A STUDY OF THE EFFECT OF SURGICAL SHOCK ON INSECTS [1]

By WILLIAM ROBINSON [2]

Division of Entomology, Agricultural Experiment Station, University of Minnesota

SURGICAL SHOCK IN MAN AND HIGHER ANIMALS

There is a form of shock in man that sometimes follows immediately after a wound is received. This form, called primary shock by Cowell,[3] resembles fainting and is caused by nervousness. It is not the direct result of the injury itself and usually lasts but a short time.

Surgical or traumatic shock is more deep seated and results from injury to the tissues. The injured individual grows pale, his skin becomes cold and often wet with perspiration, his pulse is rapid but very feeble, his breathing shallow, and his blood pressure low. These symptoms arise more slowly and last longer than in primary shock. They follow extensive burns, injury to the intestines, muscles, bones, testes, or other tissues. They also follow prolonged etherization.

The symptoms are produced, it is suggested, by the secretion into the blood stream of substances like histamine at the time of injury. Dilation of the capillaries follows and a flow of plasma takes place from the blood through the walls of the capillaries to the tissue spaces. This decrease in blood volume results in reduced blood pressure and increased heartbeat, accompanied by a reduction in the vital functions.

A POSSIBLE COUNTERPART IN INSECTS TO SURGICAL SHOCK IN HIGHER ANIMALS

In a series of experiments conducted at this laboratory there has been found in insects a phenomenon which possibly may be interpreted as associated with traumatic shock. One of the effects is evident immediately after injury is received, but obviously the general symptoms must differ from those produced by shock in mammals.

The practical point of interest in shock of insects is, of course, the possibility that it may affect the insect's functions and cause distortion of physiological measurements, for severe injury to insects does result from some physiological tests. A knowledge of, say, the hydrogen-ion concentration of the blood of insects under various conditions is certainly of value, but in making the determinations it is necessary to puncture the insect and to express some of its lymph, and it may otherwise be mutilated. Moreover, in the determination of internal temperature the insect is pierced with the thermocouple point, for

[1] Received for publication Aug. 10, 1928; issued January, 1929. Published with the approval of the director as paper No. 795 of the Journal Series of the Minnesota Agricultural Experiment Station.

[2] Acknowledgments are due to Dr. R. A. Gortner, chief of the division of biochemistry, University of Minnesota, for the interpretation herein given of the results that follow the piercing of insects; and also to Dr. F. H. Scott, professor of physiology, University of Minnesota, who supplied the writer with information regarding surgical shock to man.

[3] COWELL, E. M. THE INITIATION OF WOUND SHOCK. [Gt. Brit.] Med. Research Council, Spec. Rpt. Ser. 25: [99]–108, illus. [1919.]

rectal readings are of doubtful accuracy in entomology, while there is always the danger of puncturing the wall of the rectum and causing local shock. In these and other instances the tissues are injured, and what appears to be traumatic shock is produced.

EXPERIMENTAL DATA ON SHOCK OF INSECTS

Several species of insects, especially the pupae of the Polyphemus moth (*Telea polyphemus* Cram.), were used in the tests. Shock was administered by piercing some individuals with a needle. The body contents of others were expressed. All the tests produced an effect of such a nature that a marked disturbance of some kind was indicated. An immediate change occurred in the water relations of the tissues, due to the release of a large percentage of the water held by the cell colloids, as shown in Table 1. The technic used in making determinations of "bound" water has already been described by the writer [4] and will not be repeated here.

TABLE 1.—*Effect of shock on the quantity of bound water present in pupae of Telea polyphemus*

Percentage of bound water in—		
Normal individuals	Pierced individuals	Liquid expressed from body contents
27.5	19.1	9.6
30.5	20.4	11.2
21.3	17.4	5.3
22.1	21.2	8.8
20.8	17.6	7.6
22.3	16.1	5.2
Average..... 24.1	18.6	7.9

In normal individuals an average of 24.1 per cent of the total water, as shown in Table 1, was in the bound condition. Piercing the tissues of others caused an immediate drop to 18.6 per cent, or a decrease of about 23 per cent of bound water. Expressing the body contents of other individuals caused a drop to 7.9 per cent, or the release of a still greater proportion, namely, of 67 per cent. The pupae used in these tests weighed on an average 4 gm. each, and of this weight about 71 per cent was total water. It can thus be seen that a relatively large change in the water relations takes place when shock occurs.

Fortunately, it has been possible to confirm these determinations by other data. The liberation of a large percentage of water at the time of shock would be expected to dilute the lymph and consequently to raise its freezing point. Therefore, a series of experiments was conducted to find the freezing point of lymph from normal and pierced individuals and also that of expressed lymph. The results are given in Table 2, where a rise in the freezing point is shown from $-6.9°$ C. in normal individuals to as high as $-2.1°$ in expressed lymph.

[4] ROBINSON, W. RELATION OF HYDROPHILIC COLLOIDS TO WINTER HARDINESS OF INSECTS. Colloid Symposium Monograph 5: 199–218, illus. New York, The Chemical Catalog Company, Inc. 1928.

TABLE 2.—*Effect of shock on the undercooling and freezing points of Telea polyphemus*

[Temperatures given in degrees centigrade]

Insects in normal condition		Insects pierced with needle		Insects pierced with thermojunction, which remained in body during determination		Expressed tissues and lymph	
Undercooling point	Freezing point	Undercooling point	Freezing point	Undercooling point	Freezing point	Undercooling point	Freezing point
−15.2	−6.8	−6.7	−3.8	−7.3	−2.7	−5.8	−2.0
−15.2	−7.5	−5.2	−3.7	−6.8	−2.6	−5.1	−2.2
−15.4	−6.2	−7.5	−3.9	−5.6	−2.7	−4.7	−2.3
−15.6	−7.0	−7.6	−3.9	−6.3	−2.3	−4.8	−2.0
−15.2	−7.0	−6.5	−3.9	−6.8	−2.6	−4.8	−2.1
−15.4	−6.8	−7.1	−3.7	−6.2	−2.5	−5.4	−2.1
Average −15.3	−6.9	−6.8	−3.8	−6.5	−2.6	−5.1	−2.1

The direct correlation which is thus established between percentage of bound water and freezing-point depression is shown in Figure 1. A theory to account for the unusual rise in the undercooling point at the time of piercing is mentioned in the paper that immediately

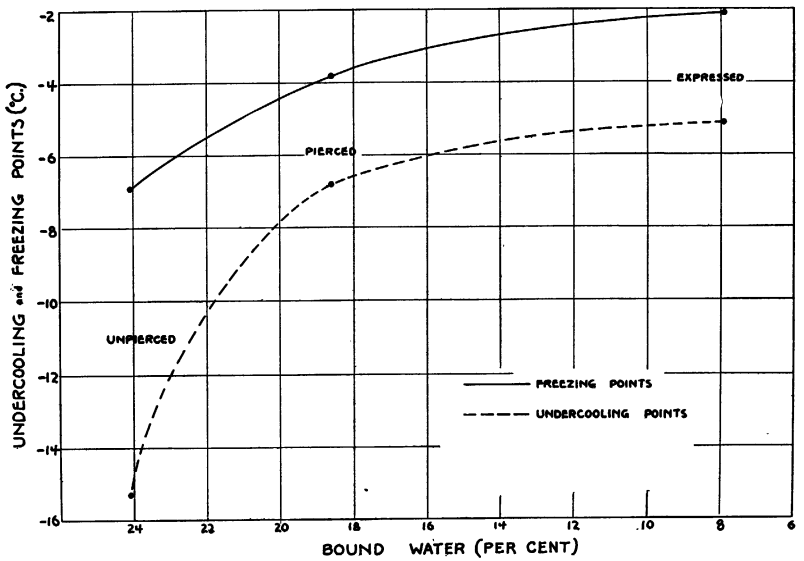

FIG. 1.—Correlation between freezing-point depression and percentage of bound water. Average of six tests

follows the present one. In the same article a description is given of a method of taking freezing-point readings without piercing.

The rapidity with which shock occurs after insects are pierced is shown in Figure 2 for pupae of *Telea polyphemus*. The broken line represents the descending body temperature of a number of unpierced individuals as the cabinet temperature fell slowly during 10 days. At practically any time during the descent the effect of shock

could be readily demonstrated. Piercing with the thermocouple caused an instantaneous rise in every case to the abnormal freezing point between −2.0° and −3.2° C. The difference between the normal and abnormal freezing points is further exemplified in this figure, for the unshocked pupae which were allowed to reach their normal undercooling point froze between −6.7° and −7.2°.

The rise in freezing point of over 4 degrees at the time of shock represents a large dilution of lymph and a great fall in osmotic pressure. It is difficult to account for this solely on the basis of liberation of bound water as determined. It may be that, due to shock, dissolved substances are removed from solution by adsorption.

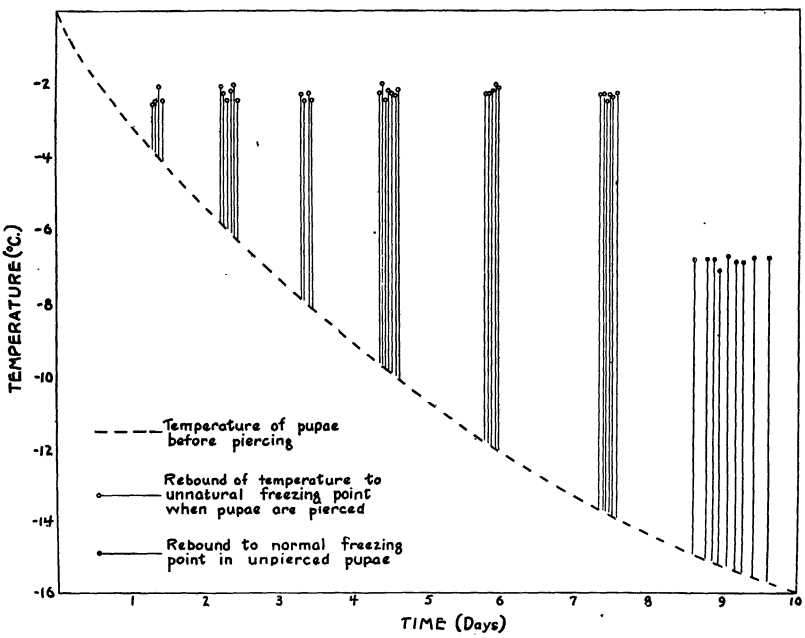

FIG. 2.—Curves showing rebound to abnormal freezing point at time of piercing and also the natural freezing point of normal specimens of *Telea polyphemus*

A DISCREPANCY IN LOW-TEMPERATURE STUDIES EXPLAINED ON THE BASIS OF SHOCK

Normal insects when placed in a low-temperature cabinet have frequently been taken considerably below the expected undercooling point without becoming frozen. Carter [5] (1925) was probably the first to point out this discrepancy, and he suggested that the higher freezing point of pierced individuals was due to injury to the tissues.

Insects evidently possess greater resistance to low temperatures than has been apparent from freezing-point determinations. There are indications of a freezing zone for the different species which exists several degrees below the expected temperatures. A series of experiments was conducted to discover the temperature difference between

[5] CARTER W. THE EFFECT OF LOW TEMPERATURES ON BRUCHUS OBTECTUS SAY, AN INSECT AFFECTING SEED. Jour. Agr. Research 31: 165–182, illus. 1925.

the normal freezing zone and the abnormal freezing points as obtained by piercing. The procedure was as follows: A large number of normal insects of different species were placed in low-temperature cabinets and their temperature was allowed to drop slowly until the predetermined or abnormal undercooling point was reached. From there downward the specimens were cooled much more slowly—about 1.5° per day. Each day several individuals were examined for the appearance of ice crystals and then discarded. It was found that every species studied could be taken below the predetermined undercooling point before crystallization began.

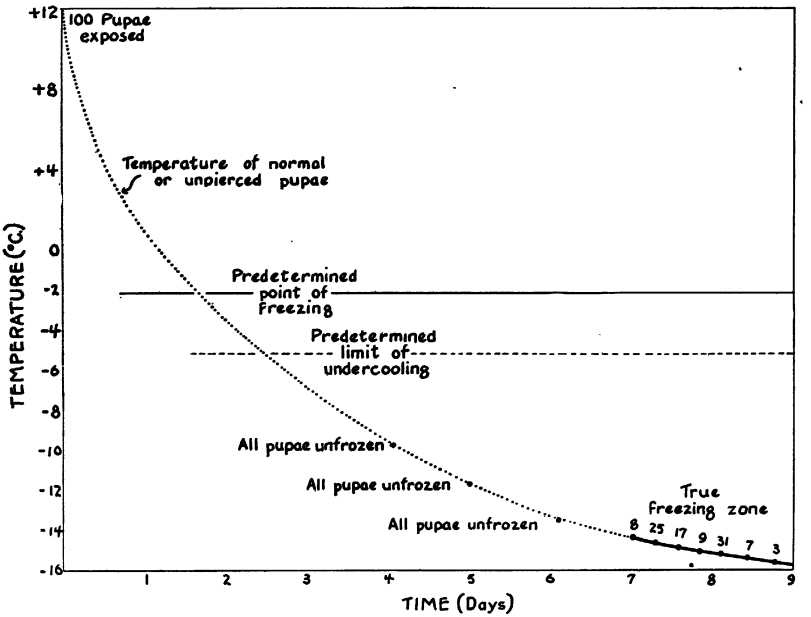

FIG. 3.—Curve showing the existence of a true freezing zone below the limit of undercooling as determined by piercing specimens of *Telea polyphemus*

The results secured for *Telea polyphemus*, which are typical of those obtained for the other species, are shown in Figure 3. One hundred normal pupae were used, and under a falling temperature they passed the abnormal undercooling point of −5.2° C. in two and a half days. The species is soft, and so freezing could be detected without dissection. The pupae were all lowered to −14.4° before freezing began, and some individuals resisted freezing down to −15.7°. This indicated a normal freezing zone between −14.4° and −15.7° for that species. Table 3 gives the results obtained for the other species in the series. In every case the normal freezing zone is several degrees below the undercooling point, and in some instances it is almost incredibly low.

TABLE 3.—*Comparison of predetermined freezing and undercooling points with normal freezing zone for all species tested*

Species tested	Average predetermined freezing point (°C.)	Average predetermined undercooling point (°C.)	Normal freezing zone (°C.)
Full-grown wireworms (*Phyllophaga* spp.)	−1.6	−3.8	−12.1 to −15.2
Colorado potato beetle (*Leptinotarsa decemlineata*)	−2.3	−4.6	−8.4 to −10.1
Pupae of Polyphemus moth (*Telea polyphemus*)	−2.5	−5.2	−14.4 to −15.7
Larvae of the willow sawfly (*Cimbex americana*)	−1.4	−3.6	−4.2 to −6.3
Pupae of the dill worm	−2.8	−4.2	−8.8 to −10.3
Pupae of the mourning-cloak butterfly (*Aglais antiopa*)	−2.2	−3.7	−7.1 to −9.9
Adults of the granary weevil (*Sitophilus granarius*)	−4.6	−8.3	−18.0 to −22.1
Black cabinet beetle (*Attagenus piceus*)	−3.2	−7.8	−15.5 to −18.6

DESIRABILITY OF USING NORMAL MATERIAL FOR PHYSIOLOGICAL TESTS

Just as piercing or mutilation obscures the true freezing point of insects, so it is possible that other tests may likewise give incorrect values. In studying the reactions of a species to the various stimuli of its environment, it is the living normal organism that should be considered. The act of taking a physiological measurement may cause disturbances sufficient to alter the true condition. The question may therefore be asked whether it is justifiable to attach much significance to values thus obtained and to interpret responses on the basis of these values.

SUMMARY

When insects are pierced, cut, or injured an effect is produced upon them that may be analogous to surgical shock in higher animals. This is most evident in the rapid change that takes place in the water relations. Since in some physiological determinations injury to the tissues is unavoidable, the data thus obtained may not accurately represent the condition in normal individuals.