

On the modifications produced in the temperature of the body by the local application of cold and heat / by Frederick Barham Nunneley, M.D.

Contributors

Nunneley, Frederick B.
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MODIFICATIONS PRODUCED
IN
THE TEMPERATURE OF THE BODY
BY THE
LOCAL APPLICATION OF COLD AND HEAT.

BY
FREDERICK BARHAM NUNNELEY, M.D.,
LECTURER ON EXPERIMENTAL PHYSIOLOGY AT ST. MARY'S HOSPITAL,
ASSISTANT-PHYSICIAN TO ST. MARY'S HOSPITAL, AND TO THE
HOSPITAL FOR SICK CHILDREN.

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1871.

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THE inflammation of internal organs is ascribed with great frequency, both popularly and by the physician, to the effect of cold acting externally, and especially to its *local* influence in the form of draughts and chills, such as are caused by currents of cold air, wet feet, &c., when the body is over-heated or is felt to be so. At the same time it is well known that the heat of the body remains nearly constant, notwithstanding great variations of the surrounding temperature.

With these facts in view, it becomes a matter of some interest to determine whether, under any circumstances, local applications of cold modify the temperature of the body generally, or of any part of it other than that on which they immediately act; or, in other words, whether any disturbance of the conditions regulating the natural heat of the body can

be induced in a moderate time by these means. The observations related below deal with some of these circumstances, and though a part of the ground has been gone over before by Edwards¹ and by Tholozan and Brown-Séguard,² my results differ so much from theirs that it seemed better to examine the matter afresh. In doing this three questions presented themselves for solution, to which direct experiment only could supply an answer, viz. what effect is produced on the temperature of any part of the body when one of the extremities is placed—1, in cold water; or, 2, in hot water; or, 3, when immersion in hot is immediately followed by immersion in cold water?

The extremities only are referred to, since they are well adapted for observations of this kind, and their temperature can be determined with great accuracy. From its convenience, water was used as the source of heat and cold.

The observations were thus conducted.

The subject of experiment was placed in a room free from draughts and of such temperature that no feelings of cold or heat were experienced, since these, as it will appear later on, seem to have a marked influence on the result. For similar reasons the cold and hot water were brought to him. A thermometer easily readable to 0.1 F. was placed in one or other hand (or foot) and the fist supported for a time by an elastic band stretched around it. When the mercury became stationary, which usually happened in 20—30 minutes, the other hand or foot was put into cold or hot water and maintained there for 15—40 minutes, and the temperature of the unimmersed hand noted at short intervals.

Brown-Séguard³ directs that observations of two minutes each should be taken of the unimmersed hand, the one before and the other after immersion of the opposite hand, in order that as far as possible the temperature of the *exposed* palm

¹ "Animal Heat," in 'Todd's Cyclopædia of Anatomy and Physiology,' vol. ii, p. 660, 1839.

² 'Journal de la Physiologie,' t. i, p. 500 *et seq.*, 1858. 'Experimental Researches applied to Physiology and Pathology,' p. 32, 1853.

³ 'Journal de la Physiologie,' t. i, p. 504.

may be ascertained; but this method seemed objectionable, inasmuch as it rendered it impossible to determine if a *rise* of temperature took place from an application to the opposite hand, as such would necessarily be the course of the mercury for several minutes more.

The heat of the body generally was examined by means of a thermometer placed under the tongue.

The experiments are arranged in a tabular form at the end of the paper, and reference will be made to them by numbers.

To proceed with the questions raised.

1. It was found in different individuals, male and female, that when one hand or foot was put into water ranging in temperature from 50° to 25° F., and maintained there for 4—40 minutes, no change occurred in the temperature of the body generally or of the other extremities. And further, that if the temperature of the unimmersed hand had not attained its maximum, it still continued to rise notwithstanding the cold applied to the other. (Exps. I, II, III and VI—XI.)

In one individual the sensation of pain was so acute as almost to mask that of cold, and yet the temperature did not fall in the opposite hand. (Exp. IV.) Similar results were obtained with others to whom cold water gave comparatively little pain, and markedly so in a lady who kept one hand immersed uninterruptedly for half an hour in water containing melting ice, the temperature of the other hand steadily rising for twenty-three minutes of this time. (Exp. V.)

A curious variation of this result was obtained in the same case on another occasion, when the subject of it was tired and the room sensibly colder than before. (Exp. VII.)

This last observation well illustrates some important points.

1. That nervous exhaustion of the subject of experiment, and coldness of the surrounding air, cause a fall in temperature which does not occur without them. 2. That this fall in temperature is ~~not~~ often coincident with a general sensation of coldness. 3. That *no* fall of temperature, so prompt as to

be fairly considered as a reflex act, follows the immersion of one hand in a freezing mixture.

2. When one hand was put into water as hot as it could be borne, which was with most persons from 110° — 120° F., it was found that the temperature of the other hand and of the feet rose from 0.8° to 3.4° , and that of the mouth under the tongue from 0.3° to 0.9° , the rise in the opposite hand and in the foot being equal. (Exps. XII, and XIV—XXIII.) The increase of heat was accompanied by a general sensation of warmth, sweat often breaking out on the unimmersed hand, and even over the body. These effects varied considerably in degree with the individual, and even in the same individual at different times. The temperature of the mouth rose in the case of the lady referred to above from 98.4° to 99.4° . (Exp. XIII.)

3. When hot water had produced the maximum effect just referred to, if the hand was removed, and it or one of the other extremities plunged into cold water and maintained there for some time, it was found that the temperature of the unimmersed hand and of the feet began to fall, and would in twenty or thirty minutes sink from 1° to 7.5° , the fall commencing very shortly after immersion. At the same time the temperature of the mouth would decrease from 0.6° to 1.4° , (Exps. XIII to XXIII.) A trifling sensation of chilliness was often coincident with this loss of heat, and persisted whilst it continued. A kind of reaction then took place, the chilliness passed off and the temperature rose; this could be hastened by warm tea, &c., and especially by immersion of an extremity in hot water; the latter method would in a short time arrest the fall of temperature when this was still going on and would again cause a rise, as just described, somewhat beyond the natural bounds. Experiments XIV and XVI illustrate this.

The results of these experiments may be thus summed up.

1. No change occurs in the temperature of any part of the body from the local application of cold, except that on which it immediately acts, unless the individual is in a state of more or less nervous exhaustion or there is decided coolness of the surrounding air.

2. The local application of heat exceeding in degree that of the blood causes a slight rise of the general temperature and a more considerable one of that of the extremities.

3. If cold is now applied locally—as to any one of the extremities—the general temperature falls slightly and that of the extremities more notably below the natural standard, but both this fall and the previous rise with heat vary considerably, not, however, with the individual susceptibility to painful sensations of temperature, but rather in proportion to the facility with which the conditions regulating the normal balance of the bodily temperature can be disturbed.

4. This change, unlike a reflex act, occurs comparatively, or even very slowly, and its amount is equal in all the extremities; hence it is not, at any rate in many cases, a reflex action, taking place between homologous parts, as Brown-Séquard has described it.¹

Perhaps these changes of temperature may be regarded as parallel in many respects with those attending a slight rigor. In both cases a disturbance, probably of the nervous system, sufficient to derange the conditions presiding over the maintenance of the natural temperature, seems first of all necessary. This may be due to heat, exhaustion from over-work, or want of food, or, in the case of disease, to a morbid poison. When the nervous system is thus, so to speak, taken at a disadvantage, slight impressions of cold may produce a rigor, as at the onset of pneumonia, or lowering of the heat of the extremities with slight chilliness, as in the artificial conditions related above. Even a true rigor, caused by a morbid poison, may be prolonged or induced by exposure to cold.²

¹ 'Journal de la Physiologie,' t. i, p. 505.

² On the subject of rigors see Wunderlich, 'Temperature in Disease,' Syd. Soc. Translation, pp. 172—199.

In both cases reaction from a state of lowered temperature occurs; in a true rigor the heat passes the natural limit and pyrexia is established, whilst in these experiments the normal temperature was slowly attained.

It would be undesirable to do more than suggest such an explanation, especially as the experiments of Dr. Brown-Séquard afforded such different results. It has been my wish rather to bring the facts observed under notice in such form as might best connect them with other and known phenomena, than to attempt to explain all the variations which occurred.

The cold air in which Brown-Séquard made his observations would, no doubt, modify the results; indeed, I have found this to be the case by actual experiment. (Exp. IX, *b*.)

Although the actual observations scarcely support Dr. W. F. Edwards's axiom,¹ "That we cannot either raise or lower the temperature of any one part of the body without all the other parts of the frame being affected and suffering a corresponding rise or fall in temperature, more or less, according to circumstances," as a general rule, they bear it out in particular cases and subject to certain conditions.

Dr. Handfield Jones² states that he has found that plunging one hand into hot water causes a speedy fall in the temperature of the opposite one. In my experience this was a comparatively rare occurrence, and did not usually exceed 0.1° or 0.2° F. (Exps. XIII and XVI.) In one instance, however, immersion of a *foot* in hot water caused an immediate fall in the temperature of the *hand* to the extent of 3.6° . (Exp. XVIII.) This had all the appearance of a reflex act, but,—and the remark applies to the whole subject of the paper,—this field of inquiry is so incompletely explored that we can well suppose the same end may be attained by different paths—that such changes of temperature may occur in some cases as the analogues of trifling rigors, in others by reflex agency. The practical lesson which the facts

¹ 'Todd's Cyclop.,' loc. cit.

² 'Functional Nervous Disorders,' 2nd ed., p. 34.

teach us, is that partial chills *can* modify the temperature, and that a condition of depressed nervous energy is one in which an individual is particularly exposed to the effects of slight impressions of cold.

The temperatures in the following tables are those of Fahrenheit's thermometer.

The extremes of temperature in each experiment, and the difference between them, have been printed in bold type for convenience of reference.

OBSERVATION OF TEMPERATURE PREVIOUS TO APPLICATION OF COLD.						APPLICATION OF COLD.			
Experiment.	Part of body in which temperature was observed.	Temperature of room.	Temperature at the end of 5—10 minutes.	Temperature at the end of 10—20 minutes.	Temperature at the end of 20—40 minutes.	Name of extremity subjected to cold.	Temperature of the water.	Time of immersion.	Remarks.
I.	Left hand.	...	...	...	96.3°	Right hand.	46°	20 min.	Water felt very cold.
II.	Left hand.	...	95.3°	95.3°	...	Right hand.	47°	10 min.	Ditto.
III.	Left hand.	...	...	...	97.6°	Right hand.	40°	30 min.	Ditto.
IV.	Right hand.	...	...	...	98°	Left hand.	36°	30 min.	Pain considerable.
V.	Right hand.	...	86°	89.2°	94°	Left hand.	36°	25 min.	Sensibility to cold slight. Temperature of cleft of fingers 55°.
VI.	Left hand.	...	96.2°	96.4°	96.4°	Right hand.	39°	20 min.	Hand was withdrawn from water at intervals as the pain was severe.
VII. (a)	Right hand.	...	...	...	96°	Left hand.	36°	15 min.	Considerable pain at first, afterwards more bearable. Temperature in cleft of fingers 52°.
(b)	Right hand.	...	...	...	93.4°	Left hand.	25°	3 min.	Pain moderate.
(c)	Right hand.	...	...	...	94.6°	Left hand.	26°	6½ min.	Ditto.
VIII.	Left foot.	...	92.8°	95.5°	95.8	Right foot.	56°	25 min.	Water felt cold. Experiment was made March.
	Mouth.	...	...	98°	98°				
IX. (a)	Left hand.	...	95.9°	96.6°	96.6°	Right hand.	49°	20 min.	Water felt very cold.
	Mouth.	...	...	...	98.2				
(b)	Left hand.	...	...	...	96.4°	...	...	22 min.	Sat in draught of air against the tap.
X.	Left hand.	75	...	97.2°	98.2°	Right hand.	36°	19 min.	Intense pain for a few seconds, more bearable afterwards.
	Mouth.	...	98.8°	...	...		
XI.	Right hand.	...	...	92.5°	98.2°	Left hand.	36°	14 min.	Only moderately painful at first.
	Mouth	75°	98.8°	...	...		

OBSERVATION OF TEMPERATURE SUBSEQUENT TO APPLICATION OF COLD

Temp. 1-2 min. after ap- plication of cold.	Temp. 3-6 min. after ap- plication of cold.	Temp. 8-10 min. after ap- plication of cold.	Temp. 12 -15 min. after ap- plication of cold.	Temp. 20 -30 min. after ap- plication of cold.	Greatest altera- tion of tempera- ture.	Remarks.
...	96.2°	96.3°	96.2°	96.2°	-0.1°	Hand grasping the thermometer and no bandage used
...	95.4°	96.3°	...	...	+ 0°	Ditto
...	...	...	97.7°	97.7°	+ 1°	A bandage was placed round the fist
...	...	98.2°	...	98.1°	+0.2°	Ditto
...	94.4°	95.8°	96.2°	96°	+2.2°	Ditto
...	96.2°	96.5°	96.8°	96.8°	+0.4°	Fist was supported by an elastic band
95.9°	96°	...	96.4°	96°	+0.4°	This observation was made on the same individual as V, but in this case she was somewhat exhausted. Directly after removing her hand from the water she felt chilly, and the temperature fell in twenty-five minutes to 92.8°, rising shortly after to 93.4°. Another observa- tion was made (b).
...	93.4°	...	...	...	0°	The temperature continued to rise when the hand was withdrawn from the freezing mixture. Obs. (c) was then made.
94.8°	94.8°	94.6°	...	...	+0.2°	Chilliness again came on, with a sen- sation of cold down the back, the tem- perature falling to 93°. A cup of hot tea was given, soon after which the chilliness passed off and the temperature rose.
95.7°	95.7°	96°	96.1°	96.2°	+0.4°	Bulb of thermometer placed under toes and foot lightly covered.
...	...	...	...	98°	0°	
...	96.2°	...	...	95.6°	-1.0°	The subject of this experiment moved to a tap of water which stood in a slight draught. No chilliness. See (b).
...	...	...	...	98.2°	...	
...	...	...	96.2°	95.2°	-1.2°	In this case the right hand was not put into water, but an equal fall of tem- perature occurred in a space of time equal to that of immersion in (a).
98.2°	98.3°	98.4°	98.4°	98.4°	+0.2°	This experiment and Experiment XI were made on two healthy adult males who had recently dined. The results in XI were almost precisely similar to those in X
...	99°	+0.2°	
98.1°	98.0°	98.2°	98.3	...	+0.1°	...
...	99.0	...	+0.2°	

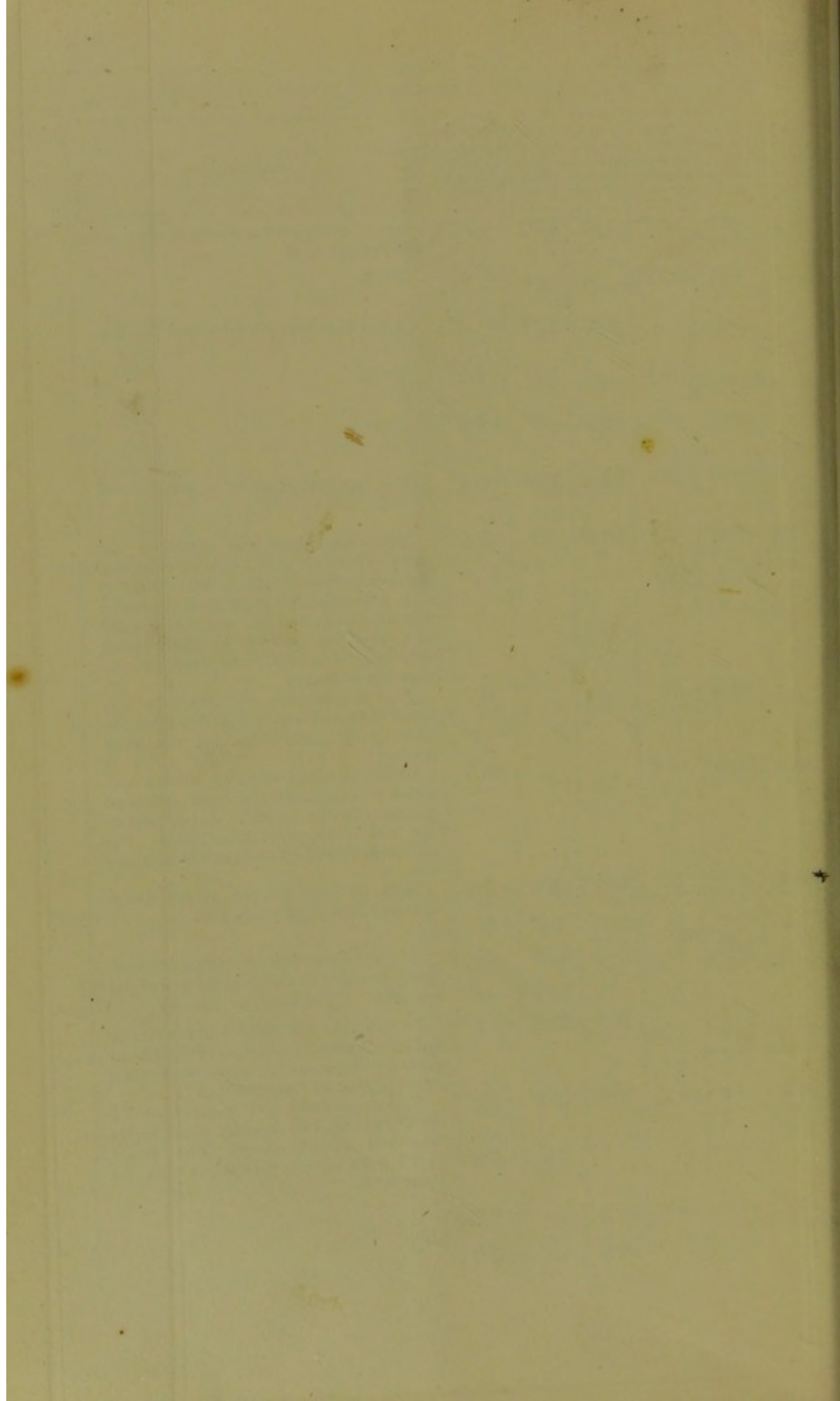


TABLE II.—Effect of heat followed by cold.

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OBSERVATION OF TEMPERATURE PREVIOUS TO APPLICATION OF HEAT.								OBSERVATION OF TEMPERATURE SUBSEQUENT TO APPLICATION OF HEAT.								APPLICATION OF COLD.				OBSERVATION OF TEMPERATURE SUBSEQUENT TO APPLICATION OF COLD.												
No. of Experiment.	Part of body in which temperature was observed.	Temp. before at end of 5 minutes.	Temp. before at end of 30-40 minutes.	Name of extremity immersed in hot water.	Temp. of water.	Time of immersion.	Remarks.	Part of body in which temperature was observed.	Temp. 1 min. after application of heat.	Temp. 3-5 min. after application of heat.	Temp. 12 min. after application of heat.	Temp. 14 min. after application of heat.	Temp. 20 min. after application of heat.	Temp. 30 min. after application of heat.	Total rise of temperature.	Remarks.	Name of extremity immersed in cold water.	Temp. of water.	Time of immersion.	Remarks.	Part of body in which temperature was observed.	Temp. 1 min. after application of cold.	Temp. 2 min. after application of cold.	Temp. 3-5 min. after application of cold.	Temp. 12 min. after application of cold.	Temp. 14 min. after application of cold.	Temp. 20 min. after application of cold.	Temp. 30 min. after application of cold.	Greatest fall of temperature.	Fall below normal temperature.	Remarks.	
XII.	Left hand.	92°	95°	Right hand.	110° to 123°	35 min.	Hand was withdrawn at intervals, as the water was too hot to bear long.	Left hand.	96°	96°	97°	97°	97°	14°	No fall of temperature occurred on the first application of heat.	Left hand.	45° to 54°	25 min.	...	Right hand.	99°	99°	98°	98°	96°	30°	09°				A feeling of chilliness came on soon after immersion of the hand in cold water, and increased in intensity.	
XIII.	Right hand.	87°	97°	Left hand.	110° to 120°	35 min.	Hand withdrawn at intervals, as the water was too hot to bear long.	Right hand.	97°	97°	98°	98°	99°	21°	Temperature fell 0.1 on first application of heat.	Left hand.	45° to 54°	25 min.	...	Mouth.	99°	99°	98°	98°	96°	30°	09°					
XIV.	Left hand.	94°	94°	Right hand.	115° to 120°	31 min.	Hand continuously immersed. Temp. of room 66°.	Left hand.	94°	94°	95°	96°	97°	34°	No primary fall of temperature occurred. Temp. of room 66°.	Right hand.	53°	23 min.	...	Mouth.	97°	97°	97°	97°	97°	06°						Chilliness came on after hand was dried, and in 30 minutes temperature in left hand was 95° F., and in mouth 97° F.; after some hot tea the temperature rose.
XV.	Left foot.	92°	95°	Right foot.	108° to 114°	21 min.	Foot continuously immersed.	Left foot.	96°	96°	96°	96°	96°	10°	Foot supported by an elastic band.	Right foot.	55°	32 min.	Felt very cold at first.	Left foot.	96°	96°	96°	96°	96°	07°	04°					The temperature of the left foot rose continuously, notwithstanding the moderate cold applied to the right foot.
XVI.	Left hand.	97°	97°	Right hand.	116° to 120°	14 min.	Hand continuously immersed. Temperature of room 69°.	Left hand.	97°	97°	98°	98°	98°	09°	A primary fall of 0.2° occurred. Temperature began to fall as soon as hand was removed from hot water being at that time 98°.	Right hand.	50° to 55°	27 min.	Water felt cold; general sensation of cold very slight.	Left hand.	98°	97°	95°	92°	60°	51°						The temperature fell another 1° after the hand was dried, but rose rapidly on reimmersion in hot water; left hand and body were sweating whilst right was in hot water, but became dry when it was placed in cold.
XVII.	Right hand.	94°	96°	Left hand.	108° to 110°	19 min.	Hand continuously immersed.	Right hand.	96°	97°	98°	98°	98°	18°	Hand grasping thermometer.	Left hand.	50° to 55°	20 min.	Slight feeling of chilliness.	Right hand.	91°	91°	90°	89°	87°	38°	44°					Subject of experiment was a feeble old man.
XVIII.	Right hand.	92°	92°	Left foot.	111° to 118°	24 min.	Foot continuously immersed.	Right hand.	88°	87°	88°	88°	88°	08°	A primary fall of nearly 4°. No sensation of chilliness attended it.	Left foot.	50° to 55°	20 min.	...	Mouth.	91°	91°	90°	89°	87°	38°	44°					The subject of this experiment had recently recovered from a long illness.
XIX.	Left hand.	96°	97°	Right hand.	118° to 122°	21 min.	Hand continuously immersed.	Left hand.	97°	97°	97°	98°	98°	10°	...	Right hand.	55°	21 min.	...	Left hand.	98°	98°	97°	97°	97°	08°					No fall below the normal occurred in this case from the application of cold.	
XX.	Left hand.	96°	96°	Right hand.	118° to 122°	33 min.	...	Left hand.	96°	96°	97°	98°	98°	17°	...	Right hand.	38°	14 min.	Much pain in hand withdrawn now and then.	Left hand.	98°	98°	97°	97°	96°	20°	03°					Notwithstanding removal of the right hand from cold water, the temperature of the left continued to fall for half an hour, and then stood at 89° F., and the mouth at 97°. A slight cessation of chilliness was coincident with this loss of heat.
XXI.	Left hand.	97°	97°	Right foot.	112° to 120°	43 min.	Foot withdrawn at intervals, as the water was very hot.	Left hand.	97°	97°	98°	98°	98°	08°	Hand grasping thermometer. General feeling of heat.	Right foot.	36°	47 min.	Sensation of pain replaced that of cold.	Left hand.	97°	97°	97°	97°	97°	08°	0°					This experiment and experiment XXIII were made at the same time, under precisely similar conditions.
XXII.	Left hand.	98°	98°	Right foot.	116° to 120°	28 min.	Foot continuously immersed.	Left hand.	98°	98°	99°	99°	99°	08°	...	Right foot.	38°	40 min.	...	Mouth.	99°	99°	98°	98°	98°	08°	0°					The subject of this experiment was in robust health.
XXIII.	Right hand.	98°	98°	Left foot.	116° to 120°	33 min.	Foot continuously immersed. Much pain; slight sweating.	Right hand.	98°	98°	99°	99°	99°	09°	Hand merely grasping thermometer.	Left foot.	38°	34 min.	...	Right hand.	99°	98°	98°	98°	98°	12°	03°					
	Mouth.	99°	99°											06°						Mouth.	99°	99°	98°	98°	98°	08°	02°					

