ART. LIII.—*The Heat produced in the Body, and the effects of Exposure to Cold;* by JOHN C. DRAPER, M.D.

THE following results were obtained in an attempt to determine the quantity of heat passing off from the surface of the body, by finding how much it would elevate the temperature of a known mass of cool water during a given period of time.

The manner of experimenting was as follows:—Seven and a half cubic feet of cool water were drawn into a bath, and the temperature taken after careful mixing. The bath was then covered over for about four-fifths of its extent to prevent the action of currents of air, and at the close of an hour the temperature was again tested. The rise of $\frac{1}{2}$ a degree represented the amount of heat absorbed from the air during one hour, and was deducted as a normal error from the results afterward obtained.

During the time occupied in determining the normal error of the bath (viz., one hour), I lay on a sofa to bring the circulatory and respiratory functions into a condition similar, as regards position of the body, to that to which they would be submitted

while in the bath. My dress during this phase of the experiment consisted of a thin flannel summer undershirt, linen drawers, and cotton socks. At the completion of the hour of rest these were removed with as little exertion as possible and I stepped into the bath, and lay down, allowing only the head to project above the surface of the fluid. At the close of an hour the temperature of the bath was again taken. I then left it, and drying the surface of the body, reassumed the same dress and lay down on the sofa. Throughout the whole of each experiment, the temperature of the air, the dew point, the temperature of the bath, of the armpit, mouth and temple were taken, together with the rate of respiration and of the pulse.

Since in these experiments two series of phenomena are investigated, I have for the sake of clearness of description separated the results in accordance with the phenomena in question, and direct attention first to the

Quantity of heat evolved from the body.

	During Rest. 1st Exper.	2d Exper.	During Motion. 3d Exper.
	July 4.	July 5.	July 11.
Temp. of air,	90° F.	84° F.	83° F.
Wet bulb thermometer,	78° F.	76° F.	74° F.
Experiment commenced at	11.45 A.M.	12.10 P.M.	11.50 A.M.
Temp. of water when drawn,	73½° F.	73½° F.	75° F.
Temp. of water at the end of an hour on entering the bath,	74° F.	74° F.	75½° F.
Temp. of water at the close of an hour on leaving the bath,	76½° F.	76½° F.	78° F.
Heat imparted to the water, deducting normal error,	2° F.	2° F.	2° F.
Volume of water in the bath,	7½ cubic feet.		
Volume of the body,	3 " "		
Weight of the body,	180 lbs.		
Height of the body,	5 feet 5¼ inches.		

In the first and second experiments I laid perfectly still; the results therefore show the quantity of heat passing off from the surface of the body in a state of rest. This, as the table indicates, could warm seven and a half cubic feet of water two degrees in one hour. The volume of the body being three cubic feet, it follows that if we consider the specific heat of the body as about the same as that of water (which it probably is), enough heat is evolved in the course of one hour to warm the body itself about five degrees of Fahrenheit's scale. The converse of this may also be considered as true, viz., that after death, the air being at 73°, enough heat is lost in the course of an hour to cool the body five degrees, at least during the first hour. It is therefore a fact of considerable importance from a

medico-legal point of view, especially in estimating the time a body has been immersed in water after recent drowning when the temperature of the water is about 73°, as is the case with the Croton and other streams in summer.

In the third experiment one or other of the lower extremities was alternately kept in motion during thirty minutes of the hour in which the body was immersed in the bath. The movement consisted in extending and flexing the leg on the thigh at the rate of fifty flexions per minute, and being performed under the surface of water involved considerable muscular exertion. Notwithstanding this violent exertion, as the table shows, there was no increase in the amount of heat imparted to the water. The consequences flowing from this result are of great physiological importance, but we reserve their consideration until we have completed the history of our experiments. We therefore pass to the examination of

The physiological effects of the cold bath on the body.

Experiment of July 4,—Rest—Temp. of Bath 74° F.

	1	2	3	4	5	6
	Temp. before entering the bath.	Immed. after entering the bath.	After 1 hour in the bath & just before leaving it.	Immed. after leaving the bath.	One hour after leaving the bath.	Two hours after leaving the bath.
Temp. of the mouth,	99° F.	99° F.	98° F.	97° F.	97° F.	—
" " armpit,	96° F.	97° F.	95° F.	92° F.	96° F.	—
" " temple,	96° F.	—	—	—	94° F.	—
Rate of respiration,	20	22	16	13	16	19
Rate of pulse,	74	73	65	54	60	72

Note.—A chill or shock was experienced on entering the bath, and the sensation of coolness remained while in the water. Skin was dry and hot for an hour and a half after coming out. Perspiration set in and skin became cool two hours and a half after coming out. Shortly after leaving the bath slept for 30 minutes.

Experiment of July 5,—Rest—Temp. of Bath 74° F.

	1	2	3	4	5	6
	Before entering the bath.	Immed. after entering the bath.	After 1 hour in the bath & just before leaving it.	Immed. after leaving it.	One hour after leaving bath.	Two hours after leaving bath.
Temp. of mouth,	99° F.	99° F.	98° F.	97° F.	97° F.	98° F.
" " armpit,	98° F.	97° F.	94° F.	94° F.	97° F.	97° F.
" " temple,	97° F.	—	95° F.	95° F.	96° F.	96° F.
Rate of respiration,	17	21	18	15	16	16
Rate of pulse,	78	66	64	55	56	60

Note.—Symptoms same as in experiment 1, but not as well marked; slept 30 minutes as in preceding.

If in the tables we compare column 1, representing the condition before entering the bath, with column 4, representing the

condition immediately after leaving it, we find that in both experiments the exposure for one hour to water at a temperature of about 74° F. lowered the temperature of the mouth two degrees, of the armpit four degrees, and of the temple two degrees. The rate of respiration is also diminished in one case two and in the other four movements, and that of the pulse twenty beats in one and twenty-three in the other. It is therefore evident that the effects of the long continued application of a degree of cold such as that employed, is to reduce the temperature of the body and the rate of respiration slightly, while it affects the rate of pulsation in a very profound manner.

One of the consequences of this effect of cold on the action of the heart was a great reduction in the quantity of oxygen introduced into the system. The rate of pulsation being reduced nearly one-third, the quantity of oxygen conveyed into the interior of the body was diminished in a somewhat similar ratio. In a short time this began to exert its influence on the nervous centers, and there was a overwhelming disposition to fall asleep, which was unconsciously indulged in in both experiments shortly after leaving the bath, notwithstanding the strong desire to keep awake for the purpose of recording the rates of pulse and respiration at given periods.

Another evident consequence of such a sluggish movement of the blood is the disposition to congestion of various internal organs, and herein we may see a partial explanation of the action of cold in causing inflammations, especially of those organs engaged in the processes of secretion and excretion.

The discussion of the results obtained has thus far been confined to the consideration of columns 1 and 4. I have followed this course because, while in the bath, a slight access of water to the armpit or to the temple causes irregularities in the thermometric indications. In the case of the respiratory movements it is also very difficult to avoid influencing them in the act of counting. The mouth temperatures are, it is true, free from the influence of external agents, but the differences are too small to be perfectly reliable. In the case of the pulse determinations none of these objections can be urged; they are considerable, and by counting for half a minute for every record made, the error is reduced to a maximum of one beat. The movements of the heart are, in addition, free from the liability to error that exists in the case of the respiratory movements.

Accepting the pulse determinations as being accurate and reliable indications of the effects produced, both while in the bath and out of it, we may return to the consideration of the tables, and compare together columns 1, 3 and 4. Recollecting that 1 represents the condition on entering the bath, and 3 that just

before leaving it, after an immersion of one hour we find that the pulse was reduced nine beats in the first experiment, and fourteen in the second. If now we compare 3, the condition just before leaving the bath, with 4, the condition just after leaving it, we find that the rate of the pulse has diminished eleven beats in the first and nine in the second experiment. The explanation of this extraordinary reduction of the pulse rate on leaving the bath is by no means clear. One thing is, however, very evident, and that is, the profound effect of the application of cold, as is shown not only by the singular phenomenon of which we have just spoken, but also by the slowness with which the original rates of pulsation are regained, as is demonstrated by columns 5 and 6 of the tables.

The motion experiment of July 11th gave the same general physiological results as the rest experiments of July 4th and 5th. The difference being, that during the motion the respiratory movements became 30 per minute and the pulse 90, both regaining the rate represented in the rest experiments very soon after the cessation of the exercise. Placing this great increase of the respiratory movement in juxtaposition with the failure of the exercise to cause any perceptible increase in the temperature of the bath, it is evident that the contact of the cold water must put an almost absolute stop to the functions of the skin, and the whole duty of exhalation of vapor of water and consequent removal of heat is thrown on the lungs; hence the increased respiratory action, and hence also the special tendency of application of cold to the surface to produce inflammations of those organs by increasing the work they are obliged to perform, and raising the pulse-respiration ratio to that actually existing in pneumonia.

In conclusion, it may be observed that the primary and most important effect of the application of cold to the whole surface of the body is to reduce the action of the heart. This reduction is still further increased on removing the cold, if the application has continued for a sufficient length of time; and, as a consequence of the reduction of the heart's action, the phenomenon of stupor or sleep appears, produced either by deficient oxidation or by imperfect removal of carbonic acid. There is also a tendency to congestion of various internal organs, especially of the lungs, and the establishment of a pulse-respiration ratio similar to that of pneumonia.

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