RATIONAL HYDROTHERAPY.

Part One.

HISTORICAL.

WATER is without doubt the most ancient of all remedial agents for disease. This fact is evidenced by the frequent reference to its use in the earliest medical literature, as well as by the habits and customs of the most ancient peoples as brought to light more fully within recent years by the study of the old Assyrian and Egyptian records. The reason for this is clearly to be found in the fact that water is a means not only usually found ready at hand, but one which adapts itself to almost every imaginable pathological condition in a remarkable manner, thus approaching more nearly to a panacea than any other known remedy. No other agent is capable of producing so great a variety of physiological effects, no other is so universally present, and hence none is so readily adaptable for meeting the various exigencies and indications arising from accident and disease.

Hydrotherapy among the Egyptians, Chinese, and Other Ancient Nations.

The ancient Egyptians, Hebrews, Greeks, Persians, and Hindus all employed water in the treatment of disease, as do the representatives of these peoples at the present time.

According to a Chinese record dating back several centuries before Christ, a physician prescribed for a woman of that country one hundred affusions of ice-water, each followed by wrapping in a linen sheet,— a treatment in principle resembling the wet-sheet pack.

The *Tokio Medical Journal* (1881) states that the cold bath has been in use in Japan for nearly eight hundred years, especially among the native country physicians, and that nearly three hundred years ago a small treatise on the medical uses of the cold bath was published by Dr. Nakagami, in which it was especially recommended for acute mania, hysteria, asthma, and convulsions in children.

Among the Spartans of ancient Greece cold bathing was made obligatory by law. The bath in various forms is also frequently referred to in Grecian mythology.

Hippocrates on the Use of Water.

Hippocrates evidently had an excellent understanding of the physiological properties of water, both hot and cold, which he employed in the treatment of fevers, ulcers, hemorrhages, and a variety of maladies both medical and surgical, giving many directions for its use which the experience of two thousand years has not improved upon. For instance, he directed that cold baths should be of short duration, and should be preceded and followed by friction; and he evidently understood the phenomena of reaction, since he records the observation that after a cold bath the body quickly recuperates its heat and remains warm, while a hot bath produces the opposite effect.

Under the Romans the bath attained a very high degree of development. Emperors vied with one another in erecting magnificent public baths, capable of accommodating thousands of persons daily. In studying the interesting ruins of some of these structures at Rome and Pompeii, the author was astonished to find the perfection attained in every detail of the equipment of these ancient bathing establishments. Hot or cold water baths, hot-air and vapor baths, might be enjoyed at will.

Asclepiades employed water in nearly every form,— hot and cold baths, douches, compresses, etc. One of his disciples, Antonius Musa, attained great fame by curing the Emperor Augustus of a chronic catarrh by means of the cold bath, as a reward for which his statue was ordered to be erected in the temple of Esculapius ; but a lack of discrimination in the use of this powerful agent led to his downfall. Being called upon to treat the emperor's nephew, Marcellus, a popular favorite, he adopted the measures which had resulted so admirably in the cure of the athletic old soldier, but they proved too powerful for the effeminate youth, and he was prostrated to such a degree that he died soon after at Naples, where he had gone to receive treatment at the hot baths of Baiæ. This enthusiastic apostle of hydrotherapy succeeded later in redeeming his reputation by the cure of the poet Horace.

Pastor Kneipp, the Bavarian water-cure empiric, a few years ago had a similar experience. Being called upon to visit the pope, who was suffering from chronic rheumatism, he was received with great honors ; but the first cold bath given the aged prelate, entirely unaccustomed to such heroic treatment, occasioned such an exacerbation of his sufferings that the poor priest was peremptorily dismissed in disgrace. Had the patient been a sturdy young German peasant instead of a feeble Italian gentleman, the prescription might have succeeded better. A similar lack of discrimination, whether by a charlatan or a legally qualified practitioner, is always attended by disastrous results. The untoward effects thus produced should not, however, be attributed to scientific hydrotherapy, but must be charged to the stupid audacity of quackery, or to the lack of information or experience of the otherwise competent physician.

The Medical Use of the Bath by the Romans and Arabs.

According to Pliny, the bath was almost the exclusive method of treatment employed in Rome during five centuries. Celsus and other prominent Roman physicians highly extolled the bath in their works, Celsus later making it one of the three essentials of what he called a perfect therapeutic system, termed "apotheraphia," the other two being exercise and friction.

During the middle ages the Arabic physicians, the most learned men of their time, were enthusiastic advocates of the bath, especially in fevers, and their directions for the treatment of smallpox and measles could scarcely be improved upon at the present time. Rhazes recommended drinking ice-water to the extent of two or three pints within half an hour, as a means of reducing the temperature in fevers. Avicenna recommended cold water for the relief of constipation.

M. Barra, of Lyons, published in 1675 an interesting little volume entitled, "L'Usage de la Glace, de la Neige, et du Froid" (The Use of Ice, of Snow, and of Cold). In this work the author anticipated many of the therapeutic uses of cold which have, by scientific experiments within the last half century, been placed upon a sound therapeutic basis. He calls attention to the fact that the Hebrews made use of melted snow for drink, and cooled water by exposing it to the action of the wind, afterward keeping it in vessels covered with straw. He pronounced cold water to be the best of all remedies for continuous fever, and especially recommended it for "erysipelas, pestilential fevers, contagious boils, frost bite, dysentery, pleurisy, the plague, inflammation of the throat, and tightness of the stomach."

Lanzani, an Italian physician, wrote an elaborate thesis on the internal use of water for the treatment of fevers, in the early part of the last century. Fra Bernardino, about the same time, acquired the name of "the cold-water doctor" by the use of iced water in the treatment of indigestion, nervous disorders, hemorrhages, etc. He required his patients to drink from three to six glasses of ice-water daily. He avoided sweating, and aimed to stimulate the bowels and kidneys.

The Popular Use of Water 150 Years Ago.

We quote below a few interesting extracts from a small work entitled, "Primitive Physick," by John Wesley, M. A., the founder of the Methodist Church, published in 1747, which afford ample evidence of the existence at that period among the common people of a very considerable amount of knowledge respecting the use of water in a variety of ailments, as well as for the preservation of health, since the remedies recommended in Wesley's work were all such as he found in successful use among the people.

For ague or intermittent fever, "go into the cold bath just before the cold fit" (this method is still in use in Germany and France); or, "drink a quart of cold water just before the cold fit, and then go to bed and sweat."

For a tertian ague, it is recommended to "use light and sparing diet on the day between," "or use the cold bath (unless you are of advanced age or extremely weak [a wise precaution, showing no little experience]). But when you use this, on any account whatever, it is proper to go in cool; to immerge at once, but not head foremost; to stay in only two or three minutes (or less at first); never to bathe on a full stomach; to bathe twice or thrice a week at least, until you have bathed nine or ten times; to sweat immediately after it (going to bed), in palsies, rickets, etc."

"Before the cold fit begins, go to bed, and continue a large sweat by [drinking] lemonade for six or eight hours. This usually cures in three or four times. If it does not, use the cold bath between the fits." The writer found this method in use among the laity of the western part of the United States more than a quarter of a century ago, and with success in cases in which quinine and other antiperiodics had failed to effect a cure.

For apoplexy, "to prevent, use the cold bath, and drink only water."

For asthma, "take a pint of cold water every morning, washing the head therein immediately after, and using the cold bath once a fortnight." "For present relief, vomit with a quart or more of warm water. The more you drink of it the better."

For dry or convulsive asthma, "use the cold bath thrice a week."

"*To prevent swelling from a bruise*, immediately apply a cloth five or six times doubled, dipped in cold water, and new dip when it grows warm."

"*To cure a swelling from a bruise*, foment it half an hour, morning and evening, with cloths dipped in water as hot as you can bear."

For a burn or a scald, "immediately plunge the part into cold water. Keep it in an hour; or if not well before, perhaps four or five hours."

"*To prevent the rickets, tenderness, and weakness* [in children], dip them in cold water every morning, at least until they are eight or nine months old."

For whooping-cough, "use the cold bath daily."

For cholera morbus, "drink two to three quarts of cold water, if strong, or of warm water, if weak."

For a cold, "drink a pint of cold water lying down in bed."

For colic, "drink a pint of cold water, or a quart of warm water, or [apply] hot water in a bladder, or steep the legs in hot water, a quarter of an hour."

For hysteric colic, "use the cold bath. Using the cold bath two and twenty times a month has entirely cured hysteric colic fits and convulsive motions."

For chronic headache, "keep your feet in warm water a quarter of an hour before you go to bed, for two or three weeks."

For headache from heat, "apply to the forehead cloths dipped in cold water, for an hour."

For one seemingly killed by lightning or suffocation, "plunge him immediately into cold water."

For mania, "apply to the head, cloths dipped in cold water, or pour cold water on the head out of a teakettle, or let the patient eat nothing but apples for a month."

For rheumatism, "use the cold bath, with rubbing and sweating."

For rickets, "wash the child every morning in cold water."

For sciatica, "use cold bathing and sweat, together with flesh-brush twice a day; or drink half a pint of cold water daily in the morning and at four in the afternoon."

For stone, to prevent its occurrence, "drink a pint of warm water daily just before dinner."

For swelling of the joints, "pour on the part daily a stream of warm water, or a stream of cold water one day and warm water the next."

"It is also useful to use the hot bath a few days before you use the cold."

Wesley recommended cool bathing for the cure of nearly all the affections of childhood, all chronic diseases, and many surgical cases.

Although Wesley was not a physician, but simply described in his work such successful remedies as he found in common use, one can not but note the sagacity and wisdom displayed in many of these recommendations, which in many instances could scarcely be improved upon at the present day, and certainly evince extended and accurate observation of the effects of hydriatic applications.

Cullen's Use of Water in Fevers.

Cullen made some very practical observations respecting the therapeutic uses of water. In his treatise on fever he commended water as a sedative when used in such a manner as to "moderate the violence of reaction," and as a tonic when used for "supporting and increasing the action of the heart and arteries." The action of cold he described as follows: —

1. Diminished temperature and pallor of the skin.

2. Weakened action of the heart and arteries, observing that in cold countries the pulse is uniformly slow.

3. Weakness and inactivity, effects observable in the inhabitants of cold countries.

4. Prolonged and very cold applications "are capable of entirely extinguishing the vital powers," cold combined with moisture chilling the body much faster than dry cold.

5. Cold applications prepare the body for applications of heat, "producing accumulation of sensibility to the stimulus of heat."

Cullen used water according to Dr. Darwin's rule — "to warm the patient in the cold fit, and to cool him in the hot one."

Hydrotherapy in Europe.

It is very interesting to observe how few of our modern methods of employing water are really new. The moist compress was well known to the ancient Greeks under the name of "epithem." According to Sir John Floyer, who wrote in the latter part of the seventeenth century, the wet-sheet pack was employed in his time by sportsmen who wished to diminish the weight of their jockies. The method is thus described: —

"Dip the rider's shirt in cold water; and after it is put on very wet, lay the person in warm blankets to sweat him violently, and he will after lose a considerable weight, a pound or two."

The same method was used in the treatment of various maladies, particularly rickets in children. The child, being prepared for bed with a gown and nightcap, was quickly immersed in cold water, then put to bed closely wrapped in warm blankets, and left in this condition all night, sweating profusely, a portion of the clothing being removed toward morning so that the body might be gradually cooled. That it was the custom to employ this method with great perseverance is evidenced by the following suggestion made by the learned author: "If one year's dipping proves not successful, it is repeated the next year, which generally answers expectation."

Floyer also mentions that in Staffordshire and other parts of England it was a custom with the people "to go into the water in their shirts, and when they come out, they dress themselves in their wet linen, which they wear all day, and much commend that for closing the pores and keeping themselves cool; and that they do not commonly receive any injury or catch any cold thereby, I am fully convinced from the experiments I have seen made of it."

The leading features of the so-called "Kneippism" are simply a revival of these rude practices of ignorant English peasants a century and a half ago.

Sir John Sinclair, in his "Code of Health and Longevity," gives an account of an English nobleman, born in the year 1700, who for a great part of his life was accustomed, immediately on arising in the morning, to wrap himself in a sheet just dipped in cold water — a wet-sheet pack.

In the fifteenth century, Savonarola, an Italian physician, made a systematic use of the cold bath, and Barizzi employed the cold vaginal douche in uterine affections. Cold affusions and general douches were employed by Baccio in Italy, while leading Spanish and German physicians recommended cold applications for insomnia.

Septala, in the seventeenth century, employed the cold douche for the relief of headache and sunstroke.

Herman, a Belgic physician, resorted to the use of cold water at the same period for the relief of constipation, migraine, paralysis, and mania,— maladies in the treatment of which cold water still holds its own against all other single remedies.

Hydrotherapy in England.

Sir John Floyer, in 1697, published a history of cold bathing, in which he directed that the patient should be made to sweat before taking the cold bath, by wrapping him in a wet sheet with blankets, precisely the same method employed more than a century later by Priessnitz, and now known as the wet-sheet pack. Floyer also erected a water-cure establishment at Litchfield, England, in the latter part of the seventeenth century. Two rooms were provided, one of which was used for hot baths and dry packs to produce sweating, while cold baths were administered in the adjoining room.

John Hancock published a work entitled "Febrifugum Magnum," in 1723, in which he demonstrated the value of water-drinking as a means of treatment in scarlet fever, smallpox, and measles. He cured ague by having the patient drink large quantities of cold water while wrapped in blankets, thus inducing profuse sweating.

Sir John Chardin, a celebrated English traveler of the last century, had bilious remittent fever when in Persia. His companion, a French surgeon, thinking his case hopeless, a native physician was called in, who made the patient fast five days, and drink large quantities of water previously cooled with snow, causing him to lie meanwhile upon a mat wet with water, and keeping the skin constantly wet with water. Water was also poured at intervals over the patient while two men supported him. In two days the fever disappeared.

This Persian physician evidently had a knowledge of the value of water-drinking, of the evaporating bath, and of affusion as a means of combating fever,—invaluable measures, of which Western physicians are scarcely yet making any considerable practical use.

The native physicians of Mohammedan countries still generally follow Galen, and so make use of water in many maladies in a very effective and practical way.

The Work of Currie and Jackson.

Two English physicians, Currie and Jackson, in the latter part of the last century, made a most intelligent and scientific study of the use of water in fevers, and with results which for a time commanded much attention from the profession in England. Currie discovered many important principles relating to hydrotherapy, some of which have not always been kept in mind by his successors in the use of water. For example, he says that the indications for the use of water in fevers, especially intermittent, are as follows:—

1. To diminish cold in cold stages.
2. To diminish heat in heat stages.
3. To diminish spasm of blood-vessels.
4. To support the powers of life till the diseased associations die away from the ceasing of their causes.
5. To unload the bowels.

He also advised cold water drinking in large quantities, immersion instead of effusion in warm countries, where the water is seldom at a lower temperature than 70° F., and suggested that after immersion the patient should be exposed to the air, so that the body might be cooled by evaporation. He recommended as a principle of the utmost importance for regulating the use of water, that it might be safely used "when there is no sense of chilliness present, when the heat of the surface is steadily above what is natural, and when there is no general or profuse perspiration." He observed that a cold pour could be used more safely than cold sponging, for the reason that it is "an energetic remedy," and "the system often accommodates itself to a cold which is general and stimulating, but shrinks from a cold which is slow and successive."

He also warned against fatigue occasioned by too much bathing, and recommended that after the bath the patient should be dried "hastily with towels," and recommended that when too severe effects had been obtained, causing too great depression, the extremities should be rubbed, and "a bladder of hot water applied to the stomach."

Currie also noted the evil effects of reaction in fever, and taught that short cold applications should not be made in cases of high fever, on account of their tendency to increase the fever. He also taught that great mischief might result from the use of hot applications immediately after cold in such cases. He made use of the "wet blanket," or pack, in fevers, and observed that it relieved delirium. He also applied cold to the feet in hemorrhage of the lungs, and in a case of pulmonary hemorrhage suddenly plunged the patient up to the hips in cold water, a method previously successfully used by Dr. Darwin for relief of hemorrhage from the kidneys.

Even before the time of Currie, Crawford, in 1781, had recognized as one of the physiological effects of cold, its influence upon oxidation, observing that cold "increases the difference in color between arterial and venous blood, while heat lessens this difference in color."

For some reason not easily understood, the work of Currie and Jackson, the ablest of the early pioneers of a truly scientific method of inestimable value in febrile disorders, was lost sight of, and it was not until the attention of the whole civilized world was attracted by the fame of an uneducated and blundering, but still successful, cold-water empiric, that the profession began to give this agent the serious attention that was its due; for the modern popularity of water as a remedy must without doubt be largely credited to the enterprise and ingenuity of a Silesian peasant, Vincent Priessnitz, born in the little village of Græfenburg, in Austrian Silesia, in 1790.

Hydrotherapy in America.

At a very early period, Dr. Benjamin Rush, of Philadelphia, used cold water with success in the treatment of rheumatism, gout, smallpox, measles, and many other maladies, including yellow fever. Currie declares that he found cold water "a most agreeable and powerful remedy . . . applied by means of napkins to the head, and to be injected into the bowels by means of the clyster, also washing the face and hands, and sometimes the feet, with cold water." In 1794 Rush introduced the use of broken ice in a bladder applied to the head in fevers, and claimed great advantage from the employment of this remedy.

Drs. Bard and Hosack, of the New York Hospital, began the use of cold water in fevers about the year 1795, three or four years before Currie's book on the medical uses of water appeared in America.

In 1799, Peter Edes, of Augusta, Me., published an interesting little work on the use of water, summarizing Currie's volume, and adding observations of his own.

Another American writer ingeniously suggested, in 1808, the employment of moistened clay as a cooling application for inflamed and congested parts. He used cold in the early stages of fever, but forbade its use in the latter stages.

Among the earliest scientific observations respecting the effects of the bath as regards both the physiological and the therapeutic effects of water, must be noted the careful experiments conducted by Henry Wilson Lockette, of Virginia. These experiments were published by him in the year 1801 in "An Inaugural Dissertation on the Warm Bath, presented to the Trustees of the Medical Faculty of the University of Pennsylvania for the Degree of Doctor of Medicine." In this treatise, a copy of which the author is so fortunate as to have in his library, Dr. Lockette details with great perspicacity the effects upon the pulse and general functions, of baths of different duration at varying temperatures. Among the observations that he made, were the following:—

1. That a foot bath at 110° F. increased the pulse from 76 to 92 beats a minute, the redness of the legs and the enlargement of the veins of the feet and legs and the slight but temporary pain in the head showing clearly the exciting effect of this treatment.

2. That a full bath at 107° F. raised the pulse from 72 to 114 beats, producing congestion of the veins, drowsiness, and profuse perspiration. The excitation continued for more than a quarter of an hour after the bath.

3. That a bath at 96° F. diminished the pulse from 79 to 64 beats in ten minutes, whereas an elevation of temperature to 100° raised the pulse to 80 beats, and a greater increase of temperature (to 105°) increased the pulse in fifteen minutes more to 92 beats. "The patient sweat freely and yawned after dressing, and was much debilitated, complaining of weakness in the legs,"— a very good description of the depressing effects of the hot bath.

4. That a bath at 90° F. lowered the pulse, in five minutes, from 80 to 64 beats. An elevation of temperature to 100° raised the pulse in ten minutes to 73 beats; and raising the temperature to 105° in twenty minutes more raised the pulse to 118 beats, with difficulty of breathing and profuse perspiration.

He noticed, among other effects, that a bath in which the temperature was gradually raised to 110° raised the pulse from 83 to 153 beats, producing intolerable pain in the head, partial delirium, confusion of thought, inability to speak, dimness of sight, vesical tenesmus, and "sensations which are commonly present in a violent state of fever." On leaving the bath, the experimenter nearly fainted, and sweat profusely for some time.

A bath at 95° F. for an hour lowered the pulse from 78 to 75 beats. Fifteen minutes after the bath the pulse-rate was 68. The experimenter says, "I experienced a considerable degree of lassitude, with an inclination to sleep," — an excellent description of the effects of the neutral bath.

A bath at 92° lowered the pulse, in five minutes, from 84 to 77 beats. At the end of thirty minutes the pulse-rate was 76.

As the result of his investigations, Dr. Lockette concluded: —

1. That a temperature below 98° F. does not increase the frequency of the pulse, and may slightly lower it, and does not produce sweating.

2. That a temperature of 98° to 105° F. "accelerates the pulse and induces free perspiration, but produces no distressing symptoms."

3. That a temperature of 105° F. "is a powerful stimulant, and should never be advised or practiced in inflammatory diseases or states of fever or violently morbid action."

Dr. Lockette made similar experiments with the steam bath, which led him to conclude it to be a more convenient method of securing perspiration than the water bath. His brochure is concluded by a chapter relating to the medical uses of the warm bath, and among the most interesting observations upon the medical uses of water are found recommendations respecting its use for the relief of sick or nervous headache, which he remarks had previously been "very little attended to by physicians." He recommends the warm foot bath, fomentations to the head, and the daily cold bath, which measures, he affirms, on the authority of Dr. Dwight, have effected a cure in many cases.

During the middle decades of the present century hydropathy flourished to a considerable extent in America, and half a century ago we were much nearer the front in this line of progress than at the present time. Many institutions devoted to the carrying out of these measures were established in different parts of the United States, and scientific hydrotherapy was ably advocated by Dr. John Bell, of Philadelphia, whose work on "Baths" has, up to the present time, remained the most complete and able treatise on the subject in the English language, though it has long been out of print, and seems to be quite unknown to the profession of to-day.

The Hydropathy of Priessnitz.

When seventeen years of age, Priessnitz met with an accident whereby he received numerous bruises and other injuries, including the fracture of two of his ribs. Local physicians gave him no hope of recovery; but having been accustomed to use water in the treatment of the domestic animals for which he cared, it occurred to him to try the same remedy for himself. He covered the affected parts with cloths kept wet with cold water, and also drank freely of water, with the result that he was in a short time completely cured. This incident made so profound an impression upon the mind of Priessnitz that, although an unlearned peasant, he determined to make a thorough investigation of the merits of water as a remedial agent, used both internally and externally. He seems even to have undertaken some experiments on animals, one of which was for the purpose of determining the relative effects of hot and cold foods. Two pigs were fed, one upon cold, the other upon hot, foods; and when the animals were killed, he made a careful examination of the intestines, and asserted that in the case of the animal fed upon cold foods the intestines were well contracted, pale, and of firm resisting structure, while in the case of the animal fed upon hot food, the intestines were red, relaxed, and so easily torn that they could not be used for making sausages.

The basis of the system of Priessnitz was perspiration, followed by cold applications. His methods were exceedingly crude and were administered with comparatively little discrimination, the natural result of his total lack of medical knowledge. However, his native tact and sagacity soon led him to recognize a difference in the ability of his patients to react to cold applications, and he accordingly made it a practice to observe in each case the effects of the first application, the readiness with which the patient yielded to the means adopted to induce perspiration, and the promptness with which reaction took place on the application of cold water.

Priessnitz discovered little, perhaps, but he succeeded in calling general attention to the efficacy of various simple methods of applying water as a remedial agent which had previously been little appreciated. And he accomplished more than this. He aided to recovery a vast number of chronic invalids whose maladies were practically incurable by the measures in common use by the medical profession of that time; and though at first denounced and opposed by scientific physicians because of his empiricism, the more sagacious among them, after a time, became convinced of the genuineness of the cures effected, and many visited him for the purpose of studying his system, such as it was.

Priessnitz found nearly all the methods of employing water which entered into his system, in use among the peasantry of his country, by whom they were commonly employed at least as early as 1737, and probably even before that time. Priessnitz, however, was one of the first to organize the use of these various measures into a system, for which he deserves much credit. Crude and empirical though his system was, his success was sufficient to compel attention, and he commanded an extensive following.

The attention thus attracted led to a careful study of the physiological effects of water in its various modes of application, for the purpose of finding a scientific foundation for its therapeutic use. Among the first to undertake this study was Fleury, who published in 1852 the first extended scientific treatise upon hydrotherapy, under the title, "Traité Pratique et Raisonné d'Hydrothérapie."

Scientific Hydrotherapy.

Liebermeister, Brand, and Ziemssen in Germany, and above all, Winternitz, of Vienna, revising, and his pupils greatly extending the work of Fleury and other pioneers, have within the last half century built up a scientific hydrotherapy which is based upon definite and accurate data. Before Fleury, the use of water was for the most part empirical; at the present time, however, thanks to the labors of the eminent investigators whose names have been mentioned, supplemented by those of Jürgensen, Rosbach, Bouchard, Delmas, Robin, Beni-Barde, Strasser, D'Arsonval, and others, it may be fairly stated that there is no therapeutic agent whose use rests upon a more thoroughly rational and scientific basis than water. It has thus been rescued from the hands of empirics and charlatans, and is now recognized by eminent medical men as one of the most potent of all remedial agents.

Hartshorne, of Philadelphia, published in 1847 a suggestive and thoughtful treatise on the use of water. In 1850, Bell, of the same city, published the best and most comprehensive work on the subject which had appeared in English before the translation and publication of the masterly treatise by Winternitz as a part of Ziemssen's therapeutics in 1883.

The work of Winternitz in establishing hydrotherapy upon a sound scientific basis so greatly exceeds that of all other investigators in modern times that we have given, at the close of this work, a complete list of the contributions to hydrotherapeutics made by this eminent pioneer in this line of medical research, which Dr. Winternitz, at the author's request, has kindly furnished him.

THE PHYSICS OF WATER, AIR, HEAT, AND LIGHT IN RELATION TO HYDROTHERAPY.

1 HOFFMAN, whose authority commands universal respect, declared water to be more nearly a panacea for all human ills than any other known agent. This fact, which has never been disproved, is largely due to the peculiar physical properties of this very versatile element. Water owes its value as a therapeutic agent chiefly to three most remarkable properties: (1) Its great power for absorbing and communicating heat; (2) its solvent properties, water being the one universal solvent; (3) the facility with which its physical state may be changed from a liquid to a solid or a gaseous form. These properties give to it the most perfect adaptability to the various modes of application which are required in hydrotherapy. It will be worth while to consider briefly each of these several properties, as follows:—

2 **The Specific Heat of Water.** Water absorbs more heat for a given weight than any other body, and is hence taken as the standard of "specific heat." A pound of water contains five times as much heat as an equal weight of glass; about ten times as much as the same weight of iron, zinc, copper, or brass; and thirty times as much as the same quantity of mercury, gold, or lead. The specific heat of the human body is nine tenths that of water.

3 The readiness with which water absorbs and communicates heat and the great amount of heat which it is capable of communicating or storing, exactly adapts it for use in making thermic applications of either heat or cold to the human body. There is no other substance which is at all capable of replacing it for these purposes.

4 Because of the large amount of water entering into the composition of the human body, its specific heat is near that of water, viz., .9°. A pound of water at 10° will raise the tem-

perature of one pound of iron or copper from zero to nearly 10°. A quantity of water equaling the body in weight, losing 1° of temperature through contact with the body in a full bath, will raise the temperature of the body a little more than 1°, taking no account of any change in heat production or heat elimination.

In the solidifying and freezing of water a large amount of 5
heat is rendered latent, as shown by the fact that a pound of ice in melting absorbs, without any elevation of temperature, heat enough to raise one pound of water 142° in temperature, the temperature of the water from the melting ice remaining at 32° or slightly above it until all the ice is melted.

Water, in passing from the liquid to the gaseous state, 6
likewise absorbs a considerable amount of heat. The amount depends somewhat upon the pressure, but may be reckoned at about 950 heat units, or the amount required to raise 950 pounds of water 1° in temperature. The total amount of heat required to raise a pound of water from the ordinary temperature to that of steam is about 1,130 heat units. This heat reappears when the steam is condensed at the ordinary temperature.

In hydrotherapy, water is most commonly used in its liq- 7
uid state, but it is also employed in the form of ice, and in the form of steam, though as steam, water is never applied directly to the body. When steam is utilized, as in the Russian or vapor bath, the body is not actually exposed to steam, but to the fog or mist formed by the condensation of the steam through contact with the atmosphere. In a vapor or Russian bath the patient is not heated by the steam, but by the hot air and the suspended particles of warm water which come in contact with the body. As the steam enters the air of the apartment from the steam-pipe or other source, it is at once condensed into a mist, giving up to the air the ten or eleven hundred heat units which it contains, and thus heating the air. A pound of steam is capable of raising from

the ordinary temperature to 130° eighty-seven pounds of air, or 1,100 cubic feet of air, the amount contained in an apartment 10 x 10 x 11 feet in size. One pound of steam applied to the body would be capable of raising the temperature of a man weighing 150 pounds nearly 8°, or ten pounds of flesh to a temperature of over 212°. It is for this reason that steam can not be brought in contact with the tissues without destroying them.

8 A pound of ice, on the other hand, is capable of removing from the tissues of the body with which it is brought in contact 142 heat units while melting. It will not, however, lower the temperature of the tissues below 32°, unless its own temperature should happen to be considerably below the freezing point, which might be the case in very cold weather. It is apparent that in the use of ice great care must be exercised in order to avoid damaging the tissues by prolonged contact.

9 The temperatures employed in hydrotherapy are practically within the limits of 32° and 140° F. Applications are occasionally employed at a lower temperature, and very hot water may sometimes be applied, at a temperature as high as 160°, as a means of stopping hemorrhages; but great care must be used. Live steam has recently been suggested as a means of checking hemorrhage, and may possibly prove to be of service in this capacity. Vapor and hot air may be tolerated at higher temperature.

10 Water is a fairly good conductor of heat. Its conductivity is much greater than that of air, but far inferior to that of the metals. Copper conducts heat one hundred times better than water. As a conductor of electricity, copper is immensely better than water. It is for this reason that water at any given temperature, hot or cold, makes a much more intense impression upon the skin than does air at the same temperature. On the other, hand, metals of all sorts feel colder or hotter than does water of the same temperatures.

Ordinary water is a good conductor of electricity, a fact 11
which enables it to render valuable service in most percutaneous applications of electricity and in such combined procedures as the hydrofaradic, the hydrogalvanic, and similar baths.

The Solvent Properties of Water.

As before remarked, water is the one uni- 12
versal solvent. In the body it is the medium by which the foods rendered soluble by digestion are conveyed to the tissues to be assimilated, and thus rendered insoluble, while the effete matters rendered soluble by disassimilation are dissolved and conveyed back into the blood current, to be acted upon or eliminated by the liver, the kidneys, the skin, and the other excretory organs.

It is interesting to note that sugar and peptone, the 13
two chief constituents of digested food, are among the most soluble of substances. Carbonic acid gas, a product of the oxidation of carbohydrates and hydrocarbons, is also highly soluble in the saline medium which constitutes the serum of the blood. Urea, a product of proteid oxidation, has a high degree of solubility in water. Uric acid, oxalic acid, and other abnormal products are, on the other hand, less easily soluble than the normal waste products, and hence, as has been shown by Haig, readily accumulate in the body, especially in those portions in which the circulation is least active.

Thus the value of water as a detergent agent, not only for 14
the surface of the body but for its interior as well, is apparent. This is, indeed, one of the most important therapeutic uses of water. It may be applied by means of water drinking, the enema, or the coloclyster (this term seems to the author preferable to the French *enteroclyster*), gastric lavage, and by subdermic injection of the normal saline solution.

Water in the liquid form readily lends itself to application 15
to the body in numerous ways, both active and stable, by the different forms of immersion, compresses, douches of

various sorts, etc. The ease with which its temperature may be varied enables us to secure by its means every degree of thermic effect desirable, while its weight renders possible various mechanical or pressure effects which are also highly valuable, as will appear later in this work.

16 **The Atmosphere** The relation of air to the thermic effects employed in hydrotherapy is perhaps less direct and important than that of water, yet it is by no means insignificant. Air as well as water is capable of absorbing heat. Although its specific heat is scarcely more than one fifth that of water, the ease and rapidity with which it circulates about the body, its continuous contact with the skin, the variability of its temperature, and especially the fact that it is concerned in the evaporation of moisture from the skin, whereby an enormous amount of heat is constantly removed from the body, render its relations as a thermic agent important.

17 The influence of the air upon the body depends not only upon its temperature but also upon the amount of water which it contains. A cubic foot of air at 32° is capable of absorbing slightly more than two grains of water. A cubic foot of air at 96° is capable of absorbing eight times as much, while air at 72° absorbs four times as much, or eight grains. It is thus apparent that air which has had its temperature raised without the addition of moisture is capable of promoting evaporation from the skin to a high degree. This fact must be taken into consideration in the management of patients at the different seasons of the year. In the summer-time the air is often completely saturated with moisture, while in the winter-time saturation of the heated air indoors rarely if ever occurs, except by the aid of artificial means. The more completely saturated the air is, the less rapidly does evaporation take place. Patients are much more likely to complain of chilliness after baths in the winter than in the summer, for the reason that the extreme dryness of the air gives rise to rapid evaporation of the small amount of mois-

ture left on the skin after leaving the bath-room, giving rise to chilliness, and occasionally resulting in a cold. On this account, patients must in the winter-time be dried with special thoroughness before leaving the bath-room, and must afterward be particularly careful about exposing themselves.

The rapid rate at which heat is removed from the body 18
by evaporation when dry warm air is brought in contact with it may be easily shown by a simple illustration: Suppose an apartment (20 x 13 x 10) contains 2,600 cubic feet of air at 96°, the temperature out of doors being 32°. The indoor air is capable of absorbing nearly fifteen grains of water, in addition to that which it already contains, for each cubic foot, or more than five and one-half pounds of water. The absorption of less than one half of this (two pounds) through evaporation from the surface of the patient's body will abstract from the body something like 2,000 heat units, and would be capable of reducing the temperature of the body more than 13°, provided no heat was in the meantime produced. The same air, if saturated with water, would absorb little water, and would take very little heat from the body. The relation of different conditions of the atmosphere to the rate of evaporation from the skin is a question which should perhaps receive more consideration in connection with hydrotherapy than has generally been accorded it.

It is also important to note that the respiratory processes 19
of both the lungs and the skin are diminished by an exceedingly dry atmosphere. Interchange of gases in the lungs is also interfered with by an atmosphere saturated with moisture.

Atmospheric pressure is likewise a matter well worthy of 20
attention in connection with hydrotherapy. In institutions located at an altitude of several thousand feet above the level of the sea, this is of special importance, on account of the tendency to pulmonary congestion due to the rarity of the atmosphere. Under such circumstances extreme care must be

taken to avoid the application of the cold douche and similar measures in such a way as to provoke disturbance of respiration ; in other words, cold applications must be made to the chest only with the greatest care, and after applications have been made to other portions of the body, so that the effect may be generalized.

21 Cold air produces a less intense sensation of cold than does cold water, for the reason that its ability to absorb heat is only one fifth as great, and its conductivity of heat is enormously less. The thermic effect produced upon the skin by an object brought in contact with it is due both to the specific heat of the object and to its conductivity. Iron, copper, and other metals are such excellent conductors of heat that they may feel colder than water at ordinary room temperature even though their specific heat is many times less.

22 **Heat.** Most of the effects of hydrotherapy are obtained by means of methodical thermic applications to the skin. In other words, the specific effects of hydrotherapy are not chiefly due to water *per se*, but to the impressions of heat or cold made by this agent when brought in contact with the skin. So far as these same effects may be produced by other means, precisely the same results may be obtained.

23 Heat and cold are relative terms, what is termed a cold application being simply one that is of a temperature a definite number of degrees lower than the so-called warm or hot application. The impression made upon the skin, as elsewhere remarked, depends not only upon the temperature of the application, but upon the relation existing between the temperature of the application and the temperature of the skin.

24 The science and art of hydrotherapy include not only applications of water in its various forms, but thermic applications made by means of hot or cold air, vapor, and various heated objects, also heat and light.

Various sources of heat may be utilized in making thermic applications to the human body for therapeutic purposes. While water is generally the most convenient agent, there are conditions to which it is not adapted, and in which other means may be more advantageously employed. Heated air, the vapor of water, or rather the fog resulting from the condensation of steam in air at a temperature near that of the body, the sun's rays, and lastly the electric ray may all be utilized. The use of hot air in the form of the Turkish bath dates from remote antiquity, and the hot-air bath and the vapor bath have been used by many primitive people. The electric ray is, however, one of the most interesting sources of thermic energy; and while only recently introduced to practical therapeutics, it is certain to prove itself of the greatest practical utility. Both forms of the electric lamp, the incandescent and the arc, may be utilized as sources of heat. **25**

The sun's rays, which the electric ray closely resembles in its action as a thermic agent, have been utilized in the treatment of the sick from the most ancient times. The amount of heat received hourly upon each square foot of the earth's surface is about equivalent to that produced by the burning of a sufficient amount of coal to produce one fourth of a horse-power of mechanical energy. The physical and therapeutic properties of sunlight and of the electric ray will be considered at greater length elsewhere in this work (**597**). **26**

This means has the advantage over others in that the rays of radiant energy received from a luminous source penetrate the skin and the tissues to a great depth, in fact, reaching without doubt, the very innermost portions of the body. **27**

When electricity meets with resistance, as in passing over a poor conductor, it is converted into heat. The same principle holds in relation to light. When light passes through a perfectly transparent medium, no heat phenomena are manifested. Very little heat accumulates in pure white glass when the sun's rays fall upon it; but if the same glass be colored or painted black, it is very quickly heated. **28**

29 As the luminous rays are intercepted by opaque particles in the tissues, they are converted into heat. Thus heat is generated in the depths of the tissues, the very place where this form of vital stimulus is required, instead of being applied only to the skin, as when hot water, air, or other media are employed. This fact renders the electric-light bath or the sun bath superior to all other heating procedures.

Thermometer Scales and Heat Units.

30 The centigrade scale divides the temperature range from freezing to boiling into one hundred degrees, making the freezing point zero, whereas the freezing point is 32 in the Fahrenheit scale, and the boiling point 212. The Fahrenheit scale thus divides the range of temperature between freezing and boiling into 180 degrees. It is apparent that 100 degrees of the centigrade scale is exactly equal to 180 degrees of the Fahrenheit scale, and that one degree Fahrenheit equals $\frac{100}{180}$, or 5–9ths, degree centigrade; while one degree centigrade equals $\frac{180}{100}$, or 9–5ths, degree Fahrenheit.

31 To find the number of degrees Fahrenheit which a given number of degrees centigrade will equal, we have only to multiply the given number by 9–5ths, or what is the same thing, but a shorter method, we may multiply by two, and subtract one tenth.

32 Example: Suppose the difference in temperature between two objects is 40° C.; what will be the difference expressed in Fahrenheit degrees?

Answer: $$40 \times \frac{9}{5} = \frac{\overset{8}{\not{4}\not{0}} \times 9}{\not{5}} = 72; \text{ or,}$$

$$40 \times 2 = 80 - 8 \ (80 \div 10 = 8) = 72.$$

33 To ascertain the number of degrees centigrade which will equal a given number of degrees Fahrenheit, we have only to multiply the number of degrees centigrade by 5–9ths, or what is the same thing, divide by two and add one ninth.

Example: Suppose the difference in temperature between **34**
two objects is 72° F.; how may the same difference be expressed in centigrade degrees?

Answer: $$72 \times \frac{5}{9} = \frac{\overset{8}{\cancel{72}} \times 5}{\cancel{9}} = 40;\ \text{or,}$$

$$72 \div 2 = 36 + 4\ (36 \div 9 = 4) = 40.$$

But in converting Fahrenheit or centigrade temperatures **35**
into equivalent expressions, we must generally take account of the fact that the zero point is not the same in both. So before beginning the calculation of converting a given fixed temperature, as shown by a Fahrenheit thermometer, into an equivalent expression in the centigrade system, we must first subtract 32; and in converting centigrade to Fahrenheit, we must add 32 at the end of the calculation.

For example: If we wish to convert 104° F. into an equivalent expression centigrade, we first subtract 32, then proceed as above (**33**). If we wish to convert 40° C. into an equivalent expression Fahrenheit, we proceed as in **31**, then add 32.

In the modern French system there are the greater and **36**
the lesser calorie. The greater calorie simply represents the amount of heat required to raise the temperature of one kilogram of water one degree centigrade in temperature. The lesser calorie represents the amount of heat necessary to raise one gram one degree centigrade in temperature. In other words, the lesser calorie is the one thousandth part of the greater calorie. In the English system, which is not much in use at present, but is convenient in popularizing the principles of hydrotherapeutics, a heat unit represents the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit in temperature.

To convert kilogram centigrade calories into gram centi- **37**
grade calories it is only necessary to multiply by one thousand by moving the decimal point three places to the right.

38 To convert kilogram centigrade calories into pound Fahrenheit units, it must be remembered that the kilogram equals 2.2 pounds, and the centigrade degree 1.8 Fahrenheit degrees; hence the converting factor will be $\frac{22}{10} \times \frac{18}{10} = \frac{99}{25}$, or, approximately, 4; that is, we may for practical purposes simply multiply by four, to convert greater calories into an equivalent expression in pound Fahrenheit heat units. To be absolutely exact, we must subtract one per cent.

Example: We wish to convert 425 kilogram calories into pound Fahrenheit heat units.

$425 \times 4 = 1700 - 17$ (1 per cent. of 1700) $= 1683$.

39 To convert pound Fahrenheit heat units into greater calories we may multiply by $\frac{25}{99}$, or, what is practically the same thing, divide by four, and add one per cent.

Example: We wish to convert 400 pound Fahrenheit heat units into an equivalent number of greater calories.

$400 \times \frac{25}{99} = 101.01$; or,

$400 \div 4 = 100$; $100 + 1$ (one per cent. of 100) $= 101$.

40 **Medical Thermometry.** The expert hydrotherapist will give minute attention to the temperature of the patient, and of the air of the sick-room, as well as that of the water employed in remedial applications. The thermometer must be in constant requisition. It is not prudent to trust to the sensations, as these are too fickle and deceptive to serve as a reliable guide.

41 The temperature of the room must be maintained at about 65° F. In fevers a temperature of 60° is best. The sick-room is generally too warm, a fact which greatly increases the depression of the patient, and often excites a rise of temperature.

42 The temperature of the bath may be accommodated somewhat to the patient's sensations and predilections, but the exact temperature must be known, notwithstanding, and should be recorded. In an emergency, if a thermometer is not at hand, the temperature may be approximately determined by the following method:—

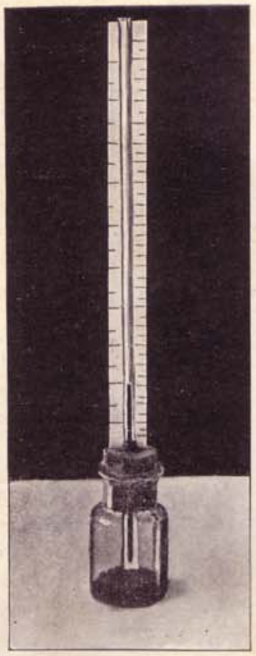

FIG. 1. AN EMERGENCY THERMOMETER (p. 50).

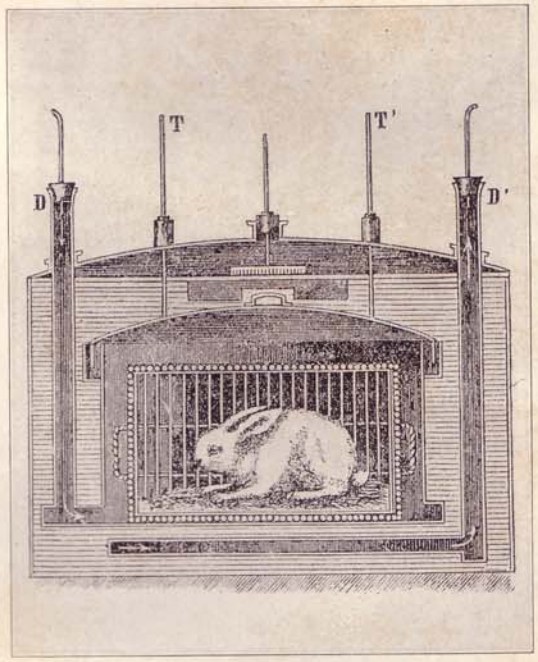

FIG. 2. WATER CALORIMETER (p. 52). (Dulong)

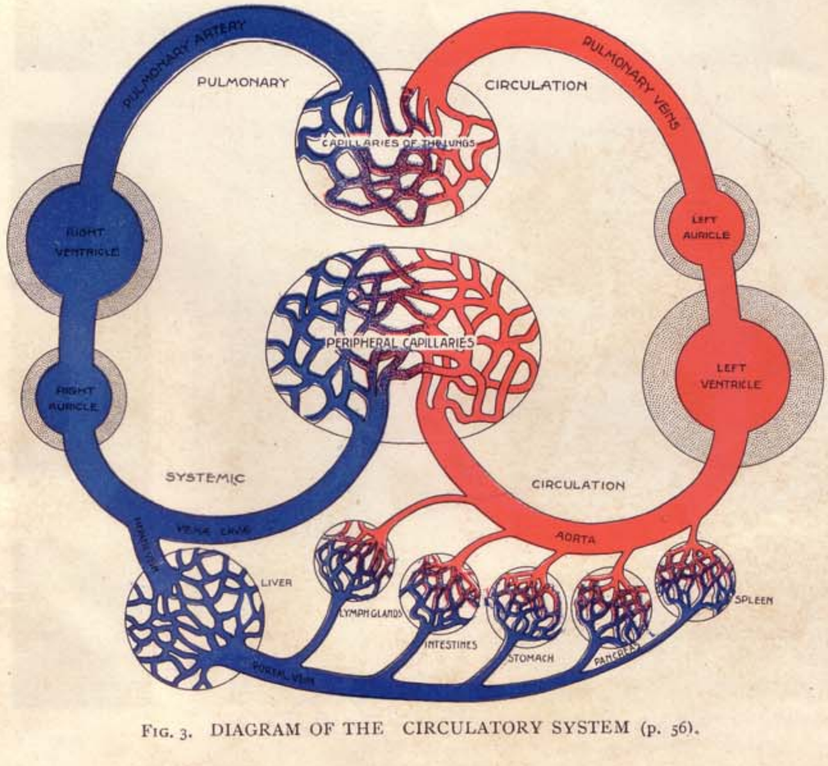

FIG. 3. DIAGRAM OF THE CIRCULATORY SYSTEM (p. 56).

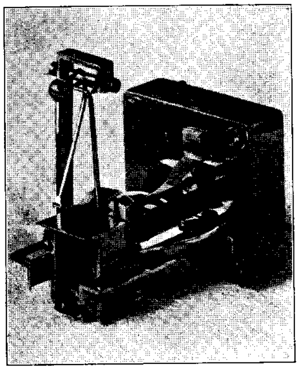

FIG. 4. SPHYGMOGRAPH (p. 60). (Dudgeon)

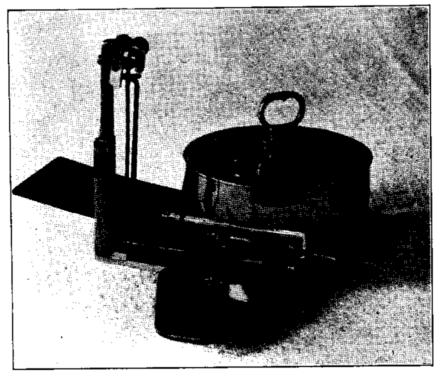

FIG. 5. SPHYGMOGRAPH (p. 60). (Granville)

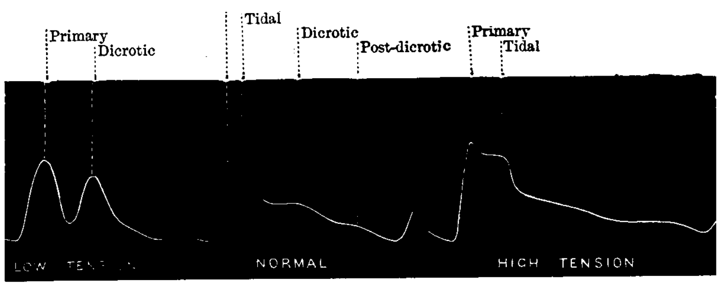

FIG. 6. DIAGRAMS OF THE PULSE (p. 60). (Waller)

FIG. 9. SPHYGMOGRAPHIC TRACING OF PULSE OF MAN AGED SEVENTY-FOUR YEARS (p. 61).

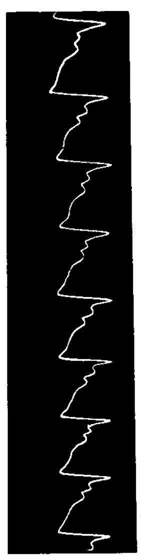

FIG. 8. SPHYGMOGRAPHIC TRACING OF NORMAL PULSE.

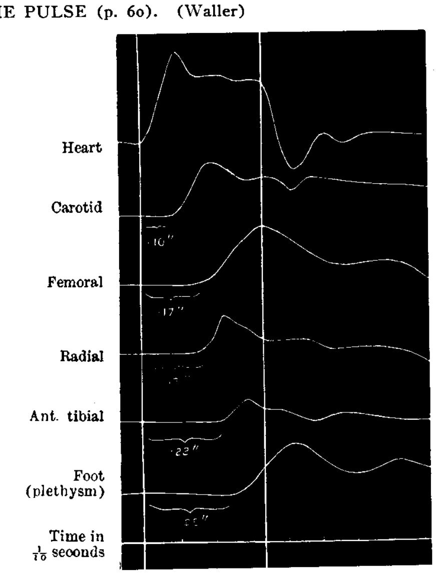

FIG. 7 PULSE IN DIFFERENT PARTS OF THE ARTERIAL SYSTEM (p. 60).

Mode of Determining and Regulating the Temperature of Water without a Thermometer.

The hand gives unreliable information respecting the temperature of water, but a more accurate judgment may be formed by plunging the whole arm to the elbow into the water, as the arm is usually protected by the clothing, and hence its temperature is more equable. When the temperature of the water is so high as to produce redness of the skin, it may be said to be hot. When there is simply a comfortable sensation of heat, it is warm. A slightly lower temperature is tepid. When the temperature is low enough to produce a goose-flesh appearance, it is cool; and a lower temperature is cold; while a temperature which within a few seconds produces pain or numbness of the parts immersed, is very cold. Water the temperature of which is so high that the hand can be held in it but a fraction of a second, perhaps, is very hot. 43

A method somewhat more accurate than the preceding, and which, with modifications, is applicable to all climates and altitudes, is as follows: The boiling-point of water at sea-level, as is well known, is 212°. In all countries the temperature of the water found in deep wells and springs is practically the same as the average of the air for the whole year. In temperate climates this is about 53°. Knowing the temperature of the well or spring water and that of boiling water, it is only necessary to combine measured quantities of water from these two sources in the necessary proportions to the amount desired. While this method is not exactly accurate, it answers for practical purposes. The following table gives the quantities to be mixed for different temperatures:— 44

Temp. 53° F.				Temp. 212° F.							
2	qts.	added	to	1	qt.	equals	3	qts.	at	106° F.	45
2½	"	"	"	1	"	"	3½	"	"	98° "	
3	"	"	"	1	"	"	4	"	"	93° "	
4	"	"	"	1	"	"	5	"	"	85° "	
5	"	"	"	1	"	"	6	"	"	80° "	
6	"	"	"	1	"	"	7	"	"	76° "	
8	"	"	"	1	"	"	9	"	"	71° "	

46 When larger quantities are needed, it is only necessary to multiply each of the combining quantities by the same number. For instance, if a gallon and a half of water is needed for a foot bath at 106°, pour into a pail or bath-tub four quarts of fresh well water and then add two quarts of boiling water. If four gallons of water are wanted for a sitz bath at 93° (a very common temperature), pour into the bath-tub three gallons of fresh well or spring water, and add one gallon of boiling water. Thus any required quantity may be obtained at the temperatures given. The cold water should be placed in the vessel first, and there should be no delay in adding the hot water, as it would rapidly lose its heat, and thus make a larger quantity necessary. The exact measurement is not necessary; it is only that the proper proportion should be maintained, the same measure being used for both hot and cold water, with both of which it is filled an indicated number of times.

47 In elevated regions, the boiling point is of course lowered, but this, being fixed, may always be known after it has once been ascertained. The temperature of deep well water or of spring water also varies little. This temperature may be ascertained, and borne in mind for use when necessary.

With ice-water and boiling water it is possible to determine the temperature of water obtained from a well, lake, or any other natural source. It is only necessary to make a mixture of ice-water and boiling water which shall have the same temperature as is noted by the hand, and to observe the percentage of each employed. For example, suppose that the proportions required are ten parts of ice-water (0° C.) to two of boiling water (100° C.). The result would be obtained thus: $10 + 2 = 12$; $200 \div 12 = 16.6°$ C., or 62° F.

48 **An Emergency Thermometer.** In Fig. 1 will be seen a simple thermometer which may be successfully used in regulating the temperature of baths, and if necessary, in determining whether or not the patient's temperature is above normal, and approximately to what degree. The instrument

consists simply of a small, thin-walled bottle, the mouth of which is closed with a cork, through which passes a tube having an opening of about one sixteenth of an inch. The tube should be about ten inches in length. In the bottom of the bottle should be placed about half an inch of a colored solution. Some aniline color dissolved in water or alcohol answers the purpose well. The tube should be passed through the cork to such a distance that when the cork is inserted in the mouth of the bottle, by pressing the cork in a little the fluid will be made to rise in the tube, and by a little management the liquid may be made to stand in the tube just at the top of the cork. Grasping the bottle in the hand, the air in the tube will be warmed and, expanding, will force the liquid farther up the tube. It is only necessary to place a foot rule behind the tube, letting the lower end rest upon the cork, and we have a very delicate thermometer with a scale which will answer a very practical purpose in the absence of a better instrument. The normal point is determined by applying the instrument to the axilla of a healthy person.

In the use of the clinical thermometer the temperature of **49** the patient should be taken in the rectum, if possible, unless enemas are being administered for cooling or nutritive purposes. If the temperature is taken in the mouth or the axilla, great care must be used to see that the lips are kept tightly closed or the arm in contact with the body.

Currie noted the fact that temperature observations made **50** by placing the thermometer in the mouth are sometimes rendered inaccurate when cold applications are administered, by the chattering of the teeth and consequent separation of the lips, admitting air.

Calorimetry. In the technical study of hydrotherapy it is **51** absolutely necessary to take into consideration not only the indications of the thermometer, or the temperature of the body as a mass, but it is of even greater importance to know what are the capabilities and the conditions of the body as a generator of heat. Information of this sort is not afforded by the thermometer alone. The data required must be obtained by means of the calorimeter. This instrument determines the number of heat units which escape from the body in a given time, and thus, as the temperature of the body remains practically uniform, the amount of heat actually produced in the body is known (Fig. 2).

In the absence of a calorimeter, it is still possible to form a very close approximate estimate of the rate of heat loss from the surface of the body. The chief means by which the body loses its heat is by radiation, in common with all other bodies, and by the contact of its surface with atmospheric air. There is a slight loss by conduction, but for practical purposes this may be ignored. A considerable loss also occurs through the evaporation of the sensible and the insensible perspiration from the skin. A dry skin gives off heat very slowly, being a poor conductor; an oily skin radiates heat fifty per cent. more rapidly than a dry or unoiled skin. This fact the author believes he was the first to point out, although it seems as if the fact ought to have been suggested long ago by the custom of the natives of tropical Africa, who smear themselves with oil when exposed to the hot sun, and take special care to cover the head well with melted fat.

The loss of heat by evaporation ordinarily amounts to about 100 heat units per hour. By means of formulæ given elsewhere (**733**) it is made clear that the rate of heat loss both by radiation and by air contact may be determined by mathematical calculation based upon the laws of heat dissipation.

A consideration of the heat loss sustained by the body as determined in this manner quickly discloses the important influence of clothing, as it shows that the amount of heat actually produced and eliminated by the skin each twenty-four hours corresponds to the heat loss which would occur with the body unprotected in an atmosphere at a temperature of 78° F.,—a temperature which the primitive tribes of men readily endure without other clothing than the smallest amount necessary to satisfy the demands of savage modesty.

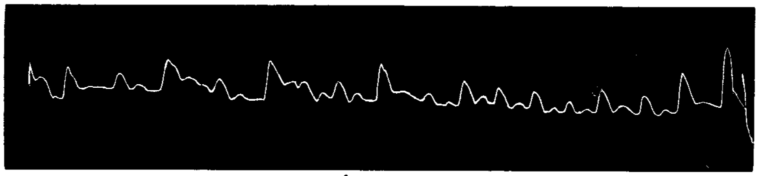

FIG. 10. PULSE OF AORTIC REGURGITATION (p. 61).

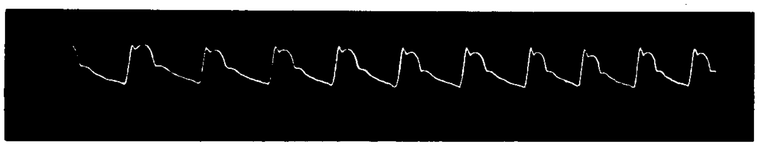

FIG. 11. SPHYGMOGRAPHIC TRACING OF A HARD (High-tension) PULSE.

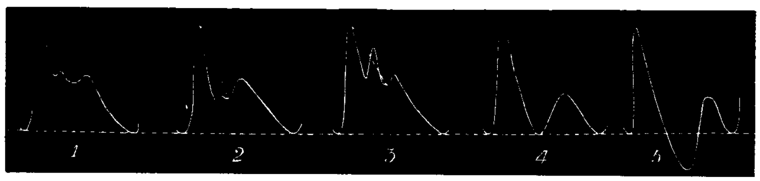

FIG. 12. DIAGRAMS OF PULSE. 1, Normal; 2, Low Tension and Soft Pulse; 3, High Tension and Hard Pulse; 4, Soft Pulse fully Dicrotic; 5, Very Soft Pulse and Hyperdicrotic. (Landois & Stering).

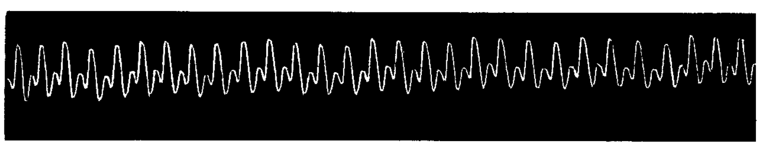

FIG. 13. DICROTIC PULSE (p. 61). (Author's Collection)

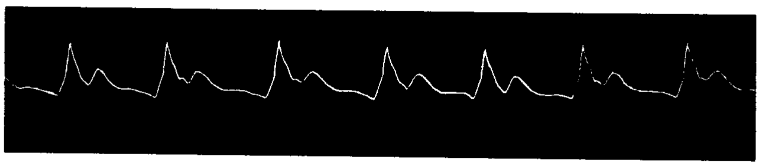

FIG. 14. SPHYGMOGRAPHIC TRACING OF A SOFT (Low-tension) PULSE.

ANATOMY AND PHYSIOLOGY IN RELATION TO HYDROTHERAPY.

THERE is no remedial agent the scientific use of which demands so thoroughgoing and practical a knowledge of physiology as does hydrotherapy. Used empirically, water is certainly less likely to lead to disastrous results than some medicinal agents, the consequences of their unscientific use being only too forcibly illustrated in the terrible damage resulting from the use of patent medicines. Nevertheless, water as a remedial agent is, like powerful drugs, a two-edged sword, and its unscientific use has not infrequently produced most untoward results. Indeed, it may well be believed that the very general prejudice prevailing, among physicians as well as the laity, against the employment of water in treating disease, is largely due to the injurious effects which have followed its bungling and unsuccessful use by so-called water-cure doctors, and well-meaning, but unfortunately not well-informed, enthusiasts, who, having themselves experienced good results from the use of this simple and versatile therapeutic agent, have unwisely undertaken to cure all their sick friends by means of the same prescription through which they were themselves benefited. **52**

Physiology the Basis of Hydrotherapy.

It is only, by an exact knowledge of the human body, its normal functions, and the modifications of tissue and function resulting from disease, that water can be therapeutically employed with the unrivaled results which this agent is capable of rendering. Not all cases, of course, are curable, but even in those that are incurable, it is marvelous to note the wonderful degree to which pain and various other symptoms may be mitigated by accurately adapted hydriatic prescriptions. **53**

54 To use water intelligently, one must be a thorough physiologist, and must have an especially good understanding of the anatomy and physiology of the skin and the nervous system. Thus, for the convenience of the student, and that he may have freshly in mind those anatomical and physiological facts that are most essential to an understanding of the general principles of hydrotherapy, this chapter is devoted to a brief summary of the anatomy and physiology of the circulation, the skin, and the nervous system, so far as they are particularly concerned in the physiologic and therapeutic effects of hydriatic procedures.

THE CIRCULATION.

55 We have neither the space nor the purpose to review the whole subject of the anatomy and physiology of the circulation, but desire to recall simply the leading facts and to emphasize a few points which have a special relation to hydrotherapy.

56 The organs of the circulation are the heart, the blood-vessels (arteries, capillaries, and veins), the lymphatics (glands and ducts), and perhaps the spleen also may be included.

57 The heart is a muscular organ, having in its walls nerve ganglia which give origin to motor impulses whereby its activity is initiated and maintained. The heart's action is regulated by nerves from the cerebrospinal system: (1) The accelerator nerve, consisting of non-medullated fibers; (2) the inhibitory nerve (vagus), consisting of fine, medullated fibers.

58 The arteries, especially the smaller ones, and the smaller veins, though to a less extent, are also muscular structures capable of contracting, and, like the heart, controlled by automatic ganglia, the distal ganglia of the sympathetic system, which, like those of the heart, are capable of emitting motor impulses which cause contraction of the involuntary muscular fibers, and thus lessen the caliber of the artery. In addition, the arteries are, like the heart, controlled by two sets of nerves: (1) The vasoconstrictors, corresponding to the accel-

erator nerve of the heart, consisting of fine non-medullated fibers which pass out from the spinal cord with the anterior thoracic nerves; (2) the so-called vasodilators, which are simply inhibitory nerves, capable of retarding or counteracting the action of the vasoconstrictors, or of the muscles contracting under their influence. The vasodilators, like the inhibitory nerve of the heart, consist of fine, medullated fibers.

The capillaries are narrow tubes, the walls of which are 59
composed of nucleated cells, which, like the muscles of the heart and the small arteries, are capable of contracting, the seat of contraction being apparently in the nuclei of the cell.

It thus appears that the blood-vessels, arteries, veins, and 60
capillaries simply constitute an enormously extended and branching heart, just as the neuraxons and the nerve trunks are simply extensions of the brain and spinal cord.

The lymphatics consist of small vessels which exist in the 61
cellular spaces outside of the blood-vessels, and form a network extending throughout the entire body. The lymphatic channels connect at definite points with the lymphatic glands, which act as filters, by means of which foreign particles, germs, and other infectious elements are removed from the lymph. The walls of the lymphatics also are contractile.

The spleen is closely associated with the portal circula- 62
tion, and is also a contractile organ. It does not contract synchronously with the heart, but makes a cycle about once a minute. Its circulation is independent of blood pressure.[1]

Circulatory Systems.

There are four so-called systems of circula- 63
tion: —

1. The *systemic circulation*, consisting of the arteries, capillaries, and veins, by which the blood is propelled from the left side of the heart to the periphery, and is brought back to the right side of the heart.

2. The *pulmonary circulation*, by which the impure blood 64
sent out from the right side of the heart passes through the lungs, and is returned to the left side of the heart, to be again distributed throughout the body.

65 3. The *lymphatic circulation*, by which the lymph that escapes from the blood-vessels through the capillary walls is gathered up from the connective tissue spaces and returned to the circulation through the lymph channels and the thoracic ducts which empty into the subclavian veins.

66 4. The *portal circulation*, which consists of veins only, the venous blood from the stomach, spleen, pancreas, intestine, and liver being gathered up in one large vein and conducted to the liver, where it is filtered before being introduced into the general circulation through the hepatic vein. The accompanying diagram shows clearly the relation between the systemic, pulmonary, and portal circulations (Fig. 3).

67 The amount of blood contained in the body is about eight or nine pounds, and of this about one fifth is found in the pulmonary circulation, and four fifths in the systemic circulation. The capacity of the veins is at least twice that of the arteries. The sectional area of the capillaries is about five hundred times greater than that of the aorta, but their capacity is very small because of their short length, which is only about one twenty-fifth of an inch. The contents of the lymphatic vessels is about three or four times the quantity of the blood; that is, the lymph constitutes about one third the body weight.

The Mechanism of the Circulation.

68 Landois and others have shown that the force of the heart-beat is sufficient to account for the circulation of the blood through the entire circulatory system. The chief cause of the movement of the blood is evidently the difference in the blood pressure existing in the aorta at the heart and that in the vena cava at its junction with the right auricle. The pressure in the aorta is equivalent to about six inches of mercury, while that in the vena cava is never more than half an inch, and during inspiration, is negative. The heart is compelled to do something more, however, than simply to move the blood around the circuit of the blood-vessels. It must maintain a certain pressure, or tension, within the vessels, this be-

ing one of the means by which the various processes of secretion and other forms of metabolism are maintained and regulated.

Blood pressure results chiefly from the force of the heart- 69
beat, and the peripheral resistance at the distal end of the vascular loop in the small arteries, venules, and capillaries, through the narrowing of these parts by the contraction of their muscular walls under the influence of nerve impulses excited by various conditions and agents. In the light of present knowledge it is not, however, possible to regard the heart as the only source of energy in the circulation of the blood. For more than a score of years physiological facts have been coming to light which point with much certainty to the muscular coats of the smaller vessels, the arterioles, possibly the venules, and very probably also the capillaries, as a source of propulsive energy in maintaining the movement of the blood. Schiff showed long ago that there is a rhythmical contraction of the muscles in the arteries in mammals as well as in amphibians, the latter fact having long been recognized. Stricker observed the contraction of the capillaries, and Severini considered the contractility of the capillaries, at least of their nuclei, as of great importance in "influencing the blood stream." Roy and Graham Brown have also shown that the capillaries are contractile.[2] The writer has so long been thoroughly convinced of this fact, that in 1879, in describing the forces of the circulation in a popular work on Physiology and Hygiene, he remarked: "The contraction of the heart, which gives the blood a propulsive impulse, is followed up by the contraction of the arteries. The small arteries are supposed to be specially active in assisting the circulation. Some observers claim that the small arteries, or arterioles, keep up a constant peristaltic action, by means of which the blood is urged forward."

It may be said in short that, in addition to the heart 70
proper, the body is provided with what might be termed a *peripheral heart*, which serves several important purposes: (1) The regulation of the local nutritive and secretory proc-

esses; (2) to a certain extent the control of the heart's action by maintaining just the right degree of tension or intravascular pressure through the narrowing of the arterial outlet; (3) an active rhythmical contraction which acts like a combined suction- and force-pump at the periphery of the circulatory system, relieving the heart of a part of its burden, while at the same time aiding in maintaining the proper standard of blood pressure.

71 This action of the small vessels is of course not confined to the exterior of the body, but is doubtless present in the blood-vessels in all parts of the body, especially in the muscles. That an action of this sort is also maintained in the skin is altogether probable, as it has been observed in the ear of the rabbit. The capillaries of the skin are for the most part arranged in simple loops, which would favor a propulsive action of this sort. It is true, the arterioles of the skin have little muscular tissue in their walls; however, this lack is to a large degree compensated for by the peculiar arrangement of the yellow elastic tissue which surrounds the vessels and by the obliquely placed involuntary muscle fibers, both of which favor contraction of the vessels if they do not aid in the automatic or rhythmical action above referred to.

72 The rich vascular area of the muscles, which is capable of holding one half of all the blood in the body, may be normally more active than the skin in aiding the systemic circulation; but the remarkable readiness with which the skin responds to vascular stimuli, both those which excite the vasodilators and those which bring the vasoconstrictors into activity, shows very clearly that there is in the skin an enormous body of muscular structure connected with the circulatory system which is under the control of the nerve centers.

73 Another force which is by no means insignificant as an aid to the circulation is the inspiratory activity of the lungs acting upon the heart and the large vessels in the thorax. The negative pressure induced in the chest cavity during respiration

accelerates the movement of the blood through the heart to a marked degree. This influence is especially helpful to the portal circulation, and to the venous circulation of the brain.

The rhythmical contractility of the spleen, already referred 74
to, constitutes it a sort of heart for the portal circulation. When the spleen is contracted, the liver is slightly enlarged, showing an increase of tension in the portal circulation which must accelerate the movement in this portion of the venous system, hedged in as it is at each end by a capillary network.

The pumping action of the spleen is doubtless service- 75
able as a means of regulating the blood flow through the liver and in maintaining the necessary pressure to secure the highest degree of functional activity of this large and important gland.

The Blood Current.

When the blood leaves the heart, its move- 76
ment is at the rate of several feet per second, while in the capillaries the rate of movement is reduced to one inch in two minutes. The rapidity of movement of the blood in the vessels is constantly changing with the changes in the relative conditions of the heart and the contractile walls of the small vessels. The following table from Waller represents the several modifications which may occur, and the conditions which give rise to them. The table is so nearly self-explanatory that it is only necessary to add that in some conditions the blood pressure and the blood flow may be neither increased nor diminished, but normal.[8]

Case.	Heart.	Arterioles.	Blood Pressure.*	Blood Flow.*
1	Force constant.....	Resistance increased...	+	—
2	Force constant.....	Resistance diminished..	—	+
3	Force increased....	Resistance constant....	+	+
4	Force diminished...	Resistance constant....	—	—
5	Force increased....	Resistance diminished..	+ —	+ +
6	Force diminished...	Resistance increased...	— +	— —
7	Force increased....	Resistance increased...	+ +	+ —
8	Force diminished...	Resistance diminished..	— —	— +

* The plus sign (+) indicates increase; the negative sign (—), decrease.

77 **The Pulse.** A very good knowledge of the pulse may be obtained by its study with the finger, in the usual way, but the record afforded by the sphygmograph makes clear many peculiarities in the pulse which are difficult to understand without this graphic representation to the eye, and adds greatly to the knowledge obtained by examination with the finger.

78 The accompanying cuts (Figs. 4 and 5) show both Dudgeon's and Mortimer Granville's sphygmographs. The latter is more convenient for clinical purposes. It is, I think, very little known in this country. Figs. 6 and 7 will aid in understanding both the graphic record of the pulse and the pulse itself. The tracing is obtained by means of an arrangement which enables the upward movement of the artery to operate upon the short arm of a lever, the long arm of which rests upon a strip of smoked paper. The paper is moved along by clock-work while the instrument is in use, making a record such as is shown in Fig. 8. The curved lines between the dotted lines X and Y represent one heart-beat.

The meaning of the several parts of this curve is as follows: —

79 The first portion of the curve represents the upward stroke produced by the lever, due to the expansion of the artery under the impulse of a wave of blood sent from the heart. This is called the *primary*, or *percussion, wave.* The maximum of expansion is maintained for only a brief period, the length of which depends upon the condition of the arterial walls. At the end there is sometimes a slight rise.

80 This interruption of the decline or elevation of the curve is known as the *tidal wave.* This is followed by a slight depression, which is again followed by a slight rise, the so-called *dicrotic wave.* The depression between the dicrotic and the tidal waves often amounts to a very sharp notch, which is sometimes very deep, and is known as the *aortic notch.*

81 After the dicrotic wave there is usually one, sometimes several, small waves, which are commonly due to oscillations

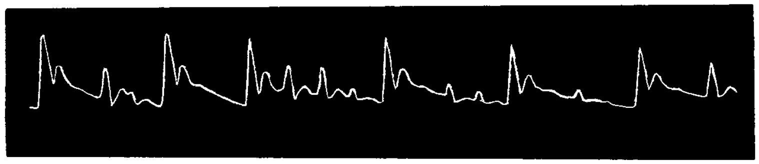

FIG. 15 (*a*). IRREGULAR PULSE (p. 62).

FIG. 15 (*b*). IRREGULAR PULSE OF TOBACCO USER. (WALLER)

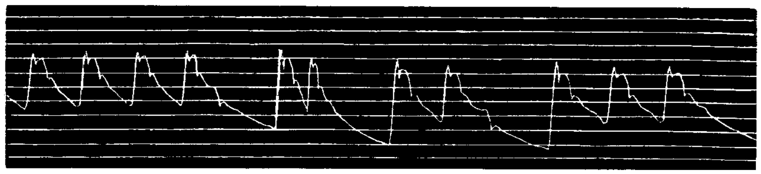

FIG. 16. INTERMITTENT PULSE (p. 62).

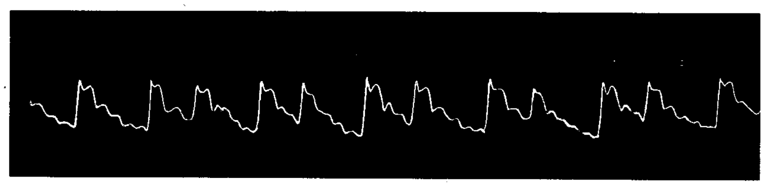

FIG. 17. INTERMITTENT PULSE.

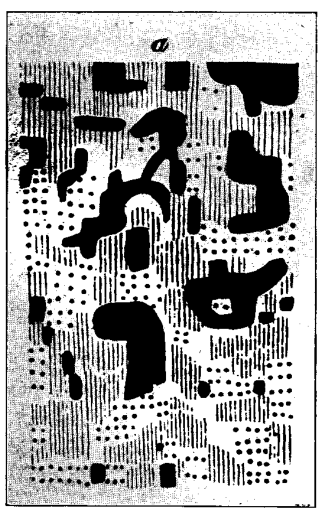

FIG. 19 (*a*). HOT SPOTS (p. 69).

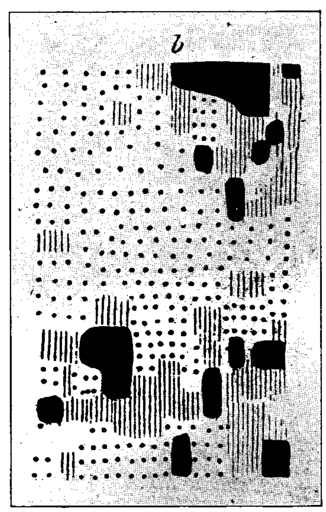

FIG. 19 (*b*). COLD SPOTS (p. 69).

of the instrument. The three points of importance to be observed in the curve are the primary, the tidal, and the dicrotic waves.

The *primary wave* marks the expansion of the artery 82
under the impulse of the wave of blood from the heart. It measures in a general way the force and amplitude of the cardiac impulse; the *tidal wave*, extending from the apex to the "aortic notch," represents the sustained propulsion of the blood resulting from the energy stored up in stretching the arteries. As the stretched arteries contract, the pressure or tension is more or less maintained, according to the degree of elasticity in the vessel walls. With a rigid, atheromatous artery, the pressure quickly falls.

The rigid arteries of old age produce a marked but short 83
tidal wave, followed by a very marked fall (Fig. 9). In aortic regurgitation, the fall is equally marked (water-hammer pulse) because of the sudden emptying of the artery into the ventricle (Fig. 10). In the high-tension pulse (Fig. 11), there is a slower and more gradual decline after the tidal wave, which is very well marked (Fig. 12). To the finger, the pulse of old age and of regurgitation feels "empty" between the beats. The pulse of high tension feels "full."

The *dicrotic wave* is little marked in high tension, but in 84
low tension is so marked that the low-tension pulse of *high fever* is often termed the *dicrotic pulse*. In such a case the dicrotic wave is so much exaggerated that it may be easily felt under the finger (Fig. 13).

In the low-tension pulse the tidal wave, if present, will 85
fall below a line drawn from the apex to the bottom of the aortic notch (Fig. 14). In the high-tension pulse the tidal wave is marked, and rises above the line described. The high-tension pulse is *hard* to the touch; the low-tension is *soft*.

A *frequent* pulse is one in which the number of beats per 86
minute is abnormally great. In fever the pulse-rate increases ten beats (approximately) for every degree Fahrenheit rise of temperature.

87 A *quick*, or *short*, pulse is one in which the beat itself seems very sharp and quick beneath the finger. These terms are unnecessary, as the quick pulse is always a *soft*, or low-tension, pulse.

88 A *long*, or *slow*, pulse is the opposite of the quick pulse. These terms are not needed, as the long pulse is always a *hard*, or high-tension, pulse.

89 In the *irregular* pulse, the beats do not occur with rhythmical succession, but the intervals are irregular (Fig. 15).

90 An *intermittent* pulse is one in which a pulse-wave is now and then lacking, a heart-beat being omitted. Sometimes a pulse seems to be intermittent when there is no actual omission of beats, but the occurrence at regular or irregular intervals of a beat too feeble to be recognized by the finger. The sphygmograph shows the presence of pulse-beats not otherwise recognizable (Figs. 16 and 17).

The accompanying cuts of sphygmographic tracings are chiefly copied from the author's collection of many hundreds of tracings, representing a great variety of conditions, normal and pathological.

THE SKIN AND ITS FUNCTIONS.

91 Since in by far the greater share of the medical uses of water the skin is involved, it will be profitable to devote a few paragraphs to a cursory review of the anatomy and physiology of this remarkable organ.

92 Anatomically, the skin is a structure about one eighth of an inch in thickness, consisting of a framework of white and yellow elastic fibers, in which are suspended a countless number of glands, blood-vessels, and nerves. The whole is covered with cells joined by a cement-like substance (Fig. 18).

93 The deeper layers of the skin contain, in certain portions of the body, especially on the extensor surfaces, and connected with the hair follicles, an abundance of smooth muscular fibers, which are capable of contracting the skin.

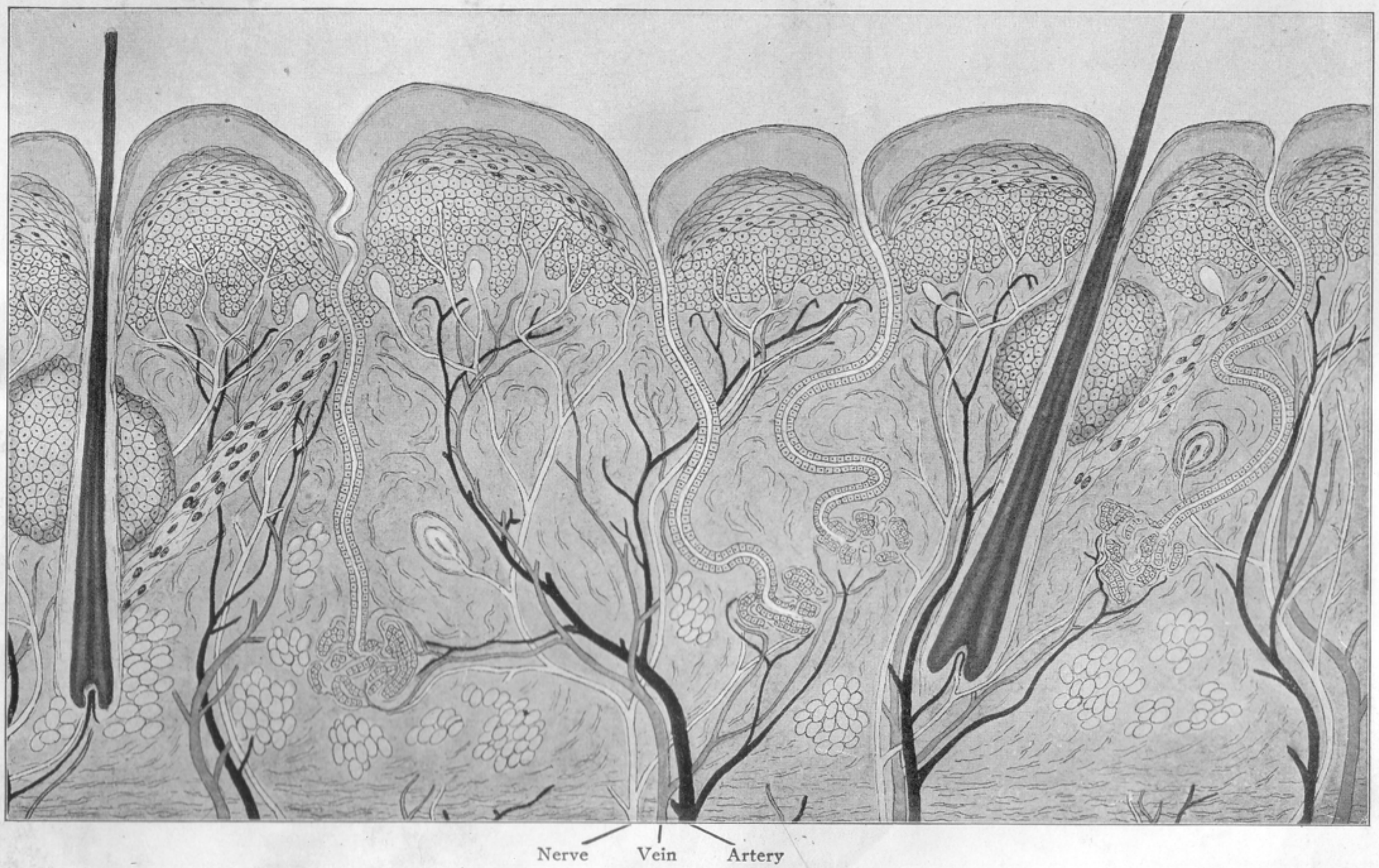

Fig. 18. VERTICAL SECTION OF THE SKIN (p. 62).

The area of the skin covering the whole body is about 19.6 square feet. 94

The Sweat. The sweat-glands are, in man, present almost everywhere in the skin, but are largest and most numerous in the skin covering the palm of the hand, the sole of the foot, the forehead, and the axilla. There are very few sweat-glands in the skin covering the back. 95

Each sweat-gland receives an artery and a number of nerve filaments, and has a duct through which its product is discharged upon the surface. 96

The perspiratory ducts present an aggregate surface of nearly eleven thousand square feet. 97

The amount of perspiration produced daily is about two pints, or one sixty-fourth the weight of the body, this being double the amount of water thrown off by the lungs. The usual rate of sweat secretion is one ounce or an ounce and a half per hour. 98

Three degrees of activity of the sweat-glands are recognizable; viz.: (1) Ordinary, so-called insensible perspiration, in which the quantity is so small in amount that the water and volatile constituents of the sweat are evaporated as rapidly as formed; (2) sensible perspiration, in which the activity is so great as to produce slight moisture of the skin; (3) profuse perspiration, in which the quantity of secretion produced is so abundant that it appears in drops or minute streams coursing over the surface, and may amount to two or three pounds an hour. 99

The function of perspiration presents some interesting variations in different animals. A horse sweats, as does man, over the whole surface of the body. The same is true of the ox, but to a less extent. In the cat and the hedgehog, sweating is confined to the soles of the feet. Apes sweat in the palms of their hands. In the pig it is the skin covering the snout which sweats. The goat, rabbit, rat, and mouse do not sweat. 100

101 **Conditions that Control the Secretion of Sweat.**

The secretion of sweat is increased by the following agents and conditions: —

1. Increased temperature of the surrounding medium, as by the contact of hot air, hot water, or other heated substances with the skin. Water at 122° F., or above, *arrests the action of the sweat-glands.*

2. A diluted condition of the blood, such as results from the copious drinking of water, especially warm water.

3. Increased action of the heart, with rise of blood pressure.

4. Increased temperature of the blood. The sweat centers are excited by a rise of temperature amounting to .7° F.

5. Exercise, which increases the activity of the skin not only by increasing the activity of the heart, but by raising the temperature of the blood, and thereby stimulating the sweat centers. The temperature may be raised by violent exercise to 104° F.

6. Percussion and friction.

7. Certain drugs.

8. Stimulation of the secretory nerves by electricity or other means.

Physiological experimentation has shown that there are special sweat centers and nerves. The sweat nerves of the hind leg of a cat lie in the sciatic nerve. Stimulation of this nerve has caused sweating in the sole of the foot of a cat forty-five minutes after death. Mustard held in one side of the mouth will cause perspiration of the skin of the face of the same side. The centers of the sweat nerves for the palms lie in that portion of the cord that gives origin to the brachial plexus. Stimulation of the cervical sympathetic of one side causes sweating of the face and arm of the corresponding side.

The small blood-vessels are usually dilated in conjunction with sweating through excitement of the vasodilator nerves;

but sweating may occur with a pale skin,— the result of fear, pain, collapse, shock, or the death-agony.

Stimulation of a motor nerve causes sweating of the skin over the muscles supplied by the nerve, and of the same area of the opposite side of the body, and independently of any change in the circulation.

9. Mental excitement, as in hysteria and neurasthenia, often gives rise to sweating, especially of the head, palms, and soles, and sometimes of only one side of the face.

10. Profuse perspiration occurs as a symptom in certain diseases, as intermittent malarial fever, phthisis, and acute rheumatism.

11. The appearance of sensible perspiration is encouraged by a moist, warm atmosphere, in consequence of the lessened rapidity of evaporation.

Perspiration is decreased by — **102**

1. Cold.

2. A profuse watery discharge from the kidneys or bowels. The skin and the kidneys seem to act reciprocally. When the secretion of one organ is increased, that of the other is decreased. In warm weather the volume of urine is usually diminished ; in cold weather, increased. The opposite is true of the cutaneous secretion.

3. Certain drugs, as atropia.

4. Certain forms of disease, as in some cases of paralysis, in diabetes, cancer, and many cases of chronic dyspepsia.

Perspiration is one of the most important means by **103** which the danger of excessive accumulation of heat within the body is averted. When the skin fails to perform this important function, as it not infrequently does in fever, the body temperature often rises to a most dangerous degree.

Toxins of the Sweat.

Not only uric acid and urea, but more subtle **104** and potent poisons are found in the sweat, as shown by the investigations of Bouchard. Perhaps most important of these is a peculiar substance which manifests its properties by inducing a fall of temperature.

The retention of this poison in the body may cause death, as has been proved by varnishing the skin of animals.

105 In diabetes the sweat frequently contains grape-sugar. Sweat from bad-smelling feet contains leucin, tyrosin, and ammonia. The sweat of rheumatism may contain albumin, and that of puerperal fever, lactic acid. Bloody sweat sometimes occurs in yellow fever, and bile pigments are found in the sweat in cases of jaundice.

106 Chromogenic microbes may give rise to red, blue, and yellow coloring matters in the perspiration. Mercuric chloride and other toxic substances have been found in the sweat after their internal administration. Pathogenic microbes have been found in the perspiration after a hot bath in infectious maladies.

107 **The Sebaceous Glands.** Fat-making glands are found in connection with both the coarse and the fine hairs of the skin. They are absent only from the palms of the hands and the soles of the feet, and are largest in the skin of the nose and the labia. The purpose of these glands is to oil the hair and skin. The layer of oil covering the skin protects it to some degree. Anointing the skin with oil hinders conduction. It is a method adopted by swimmers and mountaineers for protection.

108 A minute band of involuntary muscular fibers is connected with each hair, one end being attached near the bottom of the hair pouch, the other to the skin in such a way as to form an acute angle with the hair. The sebaceous gland connected with each hair lies in the angle between this muscle and the hair. By contraction of the muscle, the hair is slightly straightened and lifted up, gently elevating the skin near the hair and compressing the gland, thus emptying it of its secretion. This action of the involuntary muscles may be excited by both heat (**536**) and cold (**328**). Heat not only causes contraction of the muscle, but softens the contents of the sac, and thus aids in their expulsion.

Absorption by the Skin. The skin absorbs substances in watery solution with difficulty, on account of the oil lying upon and in the epidermis and in the ducts. Solutions administered in a fine spray, and substances dissolved in oil and rubbed in, are more readily absorbed. Absorption takes place readily after the oil of the skin has been removed by ether, chloroform, or alcohol. By means of a galvanic current, absorption of watery solutions of iodide of potash, strychnia, and other drugs may be effected. This process is technically known as *cataphoresis*. 109

Cutaneous Respiration. Respiration by the skin in man varies in different individuals, from one half to one per cent. of the total amount of oxygen taken in by the body being received in this way. A somewhat less proportion of CO_2 is eliminated through this channel. In frogs and some other closely related animals the skin eliminates from two thirds to three fourths of the total amount of CO_2 excreted, thus becoming a more important respiratory organ than the lungs. Dipping a frog in oil and thus suspending cutaneous respiration will kill it more quickly than ligature of the trachea. Some creatures, as the earthworm, breathe wholly by the skin. 110

Respiration by the skin occurs through the thin walls of the perspiratory tubules, which present a surface of 11,000 square feet. Cutaneous respiration is most increased (1) by rise of internal temperature, (2) by increased cutaneous circulation, (3) by circumstances that hinder lung respiration, as asphyxia or dyspnea, and (4) during digestion. The amount eliminated at 94° F. is double that at 92° F.[4] 111

Nervous Functions of the Skin. The skin is without doubt one of the most important and interesting of all the sense organs, being provided with a greater variety of nerves than any other portion of the body. The nerves which supply the skin are the following:— 112

1. The nerves concerned in the tactile sense; viz., those which recognize *pressure* and *locality*.

2. The two sets of nerves concerned in the *temperature sense*, which terminate in the skin in the so-called *hot* spots and *cold* spots.

3. Nerves which recognize *pain*.

4. *Vasoconstrictor* nerves.

5. *Vasodilator* nerves.

6. *Sympathetic* nerves.

In all, at least seven distinct sets of nerves, which are connected with corresponding nerve centers.

113 In making thermic applications to the skin, the effects upon each one of these several sets of nerves must be taken into consideration. It is evident that those areas of the skin which possess the richest nerve supply must be most profoundly affected by hydriatic applications, and most capable of producing reflex effects through their connection with the internal viscera by means of their centers of origin.

114 **The Tactile Sense.** The acuteness of the pressure sense in different parts of the body is in the following order, beginning with the most sensitive: The forehead, lips, cheeks, and temples, the back of the fingers and forearm, the anterior surface of the leg and thigh, the back of the feet, the toes, the soles of the feet, and the posterior surface of the leg and thigh. The extreme delicacy of the pressure sense is shown by the fact that vibrations may be felt when exceeding the rate of 1,500 per second. This fact emphasizes the importance of giving careful attention to the exact regulation of pressure as well as temperature in hydrotherapeutic applications, a matter which has generally received less consideration than is necessary for accurate and reliable results.

115 The nerves of touch are connected with the motor centers controlling the muscles of the corresponding part. Rumpf has shown that increased sensibility of one part, whether produced by an application of heat or otherwise, is accompanied by a lessening of sensibility in the corresponding region of the opposite side.

The Temperature Sense. This is one of the most interesting of the functions of the skin, and the one most directly involved in hydrotherapy, as many of its most profound effects are the result of the influence of thermic applications upon the temperature nerves, and through them, upon the cerebrospinal and sympathetic systems. 116

The temperature sense is not uniformly distributed throughout the skin, but is confined to certain spots, of which there are two kinds,—*hot spots* and *cold spots*. These are arranged in curved lines or chains, starting from the hair roots, near which temperature spots are always to be found (Fig. 19). 117

Menthol excites the cold spots, and so produces a sensation of cold. CO_2 excites the warm spots, and thus gives rise to a sensation of heat. 118

These hot and cold spots are not sensitive to impressions of pain or pressure. 119

A "sleeping" limb recognizes heat only, and not cold. 120

The acuteness of the thermal sense differs in different portions of the body, and in the following order, the most sensitive being named first: Tip of finger, eyelids, cheeks, lips, neck, arm, back of hand, palm, thigh, leg, back. The back of the foot, the breast, and the palm of the hand have the same degree of acuteness. 121

The more acute areas recognize a difference in temperature of less than .1° F. Regions situated in the median line, as the nose, are least sensitive. 122

The temperature is estimated higher when a large surface is exposed. Water at 85° feels warmer if the whole hand is immersed than water at 90° in which the finger alone is dipped; but sudden immersion of the whole body in cold water produces a less unpleasant effect than when the body is introduced gradually. 123

Cold bodies feel heavier than warm ones. The pressure of a stream of water, as in a horizontal jet douche, feels greater when cold than when warm. 124

125 *The skin is more sensitive to cold than to heat*, impressions of cold being felt at once, while the sensation of heat develops gradually.

126 Thermic sensations are felt as warm or cold according as the temperature of the object or medium brought in contact with the skin is greater or less than that of the skin itself; hence *the temperature of the skin is the zero of the temperature sense.* Objects of a higher temperature than that of the skin are felt as warm or hot; those of a temperature below that of the skin, cool or cold.

127 Thermic impressions are most intense when the difference between the temperature of the application and that of the skin is greatest.

128 Objects that are *good conductors of heat feel warmer or cooler than poor conductors* at the same temperature. It is doubtless for this reason that hot or cold water makes a very much stronger impression than air of the same temperature.

129 *The temperature sense is most delicate at temperatures near or a little below that of the blood* (80° to 90° F.). It is less delicate at temperatures below 80° and above the temperature of the body. *Impressions of pain only are made by a temperature of 130° or above.*

130 *Rapid variations of extremes of temperature produce more marked effects than gradual changes.* The strongest impressions are made by alternations of very hot and very cold applications.

131 *The sensibility of the temperature sense improves with practice and with diminution of the blood supply.* Venous congestion of the skin diminishes the temperature sense.

132 *Fatigue of the temperature sense develops quickly;* hence marked tolerance within quite wide limits is quickly established.

133 The nerves of the temperature sense are associated with the heat-generating and heat-regulating centers of the brain and spinal cord.

Vasomotor and Secretory Nerves.

The blood-vessels are supplied with both constricting and dilating nerves, which arise from different centers, located at various levels in the spinal cord. It is through impressions made upon these nerves either singly or in succession that some of the most important effects in hydrotherapy are produced. The relation of the principal vasomotor centers to the principal surface areas and to the viscera of the chest and abdomen, is briefly stated elsewhere (**153-166**). 134

Each one of the several million sweat-glands and sebaceous glands of the skin is supplied with secretory nerves which are connected with the great sympathetic centers and with centers in the spinal cord. 135

GENERAL VIEW OF THE NERVOUS SYSTEM AS RELATED TO HYDROTHERAPY.

The skin, as has been aptly remarked, is a harp of a thousand strings, upon which one who is a master of the necessary means may play in such a manner as to produce almost any desired physiological or therapeutic effect. The skin is the keyboard, and the nerves and nerve centers are the internal mechanism. An understanding of the relation of the skin to the nerves and nerve centers is as essential to the physician who desires to employ hydrotherapy intelligently as is a knowledge of the rules of musical harmony and technique to the pianist. 136

It is necessary to understand not only the relation of the nerve endings in the skin with the nerve centers in the brain and spinal cord, but also through them the relation of the skin with the internal viscera supplied with nerves from the same or associated centers, and hence in special reflex relation. 137

Applications to the skin are sometimes made for the purpose of influencing the nervous system as a whole, but not infrequently it is desirable that the application should be limited in its effect to some single internal region. 138

139 There is no other class of therapeutic agents that requires so profound a knowledge of physiology, especially the physiology of the nervous system, and such constant employment of this knowledge, as do the various procedures included under the general term "hydrotherapy." We have space here only to call attention briefly to such physiological and anatomical data as are essential to a proper comprehension of the facts rehearsed in the chapters devoted to the physiological and therapeutic effects of water.

140 While every nerve center in the body is more or less profoundly affected by general applications to the skin, there are four sets of centers that are especially involved, as follows:—

1. The *sensory centers*, located in the brain.
2. The *heat centers*, located in the brain and spinal cord.
3. The *vasomotor centers*, located in the spinal cord.
4. The *secretory centers*, located in the spinal cord and the sympathetic system.

141 As most of the nerves connected with these ganglia are closely connected with the spinal nerves, it is of importance to bear in mind a few facts respecting the relation of the several *spinal centers* to the spine itself or to the vertebræ. These relations may be briefly stated as follows:—

1. The eight *cervical* ganglia correspond to the seven cervical vertebræ.
2. The twelve *dorsal* ganglia correspond in general to the several dorsal vertebræ, ending, however, with the eleventh.
3. The five *lumbar* ganglia are located at the level of the twelfth dorsal vertebra.
4. The ganglia of the five *sacral* and the *coccygeal* nerves are found at the level of the first and second lumbar vertebræ. No ganglia are found below this point because of the formation of the *cauda equina*.

In making applications to the spine, intended to influence the centers directly, it is essential to keep in mind the above facts respecting the location of the spinal ganglia.

The Superficial Reflexes.

As hydrotherapeutic applications are capable 142
of exciting each and all the classes of reflexes that may be set up by stimulation of the cutaneous nerves, it is useful to bear in mind the location of the several reflex areas, and their relation to the spinal centers.

The *scapular reflex area* (the skin between the shoulder- 143
blades), in relation with the first to the fourth dorsal ganglion.

The *epigastric reflex area* (the skin overlying the lower 144
lateral portion of the chest), in relation with the fifth to the seventh dorsal ganglion.

The *abdominal reflex area* (the skin lying along the bor- 145
ders of the recti muscles), in relation with the eighth to the twelfth dorsal center.

The *gluteal reflex area* for lower portion of the nates in 146
relation with the fourth and fifth lumbar.

The *cremasteric reflex area* (inner and upper portion of the 147
thigh), in relation with the fourth and fifth lumbar ganglia.

The *plantar reflex area* (the soles of the feet), in relation 148
with the five sacral and the coccygeal ganglia.

In the application of the douche with strong pressure, the location of the several reflex areas as described above may with advantage be kept in mind, especially in cases of organic disease of the spine.

The Vasomotor Centers.

The *controlling vasomotor centers*, both con- 149
stricting and dilating, are located in the medulla. Subordinate vasomotor centers are located in the spinal cord. The vasoconstricting centers are found chiefly in the cervical and thoracic regions; the vasodilator centers are scattered throughout the cord.

Strong stimuli act on the vasoconstricting nerves; mod- 150
erate, on the vasodilator fibers.

The veins and the lymph-vessels are also supplied with 151
vasomotor nerves; and though at the present time nothing more is known of these nerves than that they exist, it is reasonable to suppose that they obey the same general laws as those connected with the small arteries.

152 The vasodilators differ from the vasoconstrictors in that they are made up of medullated fibers, and that they pass directly to the visceral ganglia of the blood-vessels without passing through the prevertebral ganglia. Their relation to the blood-vessels is the same as that of the vagus to the heart.

153 The blood-vessels of the head are controlled by vasomotor nerves from a center in the medulla, which pass to the head through the cervical sympathetic.

154 The lungs receive vasomotor nerves from the second to the seventh dorsal ganglion.

155 The intestines and abdominal viscera receive their vasomotor fibers through the three splanchnics. The great splanchnic is the largest vasomotor nerve in the body. Paralysis of the splanchnics causes death from accumulation of blood in the portal circulation, being equivalent to a hemorrhage, or ligature of the portal vein.

156 The principal vasoconstrictor and vasodilator nerves of the kidney leave the spinal cord with the last three dorsal nerves.

157 The liver receives its vasomotor fibers from the splanchnics and the vagus.

158 The spleen receives vasoconstrictor and vasodilator fibers from the splanchnics.

159 The pelvic organs in both sexes receive vasoconstrictor fibers from the lumbar nerves and vasodilators from the sacral nerves.

160 The arms receive their vasoconstrictor nerves from the middle dorsal region, through the first thoracic ganglion of the sympathetic.

161 The vasomotor nerves of the lower extremities pass through the lumbar and sacral plexuses to the sympathetic, thence to the lower limbs.

162 The skin of the trunk receives vasomotor fibers through the dorsal and lumbar spinal nerves.

163 The muscles receive their vasodilators through the trunks of the motor nerves.

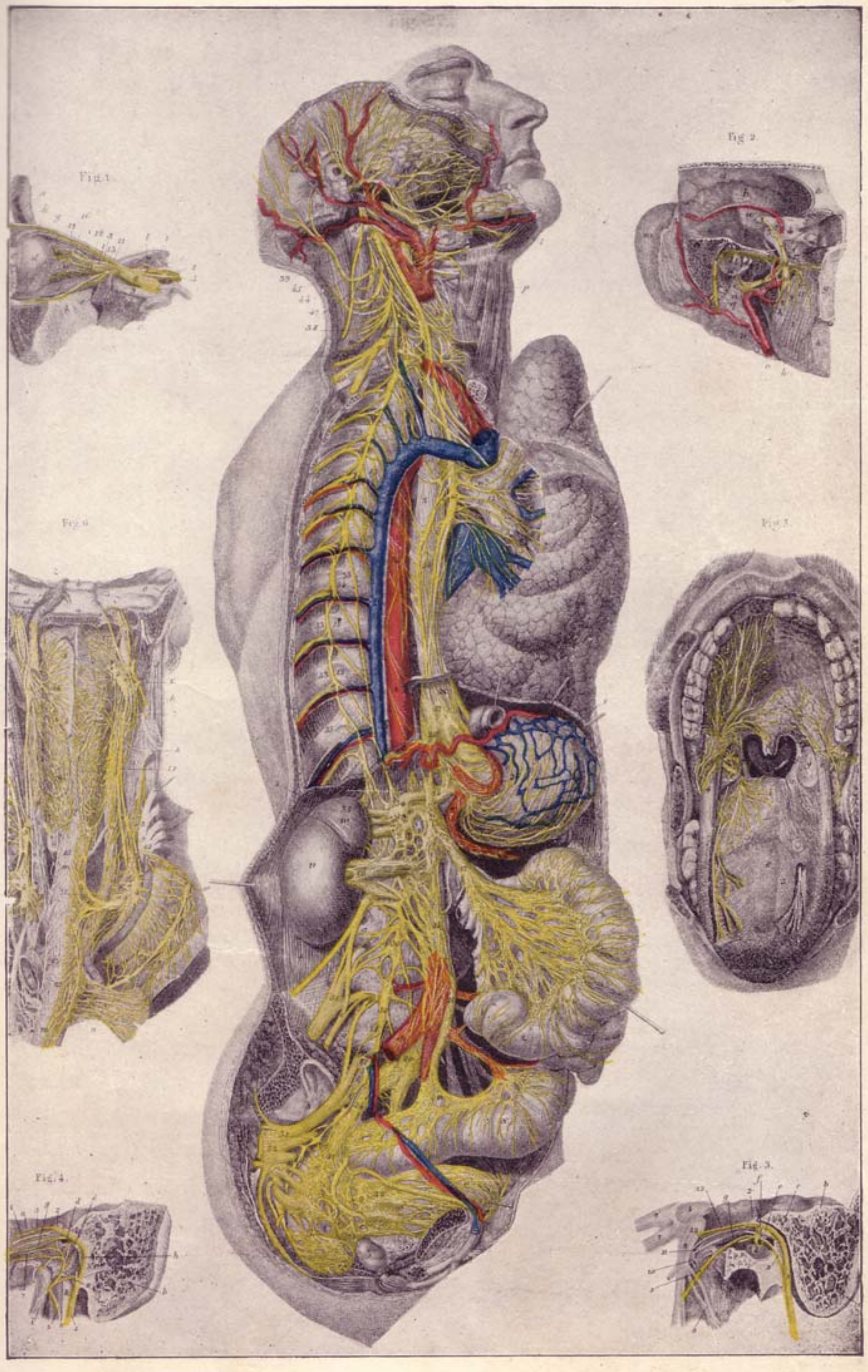

FIG. 20. SYMPATHETIC NERVOUS SYSTEM (p. 75).

The larger proportion of vasomotor nerves leave the spinal cord between the fifth cervical and the first dorsal vertebra. 164

The richest vasomotor areas are found in the skin covering the palms, fingers, soles, toes, and ears. 165

The Visceral Motor Nerves. The nerves that excite the peristaltic movements of the esophagus, stomach, and intestines (excito-motor) leave the spinal cord in the upper part of the cervical region, reaching the intestines through the pneumogastric. 166

The Sympathetic Nervous System. The sympathetic nervous system (Fig. 20) consists of three distinct sets of ganglia; namely:— 167

1. The *lateral*, or *vertebral*, *ganglia*, consisting of a series of ganglia arranged along on either side of the anterior surface of the vertebral column, distributed as follows: three cervical, twelve dorsal, four lumbar, five sacral, one coccygeal. These two chains of ganglia form an ellipse, the ends being joined at both top and bottom in a single ganglion.

2. The *prevertebral ganglia*, or *gangliated plexuses*, consisting of the *cardiac*, *solar*, and *hypogastric plexuses*, or the 168
thoracic, *abdominal*, and *pelvic* prevertebral ganglia, and the umbilical ganglia.

3. Still farther removed from the vertebral chain of ganglia are the *visceral*, *terminal*, or *automatic* ganglia, which are found in the several viscera,—the liver, kidneys, spleen, pancreas, intestines, and blood-vessels. In the intestines there are two sets of these ganglia,—one between the two muscular layers, *Auerbach's* plexus, controlling the intestinal muscles; and another lying beneath the mucous membrane, *Meissner's* plexus. The latter controls both the intestinal glands and the involuntary muscular fibers of the villi. 169

The Splanchnics. The vertebral ganglia are connected with the three sets of prevertebral ganglia by *visceral* or *splanchnic* nerves, which may be properly termed the *thoracic*, the *abdominal*, and the *pelvic splanchnics*. The splanchnics are in the chest known as the 170 three *cardiac nerves;* in the abdomen, as the *great, lesser,* and *least splanchnics.*

171 A rich supply of sympathetic nerve branches connects the prevertebral ganglia with the automatic ganglia, following the blood-vessels in their minutest ramifications.

Functions of the Sympathetic.

172 Every ganglion is a brain, and stores up energy to be afterward used in some way in exciting or controlling some form of vital activity in the subordinate structures associated with it.

173 The prevertebral ganglia, or gangliated plexuses, act, perhaps, as reorganizing centers, receiving impulses from all parts of the body and sending them out again to the same and other parts, thus maintaining a constant universal reaction to all sorts of physical impressions received from without.

174 The distal, automatic, or visceral ganglia preside over the minute details of vital work, each controlling its own little sphere of activity.

175 The sympathetic nervous system presides over the processes of secretion and excretion, all gland action, and also the circulation. This fact alone gives to the sympathetic practical control over all the processes of nutrition and organic change, as well as of voluntary activity. Through the grasp of the sympathetic upon the cerebral circulation, mental activity, even consciousness, is under its control.

176 The automatic ganglia of the heart, the intestines, the blood- and lymph-vessels, the Fallopian tubes, and the uterus are capable of independent activity, and may perform their functions when cut off from all connection with other nerve centers, although they are, under ordinary conditions, influenced in the direction of either inhibition or excitation by nerves received from the central nervous system.

177 It is through the influence upon the great sympathetic of thermic and percutient applications to the skin that the most remarkable effects of hydrotherapy are obtained. Through the powerful impressions that may be made upon this portion of the nervous system by external and internal applications of

water, every nutritive process, indeed every vital process taking place within the body, may be modified, being augmented or retarded as circumstances may require.[5]

ANIMAL HEAT.

Since hydrotherapy consists, for the most part, in proce- 178
dures which have for their object the making of thermic impressions upon the skin, it is evident that a correct knowledge of the phenomena and mechanism of heat production and regulation in the human body is essential to a proper appreciation of the methods and principles of hydrotherapy. Recent advances have been made toward the solution of the numerous difficult problems involved in the subject of heat production and regulation, which render this study especially important, interesting, and profitable from a practical point of view.

Sources of Animal Heat.

The heat of the body is wholly derived from 179
foods, which, as has been shown by careful calorimetric studies, produce, when completely oxidized within the body, practically the same amount of heat and energy that would be generated by their combustion outside the body. The actual caloric value is about twenty per cent. less than the estimated amount.

A study of the heat-producing properties of the various 180
elements of food shows that an ounce of dried albumin produces in the body sufficient heat to raise nearly 680 pounds of water one degree in temperature; an ounce of fat produces eighty per cent. more heat, or sufficient to raise 1,200 pounds of water one degree; and an ounce of starch produces a little more than four fifths as much as an ounce of albumin, or sufficient to raise 550 pounds of water one degree F.

The combustion, or oxidation, of food is not direct in the 181
body, as in a furnace, but occurs as a process of disassimilation, under the influence of special ferments which operate under the control of nerves and nerve centers. Oxygen is assimilated, CO_2 is excreted. Heat is the result of the tearing

down of molecules, and the reappearance in the form of molecular vibration of the energy that was previously employed in holding the molecules together in the organized state. These changes take place in all the tissues, and even, as recently shown, in the blood to some extent.[6]

182 The total amount of heat produced in the body each twenty-four hours is 2,500,000 gram centigrade calories, or sufficient to raise 10,000 pounds of water one degree F. in temperature, or to raise from the temperature of freezing to the normal body temperature, the body of a man weighing 170 pounds. This amount of heat would be obtained by the complete oxidation within the body of eighteen ounces of starch or a little less than half that quantity of fat. The generation of this large amount of heat within the body is necessary in order to maintain its temperature.

Cold-Blooded and Warm-Blooded Animals.

183 Cold-blooded animals take the temperature of the medium in which they exist, or maintain but a slight difference between the body temperature and the surrounding medium, the temperature rising and falling with that of the water or the air. The frog, in water of 68° F. or less, maintains a temperature of from two or three degrees to a few tenths of a degree above the water. In warmer water its temperature is a little below that of the water.

184 The temperature of mollusks and fish may fall to 33° F., or scarcely a degree above the freezing-point, in ice-water.

185 Most mammals have a normal temperature near that of human beings; namely, 98.6°. There are a few exceptions. The mouse has a normal temperature of 100°; birds, from 107° to 111°.

186 A warm-blooded animal maintains its normal temperature independently of the temperature of the surrounding medium within the limits of its usual conditions of life; and even when exposed to extreme or unusual temperatures, its organism struggles against any marked change of temperature until its powers of heat regulation or production are exhausted.

A young child approaches somewhat the condition of a cold-blooded animal in its susceptibility to the influence of external temperatures. This fact should be kept in mind in the employment of hydriatic processes with infants and young children. The ability to react to cold, and to adjust the body temperature to that of the environment, increases with age during the early years of life. 187

The Normal Temperature in Man.

Different observers report varying figures, but the normal temperature of man is generally considered to be approximately 98.6° F. in the axilla, the normal limits of variation being 97.2° and 99.5°. The temperature of the mouth is about .5° higher than that of the axilla, and that of the rectum and the vagina a degree higher than that of the mouth. 188

The temperature of the surface varies considerably; that of the various internal organs varies less, yet to a marked extent. 189

Surface Temperatures.

With the temperature of the room about 68°, Kunkel found the temperature of various parts of the body surface to be as follows:— 190

	Centigrade.	*Fahrenheit.*
Forehead	34.1–34.4°	93.38–93.92°
Cheek	34.4°	93.92°
Tip of ear	28.8°	83.64°
Back of hand	32.5–33.2°	90.5 –91.76°
Hollow of hand (closed)	34.8–35.1°	94.64–96.18°
Hollow of hand (open)	34.4–34.8°	93.92–94.64°
Forearm	34.3°	93.74°
Sternum	34.4°	93.92°
Pectoral region	34.7°	94.46°
Right iliac fossa	34.4°	93.92°
Upper part of thigh	34.2°	93.56°
Calf	33.6°	92.48°

The temperature of the skin is higher over muscle than over bone; over an artery than over a tendon; over an active organ than over an organ at rest. The skin of the forehead has a higher temperature than that of the occiput.

191 **Internal Temperatures.** Davy and others give the following as the temperatures found in various internal parts: —

Brain	104° F.
Left ventricle	107° F.
Right ventricle	106° F.
Liver	106.5° F.
Rectum	100° F.

192 The average temperature of the blood is about 102° F. The average temperature of the venous blood is nearly two degrees lower than that of the arterial blood. The temperature of the blood in the carotid artery is from one to four degrees higher than that in the jugular vein; in the crural artery it is from one and a half to two degrees above that of the crural vein. The coolest blood in the body is that coming from the nose and the ears. The external temperature is ten or twelve degrees below the internal (Senator).

193 The temperature varies with age; that of the infant or child is normally about one degree higher than that of the adult. After the age of thirty, the temperature gradually falls to about one degree below the average standard, while in very advanced age it rises one degree.

HEAT PRODUCTION.

194 Heat production in the body is the result of vital work. Every organ and cell participates in the work of generating animal heat. The higher the degree of activity, the greater the rate of heat production. Those organs that are most active functionally produce the greatest amount of heat.

195 In the hepatic vein during digestion the temperature is 3° or 4° F. higher than in the portal vein. The blood leaving a muscle when in a state of rest is ordinarily about .4° F. higher than that supplied to it. When the muscle is active, the difference is three times as great, or about 1.3° F.

196 The body of the average man produces each minute sufficient heat to raise seven pounds of water 1° F. in temperature. In the horse and the dog, the rate of heat

production per pound of body weight is about the same. In a child weighing fifteen pounds, the heat production is twice as great; in the guinea-pig, five times as great. In the mouse the rate of heat production is twelve times greater, and in the sparrow, twenty-four times greater, than in man. The rate of heat production in an animal appears to increase with the extension of its superficial surface.

Heat production is more active in strong and robust than 197
in weak persons. It is more active in young persons or young animals than in adult persons or full-grown animals, because of the larger proportion of radiating surface and the consequent necessity for greater heat production to retain a normal temperature.

Conditions that Increase Heat Production, and the Tendency to Temperature Rise.

There are various conditions that profoundly 198
affect the process of heat production, each of which must be recognized and remembered in dealing with febrile cases. These conditions may be enumerated as follows:—

1. *Glandular Activity.*— Freshly secreted saliva is found 199
to have a temperature of 2.7° F. above that of the blood in the carotid artery. The blood of the renal vein is warmer than that of the renal artery. Blood in the hepatic vein during digestion may have a temperature three or four degrees higher than that of the portal vein, though at other times the difference is but one degree, or even less.

2. *Muscular Activity.*— The temperature of an oarsman 200
was found to be 104° after rowing one and one-fourth miles (Experiment 1). Heat production is increased by exercise, according to Helmholtz, from 7.5 to 18.1 heat units per minute. Strong shivering also increases heat production.

3. *Mental Activity.*— Mental activity has less effect on 201
temperature than muscular or glandular activity, but an increase of one half a degree has been observed as the result of vigorous mental effort.

4. *Digestive Activity.*— Langlois proved that heat pro- 202
duction is increased thirty-five or forty per cent. during digestion. The body temperature often rises half a degree.

The contents of the stomach may have a somewhat lower temperature during digestion, owing to the fact that heat is rendered latent by the changes taking place in the food, and the low temperature at which a considerable proportion of the food is usually eaten.

203 5. *Brief Applications of Cold Water* (Exp. 2).

204 6. *A Low External Temperature.*— A temperature of 40° F. and below causes increased heat production when the body is so exposed as to cause shivering or a goose-flesh appearance. If these symptoms, which are due to muscular action, do not appear, heat production is not increased, and may even be diminished. Prolonged cold applications lessen heat production in fever.

205 7. *A High External Temperature.*— This causes, for a time at least, increased heat production through the increased tissue activity induced. The rate of heat production begins to rise slowly at 60° F., although temperatures between 60° and 70° F. may be regarded as practically neutral in their effects. Voit fixed the exact neutral point in men at 58° F. Page found the neutral point in dogs to be 77° F. With an external temperature of 104° F. the rate of heat production was three and one-half times the normal.

The influence of external temperature upon heat production is a matter of great practical importance in dealing with many classes of morbid conditions, and especially fevers.

Conditions that Decrease Heat Production.

The following conditions decrease heat production: —

206 1. *Fasting.*— Abstinence from food has a decided influence upon the temperature. At first the temperature falls one or two degrees, then marked emaciation is developed, and shortly before death the temperature declines rapidly. Fasting and badly nourished patients have little heat-making power, and bear cold applications badly.

207 2. *Sleep.*— The temperature falls half a degree or more during sleep. It is for this reason that the temperature is

usually higher at night than in the morning. The morning temperature is higher in a person who works at night and sleeps during the day. In hibernation the heat production is diminished to such an extent that the absorption of oxygen is less than one fortieth as much as during normal activity, and the elimination of CO_2 only one seventy-fifth the normal amount. According to Helmholtz, the amount of heat production is only one third that during rest when awake, or 2.4 heat units per minute as compared with 7.5.

3. Short applications of heat lessen heat production while increasing heat elimination, and thereby cause a decline in the body temperature. 208

HEAT REGULATION.

Modern researches upon this subject apparently demonstrate that the heat-producing and heat-regulating mechanism of the body consists of three elements,—*thermogenic centers, thermogenic nerves,* and *thermogenic tissues.* 209

Of the thermogenic centers there are three classes:—

1. *The automatic centers*, located in the spinal cord, which have immediate charge of the thermogenic tissues, and under the control of which the process of heat production is carried on. 210

2. Accelerator centers, located in the brain, which increase heat production by stimulating the automatic centers. 211

3. Inhibitory centers, also located in the brain, which restrain the action of the automatic centers. 212

The automatic centers appear to be entirely uninfluenced by the various forms of stimuli which influence the body temperature, while the regulating centers in the brain are extremely sensitive to such stimuli. 213

The Mechanism of Heat Regulation.

The inhibitory thermogenic centers of the brain appear to rule in a remarkable manner a group of important functions which are utilized in heat dissipation when it is necessary to combat a tendency to temperature rise. These are— 214

1. Diminished production of heat through inhibition of the automatic thermogenic centers.

2. Increased activity of the heart.

3. Dilatation of the surface vessels.

4. Increase of cutaneous secretion.

5. Increased rate of breathing.

215 Heat applied to the skin acts reflexly through the nerves, and a blood temperature above normal acts directly upon the nerve cells. These two causes excite the inhibitory centers. Cold applied to the skin, and a lower temperature of the blood, in like manner excite the accelerator centers. These centers in turn diminish or increase the activity of the automatic centers of the cord, as may be required to maintain the particular temperature which the system itself seems to establish as the standard for a given set of conditions or circumstances. In sleep, for example, the temperature is lower than during waking hours, and in fever the standard for the body temperature is set higher than normal.

216 The blood is a circulating medium which is used not only to convey nutrient material from the stomach to the tissues, and excrementitious matter from the tissues to the excretory glands, but for the purpose of equalizing the temperature, conveying the surplus heat of the interior of the body to the surface, where it may be dissipated by conduction, radiation, and evaporation. Nearly nine tenths of the daily heat loss occurs from the skin. By the increased rate of heart beat, the complete exchange of blood between the center and the periphery takes place more frequently, and the blood is thus more rapidly cooled.

217 By active dilatation of the surface vessels a larger surface is exposed to the cooling influences that act upon the skin. The surface over which the blood is spread is not fully represented by the seventeen square feet of skin surface, but rather by the eleven thousand square feet of surface over which the capillaries are spread in the walls of the perspiratory tubules, — six times the surface presented by the lungs.

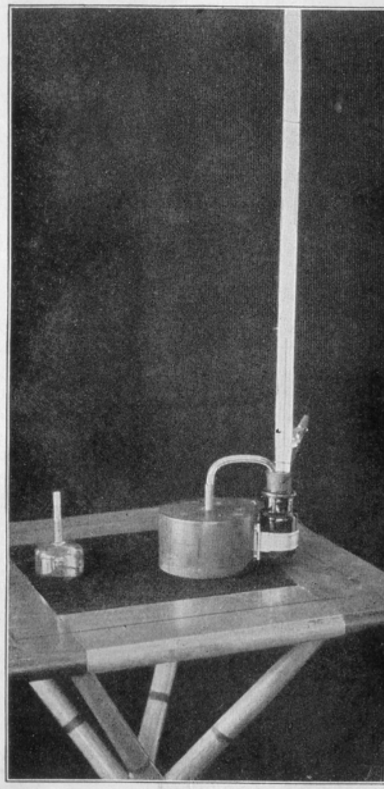

Fig. 21. FEVER CALORIMETER (p. 88). (Kellogg)

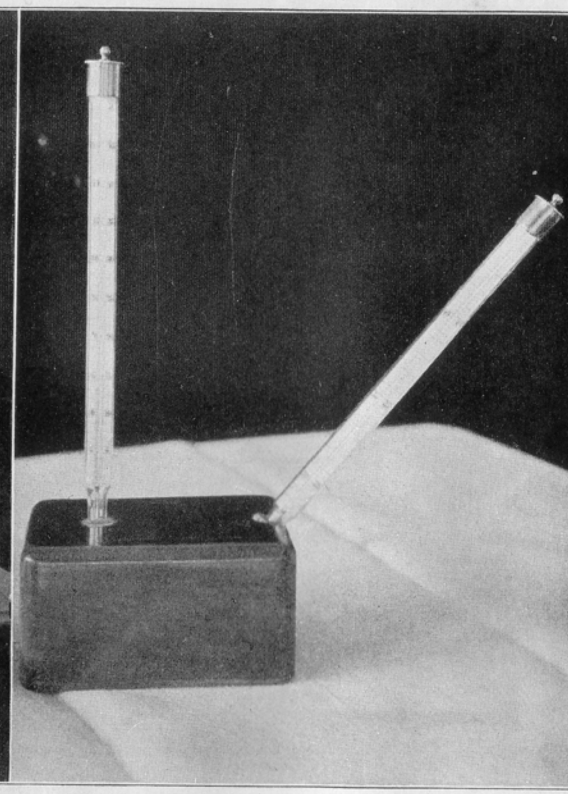

Fig. 22. FEVER CALORIMETER (p. 89). (Winternitz)

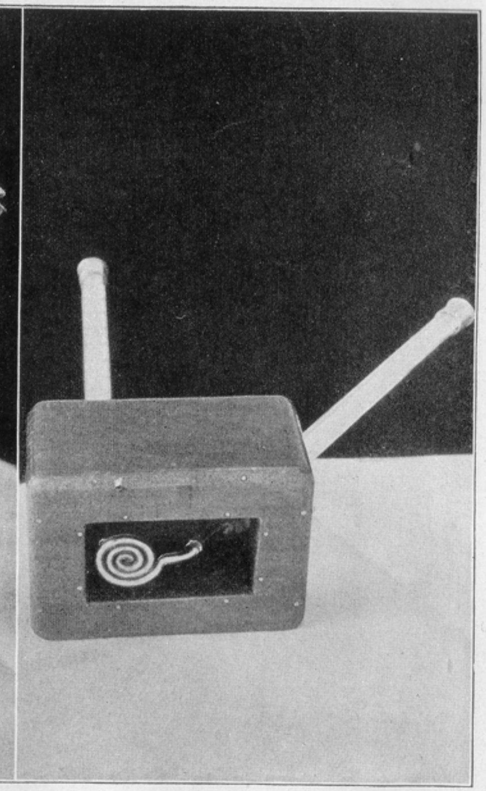

Fig. 23. FEVER CALORIMETER (p. 89). (Winternitz)

One seventh of the total heat loss by the skin is due to evaporation. Evaporation of the increased amount of water brought to the surface by profuse sweating enormously increases the heat loss. Each ounce of water evaporated from the skin absorbs heat sufficient to raise the temperature of about seventy pounds of water one degree Fahrenheit. By various means the amount of perspiration may be increased to two or three pounds an hour. 218

The increase of respiratory activity increases heat loss, not only by the increased amount of the air that is warmed, but by the evaporation of water from the two thousand square feet of surface presented by the pulmonary mucous membrane. 219

In like manner the thermogenic centers control a number of mechanisms by which heat production is increased and heat loss lessened. When cold is applied to the surface, or when the temperature of the blood is lowered, the accelerator thermogenic center is excited, and as the result — 220

1. The automatic thermogenic centers of the spinal cord are excited to increased heat production.

2. The heart's action is slowed.

3. The surface vessels contract.

4. Perspiration is checked.

5. The erector pili and other involuntary muscles of the skin contract, lessening the conductivity of the skin.

6. The respiratory movements are slowed.

The automatic thermogenic centers of the spine are excited by the accelerator center of the brain, and stimulate the thermogenic tissues to increased activity, thus increasing heat production; the decreased activity of the heart lessens the rate at which the blood is sent to the surface; the contracted vessels of the skin diminish the area of blood exposed to cooling influences, thereby lessening evaporation and heat loss; the contraction of the erector pili, by increasing the firmness of the skin, decreases its conductivity; the diminished respiratory movement lessens the amount of air heated by the 221 lungs, through which more than ten per cent. of the total loss of heat occurs. Thus, by the combined action of these various mechanisms, loss of heat is diminished while its production is increased.

Heat Production and Heat Dissipation Associated.

222 It is interesting to note that the functions of heat production and heat dissipation are reciprocal. If heat dissipation is suddenly increased by a reflex influence acting upon the heat-regulating center, heat production is also at once increased, and measures are set in operation to conserve the body heat; while, on the other hand, if heat production is unduly increased, heat dissipation is immediately increased. Every agent that tends to increase heat dissipation, at the same time reflexly excites heat production; and whatever diminishes heat dissipation, likewise, by reflex action, diminishes heat production. This action of the thermogenic centers, whereby heat production is increased or diminished, occurs independently of any effect upon the circulation.

223 A simple illustration will make clear the necessity for this apparently paradoxical relation of heat production and heat elimination. A healthy man, whose temperature, heat production, and heat elimination are normal, is made to perspire so freely that water is evaporated from the surface of his skin at the rate of one and a half pounds an hour. The amount of heat absorbed by the water in evaporation would be about 1,500 pound Fahrenheit heat units. At the normal rate of heat production — seven heat units per minute — there should have been produced within one hour 420 units of heat. Subtracting this from 1,500, we have a net loss of 1,080 heat units, provided there were no increase of heat production. Suppose the patient's weight to be 160 pounds, his temperature would be lowered 6.75°. Upon examination of the patient's temperature, however, we find it to be normal. It is evident, then, that he has produced within the hour 6.75 heat units for each pound of his body weight, in addition to the usual amount, thus preventing the fall of temperature.

The special thermogenic tissues are found in the muscles, in which heat production is constantly taking place through the connection of these tissues with the automatic centers of the spine by means of the thermogenic nerves. Heat is constantly produced in the muscles even when at rest. When the muscle is active, four fifths of the energy consumed appears as heat, and only the remaining fifth as muscular energy. The muscles are the chief seat of heat production. They store up glycogen for heat and work. 224

Water-Bath Calorimeter.

In the clinical study of the phenomena of animal heat there has long been need for a calorimeter which could be used at the bedside. Several years ago (1890), while engaged in instructing a class of medical students in hydrotherapy, the author employed a common bath-tub for this purpose.* 225

The method is a very simple one. Water is placed in a common full bath-tub, in a room of nearly constant temperature, in quantity sufficient to immerse the patient, all but the head. The water should be carefully weighed, and its temperature accurately determined. This may be fixed at a convenient point. It must be some degrees below the body temperature, and should not be too far removed from the room temperature. The temperature of the room should be about 70° to 80° F., and as constant as possible. 226

After placing the water in the tub, it should be thoroughly stirred for fifteen minutes with a wooden paddle having a thermometer attached. Careful note should be taken of the temperature of the water every five minutes. By this means the rate of the cooling may be ascertained. It is evident that the body of a person placed in the bath will give off heat to the water, and the rate of cooling be thus diminished. By a simple calculation the rate of heat elimination by the body may be readily estimated in both normal and pathological conditions. This is a very practical and accurate method (Exp. 3, 4, 5).

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*Since writing the above, the author has learned that Liebermeister employed the same simple calorimeter thirty years ago.

227 **The Author's Fever Calorimeter.** The author has recently (1899) devised a convenient instrument for determining quickly and approximately the rate of heat elimination in a patient under examination as compared with a normal individual. The instrument may be briefly described as follows : —

It consists of two parts (Fig. 21, *a* and *b*); first, a glass cylinder one inch in length, and of such diameter as to give its bottom an area of three square inches, making its cubic capacity three cubic inches. This cylinder is protected by a solid wooden case an inch in thickness, which may be readily removed. It is connected with a small bottle filled with colored liquid, through the cork of which is passed a piece of barometer tubing 75 cm. in length, which serves as an indicator. A scale placed behind the barometer tubing marks the height to which the column of colored liquid rises.

This instrument is extremely sensitive. When applied to the surface of the body, the column of liquid rises with great rapidity, to a greater or less height according to the temperature of the surface.

In the use of this calorimeter, the temperature of the surface is taken at the same time by a surface thermometer. The time for reaching the maximum is noted. This determines the time required to raise a given quantity of air — three cubic inches — a determined number of degrees in temperature (the difference between the room temperature and the surface temperature) by the heat thrown off from a definite area of the skin — three square inches. By means of the data thus obtained and the use of the formula given elsewhere (page 316) for determining the skin area of a body of given weight, a numerical basis is found for comparison of the amount of heat loss by a person who is in a febrile state as compared with that by a healthy person. In one patient examined with this instrument, heat elimination was found to be nearly double the normal, although the temperature was 102° F.

The Fever Calorimeter of Winternitz.

This instrument (Fig. 22) consists of two thermometers placed in a chamber with thick wooden walls, about four inches square on the inside. The chamber is open on one side, and one of the thermometers rests upon the skin when the instrument is in position with the open side next the skin. The other thermometer determines the temperature of the air in the chamber. With this instrument Winternitz has made a series of most interesting observations respecting the influence of friction and other measures upon heat elimination. This instrument, of which the writer learned on a recent visit to Vienna and Kaltenleutgeben (summer of 1899), is of great use, and renders invaluable service in the prosecution of physiological researches respecting heat elimination (Fig. 23). 228

D'Arsonval's Calorimeter.

D' Arsonval, of Paris, has devised a convenient and portable calorimeter (Fig. 24), which, while less exact than the water-bath calorimeter, is so convenient and portable that it should be briefly described, as it is an appliance which the writer has found of service in the scientific study of hydrotherapy. A cylindrical chamber made of pasteboard or binder's pressboard receives the subject. The chamber is about two and one-half feet in diameter, and about six feet in height. An opening of proper size is made in the top, and in this opening a small anemometer is placed. 229

The patient to be tested stands up while the cylindrical chamber is lifted over his head (Exp.6,7). Through a few openings in the bottom of the cylinder a current of air is allowed to pass in and through it. Coming in contact with the patient, the air is warmed and made to pass upward; and in passing out through the anemometer, its mechanism is set in operation, and a record is made upon the dial which indicates the rate at which the air current travels in passing through the instrument. It is also easy to estimate the volume of the air that has passed through the cylinder in a given time. The greater the amount of heat elimination, the more rapid will be the movement of the anemometer, and in a given time the greater the amount of heat eliminated.

This instrument is a convenient and interesting one, but we have found it much less accurate and more cumbersome than the fever calorimeter previously described, and it is certainly considerably less exact than the bath-tub calorimeter.

230 **Fever.** Fever is due to the disturbance of the heat-regulating centers. Such disturbances may result from three classes of causes; viz., (1) toxic substances, (2) nervous impressions, (3) changes in the temperature of the blood. Fever is no longer, as formerly, regarded in the light of an unmitigated evil, and to be combated irrespective of other symptoms, as it has been clearly shown that a rise of temperature is, at least in some cases, curative in its tendency. It is the result of a curative effort on the part of the body. It is not the fever, but the cause of the fever, that we must combat. An infected frog dies without rise of temperature.

The temperature has been known to rise as much as 15° above the normal in pathological conditions, and even a higher temperature has been noted just before death. Recovery rarely occurs when the temperature exceeds 107° F.

231 In fever, the functions of the heat-regulating centers are so greatly disturbed that influences which, under ordinary conditions, would not affect the body temperature, may occasion a rise of temperature of several degrees. In other words, there is, in fever, a disablement of the heat-regulating centers of such a character that the generation and elimination of heat are not properly controlled, and there is a marked loss of resistance to the causes of thermic disturbance in both directions.

232 **Influence of a Warm Atmosphere upon Heat Production.** A warm atmosphere in febrile conditions tends far more than in health to cause rise of temperature, both by decreasing heat elimination and by increasing heat production. Under normal conditions an atmospheric temperature continuously above 60° F., as elsewhere remarked, tends to

increase heat production, and at a temperature of 104° F. heat production is increased to more than three times the normal amount. In health this increase of heat production is of course very largely balanced by increased heat elimination; but in fever this balance is not maintained. The skin in fever is commonly dry under conditions which in health would induce profuse perspiration. Hence heat elimination is greatly diminished. Fortunately, heat production is increased much less in fever than in the normal state, when an equal rise of body temperature is induced by exposure to hot air or by exercise. If heat production were increased in fever to anything like the degree that the elevation of temperature might lead us to expect, the temperature would rise much higher than it does, because of the disproportionately small increase of heat elimination.

From the foregoing, the importance of proper regulation of the temperature of the air surrounding the patient in fever cases is apparent. A cold atmosphere, that is, air at a temperature below 60° F., increases heat production in fever, but to a less degree than in health. The neutral temperature for air is from 58° to 68°, while for water it is from 92° to 95°.

Exercise, either muscular or mental, even so slight as sit- **233**
ting up in bed or conversing with a visitor, will affect the temperature by increasing heat production, sometimes to a very unusual degree, and may even cause relapse when a patient is just convalescing from a fever.

Although the body is at rest in bed, there is usually in **234**
fever great activity in the thermogenic tissues. The predominating feature in fever is increased heat production.

Relation of Heat Production to Temperature.

For each degree centigrade (1.8° F.) elevation **235**
of body temperature there is ordinarily an increase of heat production of six per cent., according to Liebermeister, or 3.3 per cent. for each degree Fahrenheit. The following table represents the percentage increase for each degree Fahrenheit within the ordinary range of fever temperatures:—

Temperature.	*Percentage Increase of Heat Production above Normal.*
98.6° F.	0
100° F.	4.6
101° F.	8.0
102° F.	11.3
103° F.	14.7
104° F.	18.0
105° F.	21.3
106° F.	24.7
107° F.	28.0

236 **Modifications of the Thermic Functions Which Cause Change of Body Temperature.** Heat dissipation is generally increased in fever, but in less proportion than heat production. When the skin is red and moist, heat elimination is more than three times the normal. The body temperature represents not the amount of either heat production or heat elimination, but the balance that is at the moment maintained between these two functions.[7]

The following table shows the various relative conditions that may result in increase or decrease of the body temperature :—

237 CONDITIONS UNDER WHICH RISE OF BODY TEMPERATURE MAY OCCUR.

1. Increased heat production with increased heat elimination. (Heat production increased more than heat elimination.)
2. Increased heat production with normal heat elimination.
3. Increased heat production with decreased heat elimination.
4. Normal heat production with diminished heat elimination.
5. Diminished heat production with diminished heat elimination. (Heat elimination diminished more than heat production.)

CONDITIONS UNDER WHICH DEPRESSION OF BODY TEMPERATURE MAY OCCUR.

1. Diminished heat production with diminished heat elimination. (Heat production diminished more than heat elimination.)
2. Diminished heat production with normal heat elimination.
3. Diminished heat production with increased heat elimination.
4. Normal heat production with increased heat elimination.
5. Increased heat production with increased heat elimination. (Heat elimination increased more than heat production.)

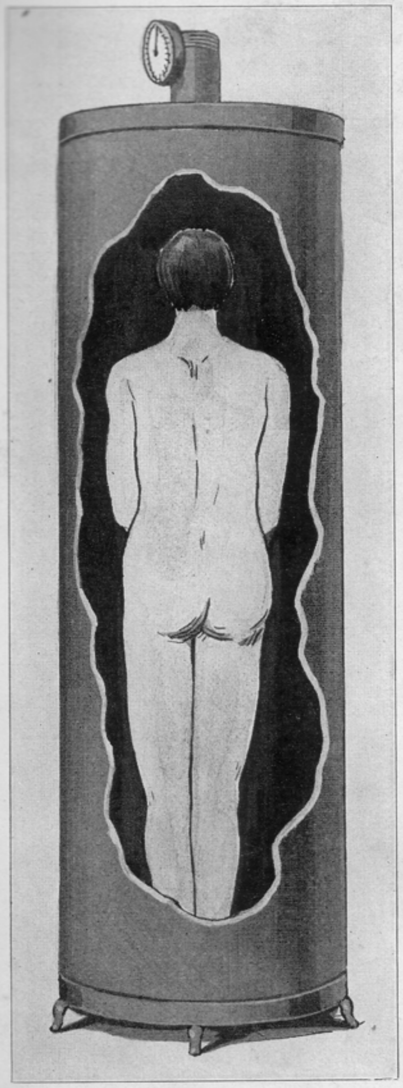

Fig. 24. CALORIMETER OF D'ARSONVAL (p. 89).

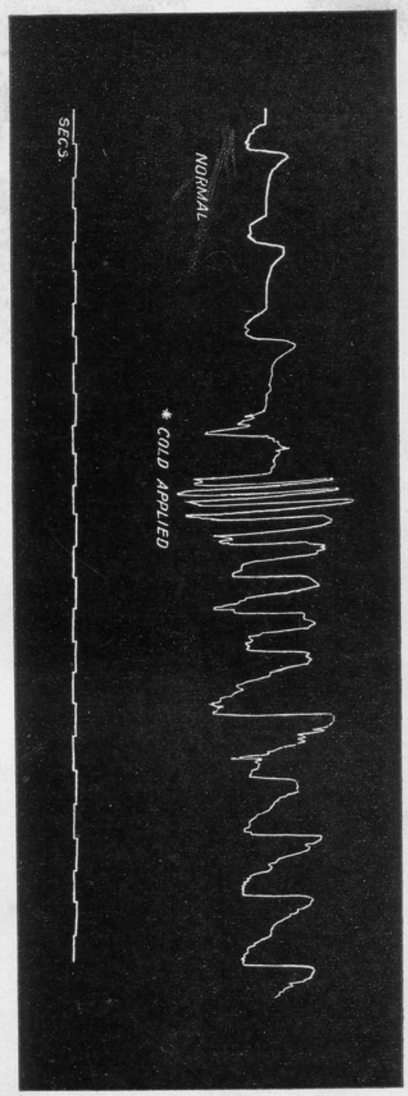

Fig. 26. PNEOGRAPHIC TRACING (p. 110.)

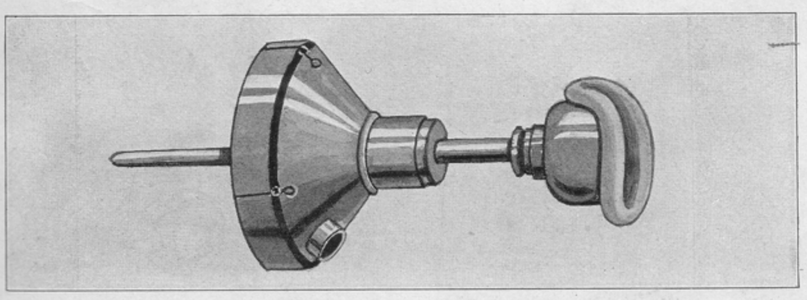

Fig. 25. PNEOGRAPH (p. 110). (Kellogg)

Control of Heat Functions.

The temperature may be reduced in fever either by diminishing heat production or increasing heat elimination, or by both means combined; and therapeutic applications may be made in such a manner as to influence either of these processes, or both of them. 238

It may not be out of place just here to mention the leading physiological means by which fever may be controlled; viz., rest, fasting, water drinking, regulation of air temperature, hydrotherapy.

A careful study of the influence of cutaneous irritation, 239
thermic applications, and changes in the condition of the blood-vessels of the skin has been made by Pospischil. The following are some of the interesting results obtained:—

Short, cold shower baths increased heat elimination to the 240
amount of from twenty-five to sixty-six per cent., according as the patient rested or exercised after the application; cold, wet rubbing caused increased heat elimination to the extent of eighty per cent.; mechanical irritation or friction produced a still greater heat loss,—ninety-five per cent.; agents producing a "goose flesh" appearance of the skin were found to diminish heat elimination more than forty-four per cent.; weak chemical irritants produced increased heat elimination to the extent of forty per cent., five times more than strong chemical irritants.

Both heat production and heat dissipation may be influ- 241
enced by various antipyretic drugs, but the effect thus produced is purely toxic in character, and involves not simply the heat-producing or heat-regulating centers, but other nerve centers as well, and thus lessens the resistance of the body and the activity of the reparative processes by which the remedial forces of the system seek to effect a cure. It is encouraging to note that the pernicious effects of fever-controlling drugs of all kinds are being recognized by physicians at the present time, and that reliance is being placed on those physiological antipyretic measures whereby the end

sought may be safely and far more efficiently attained than by the use of drugs. It is safe to predict that when these rational means of combating fevers of all types are more thoroughly understood and more generally used, the mortality from this class of diseases will be reduced to less than one third the present rate.

The experimental researches of Maragliano have shown that quinine, antipyrine, thallin, and salicylic acid cause reduction in temperature by inducing a most pronounced dilatation of the cutaneous vessels. Alcohol operates in the same way. All of these drugs depress the heart as well as the vessels, and seriously interfere with the healing process, and therefore their use is irrational and unphysiological.

Incidentally it may be mentioned that in dealing with fever by any method, it is always important to give attention to the cause of the condition, which may be simple exposure to excessive heat, sunstroke, violent exercise, exhaustion (fatigue fever), a cold (retained excretions), toxemia from the use of decomposing food or the decomposition of food by long retention in the alimentary canal, uric acid, toxins produced in infectious disease, local inflammation, gastritis, peritonitis, infected surgical wounds, nervous impressions, etc.

Heat Production after Death. The temperature may rise four or five degrees after death from tetanus or hydrophobia, oxidation and heat production continuing until all the oxygen remaining in the tissues has been consumed.

THE PHYSIOLOGICAL EFFECTS OF EXTERNAL AND INTERNAL APPLICATIONS OF WATER.

AS elsewhere remarked, Currie was the first to observe and study the physiological and therapeutic uses of water in a thoroughly scientific way, he having the advantage over his predecessors in possessing a thermometer, the invention of John Hunter, whereby the temperature of the animal body might be accurately ascertained. 242

Soon after (1801), Henry Wilson Lockette, of Virginia, published a report of important observations and experiments. 243

Next, Fleury, in France, conducted an extensive series of researches as to the effects of water upon internal and external temperatures, making a special study of its tonic effects. His labors placed the use of the cold douche upon a scientific basis. Indeed, the efforts of Louis Fleury in this direction were so extensive and thorough that although Scoutetten, a military physician who was sent by the French government to study the work of Priessnitz, and who introduced the science of hydrotherapy into France, remarked in 1843, "Hydrotherapy is not a new medical system, but it may be made such," Raige Delorme wrote less than ten years later, "Thanks to L. Fleury, hydrotherapeutic medical practice must take its place in rational therapeutics." 244

Dr. John Bell, of Philadelphia, published in 1850 his remarkable work on "Baths." 245

Schüller published in 1874 the results of a remarkable series of experiments made upon trephined rabbits, in which he demonstrated the effects upon the internal circulation of thermic and mechanical applications to the surface. 246

Vinaj, in 1892, reported experiments upon a man whose brain had been exposed by an accident, which confirmed the observations of Schüller on trephined rabbits, respecting the influence upon the brain and circulation of thermic applica- 247 tions to the skin in various parts and under various temperatures. These experiments of Schüller and Vinaj laid the foundation for our exact knowledge of the effects of cutaneous thermic and mechanical applications upon the circulation of the viscera.

248 The physiological effects of water are due to those qualities which enable it to be used—

1. As a nutrient, entering into the composition of every structure, and serving a useful purpose in nearly every function, especially as a vehicle for conveying food material to the tissues and removing wastes.

2. As a means of abstracting heat from the body by contact and by evaporation.

3. As a means of communicating heat to the body.

4. As a means of producing certain mechanical or percutient effects.

249 Similar effects may be obtained by other agents which are capable of impressing the system in like manner, as, for example, hot and cold air, hot vapor, the electric light, sunlight, and friction or percussion of the skin administered either by the hands of an attendant or mechanically. These means, because of the kindred effects produced by them, are universally employed in connection with water in hydrotherapy, and hence wiil be considered in connection with measures which are more strictly hydriatic in character.

The General Effects of Thermic Irritation upon the Circulation.

250 A very large proportion of the applications of water made to the surface of the body depend for their efficiency upon the fact that the skin is reflexly connected with the interior of the body, each portion of the skin periphery being associated, through the nerve centers which supply it with nerve filaments, with some special visceral periphery or vascular area.

251 In the study of the reflex effects of water upon the internal structures, it should be noted that whatever effect is produced upon a vascular area of the skin, is likewise produced

in the internal vascular area associated with it. The intensity of the effect produced in the internal area, is, however, generally less intense than that produced upon the surface, although this is by no means always the case.

It must be remembered, however, that in addition to the 252
reflex effect produced, there is also produced a mechanical effect, which is commonly the reverse of the reflex effect. The real effect is the sum of these two effects, and depends upon the relative intensity of the two actions. The effects of external applications of water may thus be simply divided into two classes,— reflex and mechanical.

Any sort of irritation of the cutaneous nerves which gives 253
rise to contraction of the blood-vessels of the surface, whether cold, heat, friction, percussion, pinching, or mechanical irritation, likewise causes contraction of the small blood-vessels of the interior of the body, stimulating the accelerator nerves of both the blood-vessels (vasoconstrictors) and the heart.

The duration of the reflex effect depends upon the inten- 254
sity of the stimulant and of the irritant, and also upon the area involved. When the cutaneous vessels of a large portion of the surface of the body are excited to contraction by cold, heat, friction, or otherwise, the contraction of the interior vessels is exceedingly brief. It may, indeed, be of so short duration as to escape notice. The reason for this is the development of the mechanical effect (**252**).

If the surface area to which the application is made is 255
small, the reflex effect may be confined to the internal area in sympathetic relation therewith (**349**), and will be greater and more prolonged for the reason that the reflex influence being concentrated upon the circumscribed area, the mechanical effect is distributed over the rest of the body, so it does not overshadow and wipe out, so to speak, the reflex effect on the smaller area involved.

The mechanical effect is necessarily the reverse of the 256
reflex; for when the blood-vessels of the skin are made to contract as the result of the application of an irritant of any

sort, there is an inrush of blood to the interior of the body causing mechanical distension of the internal parts. This effect follows more or less quickly the primary, universal constriction of the small vessels according to the intensity of the irritation and the extent of the application. A knowledge of these facts, to which we are chiefly indebted to Schüller and Vinaj, affords us a rational basis for the explanation of nearly all the phenomena resulting from hydriatic procedures.[8]

THE PHYSIOLOGICAL EFFECTS OF COLD.

257 **Is Cold a Sedative or an Excitant?** Cold is a vital depressant. Under all circumstances and in all modes of application this is its primary and intrinsic effect. The discussion of the question whether cold is primarily a stimulant or a depressant began soon after the first publications of Currie, and waxed especially warm half a century ago. The controversy doubtless grew out of the fact that those who maintained cold to be a stimulant, failed to observe that its so-called tonic, or stimulant, effects were reflex and secondary results.

258 A low temperature, in whatever way produced, checks cell or protoplasmic activity. This may readily be seen by a microscopic study of the pond ameba, the white blood-corpuscle, or the heart of the embryo of a chick, the movements of which are at once suspended when the temperature is lowered, but begin again with the application of heat by means of the warming stage.

259 **Hibernation.** The life processes of warm-blooded animals are slowed when the body temperature falls a few degrees below the normal standard of temperature for the individual class or species of animals under investigation. This accounts for the phenomena of hibernation. In a bear in the state of hibernation the temperature has been found as low as 35° F., the pulse eight per minute, and the respiratory chest movements entirely suspended, showing almost complete cessation of vital activity. In this state, little waste of

tissue takes place, so that the animal may pass several weeks without eating or drinking.

In fishes, whose temperature is generally only a degree or two above the water in which they live, the temperature may be reduced so low that actual freezing takes place, when there seems to be complete suspension of vital activity, but not actual death, the animal living in this condition for weeks and even months.[9] 260

The depressing influence of cold upon vital activity is utilized in the preservation of food, the germs which give rise to putrefactive processes being unable to multiply and produce their peculiar ferments and toxins at a temperature of 32° F. It is through this depressing influence also that diphtheria, phlegmon, and other localized maladies, even cancer, may often be beneficially controlled by applications of ice to the affected parts. The activity of the perspiratory glands is at once checked by the application of cold to the skin, and so also is the secretion of gastric juice by the peptic glands when cold water is swallowed, as witnessed by Beaumont in his observations upon the stomach of Alexis St. Martin. 261

Hydriatric Measures Consist Chiefly of Thermic Applications.

In the study of the physiological effects of water at different temperatures upon the various structures and organs of the body, the fact must be kept in mind that as employed in hydrotherapy, water is chiefly useful as a means of communicating heat to the body or abstracting heat from it. In its internal use, the thermic effects of water are supplemented by effects arising from its solvent and nutrient properties. In its external use, certain mechanical effects are added to its thermic effects in some forms of application, particularly the several varieties of the douche. 262

Heat and cold, as before remarked, are relative terms, objects being recognized as cold when they have a temperature less than the zero of the temperature sense,—that is, the temperature of the skin,—and the reverse. For convenience, 263 however, in the study of the physiological effects of water, as well as in directing its therapeutic application, it is necessary to make use of terms more accurately indicative of the approximate temperature of the application. Those which have been most commonly applied are the following: *Very cold, cold, cool, tepid, warm, hot, very hot.*

264 The terms "temperate," "nauseating," "excessively hot," and "excessively cold" are used, especially by French hydrotherapeutists, but the utility of these terms is so restricted that we have eliminated them.

265 **Classification of Temperatures.** As the classification proposed is necessarily artificial and arbitrary, it is not easy to fix the exact limits of temperature to which each term should be applied, and this fact has given rise to considerable discussion and to a diversity of views. The following table is used by the author, and is found to be very convenient in practice: —

Very cold	32°	to	55°	F.
Cold	55°	to	65°	F.
Cool	65°	to	80°	F.
Tepid	80°	to	92°	F.
Warm (neutral, 92°–95°)	92°	to	98°	F.
Hot	98°	to	104°	F.
Very hot	104°	and above.		

266 The effects of applications at these various temperatures differ according to the part of the body to which the application is made, and the extent of surface involved.

267 Whether or not the final effect of a cold application is sedative or excitant, depends much on the mode of application and the temperature employed, but most of all on the length of the application and the state of the patient.

268 **Primary and Secondary Effects of Cold.** When a cold application is made to the body in any form, whether internally or externally, the first effect is a lessening of the activities of the living structures with which the cold medium comes in immediate contact. If the application is

continued for a long time, this vital depression continues likewise, and is maintained for a time after withdrawal of the application. The longer the application, the longer the depression that follows. Sooner or later, however, the parts return to their normal condition; and if the depression has not been so great and so prolonged as vitally to damage the parts, in the return to normal activity the pendulum swings, so to speak, beyond the normal line, so that for a time a higher degree of vital activity is maintained than before the application. This increased physiological activity is termed *reaction;* or as the writer will undertake to show later (435), *tonic reaction.*

When the cold application is a short one, the reaction follows quickly, and is as much more intense as the application made is energetic; that is, *low in temperature* and with considerable pressure, as in the form of the douche. **269**

The application may be so managed that the primary effect or action — in other words the sedation — may be diminished; or the secondary effect — the reaction or state of excitation — may be diminished; or both may be lessened. **270**

Cold applications may be made by means of ice, cold water, cold air, or by the evaporation of water or other volatile liquids from the surface of the body, which may be either spontaneous or increased by a current of air. All these means are employed in hydrotherapy. The same principles apply, however, whatever the mode of application. **271**

In discussing the physiological effects of cold applications, Currie very well says ("Medical Reports," page 68) that it is "not the cold that stimulates, but the sensations which the cold produces." This may at first seem like a distinction without a difference, yet it seems to the writer that Currie was right. The intrinsic effect of cold is depressant, while that of heat is stimulant. Nevertheless, a recognition of the thermic impressions made upon the temperature nerves of the skin, through reflex influence provokes vital activities which serve to antagonize the depressing influence of the cold, which may in a given case so far overbalance these **272** effects that the effects which are actually apparent are those of excitation instead of sedation.

273 All discussion respecting the mode of "action" of cold must cease with the recognition of the fact that it really has no vital action whatever, serving only as a physical agent to lower the temperature of those parts with which it comes in contact. Its so-called physiological action is wholly due to the action of the body itself,— first, in recognizing the presence of an agent that interferes with its functions, and is capable of injuring the integrity of its tissues; and secondly, in rallying its forces to repel the invader, or to avert the danger arising from its presence. While cold is primarily a depressing agent, its first contact with the skin gives rise to irritant phenomena through the protective reflex activities above referred to.

Effects of Peripheral Irritation.

274 A series of interesting experiments upon animals reported by Wertheimer, in 1893, showed that the general effects of excitation of the sensory nerves of the skin by cold are in accord with the general law relating to the reflex influence of peripheral irritants of all sorts,— chemical, electrical, etc.; namely, short and intense applications cause a brief preliminary contraction of the vessels of the internal viscera, which is quickly followed by dilatation of the same; while a prolonged, more moderate application of cold to the surface results in a renewed and prolonged contraction of the small vessels in the internal regions of the body.

275 This contraction is one of the several methods by which the body defends itself against injury from the loss of heat through the application of cold. By the slowing of the rate at which the blood passes through the internal organs, these organs are deprived of less heat than if the circulation were continued at the usual rate. The vessels of the skin being contracted at the same time, it is apparent that by this wise provision of nature the body is most efficiently protected against injury from cold.

Naumann, operating upon frogs, detached all portions of one of the hind legs with the exception of the sciatic nerve, and then applied cold and irritating substances to the skin of the separated leg, and noted with the microscope the effects upon the mesenteric circulation. He observed that gentle irritation of the skin of the leg produced contraction of the vessels and quickened heart action, while strong irritation produced dilatation and slowed heart action from excitation of the vagus, the inhibitory nerve of the heart, and of the vasodilators, the inhibitory nerves of the vessels. These effects are general in the body.[10] 276

Schüller * found that the application of cold water to a nerve trunk caused contraction of the vessels of the brain; while warm water caused dilatation of the cerebral vessels, his observations agreeing in this regard with those of Naumann. 277

General applications to the skin by means of compresses and full baths were found to produce opposite effects. A warm bath produced *dilatation* of the surface vessels, but *contraction* of the vessels of the brain; while a cold bath produced contraction of the vessels of the skin, with dilatation of the cerebral vessels. 278

These observations show clearly that two classes of effects are produced in applications of water to the surface; viz., (1) *reflex;* (2) *mechanical,* or *derivative.* 279

Doubtless both of these effects are always produced. When the application is general, the mechanical effect is dominant; when the area involved is limited, the reflex effect is most prominent. In general applications the primary reflex effect is quickly effaced by the succeeding mechanical effect due to the in-rush of blood from the periphery. This diversion of blood from the surface vessels to the interior of the body is termed *retrostasis.* Marked retrostasis is produced only when the cold application is made simultaneously to a very large cutaneous area. 280

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* *Archiv für Klinische Medicin,* Vol. 14, 1874, Leipsic, page 566.

281 The effects of general warm (99°–100° F.) and cold (52°) applications were observed to be transient, lasting not more than ten minutes, usually less, whether the application was continuous or interrupted. Secondary effects of an opposite character then appeared; viz., contraction of the cerebral vessels after cold and relaxation after a warm bath.

282 Dilatation of the vessels of the viscera after a short, intense general cold application follows so quickly that this may be recognized as practically its primary effect. The subject is further discussed in paragraphs 669–672, and 1256–1292.

THE EFFECTS OF COLD UPON THE SKIN.

The surface phenomena observed to follow an application of cold water to the skin are as follows : —

1. Contraction of the Small Blood-Vessels.

283 A short application of cold or very cold water (from 32° to 65°) produces pallor and coldness of the skin, due to the contraction of the small vessels (Exp. 8).[11]

284 When the application of cold is long continued, the surface becomes blue, because the muscles of the small veins, being weaker, soon become exhausted and relaxed, while those of the arterioles are still active. The capillaries being contracted, the pressure in the veins is lessened, the flow of blood is slowed, and the venules are thus distended with blood the hemoglobin of which has been reduced; and the skin consequently shows a blue or purplish color. This is the *primary* effect of cold, or rather of the vital *action* or resistance against it developed during its application.

285 When the application is withdrawn, if it has not been too greatly prolonged, the pallor or blueness quickly gives place to redness, the result of active dilatation of the small arteries of the skin. This is the *secondary* effect of cold, or so-called *reaction*, one of the most interesting and important phenomena connected with the application of water (**429**).

Percussion, or slapping, and friction have much the same effect on the small vessels as cold water, causing first excitation of the vasoconstrictors, and later the reverse (Exp. 9). 286

2. Decrease or Suspension of Perspiration.

The almost instant suspension of the glandular action of the skin as the result of the action of cold is even more remarkable than the excitation of these glands by the application of heat (Exp. 10). It is evidently a purely reflex phenomenon, as suspension of sweating takes place before the application of cold has continued long enough to occasion a lowering of the general temperature of the blood, the cessation of the action of the perspiratory glands thus taking place while the sweat centers are still experiencing the stimulating effect of a blood temperature sufficiently high to provoke intense action of the glands. 287

It is noteworthy that suspension of the action of the sweat-glands of the entire skin surface may be brought about by a cold application to a very small area, as the feet, the shoulders, and in some cases the hands or other equally limited surfaces,—evidently a reflex effect.

This sudden checking of perspiration as the result of cold applications is injurious or dangerous only when the body is in a state of fatigue, or when the perspiratory activity is the result of an effort on the part of the system to antagonize a febrile movement, as in the sweating stage of malarial fever, in sweating sickness, etc. 288

With the occurrence of reaction, the action of the sweat-glands is resumed, and may be greatly increased. 289

3. Decreased Heat Elimination and Increased Heat Production.

Cold applications, by causing contraction of the small vessels, lessen the amount of blood circulating through the skin, and thus diminish heat elimination, during the application. At the same time, the reflex effect upon the centers controlling heat production stimulates the development of animal heat in the body. 290

291 When reaction occurs, however, the result is an accelerated circulation of blood through the skin, whereby an increased quantity of blood is exposed to the cooling influences that act upon the surface of the body, so increasing heat elimination.

292 If the application of cold is long continued, the temperature of the muscles lying beneath the skin, as well as that of the skin itself, is lowered, thus checking the heat-producing processes that are active in the muscles, where about one half of the heat of the body is produced.

4. Diminished Tactile Sensibility.

293 Applications of a temperature below 92° to 98° lessen the acuteness of the tactile sense (Exp. 11). Even a very brief application of ice or very cold water will abolish tactile sensibility, and the same effect is obtained by a prolonged application of cold water. This fact is taken advantage of by dentists, who freeze the gum by the application of ether or rhigolene spray, as a means of obviating the pain of teeth extraction. Other operations are also thus rendered painless.

294 Applications below 32° F. do not excite the temperature sense, but give rise to pain. Even moderately cold applications are to most patients at first painful and shocking.

295 The impression made by a cold bath is more painful if the cold water is gradually brought into contact with the body than if the application is brought to bear upon the whole surface at once, as in the plunge bath. By sudden immersion the sensation is generalized, whereas in gradual applications it is concentrated upon the limited surface that is at each instant coming in contact with the water.

296 A fine spray feels cooler than a douche at the same temperature, for the reason that the douche stuns the skin by its mechanical effect, and thus lessens its sensibility. Immersion in cold water, for the same reason, gives rise to greater shock or pain than the douche, though at the same time it is less excitant, because of the lack of percussion effect.

297 A curious fact not infrequently noted is that more distress is experienced from the application of water at a temperature

of 55° to 65° F. than at 45° to 55°. This effect is perhaps due to the more prompt reaction at the lower temperature, as well as to the lessened sensibility.

THE EFFECTS OF COLD UPON THE CIRCULATION.

Cold slows the circulation and diminishes the frequency of **298** *the heart beat.* The shock occasioned by a sudden application of cold water increases momentarily the activity of the heart, but the pulse-rate quickly returns to normal, and is soon perceptibly slowed, the effect depending upon the intensity and the duration of the application. This effect is the result of the reflex influence of the stimulation of the skin upon the nervous mechanism of the heart, and is due to the fact that the accelerator nerves of the heart are first excited, and later the pneumogastric, whereby the heart's movements are slowed. It should be remembered also that in the reaction following a short cold application the increased activity of the small vessels aids the heart, while by the continuous contraction *during* a cold application the labor of the heart is greatly increased.

It thus appears that *very short applications of cold pro-* **299** *duce increased activity of the heart, while prolonged applications slow its action* (Exp. 12, 13, 14, 15) (Roehrig).

A short, very cold (40° to 55° F.) *application produces* **300** a very brief contraction of the visceral vessels, which is followed by dilatation lasting for a few minutes (3 to 10), which later gives rise to contraction. Through all these vascular changes, however, there is a constant elevation of blood pressure.

A prolonged cool or cold application (60° to 80° F.) *with-* **301** *out percussion produces vasoconstriction* in the parts which are in reflex relation to the area operated upon.

Local cold applications produce varied effects, some of **302** which may be regarded as reflex, others as due to the direct influence of cold upon the sympathetic ganglia in the vessel walls. Some of the most important of the effects of local cold applications are the following: —

303 Plethysmographic experiments made by Franck showed that a piece of ice held in one hand causes shrinking of the other within two or three seconds, with a return to the normal at the end of a minute (Exp. 16).[12]

304 Snow rubbed on the inside of the arm at the bend of the elbow, or ice applied to the subclavian region diminishes the height of the pulse tracing (Winternitz), showing a contraction of the distal portion of the radial artery.

305 *A compensatory effect is sometimes observed.* Winternitz has noted that placing the elbow in water at 50° F. for 30 minutes gives rise to an elevation of temperature in the axilla, showing an increase in the internal temperature coincident with a lowering of the external.

306 Waller observed that the application of ice over the cubital nerve at the elbow produces a rise of temperature of 7° F. in the fourth and fifth digits, while the temperature of the other fingers falls an equal number of degrees. The muscles of the hypothenar region are at the same time paralyzed. The phenomena developed by this interesting experiment are closely akin to those observed to follow the division of the sympathetic nerve of the ear of a white rabbit, which occasions reddening of the ear of the side operated upon, while the opposite ear becomes pale.

307 *Cold applications made across the trunk of an artery cause contraction in its distal portions.* An ice-bag applied to the axilla lessens the circulation in the arm (Exp. 18). An ice cravat, or an ice-cold compress applied about the throat, lessens the cerebral circulation, through its influence upon the carotid and the vertebral arteries. The vertebral arteries alone may be influenced by an ice-bag applied to the back of the neck. An ice-bag over the femoral artery in like manner lessens the circulation in the leg. The circulation in the hand or the foot may be controlled by the application of an ice-bag to the bend of the arm or of the knee. (Exp. 18, 19).

An ice-bag applied over the heart continuously for several hours diminishes its activity and lessens rate of blood movement through the body. 308

A short, cold application over the heart acts as a tonic to the heart, increasing its force and raising arterial tension. 309

A short general cold application is a powerful heart tonic, increasing greatly the force and efficiency of the heart in appropriate cases. Direct application of cold, as by cold water dripped upon the exposed part or a cold fluid passed through it, slows and weakens it. 310

A prolonged cold application slows the heart's action, increasing arterial tension (Exp. 20). 311

Winternitz noted that *cold applications to a limited surface of the skin increased the pulse-rate for three minutes*, after which it gradually diminished in frequency. 312

The influence of cold upon the mucous membrane is essentially the same as that upon the skin, except that the mucous membrane is somewhat less sensitive to thermic impressions, having a smaller number of sensory nerve fibers. The mucous membrane is, however, richly supplied with vasomotor and sympathetic fibers, through which decided reflex effects may be produced. 313

A quantity of cold water taken into the stomach produces more marked effects than water applied to an equal area of the skin. The general temperature may be lowered by this means, and the heart's action may be slowed. Cold water drinking may lessen the pulse-rate ten to fifteen beats per minute (Exp. 21). Cold water drinking produces the same effects upon the visceral vessels and the blood pressure as do cold applications to the skin, though in less degree. The quantity of water is also an important factor. 314

Even more marked effects may be readily produced by the cool enema, which, together with water drinking, is one of the most efficient means of combating fever. The writer has often seen the general temperature fall one or two degrees in a fever case as the result of an enema administered at 80°. 315

The effect is, of course, less marked in health, which is also true of other applications of cold water (Exp. 22).

316 In this depressing effect of cold water when taken into the stomach, we have the explanation of the results that sometimes occur from drinking cold water when the body is in a state of fatigue. The power of reaction being diminished, chill and internal congestion are produced, often resulting in great injury. Cold water drinking is not contraindicated by active perspiration, but rather by fatigue, and this is true whether the skin is in a state of excessive activity or not.

THE EFFECTS OF COLD UPON RESPIRATION.

317 The observations reported by Halle, Fleury, Richter, Johnson, and others seem to indicate no regularity in the effects of cold upon the respiratory movements. One reports no appreciable effect; another, quickening of the respiratory activity, with slowing of the heart; another, sometimes quickening, sometimes slowing, of respiration. This confusion seems to be the result of failure to note the difference in the effect produced by different modes of application.

318 **Respiratory Movement.** When the cold application takes the form of the douche, the effect is to produce at first short, gasping respiratory movements, this effect being more pronounced the lower the temperature, the more abrupt the application, and the stronger the pressure employed. If, however, the patient is immersed in a cold full bath, respiratory movements after the first instant are slowed to a marked degree, and are decidedly fuller and deeper; that is, the amount of tidal air is increased.

319 The effect of the cold douche or spray in increasing the rate of the respiratory movements is especially pronounced when it is applied to the chest or upper part of the body. Thus employed, an unpleasant sensation of constriction in the chest is also produced, the very opposite of the effect following an application of warm water. These effects are clearly indicated in the tracings made by means of the author's pneograph (Figs. 25, 26) (Exp. 23).

This property of cold water must be borne in mind in the treatment of asthmatics, in whom a cold douche to the chest will generally produce a paroxysm of asthmatic breathing, and sometimes a most distressing sense of suffocation. The pulmonary vessels being made to contract suddenly by the powerful excitation of the vasoconstrictor centers of the cord, the area of blood presented for gaseous interchange in the pulmonary mucous membrane is very greatly diminished, while at the same time the demand for oxygen and for the elimination of CO_2 is increased, thus producing the painful sensation experienced in suffocation. 320

This sensation of suffocation ordinarily disappears at once when reaction occurs, and the quickened respiratory movements are succeeded by slower and fuller movements, accompanied by increased absorption of oxygen. 321

CO_2 Elimination.

An examination of the expired air shows that an increased amount of oxygen is absorbed and an increased amount of CO_2 is exhaled under the influence of cold applications. 322

Crawford showed more than a century ago (1781) that cold increases the difference in color between arterial and venous blood, the result of increased oxidation. 323

The oxidation of organic waste substances which takes place in the lungs is doubtless also increased, as is the oxidation of sugar in the blood of the general circulation. 324

Liebig observed more than half a century ago that cold air, cold water, and exercise, habitually employed, are the most powerful of all means of stimulating tissue activity. 325

THE EFFECTS OF COLD UPON THE MUSCLES.

The Muscular Sense. Muscular Irritability.

Prolonged applications of water at a low temperature decrease muscular irritability and muscular energy. This is shown in the stiffness and clumsiness of the fingers as the result of exposure to a low temperature. 326

A short, cold bath, as a douche or a spray, lasting for a few seconds, augments muscular energy and tone to a very 327 remarkable degree. The exaggerated tonicity thus induced is the cause of shivering. The cold bath, if short (1 to 2 secs.) and given with much pressure (25 to 35 lbs.), is a powerful restorative in fatigue resulting from severe muscular effort, but it must be immediately preceded by a short hot bath, and must be followed by rubbing and warm wrapping. The restorative effects of the cold bath are well shown in Exp. 24.[13]

328 **The Involuntary Muscles.** It is a curious and interesting fact that while cold lessens the irritability of the voluntary muscles, it excites the activity of the smooth muscular fibers of the skin, thus giving rise to the appearance known as goose-flesh. It also causes contraction of the smooth muscles of the small blood-vessels; and when applied to a large area of the skin or over special regions, as the feet or lower abdomen, may excite the involuntary muscles of the bowels and bladder, causing evacuation of these cavities.

329 Shivering is due to an involuntary action of the voluntary muscles, set up automatically as a means of combating the influence of cold by increasing heat production.

330 The application of cold water to the feet, as by means of the spray or stepping into a cold bath, may produce a goose-flesh appearance over the entire surface of the body, with shivering. The application of a cold spray or douche to one side of the body will produce a goose-flesh appearance on the opposite side, together with the usual phenomena attending the application of cold to the entire surface of the body, thus demonstrating that the powerful reflexes set up by cold applications are universal in extent within the body.

THE EFFECTS OF COLD UPON THE NERVOUS SYSTEM.

331 Nearly all the phenomena arising from applications of cold water are illustrations of the effect of cold upon the nervous system, whereby special effects are produced in various organs, as described under their respective heads. In this

section attention will be called especially to those effects of cold that are chiefly confined to the nervous system itself.

The Neuron. Recent discoveries in the minute anatomy of the nervous system throw much light upon the method by which the nervous functions are influenced by cold as well as by other agents. The discovery of the fact that each nerve cell, or neuron, is an independent entity, connected with other nerve cells by contact only, and not by actual continuity of structure, and the further discovery that in its activities the nerve cell actually executes movements and undergoes distinct changes in form, retracting or protracting its dendrites and the delicate filaments constituting the end-tuft of its neuraxon, has afforded a rational explanation for much that was before mere surmise or conjecture. 332

The neuron is by these discoveries found to be subject to 333
precisely the same laws that govern protoplasmic structures elsewhere than in the human nervous system. A careful study of the influence of heat and cold upon the ameba and the white blood-corpuscle shows that the influence of heat is to cause increased activity of the cell, with extension of protoplasmic processes, or arms, while cold diminishes its activity, causing retraction of its processes. We may thus justly conclude that when cold applications are made in such a manner as to influence the nervous system directly, similar effects are produced.

It is held, for example, that insensibility is due to
retraction of the dendrites, or protoplasmic processes, of 334
the neurons, thus cutting off connection with the rest of the nervous system by breaking contact at the points at which connection is necessary for the maintenance of the state of consciousness. The same principle applies to all other nervous functions. Increased nervous activity of any particular sort means simply increased movement of the neurons, active protraction of their dendrites, and an increased number of contacts with other neurons by means of the neuraxons with their collateral branches, end-tufts, and innumerable gemmules, or contact globules.

335 With these facts in mind, it is not difficult to understand that cold applications to a nerve trunk may greatly diminish or even entirely abolish its functions, paralyzing the parts to which it is distributed, as Waller showed by an application of ice to the cubital nerve at the elbow.

Nervous and Mental Activity.

336 Helmholtz showed that the application of cold to a nerve may diminish the rate of transmission of nervous impulses over it to one sixth the normal rate (Exp. 25). After such an application of cold to a nerve trunk and its withdrawal, the nerve quickly recovers, unless the application has been very intense and prolonged, and the part to which it is distributed becomes the seat of pain, sometimes very intense in character, showing that nervous sensibility is heightened in the reaction that follows the benumbing effect of a cold application.

337 If the application of cold is more intense in character and less prolonged, the sedative effect may be so slight as to be unnoticed, and the effect observed be that of excitation, which, however, as previously shown, is simply the rebound, or reaction, that naturally follows vital depression, owing to awakened resistance.

338 In like manner a short, cold application to the head results in increased cerebral activity, the reaction effect completely overshadowing the brief depression first produced. A prolonged application of intense cold to the head results, however, in a decided lessening of cerebral activity, and may give rise not only to stupidity and drowsiness, but to absolute unconsciousness, a fact which has for centuries been made use of in prisons, cold water being poured upon the head as a means of subduing refractory prisoners.

339 Schüller showed (1874) by experiments upon trephined rabbits the following interesting facts in relation to the effects of thermic applications upon the brain: —

340 1. Water at neutral temperature (92°–95° F.) applied directly to the brain produced no effect.

2. Ice applied to the brain coverings caused contraction of both veins and arteries, the contraction continuing for a short time after the withdrawal of the ice. 341

3. Ice applied to the scalp caused contraction of the cerebral vessels when carried to the point of producing general chilliness and shivering. 342

4. A cold compress applied to the spine or abdomen, or a cold full bath caused instant dilatation of the cerebral vessels, lasting from 3 to 10 minutes, then giving place to contraction. 343

5. Hot compresses or a hot full bath caused contraction of the cerebral vessels, later followed by dilatation. 344

6. Cold and warm applications applied to a nerve trunk produced an effect exactly opposite to that produced by the same applications made to the skin; that is, a cold application to a nerve trunk caused contraction of the cerebral vessels, while a warm application caused dilatation. Unquestionably the same effects, which are evidently reflex in character, occur when the sensory nerves of the skin are influenced by thermic applications, but they are overwhelmed and quickly wiped out by the mechanical dilatation of the cerebral vessels, resulting from the elevation of blood pressure and the displacement of a large quantity of blood toward the center of the body through the contraction and partial emptying of the vessels of the skin. 345

7. A heating compress or moist trunk pack of three hours' duration caused, first, dilatation, then contraction, of the cerebral vessels, and bulging of the membranes from accumulation of lymph. 346

8. Pinching the skin produced the same effects as hot applications.

These interesting experiments, which have since been confirmed by observations made upon a man whose brain had been exposed by accident, laid the foundation for a scientific therapy of the brain, which has received far less attention than 347 it deserves at the hands of medical men. These experiments show most clearly how cerebral congestion may be successfully combated by properly managed applications, and explains the relief afforded in insomnia by the moist girdle and the tonic effects of the cold douche.

348 Attention may be especially called to the effect of the moist abdominal bandage upon the blood and lymph circulation of the brain. There is normally maintained a constant balance between the blood supply of the brain and the amount of lymph present in the ventricles. The more blood in the brain, the less lymph in the ventricles and the nerves, an arrangement necessary for the protection of the delicate cerebral vessels, from the fact that the brain is inclosed in an inelastic case. The moist bandage so influences the lymph and blood circulation of the brain that the quantity of blood is notably diminished, while the quantity of lymph is greatly increased, as shown by the bulging of the membranes, thus supplying just the condition needed for normal sleep.

REFLEX EFFECTS OF COLD APPLICATIONS.

349 Edwards showed that immersion of one hand in cold water causes a lowering of temperature in the other hand. The experiments of Winternitz, and later those of Franck, showed by means of the plethysmograph that cold applied to one hand causes contraction of the vessels in the other hand.

The interesting facts already presented in relation to the influence of cold applied to the skin, both locally and upon distant parts (**339**) are examples of reflex effects. These effects include not only dilatation and constriction of the blood-vessels, but also contraction of the smooth muscles found in the bowels, bladder, and other hollow organs of the body. The muscular walls of the minute air-tubes of the lungs, the so-called ligaments which support the viscera, the secreting structures,—the liver, kidneys, digestive glands, and other allied organs,—are also influenced reflexly by applications of cold to the external areas in relation with them.

Special Effects of Applications to Muscular Reflex Areas.

In accordance with the facts just mentioned, it becomes apparent that to produce reflex effects in the muscles we have but to make cold applications to those areas the stimulation of which is capable of developing muscular contraction. These areas, as elsewhere pointed out, are:— 350

The *intra-scapular* (space between the shoulder-blades).

The *epigastric* (the sides of the chest at about the level of the fourth rib).

The *abdominal* (the borders of the recti muscles).

The *cremasteric* (the inner and upper surface of the thigh).

The *plantar* (the sole of the foot).

By gentle irritation of the skin of these several areas, the greater portion of the several muscular groups may be brought into activity. This is particularly true of the plantar surface. 351

Short, very cold applications, at high pressure, made upon these surfaces may be very serviceable in all cases in which it is desirable to stimulate the nutrition of the muscles, as in general muscular weakness, paresis or paralysis, progressive muscular atrophy, and other maladies in which there is wasting of the muscular structures. Although muscular action may not be induced, the nutritive processes in the muscles are influenced favorably by applications made to these reflex areas. Most important of all is the plantar surface.

An application of a jet of either cold or very hot water to the abdomen causes instant and vigorous contraction of the abdominal muscle, and is likewise a most valuable means of exciting intestinal peristalsis. 352

Special Skin Areas in Reflex Relation with the Internal Viscera.

Cold applications to the face and neck, short and intense, cause dilatation of the cerebral vessels. 353

A prolonged contraction of the cerebral vessels is produced if the application is greatly lengthened, and vertigo and even unconsciousness may result. This is true, however, only of very vigorous applications, as the long cold "head pour." 354

355 Short applications of intense cold to the neck and chest produce an acceleration of the pulse and of the respiratory movements, followed by a slowing of the heart and the respiration.

356 Prolonged immersion of the hands in cold water causes contraction of the vessels of the brain and of the mucous membrane of the nose. This measure is thus useful in combating cerebral hyperemia.

357 A prolonged cool foot bath causes contraction of the vessels of the uterus, and may thus be useful in combating uterine hemorrhage.

358 Very cold applications to the breasts, abdomen, hands, and feet cause contraction of the involuntary muscles of the bladder, bowels, and uterus. It is more than probable that the muscular structures of the liver, spleen, and other viscera are likewise influenced by such applications, as well as by applications made to the overlying areas of skin.

359 A short, very cold douche to the feet, with strong pressure (25 to 35 lbs.), dilates the vessels of the uterus, and is hence useful in amenorrhea.

360 A prolonged cold application to the upper dorsal region relieves congestion of the nasal mucous membrane, and is thus useful in nosebleed. The popular practice of applying cold metal to the spine to check nosebleed shows the relation of this surface to the nasal mucous membrane.

361 A prolonged cold application over the upper dorsal and lower cervical region causes contraction of the pulmonary vessels, and is useful in pulmonary congestion and hemorrhage.

362 A prolonged cold application to the occiput and neck shows the action of the heart.

363 Application of the ice-compress or ice-bag to the lumbar region produces dilatation of the vessels of the uterus and lower extremities, if prolonged, and is useful in amenorrhea.

364 A cold lumbar douche at moderate pressure, and continued from 15 to 45 seconds, produces contraction of the vessels of the uterus.

A very cold and very short douche (2 to 4 secs.), with strong pressure (25 to 30 lbs.), to the lumbar region, produces dilatation of the uterine vessels. This measure is accordingly useful in amenorrhea. 365

Prolonged cold applications to the breasts and the inner surface of the thighs produces contraction of both the vessels and the muscles of the uterus. 366

Winternitz has shown that cold applications to the thighs also influence the pulmonary circulation, combating congestion. 367

A short, cold douche applied to the lower portion of the sternum stimulates the kidneys, increasing the flow of urine. 368

A short, cold douche, with strong pressure, over the liver, stomach, spleen, or bowels, produces dilatation of the blood-vessels, with increased activity in these organs. 369

Contraction of the small vessels may be produced in the liver, spleen, stomach, bowels, and other internal viscera by prolonged cold applications of moderate intensity (60° to 75° F.) to the skin overlying these organs. This measure is of great service in the treatment of pathological conditions involving congestion of these organs. 370

Cold applications to a reflex area often give rise to a sense of constriction in the parts reflexly connected. When a cold douche is applied to the feet, a strong sensation of constriction is felt in the lower abdomen; while cold applied to the chest occasions a sensation of constriction in the thorax. 371

Summary of Methods for Reflexly Influencing the Internal Viscera.

The vessels of the important viscera may be caused either to dilate or contract by cold applications to the skin, according as the application is short and intense (1 to 4 secs., temp. 40° to 60° F., pressure 25 to 35 lbs.) (dilatation), or long and moderate (contraction), by the following methods:— 372

The *brain*, by applications to the head, neck, face, hands, and feet. 373

374 The *nasal mucous membrane*, by applications to the neck, face, upper dorsal spine, hands, and feet.

375 The *stomach*, by applications to the lower dorsal spine and the epigastrium.

376 The *kidneys*, by applications to the lumbar region, the lower portion of the sternum, and the feet.

377 The *bowels*, by applications to the feet and the abdomen.

378 The *bladder*, by applications to the feet and the lower abdomen.

379 The *liver*, by applications to the lower right chest.

380 The *spleen*, by applications to the lower left chest.

381 The *lungs*, by applications to the chest and the thighs (Winternitz), and to the upper dorsal region.

382 The *uterus*, by applications to the lumbar region, the abdomen, the breasts, the inner surfaces of the thighs, the feet, and to the cervix uteri, through the vagina. Applications made to the cervix uteri are usually very hot rather than cold.

THE EFFECTS OF COLD UPON THE BLOOD.

383 In 1893, Professor Winternitz, of Vienna, called attention to the remarkable influence of cold applications in increasing the number of blood-corpuscles, both red and white, and also the amount of hemoglobin, it being noted, however, that the white blood-corpuscles were increased in much greater proportion than the red corpuscles. In one case reported by Winternitz, the increase of blood-corpuscles by a hot bath followed by cold was 1,860,000 per c.mm. The number of white corpuscles was sometimes increased three hundred per cent. In a case observed by the writer, the increase was more than half a million.[14 15 16]

384 This remarkable phenomenon is due, according to Winternitz, not to the sudden creation of new blood-corpuscles, but to the contraction of the vessels of the viscera, caused by the application of cold to the surface, whereby great numbers of corpuscles, which have been collected in the vessels of the liver, kidneys, spleen, and other internal viscera, are driven

into the circulation. That this explanation is not entirely complete, however, is shown by the fact that local applications of cold water are followed by an increase in the number of corpuscles and of the hemoglobin at the seat of the application, though no such increase is observed elsewhere (Exp. 26).

According to Henocque, both hot and cold applications 385
increase the rate at which the oxyhemoglobin of the blood is reduced. A freezing temperature reduces the rate one-half.

Crawford, of England, showed in 1781, in a paper pub- 386
lished in the "Transactions of the London Philosophical Society," that cold baths increase the contrast of color between the arterial and the venous blood, the natural result of increased tissue activity and oxidation.

D'Arsonval and others have shown by the estimation of 387
the gases contained in the blood at different points of the body simultaneously, that the interstitial combustions are increased by cold applications. These observations have been confirmed by others, who have shown that the gaseous exchanges are decidedly increased by cold applications, so that a greater amount of oxygen is passed through the body in a given amount of time.

Strasser (*Deutch. Med.-Zeit.*, June 15, 1896) has shown 388
that general cold applications increase the alkalinity of the blood, the diminution in acid phosphate amounting sometimes to fifty per cent.

THE EFFECTS OF COLD UPON ABSORPTION.

By introducing belladonna into the rectum and observing 389
the length of time that elapsed before dilatation of the pupil and other characteristic physiological effects appeared, Fleury showed that absorption from the alimentary canal is very greatly accelerated by the cold douche. His experiments and those of others show clearly that cold applications to the surface stimulate absorption by the gastric and intestinal mucous membrane, and consequently that such applications must favor nutrition by promoting alimentation.

THE EFFECTS OF COLD UPON SECRETION AND TISSUE CHANGE.

390 A short, very cold douche, administered with strong pressure (25 to 35 lbs.), over the stomach and liver, has the effect to increase the secretory activity of these organs by dilating their vessels, thus bringing a larger quantity of blood in contact with the secreting cells, and also by directly exciting cell activity.

391 The cold douche and the ice-bag or compress over the region of the stomach, increases the amount of hydrochloric acid formed by the stomach, and is thus exceedingly useful in hypopepsia (Exp. 27).

392 Experiments made upon the rabbit and the dog show that intense general applications of cold give rise to increased production of sugar, the sugar appearing in excessive quantity in the blood, and if the application is of sufficient intensity, in the urine also. Similar effects of very cold applications have been observed in man.

393 As it is generally conceded that the glycogenic function of the liver may be taken as an indicator of its activities in other directions, it is evident that cold applications may be made in such a manner as to produce greatly increased activity of the hepatic functions.

394 It is evident that all applications of water which increase the activity of the liver in the destruction and elimination of tissue poisons and pathological toxins, must be capable of rendering valuable service in the treatment of diseases in which there is an excessive production of these elements, as in typhoid fever, malarial fever, the malarial cachexia, "biliousness," many forms of dyspepsia accompanied by chronic toxemia and resulting neurasthenia, and in chronic liver disorders,—congestion, sclerosis, hypertrophy,—and other morbid states which so often accompany chronic indigestion.

395 The most pronounced effects upon the liver and stomach are to be obtained by the use of the alternate circle or horizontal douche and the percussion douche.

General cold applications, especially the cold douche, increase the production of HCl, and hence improve the quality of the gastric juice. The alternate circle douche is perhaps the most efficient of all means for promoting peptic secretion. 396

Thermic applications to the skin unquestionably produce the most profound effect upon the thermotaxic centers, but this influence is to a considerable degree masked by the fact that there is little disturbance in the body temperature. By the aid of the author's bath calorimeter, it is easy to observe that these thermic applications influence heat production and dissipation to a most profound degree (Exp. 28). 397

In an observation elsewhere described (Exp. 29), made by the author with his bath calorimeter in 1890, and many times repeated since with the same results, it was found that the patient lost, during the bath, 103,354 heat units within fifteen minutes. This represented four per cent., or one twenty-fifth of the total amount of heat produced in twenty-four hours. As the patient's temperature remained the same at the close of the bath as at the beginning, it is evident that the increase in heat distribution was compensated for by an equal increase in heat production, which must of course involve the destruction of tissue, at least the oxidation of carbohydrate material in the form of glycogen. 398

Dr. Strasser, assistant to Professor Winternitz, of Vienna, in a paper contributed to a volume published in commemoration of the fortieth anniversary of Professor Winternitz's graduation in medicine (Vienna, 1897), gave an account of a classical and exceedingly interesting study of the effects of cold water upon tissue change.[17] Strasser found, for example, that a cold bath increases the amount of urea, uric acid, ammonia, earthy phosphates, the xanthine bases or extractives, and the total nitrogen, which proves conclusively that short so-called tonic applications have the effect of stimulating to a high degree the processes of tissue change in the body. A very interesting and notable fact observed was that while 399 before the bath the quantity of imperfectly oxidized extractives constituted about 8.7 per cent. of the total amount excreted, under the influence of the bath the amount of imperfectly oxidized extractives produced was but 1.5 per cent.

It is also worthy of note that the increased amount of phosphates eliminated was almost altogether in the form of earthy phosphates, which, as Strasser states, is derived from the food, thus affording an evidence of the improved absorption due to the application of cold water to the surface. These facts account for the wonderful effects observed in the application of the cold bath in rickets, the increased absorption of earthy phosphates contributing in these cases to the development of healthy bone structures.

THE EFFECTS OF COLD UPON EXCRETION.

400 Short cold applications to the skin, being followed by dilatation of the surface vessels, favor perspiration; while prolonged cold applications have the opposite effect.

401 As a rule, an increase in the quantity of fluid eliminated through the skin is accompanied by a decrease in the quantity of urine. This is not universally the case, however; and it should also be remembered that the quantity of urine is not the true measure of renal activity, but rather the quantity of poisons removed from the system.

402 Applications of ice-water to the skin of a dog cause temporarily a decided decrease in the size of the kidneys, due to contraction of their vessels and tissues. The reaction following a cold application gives rise to dilatation of the vessels, relaxation of the tissues, and increased functional activity.[18]

The effects upon the kidneys of cold applications to the skin are so profound that they must sometimes be interdicted in cases of renal disease. In experiments upon animals, prolonged and very cold applications have caused the appearance of albumin in the urine.

Short general cold applications increase the elimination of CO_2 and the absorption of oxygen, a fact which agrees with the influence of cold upon heat production; while prolonged cold applications lessen heat production and CO_2 elimination.

Cold applications which give rise to increased heat production and a corresponding increase of CO_2 do not give rise to an increase in urea unless they affect the body temperature. The production of urea seems to be regulated, to a degree at least, by the body temperature. An increase in the body temperature is accompanied by an increase of urea, as in fever; while with a depression of the body temperature, urea production and elimination are decreased. **403**

Cold applications to the lower third of the sternum (the renal douche) excite renal activity. Cold immersion and other baths also increase the amount of urine and the total solids. In cases of fever treated by the cold bath the toxicity of the urine may be increased sixfold, thus proving the great influence of cold in increasing renal efficiency. **404**

THE EFFECTS OF COLD APPLICATIONS UPON TEMPERATURE.

Currie showed ("Medical Reports," London, 1797) by thermometric observations that applications of cold water to the surface are capable of lowering not only the surface temperature, but also the internal temperature of the body. This was the beginning of scientific hydrotherapy. **405**

In an experiment related by Currie, a healthy man was put into a bath at 40° F., his temperature at the time being 97.5°. His temperature, according to the observer's statement, quickly fell to 83.1°, but rose at the end of fifteen minutes to 91.9°; at which point it remained for nineteen minutes, when it again rapidly descended, reaching in three minutes 84.9°. The subject was then removed from the cold bath, where he had been for thirty-seven minutes, and placed in a full bath at 96°. As he continued to shiver vigorously, the temperature of the bath was raised to 109°. At the end of twenty-eight minutes the body temperature was found to be normal. These observations may have been inaccurate. **406**

407 J. Lefevre has shown that the rate of heat loss when the body is exposed to cold air or cold water does not decrease as the temperature is lowered, but increases out of proportion to the temperature lowering.

408 Fleury observed a lowering of seven degrees in temperature in a man by immersion in a bath at 50° F. for 25 minutes.[19]

409 Jurgensen observed a reduction of 6.5° in temperature as the result of a cold bath.

410 The majority of observers have not noted so great lowering of temperature from local applications as those named above. Draper obtained a fall of 1.5° from an hour's immersion in a bath of 73.5° to 75°.

411 The effect of the cold bath in lowering the temperature of the body is increased as the temperature of the bath is lowered and its duration prolonged. The effects of cold applications upon the body temperature are much more pronounced in fever than under normal conditions.

412 The surface often continues cold for some time after it has become reddened by reaction,—an evidence that cooling of the blood is still going on.

413 Fleury was the first to note that the body temperature sometimes does not begin to fall until some minutes after the subject has been removed from the bath.

414 The reduction of temperature in the cold bath is greatly increased by friction of the surface, as by this means the surface circulation is maintained, so that a larger amount of blood is brought under the influence of the cooling medium. The experiments of Winternitz showed that the rate of heat elimination from the skin in the cold bath may be increased 30 per cent. by vigorous friction of the surface (Exp. 30). Pospischil showed an increase of more than 44 per cent.

415 It must be remembered, however, that by very vigorous friction, heat production may be increased to such a degree that the antithermic effect of the bath may be undesirably diminished.

The necessity for the prolonged application of cold grows 416
out of the fact that when a cold application is made, the forces of the body instantly rally to resist its influence, heat production being increased and heat elimination diminished. The system thus endeavors to maintain the normal temperature. If the application is withdrawn before this effort is, in a measure, at least, suppressed or exhausted, the normal temperature will be quickly recovered, and may be even exceeded. This, with the other phenomena of reaction, will be discussed elsewhere.[20]

Prolonged Cold and Suppressed Reaction.

When a cold application is considerably 417
prolonged, the tendency to reaction is, to a large extent, suppressed, as a result of the exhaustion of the nerve centers involved, the lessening of the sensibility of the sensory nerves concerned in the reflex movement upon which reaction depends, as well as by the exhaustion of the powers of calorification. Thus the system gradually loses its power to resist the depressing effects of cold, and its antithermic effects are developed.

If the application is continued for a very long time, the thermal and other vital activities of the body are depressed to such a degree that two or three hours may elapse before the normal temperature is restored.

Edwards, an English investigator, has shown that repeated 418
chilling of an animal increases the length of time required for return of the normal internal temperature; hence the value of repeated cold baths in typhoid fever.

The Effects of Local Cold Applications upon the Body Temperature.

Applications of water at a temperature below 419
that of the body always lower the temperature of the part to which the application is made.

Circumscribed local applications of cold 420
water, such as immersion of the hand or foot, reduce the temperature of the part, but have no appreciable effect upon the general temperature, unless a considerable amount of surface is involved, as in the employment of large cold compresses to the trunk, except in case of

internal applications or applications to special regions, as the head.

421 Brown-Sequard showed that immersion of the hand in cold water gives rise to lowering of the temperature of the other hand.

These local applications of cold were, however, found to be without influence upon the general temperature.

422 Winternitz showed that the application of snow to the forearm produces, first, a lowering of temperature in the hand to the extent of 2° and then an elevation of 1.3° F. (Exp. 31).

423 Ice held in the mouth causes a lowering of the temperature of the cheek of the corresponding side. Copious drinking of ice-water likewise produces a fall in the temperature of the skin of the epigastrium (Exp. 32). This lowering of temperature is so marked that it may be used as a method of locating the stomach by the aid of the surface thermometer. This fact was first shown by an experiment made under the writer's supervision, by one of his students, in 1898.

424 The application of cold water to the soles of the feet, especially if in the form of a spray, lowers the temperature.

425 An ice-cap applied to the head is an efficient means of lowering the general temperature, through exercising a depressing effect upon the thermogenic centers.

426 The application of an ice-bag over the heart lowers the general temperature, slowing the circulation, and cooling the blood (Exp. 33).

427 Copious cold water drinking and the large cold water enema, although local applications, have a very decided effect in lowering the general temperature, especially in febrile conditions (Exp. 34).

THE EFFECTS OF COLD UPON THE THERMO-ELECTRICAL CURRENTS OF THE TISSUES.

Gautrelet has made the interesting suggestion that the 428
difference of temperature created between the exterior and the interior of the body by cold applications to the surface must directly augment the intensity of the organic thermo-electrical currents which are constantly playing within the body, thereby modifying, in an important way, various nutritive processes, and perhaps especially those concerned in the storing and discharge of nervous energy. This is a subject which deserves further investigation.

THE PHENOMENA AND RATIONALE OF REACTION.

Reaction, using the term as it is employed in hydro- 429
therapy, is one of the most complex and interesting of physiological phenomena. The term is perhaps somewhat misleading, as it suggests the idea of a single process, whereas there is a series of complicated actions and reactions. The most important of these are two, which may be distinguished as the *circulatory action and reaction* and the *thermic action and reaction.* Ordinarily we speak only of the circulatory reaction, as this is the one most commonly sought. Generally, however, they occur together. These reflex activities come into play in most of the process of hydrotherapy, but especially in those employed for general effects.

Suppression of Reaction.

Applications designed exclusively for local 430
effects are usually managed in such a way as to suppress reaction, either partially or wholly; as, for example, when it is desired to restrain local inflammatory processes,— pain, congestive headache, or hemorrhages, — reaction is suppressed as much as possible by continuous applications of cold of the necessary degree of intensity.

On the other hand, in the employment of the cold or cool 431
shampoo to the scalp for baldness, the cold douche to stimulate perspiration, or the heating compress to a rheumatic

joint, reaction is encouraged by means of friction, strong percussion, or high pressure, or by protection from evaporation.

432 In some general applications, also, reaction is suppressed as much as possible, as in the employment of the tepid bath for the reduction of temperature, or the neutral bath for insomnia; whereas, in other applications it is encouraged, as in the cold full bath with friction, for reduction of the temperature, and the short, cold spray or douche administered for tonic effects.

433 **Definition of Reaction.** Reaction consists of a series of vital processes which follow the making of either hot or cold applications to the skin or the mucous membrane. The reflex vital activities induced by cold applications are much more pronounced than those produced by heat, and differ in character; nevertheless, the vital reactions produced by applications of heat are clearly defined and constant in character, and may be most advantageously utilized in hydrotherapy. In view of these facts, it is indeed remarkable that the reaction of heat has been almost absolutely ignored by writers upon hydrotherapy. Even Hippocrates observed that a cold bath warms the body by reaction, while a warm bath cools it.

434 The reaction following the application of heat or cold to the skin is much more pronounced than that resulting from similar applications to the mucous membrane through the stomach and the colon.

435 **The Reaction of Cold.** We have here to consider only the reaction following short cold applications, the reaction of heat being left for consideration elsewhere (**577**). The phenomena resulting from a very cold application to the skin, with strong pressure and of short or moderate duration (3 to 30 secs.) may be divided into three classes:—

1. The immediate effects that accompany the application, which may be called the primary effect, or *action*.

2. The secondary effects, which constitute the phenomena of *reaction*.

3. The remote effects, that is, the final result of the application or series of applications in modifying normal or pathological nutritive processes. These later effects, being too varied and numerous to be presented in tabulated form, will be referred to elsewhere under the head of "Tonic Effects."

The most clearly defined of the phenomena included in these primary and secondary effects may be summarized as follows: — **436**

ACTION.	REACTION.
1. Contraction of the small blood-vessels of the skin, with dilatation of internal vessels after a very brief contraction.	1. Dilatation of the small blood-vessels of the surface, with contraction of internal vessels.
2. Pallor of the skin.	2. Redness of the skin.
3. Goose-flesh appearance and roughness of the skin.	3. Skin soft, smooth, and supple.
4. Sensation of chilliness.	4. Sensation of warmth.
5. Trembling, shivering, chattering of the teeth, in some cases decidedly painful and distressing sensations of "constriction," etc.	5. A sensation of comfort and well-being.
6. First quickening, then slowing of the pulse, with increase of tension.	6. Slowing of the pulse, with increased tension.
7. First checked, then quick, deep, gasping respiration.	7. Respiration free, slower, and deeper.
8. Cooling of the skin.	8. Heating of the skin.
9. In most cases slight rise of internal temperature.	9. Fall of internal temperature.
10. Perspiration checked.	10 Increase of perspiration.

The initial symptoms following an application of cold water are evidence of a protective effort on the part of the system to prevent undue loss of heat by contracting the blood and lymph channels of the skin, thus decreasing its conductivity, and by increasing heat production through the muscular action of shivering. **437**

If the application is very cold, at high pressure, and of short duration, the phenomena of reaction begin immediately when the application ceases. **438**

439 If the patient has exercised actively just before the bath, or if vigorous friction of the skin or a hot bath has been administered, and not infrequently in healthy persons without the preparation referred to, the phenomena of reaction begin even before the termination of the application, as shown by reddening of the skin, and by the disappearance of goose-flesh and other unpleasant symptoms.

440 **Second Reaction.** If, after reaction has set in, a renewed application of cold is made, a second reaction will occur in most cases, but the vital movement will be much less prompt and pronounced; and if the subject is feeble or fatigued, a second reaction may not occur. In some very vigorous subjects, even a third or a fourth reaction may be secured by as many successive cold applications, but each time with diminished vigor; and sooner or later a point will be reached at which no reaction will occur, or only after a very long delay.

441 If, instead of administering a short, cold douche, the patient is placed in the cold bath, essentially the same thing occurs. After the first contact with cold water, the tendency to reaction appears, amounting in some cases to actual reddening of the skin, especially if the patient is rubbed. The continued contact of the water with the surface, however, prevents the complete development of reaction, and sooner or later a second chill occurs, reaction from which may be entirely suppressed.

442 **Incomplete Reaction.** The symptoms experienced by a person when prompt reaction does not occur are exceedingly unpleasant. The most prominent are prolonged chilliness, a disposition to nausea or faintness, giddiness, weakness, and great depression. The surface remains pale and cold, and the internal temperature also may be below normal, as the chill indicates the beginning of a decline of temperature below the normal level. These symptoms show that the energies of the body, by which it is naturally able to combat the disturbance created by the

application of cold to the surface, are unable to respond to the demand made upon them under existing conditions.

Conditions that Favor Reaction. The phenomena of reaction will seldom fail if the cold application is made in a proper manner. There are various controllable conditions and measures by means of which the energies of the body may be aided in developing prompt and vigorous reaction. By the employment of these in connection with the proper adaptation of the modes of applying cold to different cases, it is possible to modify at will the degree of intensity of the reaction effects obtained in any given case. 443

These conditions and measures may be classified thus: — 444

1. Those applicable *before the bath.*

2. Those that influence the condition of the patient *during the bath.*

3. Those that may be employed *after the bath.*

These several conditions and applications may be enumerated as follows: —

1. *Measures and Conditions which Favor Reaction, to be Employed before the Bath:* — 445

(1) Warm clothing.

(2) Exposure to the air of a warm room.

(3) A hot bath of some sort.

(4) Drinking hot water or some other hot beverage.

(5) The hot enema.

(6) Exercise more or less vigorous in character, according to the strength of the patient, but never carried to the degree of even incipient fatigue.

(7) Friction of the skin until warm and well reddened (Exp. 35).

(8) A warm, dry, or slightly moist skin.

(9) A state of general health and vigor.

2. *Conditions Pertaining to the Bath Itself or Acting in Conjunction with It:* — 446

(1) A very low temperature; the lower the temperature the more prompt the reaction.

(2) Short, sudden applications.

(3) Pressure or percussion effects, as in some form of the douche or spray (Exp. 36).

(4) Friction in the full bath, the half bath, the massage-douche, or the rubbing wet sheet (Exp. 37).

(5) Alternating and revulsive spray or douche, the difference in temperature employed being as great as possible.

447 3. *Measures that Encourage Reaction after a Bath:* —

(1) Heat in the form of hot, dry air, warm clothing, or hot-water drinking. It is even possible to induce reaction in frozen parts by rubbing with snow or ice in a warm room. The lumberman in the north woods warms his feet by taking off his shoes and stockings, and rubbing his bare feet with snow, immediately dressing them again. A high external temperature favors reaction, both by lessening heat elimination and by increasing heat production.

(2) Exercise as vigorous as the strength of the patient will allow (Exp. 38).

(3) Friction of the surface with the hand, rough towel, or flesh-brush, practised by the subject or the attendant, or both.

Conditions that Discourage Reaction.

448 Omitting many of the specific conditions of disease that hinder reaction and contraindicate cold applications to the skin, the following may be enumerated as among the most important conditions which prevent or delay reaction, and must therefore be taken into consideration in the employment of general cold applications: —

449 1. *Old Age.* It is well to bear in mind the adage formulated by an eminent French writer, "A man is as old as his arteries." Subjects in whom arterio-sclerosis has begun, react with difficulty, and thus require special care. Very cold baths must be avoided altogether, unless the area involved is very small.

450 2. *Infancy.* Very young children react badly.

451 3. *Exhaustion*, either of a temporary nature from excessive exercise or loss of sleep, or extreme nervous exhaustion,

owing to the weak condition of the nerve centers upon which prompt reaction depends.

4. *Obesity*, owing to relative anemia of the skin. **452**

5. *Rheumatic diathesis*, owing to the weakening influence **453** of uric-acid poisoning and resulting inability of the body to adjust itself readily to change of temperature.

6. *Unhealthy or inactive skin.* **454**

7. *Profuse perspiration*, but only when accompanied by **455** great fatigue.

8. *Extreme nervous irritability.* **456**

9. *Very low temperature of the skin.* **457**

10. *An immediately preceding or impending chill.* **458**

11. *Extreme aversion to cold applications.* **459**

Thermic Reaction.

As the previous observations relate chiefly **460** to that portion of the phenomena of reaction designated as circulatory reaction, it may be profitable to consider briefly by itself the interesting series of vital activities which constitute what is known as thermic reaction.

Thermic reaction to cold may be defined as the effort **461** of the body to replace the heat which has been lost by exposure to cold, and to restore the equilibrium of the body temperature.

All general cold applications of whatever sort, whether **462** made to the skin or to the mucous membrane, lower both the temperature of the surface to which they are applied, and the internal or general temperature of the body. This has been abundantly proved by Fleury, Liebermeister, Bottey, and others. In a considerable proportion of the cases, however, the ultimate lowering of the internal temperature is preceded by a slight rise, which begins almost simultaneously with the cold application, and continues for 10 or 12 minutes afterward.

After the initial rise and subsequent lowering of the tem- **463** perature, there is a gradual return to the normal temperature.

This vital movement is very well shown in the following diagram, which is modified from that given by Bottey: —

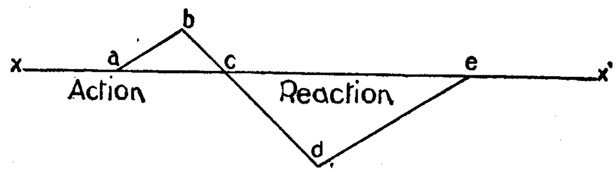

Diagram indicating the vital movement following a general cold application.

In this diagram, which represents the effect obtained from a short, very cold jet douche or spray applied to the skin with high pressure, the line *xx'* represents the normal temperature, 98.6° F.; the line *ab* represents the brief elevation of internal temperature which follows the receding of the blood from the surface the first instant after a cold application; the line *bcd* represents the fall in internal temperature which immediately succeeds the rise; and the line *de* represents the *reaction* by which the normal temperature is restored. The line *abcd* may be said to represent the *action* which precedes reaction.

464 **Modifications of Thermic Reaction.** Vigorous exercise or a hot bath taken just before a cold bath increases the initial rise of temperature, which is doubtless due to the fact that muscular activity increases heat production to so marked a degree that the cold application finds the thermogenic processes in full play, and hence more able to produce a strong thermic reaction.

465 Warm or tepid baths (80° to 92°) do not produce the initial rise of temperature. The following diagram represents the thermic action and reaction accompanying and following a tepid bath.

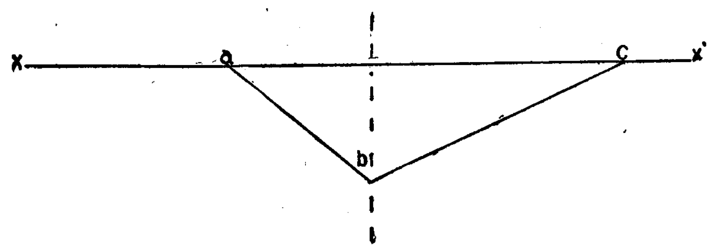

Diagram representing the vital movement following a warm or tepid bath.

In this diagram, xx' represents the normal temperature, 98.6° F. The line *ab* represents the action whereby the body is cooled; the line *bc*, the reaction. The perpendicular dotted line is the point of division between the two classes of phenomena.

A tepid or neutral bath causes lowering of the body temperature purely in a physical and mechanical way, independently of any reflex action. The surface blood-vessels do not contract, and hence the blood is rapidly cooled as it comes in contact with the water at a temperature a few degrees below the body temperature, and by the circulation of the blood current the internal temperature is lowered. **466**

Not infrequently the rise of body temperature produced by the thermic reaction after a cold bath does not cease at the normal point, but rises slightly above it. Several oscillations of this sort may occur before the normal point is permanently gained. **467**

The cause of the initial rise of temperature produced by a short, intensely cold application to the skin is evidently the slowing of the blood current. The blood is heated in the internal viscera, and cooled at the surface of the body. A complete circuit of the blood through the heart is effected by every twenty-seven or thirty heart-beats, or in a little less than half a minute. It is evident that the more rapidly the blood is passed through the skin, the more heat will be given **468** up to the skin and the air, and hence the greater will be the cooling of the whole mass of blood, and the lower will be the internal temperature, the rapid blood current tending to equalize the temperature of the body, warming the surface and cooling the interior.

469 It is equally evident that slowing of the circulation must have exactly the opposite effect: the blood, remaining longer in the skin, loses more of its heat, and the skin is accordingly cooled to a greater extent; whereas the blood which traverses the viscera, in which the thermogenic processes are most active, will remove a smaller amount of heat, thus occasioning a rise of temperature in the interior of the body, and so in a double manner increasing the difference between the external and the internal temperature. General intense cold applications to the surface cause contraction of the small arteries in every part of the body, in the viscera as well as in the skin (M. Wertheimer). The contraction of the vessels of the viscera is much briefer in duration than in the skin, but is long enough to check the movement of the blood current, thus momentarily encouraging the fall of temperature in the skin and the rise of temperature in the internal parts, as just explained.

470 Simultaneously with the development of the internal rise of temperature, there occurs an increase of heat production as the result of reflex action through the sympathetic nervous system, accompanied, as shown by Liebermeister, with increased production of CO_2, as shown by Winternitz.

Counterbalancing Reaction.

471 Curiously enough, the influences which give rise to an increase of internal-heat are antagonized by a reflex action effected through the sympathetic, or vasomotor, system, which tends to cool the body either by inhibiting the automatic thermogenic centers of the cord, or through the intervention of a special refrigerating center.

472 The initial rise of temperature in the interior of the body is very brief in duration, for the reason that by the circulatory

reaction which dilates the surface vessels, heat elimination is greatly increased, both through the enlargement of the area of blood exposed to the cooling influences acting upon the skin, and through the increased rapidity of the blood current, whereby the skin is rapidly warmed and the interior cooled. When the minimum temperature is reached, which may be from a few tenths of a degree to three or four degrees below the normal, a rise in temperature takes place, and continues until the normal point is reached, or even surpassed.

The thermic phenomena following an intense application of cold to the surface may be briefly epitomized as follows:— 473

1. Cooling of the skin by conduction and evaporation. 474

2. Cooling of the skin and of the viscera by reflex refrigerating influences due to the action of the sympathetic nerves. 475

3. Elevation of the internal temperature in consequence of the slowing of the blood current following contraction of the small blood-vessels throughout the body. 476

4. General increase of temperature internally and externally through reflex stimulation of the thermogenic centers. 477

Thermic Reaction a Useful Indicator.

The thermic reaction is a useful indicator both of the extent to which the bodily functions may be modified by hot or cold applications to the surface, and of individual susceptibility. The author has found the following a useful means of testing the reactive power of an individual:— 478

A vessel of sufficient size to receive the arm immersed to the elbow is provided with water at a temperature of 50° F. The patient immerses the bared hand and arm to the elbow for one-half minute. Note is taken of the surface temperature of the arm before immersion and every five minutes after removal, until the original temperature is restored (Exp. 39). 479

The appearance or non-appearance of goose-flesh and the length of the continuance of this phenomenon are noted, and also the appearance and duration, or non-appearance, of reaction, as indicated by increased surface temperature and redness. 480

This test is a valuable means of determining the condition of the nervous system as regards the tone of the spinal and sympathetic centers, and also gives important information concerning the general vital resistance of the patient, or his power to resist disease.

A more convenient and practical, though somewhat less accurate, method of applying this test is the following: Dip the corner of a towel in ice-water, hold the saturated towel against the bared forearm of the patient for one minute, covering a surface of at least ten or twelve square inches. Do not rub the surface, simply maintain contact of the cold wet towel with the skin. On withdrawing the towel, dry the surface by light pressure with the dry end of the towel, cover to prevent slow cooling by evaporation, and note the length of time required for the occurrence of reaction, as shown by the return of redness and natural heat. General chilliness produced by this application indicates an extreme irritability of the vasomotor nerves and nerve centers and undue activity of the reflexes. A mottled blueness shows great cardiac weakness and a dangerous threatening of collapse. This fact renders this method valuable as a means of ascertaining a patient's ability to take an anesthetic without undue risk of heart failure. Good reaction ought to occur with distinct reddening of the surface, within 1 or 2 minutes after the application of ice-water.

481 **Thermic Reaction and Metabolism.** It is through thermic reaction that the cold bath produces its marvelous, renovating and alterative effects. The tissue activity set up in the thermogenic tissues of the muscles as the result of exposure of the skin to a cold medium for a short time, is participated in by every cell and tissue in the whole body. Tissue building is accelerated to keep pace with the increased rate of oxidation; and thus more food is required, more blood is in circulation, more oxygen is absorbed, more CO_2 and urea are eliminated, and all the vital functions are quickened, thus causing the stream of life to flow at a more rapid rate. This is tonic thermic reaction.

THE PHYSIOLOGICAL EFFECTS OF HEAT.

Heat may be applied to the body for therapeutic purposes in a variety of ways, as by means of hot water, steam, hot air, or by radiation from an incandescent body. Illustrations of these several modes of application are to be found in the full bath, the fomentation, the Russian or vapor bath, the vapor douche, the hot air or Turkish bath, and the electric-light bath. 482

The effects produced in the application of heat to the body depend upon (1) the mode of application, (2) the temperature, (3) the duration, and (4) the condition of the subject. 483

Water is recognized as hot when above the temperature of the surface of the body, or between 98° and 104° F., and is termed very hot when above 104°. At a temperature of 120° a full bath becomes unendurable, although small areas, as in the hand or foot bath, or in the application of a fomentation, may be gradually trained to endure a temperature ten or fifteen degrees higher. 484

The mucous membrane readily endures a temperature ten or fifteen degrees higher than can be tolerated by the skin. 485

A full bath of 120° can not be prolonged beyond 2 or 3 minutes without danger to life, and for some persons it would be hazardous for even a few seconds. 486

In the vapor or Russian bath, a temperature of from 112° to 120° F. is not uncomfortable, and 130° to 145° can be tolerated for a short time. 487

The ordinary temperature of the Turkish bath is from 140° to 180° F., but it is often raised to 220° or even 250° without ill effects. Temperatures much higher than this have been endured for a short time in dry air by specially trained persons. 488

In the employment of the electric-light or radiant-heat bath, the body is subjected to the influence of radiant heat. 489

A thermometer exposed upon the surface of the body in a bath of this kind has been seen by the writer to register a temperature of 116.6°, although that of the air about the patient, as measured by a thermometer protected from the direct rays of the incandescent lights, was but 95° F.

490 The body expands under the influence of heat, in this respect behaving like most other bodies. The rate of expansion is very nearly the same as that of water. The body of a man weighing 132 pounds expands 21 c.c. for every degree centigrade, or .6 cubic inches for every degree Fahrenheit, elevation in temperature, or three cubic inches for every 5° F., an amount inappreciable under ordinary conditions.

491 White fibrous tissue expands under the influence of heat, while yellow elastic tissue, like rubber, contracts. The ligaments of joints are composed of white fibrous tissue, hence they are relaxed by hot applications.

492 **Heat a Vital Stimulant.** Heat is without doubt one of the most powerful of all vital excitants. The heat of the sun is the direct source of all animal and vegetable life. Heat stimulates protoplasmic activity, as shown by many laboratory experiments. A clinical illustration of the same fact is found in the remarkable pigmentation of the skin produced by the prolonged use of fomentations or poultices.

In the following pages we shall consider the effects of heat as applied to the body by means of water in its ordinary or liquid state, except when otherwise stated.

THE EFFECTS OF HEAT UPON THE SKIN.

493 The effects of heat applied to the skin differ somewhat according to the intensity and the mode of application, but they may, in general, be stated to be as follows:—

494 **1. Dilatation of the Capillary Vessels.** The effect of moderate heat, that is, water applied at a temperature of from 100° to 104° F., is to produce a reddening of the surface, more or less intense according to the thickness or natural com-

plexion of the skin and the temperament of the subject. This reddening of the skin is due to the influence of heat upon the vasomotor nerves, which is to paralyze the vasoconstrictors and stimulate the vasodilators; while cold produces the opposite effect (Exp. 40).

Currie observed* that water at moderate heat (99° to 101° F.) relaxed the surface vessels, while very hot applications (104° and above) gave rise to vascular contraction in the skin. **495**

The application of a higher temperature (110° to 130° F.) produces, at first, pallor of the skin, due to stimulation of the vasoconstrictors. At the same time the surface is roughened, presenting a goose-flesh appearance, due to contraction of the involuntary muscle fibers connected with the hair bulbs. Slight shivering may also be produced, as from an application of cold, which proves that the phenomenon of shivering is not due exclusively to the influence of cold, but is, to some extent at least, connected with the excitation of the vasoconstrictor nerves from whatever cause. **496**

The pallor and other phenomena due to excitation of the vasoconstrictors from very hot applications are of but short duration. The pallor soon gives place to a dusky redness and the other appearances which accompany a hot application of more moderate degree. If the application is increased gradually in temperature from moderate heat, as from 100° to 104° F., a final temperature of 130° or even higher may be reached without excitation of the vasoconstrictors, the surface remaining reddened. **497**

Some time after the end of a hot application, if continued from 15 to 30 minutes, vasoconstrictor phenomena occur. **498**

The effects of heat upon the circulation of the mucous membrane are the same as upon the skin, except that a somewhat higher temperature is required to produce parallel results. **499**

The stimulating effect of a high temperature upon the vasoconstrictors renders very hot water useful as a means of **500**

*"Medical Reports," 4th ed., pp. 99-101.

checking hemorrhage, and in capillary oozing from surgical wounds. It must be remembered, however, that when applied for such purposes, the water should be at a temperature of from 120° to 160° F., or hot enough to cause pain; and some allowance must be made for lowering of temperature during the application.

501 A blast of highly heated air has been successfully used as a means of checking hemorrhage in cases of metrorrhagia, also a jet of steam. The author makes use of a metallic instrument, really a hollow uterine sound, through which a stream of hot water is passed at a temperature of 170° F. The small vessels are thereby sealed up, and the hemorrhage is thus checked.

502 It is useful also to remember that hot applications to the skin produce not merely dilatation of the arteries, but especially the small veins, and a like dilatation of the lymph channels.

2. Increase of Cutaneous Secretion and Respiration.

503 A general hot bath or even the application of heat to a comparatively small area of the surface produces a general increase of activity of the glands of the skin, both perspiratory and sebaceous. Perspiration may be induced either to the degree of producing slight moisture of the skin or profuse sweating, according to the length or intensity of the application made. The ordinary rate at which moisture is thrown off by the skin is from one to one and one-half ounces per hour; but by application of heat in the form of a very hot bath at a temperature of from 110° to 115° the rate of perspiration may be increased to more than an ounce a minute, or from fifty to sixty times the ordinary amount. The most pronounced effects possible may be secured by the electric-light bath and the sun bath.

504 These facts strongly emphasize the importance of administering water internally in connection with applications of heat. Loss of fluid from the blood has a depressing effect upon the heart similar to that produced by bleeding, though somewhat less marked; hence the vital necessity for making good the

amount removed, by drinking water during as well as before and after the bath, if prolonged, or, if necessary, by means of rectal injections.

Prolonged and repeated perspiration induced by artificial means weakens the skin, and thus lessens its power to react and to resist cold impressions unless counteracted by frequent cold applications. 505

It is interesting to note in this connection that while the absorption of oxygen and the elimination of CO_2 by the lungs is diminished as the result of hot applications to the surface, the opposite effect is produced upon the skin. Ordinarily the skin performs about one per cent. of the total amount of respiratory work done by the body, but under the influence of heat this proportion is often doubled. This fact is evidently due to the dilatation of the blood-vessels of the skin, and to the moistening of the horny layer, whereby the interchange of gases between the skin and the air is facilitated. 506

3. Increased Loss of Heat by the Skin.

A brief application of heat to the surface increases the loss of bodily heat by the skin in several ways: — 507

(1) By dilating the surface vessels, thus increasing the area of the blood exposed to the cooling influences operating upon the surface of the body. 508

(2) By increasing the rate of the blood current in the skin through the stimulation of the vasodilators and the heart.

(3) By increasing the amount of evaporation from the surface through increased activity of the sweat-glands and increased osmosis, and by heating of the skin.

(4) By increasing the conductivity of the skin, thereby increasing loss of heat by radiation.

4. Decrease of Tactile Sensibility.

The tactile sensibility of the skin is greatest from 95° to 98°, or the normal temperature of the surface, very hot applications (113° and upwards) having the effect to lessen sensibility (Exp. 41). This fact explains the special value of the alternating douche, or the so-called Scotch douche, which 509 renders such marked service in the treatment of sciatica and other forms of neuralgia. At a temperature of 130° and above, the tactile sensibility seems to be abolished, though the sensibility to pain still remains. It is a curious fact that the sensation produced by the application of intense heat is practically the same as that from intense cold.

5. Preparation of the Skin for the Application of Cold.

510 The thermic impression made by an application of any sort depends primarily upon the difference between the temperature of the skin and that of the application. By beginning the application at about the temperature of the skin, and gradually increasing it, a very high temperature may be borne without pain, as the zero of the temperature sense is thus gradually raised. This raising of the temperature of the skin has a special value in hydrotherapy as a preparation for the application of cold, the skin being thereby not only rendered more susceptible to the influence of cold, but likewise prepared to react after a cold application by reason of the increased nervous and vascular activity, and the large amount of heat stored up. For these reasons, the hot bath, contrary to what might naturally appear to be the case, prepares the skin for cold applications, — a fact which is of great importance in therapeutic applications of water.

511 When the skin is cold, or in cases of fatigue, in rheumatism with painful joints, in neuralgia, in anemic and feeble persons, and in many other conditions elsewhere indicated (**1028**), this preliminary heating of the skin is of the greatest importance.

THE EFFECTS OF HEAT UPON THE CIRCULATION.

512 In studying the influence of heat upon the circulation, we must consider not only the heart, as the center of this system, but especially the three great vascular areas, — the muscles, the portal system, and the skin, particularly the latter. Each of the parts named may be regarded as a great reservoir, capable of retaining a large share of all the blood

in the body. The portal area is excited and filled by digestive activity; the muscles, by vigorous exercise; and the skin, by percussion, friction, reaction from cold and heat, especially the latter.

It is impossible for each of these vascular areas to be excited to full activity or completely filled with blood at the same time. When one of these areas is in a state of congestion, the others must be in a condition of more or less marked anemia. This explains the pallor often occasioned by excessively violent exercise, and the pallor and giddiness which sometimes follow almost immediately upon the taking of food in certain forms of indigestion, also the faintness which not infrequently overcomes a person subjected suddenly to a high degree of heat in a vapor bath while sitting in an upright position. A bath at 102° F. produces venous congestion of the brain for the first three or four minutes, then cerebral anemia, which continues for some time after the bath, notwithstanding marked acceleration of the pulse. The same effect upon the cerebral circulation, though less pronounced, may be obtained by a foot or leg bath at from 104° to 108° F.[22] 513

Increased Activity of the Heart.

The effect of a general application of heat is to produce at once a notable increase in the force with temporary slowing of the heart's action (Exp. 42). This diminishes, however, as soon as free perspiration begins, owing to the lessening of the arterial tension by the dilatation of the cutaneous vessels, and the tolerance established through fatigue of the temperature sense. The final effect of a hot application is to lower arterial tension while quickening the pulse.[23] 514

The first effect of a very hot application to the skin, as already remarked (496), is to stimulate the vasoconstrictors, which results in contraction of the small blood-vessels of the surface; and this, together with the reflex stimulus received by the heart from the periphery, accounts for the sudden increase in the force and frequency of the pulse. This effect 515 is greatly increased if the water is applied in the form of a spray or a jet douche, owing to the mechanical effect thus added.

516 The first effect of a hot application to the surface is to produce a very transient contraction of the internal blood-vessels simultaneously with the surface contraction. This instantly gives way to a marked dilatation, which is in turn replaced by contraction as soon as the surface vessels are well relaxed.

517 This temporary excitation of the heart in connection with stimulation of the vasoconstrictors of the skin is liable to give rise to intense congestion of the internal viscera, especially the brain, hence the danger of administering this form of bath to plethoric persons, those who have suffered from apoplexy, or who have symptoms of incipient arterio-sclerosis. This condition of internal congestion is often indicated by a sensation of throbbing and fulness in the head, and the visible beating and pulsation of the vessels of the throat and temples, with flushing of the cheeks.

518 The reason for this increase of cardiac and vascular activity as the result of the application of heat is apparent when we consider the relation of the heart action to the condition of the surface vessels as regards heat elimination. One of the most important functions of the skin is the cooling of the blood. Now it is evident that if the temperature of the skin is raised, these cooling processes will occur at a slower rate; and thus, to secure an equal amount of cooling, the blood must be passed through the surface vessels more rapidly. Hence the nervous reflexes which regulate heat elimination are so arranged that an increase in the temperature of the skin or the media to which it is exposed, results in a quickening of the cardiac activity as well as an increase in the size of the blood-vessels of the skin, whereby a larger area of blood is exposed upon the surface of the body.

519 The very opposite of this occurs, of course, in connection with cold applications (**283**). Very hot applications also induce, at first, a protective contraction of the surface vessels (**497**). This compensatory arrangement is continually brought into activity in the practice of hydrotherapy.

Various physiologists have noted that when a limited portion of the body is warmed, a reduction of temperature takes place in contiguous parts. This effect is purely a mechanical one. The overfilling of the blood-vessels of one portion of the area supplied by a single arterial trunk naturally results in robbing another portion of the same area, the vessels of which are not distended. **520**

THE EFFECTS OF HEAT UPON THE RESPIRATION.

General applications of heat increase the rate and facility of the respiratory movements. This is true, however, only of moist heat, so called, as dry heat, or rather the inhalation of dry hot air, produces the opposite effect, through its exciting influence upon the small air-tubes. Excessive dryness of the air also hinders the gaseous exchanges in the lungs, while moderate dryness promotes them. The increase of the chest movements in moist hot air does not indicate an increase of oxidation in the body, but is probably due to a lessened rate of CO_2 elimination. **521**

Nothing so quickly relieves an asthmatic patient as a hot full bath or a vapor or electric-light bath; but an examination of the products of respiration shows a decided decrease in the amount of CO_2, the natural result of diminution in vital combustions from the influence of heat upon the thermogenic centers. **522**

It should be noted, also, that while the respiratory movements are made with greater ease and frequency under the influence of heat, the depth of movement is considerably decreased; that is, the amount of tidal air is lessened. (Exp. 43). **523**

The effect observed *after* a hot bath is a temporarily diminished rate and depth of respiration. **524**

Such general applications of heat as raise the temperature of the blood excite the heat-controlling centers, and bring into **525** play the processes of heat dissipation, which include an increase of lung activity, as well as of skin perspiration and respiration. This fact explains the rapid respiration in high fever.

526 The influence of the hot bath upon respiration is in some respects quite similar to the effects of cold. With quite high temperatures (110° to 112° F.) a sense of constriction is felt when the body is immersed to the head in the full bath; the abdominal walls are contracted. The effect is most marked if the application is made by the aid of a douche with considerable pressure.

THE EFFECTS OF HEAT UPON THE MUSCLES.

527 Prolonged applications of heat, that is temperatures above 100°, diminish muscular excitability and capacity for muscular work to a notable extent. Maggiori and Vinaj have demonstrated this very clearly by an extended series of experiments. In one instance the muscular capacity, as shown by the results obtained by means of Mosso's ergograph, was diminished 8.043 kilogrammeters. It is this weakening of the muscles which gives rise to the very sensible enervating effects of a long hot bath. The writer has noted results in accord with those of these investigators (Fig. 27, A and B).

528 A vigorous young man experienced such great weakness after a hot full bath (Exp. 44) that he felt hardly able to walk. It is indeed surprising that the available energy of the body should by this means be so greatly reduced within so short a time. It can not be supposed that the actual store of force-producing material in the muscles or nerve centers is exhausted by the bath; hence we must conclude that the results observed are due simply to lessened muscular excitability.

Lessened Irritability of the Voluntary Muscles.

529 Muscular irritability lessens very rapidly under the influence of a water bath at a temperature of 120° F. and above, and even at somewhat lower temperatures it is decidedly lessened. This phenomenon may be observed very readily in cold-blooded animals, in which a temperature of

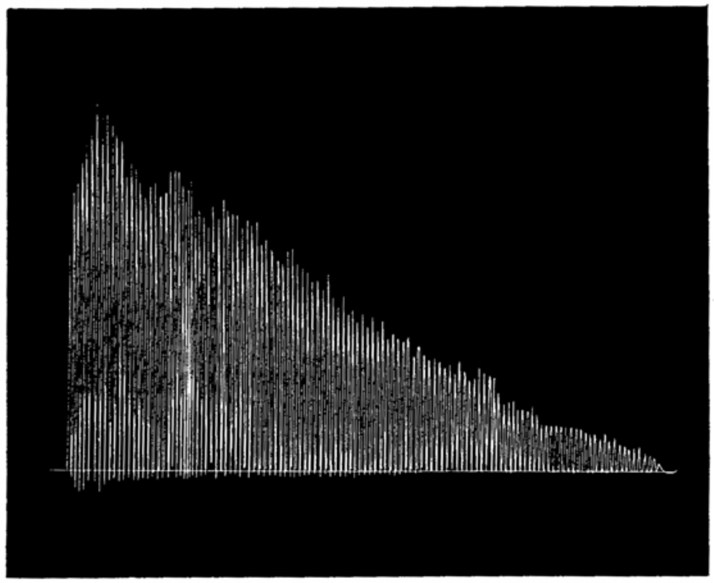

Fig. 27 *(a)*. Normal Fatigue Curve of Man Aged Twenty-four Years. Total work, 8.088 kgm.

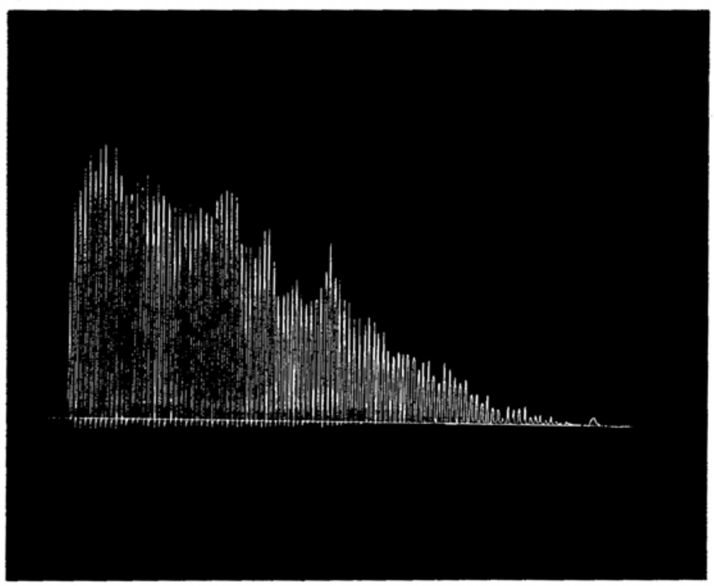

Fig. 27 *(b)*. Fatigue Curve of the Same Subject after a Hot Bath. Total work, 5.152 kgm.

a few degrees above that of the medium in which the animal lives, produces almost complete paralysis, and a few degrees higher at once gives rise to absolute muscular inactivity, through heat-stiffening of the muscles. Very prolonged hot applications at temperatures not much above the normal body temperature similarly give rise to muscular weakness in man.[24]

Notwithstanding these facts, experience shows that *very* 530
short hot applications are the best of all means for recovering a person exhausted by prolonged or violent exercise. This measure has often been employed for the relief of exhausted soldiers. An eminent English army surgeon made use of the hot enema for this purpose more than a century ago. The nerve centers of a person in a state of extreme exhaustion do not readily respond to the stimulation of cold; in other words, a person in that condition will not react to cold, hence the necessity for an application of heat. The restorative effects of an application of heat in such cases is perhaps due in part to the elimination of the fatigue poisons which is thereby encouraged, as well as to reflex stimulation of the nerve centers. The good results are rendered much more decided and lasting if the hot application is succeeded by a short cold application, such as a broken cold horizontal jet to the spine for 3 or 4 seconds, or a rubbing wet sheet, or a cold friction bath.

It is worth while to note in this connection that the 531
exhausting effects of a hot bath may be readily neutralized by an application of cold water in the form of a douche or a shower bath, since the sensation is not due to an absolute loss of strength or energy in either the muscles or the nerve centers, but is a purely nervous phenomenon, expressing the peculiar effect upon the nerve centers of impressions of heat communicated through the peripheral nerves. The restorative effect of a cold bath administered after a hot bath, the author has demonstrated frequently by clinical experience as well as by laboratory experiment (Exp. 45).

532 A young man of twenty years, when subjected to a careful dynamometric test, was found to have a total strength of 8,550 pounds, as shown by *a* on the accompanying chart. After a hot bath at a temperature of from 110° to 118° F. for ten minutes, the total strength was found to be 6,840 pounds. The details of this test are shown in the tracing marked *b* on the accompanying chart. After a cold shower bath for one minute, followed by vigorous rubbing, the same dynamometric test was again tried, with a total strength result of 8,195 pounds, as shown by the tracing *c* on the accompanying graphic.

533 To secure the maximum of restorative results, the hot bath should not be continued more than five minutes, and should be followed by a cold shower or spray douche from 5 to 20 seconds, ending in a very cold broken douche to the spine for 2 seconds.

534 Excessive muscular irritability, as in a person suffering from cramps, fidgets, or irregular muscular twitchings, is quieted by a prolonged neutral full bath (92° to 95° F.).

535 The effect of very hot applications in lessening muscular irritability is often utilized therapeutically in the treatment of deformities resulting from muscular contraction, for the relief of vaginismus, and in cases of contraction of the anal muscle.

Increased Irritability of Involuntary Muscles.

536 Very hot applications increase the irritability of the smooth, or non-striated, muscles. This is shown by the fact that very hot applications to the skin cause contraction of the muscular walls of the small blood-vessels and the minute muscles connected with the hair bulbs, giving rise to goose-flesh and pallor. This physiological property of heat is utilized in the application of hot water to the uterus by vaginal injection for the relief not only of hemorrhage but of chronic catarrh and congestion of this organ, and in the condition known as subinvolution.

537 Hot rectal irrigation is one of the best means of combating chronic congestion and enlargement of the prostate.

A large hot enema or coloclyster will not infrequently relieve constipation when other means are ineffectual, by stimulating the involuntary muscular fibers of the intestines. 538

THE EFFECTS OF HEAT UPON THE NERVOUS SYSTEM.

Heat may excite or exhaust the nervous system according to the mode of application. An application may be at first excitant, then depressant. The effect of a neutral bath (92° to 95° F.) is to diminish nervous irritability, thus producing a true sedative effect. This result is obtained through the protective influence of a neutral medium. The body immersed in water near its own temperature is almost entirely shut away from a variety of perturbing influences which continually play upon the nerve centers through the sensory impulses transmitted from the periphery. As a result, opportunity is afforded for the accumulation of nervous energy in the cerebro-spinal centers. To obtain a sedative effect, the bath must be considerably prolonged (from 30 minutes to an hour and a half). 539

Baths of a high temperature (100° F. and upwards) produce, first, very exciting effects, manifested by nervousness, headache, etc.; later, symptoms of exhaustion appear. 540

Heat Stimulates Protoplasmic Activity.

This is the fundamental fact upon which the physiological phenomenon developed by its application is based. Heat is indeed one of the most powerful of all physiological stimuli. Both the excitant and the exhaustive effects of hot applications are explainable by this single fact. The excitant effects are due to the direct influence of heat upon the nerve filaments and other tissues; while the exhausting effects are due to the fact that while the protoplasmic or vital activities of the body are excited by certain forms of hot applications, thus giving rise to an accumulation of tissue wastes or excrementitious elements, the oxidation of these wastes is diminished by the effort of the body to prevent excessive accumulation of heat through inhibition of the auto- 541 matic thermogenic centers. The result is an accumulation within the body of tissue poisons, which produce phenomena similar to those resulting from prolonged or violent exercise, — the so-called "fatigue poisons," which have been shown to possess properties almost identical with those of curari.

542 In harmony with this idea is the interesting fact recently ascertained that sunstroke is really a toxemia resulting either from the excessive accumulation of poisons within the body, or the development of special poisons under the influence of heat. May it not be possible that the well-recognized debilitating influence of excessive heat is, in part at least, due to the same cause?

Reflex Effects Produced by Hot Applications.

543 Special reflex effects are obtainable by hot applications to certain areas of the skin, which sustain a known reflex relation to the internal viscera. These effects are obtained through impressions made on the ganglia of the great sympathetic and the vasomotor and other ganglia of the cord. To obtain effects of this sort, heat may be applied either alone or in conjunction with cold water in the alternating douche. The reflex effects thus obtained are either those of vasodilatation or vasoconstriction, according to the degree of heat employed. Warm or hot water stimulates the vasodilators, while very hot water (115° to 130° F.) produces vasoconstriction.

544 Winternitz, Brown-Sequard, Tholozan, Rosbach, and others have experimentally worked out the topography of this reflex action with reference to all the more important internal viscera, pointing out the exact area of the surface which must be operated upon in order to obtain the effects desired. Among the most important of these associated areas are the following: —

545 1. The face and the back of the neck, which are in relation with the brain.

546 2. The upper portion of the spine, the chest, and the shoulders, which are intimately associated reflexly with the lungs through the pneumogastric.

3. The hands and feet, which are associated with the brain, the mucous membrane of the nose, and the organs of the chest. 547

4. The middle dorsal region, with the stomach. 548

5. The breasts, with the uterus. 549

6. The skin covering the lumbar region, with the kidneys. 550

7. The lower lumbar region, with the uterus and the lower extremities. 551

8. The internal surface of the thighs, with the uterus. 552

9. The plantar region, with the uterus. 553

10. The feet, with the kidneys. 554

11. The skin covering the lower third of the sternum, with the kidneys. 555

12. The skin surface over the liver, spleen, stomach, bowels, and bladder, with the corresponding organs. 556

Very hot applications made over these surfaces stimulate simultaneously the vasoconstrictors of the area to which the application is made, and those of the internal region which is in reflex relation with it, as just designated. The explanation of these interesting relations will be found in a study of the anatomical relations of the vasomotor centers of the spine and other special ganglia with the areas innervated by them. 557

The reflex effects of these localized applications at a high temperature are of great service in hydrotherapy; for example, cerebral congestion may be relieved by the hot foot bath, which, as Mosso proved by experiments on a man a portion of whose skull had been removed, is capable of producing even cerebral anemia. The temperature should be from 105° to 110° F. A hot full bath at 102° F. is often most effective in relieving cerebral hyperemia. Bathing the face with very hot water is a most effective means of checking nosebleed. Hot sponging of the head and neck often gives complete relief in insomnia from cerebral congestion. 558

Splenic and hepatic congestion, the usual accompaniment of malarial disease, is relieved by very hot fomentations 559 applied over these organs. Uterine hemorrhage may often be checked by a short, very hot foot bath (105° to 115° F.), although the warm foot bath (92° to 100° F.) causes dilatation of the uterine vessels. Relief from congestive headache is obtained by very hot sponging of the back of the neck.

560 In employing heat to the spine for the relief of pulmonary hemorrhage, the best effects are obtained by making the application to the skin overlying the first dorsal vertebra, as the vasomotor center controlling the vessels of the lungs is situated at this level of the spinal cord.

THE EFFECTS OF HEAT UPON THE BLOOD.

561 Winternitz and many other observers have pointed out the interesting fact that under the influence of hot baths the blood count is considerably diminished, through detention of blood cells in the viscera, as shown by Breitenstein.

562 There is also observed a diminution in the percentage of hemoglobin present in proportion to the decrease of red blood-corpuscles. Winternitz has also pointed out the remarkable fact that, while there is a marked increase in the number of leucocytes in the circumscribed part subjected to the influence of heat, there is a decided decrease in the number of red cells, while Henocque has observed an increase in the rate of reduction of oxyhemoglobin.[25] These effects in part at least explain the mottled appearance of the skin induced by hot applications.

563 Strasser showed (*Deutsche med.-Zeit.*, 1896) that general hot applications diminish the alkalinity of the blood by increasing the amount of acid phosphate, often to the extent of double the normal quantity.

THE EFFECTS OF HEAT UPON NUTRITION.

564 The stimulating effects of heat upon cell life may be easily studied under the microscope by the application of heat to the ameba, or the white blood-corpuscle. Nothing could be more interesting than to note the readiness with which

these cells respond to the very slightest increase of temperature. When heat is applied to the surface of the body, not only the skin, but the entire body is to some degree excited thereby, both through the transmission of heat by the conductivity of the tissues to the internal parts, and its transportation by the blood current from the skin to the viscera. The result is an increase of the activity of the cell life of the body so far as is possible without increased absorption of oxygen. Oxidation is diminished, as is indicated by the diminished absorption of oxygen and exhalation of CO_2. But the increase of cell activity is nevertheless shown by the greater amount of nitrogen eliminated, largely in the form of uric acid.

The diminution of oxidation may occur to such a degree **565** as to produce an increase of sugar in the blood, and may even give rise to its appearance in the urine. It is for this reason that hot baths must be used with great discretion in diabetes and in all other maladies characterized by deficient oxidation.

That heat stimulates vital activity is clearly shown by its **566** influence upon the skin. A patient who has worn the moist abdominal bandage for some time, or has been subjected to the daily application of fomentations to some portion of the body for a few weeks, will present a mottled appearance of the skin of the part to which the application has been made, — a very striking illustration of the stimulating effects of heat upon the pigment cells. The heat from the direct rays of the sun produces a similar effect, giving rise to freckles, and deepening the color of the complexion often to a remarkable degree. The same effects are likewise produced by the electric light, and even by the newly discovered X-ray. The stimulating effect of the electric light upon the growth of plants and the ripening of fruits affords further evidence that heat and light act powerfully in stimulating vital activity.

Elevation of the body temperature above normal increases **567** the oxidation of nitrogen. This is shown by the increase of urea and other proteid wastes, and accounts for the rapid wasting of the muscles during febrile disease under the influence of high temperature.

THE EFFECTS OF HEAT UPON THE STOMACH, LIVER, AND OTHER DIGESTIVE ORGANS.

568 It has been experimentally proved that the amount of hydrochloric acid secreted by the peptic glands may be very perceptibly increased by means of fomentations placed over the stomach for an hour or two after eating. A hot water bag may be more conveniently employed for this purpose.

569 The hot douche over the stomach and spine opposite diminish the secretion of HCl in hyperpepsia. General hot baths produce the same effect (Simon), perhaps from excessive loss of sodium chloride in the perspiration.

570 Hot applications made over the region of the liver by means of hot compresses or fomentations also unquestionably increase the flow of bile, and doubtless stimulate all the other activities of the liver.

571 Applications of heat over the abdomen may also increase the activity of the digestive processes in the intestines and the functional activity of the pancreas and the spleen.

THE EFFECTS OF HEAT UPON BODY TEMPERATURE AND HEAT PRODUCTION.

572 The immediate effect of a general application of heat to the body is to occasion a rise of temperature; in fact, immersion of the body in a bath at the body temperature will in the course of an hour cause a rise of temperature of 1.8° F., while water at 104° F. may occasion a rise of three or four degrees within fifteen minutes (Exp. 46, 47).

573 An interesting observation first made by Hippocrates, and verified by all students of hydrotherapy, is that a short application of heat to the body is followed by a lowering of the temperature, with increased susceptibility to the influence of cold. Modern calorimetric studies have shown that the effect of short applications of heat to the body is to diminish heat production, while at the same time heat elimination is encour-

aged, as shown by increased perspiration, relaxation of the surface vessels, and increased activity of the heart. This is the *atonic reaction* of heat.

Prolonged applications of heat always give rise to increase 574
of temperature, both by diminishing heat elimination and by increasing heat production. Heat stimulates vital activity; indeed, there is perhaps no other agent capable of exerting so remarkable an influence upon vital processes. By a prolonged bath at a few degrees above the normal temperature, heat production and heat accumulation may be so increased as to become dangerous to life in a few minutes.

Even warm air increases heat production to a most remark- 575
able degree. An external temperature a few degrees above the body temperature may increase heat production more than 300 per cent. This fact is illustrated by the prevalence of heat-stroke, or thermic fever, during a period of hot weather, especially in damp climates. Whatever causes a rise of the body temperature increases heat production, at least in all physiological conditions, although there may be exceptions in some conditions of disease. So also whatever increases heat elimination tends to increase heat production.

A rise of 20° F. in external temperature occasions an ele- 576
vation of 1° F. in body temperature, and a further elevation of 1° takes place for each additional rise of 20° F.

It is not necessary in order to obtain the effects of heat 577
that the application made should be above the temperature of the body. A bath at the exact temperature of the body will cause a general rise of temperature (Exp. 48.)

REACTION FOLLOWING AN APPLICATION OF HEAT.

For most purposes it is doubtless true that the reaction 578
effects resulting from cold are to be preferred to those from hot applications: nevertheless, the peculiar effects obtainable from heat will sometimes be found better suited to the case in hand than those arising from cold. Indeed, not infrequently the dread of cold water on the part of the patient

is so intense as to make its use inadmissible without a course of gradual training. In these cases, the effects obtainable from heat are particularly serviceable, and its employment may prevent the development of a positive idiosyncracy against cold.

579 The general reaction effects produced by intense, short, general applications of heat are as follows: —

ACTION.	REACTION.
1. Brief contraction, then dilatation of the surface blood-vessels, especially of the small veins.	1. Vasoconstriction.
2. Slight pallor if previously red, followed by dusky redness.	2. Pallor.
3. Sometimes goose flesh appearance and slight shivering.	3. Skin smooth, soft, and moist.
4. Slowed, then quickened high-tension pulse.	4. Pulse frequent, tension low.
5. Respiration at first checked, then frequent, CO_2 diminished.	5. Respiration frequent, free, superficial.
6. Perspiration at first checked, then increased.	6. Perspiration lessened.
7. Heating of the skin.	7. Gradual cooling of the skin.
8. Rise of internal temperature from diminished heat elimination.	8. Depression of internal temperature from increased heat elimination and decreased heat production.
9. General nervous excitation; at moderate temperature, sense of comfort and relief.	9. Diminished nervous and mental irritability, drowsiness, and depression.
10. Increased muscular irritability.	10. Muscular weakness and indisposition to muscular effort.

From the above it will be readily apparent that the general and usual reaction effects of heat are of an atonic or depressant character.

580 **The Neutral Bath.** A bath which is absolutely neutral is practically impossible, for the reason that a bath exactly at the temperature of the skin checks the elimination of heat, and hence occasions a rise of the

body temperature, while a bath a few degrees below the temperature of the body excites the temperature sense, and thus gives rise to increased heat production and other reflex effects.

The vital perturbations set up by the warm bath, however, are so slight as to be scarcely perceptible, and the characteristic effect of the bath is its calmative or quieting effect. This result is not obtained by any depressing action, but by the protection afforded by the medium of water so employed as to be absolutely unirritating, without percussion, and of such a temperature as to shield the body from the continued excitation resulting from the contact of the skin with the clothing, constantly changing temperature, force of movement, and various other disturbing influences. 581

As the result of this protection, the nerve centers, being completely at rest, are afforded an opportunity to accumulate a store of energy, so that the warm, or so-called neutral, bath is, after all, not really neutral in its physiological effects, but is recuperative and energizing through promotion of the nutritive processes, and the accumulation of force-producing material in the nerve cells. The irritability of the cutaneous nerves is perhaps lessened by the imbibition of water.

THE EFFECTS OF ALTERNATE HOT AND COLD APPLICATIONS TO THE SKIN.

The Scotch Douche. In this form of application the skin is first heated considerably above its normal temperature, then the temperature is lowered by the use of cold water. In alternate applications the heating and cooling are several times repeated. The reaction which takes place as the result of the Scotch or the alternating douche may be made chiefly circulatory in character, or both circulatory and thermic. This form of application is therefore a most efficient means of stimulating nutritive changes, obtaining derivative effects, etc., and that without creating thermic disturbances of any kind in the body. 582

583 Pflüger found that a short hot bath following a cold bath increased the reduction of temperature.[26]

584 Vinaj based upon this observation the recommendation to follow the cold bath employed for reducing temperature in fever with a hot bath, continued for two or three minutes. For further considerations respecting alternate applications, see paragraphs **677, 681.**

GENERAL VITAL REACTIONS RESULTING FROM HYDRIC PROCEDURES.

585 As previously intimated, the circulatory and thermic reactions which occur from cold applications to the surface are only two of a considerable number of distinct reactions resulting from the cutaneous excitation occasioned by an intense application of cold. A consideration of the effects of this form of stimulation in the light of modern physiological research, leads at once to the conclusion that the reactions produced involve not only the nerve centers, blood-vessels, and involuntary muscles, but every cell and tissue in the body.

586 A careful study of the effects of local application leads to the conclusion that there are many subtle and not easily observed reactions to which many of the effects of hydrotherapy may be properly attributable. Doubtless every viscus, even every gland and probably every individual cell has its own mode of reacting to the powerful stimulus of thermic impressions made upon the skin.

587 The profound effects produced upon the nervous system by the application of water to the skin enables us through this agent to influence every bodily function, for, as one has well said, "The nervous system dominates all the phenomena of organic life directly or indirectly; all depends upon it. Nothing transpires in the body of the animal without its intervention. The cells are the artisans in the organic workshop, but the nerves are the overseers."

588 Whatever agent affects the heat-producing processes of the body, affects, likewise, in a most pronounced degree, all the vital processes. As Lubansky has well said: "To touch

calorification is, in a certain sense, to touch the springs of existence ; and disturbance of the heat-making functions of the body produces a corresponding disturbance in the most important functions of the system. It is to create the necessity for repair, and to impress directly and profoundly the general nervous system."

SUMMARY OF ORGANIC CHANGES PRODUCED BY HEAT AND COLD.

1. Elevation of body temperature is accompanied by 589
increase of metabolism.

2. A fall of temperature is accompanied by decreased metabolic change.

3. Short cold applications cause rise of temperature and increase of metabolism.

4. Prolonged cold applications cause fall of temperature and diminished metabolism.

5. Short hot applications cause fall of temperature with diminished metabolism.

6. Prolonged hot applications cause rise of temperature and increased metabolism, especially increased oxidation of albumin.

7. No disturbance of metabolism occurs as the result of baths at neutral temperatures, or while the body temperature remains normal.

8. Strasser showed increased alkalinity of the blood after cold baths, and diminution after hot baths.

9. Jardet has shown that the acidity of the urine is decreased by warm baths, and may even become alkaline.

In febrile conditions, when heat production is increased, antipyretic applications do not lessen the heat production unless applied in such a way as to cool the muscles and produce a diminution in the general body temperature.

The primary effect of cold applications is to increase CO_2 production. In the reaction period there is elevation of temperature, which, if sufficiently pronounced, is accompanied by an increased oxidation of albumin.

THE PHYSIOLOGICAL EFFECTS OF FRICTION OR MECHANICAL IRRITATION OF THE SKIN.

590 MECHANICAL irritation of the skin produces effects so closely allied to those of hydric applications, and in the practical employment of hydriatic measures is so constantly and so intimately associated with the use of water, that it is proper to devote a few paragraphs to the consideration of the physiological effects of this powerful means of vasomotor excitation, which may be properly classed as mechanical rather than chemical or thermic stimuli.

The forms of mechanical stimulation especially utilized in hydrotherapy are *friction* and *percussion*.

591 **Friction.** This procedure consists in rubbing the surface of the body with the bare hand, or with the hand reinforced by a mitt, glove, or towel, either dry or moistened with water at any desired temperature. Percussion may be applied by the hand, usually in connection with friction, but this mechanical effect is usually obtained in connection with water in the different forms of the douche.

Physiological Effects. The effects of friction and percussion are essentially the same, the magnitude and the intensity of the effect depending upon the force employed and the duration of the application. The effects of percussion as connected with the douche will be described elsewhere (**1015**). The physiological effects of friction have been carefully studied by Naumann (1867), Röhrig (1873), Winternitz, and other eminent investigators. Three grades or degrees of friction are recognized; namely, "light," "energetic," and "very vigorous." Briefly summarized, their effects may be described as follows : —

592 1. *Light Friction.*— Light centripetal friction applied to the surface accelerates the circulation, causing rise of blood

pressure, increases the force and frequency of the pulse, and lessens the frequency of respiration.

Very light friction continued for some time gives rise to contraction of the small blood-vessels, which may persist for several hours. There is also a slight rise of temperature, due to a small increase of heat production and a slight diminution of heat elimination.

2. *Energetic friction* causes first very marked contraction 593
of the blood-vessels, which is quickly followed by dilatation of the vessels, arteries, veins, capillaries, and lymphatics, with great acceleration of the blood current.

The increase of heat elimination reduces the temperature several tenths of a degree.

3. *Very vigorous friction*, or violent irritation of the 594
skin, produces almost instant and very marked dilatation of the cutaneous vessels, the preliminary period of contraction being so brief as be practically imperceptible.

The heart's action is slowed, as is also the respiration.

Heat elimination is increased nearly fifty per cent (Winternitz, Pospischil), and the temperature may fall as much as 1° or 2° F. (Mantegazza).

Examination of the products of respiration show marked increase of CO_2 (Pflüger), which would indicate increased heat production, notwithstanding the lowered temperature, showing that the increase of heat elimination is much greater in proportion than that of heat production.

There is, also, according to Pflüger, a marked increase in the production of urea, showing that there is a general increase of catabolism, since both nitrogenous and carbonaceous wastes are augmented.

Very violent friction or irritation produces marked weakness of the heart, dyspnea, and in rabbits, albumin in the urine (Walkenstein), in which again we see an effect identical with that which follows an excessively severe cold application.

All the functions of the skin are stimulated by friction. Under its application a dry skin becomes moist and oily, through the increased activity of the perspiratory and sebaceous glands. It is also a common observation that friction promotes the development of hair upon the parts to which it is applied. Weyrich and Winternitz have shown that by the application of friction to the skin, the amount of moisture thrown off may be increased more than fifty per cent. Under the influence of friction the temperature of the skin is raised to a very marked degree, through dilatation of the surface vessels, which brings an increased amount of blood to the surface. This is, of course, the cause of the increased heat dissipation under the influence of friction. This fact explains the interesting observation of Winternitz, that friction of the patient in the cold bath very greatly increases its temperature-lowering power. In experiments made by the writer, a rise of surface temperature amounting to 2° F. has been observed as a result of friction of the skin of a healthy person (Exp. 49). This would represent an increase of heat elimination of at least eight per cent. In a person with a cold skin the increase may be sixty or even seventy-five per cent.

The mechanical effects of friction vary with its direction. When the friction is applied in the direction of the blood current in the veins (centripetal friction), the movement of blood toward the heart is accelerated, and thus the activities of the part are increased. The circulation of lymph is also encouraged, there is an increase in the rapidity of the vital exchanges, and a promotion of all the metabolic processes.

On the other hand, friction made in the direction opposite to that in which the blood moves in the veins (centrifugal friction) slows the circulation, diminishes metabolic activity, and thus produces a sedative effect.

The foregoing facts demonstrate most clearly the potency of mechanical irritation as a means of vasomotor stimulation, and through this powerful influence upon one of the most vital functions of organic life, its importance as a rational therapeutic procedure. The practical application of the principles thus set forth will be dwelt upon elsewhere (**1209**).

Dermographism. The phenomenon to which the term "dermographism" is applied is closely allied to urticaria. Pressure made upon the skin, as in drawing a line with the tip of the finger or the end of a lead-pencil, ordinarily produces but a very slight effect, merely a temporary pallor, quickly followed by a barely perceptible redness of the skin. In certain persons, however, a simple stroke with the finger tip produces a raised white or rose-colored area corresponding to the surface touched. 595

Dermographism indicates a disordered state of the vasomotor nerves or nerve centers. These structures are affected by some poisonous substance, received from without or produced in the alimentary canal, and in such a manner that the vessels have lost their tone, or are unable to maintain their normal equilibrium. Demographism also affords information respecting the condition of the nervous system in general. It indicates that there exists in the body of the patient some toxic agent against which the nervous system has ceased to be able to defend itself.

This curious symptom is most often present in certain forms of neurasthenia, especially gastric neurasthenia, in hysteria, diabetes, rheumatism, stomach dilatation, and gastro intestinal fermentations.*

This test is one of the means whereby the physician may judge of the susceptibility of his patient to hydric applications. The test should be applied to each patient received for treatment as a means of determining his power of reaction to mechanical stimulation. Persistent spasm of the vessels, as shown by pallor remaining for some minutes, indicates an abnormal irritability of the vasomotor nerves or of the visceral ganglia of the small vessels. A quickly appearing and prolonged redness indicates that the vessels lose their tone with abnormal readiness. All these facts should be noted and considered in the hydriatic treatment of invalids.

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* "Étude sur le Demographisme," T. Barthélemy, Paris.

THE PHYSIOLOGICAL EFFECTS OF LIGHT.

596 THE therapeutic use of light is so closely associated with hydriatry that it seems proper to make here a brief statement of the physiological effects of this powerful agent, which, though in use from ancient times, has never been scientifically studied until within recent years. Limited space will, however, permit nothing more than an exceedingly brief summary of the important fundamental facts bearing upon this subject.

Considered from the standpoint of physics, light is not a force, but a mode of motion, — a movement of the ether particles resulting from the energy set free by the sun or some other incandescent body. For a minute study of the physical properties of light, and for purposes of spectrum analysis, and in the study of the physiology of vision, light is considered as being composed of three primary colors, — red, green, and violet; but in a study of the question from a therapeutic basis, another classification of the nature of the sun's rays is more practical and useful. Thus, the sun's rays may be divided into three classes; viz., *heat* rays, *luminous* rays, and *actinic*, or *chemical*, rays. The whole gamut of light rays, if considered analogous to the musical scale for the purpose of comparison, is found to extend through about four octaves, of which the luminous rays occupy as much space as would be represented by the interval of the sixth in music. Two of the four octaves are found below the luminous rays, and another octave above. The heat rays occupy the lower two octaves, and include also the red and ultrared, while the chemical rays include the violet, the ultraviolet, and the upper octave of non-luminous rays.

Of these three classes of rays, the heat rays and the chemical rays are those of special interest in therapeutics. The heat rays while in the form of radiant energy passing through space do not manifest heat, but when they come in contact with objects which offer resistance to their passage,— in other words, objects opaque to heat rays,— they are transformed into heat, and the temperature of the opaque object is raised. So likewise the actinic, or chemical, rays manifest their special properties only when they come in contact with substances in which they are capable of setting up molecular changes, the radiant energy being then transformed into chemical energy.

It has long been known that the three sets of rays may be separated by the employment of glass of different colors. Red glass, for example, gives passage to rays which are almost wholly thermal in character, while blue or violet glass allows only the chemical, or actinic, rays to pass through it. Yellow and green glass, on the other hand, while transparent to the luminous rays, permit also the passage through of a few of the thermal and actinic rays.

The art of photography illustrates the action of the chemical ray upon various chemical substances. Its action may also be observed in the coloration of flowers and leaves and other phenomena in the animal and vegetable world. One of the most interesting illustrations of the action of the actinic ray upon animals is to be observed in the curious phenomenon known as "sunburn." That this is not really a burn, but erythema due to the noxious action of the actinic rays, is shown, first, by the fact that the swelling, redness, and pain do not appear until several hours after exposure to the sun's rays; and secondly, by the fact that exposure of the skin to light from which the actinic rays have been separated, but which present the heat rays in all their original intensity, prevents entirely the ordinary effects of the intense rays of the sun upon nude surfaces unaccustomed to such exposure. The term "solar erythema" is preferable to the expression "sunburn."

Within the last few years numerous experiments have 597
been made by Arloing, d'Arsonval, Geisler, and others, for

the purpose of determining the influence of different classes of rays — luminous, thermal, and actinic — upon microbic life. Investigations have shown that the chemical rays — violet and ultraviolet — are unfavorable to the growth of bacteria, at least such pathogenic bacteria as the bacillus anthracis, the bacillus pyocyaneus, and the typhoid bacillus. Graber showed that the earthworm, which habitually hides itself away from the light, behaves toward a red light as toward absolute darkness, while the violet and ultraviolet have the same effect upon it as ordinary light. Experiments made by Paul Bert, Du Bois, and others have given similar results.

The influence of light in producing pigmentation of the skin in human beings is a matter of common observation. Solar erythema, or so-called sunburn, is always followed by a deepened color of the skin; after this pigmentation has taken place, the surface involved is less subject to sunburn, and may be wholly protected so long as this deepened color is retained. This process in the skin may accordingly be looked upon as a protective action for the purpose of preserving the deeper and more important structures of the body from injury through the noxious influence of the chemical rays. Negroes and other dark-skinned races are not subject to solar erythema, their skins having by long residence in a hot climate, and through the action of heredity, acquired a natural protection against the chemical ray. We are doubtless unaware how much our ordinary life depends upon the action of the thermal and actinic rays of the sun, especially the latter. The fact that an excessive action of the chemical rays gives rise to an acute inflammatory process in the superficial layers of the skin, is sufficient evidence of its powerful influence upon animal life. In conditions of disease persons have been found so sensitive that exposure to even the diffused light of day was sufficient to give rise to a marked erythema of the face.

598 A most remarkable and interesting fact, first pointed out by Picton in 1832, and more recently studied by Black and Barlow

in England, Lindholm of Norway, and Finsen of Copenhagen, is the noxious influence of the actinic ray in smallpox. It has been found that if the chemical rays are excluded by hanging thick red curtains before the windows of the sick-room during the suppurative stage of the eruption and the consequent secondary fever, ulceration may be almost uniformly averted. Finsen has within the last half dozen years undertaken an extensive series of observations for the purpose of studying more accurately the physiological effect of the actinic ray, making numerous experiments upon flies, worms, embryos, and other forms of animal life. These experiments have demonstrated very clearly that the chemical ray is an excitant of the nervous system; and that under ordinary circumstances it may be considered as one of the most important promoters of animal life and energy. The importance of the thermic influences derived from heat rays need not be emphasized, as this has long been well known and appreciated; but the fact that the actinic ray is a direct stimulant of the functions of animal and vegetable life, and thus a means of supporting vital energy in all its forms, is a discovery of the highest importance, and one which will doubtless prove of great utility in the future. To the chemical rays rather than to the thermic rays must in all probability be attributed the greater part of the wonderful results which have long been recognized as following the proper employment of the sun bath, or so-called insolation.

Upon the discovery of the electric light and practical 599
methods of producing it, numerous experiments were undertaken for the purpose of ascertaining whether this excellent artificial substitute for sunlight possessed the property of stimulating the vital processes of plant life in a manner analogous to the action of sunlight. An interesting paper by Wm. Siemens, published in March, 1880, contained a detailed account of experiments made for the purpose of determining the influence of the electric light upon vegetation, with the following conclusions: —

1. That the electric light is efficacious in producing chlorophyl in the leaves of plants and in promoting growth.

2. That an electric center of light equal to 1,400 candles, placed at a distance of two meters from growing plants, appeared to be equal in effect to average daylight at this season of the year (March), but that more economical effects may be attained by more powerful light centers.

3. That the carbonic acid and nitrogenous compounds generated in diminutive quantities in the electric arc, produce no sensible deleterious effects upon plants enclosed in the same space.

4. That plants do not appear to require a period of rest during the twenty-four hours of the day, but make increased and vigorous progress if subjected during the daytime to sunlight, and during the night to electric light.

5. That the radiation of heat from powerful electric arcs can be made available to counteract the effect of night frosts, and is likely to promote the setting and ripening of fruit in the open air.

6. That while under the influence of the electric light, plants can sustain increased stove heat without collapsing,—a circumstance favorable to forcing by electric light, and showing the influence of light as a vital stimulant.

Similar experiments have been made by others, the pioneer in this line of investigation being Hervé-Mangon (Compt. Rend. 53, 243). These experiments showed that the electric light is capable of causing the development of chlorophyl and inducing heliotropism, or the phenomenon of turning or bending toward the light.

Prillieux (Compt. Rend. 69, 410) showed that the electric light is capable of promoting assimilation in plants, or decomposition of carbon dioxide and water.

Siemens found that plants exposed to ordinary daylight and six hours of electric light in addition "far surpassed the others in darkness of green and vigorous appearance generally." Strawberries and other fruits were fully equal to those raised under ordinary conditions, and grapes were of stronger flavor than usual. Melons were remarkably large and aromatic, and bananas were pronounced by expert judges to be "unsurpassed in flavor."

Many of these experiments have been repeated in this country with similar results. The most important experiments were those conducted at the Cornell University Agricultural Station in 1889–90. The results obtained showed clearly —

1. That the electric light may be used under such conditions as to make it fairly comparable to sunlight in its power to promote protoplasmic activity.

2. That the electric light acts as a tonic to plants, so that they are able to endure adverse conditions which otherwise would cause them to collapse.

3. That the electric light is a true vital stimulus, since the effect of its use at night, upon plants, is essentially the same as that of the longer day of the Arctics upon plants growing in that region.

De Fontaine, in an article in *Semaine Médicale*, 1888, entitled "Coup de Soleil Électrique," gives an interesting account of the results of exposure to a powerful electric light, undertaken for experimental purposes by a physician, M. Maklakow, surgeon to a large factory near Moscow, in which the electric arc is employed in soldering metals. The first symptoms felt were tingling of the skin; a few moments later, pronounced coryza and lachrymation, the eyes being swollen so that they could not be opened. There was marked photophobia, and a sensation of burning heat upon the right side of the face and neck. After a short sleep, the experimenter awoke with all his symptoms aggravated. By evening of the same day the face had become brick-red in appearance, was very much swollen; there was marked chemosis of the conjunctiva, and all parts which had been exposed to the light were greatly inflamed, the investigator suffering much during the entire night. An interesting fact noted was that while the whole conjunctiva covering the ball of the eye was intensely inflamed, the mucous lining of the lids was not at all affected, evidently because not directly exposed to the light rays. The following day the erythema increased, becoming edematous, hot, dry, and painful to the touch. The night of the second day the symptoms began to abate considerably, and toward night of the following day the epidermis began to separate, and a few days later desquamation of the skin took place in large scales, as after scarlet fever. The pigmentation of the skin remained for some time after the acute symptoms had disappeared. The amount of heat to which the individual was subjected in this experiment was not sufficient to occasion any inconvenience, and the painful symptoms did not appear until some hours after the exposure.

This experiment proves very clearly not only that the noxious effects of light are due to the chemical rays, but that the electric light is capable of producing results identical with those produced by the sun's rays.

600 According to Dolbear, the earth receives in the form of sunlight about one-fourth horse-power for each square foot of its surface, or about one forty-thousandth of the amount of energy thrown off by the sun from each square foot of its surface. The ordinary electric arc light presents an intense radiating surface having an area a little less than one tenth of an inch square. The temperature of this radiating surface is more than 6,000° F. If this area could be increased so as to present a square foot of surface, the amount of energy would be practically the same as that emitted from an equal area of the surface of the sun. It thus appears that the electric arc light is an exceedingly efficient source of light, and that it may be used as a substitute for sunlight, over which it enjoys the advantage of being more easily controlled and manipulated, and always available.

The influence of sunlight upon the vital processes has been recognized from the most ancient times. The old Greeks and Romans employed the sun bath, or insolation, very frequently in the treatment of chronic maladies of all sorts. The natives of the South Sea Islands and other primitive peoples still utilize this powerful agent in the treatment of the sick. The natives of the *terre caliente* of Mexico have long practiced exposure to the sunlight on the sea-beach, partially covered with sand, as a means of treatment for syphilis, the patients thus treated being made to drink large quantities of infusions of leaves of various sorts while exposed to the sun. The natives of Haiti are said by M. Delow to employ similar practices.

All physicians place the highest value upon exposure to the sun by an out-of-door life as a means of stimulating the nutritive processes of the body in many chronic disorders, as anemia, chlorosis, tuberculosis, in convalescence from fevers, and other similar conditions. The value of the sun bath as a therapeutic measure will be readily appreciated by noting the facts respecting its remarkable physiological influence, which must be very largely attributed to the actinic ray, although a share of it must be attributed to the calorific effect of the sun's rays. But though its value has been so long and so generally recognized, the various practical difficulties in the way of utilizing the sun's rays for therapeutic purposes, and the great uncertainty of sunshine in the larger part of this and other civilized countries, have been so great obstacles that little use has thus far been made of this powerful agent, even in institutions largely devoted to the use of physiological measures.

The author has made more or less use of the sun bath **601**
during the twenty-five years in which he has been engaged in institutional medical work, but the difficulties encountered, long ago led him to the study of the electric light as a substitute for sunlight. The most definite and practical experiments along this line were begun by him about ten years ago. In a paper read before the American Electrotherapeutic Association at its meeting in New York City, in September, 1894, he presented a description of a new method of apply-

ing heat to the body, in which the incandescent electric light was utilized as the source of heat. This paper gave the details of many experiments which had been conducted for the purpose of determining the physiological effects of this bath, and also a comparison of the effects obtained by this bath with those obtained by the Turkish and Russian baths. The general conclusions resulting from his investigations were as follows: —

1. The electric-light bath stimulates the elimination of CO_2 in a very marked degree. In an electric-light bath lasting 30 minutes, the percentage of CO_2 elimination during the last ten minutes was 5.13 as compared with 3.60, the average of CO_2 elimination before the bath. In a Russian bath the percentage of elimination was 3.96. In a Turkish bath of 30 minutes' duration, the percentage of CO_2 elimination was 4.01, while the elimination of urea was diminished.

2. The elimination of nitrogenous wastes represented by urea, and also the elimination of total solids, was greatest in the Russian bath, and least in the electric-light bath.

3. The amount of perspiration produced by the electric-light bath was fully double that induced by the Turkish bath in the same length of time. The time required for the first appearance of perspiration was, in the electric-light bath, about one half the time of that in the Turkish and Russian baths. The reason for this is apparent when one recalls the fact observed by Bouchard, that perspiration begins when the temperature of the blood has risen .7° F. above the normal. In the study of the physiological effects of the electric-light bath in 1891, when the author made his first experiments upon this subject, he found the internal temperature was raised by the bath 1.6° F. in five and one-half minutes, the surface temperature rising, in the same time, 2.3° F.

602 From these facts it is evident that the electric-light bath raises the temperature of the blood more quickly than any other form of bath. The reason for this is apparent when it is remembered that the skin and other structures of the body

readily permit the transmission of the radiant energy of the electric light, which, entering the body as light, becomes, by the resistance which it meets, transformed into heat. Thus heat is developed in the deeper tissues instead of being slowly carried in by conduction from the surface. The skin is, like glass, a poor conductor, but at the same time allows the passage of radiant energy in the form of light. This fact explains the readiness with which perspiration is induced by the electric-light bath.

Prior to the author's experiments upon this subject, there had been no scientific study of the physiological effects of the incandescent electric-light bath upon human beings. He had constructed, as early as 1891, various experimental forms of baths, which he has gradually perfected. Some of these admit the whole body in a sitting posture, others lying down. Some are adapted to the application of heat to a circumscribed portion of the body, as the trunk, the feet, or the spine. The photo-reproductions show the principal forms of the bath in use at the present time. These baths are now employed in various places in this country and in foreign lands. Fig. 133-138 (p. 707, 708).

The electric-light bath has been received into special **603**
favor in Germany. Professor Winternitz, the greatest living authority on hydrotherapy, speaks as follows respecting it in his recently published treatise, "Physiologische Grundlagen der Hydrotherapie:"—

"The electric-light bath is a method of recent origin, and equal to the sun bath. It was at first employed empirically. [Only the arc light was thus employed, and in the most inefficient and unscientific manner.] Dr. Kellogg (Battle Creek, Mich., U. S. A.) has constructed one for the entire body as well as for the separate parts thereof, various-shaped cabinets which are supplied with mirrors internally and a great number of electric lights.

"It has been undoubtedly demonstrated that radiant heat penetrates the tissues much better than conducted heat, and it is quite probable that cellular activity is powerfully modified by these rays of heat (either qualitatively or quantitatively). The effects of the vapor bath can be brought about in the cabinet, and the differences thus far determined are the following:—

"The giving off of the CO_2 is more abundant than in the vapor bath, and what is especially noteworthy is that the perspiration appears very soon and at a very low temperature, and is very profuse. We notice the earlier appearance at 95° F. (Kellogg averaging 85° F.), while in the vapor bath a much higher temperature is generally required to produce the same effect. The time at which perspiration in the electric-light bath appeared averaged three and one-half minutes, while in the vapor bath almost five minutes was required. Finally, the quantity of perspiration in the electric-light bath is considerably larger. That the rays of heat here play the most important part, and that it is not on account of the temperature of the air in the cabinet, is further shown, for instance, by the fact that the external surfaces of the thighs, which were directly opposed to the light, perspired much more rapidly and profusely than the inner surfaces, which received only reflected rays. Within ten to thirty minutes, the temperature reached 104° F., pulse 160, respiration 42, with symptoms of fever-like condition. We have, thus far, employed the electric-light bath like the vapor bath in only a few disorders, such as chlorosis, chronic rheumatism, and gout, and have obtained satisfactory results. More extensive experience is wanted. Kellogg reports very favorable results in the treatment of chlorosis, gout, and a number of cases in which there is need of increased metabolism. Lehmann reports regarding psoriasis.

"As we now possess a thermic method in the electric-light bath by means of which we are able to measure the exact dose, and knowing the powerful influence on cell life and the entire organism, we believe this method of thermic application should receive an important place. It enables us to influence a number of maladies much more rapidly, better, and more intensely than we have heretofore been able to do."

The skin, as well as the air, is to a large extent trans- 604
parent to light, and the same is true of all the living tissues. This is evidenced by the phenomenon of trans-illumination. By a speculum placed in the vagina or rectum, and a suitably arranged electric light of 16 or 32 candle-power placed over the abdomen, one may see the interior of the pelvis illuminated and glowing with a bright red light, the red color being due to reflection from the red corpuscles of the blood. Even the bones when in a living state are translucent to light. This is clearly shown by placing the hand between an electric light and the eyes, with the fingers in close contact. The hand being placed near enough to the light, the whole of each finger will be seen to be illuminated by the light, and not simply the soft part. Light penetrates the body in the same manner as it penetrates any other transparent or translucent medium.

That the actinic ray penetrates the body to a considerable depth is readily shown by the following experiment: —

The hand is placed over a piece of sensitive film, such as is used by photographers, the opaque object being placed between the hand and the paper, and exposure made in such a manner that the light which reaches the sensitive tissue must pass through the hand. The fact that the chemical rays are transmitted is shown by their action upon the sensitive paper beneath the hand, and the complete absence of their action upon the surface protected by the opaque object placed between the hand and the paper.

In case of the water bath, the Turkish bath, the vapor and hot-air baths, heat reaches the interior of the body by conduction, passing through successive layers of living tissue, which, while affording great resistance to the conduction of heat, readily allow the passage of the luminous rays from the incandescent film.

The electric-light bath does not depend for its effect upon the heat of the air surrounding the patient, but upon the radiant energy which passes in straight lines from the incandescent filament into the patient's body without heating the air, the air about the patient being of the ordinary temperature; just as a person standing before a log fire out of doors on a frosty night may expose one side of his body to intense heat, while the other is chilled by the zero atmosphere which surrounds him.

The incandescent-light bath enjoys a great advantage over other methods of applying heat in that it produces strong tonic effects at the same time that it encourages powerful elimination.

605 The electric arc-light bath has been used more or less both in this country and in France, but its physiological effects have not thus far been accurately ascertained. The author is at the present time engaged in a series of studies of this subject, the results of which, it is hoped, will place the use of this form of bath upon a sound scientific basis. The apparatus employed is described elsewhere in this work (**1251**).

The technique of the incandescent electric-light bath and of the electric arc-light bath will be found in the section devoted to the technique of hydric applications.