mortisaga	A.M.	4	......	......	71	71·3	·3	Still more active.

* In my Paper on the Respiration of Insects in the Philosophical Transactions, Part II. 1836, p. 552, Table I. the cubic bulk of *Carabus cancellatus*, Nos. 33 and 34, and of *Meloe violaceus*, No. 36, has been erroneously printed 0·4 instead of 0·04.

IV. *Temperature of Insects which live in Society.*

We pass now to those insects which live in society, all of which belong to that great division the Hymenoptera, which have been shown to possess the highest temperature and greatest amount of respiration. Naturalists hitherto have examined only two genera of this great division with reference to the subject of temperature of these insects in their dwellings. These are the *Apis Mellifica*, or common Honey Bee, and the society of Ants; and the existence of a higher temperature than that of the atmosphere in the other families has only been inferred. Those species unto which I have devoted particular attention are the *Bombus terrestris* and *Apis Mellifica.*

Bombus terrestris.—1. *Temperature of Nests under observation.*

During the summer of 1830, having obtained a colony of this species, with the original parent bee, from the neighbourhood of Richborough, near Sandwich, (which locality had before that time afforded me opportunity of observing the habits of other species of this interesting family of insects,) I removed it from its locality in the earth to my own residence, the distance of a mile, and placed it in a small insect breeding cage for the purpose of more closely watching the economy of this species. The bees at first were somewhat irritable, and of course were kept in close confinement, and were fed with moistened sugar; but within a day or two they became quite accustomed to their new residence, and I had ample opportunity of watching the economy of the nest. On the third day they were placed on a table in my sitting-room near the window, which remained open, and also the door of the cage, that the bees might go abroad and return at pleasure, which they did with as much regularity after the first day or two as if the nest had been placed in its proper locality in the earth. I had thus most ample opportunity of watching their habits. The nest consisted of from forty to fifty individuals, and it gave me great pleasure in being able to confirm many of the statements made respecting these insects by HUBER. During the time the bees were in my possession, a period of nearly three weeks, I observed upon introducing a thermometer among them, that the temperature of the nest varied at different times, and was considerably higher when they were in a state of excitement; but the circumstance did not then attract my particular attention. In the summer of 1834, while engaged with the observations before detailed, I determined to repeat the observation which I then remembered having made in 1830; and accordingly on the 10th of July 1834, having taken a nest of *Bombus terrestris* with brood comb, it was placed on a table near the window of my apartment, in a small box about eight inches square, and four deep, covered with green gauze, and after the first day's confinement the bees were allowed to go and return as on the former occasion. Soon after commencing my observation, I was interested in observing that the bees were at first greatly affected and agitated by the slightest noise, such as the removal of a chair, or one's footsteps about the room, or the passing of carriages along the road, which was at least thirty feet distant from the window of the apartment; but they were not in

the slightest degree affected by persons talking loudly in the room, while a gentle tap with one's finger on the table put them immediately into a state of the greatest agitation. Hence during the observations it was necessary to be cautious, and not disturb the bees when wishing to take the temperature of the nest. The bees, however, in the course of a day or two became accustomed to their situation, and were not disturbed by slight noises or vibrations; and I was then enabled to take their temperature under all circumstances. The observations were commenced at 12 A.M., July 10, about two hours after the bees were placed in the box. The temperature of the atmosphere was then 70°·5 FAHR., that of the box and nest 73°; but when they became excited it soon rose to 77° but gradually subsided again to 73° as the bees became quiet. The thermometer was introduced very carefully under the gauze covering, and was not allowed to touch the bodies of the bees in this and the subsequent observations. At $1\frac{1}{2}$ P.M., the insects having remained at rest for more than a quarter of an hour, atmosphere 70°, the thermometer, introduced as before, rose to 75°, and in a few minutes afterwards, when the bees had become much excited, to 80°·2, a difference of 10°·2 between the temperature of the atmosphere and that of the box; and when the body of a bee touched the bulb of the thermometer, even but for an instant, the mercury immediately rose at least a degree on the scale. At $2\frac{1}{2}$, atmosphere 70°·5, bees quiet, atmosphere of the box 76°; but when they became much excited it rose in four minutes to 80°·4. At $12\frac{1}{2}$ midnight, atmosphere 68°·5, interior of the box was 73°, the bees having been quiet during the previous nine hours; but when they became greatly excited it rose to 80°·3, a difference of 11°·8. At 6 o'clock on the following morning, July 11, atmosphere 67°, the interior of the box was 71°, but when the bees became much excited it rose to 77°·3. At $12\frac{1}{2}$ midnight, atmosphere 67°·5, box with bees at rest 73°, when agitated 78°. At 7 A.M., July 13, the box in which the bees were confined had remained closed during the night, which had been perfectly calm and still, and at the time of making the present observation there was not a breath of wind stirring; indeed the air was suffocatingly calm, and its temperature 68°·7; when the thermometer was carefully introduced under the lid of the box the mercury rose to 72°, which was the temperature of the interior of the box around the nest, but when the thermometer was placed in the nest itself the temperature stood at 76°·5.

2. *Nest of Bombus in its natural haunts.*

Having proceeded thus far with my observations on the temperature of the nest, removed from its proper locality in the earth for the purpose of experiment, it became a matter of interest to endeavour to ascertain its temperature while undisturbed in its natural haunts. Having at length discovered the nest of a species of Bombus nearly allied to *Bombus terrestris* situated in a shaded chalk bank near the ground, and about eight inches from the surface, at 10 A.M.,—the temperature of the atmosphere in the shade four feet from the ground being 68°·7, while that of the exterior of the chalk bank in which the nest was situated, and near the entrance to it was 66°,—I very carefully

introduced a small thermometer without disturbing the inmates, and found that the temperature of the interior of the nest was 83°, but in a few minutes it rose to 85°; it was thus evident that the temperature of the nest upon which I had made the preceding observations was at about its average temperature in its natural haunts.

3. *Nurse Bees.—Voluntary Power of generating Heat.*

The above experiments on the nest of *Bombus terrestris* thus confirmed the results of my observations made a short time before on individual insects with regard to the rapid transmission of heat from the body of the animal when in a state of excitement, and also in a less degree when in a state of rest; but during the time I was engaged upon them they also afforded me a new and totally unexpected phenomenon, and one which is not a little interesting and important as regards its connection with the origin of animal heat;—it was the capability which these insects possess during the act of incubation on the cells which contain nymphs, of increasing their own temperature many degrees above that of the surrounding medium, of in fact a voluntary power of generating heat through means of respiration. HUBER has stated that there are certain individuals in the nests of the Humble Bees, and among the bees in a hive, which at a particular season of the year are employed to impart warmth from their bodies to the young bees in the combs by brooding over them, and these he called Nurse Bees. It gives me great pleasure in being able to bear testimony to the correctness of his statement, particularly with regard to those in the nest of the Humble Bee, which I had ample opportunity of observing. These individuals are chiefly the young female bees, and at the period of the hatching of nymphs they seem to be occupied almost solely in increasing the heat of the nest and communicating warmth to the nymphs in the cells by crowding upon them and clinging to them very closely, during which time they respire very rapidly, and evidently are much excited. These bees begin to crowd upon the cells of the nymphs about ten or twelve hours before the nymph makes its appearance as a perfect bee. The incubation during this period is very assiduously persevered in by the Nurse Bee, who scarcely leaves the cell for a single minute; when one bee has left another in general takes its place: previously to this period the incubation on the cell is performed only occasionally, but becomes more constantly attended to the nearer the hour of development. The manner in which the bee performs its office is by fixing itself upon the cell of the nymph, and beginning at first to respire very gradually; in a short time its respiration becomes more and more frequent, until it sometimes respires at the rate of 120 or 130 in a minute. I have seen a bee upon the combs perseveringly continue to respire at this rate for eight or ten hours, at the expiration of which time its body has become of a very high temperature, and on attentive observation the insect is often found in a state of great perspiration; when this is the case the bee generally discontinues her office for a time, and another individual will sometimes take her place. Very frequently the Nurse Bee respires with much less rapidity, and

remains many hours on the cells. The very high temperature unto which the insects are able to raise their own bodies, and the cells upon which they are incubating at this period, will be best shown by detailing the continued observations on the nest.

At 8 A.M., July 13, when the temperature of the atmosphere was 71°·8, and the temperature of the interior of the box around the nest 72°·5, I inserted the bulb of a fine thermometer very carefully between the abdomen of several bees and the cells upon which they were incubating, and which contained nymphs, and found the body of a single nursing bee was 84°·1, while the exterior of some cells that contained nymphs, but which were not covered, was 76·5. At 8½ the temperature of the outside of the waxen cover, or top of the nest, was 77°·7, and that of the atmosphere 72°·5, while the interior of the nest, where the bulb of the thermometer was introduced among four bees which were nursing upon the cells, was 89°·2. At 8¾, atmosphere as before, when the thermometer was introduced among seven nursing bees at the same spot, three of which were large females, and the others males, which also assist in the process of incubating, the mercury of the thermometer rose to 90°·2 FAHR. At 9 A.M., atmosphere still 72°·5, the temperature of the same bees still incubating was 92°·3, and of others incubating in another part of the same nest 91°·5; at 9½, atmosphere 72°·7, that of the bees still nursing was 91°. At 12 A.M. the observations were resumed: in the interval between the last observation and the present time there had been a gentle shower with light wind, and the atmosphere had sunk to 70°·2; the temperature of the Nurse Bees on the cell was now 92°·5. The thermometer was raised to this height within about ten minutes, and was maintained at that standard as long as the bulb of the instrument was allowed to remain in contact with the bodies of the insects, while the temperature of some of the adjoining cells beneath the same cover, but which were not covered by the bees, was maintained at only 80°·2. Within a quarter of an hour after these observations were made three large female bees were hatched from the cells upon which the seven bees had been incubating; the temperature of the atmosphere was then 72°·2, while that of the Nurse Bees, which had now desisted from incubating, and consequently were respiring less rapidly, had sunk to 85°. It was thus evident that the greatest amount of heat is generated by the Nurse Bees just before the young bees are liberated from the combs, at which period they require the greatest amount of invigorating heat. It is at this period also, as before noticed, that the young bee is most susceptible of diminished temperature; it is then exceedingly sleek, soft, and covered with moisture; perspires profusely, and is highly sensitive of the slightest current of air. It crowds eagerly among the combs and among the other bees, and everywhere where there is the greatest warmth. In the course of a few hours it becomes a little stronger, and is less sensitive, and better able to bear a diminished temperature. It then moves about with less circumspection, and its wings, which at first are soft and weak, and bent upon its trunk, become plain and straight. When the young bee first leaves its cell it is entirely of a whitish or pale grey colour, but within half an hour the black markings on the thorax become very distinct,

although they retain a tinge of grey colour for a much longer period; the yellow bands on the body and thorax are at first quite white, and it is not until an hour or two has elapsed that the principal yellow band on the thorax begins at length to gain colour, while it is several hours before the yellow bands acquire their full shade or degree of colour. During all this time the bee continues in an enfeebled state and takes no part in the business of the nest, but seeks for itself the warmest place among the combs, and it is not until sometime after it has acquired its proper degree of colour that it becomes active like the other bees, and is able to maintain its own proper temperature. It is thus evident, that the same principle which has been shown by Dr. Edwards to prevail with regard to the young of some of the mammiferous animals, that they are unable for a certain period after birth to generate and maintain within themselves a proper amount of temperature, but require to be cherished by external warmth, regulates also the development of the individuals of this family of Hymenopterous insects, from their pupa or nymph to their perfect state, and further tends to prove to us how universal and simple are the great laws which regulate the continuance of animal life. It is a curious fact that these bees do not incubate on the cells which contain only larvæ, the temperature of the atmosphere of the nest being sufficiently high for them in that condition; consequently the larvæ at an advanced period do not require so high a temperature before changing into nymphs as that which has just been shown to be required by the nymphs before coming forth as perfect insects. This will be shown in some observations made on larvæ in the nest now under examination, at the same time with those just described, and also with others which were made on nymphs. The temperature of the atmosphere being 76°, some of the cells which were open and contained larvæ were exposed in the nest, and the Nurse Bees therefore covered them lightly with dried grass, of which the nest of this species of Bombus is usually composed; but when the temperature of the atmosphere a few hours afterwards had risen to 73°·5, most of the dried grass with which these cells had been covered was removed, and the larvæ were more exposed; the temperature of these cells and the larvæ being 77°·4, while that of the cell of a nymph, with the Nurse Bee upon it, in another part of the nest was 92°, and subsequently when four large females were nursing around it was 94°·1, the temperature of the atmosphere being still 72°·5.

When there are no longer any nymphs which are soon to be developed into perfect insects the necessity for generating a larger amount of heat is diminished, and the Nurse Bees remain in a state of quietude; the temperature of the nest is then much lower than when young bees are about to be produced. This was the case on the 14th of July; the atmosphere was then 69°, while that of the nest was in no part higher than 72°·5; and even when the bulb of the thermometer was in contact with the bodies of several of the bees, the mercury scarcely rose to 73°·5, while at 12 o'clock on the preceding night, when the atmosphere was 68°, and several young bees were soon to come forth, the temperature of the box was 70°·5, and that of some bees

very moderately excited in the act of nursing 83°·2. It is not only at the moment when the young bee is about to come forth that the Nurse Bees produce a larger amount of heat; they keep up the heat to a considerable amount for some time after the young bee is developed. At $1\frac{1}{2}$ P.M., July 14, the bees were again incubating, the atmosphere 69°·5; the cells immediately beneath the cover of the nest were 89°·4. At 2 P.M., atmosphere 69°·5, the same cells were 92°·2, at which time most of the bees were crowding around this part of the comb, from which at 6 P.M. several young ones came forth. At 3 P.M., atmosphere 69°·5, the temperature of a single bee nursing on these cells was 91°. At 5 P.M., atmosphere 73°·4, atmosphere of the box was 75°·3, and that of four bees nursing 94°·2; while at 11 P.M., five hours after the young bees had been developed from this part of the comb and when no bees were present, the temperature at the very same spot was only 68°, exactly that of the open atmosphere; but in another part of the nest where the bees were again nursing it stood at 83°. It was in this way that the nurse bees constantly raised their own temperature and that of the cells upon which they were incubating whenever new bees were to be produced. In order to prove that this great amount of heat resulted directly from the temperature of the nursing bee, I placed the bulb of a thermometer on the back of a single individual that was nursing on the upper surface of a comb that was exposed to the temperature of the atmosphere, 71°·6, when it rose to and was maintained exposed as it was at 85°, while the temperature of the cell immediately after the bee had quitted it was 75°·3, and it was maintained at that temperature several minutes. In other observations I found that on one occasion, when the atmosphere was 72°·5, a single female bee while nursing upon a single cell, from which a perfect insect was developed about eight hours afterwards, had a temperature of 92°·3: the bulb of the thermometer in this instance was placed upon the cell immediately beneath the abdomen of the bee, which was respiring at the rate of 120 per minute. In another observation, when the temperature of the atmosphere was still the same, 72°·5, a single bee while nursing had a temperature of 94°·5, but a little while afterwards when the atmosphere was 72°·7 it had subsided to 91°.

These facts distinctly prove that bees have a voluntary power of evolving heat, while it seems only fair to conclude, on comparing the facts, that the quantity of heat produced in a given time and space, has relation to the number of respirations performed by the individual; and from the quantity of atmospheric air consumed, and of carbonic acid gas evolved, that animal heat is greatly and perhaps almost entirely dependent upon the chemical changes which take place in the air respired.

Temperature of the Hive Bee, Apis mellifica, LINN., *during the Winter.*

The many curious facts connected with the production of heat in the Humble Bee and other insects, naturally disposed me to wish to extend my inquiries to the ascertainment of that of the inhabitants of the hive, and fortunately circumstances enabled me to carry my wishes into execution, and commence my observations in the summer

of 1835. They were continued almost uninterruptedly until the spring of the present year. I had long doubted the statements of naturalists that the Hive Bee does not hybernate, but maintains a very high temperature in its dwelling throughout the whole winter. This statement is so at variance with everything that is known with regard to the habits of insects in this country, especially those of the same class, the Humble Bees, that were it really the case it could not fail to be looked upon as quite anomalous in the economy of British insects. SWAMMERDAM, REAUMUR, and HUBER were all of opinion that the Hive Bee does not at all enter into a state of hybernation, but continues active during the winter. HUBER states expressly*, that so far from bees becoming torpid in winter, the temperature of a populous hive ranges from 86° to 88° FAHR. when the thermometer in the open air is several degrees below freezing. But these authors have been deceived with regard to the real fact. The Hive Bee certainly does not become *torpid*, but if entirely undisturbed it passes into that condition in which its temperature of body and quantity of respiration are very greatly diminished;—a state of deep sleep in the combs, but a sleep which, so far from being continued at a very low atmospheric temperature, then becomes broken, and is only continued at a moderate temperature. It is true that when the hive is disturbed in the winter, and it becomes so very readily, its temperature is soon raised to a great height. There can be no doubt but that this was the case in the observations made by the authors just noticed. They must necessarily have disturbed the bees when they introduced the thermometer to take the temperature of the hive, since, as I am about to prove, there are periods during the winter when the temperature of the hive is so greatly reduced, and the bees are so inactive, that the temperature is scarcely above that of the open atmosphere; and when the temperature of the air is increased rapidly, that of the hive is even below it for a short period, just as we saw in the observations on the temperature of larvæ during sleep; but if at that very period the hive become disturbed, its temperature is raised in the course of a few minutes by the excitement of the bees to a very great amount above that of the atmosphere, as shown in Table XVI. Nos. 204, 205, so that we may fairly conclude that HUBER and the other naturalists were deceived in their observations by arousing the bees while introducing the thermometer.

The observations detailed in the accompanying Tables on the hive were commenced in October, when only a very few bees venture abroad, and were continued with but few intermissions to the end of September in the following year, when the bees are becoming inactive, and the temperature of the hive is very much reduced. All my observations on the Hive Bee were confirmatory of the conclusions deduced from observations on other insects, and proved that this useful and interesting little species does not form an exception to the general rule.

From previous observations on the temperature of insects I had found that the

* New Observations on the Natural History of Bees, by F. HUBER. (Translation.) Third Edition. Edinburgh, 1821, p. 224.

amount of heat developed in a given time was in proportion to the quantity and activity of respiration, and that the temperature of each species of insect can only be increased to a certain extent above the temperature of the medium in which it is living, and that when it has arrived at that point, whatever it happens to be, a copious cutaneous transpiration takes place; and if the temperature be still increased, the body of the insect becomes bathed in perspiration, and its temperature is immediately begun to be reduced. Now the degree unto which the temperature of insects may be increased above that of the medium in which they are living, varies in the different species as well as in the different genera of insects; each species has a certain standard of its own, beyond which its increase of temperature cannot be carried. In some insects, as in the Hive Bee, this may perhaps amount to from fifteen to twenty degrees, while in others it perhaps scarcely exceeds one or two degrees above the temperature of the surrounding medium. Besides this, it has been found that insects have a power of generating heat when confined in a given space, and that this power is in proportion to the activity of respiration. I have had numerous proofs of this fact in my observations on the varying temperature of the hive.

My experiments on the hive were conducted in the following manner: a common straw hive was placed with its entrance hole in the direction of another wooden hive, which was standing beside it in a bee-house, which was so constructed that the whole of the back part of the house could be removed or closed at pleasure. The proper entrance for the bees at the front of the bee-house was directly into the wooden hive, from the side of which there was a little covered communication with the entrance hole of the straw hive, to serve as a passage for the bees and a connection between the wooden and straw hive. The object of this was to prevent any sudden effect upon the temperature of the hive by changes which might occur in the temperature of the air without. The interior of the straw hive was thus subjected as little as possible to the variations in the open atmosphere, since the bees were obliged to pass through the empty wooden hive to its entrance hole before they could reach the open air. In order to make the experiment with the greatest accuracy, it was necessary that the bees should never be disturbed while making an observation, and therefore a small crow-quill sized thermometer, with a long free bulb, was passed through a hole just large enough to admit it in the top of the straw hive, about eight inches from the centre, and retained there during the whole of my subsequent observations without being removed or touched. The bees at first seemed a little inconvenienced by its presence, but within two or three days they became accustomed to it, and, as I had reason to believe, removed the comb and wax from around it, so that the bulb of the instrument was remaining about an inch within the free space of the hive, and the observations were then made at intervals, and with the greatest accuracy. The temperature of the atmosphere was taken with a thermometer of similar size and construction to the one used for the hive, and the two had been carefully compared before the first was passed into the hive. It was thus only necessary to notice from

time to time the rise and fall of each thermometer, and to note the difference between them, the temperature of the air being of course taken in the immediate vicinity of the bee-house. By this course of observation it was found that the temperature of the hive, when the bees are in a state of repose, varies with that of the atmosphere, but that the change within the hive is never so rapid as in the atmosphere, unless the bees have been disturbed. When the temperature of the atmosphere has risen very suddenly, I have found it exceed that of the hive by one or two degrees, as in Table XVI. No. 173, provided the bees continue in a state of entire rest; but if, on the contrary, the temperature of the atmosphere be suddenly diminished, that of the hive will subside also, but with much less rapidity. These facts are shown in the observations, Table XIV. Nos. 85 and 86, and also in all the observations on the tables which were made after one o'clock at noon on each day during the winter. Sometimes the thermometers became exactly equal to each other, as in No. 124. On the other hand, when the bees are in a state of activity and respiring quickly, the hive is even then affected in the winter months by great changes in the temperature of the external atmosphere, particularly if these changes occur late in the autumn or in the beginning of the winter season. But a change in the temperature of the atmosphere in summer does not so readily affect the temperature of the hive, because in summer, when the general temperature of the atmosphere ranges from 45° Fahr. upwards, the bees are always in a state of activity, and are not themselves so readily affected by sudden atmospheric changes of temperature; while in winter, when the temperature of the season ranges from 45° Fahr. downwards, the bees are very soon affected by diminished heat, and become disposed to pass into a state of hybernation, in which state, as we have before shown, scarcely any respiration takes place, and the temperature of the little animals sinks down, or very nearly so, to the temperature of the medium in which they are placed; and if there be a direct and free communication between that medium and the external atmosphere, even down to that also. The amount of temperature in the individual bee I have been led to believe, as before stated, is in general from 10° to 15° Fahr. above the temperature of the medium in which it is living, when in a state of moderate excitement, but it seems liable to be still further increased at certain periods, as in the hive a short time before swarming, and when clustering together on the alighting board of the hive a short time before the colony departs. In some observations made on the 5th and 27th of June, when the temperature of the atmosphere ranged only from 56° to 58° Fahr., the temperature of the hive was 96° and 98°, being at least 40° above that of the atmosphere. Now the occurrence of this amazingly high temperature at these periods is readily explained by what we have learned of the habits of bees in incubating on the combs, and voluntarily increasing their heat, by means of respiration, before the new bees come forth, that being the season in which the population of the hive is perhaps doubled within a very few days. A similar explanation is also afforded to us, i. e. the excitement of the insects, and consequent greatly increased quantity and activity

of their respiration,—of the surprising amount of temperature that may suddenly be developed in the hive, even in the midst of winter, when the bees are disturbed, as in the observations 190, 193, 195, 205, 214, 221, and many others on these tables. I have found that be the insects ever so quietly at rest, and even passing into a state of hybernating sleep, and although the temperature of the atmosphere be very much reduced, as in the observations just noticed, and also in Nos. 52, 134, 137, and 139, yet by exciting and arousing them, by gently tapping and shaking the hive, the bees are immediately put into a state of great agitation, and in less than ten or fifteen minutes the mercury will be raised on the scale of the thermometer upwards of 30° FAHR. above the temperature of the hive immediately preceding the experiment, when the bees were quiet, although the temperature of the atmosphere may scarcely exceed 35° FAHR., and although the temperature of the hive itself had previously been not more than 6° above that of the atmosphere. But this is not the greatest difference I have observed between the temperature of the excited hive and that of the atmosphere. It may appear surprising that any part of a well-peopled hive should at any time have a temperature lower than that of freezing, 32° FAHR., yet I have occasionally found this to be the case both during the last winter, 1836–37, and once in the preceding of 1835–36. In the latter instance it occurred but once, as indicated by the thermometer. This was in the hive upon which I have made the whole of my series of observations, and the hive at the time was well populated. It happened on the morning of January 2, 1836, at a quarter past seven, just before sunrise, when there was a clear intense frost, and the thermometer stood at 17°·5 FAHR. The bees were perfectly quiet, and the thermometer which had been untouched since its first introduction into the hive stood at 30°, or only 12°·5 above that of the atmosphere. The bees were then aroused in the usual manner by tapping the exterior of the hive, and in sixteen minutes the mercury of the thermometer had risen to 70° FAHR., but I was unable to excite the hive sufficiently to increase the temperature beyond this standard. This was 52° FAHR. above that of the external atmosphere, and 40° FAHR. above the previous temperature of the hive at that spot; but this was only the apparent, and not the real temperature of the hive, and resulted from the great accumulation of excited bees in the immediate vicinity of the bulb of the thermometer, within the hive, because a second thermometer having been introduced at a corresponding part of the top of the hive, at about five inches' distance from the first, indicated a temperature in that part of only 45° FAHR. These observations were sufficient to prove the incorrectness of attempting to ascertain the temperature of a hive of bees by occasionally introducing a thermometer among them and taking the temperature of the bees when excited by its presence. This circumstance was not lost sight of in my subsequent observations. At 12 A.M. on the same day the temperature of the atmosphere had risen to 30°·7 FAHR., while that of the hive, as indicated by the first thermometer, had subsided to 46° FAHR., and the bees within had become perfectly quiet. On the 5th of January at 1 P.M., the temperature of the atmosphere having risen to 50° FAHR.,

that of the hive stood only at 55° FAHR., while the bees aroused by the suddenly increased temperature of the atmosphere were becoming active; and when the hive was again excited by tapping it for a few minutes, the thermometer rose to 82°·2, a difference of 32° above that of the atmosphere, and 27° above that of the previous temperature of the hive, after which the temperature of the hive was maintained at 78° during several hours, while the bees continued in a state of activity, the temperature of the atmosphere being then congenial to their habits, and equal to the average temperature of the month of April, when the hive is again becoming active. But these are not the greatest amounts of temperature observed in the hive on its becoming excited during winter. In a second straw hive, which was exposed like the usual cottage hives to the open air, I found the interior temperature, at 10 A.M., on the 2nd of February, after the hive had been disturbed by tapping on its exterior, raised to 102° FAHR., the temperature of the atmosphere being 34°·5, a difference of 67°·5, while the first hive, which had not been disturbed, was then 48°·5, a difference of only 14° FAHR. between it and the surrounding atmosphere.

Although the hive be very much disturbed and its temperature be greatly increased by exciting the bees during the middle of winter, it will soon become quiet, and its temperature be reduced again to within ten or twelve degrees of the temperature of the atmosphere within ten hours, as in the observations No. 205 and following, made on the 2nd of January.

When the temperature of the hive has been increased suddenly, during the earlier or latter part of the winter, which we have just seen is the case when the hive is disturbed, the sudden increase of heat in their dwelling becomes intolerable to the little inhabitants, and they immediately endeavour to reduce it by ventilation, provided the temperature of the external atmosphere be not too low to endanger them, by exposing themselves at the entrance of the hive. When the temperature of the atmosphere is at or near 40° FAHR., at the time when the hive is disturbed the heat soon becomes oppressive, and although the degree of excitement within the hive be very great, its temperature is quickly moderated by the assiduity of the bees. I have often been amused by observing them, after the hive has been disturbed for a short time, although but a few minutes before there was not a single bee on the alighting board, come hastily to the entrance of the hive, and having arranged themselves within three fourths of an inch of the doorway, begin to fan with their wings most laboriously, to occasion a current of cool air through the interior of the hive. This act is the more assiduously performed, when, as in the hive under observation, there is not a free communication between the interior of the hive and the open atmosphere. On one occasion, No. 138, when the temperature of the hive had been raised to about 70° FAHR., the external atmosphere being scarcely more than 40° FAHR., the bees at midday maintained the temperature of the hive steadily at 57° by this mode of ventilating, the hive still continuing excited.

Although the bee can bear the transition from a hot to a cool atmosphere without

inconvenience during the spring when the temperature of the atmosphere is only 45° FAHR., yet it cannot bear a sudden transition from hot to cold in the winter, even when the temperature of the atmosphere is at 40° FAHR. I had a striking proof of this while making the above observation, No. 138, at 11 A.M., on the 14th of November. The hive had been for a considerable time in a state of excitement, and its apparent temperature was raised to nearly 70°, while a great many bees were ventilating at the entrance, and others flew abroad into the open air while the sun was shining, but they very soon returned to the hive again. Shortly after this I found one individual lying within the entrance of the wooden hive apparently dead. On exposing it for a few minutes to the sun it began to revive, and was completely recovered, and able to fly again to the entrance of the hive, in six minutes. A thermometer placed close to the torpid bee in the sun rose only to 53°·5 FAHR. It was thus shown that the bee cannot bear a sudden transition in winter from a high to a low temperature, yet it will be seen by the Tables at Nos. 116 and 133, that the bees were active when the temperature of the hive was not higher than 43°, that of the atmosphere being 35° FAHR., so that it is not until the medium in which the bees are residing is below 40°, that the insects begin to pass into a state of repose.

From a gradually increased temperature through the months of March and April, the hive acquires its maximum amount of temperature in the months of May and June, the periods of the greatest activity, and when the largest proportion of young bees is produced. We are now aware of the circumstances connected with the great amount of temperature in the hive at this season, and of the power which the bees themselves possess of increasing it at pleasure, or as the necessity for imparting it to the young may demand. These facts will explain a circumstance connected with the temperature of the hive, which without a previous knowledge of them might have been of difficult solution. It is the circumstance before alluded to of one part of the hive being of a higher temperature than another. This is the case in the hive even when the bees are not in a state of excitement. I had been led to the observation of this fact during the winter when making experiments on the bees in a state of excitement. Being anxious to know whether this was also the case in the spring and summer, I introduced another thermometer through the top of the straw hive, at the same distance from the centre, but on the side opposite to the one previously inserted. This was on the evening of the 12th of May, when the temperature of the atmosphere was 58° FAHR. The instrument on passing through the top of the hive was plunged into a cell of honey, and the mercury rose to 78° FAHR., which of course indicated the real temperature at that time of the honey and interior of the hive. The mercury in the first or original thermometer was very quickly raised to 90° FAHR. in consequence of the excitement of the bees within the hive, but shortly afterwards sunk to 84°. During this time the temperature of the opposite side of the hive, as indicated by the newly introduced thermometer, rose to and remained at 79° FAHR. Here then we have a clear proof that the sudden increase of temperature when a thermometer

is passed into the hive arises from the bees flocking around it, and it is also a proof that the natural temperature of these insects in a state of excitement may be raised to 20° FAHR. above that of the medium in which they are living, as shown in the observations on the Humble Bees. But this variation in the amount of temperature in different parts of the hive does not very much affect our means of judging of the average amount of the temperature of the hive at different periods when the thermometer remains entirely undisturbed, because it is found that when the temperature of the air is examined at about the same hour of the day, on two or more successive days, and all other circumstances being nearly the same, there will be but little variation in the average amount of temperature; so that we find the temperature of the hive, at the period of swarming, amounts to about 96° FAHR., while in the month of August it is seldom more than 80° FAHR., or perhaps 86°, even in the middle of the day, when the temperature of the atmosphere is often more than 78° FAHR. The cause of this difference between the amount of heat in the hive at this period and in the time of swarming is readily explained by reference to the facts connected with the production of heat. Less heat is in reality produced from the same volume of air consumed at the high temperature of 78° FAHR. than when the atmosphere is not more than 66° FAHR., as is often the case at the period of swarming, while in reality a far less volume of air is consumed in August than in May, because the bees are not in the same state of excitement. These facts readily account for the diminished temperature of the hive in the month of August, when the temperature of the atmosphere is in general higher than when the bees are most active.

During the period of swarming in 1836 I availed myself of the opportunity afforded me by the annular eclipse of the sun on the afternoon of the 15th of May, of watching the effect of diminished light and atmospheric temperature on the temperature of my hives, and the activity of their inhabitants, and found, as shown in the accompanying Table, that in proportion to the diminution of light the hives became quiet, and the temperature of the hives decreased until after the eclipse had passed its maximum, when as the light began again to increase, the activity of the hives became restored, and with it a considerable increase of heat.

Table VII.

Showing the variation in the Temperature of two Bee-hives compared with the Temperature of the atmosphere, as observed at Chichester, in Sussex, during the Annular Eclipse of the Sun on the afternoon of May 15, 1836.

No. of Exp.	Period of Observation.	Wind.	Weather, &c.	Atmosphere.	Hive No. 1.	Difference.	Hive No. 2.	Difference.	Remarks.
1	1836. May 15 A.M. 9 ′ ″	E.	Light wind, fine	67·7°	87°	18·3°	90·8°	23·1°	The bees have been clustering on the alighting board of the hive No. 2 for the last two days. The hive was now raised an inch to prevent swarming. In No. 1 there are no indications of swarming.
2	A.M. 10	E.	Light wind, fine	69·3	88·5	19·2	91·2	21·9	Hives calm, but not many bees abroad at work.
3	A.M. 12	E.	Calm, fine	71·5	93·6	22·1	90·7	19·2	Drones beginning to come abroad, no bees clustering.
4	P.M. 1½	N.	Light wind, fine	70	92·3	22·3	92	22	Abundance of bees around the hives, loud humming.
5	P.M. 2	N.N.W.	Light wind, fine	69·5	93·8	24·3	92·6	23·1	*Eclipse* has commenced, many drones abroad, bees greatly excited, flying around the hives.
6	P.M. 2¼	N.	Light wind, fine	69·3	92·3	23	93·3	24	Sunlight sensibly diminished, bees flocking home, very few go abroad.
7	P.M. 2½	N.	Calm, fine	67·5	93	25·5	93	25·5	Light still diminishing, scarcely a bee goes abroad.
8	P.M. 2¾	N.	Light wind, fine	63·5	91·5	28	92·5	29	Bees flocking home very rapidly, a few drones still abroad.
9	P.M. 3	N.	Light wind, fine	62	91·4	29·4	92·5	30·5	Light greatly diminished. *Geotrupes stercorarius* on the wing.
10	P.M. 3¼	N.	Light wind, fine	59	91·3	32·3	91·7	32·7	Light more obscured, hives quiet as in the evening, not a bee goes abroad; cocks crowing, town in the distance hazy, cool light wind, sky very clear.
11	P.M. 3 20	N.	Light wind, fine	57·5	87·5	30	90·8	33·3	Eclipse past its maximum, two bees have just come home again.
12	P.M. 3½	N.	Light wind, fine	58	87·2	29·2	91·4	33·4	Light sensibly increased, bees at the entrance of the hives and going abroad.
13	P.M. 3¾	N.	Less wind, fine..	57	85·5	28·5	90·7	33·7	Light still increasing, a few bees going abroad.
14	P.M. 3 50	N.	Less wind, fine..	57·5	85·7	28·2	90·9	33·4	Light much increased, bees still going abroad.
15	P.M. 4	N.	Less wind, fine..	57·8	87·1	29·3	91·4	33·6	Great increase of light; one bee has again returned with pollen.
16	P.M. 4¼	N.	Light wind, fine	58·5	87·5	29	90·5	32	Buzzing and activity in the hives increasing, bees departing.
17	P.M. 4 20	N.	Light wind, fine	58·7	86·7	28	89·8	31·1	Eclipse nearly terminated. But few bees abroad from No. 1.
18	P.M. 4½	N.	Calm, fine	59·5	87·5	28	89·9	30·4	Bees abroad from No. 2; eclipse terminated.
19	P.M. 5	N.	Calm, fine	61·5	86·5	25	90·3	28·8	Bees abroad from both hives; sky clear, very fine.

5. *Quantity of Free Heat in the Hive.*

Having endeavoured to ascertain the quantity of heat radiated from the bodies of single insects, and also from one species of bee in society, I was desirous of gaining some information respecting the quantity of free heat developed within the hive. The information derived from the thermometer inserted at the top of the hive was not sufficiently satisfactory, owing, as before stated, to the bulb being very frequently in contact with the bodies of the bees. I therefore made the following trial, both with the view of preventing the hive from swarming and of ascertaining the amount of heat radiated from the bodies of the bees. So late as the middle of June, the bees in the hive No. 1 had not swarmed, but appeared at that time as if about to do so. I therefore elevated the straw hive upon a wooden one, of about thirteen inches square, with a hole in the top of it about eight inches in diameter, which allowed of a very free communication with the straw hive. In the back of this wooden hive was a window for observing what occurred within, and the bees were obliged to pass and repass

through this wooden hive into the straw one above it. The hive being thus enlarged the bees did not swarm, but extended their combs from above downwards, and filled about one fourth of the interior with them. When they had become perfectly reconciled to their enlarged dwelling, a second thermometer, similar to the one introduced through the top of the straw hive, was passed through the side of the box, about three inches from the top, so that it might not touch the combs, from which it was distant about three or four inches, while its bulb extended about an inch into the interior of the box or wooden hive, and the mercury in the scale indicated from time to time the amount of free heat developed, uninfluenced by contact with the bodies of the bees. The original thermometer still indicated the apparent temperature at the top of the hive among the combs as before. The observations were begun upon the temperature of the wooden, or sub-hive, in the middle of July, when the bees had become more quiet than in the time of swarming, and when the internal temperature of the hive is diminishing. It was soon evident that the quantity of free heat developed under these circumstances in the lower part of the hive, where there were no bees congregating, was very considerable, and was often equal to, or even greater than that of the apparent heat of the top of the straw hive, where the bees were in a state of great activity. Sometimes the quantity of free heat at the bottom of the hive amounted to 12°·8 above that of the external atmosphere, when its temperature was 67°·2 Fahr., and when the temperature at the top of the hive was only 13°·1 above, even at 3 o'clock in the afternoon, at which time, in the month of July, the hive is generally hottest, from the numbers of bees which then return from the fields. Sometimes in the evening, when the temperature of the atmosphere is almost always sinking, the free heat in the lower part of the hive has amounted to 16°·8 above that of the external atmosphere at a temperature of 64°, while at the top of the hive the difference has been only 15°·7. In these cases the quantity of free heat developed must very far have exceeded the amount indicated by the thermometer, since the constant ventilation at the entrance of the hive admitted the cool air, and expelled the warm. In all the observations thus made care was taken to notice through the window at the back of the hive that there were no bees in contact with the bulb of the thermometer. This I had ample opportunities of doing, and found that when a bee alighted, even but for a moment, upon the bulb of the thermometer, the mercury rose in the scale at least one degree, and immediately subsided again when the bee had departed. This is a further proof that the temperature of a single bee in a state of activity is greatly above that of the medium in which it is living. But it may be urged, perhaps, that this proves very little, ana that the rising of the thermometer may occur from the circumstance that the bee which came into contact with the bulb had passed suddenly from the top, and heated part of the hive, to the lower and cooler, and that the transition of the insect from one part of the hive to the other was too sudden to have allowed of its being cooled down to the temperature of the lower medium before it touched the thermometer. That this was not the case is proved by the circumstance that the

same thing occurred both when the temperature of the medium in the upper hive was hotter, and also when it was cooler than that of the lower, and also when both were of exactly the same temperature. When the temperature of the external atmosphere is very high, as at 75° or upwards, the temperature of the interior of the hive, except at the period of swarming, is seldom more than a few degrees above it, either at the top or in the free space at the bottom of the hive. The bees then are generally very inactive, the heat becomes oppressive to them, and they leave the hive in great numbers.

6. *Mean Temperature during Summer and Winter.*

We have seen that the natural temperature of the hive during the winter is very much lower than during the summer, and that instead of the hive possessing a temperature of 86° FAHR., as stated by HUBER and other naturalists, it occasionally has a temperature even below 32° in very low states of the atmosphere, while its mean, or average amount in the months of January and December, when it appears to have the lowest temperature, may not exceed 45°. It is, however, regulated by the temperature of the external atmosphere, being in a very mild season higher, and in a very severe season lower than its usual mean. Without very much digressing from the subject of the present paper, I cannot help remarking that a knowledge of these facts may lead us to a practical application of them, in the preservation and culture of the valuable insect which is the subject of these remarks, the Honey-bee. It tends to confirm our opinion of the utility and prudence of the practice which is adopted by some cultivators, of placing their beehives during the winter in vaults, or other subterranean recesses, where they may remain in quietude, and in an almost uniform temperature, unaffected by the changes of the varying season.

From the accompanying tables of the mean temperature of the hive, throughout nearly the whole year, it is seen that the mean temperature in the different days and months constantly maintains in every hive a certain relative amount of difference above the temperature of the atmosphere, and that although occasionally interfered with by casual circumstances, it is gradually increased from its minimum, in the month of January, when probably it is not more than 6° or 7° above the atmosphere, to its maximum, in May and June, when it amounts to from 25° to 26° or 27° FAHR., after which it again declines through the months of July, August, and September, until in the months of October and November it amounts to no more than 8° or 9°, and the bees are again passing into a state of inactivity. The mean difference of the first half of the year from February to the end of May, or up to the period of swarming, greatly exceeds that of the second half, from June to the end of November; in the first half of the year the difference varies from 17° to 21° FAHR., while in the second half it is only from 10° to 8° FAHR. It will also be seen from one of the accompanying tables that the mean hourly difference of temperature is almost uniform at the same hour and day of the same month in different years, even when the observations are made in different states and temperatures of the atmosphere.

V. *Temperature of Insects as connected with the other Functions of Life.*

On reviewing all the circumstances connected with the temperature of insects, we cannot fail to observe the remarkable coincidence between the amount of heat produced, and the quantity of respiration in these animals, under all the circumstances of their existence. We have seen that whether sleeping or waking,—whether inactive or in a state of great excitement,—the quantity of heat evolved by an insect is always in proportion to the quantity and activity of its respiration. But there are other circumstances which also claim our attention. When the temperature is increased, the circulation of the fluids of the insect are also much accelerated, and there is a greater amount of gaseous expenditure from the surface of the body. On the other hand it is observed, that when the process of digestion is suspended, not only is there a less expenditure of gaseous and fæcal matter from the surface of the body and from the alimentary canal, but the power and velocity of the circulation, the quantity of heat, and the activity of the respiration of the insect are diminished. These circumstances are readily demonstrated by experiments on insects, and lead us to inquire what relation subsists between the great functions of life, and the production, and variations, of temperature in these "little miniatures of creation," and whether the temperature of their bodies depends mainly upon one or more of these functions, or upon the agency of that inexplicable source of all the voluntary energies of the animal,—the nervous system.

1. *Respiration.*

The circumstances which affect the respiration of insects have been particularly considered on a former occasion*. It was then seen that the contractions of the segments of the body in insects correspond with the acts of respiration in other animals, and that these are greatest during a state of activity, and less frequent during a state of repose. It is exceedingly difficult to determine the number of these respiratory motions, per minute, in the larva state, even of the large Lepidopterous insects, and to ascertain what relation they bear to the temperature, quantity of respiration, and rate of pulsation of the dorsal vessel; but from a great number of observations on the larva of the Sphinx in its fifth or last period, I am inclined to think that they are not so frequent as in the perfect insect. It has been suggested by some naturalists that since the progressive movements of the larva are mainly performed by means of the longitudinal contractions of the body, that these are concerned in the function of respiration, and this appears highly probable from the circumstances which take place when a larva is submerged in spirits of wine or other fluid for the purpose of destroying it. At first it does not appear to be incommoded by contact with the spirit, but as soon as it attempts to inspire it is immediately affected, and the four posterior segments contract, and the whole body becomes shortened, as in the act of forcible expiration,

* Philosophical Transactions, 1836, Part II. p. 547. *et seq.*

while strings of air bubbles issue from the spiracles, particularly from the posterior ones; an interval of a few moments succeeds, and then another contraction follows, and more air-bubbles issue forth; and this alternate contraction of the segments, and expiration of bubbles, takes place until the insect is completely asphyxiated, while its body becomes contracted both in length and diameter. From these circumstances it seems highly probable that the contraction of the longitudinal muscles of the body of the larva, during its progressive motions, are connected with the *expiratory* act of respiration of the insect, just as similar parts in the body and thorax of the perfect individual of the species are connected with the respiratory functions during the motions of flight. In every condition of the insect the number of respirations is in accordance with the activity of the animal, and with the quantity of air it deteriorates in a given time, and they are also in accordance with the amount of heat developed. Thus in the pupa state I have not observed more than three inspirations per minute, and these only when the pupa has been disturbed; and the number of these corresponds with the small amount of respiration, and the low power of generating heat in this condition. In the perfect insect of the same species, the Sphinx, when in a state of excitement after great exertion, TABLE V. No. 21, I have counted forty-two, but at the expiration of an hour and a quarter, No. 23, when the insect had become quiet, there has been only fifteen inspirations per minute. In the Hive Bee and Humble Bees, the number of respirations has amounted to from one hundred and ten to one hundred and twenty, when in a state of excitement, but when very moderately active, to no more than forty. The same, and even greater difference, is found in the Wild Bee, *Anthophora retusa*, STEPH., in which, in a state of violent excitement, the number of respirations once amounted to two hundred and forty in a minute*; while in the very same insect when first removed from its hybernaculum in the autumn, or in the spring of the year, and when it has a temperature only a little above that of the medium in which it has been living, it has scarcely more than two or three respirations in the same space of time. In the common Green Grasshopper, when moderately excited, TABLE VI. Nos. 11, 12, and after it had fasted during several hours, there were about thirty-seven or thirty-eight. In all these cases the number corresponds with the amount of respiration or quantity of air deteriorated.

2. *Velocity of the Circulation.*

But there is not merely an accordance between the activity of the insect, its quantity of respiration, and amount of heat developed, but also between these and the general rate of pulsation, or the circulation of the blood in its body. This therefore demands our particular attention.

When an insect is remaining perfectly at rest, its rate of pulsation, like its respiration and temperature, is greatly diminished. We are enabled to observe the pulsation of the heart, or dorsal vessel, both in the larva and perfect state of many insects,

* Philosophical Transactions, 1836, Part II. p. 550.

but in none better than in the large Moths and Sphinges. When an insect has remained for some time in a state of repose, both the power and rate of pulsation are greatly diminished, but are again increased immediately the insect awakes. The manner in which the pulsation takes place, as seen through the delicate skin of the larva of the Puss Moth, *Cerura vinula*, STEPH., appears to be as follows: at the moment the insect begins to awake there is a slight extension of the posterior segments of its body, followed immediately by a slight contraction of the same parts; and almost immediately afterwards there is an increased motion in the posterior part of the dorsal vessel, in the twelfth or penultimate segment, where the vessel is broadest, and as shown by CARUS and WAGNER, receives a current of blood which flows into it on either side. The contraction, or ventricular action of the vessel, commences first in this segment, and is gradually continued onwards through the chambers of the vessel in the preceding segments by a series of successive impulses, from behind forwards, communicated in succession by the valves in each chamber*, but which in the Cerura and Sphinx are not observed through the skin of the insect. These contractions force along the blood through the chambers of the heart in the ninth, eighth, seventh, sixth, and fifth segments with intermitted or pulsatory motion, so that while the middle and anterior chambers are contracting the posterior is again filling. The auricular, expanding, or receiving action of the vessel begins also in the twelfth segment, where, indeed, the greatest amount of blood seems to be received from the body, although it is also received by the other valves in the different segments. Immediately the posterior valve has impelled the blood onward to the next one, it begins again to expand. If the action of the vessel be carefully examined, the expansion and contractions of the chambers in the different segments in gradual succession from behind forwards, at every impulse, may be readily observed. Each pulsation of the vessel is, I think, divisible into three periods: first, the *auricular*, or filling, which is rather the longest; second, the *ventricular*; and thirdly, the *period of rest*, which is immediately subsequent to the ventricular, but is of rather shorter duration. From these causes the true arterial motion of the fluids through the thorax of the insect is later by one whole contraction of the vessel than in the posterior segment or division of the organ; and it is also evident, on watching the motions of the vessel, that the period of rest is longer in the anterior or aortal portion of the vessel, which passes through the thorax, than in the posterior or true dorso-abdominal. It has been shown in other parts of this paper that after the insect has arrived at its full size as a larva there is a gradual diminution in its quantity of respiration and temperature; and it is interesting to observe that this is coincident with a similar diminution both in its actual weight and in the pulsation of its dorsal vessel, and that the diminution continues until after the insect has changed to its pupa state, as shown in the accompanying Table.

* See BOWERBANK on Circulation of Insects, Entomological Mag. vol. i. p. 240.

Table VIII.

A Table exhibiting the Temperature, Pulsation, Weight, &c. of the Larva of *Sphinx ligustri* during its last or adult period, and their gradual and coincident diminution after the ninth and tenth days of that period.

No. of Exp.	Species.	Period of Observation. (h ′)	Atmosphere.	Insect.	Difference.	Pulsation.	Weight in Grains.	Fæces in Grains.	Increase in Grains.	Age.	Remarks.
1	Sphinx ligustri (larva) ...	1834. July 30. A.M. 8	70	......	......	...	....	......	......	....	Just entered its fifth and last skin.
2	Sphinx ligustri (larva) ...	P.M. 4	74·6	75·5	·9	...	15·1	......	......	8 hours	Quiet; has voided no fæces for 10½ hours.
3	Sphinx ligustri (larva) ...	31. P.M. 4	......	......	......	...	19·9	6	4·8	2 days	
4	Sphinx ligustri (larva) ...	Aug. 1. P.M. 4	......	......	......	...	27·4	......	7·5	3 days	Has voided no fæces.
5	Sphinx ligustri (larva) ...	2. P.M. 7	73·8	·2	·4	...	41·3	6·5	13·9	4 days	Sleeping.
6	Sphinx ligustri (larva) ...	3. P.M. 4 15	72·4	73·4	1·	50	56·6	8·6	15·3	5 days	Quiet.
7	Sphinx ligustri (larva) ...	4. P.M. 5	71·9	72·9	1·	50	69·1	19	13·5	6 days	Quiet, but not feeding.
8	Sphinx ligustri (larva) ...	P.M. 5 45	72·5	73·8	1·3	56	71·5	......	......	....	Active and feeding.
9	Sphinx ligustri (larva) ...	5. A.M. 9	71·3	72·6	1·3	51	77·5	11·4	6	7 days	Aroused and beginning to feed.
10	Sphinx ligustri (larva) ...	P.M. 8 30	69·9	71·1	1·2	51	85	10·8	7·5	....	Just aroused.
11	Sphinx ligustri (larva) ...	6. A.M. 7 30	71·1	72·3	1·2	50	90·5	16·9	5·5	8 days	Aroused; beginning to feed.
12	Sphinx ligustri (larva) ...	P.M. 5 30	70	71·2	1·2	47	93	12·5	3·5	....	Feeding.
13	Sphinx ligustri (larva) ...	7. A.M. 6	68·3	68·7	·4	36	98·8	14	5·8	9 days	Sleeping.
14	Sphinx ligustri (larva) ...	A.M. 6 15	68·4	69·3	·9	42	98·8	......	......	....	Aroused and beginning to feed.
15	Sphinx ligustri (larva) ...	P.M. 4 30	69·2	70·3	1·1	43	100·1	12·6	1·3	....	Quiet; feeding.
16	Sphinx ligustri (larva) ...	8. P.M. 3 30	72	72·9	·9	42	92·1	23	......	10 days	Very active; discoloured; refuses food.
17	Sphinx ligustri (larva) ...	P.M. 5 30	71·3	72·1	·8	40	91·9	......	......	....	Active; more discoloured; pulse laborious.
18	Sphinx ligustri (larva) ...	P.M. 6 30	71·5	72·3	·8	40	91·7	......	......	....	Very active; no food eaten.
19	Sphinx ligustri (larva) ...	P.M. 7 30	70·4	71·4	1·	40	91·5	......	......	....	Much excited; fasting; no fæces passed.
20	Sphinx ligustri (larva) ...	P.M. 10 30	68·3	69·1	·8	37	90	·9	......	....	Active; more discoloured; voided soft discoloured fæces.
21	Sphinx ligustri (larva) ...	9. A.M. 7 30	67·4	67·8	·4	24	88·7	......	......	11 days	Has slept during several hours.
22	Sphinx ligustri (larva) ...	A.M. 7 45	68·5	69·1	·6	28	88·6	......	......	....	Awaking; temperature of air rising rapidly.
23	Sphinx ligustri (larva) ...	P.M. 11 30	68·3	68·8	·5	29	80·3	......	......	....	In incessant action; about to enter the earth.

This difference in the velocity of the circulation at certain periods is an important circumstance as connected with the present subject,—the relation of the velocity of circulation to the temperature and respiration of the insect. For the purpose of ascertaining the rate of pulsation at different periods of the larva state with precision, I selected a healthy specimen of *Sphinx ligustri,* and commenced my observations upon it exactly seventy hours after it had left the ovum. At the moment of leaving the ovum it weighed only one eightieth part of a grain, but I was accidentally prevented from watching the rate of pulsation at that time. This individual was kept apart from other specimens from the moment it escaped from the egg until it changed into the pupa state. During this time, its weight, fæcal expenditure, rate of increase from the making of one observation to the making of another, were all carefully noted, as well as the velocity of the circulation at different periods of its growth. Unfortunately, however, I was then without my thermometers, which prevented me from observing the temperature of the insect, and thereby completing the examinations. From these observations it appeared that the rate of pulsation is greatest

during the first and second periods of the larva state, or before it has entered its third skin, and when its weight is no more at most than two thirds of a grain. From not knowing the temperature of the atmosphere at the period of making the observations on this insect in its second skin, I am doubtful whether the rate of pulsation be not in reality greatest during the earlier life of the larva, before it has thrown off its first skin, because this was really the case in all the observations, if we except only two which were made on the afternoon of the same day, when the larva was at about the age of two hundred and seventeen hours. These observations being excepted, it will be seen from Table IX. that the rate of pulsation is gradually diminished from the earliest period of the larva state until the insect has changed into a pupa,—that while the rate of pulsation within a few hours after the insect has left the egg varies from seventy-five to ninety, and in its second skin, or at an average age of about two hundred and forty hours, it is but very little lower, it becomes in its third reduced to an average of seventy-five, in its fourth to less than sixty, in the middle period of its fifth to a maximum of fifty-five, and the latter period of the same to scarcely more than thirty-two pulsations per minute. These are interesting facts as connected with the power which the insect possesses of generating heat. It is, as before stated, at about the middle period of its fifth state or condition as a larva, when it is feeding most voraciously, that the insect is able to generate the greatest amount of heat.

Although it will be seen from the additional facts about to be stated that both during sleeping and activity, when most vigorous as a larva, as also when passing into the enfeebled condition of a pupa, there is a coincident and correspondent activity or diminution in the rate of pulsation with the increase of motion, respiration, or digestion; yet the primary source of the development of heat is not dependent upon the velocity or rapidity of the circulation, since the period in which there is the greatest rapidity of circulation is that in which the larva is least able to generate and maintain its greatest amount of temperature. Another circumstance which tends greatly to prove that the amount of heat does not necessarily depend upon the rapidity of the circulation is the different rates of pulsation when the insect is placed in different temperatures, or when in different states of health in the same temperature. In the first case the rate of pulsation may be very considerably increased, while the amount of temperature remains nearly, or perhaps exactly the same. In the latter instance the temperature may continue exactly the same, but the rate of pulsation be diminished. Thus in two specimens of *Sphinx ligustri* which were both of the same age, and in similar conditions of activity, feeding in the same atmospheric temperature, when the observations were made upon both at the same time, the temperature of the insects was exactly the same, ·9 above that of the atmosphere, but the rate of pulsation in one specimen, which was perfectly healthy, was forty-one beats per minute; while in the other, which was unhealthy, it was only thirty-eight.

Table IX.

A Table showing the rate of Pulsation of the Dorsal Vessel at different periods of the Larva and Pupa state of the *Sphinx ligustri*, Linn.

No. of Exp.	Species.	Period of observation.	Pulsation.	Weight in grains.	Fæces in grains.	Increase.	Loss.	Age in days or hours.	Remarks.
		1835.							
1	Sphinx ligustri (larva)...	July 14 P.M. 2	......	1/80	......	......	......	1 day	Larva has just burst from the egg.
2	Sphinx ligustri (larva)...	15		......	......	......	......		
3	Sphinx ligustri (larva)...	16 P.M. 5	......	1/35	......	......	......	3 days, or 51	After leaving the egg.
4	Sphinx ligustri (larva)...	17 A.M. 12	85	1/25	......	......	......	4 days, or 70	
5	Sphinx ligustri (larva)...	18 P.M. 2	85	1/20	......	......	......	5 days, or 96	Quiet, but not sleeping.
6	Sphinx ligustri (larva)...	19 P.M. 2	90	1/15	......	......	......	6 days, or 120	A little excited.
7	Sphinx ligustri (larva)...	P.M. 4	75	1/15	......	......	......	 122	Has been perfectly at rest for an hour.
8	Sphinx ligustri (larva)...	20 P.M. 2	80	1/14	......	......	......	7 days, or 144	Sleeping.
9	Sphinx ligustri (larva)...	21 P.M. 2½	32	1/8	·04	......	......	8 days, or 168½	Sleeping, preparing for change.
10	Sphinx ligustri (larva)...	22 A.M. 12	......	......	......	......	......	9 days, or 190	Has just assumed its *second* skin.
11	Sphinx ligustri (larva)...	P.M. 3½	80	1/10	......	......	·02	.... 193½	Sleeping, but has not yet eaten.
12	Sphinx ligustri (larva)...	23 A.M. 7½	73	......	......	......	......	10 days, or 209½	Quiet, but not sleeping.
13	Sphinx ligustri (larva)...	P.M. 1	108	1/4	·05	......	......	 215	Sleeping.
14	Sphinx ligustri (larva)...	P.M. 3½	103	......	......	......	......	.... 217½	Quiet, but not sleeping.
15	Sphinx ligustri (larva)...	24 P.M. 3½	85	2/3	......	......	......	11 days, or 241½	Sleeping.
16	Sphinx ligustri (larva)...	25 A.M. 9½	87	......	......	......	......	12 days, or 259½	Sleeping, and preparing for change.
17	Sphinx ligustri (larva)...	26 A.M. 8	......	......	......	......	......	13 days, or 282	Has just assumed its *third* skin.
18	Sphinx ligustri (larva)...	A.M. 12	79	9/10	·25	......	......	 286	Sleeping.
19	Sphinx ligustri (larva)...	27	......	......	......	......	......	14 days	
20	Sphinx ligustri (larva)...	28 A.M. 7½	70	1·9	......	1·0	......	15 days, or 329½	Feeding, atmospheric temperature reduced.
21	Sphinx ligustri (larva)...	P.M. 1	50	2·3	......	·4	......	 335	Sleeping.
22	Sphinx ligustri (larva)...	29 A.M. 7½	50	......	......	......	......	16 days, or 353½	Quiet, but not sleeping.
23	Sphinx ligustri (larva)...	A.M. 10	36	3·5	·7	1·2	......	 356	Sleeping, preparing for change.
24	Sphinx ligustri (larva)...	30 P.M. 1	......	......	......	......	......	17 days, or 383	Has just assumed its *fourth* skin.
25	Sphinx ligustri (larva)...	P.M. 7½	44	3·5	·2	......	......	.... 389½	Sleeping, has fed a little.
26	Sphinx ligustri (larva)...	31 P.M. 6	56	5·9	1·4	2·4	......	18 days, or 412	Sleeping.
27	Sphinx ligustri (larva)...	Aug. 1 P.M. 3½	53	9·4	2·	3·5	......	19 days, or 433½	Sleeping.
28	Sphinx ligustri (larva)...	P.M. 9½	48	10·5	·5	1·1	......	.... 439½	Sleeping.
29	Sphinx ligustri (larva)...	2 A.M. 11¼	37	13·4	1·6	2·9	......	20 days, or 453¼	Sleeping.
30	Sphinx ligustri (larva)...	P.M. 3½	47	14·7	·7	1·3	......	.... 457½	Sleeping.
31	Sphinx ligustri (larva)...	P.M. 6½	52	15·1	·6	·4	......	.... 460½	Quiet, but not sleeping.
32	Sphinx ligustri (larva)...	3 A.M. 7	33	18·3	2·4	3·2	......	21 days, or 473	Sleeping.
33	Sphinx ligustri (larva)...	P.M. 1¾	43	19·7	1·1	1·4	......	.... 479¾	Sleeping.
34	Sphinx ligustri (larva)...	4 A.M. 12	29	......	......	......	......	22 days, or 502	Has been sleeping 12 hours for changing.
35	Sphinx ligustri (larva)...	5 P.M. 5	......	......	......	......	......	23 days, or 531	Has just assumed its *fifth* skin.
36	Sphinx ligustri (larva)...	P.M. 10½	34	17·1	·7	0	2·6	.... 536½	Sleeping.
37	Sphinx ligustri (larva)...	6 A.M. 12	39	19·7	1·6	2·6	......	24 days, or 550	Sleeping.
38	Sphinx ligustri (larva)...	7 A.M. 7½	38	27·7	5·	8·	......	25 days, or 569½	Sleeping, pulse irregular.
39	Sphinx ligustri (larva)...	P.M. 7¾	37	33·3	3·1	5·6	......	.... 581¾	Quiet.
40	Sphinx ligustri (larva)...	8 A.M. 8¾	41	40·2	3·8	6·9	......	26 days, or 594¾	Quiet, pulse full and quick.
41	Sphinx ligustri (larva)...	P.M. 1½	47	42·6	2·7	2·4	......	.... 599½	Feeding.
42	Sphinx ligustri (larva)...	P.M. 10	39	49·1	4·2	6·5	......	 620	Sleeping.
43	Sphinx ligustri (larva)...	9 A.M. 6½	28	54	5·	4·9	......	27 days, or 628½	Perfectly at rest, and sleeping.
44	Sphinx ligustri (larva)...	A.M. 11½	36	58·1	2·75	4·1	......	.... 633½	At rest.
45	Sphinx ligustri (larva)...	A.M. 12	55	59·1	0	1	......	 634	Feeding.
46	Sphinx ligustri (larva)...	P.M. 5½	43	63·6	5·6	4·5	......	.... 639½	Sleeping.
47	Sphinx ligustri (larva)...	10 A.M. 7	29	72·7	8·3	9·1	......	28 days, or 653	Sleeping.
48	Sphinx ligustri (larva)...	P.M. 1½	53	83·5	4·9	10·8	......	.... 659½	Sleeping.
49	Sphinx ligustri (larva)...	P.M. 7	46	86·7	8·9	3·2	......	 665	Sleeping.
50	Sphinx ligustri (larva)...	11 A.M. 7	29	90·2	13	3·5	......	29 days, or 677	Sleeping.
51	Sphinx ligustri (larva)...	P.M. 2½	50	102	8·7	11·8	......	.... 684½	Sleeping.
52	Sphinx ligustri (larva)...	P.M. 7½	45	106·6	9·6	4·6	......	.... 689½	Feeding.
53	Sphinx ligustri (larva)...	12 A.M. 7½	44	118·2	19·3	11·6	......	30 days, or 701½	Feeding.
54	Sphinx ligustri (larva)...	A.M. 12	52	117·4	18·7	0	·8	 706	Feeding.
55	Sphinx ligustri (larva)...	P.M. 1¼	52	116·7	2·2	0	·7	.... 707¼	Has been feeding during the last hour.
56	Sphinx ligustri (larva)...	P.M. 9½	47	123	13	6·3	......	.... 715½	Quiet.
57	Sphinx ligustri (larva)...	13 A.M. 6½	33	114·4	0	0	8·6	31 days, or 724½	Has escaped unfed during the night.
58	Sphinx ligustri (larva)...	P.M. 4	34	123·3	10·4	8·9	......	 734	Quiet.
59	Sphinx ligustri (larva)...	14 A.M. 7½	28	124·7	17·2	1·4	......	32 days, or 749½	Sleeping.
60	Sphinx ligustri (larva)...	P.M. 1¾	36	118·2	4·7	0	6·5	.... 755¾	Active, and discoloured for change.
61	Sphinx ligustri (larva)...	15 A.M. 9	34	100·1	0	0	18·1	33 days, or 775	Very active, preparing for change.
62	Sphinx ligustri (larva)...	A.M. 12½	31	97·2	0	0	2·9	.... 778½	Restless, discoloured.
63	Sphinx ligustri (larva)...	P.M. 5	26	......	......	......	......	 783	Just entered the earth for changing.
64	Sphinx ligustri (pupa)...	20 A.M. 10	22	71·1	Skin. 3·2	......	28·1	38 days, or 903	Pupa still soft, has very recently changed.

Thus also in the larva of the Puss Moth, Table X. A. No. 7 to 27. Although the temperature of the atmosphere was gradually raised through twelve successive hours from 69°·5 FAHR. at 5½ A.M.,—when the larva, which had been sleeping through several hours, and had a temperature of only °·5 above that of the atmosphere, and its pulse was beating at the rate of forty-seven per minute,—to 80°·4 FAHR. at 5½ P.M. the insect then had a temperature of only °·8, while its pulse was beating at the rate of eighty-eight per minute. Again, at 7 on the following morning, atmosphere 75°·2 FAHR., the temperature of the insect at rest was only °·9; at the expiration of one hour and a half it had not been increased, and the insect was still at rest, but the pulse had risen to sixty-eight, while at 9 A.M., when the insect was aroused and feeding, its amount of temperature was still the same, but the number of its pulsations then amounted to seventy-two. At 7 o'clock on the following morning, when the insect was active and preparing for transformation, its temperature being °·7, its pulsations were at the rate of sixty per minute; but half an hour afterwards, when the temperature of the insect was °·9, the number of pulsations was not increased; and at the expiration of an hour, when the temperature had again sunk to °·7, the pulse had also subsided to fifty-four. This very insect, A. No. 1, which immediately after it was captured had been placed in a box in my coat-pocket, and after remaining there for some time, excited by immoderate warmth, had a temperature of 13°·5 FAHR. above that of the atmosphere, which was then 68° FAHR., while the pulse of the insect was ninety-nine per minute. But one hour afterwards, when its temperature had sunk to 2°·3, the pulsations were only sixty-four. At the expiration of another quarter of an hour they had risen again to seventy-two, while the temperature of the insect had sunk to 1°·6 FAHR. Thus then, although in general we cannot fail to observe the almost constant uniformity or correspondence between the number of pulsations and the temperature of the insect, as in Nos. 6, 14 and 17, it is evident that the amount of temperature does not necessarily depend upon the rate or mere velocity of pulsation.

On examining the Table now referred to it will be seen that there is a remarkable difference in the rate of pulsation, as well as in the temperature of the larva of the Puss Moth and of the *Sphinx ligustri* of the same age, and at about the same temperature of the atmosphere as on Tables VIII. and X., from which it is seen that neither the temperature of body nor the rate of pulsation is so great in the Sphinx as in the Puss Moth, while in both is observed the general coincidence of the rate of pulsation with the amount of temperature. In both the Tables VIII. and IX. it is seen that when the larva is about to change into the pupa state the pulsations are reduced from thirty-two to twenty-eight, and even to twenty-six; and when the change into the pupa state is completed, the rate of pulsation is not more, in some instances, than twelve beats per minute. When the insect is in its most complete state of hybernation the circulation in the pupa is reduced to its lowest condition, and there is perhaps an almost entire absence of pulsation, although I have reason to believe that the fluids still circulate even when there is no development of external heat.

Table X.

Showing that the Temperature is greater and the Pulsation more frequent in the larvæ of those insects which undergo their metamorphoses in the open air, as the Puss Moth (*Cerura vinula*), than in those which undergo their changes in the earth, as the *Sphinx ligustri*, and others.

No. of Exp.	Species.	Period of observation.	Atmosphere.	Insect.	Difference.	Pulsation.	Age.	Remarks.
		1834. h m	°	°	°			
1	Cerura vinula (larva), A.	July 16 A.M. 9	68	81·5	13·5	99	7th day.	Just captured, and confined in my box in my pocket, perspiring copiously.
2	Cerura vinula (larva), A.	A.M. 10	70·5	72·8	2·3	64	....	Insect active, but more calm; pulse full, sinking.
3	Cerura vinula (larva), A.	A.M. 10 15	72·7	74·3	1·6	72	....	Very active, in constant motion, pulse small.
4	Cerura vinula (larva), A.	A.M. 10 30	......	......	......	66	....	Has rested a few minutes, asleep.
5	Cerura vinula (larva), A.	A.M. 11	73·5	......	......	64	....	Has been sleeping half an hour.
6	Cerura vinula (larva), A.	A.M. 11 15	73·5	74·8	1·3	71	....	Aroused and excited.
7	Cerura vinula (larva), A.	17 A.M. 5 30	69·5	70	·5	47	8th day.	Has been sleeping during several hours.
8	Cerura vinula (larva), A.	A.M. 7	71·4	72·3	·9	64	....	Moderately active.
9	Cerura vinula (larva), A.	A.M. 7 30	72	72·9	·9	57	....	At rest.
10	Cerura vinula (larva), A.	A.M. 7 45	72·3	72·9	·6	55	....	Sleeping.
11	Cerura vinula (larva), A.	A.M. 8	72·5	73·2	·7	56	....	Still sleeping.
12	Cerura vinula (larva), A.	A.M. 9	72·2	73·2	1·0	68	....	Active, and feeding.
13	Cerura vinula (larva), A.	A.M. 9 15	72·2	73·3	1·1	59	....	Resting.
14	Cerura vinula (larva), A.	A.M. 9 30	73·1	74·2	1·1	70	....	Feeding.
15	Cerura vinula (larva), A.	A.M. 9 45	73·2	74·4	1·2	68	....	Still feeding.
16	Cerura vinula (larva), A.	A.M. 10 15	73·2	74·3	1·1	67	....	Active, but not feeding.
17	Cerura vinula (larva), A.	A.M. 11	74·4	75·7	1·3	72	....	Very active.
18	Cerura vinula (larva), A.	A.M. 12 45	78·5	80	1·5	77	....	Very active.
19	Cerura vinula (larva), A.	P.M. 1 15	78·5	80·2	1·7	78	....	Still very active.
20	Cerura vinula (larva), A.	P.M. 4 45	80·5	81·9	1·4	88	....	Moderately active.
21	Cerura vinula (larva), A.	P.M. 5 30	80·4	81·2	·8	88	....	Less active.
22	Cerura vinula (larva), A.	18 A.M. 7	75·2	76·1	·9	66	9th day.	Sleeping, or quiet.
23	Cerura vinula (larva), A.	A.M. 8 30	75·4	76·3	·9	68	....	Quiet.
24	Cerura vinula (larva), A.	A.M. 9	76·1	77	·9	72	....	Aroused and feeding.
25	Cerura vinula (larva), A.	19 A.M. 7	70·7	71·4	·7	60	10th day.	Changing colour for transformation.
26	Cerura vinula (larva), A.	A.M. 7 30	70·9	71·8	·9	60	....	More discoloured.
27	Cerura vinula (larva), A.	A.M. 8	70·7	71	0·3	54	....	Preparing to spin its cocoon.
28	Cerura vinula (larva), B.	16 A.M. 10 30	71·8	72·3	·5	49	....	After feeding 36 hours, just fed, sleeping.
29	Cerura vinula (larva), B.	A.M. 10 45	71·8	72·5	·7	......	....	A little active.
30	Cerura vinula (larva), B.	17 A.M. 5 30	68·5	68·7	·2	......	....	Is spinning its cocoon for transformation.
31	Cerura vinula (larva), B.	P.M. 1 15	78·5	78·9	·4	50	....	Still spinning its cocoon.
32	Cerura vinula (larva), B.	P.M. 4 45	78·9	79·2	·3	46	....	Still spinning.
33	Cerura vinula (larva), B.	19 A.M. 7 30	70·9	71·3	·4	31	....	Has been retarded from changing.

But it is not only at the period of change into the pupa state that the pulsation is greatly reduced, the same thing takes place immediately before each change of skin in the larva, as shown on Table IX. Nos. 9, 23, 34, and 63. At those periods the temperature and respiration are also reduced, and the insect ceases to eat; but soon after the change of skin has taken place the respiration and temperature are again increased; but the average rate of pulsation is never so great as before the previous change of skin, and it continues to be diminished at each succeeding change.

The following observations made on larvæ of *Sphinx ligustri* of the same age, at different periods after entering their fifth or last skin, and when the pulse in each was regular and full, will further illustrate the general accordance which exists between the rate of pulsation and amount of temperature when the pulsation has not been accelerated by inordinate activity or other causes.

TABLE XI.

Period of observation.	No.	Age of the Insects.	Atmosphere.	Insect.	Difference.	Pulse.
July 31, 1834.	1	*Three* days in last skin, feeding	71°·2	72°·3	1°·1	54
	2	*Three* days in last skin, resting	71·2	72·2	1	49
	3	*Five* days in last skin, feeding	71·2	72·2	1	49
	4	*Five* days in last skin, feeding	71·6	72·6	1	50
	5	Seven days in last skin; has been long sleeping	71·2	71·6	·4	29
	6	Seven days in last skin; aroused and active	71·6	72·4	·8	38

The same general accordance which exists in the larva between the quantity of respiration, amount of heat developed, and number of pulsations, exists also in the perfect insect. In order to observe the number of pulsations in the perfect insect it is necessary to denude the dorsal surface of the abdomen of its thick covering of scales, and when this has been done completely the pulsation of the vessel is readily observed. In a male specimen of *Sphinx ligustri* which had been exerting itself in active flight for several minutes around my sitting-room, I found the number of pulsations was 127 per minute, while the insect then had a temperature of 9° FAHR. above that of the atmosphere, which was 70° FAHR. On the following day, after it had been exerting itself in a similar manner for a much longer space of time, the temperature of the atmosphere being 69°·5, the number of its pulsations was then 139, and its number of respirations forty-two per minute, but its amount of heat was only 5°·5 FAHR. When it had remained at rest about half an hour its temperature was only °·5, while the number of its respirations was eighteen, and of its pulsations forty-nine; and at the expiration of three quarters of an hour, when it was perfectly quiet and apparently asleep, its temperature was only °·2, its number of respirations fifteen, and its pulse forty-two. In these instances the accordance between the number of respirations and pulsations, and the temperature of the insect was nearly uniform, but in some of the other observations the same uniformity between the amount of heat developed and the number of pulsations is not so strictly observed. Thus in No. 12, Table V., the temperature of the insect after violent exertion was 9° FAHR., the number of pulsations 127, while in No. 14 the temperature was only 4°·6, but the pulsations amounted to 151; and in No. 15 the temperature was 4°·3, but the pulsations only 110.

It is thus evident that in the perfect insect, as in the larva, there are sometimes similar irregularities in the rate, or velocity of pulsation, and which irregularities when compared with each other do not appear to have relation to the quantity of heat developed, while the general, or what appears to be the average rate of pulsation, is in almost uniform accordance with the amount of heat and number of respirations. But these apparent discrepancies may, perhaps, be explained by the circumstance, that when the pulsations are excessive in number they are small, rapid, and intermittent, like the pulsation in certain excited states in the human body, and this is the case in every instance of excessive pulsation, both in the larva and perfect insect; while in those instances in which there is a near accordance between the rate of pulsation, amount of heat developed, and number of respirations, the pulsatory motions are full, regular, and without intermissions, so that the relative quantity of

blood which is steadily submitted to the influence of the air in the respiratory organs is perhaps greater in the latter than in the former instances. This circumstance may also account perhaps for the smaller amount of heat generated by the larva in its earlier than in its latter condition, although the number of its pulsations is more than double in the earlier than in the latter period. In the full grown larva the pulsations are steady and full, with much power, but in the earlier state of the larva they are small, rapid, and intermitting. From these circumstances we may fairly infer that the quantity of heat developed is more dependent upon the quantity of respiration than upon the velocity of the circulation.

3. *Digestion.*

The influence which the process of digestion exercises over the production of heat is very considerable. We have before seen that in the larva the greatest amount of heat is produced after the insect has fed, or while it is feeding and becoming much excited. It is at these periods that it deteriorates the greatest quantity of air, which quantity is then necessarily required during its respiration in assimilating the new matter which has just been taken into its circulation through means of the digestive process. In the perfect insect the circumstances are exactly the same, its temperature is greatest after it has fed, and is then exerting itself, and at that time it respires the greatest quantity of air. On the other hand, when the insect is fasting, the quantity of heat evolved by it, even during great exertion, is much diminished, while the quantity of air consumed is smaller than the quantity consumed under similar excitement after it has taken food.

4. *Gaseous, or Cutaneous Expenditure of the Body.*

The cutaneous expenditure of the body is closely connected, both with the digestive process and with the regulation of the temperature of the insect. It is seen in the observations on *Melolontha solstitialis* and other species, that the amount of gaseous expenditure is exceeding great, and that after the temperature of the insect has been raised to a certain amount, a profuse perspiration breaks out, which is the natural cooling process of the body. The pulse also is considerably affected by it, as shown in the larva of the Puss Moth, which had been subjected to high temperature, and which soon became bathed in perspiration, Table X. No. 1 and 2. The exact correspondence which exists between the quantity of gaseous, or cutaneous expenditure, acceleration or subsidence of the pulse, increase or decrease of weight, and quantity of respiration in every period of the larva, pupa, and perfect state, is very remarkable. The quantity appears to be at its maximum in the very active perfect insect, and is greater than in the larva, or in the pupa, in which it is at its minimum when the pupa has the smallest amount of respiration; but in all cases it is least during the state of most complete inactivity. In the common Hive Bee in a state of activity the amount is prodigious, and very soon becomes evident, if the bee be confined in a very small glass phial, closely stoppered, and kept in a state of excitement. The perspiration from the insect is then condensed upon the interior of the phial, and if several bees be confined together, the bodies of the little insects themselves become

bathed with perspiration. In the summer of 1832, I endeavoured to ascertain the quantity of gaseous expenditure in the larvæ of Lepidoptera compared with the weight, quantity of food eaten, increase, and fæcal expenditure of the insect, in a given time, and it was then found that the quantity of gaseous is equal to, or even greater than the quantity of fæcal expenditure, even in these animals in which the latter is so enormous. The first subject of my observations was my old favourite, the larva of *Sphinx ligustri*. The specimen on which my observations were commenced had been confined fasting about twelve hours, when it weighed 79·8 grains, having at the commencement of the twelve hours weighed 83·3 grains. During this period of fasting it had passed two masses of fæces, which weighed only 1·7 grain, consequently it had expended by the skin and respiratory organs 1·8 grain, an excess of one tenth of a grain in the gaseous expenditure. It was then supplied with fresh food, of which it ate 2·8 grains, and weighed 82·1 grains at the expiration of the first hour; had passed no fæces, but had expended ·5 of a grain from the skin and respiratory organs. It was then made to fast for an hour, and afterwards weighed again to ascertain whether there was any difference in the quantity of gaseous expenditure during abstinence. It had discharged one mass of fæces weighing ·9 of a grain, and itself weighed 80·8 grains, so that during the hour of fasting only ·4 had passed off in the gaseous form instead of ·5 as in the previous hour of taking food. At this time, while the insect was lying at rest, the dorsal vessel pulsated at the rate of thirty-six beats per minute. The insect was then allowed to feed for another hour and weighed again; at the expiration of that time it had passed no fæces, had eaten 3·4 grains of food, and weighed 83·6 grains. Thus one whole grain had now been expended in the gaseous form. It then fasted for three hours, but during that time it passed only one mass of fæces, which weighed 1·2 grains, and itself weighed 81·6, so that it had now lost only ·8 in the gaseous form during three hours' fasting. It was thus evident that the greatest amount of gaseous expenditure occurs during the period of taking food, and that the quantity of gaseous expenditure decreases in proportion to the length of time the insect is kept fasting, and also that less gaseous expenditure takes place when there is the greatest amount of fæcal. When the insect had been fed for another hour, and had eaten 2·7 grains of food, it weighed 83·9, but had passed no fæces, consequently it had now expended ·4 of a grain in the gaseous form. It was thus evident that the quantity which passes off in the gaseous form during a certain length of time when the animal is taking food varies considerably, and sometimes amounts to one whole grain per hour, while at other times it is only about ·4 of a grain. These observations were continued through two successive days, with similar results. Thus after the insect had been fasting for twelve hours, during which time its amount of gaseous expenditure had been very trifling, the very first time it was weighed after feeding for one hour it had expended ·5 of a grain; but when it was kept fasting, the very next hour its expenditure was only ·4 of a grain. Similar experiments were also made at the same time upon the larvæ of the Puss Moth, *Cerura vinula*, STEPH., and *Sphinx Elpenor*, LINN., with precisely the same results relative to the quantity of gaseous expenditure. In

the observations on the *Sphinx ligustri*, it will be seen by the Table XII. that the heat developed during fasting is much less than during the period of taking food.

Table XII.—A Table* exhibiting the quantity of food eaten, with the rate of increase of weight, and the gaseous and fæcal expenditure, and their effect on the Temperature of a Larva of *Sphinx ligustri*.

No. of Exp.	Period of Observation.	Feeding.	Fasting.	Temp. of Atmos.	Insect.	Difference.	Weight of larva in grains.	Weight of food eaten in grains.	Increase.	Gaseous expenditure.	Fæcal expenditure.	Remarks.
	1832.			°	°	°	grs.					
1	Aug. 18 P.M. to 19 A.M. 10	......	Twelve hours	......	......	......	79·8	......	......	......	......	
2	A.M. 11	One hour......	......	......	......	......	82·1	2·8	2·3	·5	......	
3	A.M. 12	......	One hour......	......	......	......	80·8	......	......	·4	·9	
4	P.M. 1	One hour......	......	......	......	......	83·6	3·4	2·8	·6	......	
5	P.M. 4	......	Three hours	......	......	......	81·6	......	......	·8	1·2	
6	P.M. 5	One hour......	......	......	......	......	83·9	2·7	2·3	·4	......	
7	P.M. 6	One hour......	......	......	......	......	85·1	4·5	1·2	2	1·3	
8	P.M. 7	One hour......	......	......	......	......	85·6	3·2	·5	2·7	......	
9	P.M. 8	One hour......	......	......	......	......	85	1·5	......	·6	1·5	
10	P.M. 9	One hour......	......	......	......	......	86·5	2·1	1·5	·6	......	
11	Aug. 19 P.M. 9 to 20 A.M. 6	Nine hours ...	......	......	......	......	88	16·5	1·5	7	8	
12	A.M. 7	......	One hour......	......	......	......	87·6	......	......	·4	......	
13	A.M. 8	......	One hour......	......	**	**	85·6	......	......	·4	1·6	
14	A.M. 9	......	One hour......	65	65·5	·5	85·55	......	......	·05	......	
15	A.M. 10	......	One hour......	65·5	65·9	·4	85·5	......	......	·05	......	
16	A.M. 11	......	One hour......	66·4	70	·6	85·4	......	......	·1	......	
17	A.M. 12	......	One hour......	67	67·7	·7	85·2	......	......	·2	......	Active.
18	P.M. 1	......	One hour......	68	68·7	·7	85	......	......	·2	......	
19	P.M. 2	......	One hour......	69	69·4	·4	83·6	......	......	·05	1·35	At rest.
20	P.M. 3	......	One hour......	69·5	69·7	·2	83·55	......	......	·05	......	At rest.
21	P.M. 4	One hour......	......	69·5	70·4	·9	86·1	3·6	2·55	1·05	......	Feeding.
22	P.M. 5	One hour......	......	70·1	71·1	1	88·85	3·6	2·75	·85	......	Very active.
23	P.M. 6	One hour......	......	69·5	70·4	·9	89·15	2·4	·3	1	1·1	Feeding.
24	P.M. 7	One hour.....	......	69	70·1	1·1	90	1·8	·85	·95	......	Active.
25	Aug. 20 P.M. 7 to 21 A.M. 7	Twelve hours	......	68·5	69·4	·9	92·6	25·5	2·6	11·6	11·3	Sleeping.
26	A.M. 8	One hour......	......	68·7	69·9	1·2	93·9	1·95	1·3	·65	......	Active.
27	A.M. 9	One hour......	......	69	70	1	94·65	4·4	·75	2·1	1·55	Active.
	Total increase in 47 hours......			......	......	......	14·85	79·95	......	35·3	29·8	

A Table exhibiting the gradually decreasing amount of Weight and Gaseous Expenditure in proportion to the length of time of fasting in a Larva of *Sphinx Elpenor*.

No. of Exp.	Period of Observation.	Feeding.	Fasting.	Temp. of Atmos.	Insect.	Difference.	Weight of larva in grains.	Weight of food eaten in grains.	Increase.	Gaseous expenditure.	Fæcal expenditure.	Remarks.
28	Aug. 20 A.M. 10	......	One hour......	65·5	......	......	65·3	......	......	......	......	
29	A.M. 11	......	One hour......	66·4	......	......	65·1	......	......	·2	......	Insect in constant motion.
30	A.M. 12	......	One hour......	67	......	......	64·9	......	......	·2	......	
31	P.M. 1	......	One hour......	68	......	......	64·8	......	......	·1	......	At rest.
32	P.M. 2	......	One hour......	69	......	......	64·7	......	......	·1	......	Sleeping.
33	P.M. 3	......	One hour......	69·5	......	......	64·65	......	......	·05	......	Sleeping.
34	P.M. 4	......	One hour......	69·5	......	......	64·5	......	......	·15	......	A little aroused.
35	P.M. 5	......	One hour......	70·1	......	......	64·4	......	......	·1	......	
36	P.M. 6	......	One hour......	69·5	......	......	64·2	......	......	·2	......	Very active.
37	P.M. 7	......	One hour......	69	......	......	64	......	......	·2	......	
38	A.M. 7	......	Twelve hours	68·5	......	......	62·15	......	......	1	·85	
39	A.M. 8	......	One hour......	68·7	......	......	62	......	......	·15	......	Very active.
40	A.M. 9	One hour......	......	69	......	......	63·65	3·45	1·65	1·8	......	
	Total decrease in 23 hours......			......	......	......	1·65	......	......	4·25	·85	

* These Tables on the quantity of food eaten, loss and increase of weight, gaseous and fæcal expenditure, and temperature of the atmosphere at the time of making the observations, were made, as noticed below, in August 1832; but the two columns which indicate the temperature of the insect** were not made at that period, but have been added subsequently, having been made in the summer of 1834 upon the larva of the Sphinx under circumstances similar to those of August 1832. Indeed from the precautions necessary to be attended to while taking the temperature of the insect, as noticed in the beginning of the present paper, it will be seen that it is impossible to make the whole of the observations here detailed upon the same individual at the same time, the excitement produced in the insect while handling it in order to ascertain its weight unavoidably interfering with the correctness of the observations on its temperature. Two specimens therefore of the same weight and age must always be employed.

Table XII. (Continued.)

A Table of the Weight and Rate of Increase and Decrease, with the Fæcal and Gaseous expenditure of a Larva of *Cerura vinula*.

No.	Period of Observation.	Feeding.	Fasting.	Temp. of Atmos.	Insect.	Difference.	Weight of larva in grains.	Weight of food eaten in grains.	Increase.	Gaseous expenditure.	Fæcal expenditure.	Remarks.
				°			°	grs.				
41	1832. Aug. 20 A.M. 9¼	One hour......	....	65	......	......	76·5	......	......	......	......	This larva was fed throughout the whole of the observations upon stale food.
42	A.M. 10¼	One hour......	....	65·5	......	......	78·1	3·65	1·6	1·55	·5	
43	A.M. 11¼	One hour......	....	66·4	......	......	77·2	2·4	......	1·45	1·55	
44	A.M. 12¼	One hour......	....	67	......	......	77·6	2·55	·4	1·2	·95	
45	P.M. 1¼	One hour......	....	68	......	......	76·6	1·6	......	1·25	1·35	
46	P.M. 2¼	One hour......	....	69·5	......	......	76·3	2·5	......	1·45	1·35	
47	P.M. 3¼	One hour......	....	69·5	......	......	74·95	2·1	......	1·05	2·1	
48	P.M. 4¼	One hour......	....	70	......	......	75·9	4·4	·95	2·1	1·35	
49	P.M. 5¼	One hour......	....	70·2	......	......	74·4	1·75	......	1·1	2·15	
50	P.M. 6¼	One hour......	....	69·5	......	......	75·05	2·7	·65	1·25	·8	
51	P.M. 7¼	....	....	69	......	......	75·7	2·1	·65	·95	·5	
52	A.M. 7¼	....	Twelve hours	68·5	......	......	69·75	......	......	2·55	4·6	
53	A.M. 8¼	One hour......	One hour......	68·7	......	......	69·65	......	......	·1	......	
54	A.M. 9¼	One hour......	....	69	......	......	71·1	3·7	1·45	1·75	·5	
	Decrease in Weight in 26 hours 5·4							Food eaten 29·45		17·75	11·70	

From this Table we deduce the following facts:—First that the expenditure which takes place from the cutaneous surface of the insect and from its respiratory organs is greater than its whole amount of fæcal expenditure, is more regular and continued, and decreases in proportion to the length of time which the insect remains fasting, but never entirely ceases. It is greatest while the insect is in motion and least when it is lying entirely at rest. Thus in the observations on *Sphinx Elpenor*, Linn., which was fasting during nearly the whole of the period of observation, twenty-two hours, the insect lost only ·85 of a grain of fæcal expenditure, but 2·45 of grains by the respiratory and cutaneous surfaces, and of this expenditure, when the insect was lying at rest, only ·05 of a grain per hour, but when in violent motion the loss amounted to ·15 per hour. This difference of quantity is readily accounted for by the quicker circulation of the fluids in the active state of the insect, when its respiration is greater, and consequently a greater amount of heat is generated, and requires to be regulated by the transpiration from the surface of the body. This Table also indicates the fact that the whole process of digestion may be completed in the larva of the Sphinx in about two hours and a half, and that the average quantity of fæcal expenditure in the latter period of a moderate sized larva is about one grain per hour.

But the connection or correspondence between the quantity of respiration, temperature and gaseous expenditure in a given time, is beautifully illustrated in what occurs in the pupa state. On the 3rd of April, 1836, I weighed several pupæ of *Sphinx ligustri*, and found that one of them which on the 20th of the preceding August, immediately after it had changed to a pupa, weighed 71·1 grains, had not expended, during the long interval of nearly eight months, or two hundred and twenty-eight days inclusive, more than 3·7 grains in weight, the whole of which must have passed off from the respiratory and cutaneous surfaces. This was the identical specimen which I

had watched from the egg, and whose rate of pulsation is noticed on Table IX. At the time of entering into the pupa state in August, it weighed, as above stated, 71·1 grains. At the present time it weighed 67·4 grains. This diminution was during the period of hybernation, and is in beautiful accordance with the greatly diminished quantity of respiration during this state, respiration being reduced to its minimum in this condition of the insect, as shown in my previous observations. On the 24th of May, fifty-one days after the first weighing, the perfect insect was developed from this pupa, and then weighed only thirty-six grains, and when weighed again on the following day, only thirty-four grains, Table V. A, being an amazing diminution of nearly one half of the whole weight of the pupa in the short space of fifty-three days. Now it will be remembered that, as shown in the Tables on the Respiration* of the pupa of *Sphinx ligustri* in the month of April, that the quantity of respiration at that period is gradually increasing, and is in proportion to the degree of animation in the insect; and the degree of animation is proportioned to the quantity of stimuli, external temperature, &c., so that, as shown by Reaumur in the pupæ of the common Cabbage Butterfly, if the pupæ be kept in a very low temperature, as in that of an ice-house, development into the perfect state is greatly retarded; and as now shown, respiration, owing to the absence of a proper amount of external stimulus, being reduced to its minimum, the circulation of blood is almost suspended, the development of heat scarcely, if at all perceptible, and the expenditure of solid matter from the body of the insect in a gaseous form is so insignificant that the powers of life are in no way injured by retarded development, and the insect revives in its full vigour whenever the natural stimuli of life are sufficiently increased. At the moment of weighing the above pupa in April, I weighed several others which had entered the pupa state about the same time. One of them at the expiration of fifty-three days, on the 26th of May, had lost thirteen grains, another eight grains, a third nine grains, and a fourth ten grains, and the respiration of these had increased in the ratio of their loss of weight.

There may, perhaps, be some difficulty in ascertaining with certainty the chemical constituents of this gaseous expenditure from the body of the insect in its different stages, since a large proportion appears to be aqueous vapour, but I am satisfied that sometimes there is also a quantity of carbonic acid. However, I could not discover the carbonic acid in a quantity of vapour expelled from the bee hive and condensed during the night, but I very readily detected it in the pupa, in my earlier observations on the respiration of insects, in April 1829. A pupa of *Sphinx ligustri*, after being carefully washed to prevent the adhesion of air to the surface of its body, was placed for a few hours in a glass stoppered phial, completely filled with perfectly clear lime-water, and at the expiration of two or three hours, I had the satisfaction of detecting carbonate of lime deposited both within the entrance of the spiracles and also in the minute punctures which are distributed over the whole body of the pupa; a certain

* Philosophical Transactions, 1836, Part II. p. 552, Table I. No. 3 to 10.

proof this, both that the pupa was transpiring through the pupa case, and also that the transpired matter contained carbonic acid.

Conclusion.

The very great length unto which this paper has already been extended, necessarily prevents me from entering so fully into all the circumstances connected with the evolution of heat in insects as the great importance attached to this interesting subject demands; I shall, therefore, review the contents of this paper, and other circumstances connected with the production of animal heat, with as much conciseness as possible.

On comparing the whole of the facts we have just examined, we cannot fail to observe the very close relation which subsists between the amount of heat developed, and the quantity of respiration. We have seen in the larva, the pupa, and the perfect insect, that when the respiration is accelerated the temperature is also increased, and that when respiration is diminished the temperature subsides. When the insect is sleeping, its respiration gradually becomes slower, and its temperature continues to lessen until the insect is aroused, when immediately after the first respirations it is again increased. When the insect falls into a state of hybernation, and its respiration is suspended, its evolution of heat becomes so likewise. When the insect is most active, and respiring most voluminously, its amount of temperature is at its maximum, and is very great, and corresponds with the quantity of respiration, and, as in the Bee, an immense quantity of heat passes off into the surrounding medium. When the insect wishes to impart heat to its young it can do so at pleasure, and can voluntarily increase its own temperature. It does this by accelerating its respiration. At those times, as shown in the comparative observations, the insect evolves in one hour, in this state of activity and excitement, at least twenty times the amount of heat, and consumes nearly twenty times the quantity of air, which it consumes at the same temperature when in a state of repose. In insects which live in society the temperature of their dwellings is increased in proportion to the activity of the inmates, and consequent amount of their respiration. In the hive it is steadily increased until the time of swarming. In the winter when the bees are quiet, and their respiration is exceedingly low, and when not a bee is observed ventilating at the entrance, the temperature of the hive may be raised in a few minutes, very many degrees, by disturbing the inmates, and thereby increasing their respiration, until such an amount of heat is evolved, and so much air is deteriorated, as to become oppressive and noxious to the bees, many of whom, although the open atmosphere be too cold for them to venture abroad, will come to the entrance of the hive and begin as laboriously to ventilate the interior, by vibrating their wings, as in the midst of summer. The quantity of free heat is always greatest in the hive when the bees are most active, and least when they are most quiet. With regard to the habits and anatomical structure of insects, the amount of heat is by far greatest in volant

insects; these always have the largest respiratory organs, and breathe the greatest quantity of air. In the terrestrial insects the amount of heat is greatest in those which have the largest respiratory organs, and breathe the greatest quantity of air, whatever be the condition of their nervous system. In the larva state the respiratory organs are smaller than in the perfect insect, compared with the size of the body, and the larva, we have seen, has the lowest temperature. But in these comparisons we must observe that the activity of respiration is equal in the individuals which are compared. Thus although the respiratory organs are larger in the pupa than in the larva, the physiological condition of the insect is lower, its respiration is inactive. These facts, it will be seen, are all in strict accordance with each other, and point to the chemical changes in the air during respiration as the immediate source of animal heat. But it may be matter of inquiry how it is that the heat evolved within the body of the insect, during respiration, becomes evident so rapidly. This, it may be urged, tends to show that it results from the influence of the nervous system. But when we remember that in insects the circulatory vessels are in close and most extensive communication with the respiratory organs over the whole body of the individual, and that, unlike the vessels in those vertebrated warm-blooded animals which have extensive respiration, they are neither strictly venous nor arterial, but probably intermediate between the two, may it not arise from only a very small amount of heat evolved at each respiration becoming latent, while nearly the whole becomes free, and is liberated as quickly as produced, and that this is the occasion of the temperature of the insect being so quickly raised during its respiration, and so rapidly diminished as the acts of respiration become less frequent? That, in other words, in insects the capacity of the blood for caloric is but very little increased during respiration? With these facts in consideration, and looking at the analogical condition of insects, and with Professor GRANT* and Mr. OWEN†, comparing the vast extent of their respiratory organs, distributed over the whole body, with a like extensive respiration in birds, and finding that, like birds, insects have also a greater activity of respiration, and a higher temperature of body than any other class in the division of animals unto which they respectively belong, we can hardly withhold our assent to the opinions which have long been advocated by many of our best physiologists, that animal heat is the direct result of the chemical changes which take place in the air respired. But it may be urged that activity of respiration is coincident with increased rapidity of circulation, and hence that the latter may, perhaps, precede the former, and be in reality the source of heat. Unto this it may be replied that the larva in its earlier state has a more rapid circulation, but develops less heat than in its latter. In many of the observations on the Tables it is shown that the pulse may be rapid with a low amount of heat. It is shown in the larva, when arousing, that the pulse is not increased until

* Lectures on Comparative Anatomy.—*Lancet*, 1833–34.

† Cyclopædia of Anatomy and Physiology, vol. i. p. 341.

after the first respirations*, when the heat is becoming apparent. With regard to the digestive process, we have seen that when the animal is taking food it has the greatest amount of gaseous expenditure from its body, and that the greatest amount of heat, when in a state of quietude, is then generated. But a greater quantity of air is then consumed, in assimilating the new matter which has been taken into the system, and the quantity of heat is still further increased if the animal becomes active, and this is regulated by the increased expenditure from the surface of the body. Lastly, we have seen that in the more perfect volant insects, the Bees, Sphinges, &c., there is the largest amount of heat produced, and the greatest quantity of air consumed, but the nervous system is also largely developed, and hence it may fairly be supposed to have much influence in the development of heat. But on the other hand we find many insects, as the *Melöe* and its congeners, which produce a large amount of heat, in which the nervous system is comparatively small, while these insects have large respiratory organs, and a large amount of respiration. In the *Staphylinus* the nervous system is exceedingly large, compared with the size of the body, but the respiratory organs are by no means small, while the amount of heat is very moderate. In the *Carabus* the nervous system is also large, as are likewise the organs of respiration, but the amount of heat and activity of respiration are low, and the same is the case in the *Blaps*, in which the nervous system is rather small. If the development of heat depends upon the nervous system, or the number of ganglia, the *Leech*, which has twenty-two ganglia, ought to generate more heat than the larvæ of lepidopterous insects, which have but ten or twelve, and the larva ought to generate as much as the perfect insect. In the larvæ of the Bee, the Hornet, Ichneumon, and Tenthredo, which generate so large an amount of heat, the nervous system is exceedingly small; and if, as some suppose, heat is the result of muscular contraction, surely it ought to be most developed where there is the greatest amount of muscular contractility; it ought to be generated more in the *Leech* than in other articulated animals, and in those *Vertebrata* which are peculiarly noted as cold-blooded. These facts con-

* This is in perfect accordance with the condition of the circulation in the human body during sleep, and at the moment of waking, as noticed by Blumenbach, and as I myself once had an opportunity of observing in a female patient who was suffering from severe fracture of the skull, for which she had been trephined; subsequently to which, a large portion of the bone (the right parietal) became affected with necrosis and was removed by operation, and the patient afterwards gradually recovered. At least one-third of the whole parietal bone had been removed, and a large surface of the dura mater being thus exposed, the activity of the circulation in the brain was readily observed. I thought this a fair opportunity, as the patient was recovering, for observing the state of the circulation during sleep, and at the moment of waking. The patient was sleeping soundly at the time of the observation, and while she remained entirely undisturbed, the pulsations in the arteries of the dura mater were at the rate of ninety-four beats per minute, and were perfectly synchronous with the pulsations at the wrists; but immediately she began to inspire deeply at the moment of waking, the pulsations became much accelerated. At the instant of waking, the patient fetched a full and deep inspiration, and in less than a minute and a half after this, the patient being perfectly awake, the pulsations amounted to 104 beats per minute, thus making a difference of about 600 beats per hour in the rate of pulsation when sleeping and immediately after waking.

sidered, and connected with that very remarkable one, the voluntary power of producing heat possessed by the Bee, must lead us to conclude, that although, doubtless, the whole of the functions of the body are more or less remotely concerned in the production of heat, yet that the immediate source of its evolution seems to be chemical changes effected during respiration, and that the nervous system is only secondarily concerned.

Appendix.

Since the preceding paper on the Temperature of Insects was submitted to the Royal Society, circumstances have enabled me to ascertain a few additional facts respecting the temperature of some other species which I had not heretofore any opportunity of examining, and these the Council have kindly permitted me to subjoin to my paper.

I am not aware that the temperature of the nest of the common wasp has ever before been examined, and it is therefore pleasing to find that all the circumstances connected with the evolution of heat in the nest of this species are in perfect accordance with the observations made on the neighbouring families of hive and humble bees.

On the 11th of August, during the past summer (1837), I dug away the soil from the top of a nest of *Vespa vulgaris* which was situated in a bank of earth at the depth of about seven inches from the surface. The nest was nine inches in diameter, so that the colony was by no means a small one. The temperature of the atmosphere, when the covering of the nest was removed, at 4½ P.M. was 70° Fahr. When the thermometer was passed through the top of the nest the mercury rose immediately to 80°. In about ten or fifteen minutes afterwards, when the colony had become disturbed, and the thermometer was passed a little deeper into the nest, the mercury rose to 95°. This distinctly proves that the evolution of heat in the wasps' nest is greatly increased, as in the beehive, when the insects have become excited. At 6½ P.M. the temperature of the atmosphere was 65° Fahr., and the wasps having now become more quiet, the temperature of the nest, which had remained with its upper surface exposed since the last observation, was only 90° Fahr.; but an hour afterwards, when the temperature of the atmosphere had sunk to 63°, that of the nest had risen to 91°, the thermometer having remained undisturbed in the nest since the last observation. This increase of temperature was readily explained by a great number of the excited insects, which had been flying around the spot, having now returned to the nest. Thus the circumstances connected with the evolution of heat in the nests of the predaceous and in the melliferous Hymenoptera are precisely similar; and they are similar also in another interesting family of this order—the ants. It is elsewhere noticed* that Juch found the temperature of an ant-hill about 15° Fahr. above that of the atmosphere. My own observations are in accordance with this statement. On the 27th of July 1837 I examined the temperature of the nest of *Formica herculanea*, Linn. The temperature of the atmosphere in the shade, at 11 A.M., was 76° Fahr., but when the thermometer was exposed on the ground to the full rays of the sun the mercury rose to 95° Fahr. The nest was rather a small one, and at the time of commencing the observations was completely undisturbed. When the thermometer was first passed into it, to the depth of five inches, the temperature was maintained steadily at 84° Fahr.; but within six or eight minutes afterwards, when the insects had become excited by the presence of the thermometer, and were running about in every direction in a state of the greatest agitation, the temperature of the nest rose to 93° Fahr., and in a few minutes after this, when the insects were still more excited, to 95°·5, and a little nearer the surface, where the commotion was greatest, to 98°·6 Fahr. During these observations the ant-hill was carefully shaded from the rays of the sun, in order to avoid all source of error. When the ant-hill was again exposed to the sun, and the thermometer placed upon its surface, the mercury rose to 108° Fahr. This was a temperature much too great

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* Page 283.

for the insects to bear, since nearly the whole of them immediately retired beneath the covering of the nest, and there was scarcely a single ant to be seen. On the 2nd of September I repeated my observations on the same ant-hill. On this occasion the day was very gloomy, with steady light rain, and the temperature of the atmosphere at 11 o'clock A.M. was only 54°. The temperature of the ant-hill varied but little in its different parts but it was now greatest near the surface. At a depth of one inch it was 65°, at two inches 66°, below which it gradually diminished. At this time I also examined another nest of the same species, but which was about twice the size of the first. The atmosphere being, as before stated, 54°, the mean temperature of this nest, when the insects were a little excited, was 74°.

During the summer and autumn of the present year I have repeated my observations on the temperature of the bee-hive, and have found but little variation in its average amount at similar periods in the two years. I have also examined the nests of *Bombus lapidarius*, and *Bombus sylvarum*, and in both have found that the ordinary temperature, which is about 10° or 15° above that of the atmosphere, is considerably increased during the period of incubation, exactly the same as in the nest of *Bombus terrestris*.

On the following day after examining the nest of the wasp, I examined the temperature and pulsation of the larva of the same species. The specimens examined had been removed from the nest on the previous evening, but had not been removed from their cells. The results are given on the accompanying table. I examined also the larva of the hornet, *Vespa Crabro*, LINN., which was still contained in its cell, but had been some days removed from the nest. In this instance the temperature of the larva was found to be about 2°·5 FAHR. above that of the atmosphere, but its rate of pulsation was only thirty-two beats per minute. I should have attributed this low rate of pulsation to the specimen having been so long removed from the nest, had not the rate of pulsation in this larva been examined by my friend Mr. ORSBORN a few days before, and almost immediately after the specimen was obtained from its nest, and found at that time not to exceed thirty-three or thirty-four beats per minute. These facts therefore are in accordance with the observations on the larva of *Anthophora retusa* and *Bombus terrestris*, and also accord with other observations on the larvæ of that very destructive tenthredo or saw fly *Athalia centifolia*, KLUG; which has been so obnoxious to the agriculturist by destroying his crops of turnips during the last three summers.

London, November 7th, 1837.

TABLE.—TEMPERATURE OF LARVÆ.

No. of Exp.	Name of Species.	Period of observation.	No. of Specimens.	Atmosphere.	Soil.	Insect.	Difference.	Pulsation.	Remarks.
1	Vespa Crabro (larva)	July	1	70°	....	72°·5	2°·5	32	Full grown; has fasted three or four days.
2	Vespa vulgaris (larva)	Aug. 12	1	72·7	....	75·8	3·1	56	Nearly full grown; very active.
3	Vespa vulgaris (larva)	12	1	72·7	....	74·	1·3	52	Full grown.
4	Vespa vulgaris (larva)	12	1	72·7	....	75·2	2·5	52	Full grown.
5	Athalia (larvæ).................	Sept. 6	50	64·5	....	66·5	2·0	....	Larva nearly full grown; very active.
6	Athalia (larvæ).................	6	....	64·7	....	66·	1·3	....	
7	Athalia (larvæ).................	6	....	66·3	....	66·8	0·5	....	Larva inactive.
8	Athalia (larvæ).................	6	200	65·3	....	67·3	2·	....	Full grown; active. (8 and 9)
9	Athalia (larvæ).................	6	50	65·3	....	67·3	2·	....	
10	Melolontha vulgaris (larva)	Oct. 7	1	61·5	59·7	60·2	0·5	....	No. 1.
11	Melolontha vulgaris (larva)	7	1	61·5	59·7	60·3	0·6	....	No. 2. Full grown larvæ; the temperature taken while lying in their cells and compared with the temperature of the soil. (10–15)
12	Melolontha vulgaris (larva)	8	1	64·7	64·6	64·7	0·1	....	No. 1.
13	Melolontha vulgaris (larva)	8	1	64·7	64·6	64·8	0·2	....	No. 2.
14	Melolontha vulgaris (larva)	12	1	63·5	63·5	63·7	0·2	....	No. 1.
15	Melolontha vulgaris (larva)	12	1	63·5	63·5	63·7	0·2	....	No. 2.

Table XIII.

Showing the difference between the Temperature of the Atmosphere and that of the Bee-hive No. 1, through many succeeding days, both when undisturbed and when excited.

No. of Exp.	Period of observation.	Weather.	Wind.	Atmosphere.	Hive No. 1.	Difference.	Excited.	Difference.	Remarks.
	1835.			°		°	°	°	
1	Oct. 23 A.M. 7	Fine, hoar frost	......	36	50	14	......	......	Hive had remained undisturbed through the night.
2	A.M. 10	Sunshine	......	49·5	55	5·5	67·5	18	Bees readily excited.
3	P.M. 2	Sunshine	......	53	62·5	9·5	80	27	Bees active, loud humming in the hive.
4	P.M. 5½	Twilight	......	51	66	15	......	......	Hive slightly disturbed; cool evening.
5	24 A.M. 10½	Fine, brisk wind	W.	53·4	58·3	4·9	59	5·6	A few bees abroad, some return with *yellow pollen*.
6	P.M. 3½	Wind and rain	W.S.	52	61·8	9·8	......	......	Not a single bee abroad; faint humming in the hive.
7	P.M. 5½	Windy, cloudy	S.W.S.	53	60	7	......	......	Hive perfectly quiet.
8	25 A.M. 7¼	Frost, calm, fine	E.	40·5	52	11·5	......	......	Bees beginning to hum, and becoming active.
9	A.M. 10½	Dull, foggy, calm ...	W.S.	53	55·3	2·3	71	18	Hive quiet; a few bees abroad returning with *pollen*.
10	P.M. 2	High wind and rain	S.	56	58	2	......	......	Hive quiet; tempestuous rain.
11	26 A.M. 8	High wind, fine	W.	48	53·8	5·8	......	......	Quiet; wind and rain tempestuous during the night.
12	A.M. 8½	High wind, fine	W.	50	54	4	......	......	Quiet.
13	A.M. 11	High wind, sunny ...	W.	52·5	59	6·5	......	......	Hive quiet, but few bees abroad.
14	P.M. 2	Strong wind, showery	W.S.W.	52·9	57	4·1	......	......	Faint humming in the hive; few bees abroad.
15	P.M. 5¾	Calm, cloudy	W.S.	44	54	10	......	......	Twilight, hive quiet.
16	27 A.M. 6½	Fair, light clouds ...	W.N.	40	49·5	9·5	50·5	10·5	Much rain in the night; bees irritable.
17	A.M. 8	Fair, light wind	W.N.	41	49·4	8·4	......	......	Perfectly quiet.
18	A.M. 10	Light wind, sunny...	W.	50·5	51·9	1·4	......	......	Many bees at the entrance of the hive; irritable.
19	P.M. 2	Light wind, fine	W.N.	50·8	58·7	7·9	73	22·2	Few bees abroad; soon excited.
20	P.M. 5½	Heavy clouds	W.N.	44	52	8	......	......	Twilight, slight humming in the hive.
21	28 A.M. 6¾	Sharp hoar frost	W.N.	28·5	45	16·5	......	......	Slightly disturbed; humming; morning calm.
22	A.M. 7½	Fair	W.N.	30	52·5	22·5	......	......	Quiet.
23	A.M. 10½	Calm, fine	W.	49·3	63·7	14·4	......	......	Few bees abroad; slight humming.
24	P.M. 2	Calm, dull	W.	48·3	57	8·7	......	......	Slight humming.
25	P.M. 5	Calm, foggy	W.	44	56	12	......	......	Quiet; calm damp foggy evening.
26	29 A.M. 7	Hard rain, wind	S.W.	51	52·5	1·5	......	......	Hive quiet; hard rain and wind during the night.
27	P.M. 2½	Dull, damp	S.W.	57	67	10	......	......	Many bees abroad with *orange yellow pollen*; irritable.
28	P.M. 5	Calm evening	W.	51	61·5	10·5	......	......	Perfectly quiet.
29	30 A.M. 6½	Fair, misty	E.N.	38	49·5	11·5	......	......	A few sounds heard in the hive.
30	A.M. 10½	Fair, cold wind	E.	51·5	54	2·5	76	24·5	Many bees enter with *pollen*; irritable.
31	A.M. 12	Fair, signs of rain ...	E.S.	51	65	14	......	......	Bees abroad in numbers flocking home with *pollen*.
32	P.M. 2½	Hard rain	E.S.	50·5	60	9·5	......	......	Bees quiet; began to rain about 1 P.M.
33	P.M. 5	Steady rain	E.S.	49·5	58	8·5	......	......	Quiet; light wind.
34	31 A.M. 7	Misty	S.	52	56	4	......	......	Quiet; heavy continued rain during the night.
35	A.M. 10½	Sunshine	S.	53	59	6	......	......	Fine morning; many bees abroad.
36	A.M. 12	Sunny, light clouds...	W.S.	57·6	67·5	9·9	......	......	Many bees abroad; a few with *pollen*.
37	P.M. 2	Fair	W.S.	58	67	9	83·5	25·5	Many bees abroad.
38	P.M. 5	Calm, light clouds ...	W.N.	50·6	76·5	25·9	......	......	Twilight, dull evening; slight humming.
39	Nov. 1 A.M. 6¾	Fine	N.E.	39	56	17	......	......	Light clouds; sun just risen; hive quiet.
40	A.M. 8	Fine morning	N.E.	42	57·5	15·5	......	......	Quiet.
41	A.M. 11	Very fine	N.E.	50·5	58·4	7·9	78	27·5	Bees at entrance of the hive; very little *pollen* collected.
42	P.M. 2	Very fine	N.E.	51	65·4	14·4	80	29	Loaded bees numerous; quantity of *pollen* scanty.
43	P.M. 5	Fair, calm	W.	43·5	68	24·5	......	......	Quiet.
44	2 A.M. 7	Fair, light clouds ...	E.	39·5	51	11·5	......	......	Perfectly quiet.
45	P.M. 1	Fair	S.W.	55·5	58·3	2·8	......	......	Hive quiet; many bees abroad.
46	P.M. 6	Cloudy, rain	S.W.W.	49·5	55·2	5·7	......	......	Dark evening; hive quiet; beginning to rain.
47	3 A.M. 7½	Misty rain	S.E.	45	52·4	7·4	......	......	Quiet; light steady rain through the night.
48	A.M. 10½	Light misty rain	S.E.	47·5	52·4	4·9	......	......	Quiet; no bees abroad.
49	P.M. 3	Brisk wind	S.E.	47	57·7	10·7	......	......	Quiet; heavy clouds; signs of rain.
50	P.M. 5	Wind...	S.E.	46	53	7	......	......	Hive quiet; no bees abroad to day.
51	4 A.M. 7	Fair, with clouds	S.E.	43	49·7	6·7	......	......	Quiet; heavy clouds; cold wind.
52	A.M. 10	Fair	E.	43·5	49·6	6·1	70	26·5	Quiet, but soon excited; brisk sharp wind.
53	P.M. 2	Cloudy, wind	E.	43·2	51·5	8·3	......	......	Brisk wind; quiet.
54	P.M. 5	Rain with hail	E.	42	50·5	8·5	......	......	Quiet; brisk wind.
55	5 A.M. 7½	Heavy clouds	E.	43	49	6	......	......	Quiet; but little rain during the night.
56	A.M. 10	Steady rain	E.	45·7	49·7	4	......	......	Quiet; heavy clouds.
57	P.M. 2½	Misty rain	E.	44·6	49·8	5·2	......	......	Slight noise in the hive; light wind.
58	P.M. 5	Light rain	E.N.	43	49·8	6·8	......	......	Quiet.
59	6 A.M. 7¾	Hoar frost	N.E.	32·7	44·1	11·4	......	......	Rather misty; slight sound in the hive.
60	A.M. 9	Very calm	N.E.	37·5	44·6	7·1	......	......	Hive quiet.
61	A.M. 10	Calm, sunshine	N.E.	41	45·3	4·3	......	......	Hazy sunshine.
62	A.M. 11	Calm, sunshine	N.E.	45	47	2	......	......	Hive quiet.

TABLE XIII. (Continued.)

No. of Exp.	Period of observation.	Weather.	Wind.	Atmosphere.	Hive No. 1.	Difference.	Excited.	Difference.	Remarks.
	1835.			°	°	°	°	°	
63	Nov. 6 P.M. 1½	Calm, sunshine	E.	47·7	53·7	6	......	......	Loud humming in the hive; a few bees abroad.
64	P.M. 2½	Calm, sunshine	N.E.	45·5	51·7	6·2	......	......	A few bees return with a little *pollen*.
65	P.M. 3	Calm, fair	N.E.	44·9	50·6	5·7	......	......	A few bees still abroad.
66	P.M. 3¼	Calm, sunshine	N.E.	45·3	49·5	4·2	......	......	A few bees abroad; dew begins to condense on the grass in the shade.
67	P.M. 3½	Calm, fair	N.E.	44·7	49·1	4·4	......	......	Slight humming.
68	P.M. 3¾	Calm, fair	N.E.	44·5	48·9	4·4	......	......	Slight humming.
69	P.M. 4	Calm, fair	N.E.	43·4	49	5·6	......	......	Sky cloudless, but slightly hazy.
70	P.M. 4¼	Calm, fair	N.E.	41·5	48·1	6·6	......	......	Quiet.
71	P.M. 4½	Calm, light clouds ...	E.	41·5	53·9	12·4	......	......	Light hazy clouds.
72	P.M. 4¾	Light wind	E.S.E.	40·5	50·4	9·9	......	......	Wind shifting.
73	P.M. 5	Cloudy	S.E.	41·2	49	7·8	......	......	Thermometer varying.
74	P.M. 5¼	More cloudy	S.E.	41·7	50	8·3	......	......	Signs of rain in the horizon.
75	7 A.M. 7	Very cloudy	N.N.W.	41·5	46	4·5	......	......	Hive quiet; a little rain last night.
76	A.M. 7¼	Light clouds	N.N.W.	41·4	46·6	5·2	......	......	Hive a little excited without evident cause.
77	A.M. 7½	Light clouds	N.N.W.	41·7	46·6	4·9	......	......	Hive quiet; atmosphere clearer.
78	A.M. 7¾	Sun peeping	N.	42·2	46·5	4·3	......	......	Quiet.
79	A.M. 8	More cloudy	N.	43·1	48	4·9	......	......	Slight humming; clouds thickening from the east.
80	A.M. 8¼	Signs of rain	N.	43·5	47	3·5	......	......	Slight humming.
81	A.M. 8½	Clouds breaking......	N.E.	44·7	47·4	2·7	......	......	Slight humming; a few drops of rain have fallen.
82	A.M. 8¾	Fairer	N.E.	45·6	47·5	1·9	......	......	Slight humming.
83	A.M. 9	Fair.....................	N.E.	46·9	47·6	·7	......	......	Hive quiet; clouds dispersing.
84	A.M. 9¼	Light wind and clouds	E.N.E.	47·7	48	·3	......	......	Slight humming.
85	A.M. 9½	Fair.....................	E.N.E.	48·7	48·3	......	......	......	Clouds dispersing; hive ·4 of degree lower than the temperature of atmosphere.
86	A.M. 9¾	Fair.....................	E.N.E.	48·7	48·7	......	......	......	A few bees have been abroad.
87	A.M. 10	Fair.....................	E.N.	49	......	......	73·5	24·5	When excited temperature of hive rose in 10 minutes to 73′·5.
88	A.M. 11½	Calm, dull	E.N.	50·6	64·9	14·3	......	......	Many bees abroad; two have returned with *pollen*.
89	P.M. 1	Calm, dull	E.	52·6	70	17·4	78·3	25·7	Bees irritable; many abroad; a few with *pollen*.
90	P.M. 3	Calm, fine	E.S.	51·4	75	23·6	......	......	Many bees still abroad.
91	P.M. 5	Steady rain	E.S.	49	70	21	......	......	Hive quiet.
92	8 A.M. 7	Light frost, calm......	W.	35	53	18	......	......	Quiet; much rain fell last night.
93	A.M. 9	Fine, calm	W.	40·6	52·3	11·7	......	......	Quiet; cold, fine; a few bees dead on the alighting board.
94	A.M. 12½	Brisk wind	N.W.	48	60·3	12·3	......	......	Sunshine; many bees abroad.
95	P.M. 2	Wind, sunshine	N.W.	50	59·3	9·3	......	......	Bees abroad; no *pollen* collected.
96	P.M. 5	Calm, clear...........	N.W.N.	42·2	57	14·8	......	......	Hive quiet; calm evening.
97	9 A.M. 7½	Dull, light wind......	N.E.	40·6	49	8·4	......	......	Quiet; cold dull morning; no dew on the grass.
98	A.M. 9	Cold wind	N.E.	41·7	49	7·3	......	......	Quiet; cloudy.
99	A.M. 10	Cold wind	N.E.	42	49·4	7·4	......	......	Quiet; cold brisk wind.
100	A.M. 11	Cold, sunny	N.	42·4	50·2	7·8	......	......	No bees abroad.
101	A.M. 12	Cold, sunny	N.	43·6	49·7	6·1	......	......	Quiet.
102	P.M. 1	Cold wind	N.E.N.	42·4	49·9	7·5	......	......	Quiet.
103	P.M. 2½	Cold wind	N.E.	41·9	50	8·1	......	......	Quiet; cold misty rain.
104	P.M. 3	Wind and rain	N.E.	39·3	49·5	10·2	......	......	Quiet; light driving rain.
105	P.M. 5	No rain	N.E.	38	48	10	......	......	Quiet; cold wind with driving clouds.
106	10 A.M.	Cold brisk wind	N.E.	......	......	......	......	......	A severely cold day; wind bitingly keen.
107	11 A.M. 7½	Hazy, cold	N.E.N.	33	43·6	10·6	......	......	Quiet; cold windy morning.
108	A.M. 9	Hazy, cold	N.E.N.	35	43·	8	......	......	Quiet; a little snow has just fallen.
109	A.M. 10	Sun peeping	N.E.N.	38·5	43·9	5·4	......	......	Slight humming; a little snow falling.
110	A.M. 11	Fine rain..............	N.E.N.	40·4	44·4	4	......	......	Quiet; light rain.
111	A.M. 12	Light rain	N.	41	45	4	......	......	Quiet; sunny with rain.
112	P.M. 1	Dull, hazy	N.	41·8	45·2	3·4	......	......	Calm; dull.
113	P.M. 2	Hazy	N.N.W.	41·6	45·2	3·6	......	......	A shrill humming at intervals of a single bee is heard in the hive.
114	P.M. 4	Hazy	N.N.W.	40	44·7	4·7	......	......	Hive quiet.
115	P.M. 4¾	Hazy	N.N.W.	39·6	44·5	4·9	......	......	Quiet; heavy clouds.
116	12 A.M. 7½	Fine, light wind......	N.	35	43·4	8·4	......	......	Cold dry wind; hive quiet.
117	A.M. 9	Fine, calm	N.	40	43·3	3·3	......	......	Quiet; but excited by the slightest noise.
118	A.M. 10	Fine, calm	N.	43	44·2	1·2	......	......	Quiet; bright sunshine.
119	A.M. 11	Fine, calm	N.E.N.	45·6	45·4	......	......	......	Quiet; hive ·2 of degree lower than temperature of the atmosphere.
120	A.M. 12	Fine....................	N.E.N.	46·6	46·3	......	......	......	Hive quiet; ·3 of a degree the temperature of atmosphere.
121	P.M. 1	Sunny, clouds.........	N.E.N.	48	48·1	·1	......	......	Slight humming; a few bees abroad.
122	P.M. 2	Heavy clouds	N.E.	45·3	47·9	2·6	......	......	Hive quiet.
123	P.M. 3	Heavy clouds	N.E.	42·6	47	4·4	......	......	Quiet; very heavy clouds passing.
124	P.M. 4	Heavy clouds	N.E.	41·2	41·2	......	......	......	Quiet; signs of rain; rainbow.
125	13 A.M. 7½	Light rain	N.E.	36	43·7	7·7	......	......	Quiet; hard rain this morning.

Table XIII. (Continued.)

No. of Exp.	Period of observation.	Weather.	Wind.	Atmosphere.	Hive No.1.	Difference.	Excited.	Difference.	Remarks.
	1835.			°	°	°	°	°	
126	Nov. 13 A.M. 9	Light rain	N.E.	37·3	43·7	6·4	......	......	Quiet; cold brisk wind.
127	A.M. 10	Light continued rain	N.E.	37·6	43·9	6·3	......	......	Quiet; less wind; gloomy morning.
128	A.M. 11	Light rain	N.E.	39·6	44·1	4·5	......	......	Quiet; very light wind; sky clearing.
129	A.M. 12½	Sunny	N.E.	39·8	44·9	5·1	......	......	Clouds passing.
130	P.M. 2	Calm	N.E.	41·6	45·8	4·2	......	......	Sunshine; bees attacked by the sparrows.
131	P.M. 3	Rain	E.	39·6	45·8	6·2	......	......	Quiet; heavy clouds, with rain; sky very gloomy.
132	P.M. 4	Rain	E.	38	45·2	7·2	......	......	Quiet; heavy clouds.
133	14 A.M. 7½	Calm, cloudy	N.W.N.	35	43·2	8·2	......	......	Hive a little disturbed.
134	A.M. 8	Calm, fair	N.W.N.	35·4	43·2	7·8	67·3	31·9	When the hive was excited temp. rose in 14^{m} to 67′·3.
135	A.M. 9	Calm, fair	N.W.N.	35·4	47	11·6	......	......	Hive nearly quiet.
136	A.M. 10	Calm, fair	N.W.N.	39·4	46·3	6·9	......	......	Slight humming.
137	A.M. 11	Calm, fair, cold	N.E.N.	40·4	46·9	6·5	69·5	29·1	Raised in 11^{m} to 69′·5; bees appear, but return directly to the hive; air too cold.
138	A.M. 12	Calm, fine	E.N.	42·5	48·5	6	57	14·5	Great excitement; temperature maintained at 57′; bees ventilating, and going abroad.
139	P.M. 2½	Calm, fine	E.N.	42·2	57	14·8	65	22·8	A few bees still abroad; hive still excited.
140	P.M. 4	Calm, fine	E.N.	38	66	28	......	......	Slight humming; very fine evening.
141	P.M. 4½	Calm, fine evening	N.W.	36	56	20	......	......	Slight humming.
142	15 A.M. 8	Calm, fair	N.E.	41	49	8	......	......	Hive quiet; atmosphere rather hazy.
143	A.M. 9	Heavy clouds	N.E.	42·6	50	7·4	......	......	Humming; clouds passing.
144	A.M. 10	Sunny	N.E.	45	50·2	5·2	......	......	Clouds passing.
145	P.M. 1	Bleak wind	N.E.	47	54	7	......	......	Quiet; sky dark, cloudy.
146	P.M. 2	Cloudy, cold	N.E.	45·4	53·6	8·2	......	......	Faint humming; wind bleak.
147	P.M. 4½	Heavy clouds	N.	43·5	51	7·5	......	......	Faint humming; signs of rain.
148	16 A.M. 7½	Dull, cloudy	W.	36·8	46	9·2	......	......	Faint humming.
149	A.M. 8½	Fair, light wind	W.	37·6	46·2	8·6	......	......	Hive quiet.
150	A.M. 9½	Fairer	W.	40·3	46·4	6·1	......	......	Faint humming.
151	A.M. 10½	Dull sky	W.	40·9	46·7	5·8	......	......	Hive quiet.
152	A.M. 11½	Fair	W.N.	44	47·1	3·1	......	......	Humming.
153	A.M. 12½	Fair	W.N.	45·1	48	2·9	......	......	Humming.
154	P.M. 1½	Fair	W.N.	44·7	48·1	3·4	......	......	Quiet, excepting that the humming of a single bee is sometimes heard.
155	P.M. 2½	Fair	W.N.	44	47·8	3·8	......	......	Quiet.
156	P.M. 3½	Fair	N.	40·8	47·2	6·4	......	......	Quiet.
157	P.M. 4½	Calm, clear	N.	37·6	46·7	9·1	......	......	Hive quiet; calm clear evening.
158	17 A.M. 7	Misty, calm	W.	39	45	6	......	......	Quiet; dull misty morning.
159	A.M. 7½	Misty, calm	W.	39·5	45	5·5	......	......	Brisk humming without evident cause.
160	A.M. 8	Misty, calm	W.	40	45·3	5·3	......	......	Hive more quiet.
161	A.M. 8½	Misty, calm	W.N.	40·6	45·4	4·8	......	......	Quiet.
162	A.M. 9	Misty, calm	N.W.	41·4	45·3	3·9	......	......	Humming of a single bee.
163	A.M. 9½	Misty, light wind	N.W.	43·6	45·5	1·9	......	......	Quiet.
164	A.M. 10	Light misty rain	N.W.W.	44·6	46·1	1·5	......	......	Quiet.
165	A.M. 10½	Light misty rain	W.N.	45·2	46·8	1·6	......	......	Quiet; no bees abroad.
166	A.M. 11½	Light misty rain	W.	47·4	47·4	......	......	......	Quiet; heavy clouds.
167	A.M. 12	Light misty rain	W.	48·2	48·1	......	......	......	Quiet; hive °·1 of degree below the atmosphere.
168	A.M. 12½	Light rain	W.	48·4	48·1	......	......	......	Quiet; °·3 of degree below.
169	P.M. 1½	Clouds breaking	W.	48·6	48·3	......	......	......	Quiet; °·3 below; wind increasing; no rain.
170	P.M. 4	No rain	W.	47·6	48·5	·9	......	......	Quiet; cloudy.
171	18 A.M. 8	Very dull	W.	47·8	48·2	·4	......	......	Hive quiet; signs of rain.
172	A.M. 9	Brisk wind	W.	49·2	48·9	......	......	......	Hive quiet; °·3 below atmosphere; cloudy.
173	A.M. 10	Brisk wind	W.	51·4	49·7	......	......	......	Quiet; 1°·7 below the atmosphere; sunshine.
174	A.M. 11	Brisk wind	W.	52	50·9	......	......	......	Quiet; 1°·1 below; dull, cloudy.
175	A.M. 12	Brisk wind	W.S.	52·6	51	......	......	......	Quiet; 1°·4 below; sunny, with clouds.
176	P.M. 2½	Brisk wind	W.S.	51·9	51·6	......	......	......	Very quiet; °·3 below; a few bees abroad.
177	30 P.M. 3	Light rain	S.	54·3	60	5·7	80	25·7	Humming; bees undisturbed for the last 12 days.
178	Dec. 2 P.M. 1	Fine, calm	W.S.	51	75	24	......	......	Many bees abroad; excited without evident cause.
179	P.M. 2½	Fair, sunny	W.S.	49	72·5	23·5	......	......	Bees ventilating; still excited.
180	P.M. 3	Fair, sunny	S.W.	48	73·5	25·5	79·8	31·8	Very irritable.
181	P.M. 3¾	Fair, calm	S.W.	46·5	73	26·5	......	......	Very irritable.
182	P.M. 4	Fair, calm	S.W.	46	......	......	78	32	Clear; moonlight.
183	3 A.M. 8	Windy, cold	S.	49·2	71·5	22·3	......	......	Air damp and cold; bees abroad and very busy.
184	A.M. 9	Brisk wind, cloudy	S.	50	61·5	11·5	......	......	Hive quiet; heavy clouds.
185	A.M. 12½	Brisk wind, cloudy	S.	51	60·7	9·7	......	......	Hive quiet.
186	P.M. 4¼	Brisk wind, cloudy	S.S.E.	49·2	60·2	11	......	......	Hive quiet.
187	4 A.M. 10	Fair, calm	W.	44·2	50·8	6·6	......	......	Light clouds and rain; hive quiet.
188	5 A.M. 8	Fine, clear	W.	34	43·2	9·2	......	......	Hive quiet.
189	P.M. 4	Fine, calm	S.W.	44	47	3	......	......	Hive quiet.
190	12 A.M. 8	Fine morning, light wind	N.	23	39	16	72	49	Hoar frost; has frozen hard during the last 36 hours; bees active, although entirely undisturbed during the last six days; raised the therm. in 11^{m} to 49° above the temperature of the atmosphere.

Table XIII. (Continued.)

No. of Exp.	Period of Observation.	Weather.	Wind.	Atmosphere.	Hive No. 1.	Difference.	Hive No. 2.	Difference.	Excited.	Difference.	Remarks.
	1835.			°	°	°	°	°	°	°	
191	Dec. 12 P.M. 1	Dull, cloudy	W.	38	47·8	9·8	......	......	74·2	36·2	Bees more quiet but readily excited.
192	P.M. 4	Dull, cloudy	W.	36	56	20	......	......	......	......	Bees quiet.
193	13 P.M. 2	Fine, calm	N.W.	41·2	45·2	4	......	......	75·2	34	Slightly active; soil hard frozen in the shade.
194	14 A.M. 11½	Cloudy	S.W.	42·6	45·6	3	......	......	63·5	20·9	
195	23 P.M. 4	Clear frost	N.E.	27	38	11	......	......	72·3	45·3	Bees excited by the slightest noise, although entirely undisturbed for the last nine days, during four of which the temperature of atmosphere has been below 32°, sometimes so low as 24° Fahr. Bees raised the thermometer to 72°·3 in ten minutes.
196	24 A.M. 12	Calm, misty	N.E.	31	42·7	11·7	......	......	......	......	Bees quiet; soil still hard frozen.
197	P.M. 4	Calm, hazy	N.E.	29·5	42	12·5	......	......	......	......	
198	25 A.M. 10½	Calm, fine	N.E.	23	38·4	15·4	......	......	......	......	Bees quiet, but excitable; intense hoary frost.
199	27 A.M. 8	Cloudy, calm	W.	29	39·5	10·5	......	......	......	......	Frost during the night; temperature rising; bees quiet.
200	P.M. 4	Cloudy, thawing......	W.	37	45·4	8·4	......	......	......	......	Bees quiet; a gentle thaw.
201	28 A.M. 8	Cloudy	W.S.	42·7	45	2·3	......	......	......	......	Bees quiet.
202	29 P.M. 1	Fine....................	W.	42·8	46·2	3·4	......	......	......	......	Bees quiet.
203	30 A.M. 8	Light cold rain	N.W.	40	44·9	4·9	......	......	......	......	Bees quiet.
204	1836. Jan. 1 P.M. 2	High wind, sleet ...	N.E.	31·5	44·1	12·6	......	......	72	40·5	Quiet, but excitable; frost, with wind and sleet all day.
205	2 A.M. 7¼	Clear, intense frost...	E.	17·5	30	12·5	......	......	70	52·5	Day-break; starlight; hive excited; temperature raised in 16 minutes, and maintained for several minutes at 70° Fahr., but at 5 inches distant from this part of hive, temperature only 45°, thus giving a temperature of 25° for the bodies of the bees.
206	A.M. 7¾	Sun just risen.........	E.	16·5	63	46·5	......	......	......	......	
207	A.M. 8¼	Light wind	E.	16·5	59	42·5	......	......	......	......	Very fine.
208	A.M. 8½	Light wind	E.	17·5	59	41·5	......	......	......	......	Hive more quiet; very fine.
209	A.M. 9¼	Light wind	E.	18·5	49	30·5	......	......	......	......	Only very faint sounds in the hive.
210	A.M. 12¼	Light clouds	E.S.	30·7	46	15·3	......	......	......	......	Hive quiet; wind shifting; temperature rising rapidly.
211	P.M. 1½	Rather cloudy.........	S.E.	32·3	49	16·7	......	......	......	......	Bees irritable; wind shifting.
212	P.M. 2½	Cloudy	S.E.	31·2	45	13·8	......	......	......	......	Hive quiet.
213	3 A.M. 10	Light clouds	W.	37	43·5	6·5	......	......	......	......	Hive quiet; frost broke suddenly.
214	5 P.M. 1	Sunny, fair	S.W.	50	55	5	......	......	82·2	32·2	Bees undisturbed for three days; excited temperature continued at 70° for several hours; many bees going abroad.
215	13 A.M. 8	Hoar frost	W.	28·5	45	16·5	......	......	......	......	
216	28 A.M. 8	Fair.....................	W.	43·5	59·5	16	......	......	......	......	
217	February 19 A.M. 9	Fine day...............	N.W.	35	47·5	12·5	51	16	......	......	On the 15th inst., a very fine day, I saw many bees enter the hive with *orange, brown* and *grey pollen.*
218	A.M. 11	Fine day...............	N.W.	39·2	48·2	9	52·3	13·1	......	......	
219	P.M. 2	Fine day..............	N.	48·5	50·2	1·7	55·3	6·8	......	......	Fine day.
220	20 A.M. 8	Fine, calm	N.E.	24	44	20	45	21	......	......	Hive quiet; hard frost all night.
221	A.M. 10	Fine....................	N.E.	34·5	48·5	14	91	56·5	102	67·5	Hive No. 2. very active; light clouds.
222	A.M. 11	Light clouds	E.	39·5	48·1	8·6	93	53·5	......	......	Calm cold morning.
223	P.M. 2½	Very fine..............	E.	41·8	58·5	6·7	84·4	42·6	......	......	Bees go abroad but return quickly; air too cold.

Table XIV., showing the Difference between the Temperature of the Atmosphere and that of the same Hive at half-hourly observations, made at precisely the same periods in succeeding years, 1836 and 1837.

No. of Exp.	Period of observation.	1836. Wind, &c.	Atmosphere.	Hive No. 1.	Difference.	Remarks.	1837. Wind, &c.	Atmosphere.	Hive No. 1.	Difference.	Remarks.
	1836.		°	°	°			°	°	°	
1	March 22 A.M. 7	S.W.S. misty, calm...	47	61	14	Dull misty morning.	E. by S. calm, frost	28·6	46·3	17·7	Snow on the ground 2 inches deep; has continued to fall since 12 P.M.; very faint sounds in hive; thick, cloudy.
2	A.M. 7½	S.W.S. misty	47	62	15	Dull; hive quiet; no bees abroad.	E.S. light	29·1	46·4	17·3	Faint sounds; clouds breaking; snow falling.
3	A.M. 8	S.W.S. light wind ...	48	62·2	14·2	No rain; no bees abroad; mist dispersing	S.E.E. calm	30·4	46·4	16	Hive quiet; clouds breaking; sun peeping.
4	A.M. 8½	......	......	......	......	......	S.E.E. calm	33	46·8	13·8	Hive quiet; sun peeping.
5	A.M. 9	......	......	......	......	......	S.E.E. fine, calm	34·1	47·5	13·4	Sunny; hive quiet; birds singing.
6	A.M. 9½	S. very dull, light wind	49·2	62·6	13·4	Has been a light shower	S.E.S. light	35·5	48·6	13·1	Hive quiet; dull, cloudy.
7	A.M. 10	S. dull, moist cold air	48·3	64	15·7	Hive quiet; no bees abroad	S.E. light	33·9	49	15·1	Very dull; cloudy; snowing very fast.
8	A.M. 10½	S. fairer	48·5	64·1	15·6	Hive quiet; horizon clearing	S.E.E. brisk	32·4	48·9	16·5	Hive perfectly quiet; thick fall of snow.
9	A.M. 11	S. very dull	49·6	62·8	13·2	A few bees have just gone abroad	S.E. light	34·3	48·8	14·5	Hive quiet; snow still falling.
10	A.M. 11½	......	......	......	......	......	S.E.S. light	34·6	49	14·4	Snow still falling.
11	A.M. 12	S. fair	48·3	63·6	15·3	Hive quiet; no bees abroad	S. light	37	49·3	12·3	Sky fair; a little snow; fair.
12	A.M. 12½	S. rain, calm	......	63·9	......	Hard steady rain; hive quiet	S. light	37·8	49·9	12·1	Hive quiet; snow falling.
13	P.M. 1	S. rain, calm	48·2	63·9	15·7	Hive quiet; steady rain	S. light	38·6	50·6	12	Fine; a little snow falling.
14	P.M. 1½	S. rain, calm	49·8	64	14·2	Steady rain; hive quiet	S. light	36·6	50·4	13·8	Brisk wind; hive quiet.
15	P.M. 2	S.W.S. rain, calm ...	49·8	63·8	14	A few bees abroad; irritable	S. light	37·5	50·3	12·8	A few bees moving; none abroad; sunny.
16	P.M. 2½	......	......	......	......	......	S. fine	37·6	50·6	13	Hive quiet; sunny; light wind.
17	P.M. 3	S.W.S. rain, calm ...	48·1	64	15·9	A few bees abroad; steady rain	S. by E. fair	37·3	50·6	13·3	Hive quiet; no bees abroad; sunny.
18	P.M. 3½	S.W.S. fair	48·7	63·9	15·2	No rain; bees abroad, but no *pollen* collected	S. by E. light	36·8	50·9	14·1	Faint sounds in the hive; fair.
19	P.M. 4	S.W.S. fair	49·3	63·3	14	Many bees abroad; irritable	S. light	35·7	50·1	14·4	Hive quiet; fair; cold.
20	P.M. 4½	......	......	......	......	......	S. fair, light	35·7	50	14·3	Fleecy clouds; hive quiet.
21	P.M. 5	S.W.S. dull	49·2	63·1	13·9	No rain; a few bees abroad	S. fair, light	34·7	49·6	14·9	Sunny; light.
22	P.M. 5½	......	......	......	......	......	S. calm	33·7	49·3	15·6	Hive quiet; calm.
23	P.M. 6	S.W.S. very dull	48·3	62·5	14·2	Hive quiet; no rain	S. by W. calm	32·5	49	16·5	Dull evening.
24	P.M. 6½	S.W.S. dull	48	62·5	14·5	No rain; evening hazy	S. by W. calm	31·5	48	16·5	Dull; cold; hive perfectly quiet.
25	23 A.M. 7	S.S.W. calm, cloudy	45·5	60	14·5	Hive quiet; light rain	S. by W. light	32	45	13	Hive quiet; cloudy; thick snow last night.
26	A.M. 7½	S.S.W. hazy	45·7	60·7	15	Hive quiet; misty rain	S. by W. brisk	32·6	45·4	12·8	Hive quiet; cloudy.
27	A.M. 8	S.S.W. fair	47·2	60·3	13·1	Light wind; sun peeping	S. by W. brisk	33·3	46·9	13·6	Very faint humming; very cloudy.
28	A.M. 8½	S.S.W. fair	47·3	61	13·7	Light rain and wind; clouds dispersing	S.E. by S. brisk	33·9	48·4	14·5	Faint humming; slightly disturbed.
29	A.M. 9	S.S.W. fair	49·3	61·6	12·3	Hive quiet; a few bees come abroad	E. by S. brisk	34	49·2	15·2	Very faint humming; cloudy.
30	A.M. 9½	S.S.W. fair	51	61	10	More wind; more bees abroad	E. by S. brisk	34·7	50·9	16·2	
31	A.M. 10	S.S.W. brisk	51	63	12	Bees active; *scarlet* and *orange pollen*	E. brisk	35·5	52·6	17·1	Hive quiet; fair.
32	A.M. 10½	S.S.W. brisk	50·6	64	13·4	Many bees with *pollen*	E. by S. brisk	36·9	53·6	16·7	Hive aroused; sunshine.
33	A.M. 11	S.S.W. brisk	49·7	62	12·3	Bees active	E. by S. brisk	36·8	54	17·2	
34	A.M. 11½	S.S.W. brisk, cloudy	50·2	63	12·8	Quantity of *pollen* collected scanty	E. brisk	36·6	55·2	18·6	Slight humming.
35	A.M. 12	S.S.W. brisk	49·9	63·9	14	Hive quiet; bees abroad	E. brisk	36·5	55·5	19	Hive quiet; fair; cold.
36	A.M. 12½	S.S.W. fair	49·7	64·6	14·9	Very light rain; few bees abroad	E. brisk	37	55·9	18·9	Slight humming; cloudy.
37	P.M. 1	S.S.W. rain, calm ...	50	64·7	14·7	Steady rain	E. brisk	38·3	56·5	18·2	Slight humming; cloudy; snow has fallen.
38	P.M. 2	S.S.W. rain	47·3	64·7	17·4	Continued hard rain	E. brisk	37·5	56	18·5	Hive a little excited; sunny, with clouds.
39	P.M. 5	S. brisk	45	61·2	16·2	Hard continued rain since 2 o'clock ...	E. calm	32	56·2	24·2	Fine afternoon; calm; hive quiet; frost.
40	24 A.M. 7	W. fair, light wind...	37	57	20	Sunny; heavy dew on grass					
41	A.M. 7½	W. fair, light wind...	41	58	17	Hive quiet; sunshine; cold wind					
42	A.M. 8	W. brisk	42·5	59	16·5	No bees yet abroad					
43	A.M. 11	W. brisk, sunshine...	50	59·2	9·2	Bees active; *orange* and *yellow pollen*					
44	P.M. 1	W. brisk	50	62	12	Many bees with *pollen*					
45	P.M. 1½	W. cold, brisk wind	49·6	62·1	12·5	*Pollen* still collected					
46	P.M. 4	W. cold	45	61	16	Hive quiet; no bees abroad					
74	P.M. 5	W. cold	44·5	60·3	15·8	Hive quiet, and signs of rain					

Table XV.

Showing the Temperature of the Atmosphere and of the Bee Hives No. 1 and No. 2 every fifteen minutes during thirteen successive hours on the 2nd April, 1837, and of Hive No. 1 on the same day in April, 1836.

	1837.							1836.				
No. of Exp.	Period of observation.	Wind.	Atmosphere.	Hive No. 1.	Difference.	Hive No. 2.	Difference.	Wind.	Atmosphere.	Hive No. 1.	Difference.	Remarks on the Hives and Weather, 1837.
	1837.		°	°	°	°	°		°	°	°	
1	April 2. A.M. 6	Calm N.W.N.	26·2	53·5	27·3	52·8	26·6	......	......	......	......	Hard frost; very fine; slight humming in the hive.
2	A.M. 6¼	Calm N.W.N.	26·2	53·5	27·3	52·2	26	......	......	......	......	Slight humming; light fleecy sky.
3	A.M. 6½	Calm N.W.N.	27·6	54·4	26·8	54	26·4	High N.W.......	35	59	24	Slight humming; stratified clouds in the west.
4	A.M. 6¾	Calm N.W.N.	29·3	54·4	25·1	54·8	25·5	High N.W.......	36	61	25	Slight humming in both hives.
5	A.M. 7	Light N.W.N.	33	54·5	21·5	57·6	24·6	High N.W.......	36·8	59	22·2	Very fine; clouds fleecy.
6	A.M. 7¼	Light N.W.N.	33·5	54·6	21·1	59	25·5	......	......	......	......	Very fine.
7	A.M. 7½	Light N.N.W.	35·7	56·3	20·6	60·3	24·6	High N.W.......	38·5	58·9	20·4	Both hives quiet; very fine morning.
8	A.M. 7¾	Light N.N.W.	36·9	57·6	20·7	60·8	23·9	......	......	......	......	Quiet; stratified clouds in the west; fine.
9	A.M. 8	Light N.N.W.	38·5	56·7	18·2	60·7	22·2	High N.W.......	39·5	61·1	21·6	Hives still quiet.
10	A.M. 8¼	Light N.N.W.	42	57·6	15·6	64	22	......	......	......	......	Very fine; hives quiet.
11	A.M. 8½	Light N.N.W.	43·2	59·5	16·3	63·8	20·6	High N.W.......	41	60·5	19·5	Not a bee has yet gone abroad.
12	A.M. 8¾	Light N.N.W.	44·3	59·6	15·3	63·2	18·9	......	......	......	......	Male of *Anthophora retusa* abroad.
13	A.M. 9	Light N.N.W.	45·7	60·7	15	63·3	17·6	High N.W.......	42	60·3	18·3	Very fine; fleecy clouds in the west.
14	A.M. 9¼	Light N.	47·2	61·7	14·5	64·3	17·1	......	......	......	......	Not a bee has yet left the hives.
15	A.M. 9½	Light N.	47·6	63·7	16·1	67·3	19·7	......	......	......	......	First bee left the hive at 9h 35″.
16	A.M. 9¾	Light N.	49·3	64·7	15·4	67	17·7	......	......	......	......	Sky fleecy; two or three more bees abroad.
17	A.M. 10	Light N..	50·4	65·4	15	69·1	18·7	High N.W.......	44	61·3	17	First bee just returned with *pollen*.
18	A.M. 10¼	Light N.	49·5	66·5	17	75·6	26·1	......	......	......	......	Three more bees have returned with *pollen*.
19	A.M. 10½	Light N.	50·5	69·2	18·7	76·1	25·6	High N.W.......	44·5	61·4	16·9	Many bees abroad; sky fleecy; very fine.
20	A.M. 10¾	Light N.	49·5	70	20·5	77	27·5	......	......	......	......	Many bees returning with pollen.
21	A.M. 11	Light N.	48·3	73·9	25·6	78·3	30	......	......	......	......	Much *yellow pollen* collected, some *orange*.
22	A.M. 11¼	Light N.	47	72·7	25·7	80	33	......	......	......	......	Fine bright clouds; bees irritable.
23	A.M. 11½	Light N. by E.	45·6	72·6	27	79	33·4	......	......	......	......	Very fine; *pollen* collected.
24	A.M. 11¾	Light N. by E.	45	74	29	78·2	33·2	......	......	......	......	Very fine; hives active.
25	A.M. 12	Light N.	46	73·8	27·8	78·6	32·6	......	......	......	......	Seven loaded bees return per minute.
26	A.M. 12¼	Light N. by W.	47·5	73·6	26·1	79·3	31·8	......	......	......	......	Wind shifting; much *pollen collected.*
27	Noon 12½	Light N.N.W.	45·2	74·4	29·2	79	33·8	High N.W.W.	48	64·7	16·7	Fourteen loaded bees return per minute.
28	P.M. 12¾	Light N.N.W.	45·6	75·3	29·7	78·8	33·2	......	......	......	......	Sky fleecy; few bees going abroad; many returning.
29	P.M. 1	Light N.N.W.	49·2	75·3	26·1	82·7	33·5	......	......	......	......	Ten loaded bees per minute.
30	P.M. 1¼	Brisk N.N.W.	48·9	74·6	25·7	81	32·1	......	......	......	......	Bees fighting at entrance of the hive.
31	P.M. 1½	Light W.......	48·2	74·6	26·4	81	32·8	High N.W.W.	48	62·8	14·8	Fair; bees flocking home hastily; few go abroad.
32	P.M. 1¾	Light W. by S.	47·7	75·9	28·2	78	30·3	......	......	......	......	Rather overcast; very few bees abroad.
33	P.M. 2	Brisk W.S. ...	47·7	75·3	27·6	74	26·3	......	......	......	......	Overcast; scarcely a bee goes abroad.
34	P.M. 2¼	Brisk W.S. ...	47·5	74·4	26·9	75	27·5	......	......	......	......	Dull; cold wind.
35	P.M. 2½	Brisk W.S. ...	46·2	74·9	28·7	72	25·8	High N.W.W.	46·8	64	17·2	Dull; not a bee abroad.
36	P.M. 2¾	Brisk W.S. ...	45·5	73·6	28·1	70	24·5	......	......	......	......	Dull; slight humming in the hive.
37	P.M. 3	Brisk W.S. ...	45·3	74	28·7	68·2	22·9	High N.W.W.	44	65·2	21·2	Very dull; signs of rain.
38	P.M. 3¼	Brisk W.S. ...	45·5	73·5	28	67·3	21·8	......	......	......	......	Very dull.
39	P.M. 3½	Brisk W.S. ...	44·5	73·5	29	67	22·5	High N.W.W.	42·6	62·5	19·9	Very dull.
40	P.M. 3¾	Light S.W. ...	43·5	72	28·5	65	21·5	......	......	......	......	Very dull; hives quiet.
41	P.M. 4	Light S.	45·3	71·5	26·2	63·3	18	High N.W.W.	40·5	62	21·5	Fair.
42	P.M. 4¼	Light S.	43·1	72	28·9	64·3	21·2	......	......	......	......	Fair.
43	P.M. 4½	Light S.	42·5	71	28·5	64	21·5	......	......	......	......	Sunny, with clouds.
44	P.M. 4¾	Light S.	42·5	71	28·5	66	23·5	......	......	......	......	Dull; moist cool wind.
45	P.M. 5	Light S.W. ...	42·6	71	28·4	67	24·4	Brisk N.W.W.	41	60·3	19·3	Dull; hazy.
46	P.M. 5¼	Light W.......	41·8	69·2	27·4	64	22·2	......	......	......	......	Dull; slight humming in the hive.
47	P.M. 5½	Light W.......	41·6	69·	27·4	63	21·4	......	......	......	......	Very dull.
48	P.M. 5¾	Light W.......	41·5	68·9	27·4	62·5	21	......	......	......	......	Dull.
49	P.M. 6	Light W.......	40·3	67·2	26·9	62·	21·7	Brisk N.W. ...	41	61·1	20·1	Dull; hives quiet.
50	P.M. 6¼	Light W.......	40·5	67·1	26·6	62·8	22·3	......	......	......	......	Dull.
51	P.M. 6½	Light W.S. ...	40·2	67·2	27	62	21·8	......	......	......	......	Dull.
52	P.M. 6¾	Light N.W....	40	68	28	63	23	......	......	......	......	Dull.
53	P.M. 7	Light N.	39	67·6	28·6	62·5	23·5	Brisk N.W. ...	40·3	61	20·7	Very much overcast; hives quiet.
54	P.M. 10	Calm	32	......	......	......	......	......	......	......	......	Very cloudy.

Table XVI.

Mean daily Temperature of the Atmosphere and Bee Hive No 1. as deduced from observations made at about the hours of seven, nine, and twelve in the morning, and two and five in the afternoon, from October 23, 1835, to November 18, 1835; and of the Hives No. 1 and 2 from February 19, to September 30, 1836.

No. of Exp.	Period of observation.	Prevailing.	Wind.	Weather.	Atmosphere.	Hive No. 1.	Difference.	Hive No. 2.	Difference.	Remarks.
	1835.				°	°	°	°	°	
1	Oct. 23	....	....	Fine	47·37	58·37	11			Bees active.
2	24	W. by S.	Light	Cloudy	52·8	60·03	7·23	......	......	*Pollen* collected in the morning.
3	25	S.	High	Hard rain......	47·5	55·1	7·6	......	......	*Pollen* collected in the morning.
4	26	W. by S.	High	Showery	49·48	55·56	6·08	......	......	Scarcely a bee abroad.
5	27	W. by N.	Light	Light clouds ...	45·26	52·3	7·04	......	......	A few bees abroad.
6	28	W.	Calm	Fine	40·2	54·84	14·64	......	......	A few bees abroad.
7	29	S.W.	Calm	Hazy	54·33	60·33	6	......	......	*Pollen* collected; many bees abroad.
8	30	E. by S.	Light	Haze and rain	48·1	57·3	9·2	......	......	Much *pollen* collected in the morning.
9	31	S.W.	Shifting	Fair	54·24	65·20	10·96	......	......	*Pollen* scanty; many bees abroad.
	Mean temperature in October			....	48·80	57·67	8·87			
10	Nov. 1	N.E.	Light	Fine	45·2	61·06	15·86	......	......	*Pollen scarce*; many bees abroad.
11	2	S.W.	Light	Fair	48·16	54·87	6·71	......	......	Hive quiet; but a few bees abroad.
12	3	S.E.	Brisk	Misty rain	46·37	53·87	7·50	......	......	No bees abroad.
13	4	E.	Brisk	Showery	42·67	50·32	7·65	......	......	Hive quiet; no bees abroad.
14	5	E.	Light	Steady rain......	44·15	49·57	5·42	......	......	Hive quiet.
15	6	N.E.	Calm	Fine	40·38	47·28	6·90	......	......	A few bees abroad; a little *pollen* collected.
16	7	N.E.	Shifting	Fair	47·88	61·5	13·62	......	......	A little *pollen* collected; bees disturbed.
17	8	N.W.	Brisk	Fine	43·16	56·38	13·22	......	......	Many bees abroad.
18	9	N.E.	Brisk	Cloudy	41·16	49·14	7·98	......	......	Cold bleak wind; hive quiet.
19	11	N.E.N.	Calm	Hazy rain	38·03	44·26	6·23	......	......	Hive quiet; a little sleet this morning.
20	12	N.E.N.	Light	Light clouds ...	41·62	44·42	2·80	......	......	A few bees abroad, but return quickly.
21	13	N.E.	Light	Rain & clouds	38·34	44·66	6·32	......	......	No bees abroad.
22	14	N.E.N.	Shifting	Calm, fair	38·22	50·34	12·12	......	......	Bees greatly disturbed.
23	15	N. E.	Bleak	Cloudy	43·9	55·52	11·62	......	......	Hive nearly quiet.
24	16	W. by N.	Light	Fair	40·76	46·98	6·22	......	......	Hive quiet.
25	17	W.	Calm	Misty rain	44·96	47·04	2·08	......	......	Clouds and light wind.
26	18	W. by S.	Brisk	Cloudy	50·37	49·92	......	......	......	A few bees go abroad,
	Mean temperature in November			....	43·35	51·0	7·65			
	1836.									
27	Feb. 19	N.W.	Light	Fine	40·9	48·63	7·73	53·03	12·13	*Pollen* was collected on the 15th inst.
28	20	N.E.E.	Calm	Fine	35·7	50·2	14·5	74·13	38·43	Bees in No. 2 much disturbed.
29	21	N.W.	Light	Fine	38·3	51·1	12·8	60·26	21·96	Many bees go abroad, but soon return.
30	22	W.	Light	Fine	43·07	50	6·93	58·47	15·40	*Pollen* again collected.
31	23	W. by S.	Light	Light clouds ...	43	50·1	7·1	54·86	11·86	*Pollen* collected; bees fighting. [*diarrhœa*.
32	24	S.W.	Light	Showery	42·6	50·7	8·1	56·16	13·56	*Pollen* collected; bees of No. 1. fighting; have
33	25	W.	Brisk	Fine	42·3	54·4	12·1	60·7	18·4	*Pollen* collected.
34	26	N.E.	Light	Rain and sleet	38·9	49·47	10·57	54·25	15·35	Hives quiet; rain, sleet, snow, and wind.
35	27	W.	Light	Cloudy	39·	48·22	9·22	53·98	14·98	Hives quiet.
36	28	W.	Light	Fair	39·82	48·37	8·55	54·72	14·90	Hives less quiet; no bees abroad.
37	29	W.	Light	Fine	40·26	49·96	9·70	55·15	14·89	*Pollen* collected, bees fighting, have *diarrhœa*.
	Mean temperature in February			....	40·35	50·10	9·75	57·79	17·44	
										[*diarrhœa*.
38	March 1	S.S.E.	Brisk	Rain, cloudy...	45·66	54·8	9·14	61·5	15·84	Hives quiet; bees disposed to come abroad;
39	2	W.	Brisk	Fine	45·4	52·4	7	58·73	13·33	Many bees abroad fighting.
40	3	W.	Light	Rain	46·08	55·8	9·72	59·18	13·10	Bees abroad; only one returned with *pollen*.
41	4	W.	Light	Fine	47·2	58·48	11·28	58·74	11·54	*Pollen* collected; many bees abroad.
42	5	S. W.	High	Hard rain	46	53·54	7·54	61·92	15·92	Scarcely a bee abroad to-day.
43	6	S.S.E.	High	Continued rain	47·6	55·12	7·52	57·67	10·07	Hives quiet.
44	7	S.S E.	Light	Fair	44·6	53·04	8·44	55·2	11·60	Bees abroad, fighting, have *diarrhœa*.
45	8	N.N.E.	Light	Cloudy	40·03	50·2	10·17	55·	14·97	A little *pollen* collected.
46	9	S. by E.	Shifting	Cloudy	37·93	47·6	9·67	51·83	13·90	No bees abroad.
47	12	S.W.	High	Rain	47·6	55·7	8·1	......	......	Weather tempestuous; a few bees abroad.
48	13	W.	Brisk	Fair	47·48	57·26	9·78	......	......	Many bees with *pollen*.
49	14	W.	High	Rain	49·3	58·4	9·1	......	......	No bees abroad.
50	15	W.	Tremendous	Hard rain	50	57·1	7·1	......	......	Scarcely a bee abroad.
51	16	N.W.	Light	Fine	43·17	51·97	8·80	......	......	*Pollen* scanty; a few bees abroad.
52	17	W. by S.	High	Cloudy	49·5	55·3	5·8	......	......	No bees abroad.
53	18	S.S.W.	Light	Fine	53·34	65·5	12·16	......	......	*Pollen* in abundance; bees fighting.
54	19	E.S.E.	Light	Fine	54·64	71·6	16·96	......	......	*Pollen* collected in abundance; fighting.
55	20	W.	Light	Hazy	49·36	65·46	16·10	......	......	*Pollen* scarce, only a few bees abroad.
56	21	S.W.	Light	Misty rain	48·14	63·04	14·90	......	......	Very few bees abroad.

Table XVI. (Continued.)

No. of Exp.	Period of observation.	Prevailing.	Wind.	Weather.	Atmosphere.	Hive No. 1.	Difference.	Hive No. 2.	Difference.	Remarks.
	1836.				°	°	°	°	°	
57	Mar. 22	S.W.S.	Var. light...	Clouds and rain	48·7	62·82	14·12	......	......	Scarcely a bee abroad; no *pollen* collected.
58	23	S.S.W.	Light	Clouds, rain ...	47·4	62·28	14·88	......	......	*Pollen* collected in the morning.
59	24	W.	Brisk	Very fine.........	44·72	59·52	14·80	......	......	Bees active; much *orange* and *yellow pollen.*
60	25	S.W.	Brisk	Fine light clouds	51·3	67·6	16·3	......	......	*Pollen* collected; bees very active.
61	26	W.N.W.	High	Stormy	42·64	60·64	18	......	......	No bees abroad; rain and hail.
62	27	S.S.E.	Brisk	Fine..............	46·3	61·84	15·54	......	......	*Pollen, orange* and *yellow*, collected.
63	28	S. W.	Var. high...	Rain	43·8	62·6	18·8	......	......	No bees abroad; hive quiet.
64	29	W.	High	Heavy clouds ...	46·16	60·8	14·64	......	......	But few bees abroad; no *pollen.*
65	30	S. W.	Var. high...	Hard rain	49·8	63·8	14	......	......	Hive quiet; weather tempestuous.
66	31	W.	High	Fair..............	47·2	54·9	7·7	......	......	*Scarlet* and *orange pollen* collected; many bees abroad.
		Mean temperature in March.........			46·93	58·59	11·66	57·75	10·82	{ Mean temperature of No. 2, in the first nine days of March.
67	April 1	N.E.E.	High	Rain and snow	41·5	59·5	18	......	......	No bees abroad; hard continued rain with snow.
68	2	N.W.W.	High	Cloudy	42·9	61·66	18·76	......	......	A few bees abroad with *pollen.*
69	3	N.W.	High	Stormy	48·75	63·05	14·30	......	......	Many bees abroad perished with the wind.
70	4	N.N.W.	Light	Very fine.........	45·9	72·3	26·4	......	......	*Orange* and *yellow pollen* in abundance.
71	5	S.S.W.	Light	Fine..............	48·66	71·44	22·78	97·3	48·64	*Pollen* in abundance; Hive No. 2 much disturbed.
72	6	S.E.	Var. light...	Fair..............	45·9	71·2	25·3	67·3	21·4	But few bees abroad; cloudy, fair.
73	7	S. W.	Brisk	Sunny	51·76	72·03	20·27	68·06	16·30	*Pollen, scarlet, orange,* and *yellow* in abundance.
74	8	S.W.S.	High	Cloudy	47·5	68·2	20·7	65·27	17·77	No *pollen* collected; few bees abroad.
75	9	S. W.	Light	Fair..............	49	69·54	20·54	67·16	18·16	*Pollen* in abundance, *scarlet, white, yellow, brown.*
76	10	S. E.	Var. light...	Showery	50·56	73·44	22·88	71·42	20·86	*Pollen* abundant, *orange, yellow, scarlet, grey, white, brown.*
77	11	N. by W.	Light	Light clouds ...	51·46	72·68	21·22	72·42	20·96	Pollen abundant, *orange, yellow, scarlet, grey, white.*
78	12	S. W.	Brisk	Fair..............	48·42	69·75	21·33	69·87	21·45	Few bees abroad; signs of rain.
79	13	S. W.	Brisk	Fair..............	52·06	72·84	20·78	72·54	20·48	Bees very busy; *pollen orange, scarlet, yellow, grey.*
80	14	S.	Var. light...	Dull..............	51·45	73·5	22·05	73·75	22·30	Bees very busy; damp atmosphere.
81	15	S.E.	Light	Fair..............	57·76	76·72	18.96	81·6	23·84	Signs of rain; bees still very active.
82	16	S.E.	Light	Fine..............	54·42	76·26	21·84	85·86	31·44	*Pollen* in abundance, *scarlet, orange, grey, yellow, brown.*
83	17	S.W.S.	Var. calm...	Light rain	47·26	74·66	27·40	76·98	29·72	A few bees abroad.
84	18	W.	Light	Light rain	49·06	78·78	29·72	77·34	28·28	A few bees abroad, no *pollen collected.*
85	19	W.	Calm	Fine..............	50·72	74·77	24·05	79·62	28·90	*Pollen* in abundance, *yellow, white, grey, orange, scarlet.*
86	20	W.	Brisk	Fair..............	53·3	75·9	22·6	85·55	32·25	Bees very active; working.
87	21	W.	Light	Fine..............	51·2	73·46	22·26	86·7	35·5	Many bees abroad; working.
88	22	S.W.	High	Very fine.........	54·88	76·74	21·86	86·8	31·92	*Pollen* in abundance, chiefly dirty *white* and *orange.*
89	23	S.W.	Brisk	Rain and fair ...	51·98	75·26	23·28	85·52	33·54	But few bees abroad; showery.
90	24	S.	Calm	Steady rain	48·6	75	26·4	79·5	30·9	Very few bees abroad.
91	25	N.E.	Light	Fine..............	54·42	77·2	22·78	81·5	27·08	Bees very active; working.
92	26	N.	Light	Fine..............	55·22	81·65	26·43	82·2	26·98	Many bees abroad; *pollen abundant.*
93	27	N. E.	Var. brisk...	Fair..............	48·5	78·75	30·25	79·62	31·12	Few bees abroad.
94	28	N.	Light	Cloudy	47·25	74·4	26·15	80·9	32·65	Few bees abroad.
95	29	N.	High	Fair..............	48·36	75·83	26·47	80·93	31·57	Pollen nearly all *deep orange*; a fall of snow this morning.
96	30	E. by N.	Var. light...	Fine..............	49·26	75·62	26·36	78	28·74	{ Thick ice this morning; abundance of *pollen*, chiefly *deep orange.*
		Mean temperature in April			49·93	73·07	23·14	78·22	28·29	
97	May 1	N.	High	Fair..............	55·3	79·65	24·35	81·65	26·35	Many bees abroad; *pollen* abundant.
98	2	E.	Tremendous,	Hard rain	47·1	74·16	27·06	76·53	29·43	Snow this morning; rain all day.
99	3	N.E.N.	Very high	Fine..............	53·25	77·7	24·45	79·27	26·02	Abundance of *pollen, orange* and *scarlet.*
100	4	N.E.	Brisk	Fine..............	55·67	80·5	24·83	83·57	27·90	Abundance of *pollen, orange* and *white.*
101	5	E.	Light	Showery	50·36	84·54	34·18	83·5	33·14	Many bees abroad.
102	6	E.	Light	Very fine.........	56·67	84·12	27·45	87·87	31·20	Great commotion in the hives; young bees hatching.
103	7	E.	Light	Very fine.........	59·74	85·26	25·52	91·42	31·68	*Abundance* of *pollen, scarlet, yellow, brown, grey, orange.*
104	8	E. by S.	Brisk	Very fine.........	57·54	83·5	25·96	91·7	34·16	Many bees abroad; working.
105	9	N. E.	Light	Very fine.........	57·84	82	24·16	92·28	34·34	Bees very active.
106	10	E.	Brisk	Fine..............	57·92	83·16	25·24	89·66	31·74	Drone bees have just appeared.
107	11	W.	Light	Very fine.........	57·78	81·92	24·14	89·22	31·44	Hoar frost last night; *pollen* collected.
108	12	W.	Light	Very fine.........	51·8	87·16	35·36	91·66	39·86	Many drones abroad; bees active.
109	13	W.	Light	Very fine.........	66·98	87·06	20·08	96·17	29·19	Drones abroad; bees beginning to lay out for swarming.

TABLE XVI. (Continued.)

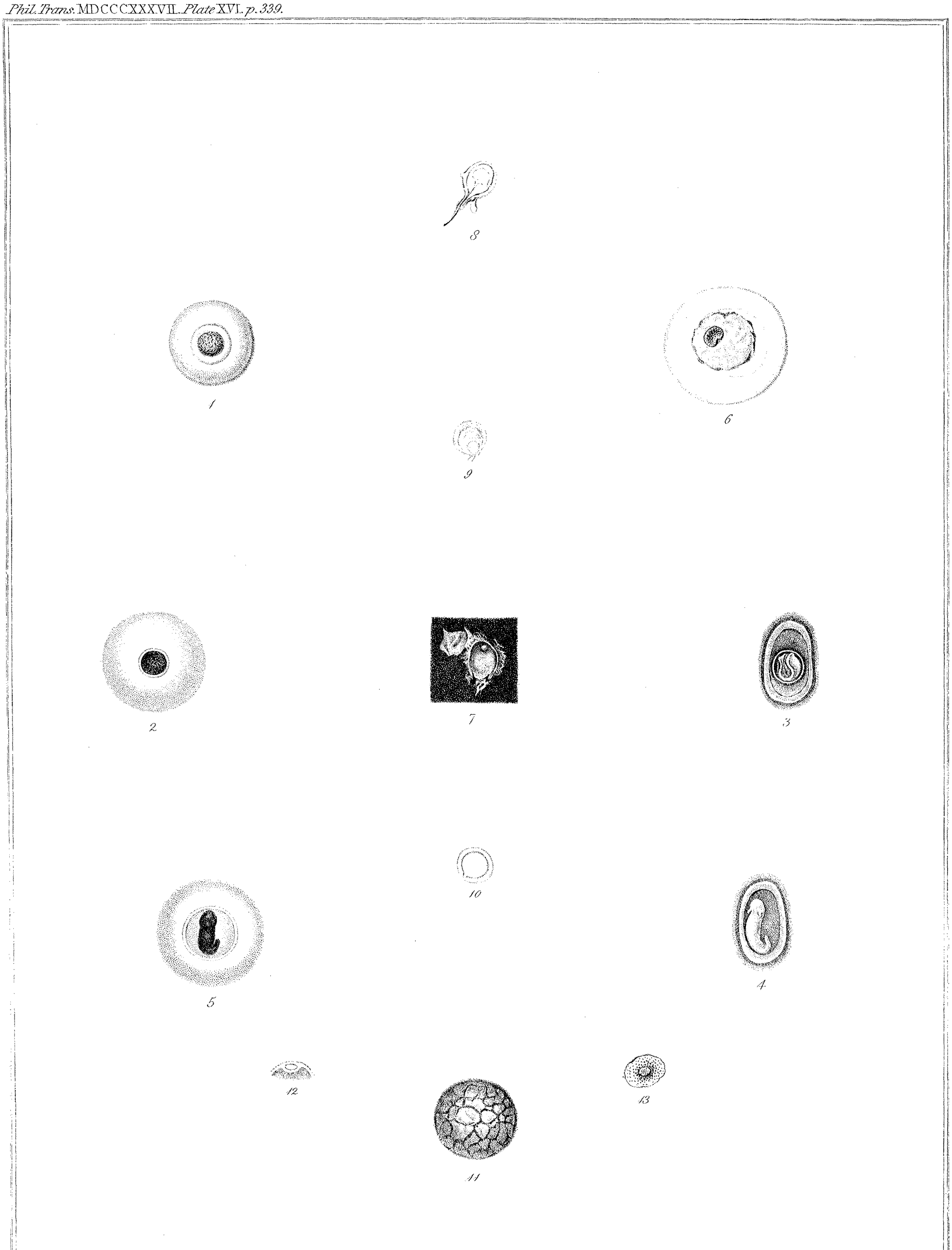
No. of Exp.	Period of observation.	Prevailing.	Wind.	Weather.	Atmosphere.	Hive No. 1.	Difference.	Hive No. 2.	Difference.	Remarks.
	1836.				°	°	°	°	°	
110	May 14	N. by E.	Calm ...	Very fine......	68·36	87·36	19	92·82	24·46	Bees hanging out; loud humming in the hives.
111	15	N.	Light ...	Very fine......	66·74	89·48	22·74	90·94	24·20	Hive No. 2 lifted to prevent swarming. *Sun eclipsed* at 2 P.M.
112	16	S.	Var. light	Fine...........	67·52	88·8	21·28	96·06	28·54	Bees hanging out, much excited; hive replaced.
113	17	E.	Light ...	Very fine......	65·4	89·28	23·88	93·98	28·58	Bees hanging out; drones abroad.
114	18	S.E.	Light ...	Very fine......	71·06	93·9	22·84	95·5	24·44	Bees hanging out.
115	19	E.	Light ...	Light clouds	67·74	92·8	25·06	93·22	25·48	No bees hanging out, except a few in the morning.
116	20	S.E.	Light ...	Very fine......	67·54	94·04	26·50	94·36	26·82	Bees again hanging out.
117	21	E.	Light ...	Dull day......	61·17	95·37	34·20	93·7	32·53	Bees still hanging out.
118	22	E.	Brisk ...	Fine...........	61·77	92·83	31·06	92·83	31·06	No bees hanging out; very few abroad.
119	23	E.	Brisk ...	Dull day......	52·75	88·41	35·66	88	35·25	No bees hanging out; very few abroad.
120	24	N.E.	Light ...	Fair...........	59·75	88·45	28·70	90·2	30·45	Many bees abroad, but not hanging out.
121	25	N.E.	Light ...	Fair...........	57·08	86·7	29·62	91·8	34·72	Many bees abroad, but not hanging out.
122	27	E.	Brisk ...	Fine...........	63·03	92·43	29·40	93	29·97	*Hive No. 2 swarmed suddenly* at 2½ P.M.
	Temperature of No. 2 up to period of swarming..................							90·06	29·89	
123	28	E.	Light ...	Fair...........	50·04	90·28	40·24	86·24	36·20	A dead drone and *queen nymph* thrown out from the swarmed Hive No. 2.
124	29	N.E.	Light ...	Very fine......	63·5	89·75	26·25	91·75	28·25	Very few bees at entrance of Hive No. 2.
125	30	N.E.	Light ...	Fine...........	65·12	90·1	24·98	90·75	25·63	*Three queen nymphs* ejected from Hive No. 2.
126	31	N.E.	Light ...	Fine...........	68·8	91·72	22·92	92·4	24·6	Abundance of *pollen* brought home.
	Mean temperature in May				60·17	87·08	26·91	90·06	29·89	
	Total mean temperature of four months before swarming				49·34	67·21	17·87	70·95	21·61	
127	June 1	N.E.	Light ...	Showery	60·37	87·7	27·33	90·1	29·73	Bees of both hives very busy.
128	2	N.E.	Shifting	Rain	56·02	84·37	28·35	86·4	30·38	Bees abroad in the morning.
129	3	S.S.W.	High ...	Rain	51·7	87·25	35·55	88·7	37	Bees very active.
130	4	S.S.W.	High ...	Fair...........	60·5	86·16	25·66	85·16	24·66	Few bees abroad.
131	5	S.W.W.	Brisk ...	Dull..	61·8	86	24·2	88	26·2	Signs of rain; few bees abroad.
132	6	S.W.	High ...	Fine...........	63·37	90	26·63	89·45	26·08	Many bees abroad.
133	7	S.	Brisk ...	Fine...........	58·4	89·15	30·75	89·8	31·4	Many bees abroad.
134	8	S.	Brisk ...	Rain	61·85	90·5	28·65	89	27·15	Bees of No. 1 working in the side box.
135	9	S.	Light ...	Dull...........	62·5	91·5	29	....	......	Working in side box; many abroad.
136	11	S.W.	High ...	Fair...........	65·75	90·7	24·95	85·95	20·20	Bees very busy; (many bees at entrance of Hive No. 1.)
137	12	S.W.	High ...	Very fine......	64·6	88·37	23·77	86·95	22·35	Symptoms of swarming again in Hive No. 2.
138	13	S.W.	Light ...	Very fine......	70·6	94·83	24·23	93	22·4	Bees much agitated at entrance of No. 2.
139	14	N.E.	Var. light	Very fine......	71·2	92·24	21·04	90·16	18·96	Loud sounds in both hives; *pollen* abundant.
140	15	E.	Light ...	Fair...........	73·64	92·14	18·50	91·94	18·30	Evening showery, and *bees hanging out again* from No. 2.
141	16	W.	Light ...	Fine...........	65·12	88·84	23·72	88·32	23·20	Evening stormy, with thunder; bees hanging out.
142	17	E.	Light ...	Fine...........	66·22	90·38	24·16	89·54	23·32	Evening stormy; bees hanging out.
143	18	S.W.	Brisk ...	Very fine......	66·04	87·17	21·13	82·66	16·62	*Second swarm* left Hive No. 2 at 7 A.M.
144	19	W.	Light ...	Fine...........	64·4	86·43	22·03	83·56	19·16	Showery; Hive No. 2 very thin.
145	20	W.	Light ...	Very fine......	65·82	89·37	23·55	84·75	18·93	Temperature of Hive 2 reduced.
	Mean temperature in June..................				63·67	*89·11	25·44	†87·96	24·29	
146	July 20	W.	Light ...	Fair...........	58·32	78·65	20·33	....	......	Has rained hard for thirty-six hours; bees active.
147	21	W.	Light ...	Showery	62	78	16	....	......	Bees very active; *pollen black.*
148	22	W.	Light ...	Showery	60·98	80·33	20·35	....	......	Many bees abroad; no drones have yet been killed.
149	23	S.W.	Var. light	Fair...........	63·96	84·14	20·18	....	......	Bees in No. 1 disturbed.
150	24	S.W.	Light ...	Fair...........	63·92	79·47	15·55	....	......	Killing drones in the *first swarm* from No. 2.
151	25	W.	Light ...	Light clouds	67	78·15	11·15	....	......	Bees very active.
152	26	W.	Light ...	Very fine......	68·15	80·15	12	....	......	Many bees abroad.
153	27	W.	Brisk ...	Dull...........	63	79	16	....	......	Massacre of drones in the swarm continues.
154	28	E. by S.	Light ...	Fine...........	65·8	80·1	14·3	....	......	Bees very active.
	Mean temperature in July				63·68	79·77	16·09			
155	Aug. 2	W.	Light ...	Very fine......	65·47	75·1	9·63	....	......	Attacking the drones in *second* swarm from No. 2.
156	4	S.	Light ...	Fair...........	67·73	81·2	13·47	....	......	Bees very active; light rain and clouds.
157	5	S.	Light ...	Rain	66·1	81·79	15·69	....	......	Bees very active; light rain.
158	7	S.E.	Light ...	Very fine......	70·83	81·03	10·20	....	......	Heavy dew last night.
159	8	S.E.	Light ...	Fine...........	69·16	79·36	10·20	....	......	Bees disturbed.
160	12	S.E.E.	Light ...	Fine...........	71·75	81·15	9·40	....	......	Massacre of drones continues.

* Mean temperature in June of No. 1, the unswarmed hive.

† Mean temperature of Hive 2, in June, after *twice swarming.*

TABLE XVI. (Continued.)

No. of Exp.	Period of observation.	Prevailing.	Wind.	Weather.	Atmosphere.	Hive No. 1.	Difference.	Hive No. 2.	Difference.	Remarks.
	1836.				°	°	°	°	°	
161	Aug. 13	E.	Light ...	Very fine......	76·4	81·1	4·7	......	......	Bees abroad in great numbers.
162	14	S. by E.	Light ...	Very fine......	77·45	82·9	5·45	......	......	Abundance of *pollen, white, orange, brown, green,* and *grey*.
163	15	W.	Light ...	Fair	71·64	84·24	12·60	......	......	Still killing the drones in the young swarms.
164	16	S.E.E.	Light ...	Very fine......	70·06	83·58	13·52	......	......	Beginning to kill the drones in Hive No. 1.
165	17	S.W.	Brisk ...	Very fine......	71·57	80·92	9·35	......	......	*Pollen* in abundance; killing drones.
166	18	W.	Brisk ...	Dull...........	63·98	78·74	14·76	74·32	10·34	Loud sounds in the hive; few bees abroad.
167	19	N.W.	Light ...	Fine...........	69·12	78·52	9·40	83·75	14·63	Bees very active.
168	20	N.W.	High ...	Hard rain ...	59·05	73·31	14·26	74·62	15·57	Three nymphs expelled from No. 2.
169	21	N.W.	Brisk ...	Fine...........	64·9	75·1	10·2	80·93	16·03	Three nymphs ejected from the first swarm from No. 2.
170	22	S.W.	High ...	Fair	66·62	74·92	8·30	76·37	9·75	A drone turned out from swarm.
171	23	S.E.	Light ...	Rain	63·38	73·26	9·88	75·28	11·90	Bees very active.
172	24	N.E.	High ...	Fair	60·64	74·88	14·24	75·28	15·64	Few bees abroad; drones have all perished.
173	25	S.	Light ...	Fine...........	63·22	74·32	11·10	74·87	11·65	Few bees abroad.
174	26	S.W.	High ...	Dull...........	68·56	75·23	6·67	74·63	6·07	Few bees abroad.
175	27	S.W.	High ...	Fine...........	65·16	73·14	7·98	76·26	11·10	Few bees abroad.
176	28	S.W.	Light ...	Showery	65·15	76·57	11·42	78	12·85	Abundance of bees abroad with *pollen*.
177	29	N.	Calm ...	Very fine......	67·3	74·82	7·52	78·5	11·2	Many bees abroad with *orange pollen*.
178	30	W.	Light ...	Light clouds	67·3	74.82	7·52	78·5	11·2	Bees very active.
179	31	S.S.W.	Light ...	Very fine......	68·7	74·86	6·16	75·3	6·6	Abundance of *pollen, yellow, orange, grey*.
		Mean temperature in August......			67·64	77·79	10·15	76·9	10·82	
180	Sept. 1	S.W.	Brisk ...	Fine...........	66·14	76·64	10·50	73·22	7·08	Much *pollen* collected, *orange, grey, yellow, and brown*.
181	2	W.	Brisk ...	Light clouds	59·58	71·08	11·50	72·96	13·38	*Pollen* less abundant; showery.
182	3	S.S.W.	Light ...	Fine...........	63·02	69·02	6	72·45	9·43	*Pollen* collected from the mignionette.
183	4	S.	Brisk ...	Showery	67·05	72	4·95	73·4	6·35	Not many bees abroad; showery.
184	5	W.	Brisk ...	Light clouds	59·18	69·89	10·71	70	10·82	Fine, but windy.
185	6	W.	High ...	Rain	56·03	64·5	7·47	67·86	11·83	A cold rainy day, with wind.
186	7	N.	Light ...	Very fine......	57·07	66·3	9·23	69·3	12·23	Many bees abroad, working.
187	8	N.	Light ...	Fine...........	60·92	67·87	6·95	69·77	8·85	A little showery, with light wind.
188	9	S.W.	Light ...	Showery	57·23	67·6	10·37	65·66	8·43	Hard rain all the morning.
189	10	W.	Brisk ...	Stormy	56·02	64·46	8·44	66·66	10·64	Bees abroad at noon; weather rough.
190	11	N.W.	Brisk ...	Fine...........	56·86	61·02	4·16	67·54	10·68	Cold wind, but fine; few bees abroad.
191	12	N.	High ...	Fine...........	57·84	64·46	6·62	66·62	8·78	Not many bees abroad.
192	13	N.	High ...	Fair	58·66	64·8	6·14	68·08	9·42	Signs of rain; hives quiet.
193	14	N.N.E.	Light ...	Fair	57·47	64·82	7·35	68·1	10·63	Signs of rain.
194	15	E.	Brisk ...	Fine...........	58·75	63·45	4·70	67·82	9·07	Bees abroad.
195	16	N.E.	Brisk ...	Fine...........	57·5	66	8·5	68·8	11·3	Weather unsettled; showery.
196	17	N.W.	Light ...	Fair	60·67	68·03	7·36	70·1	10·43	A few bees abroad.
197	19	N.	Light ...	Fair	63·87	69·20	5·33	70·38	6·51	Weather unsettled.
198	21	N.	Calm ...	Dull...........	57·4	61	3·6	65·7	8·3	Bees still abroad.
199	22	S.	Light ...	Dull...........	55·73	58·26	2·53	62·02	6·29	Hives quiet; no bees abroad.
200	23	W.	High ...	Hard rain ...	60·83	66·43	5·60	67·76	6·93	Hives quiet; hard rain to-day.
201	24	W.	Brisk ...	Very fine......	66·18	68·64	2·46	72·96	6·78	Great commotion at the entrance of the hives.
202	25	S.W.	Light ...	Fine...........	64·65	69·45	4·80	70·7	6·05	Fair; many bees abroad.
203	26	S.	Brisk ...	Dull...........	63·46	69·78	6·32	70·94	7·48	A few bees abroad.
204	27	S.W.	Light ...	Dull...........	66·06	69·1	3·04	71·4	4·34	No bees abroad.
205	28	S.W.W.	High ...	Showery	61·3	64·93	3·63	65·53	4·23	Fair, windy; a few bees abroad.
206	29	S.W.	High ...	Rain	53·1	55·7	2·6	57·03	3·93	Hives quiet; rain and wind all day.
207	30	N.W.	Light ...	Fine...........	58·76	67·83	9·07	69·2	10·44	Bees abroad again.
Mean temperature in September					60·04	66·5	6·46	66·68	6·64	
Total mean temperature of four months after swarming					63·75	78·29	14·54	77·18	13·43	
Total mean temperature of the periods before and after swarming..............................					56·54	72·75	16·21	74·06	17·52	



Ad Nat. Delt. T. Wharton, Jones. *J. Basire, sc.*