2. Presbyopia and hypermetropia cause contraction of the pupils in cases where continuous and excessive strain for near accommodation has been long continued and has produced asthenopia.

3. Pupillary atresia, consequent upon chronic irritation with posterior synechia, producing contraction of the pupil.

4. In synechia total dilatation is impossible, the iris only dilating where free, hence, the pupil is irregular. If the synechia is annular the pupil is both contracted and immobile.

5. In microria there is a congenital state of extreme contraction.

6. In glaucoma the pupil is dilated, contracting little or not at all to the action of calabar bean.

7. In colobOma, both in the congenital form and after iridectomy, there are irregularity and immobility of the pupil.

8. In idiopathic mydriasis there is little contraction to the action of light or to myotics.

9. In certain cases of amblyopia and amaurosis there is dilatation of the pupil.

10. In hippus pupillæ there are alternate contraction and dilatation often accompanied by nystagmus.

11. Inequality of the pupils exists in some who have different degrees of refraction in the two eyes, one being emmetropic and the other myopic.

THE THERMAL DEATH-POINT OF PATHOGENIC ORGANISMS.

By GEORGE M. STERNBERG, M.D.,
MAJOR AND SURGEON U. S. ARMY.

An exact knowledge of the thermal death-point of pathogenic organisms is desirable, both as a matter of general scientific interest, and from a practical point of view. As biologists, we wish to know whether the vital properties of the living protoplasm contained in the minute vegetable organisms in question are destroyed at a uniform temperature, and if so at what temperature; or whether there is a considerable range in the limits of vital resistance to heat exhibited by different organisms of this class. As sanitarians, we wish to know what temperature can be relied upon for the destruction of disease germs in the excreta of patients suffering from typhoid fever, from cholera, and from other infectious diseases transmitted by means of the alvine discharges of the sick; whether boiling of infected clothing, or of drinking water contaminated with disease germs, is a safe means of disinfection, etc.

Various experimenters have recorded observations with reference to the thermal death-point of different microörganisms, but, so far as I

know, no one has heretofore made an extended inquiry, by means of a uniform method, with a view to determining the vital resistance to heat of the considerable number of pathogenic organisms now known to bacteriologists.

All of the experiments recorded in the present paper relate to *moist heat*—that is to say, the test-organisms have in every case been in a moist condition, in fluid cultures. The effect of dry heat upon desiccated organisms is quite another question. This has been studied by Koch and Wolffhügel,[1] who have summarized the results of their experimental work as follows:

"1. A temperature of 100° C. (212° F.), maintained for one hour and a half, will destroy bacteria which do not contain spores.

"2. Spores of mould-fungi require for their destruction in hot air a temperature of from 110°–115° C. (230–239° F.), maintained for one hour and a half.

"3. Bacillus spores require for their destruction in hot air a temperature of 140° C. (284° F.), maintained for three hours." (Op. cit., p. 231.)

In my experiments I have adopted ten minutes as the standard time of exposure to a given degree of temperature.

A fresh culture of the organism to be tested is introduced into capillary glass tubes which have an expanded extremity to serve as an air chamber, by means of which the culture fluid is drawn into or forced out of the capillary tube. This is readily accomplished by heating the little bulb.

The glass tubes, hermetically sealed, are introduced into a vessel containing water, which is kept at a uniform temperature by personal supervision, a Bunsen burner being the source of heat. A standard thermometer is placed in the vessel, and this and the capillary tubes are protected from the bottom of the vessel containing them by a thick plate of glass. A uniform temperature throughout the fluid is maintained by stirring it with a glass rod.

After exposure for ten minutes to a given temperature the sealed extremity of the capillary tube is broken off with sterilized forceps, and the contents are forced, by heating the air in the expanded extremity, into a test-tube containing sterile flesh-peptone-gelatine, which has been liquefied by exposure in a water bath to a temperature of 40° C., or below. The cotton plug is only removed for a moment in order to introduce the contents of the capillary tube, and in my extended experiments I have very rarely seen any accidental contamination. A rubber cap is next placed upon the open end of the test-tube and the gelatine is spread in a uniform manner over the interior of the tube by the method of Esmarch.[2] This is accomplished by rolling the tube in iced water until the gelatine hardens.

[1] Mitth. a. d. kais. Gesundheitsamte, Bd. 1.

[2] Zeitschrift für Hygiene, Bd 1, Heft 2, S. 293

These tubes are then kept at a temperature a little below the melting point of gelatine—20° to 22° C.—for at least a week. If the test organism has not been killed by the temperature to which it was exposed colonies are developed in the gelatine, which may often be recognized by the naked eye within a day or two. In other cases development is retarded, and it is only at the end of four or five days that evidence of growth is seen. The absence of growth at the end of eight or ten days is taken as evidence that the vitality of the test-organism has been destroyed by the temperature to which it was exposed. In every case a control experiment is made with material from the same culture which has not been subjected to heat.

BACILLUS OF TYPHOID FEVER.—Since the publication of Gaffky's memoir, in the second volume of the *Mittheilungen aus dem Kaiserlichen Gesundheitsamte*, his statements with reference to the formation of spores by the typhoid bacillus have been generally accepted, and have been confirmed by most of the observers who have followed him. Seitz,[1] however, has not been able to convince himself of the presence of spores in his cultures. Buchner[2] and Michael[3] also report their failure to find spores.

Gaffky states that spores are not formed at the room temperature, but that they are developed on the third or fourth day in cultures kept in an incubating oven at 37° C. These spores are said to be shining, round bodies, which occupy the whole width of the bacilli and are situated only at the ends of the rods. A single rod is said to contain but one well-developed spore, although, according to Gaffky, an imperfectly developed spore may sometimes be seen at the opposite end of a rod containing a perfect spore.

My cultures of the typhoid bacillus are from stock brought from Koch's laboratory by Dr. Meade Bolton. The morphological characters and the characteristic growth upon potato correspond perfectly with the account given by Gaffky and other authorities, and leave no doubt as to the identity of the organism which has served for my experiments. I have repeatedly seen in my potato-cultures which had been kept at 38° for several days, shining, spherical bodies, located at the ends of the rods, which appear to be spores, and which I suppose to be identical with the bodies pronounced by Gaffky to be spores. But these bodies stain with fuchsin, and if they are in truth reproductive elements, my temperature experiments show that their vitality is destroyed by a temperature of 60° C.

As my own previous experiments upon spore-bearing bacilli, and those of other experimenters, indicated that spores require for their destruction a comparatively high temperature, I made first the following ex-

[1] Bakteriologische Studien zur Typhus—Aetiologie, München, 1886.
[2] Archiv f. Hygiene, vol. iii. p. 361. [3] Fortschr. d. Medicin, 1886, No. 11.

periments, in which material from a pure culture in veal broth was exposed for the time adopted as a standard (ten minutes), as follows:

Nov. 10. 50°, 60°, 70°, Cont.

In this, and in all subsequent records of experiments made, the figures in heavy type indicate that growth occurred; the figures in light type indicate the absence of growth—*i. e.*, the killing of the test organism by ten minutes' exposure to the temperature indicated by the figures. It will be seen that at 60° and at 70° C. no growth occurred, while in the control tube and in that at 50° (=122° Fahr.) the typhoid bacillus grew abundantly. My object has been to determine the lowest temperature which will insure the destruction of *all* germs of each species tested. I have not therefore considered it necessary to count the number of colonies which have grown out in the Esmarch tubes in those cases where the temperature has been insufficient to accomplish the object in view. Such a record has no special advantage over the simple record of growth or failure to grow. In the practical application of data of this kind to the disinfection of typhoid excreta, etc., it is evident that a few colonies, representing a few bacilli or spores, which have survived the temperature tested, are as potent for mischief as a larger number. My experiments upon the typhoid bacillus are recorded in the following table:

TYPHOID BACILLUS.

(Ten minutes' exposure.)

Date.	Culture medium.	Experiments.	Remarks.
1886.			
Nov. 10.	Veal broth.	**50°, 60, 70, Cont.**	In oven at 38° for 48 hours.
Nov. 15.	Veal broth.	**50°, 52, 54, 56, 58, 60, Cont.**	Fluid culture of November 1st.
Nov. 30.	Potato culture,	**50°, 55, 60, 70, 80, Cont.**	Culture at room temperature.
Dec. 4.	Potato culture,	**60°, Cont.**	Culture in oven at 38° for 7 days.
Dec. 24.	Potato culture,	**60°, 70, 80, Cont.**	Culture in oven for 10 days, then kept at room temperature for 15 days.
1887.			
Jan. 15.	Potato culture,	**55°, 60, 70, 80, Cont.**	Culture in oven at 38° for 7 days.
Jan. 20.	Potato culture,	**48°, 50, 52, 60, Cont.**	In oven at 38° for 10 days.
Jan. 21.	Potato culture,	**50°, 60, Cont.**	Potato in oven 7 days, then kept at room temperature 7 days.

An inspection of this table shows that no development occurred in any instance after exposure to a temperature of 56° C. and above. In one experiment (Nov. 30) growth occurred after exposure to 55° C., but in this case it was very much delayed; in the experiment of January 15, no development occurred after exposure to 55°. Differences of this kind when we are on the border-line are to be expected.

We may then safely say that the thermal death-point of the typhoid bacillus is 56° C. (= 132.8° F.).

SPIRILLUM OF ASIATIC CHOLERA ("COMMA-BACILLUS" OF KOCH).—My experiments have been made simultaneously upon the cholera spirillum and the two organisms which most closely resemble it, viz., the "cheese spirillum" of Deneke and the Finkler-Prior spirillum.

The cultures in these experiments were all made at the room temperature in flesh-peptone-gelatine.

When development was retarded, the fact is indicated in the tables by a star following the figures denoting the temperature.

Date.	Organism.	Temperature to which exposed ten minutes.
December 30, 1886	Cholera spirillum.	42°, 44, 46, 48*, Cont.
	Cheese spirillum.	42°, 44, 46, 48*, Cont.
	Finkler-Prior spirillum.	42°, 44, 46, 48*, Cont.

In this first experiment no growth was observed in the Esmarch tubes containing the three organisms, after exposure to 48° for ten minutes, for several days after the control tubes had "broken down," but subsequently a few colonies developed in each of these tubes. This considerable retardation of growth led me to think that a slightly longer exposure would be fatal to all of these spirilla. I accordingly made the following experiment at the same temperature, but varying the time of exposure.

Date.	Organism.	Temperature.	Time of exposure in minutes.
January 7, 1887	Cholera spirillum.	48° C. = 118.4° F.	2°, 4, 6, 8*, 10*, 12*.
	Cheese spirillum.	" " "	2°, 4, 6, 8*, 10*, 12*.
	Finkler-Prior spirillum.	" " "	2°, 4, 6, 8*, 10*, 12*.

This was followed by a similar experiment at 50° C.

Date.	Organism.	Temperature.	Time of exposure in minutes.
January 10, 1887	Cholera spirillum.	50° C. = 122° F.	2°, 4, 6, 8*, 10*, Cont.
	Cheese spirillum.	" " "	2°, 4, 6, 8*, 10*, Cont.
	Finkler-Prior spirillum.	" " "	2°, 4, 6*, 8, 10, Cont.

In this experiment only a few colonies developed after exposure for eight and ten minutes in the case of the cholera and of the cheese spirillum, and none at all in the case of the Finkler-Prior spirillum.

The following experiment was made at 52° C.

Date.	Organisms.	Temperature.	Time of exposure in minutes.
January 31, 1887	Cholera spirillum.	52° C. = 125.6° F.	2°, 4, 6, 8, 10, Cont.
	Cheese spirillum.	" " "	2°, 4, 6, 8, 10, Cont.
	Finkler-Prior spirillum.	" " "	2°, 4, 6, 8, 10, Cont.

It will be noted that identical results were obtained throughout with the cholera and the cheese spirillum, while the Finkler-Prior spirillum proved to have a little less resisting power to heat.

The following experiment gives a result in accord with the above. It was made for the purpose of testing the question whether a difference would be shown in the resisting power of old and recent cultures. I may remark here that the cholera spirillum retains its vitality for several months, at least, in cultures which are kept in a moist condition. On the other hand, Koch has shown that it is quickly destroyed by desiccation.

Date.	Cholera spirillum.	Temperature	Time of exposure in minutes.
January 17, 1887	Fresh culture.	52° C. = 125.6° F.	2°, 4, 6, Cont.
	Culture 13 days old.	" " "	2°, 4, 6, Cont.

Anthrax Bacillus.—Davaine first made experiments (1873) to determine the temperature required to destroy the vitality of the anthrax bacillus as found in the blood of an animal just dead. Under these circumstances no spores are present. The destruction of vitality was tested by inoculation into susceptible animals. This method is open to the objection that at temperatures approaching that which destroys vitality the development of the bacillus is retarded, and the animal is likely to suffer a non-fatal attack of the disease, which may escape observation. This is probably the explanation of the slight difference in the results obtained by Davaine and those of Chauveau made more recently.

Authority.	Temperature.	Time of exposure.	Remarks.
Davaine	45°	15 minutes.	In blood.
Davaine	50	10 "	" "
Davaine	55	5 "	" "
Chauveau	50	20 "	Cultures.
Chauveau	54	10 "	"

According to Flügge, anthrax spores are killed by exposure to 100° C. for two minutes. In a recent experiment by the writer a single colony developed after exposure to this temperature for two minutes, but there was no growth when the time was extended to four minutes.

BACILLUS OF GLANDERS—Löffler[1] has recently determined the thermal death-point of the *Rotz* bacillus. He finds it to be 55° C., the time of exposure being ten minutes.

BACILLUS OF SWINE PLAGUE (Germnn, *Schweine rothlauf;* Frenеh, *Rouget*). BACILLUS OF MOUSE SEPTICÆMIA (Koch).—Pasteur's bacillus of *rouget* is, no doubt, identical with the bacillus of *Schweine rothlauf* of the German bacteriologists. I have experimented upon cultures from both sources. The bacillus of mouse septicæmia is also supposed by some nuthors to be identical with the above. According to Eisenberg, the bacillus of mouse septicæmia forms spores. Flügge says of the bacillus of *Schweine rothlauf:*

"In bouillon cultures which have been kept for three days at the room temperature, or for twenty-four hours at 40°, one notices the formation of small spherical bodies, which probably represent spores; although, on account of their minuteness, the formation and development of these bodies have not, up to the present time, been exactly observed."[2]

My experiments upon the thermal death-point of these organisms are included in the following tables.

CULTURES IN FLESH-PEPTONE-GELATINE.

Date.	Organism.	Temperature to which exposed.
January 20, 1887	Mouse septicæmia.	50°, 60, Cont.
January 26, "	Mouse septicæmia. Schweine rothlauf.	52°, 54, 56°, 58, Cont. 52°, 54, 56, Cont.
February 7, "	Mouse septicæmia. Schweine rothlauf.	60°, Cont. 60°, Cont.
February 8, "	Mouse septicæmia. Rouget.	54°, 56°, 58, Cont. 52°, 54, 56°, 58, Cont.

CULTURES IN BOUILLON.

Date.	Organism.	Temperature to which exposed.
March 17, 1887	Rothlauf.	60°, 65, Cont.
	Mouse septicæmia.	60°, 65, Cont.

These bouillon cultures were kept in the incubating oven at 38° for three days, and afterwnrd at the room temperature for eight days. The bacilli were found to have grown out into slender filaments, which pre-

[1] Arbeiten a. d. Kaiserlichen Gesundheitsamte, Bd. 1, Heft 5. [2] Die Mikroörganismen, p. 246.

sented the appearance of having vacant places in their protoplasm, which possibly represented spores. As will be seen by reference to the table, no growth occurred after exposure to a temperature of 60° C. for ten minutes. We must, therefore, admit either that this bacillus does not form spores under the circumstances stated by Flügge, or that the spores are destroyed at the comparatively low temperature named.

In the following table I include several species of pathogenic and non-pathogenic bacilli in which the question of spore-formation has not been definitely settled. In regard to the first-named (Emmerich's bacillus) Eisenberg remarks "spore-formation not yet observed." According to Flügge, *B. sputig. crassus* "appears to form spores at a temperature of 35°." The bacillus of blue milk is said by Eisenberg to form spores in gelatine cultures after the third day. The lactic acid ferment is said by the same author to form spores at the ends of the rods, which appear as spherical, shining, highly refractive bodies. In my own examinations of stained cover-glass preparations from the cultures used in the following experiments, I have in no instance been able to satisfy myself of the presence of spores.

RECENT CULTURES IN FLESH-PEPTONE-GELATINE.

Organism.	Date.	Temperature to which exposed ten minutes.
Emmerich's bacillus	January 24, January 29, February 1,	60°, Cont. 70°, 80, 90, 100, Cont. 60°, 62, 64, Cont.
Brieger's bacillus	January 24, February 1,	60°, Cont. 58°, 60°, 62°, Cont.
Friedländer's bacillus (So-called "pneumo-coccus.")	December 24, January 8, January 11, January 20,	50°, 52°, 54°, Cont. 58°, 60, 62, 64, Cont. 54°, 56,° 58, Cont. 56°, 58, Cont.
Bacillus sputig crassus (Krelbohm.)	January 24, January 28, January 31,	60°, Cont. 50°, Coot. 54°, 56, 58, Cont.
Bacillus pyocyanus (Green pus.)	December 21, December 31, January 8, January 17, February 2,	70°, 80, Cont. 46°, 46, 50, Cont. 58°, 60, 62, 64, Cont. 52°, 54°, Cont. 54°, 56, 58, Cont.
Bacillus indicus	January 21, January 25, January 26, February 2,	56°°, 60, Cont. 56°, 58, Cont. 52°°, 54°, 56, Cont. 54°, 56, 58°, Cont.
Bacillus prodigiosus (Commonly called micro-coccus prodigiosus.)	January 21, January 25, January 26, February 2,	56°, 60, Cont. 56°, 58, Coot. 52°°, 54°, 56°, Cont. 54°°, 56, 58, Cont.
Bacillus cyanogenus (Bacillus of blue milk.)	January 28, January 31,	50°, 60, Cont. 54°, 56, 58, Cont.
Bacillus fluorescens	January 23, January 31,	50°, 60, Cont. 54°, 56, 58, Cont.
Bacillus acidi lactici	January 24, January 26, February 1, February 8,	60°°, Cont. 52°, 54, 56, Cont. 60°, 62, 64, Cont. 54°, 56, 58, Cont

POTATO CULTURES IN INCUBATING OVEN FOR THREE DAYS, AT 38°, TO TEST FOR SPORES.

(No spores seen on microscopic examination of stained cover-glass preparations.)

Organism.	Date.	Temperature to which exposed.
Bacillus pyocyanus	March 1, 1887.	60°, 65, Cont.
Emmerich's bacillus	" "	60°, 65, Cont.
Brieger's bacillus	" "	60°, 65, Cont.
Bacillus acidi lactici	" "	60°, 65, Cont.

OLD CULTURES IN FLESH-PEPTONE-GELATINE, TO TEST FOR SPORES.

(March 7, 1887.)

Organism.	Age of culture.	Temperature to which exposed.
Brieger's bacillus	36 days.	60°, 65, Cont.
Emmerich's bacillus	43 "	60°, 65, Cont.
Bacillus pyocyanus	46 "	60°, 65, Cont.
Bacillus fluorescens	42 "	60°, 65, Cont.
Bacillus cyanogenus	33 "	60°, 65, Cont.
Bacillus acidi lactici	42 "	60°, 65, Cont.

It will be seen that in all of these experiments the lactic acid ferment is the only one which resisted a temperature of 60° C; and if the presence of spores could be determined by this test, this is the only organism in the list in which there is any evidence of spore formation. I am not, however, disposed to accept this test, and think it not improbable that some of the bacilli in the list form reproductive spores, which differ from those of the anthrax bacillus and certain other spore-forming bacilli, in the fact that they are destroyed at a comparatively low temperature. The only way to settle this question will be by the method of direct observation. If the refractive spherical bodies, supposed to be spores, which may be seen in potato cultures of the typhoid bacillus, in bouillon cultures of the bacillus of swine plague, etc., are observed to develop into bacilli, they will be demonstrated to be reproductive elements, or spores, notwithstanding the fact that they are destroyed by so low a temperature as 60° C.

The following experiments have been made with pathogenic and non-pathogenic bacilli which are known to form spores.

Organism.	Date.	Temperature to which exposed ten minutes.
Bacillus alvei (foul brood of bees)	December 8,	80°, Cont.
	December 30,	90°, 100, Cont.
Wurtzel bacillus	January 24,	60°, Cont.
	January 28,	70°, 80, 90, Cont.
Bacillus butryeus	December 28,	80°, Cont.
	December 31,	90°, 100, Cont.

The following experiments have been made upon these spore-forming bacilli at a temperature of 100° C. (212° F.), the time of exposure being varied.

Organism.	Date.	Time of exposure in minutes.
Anthrax bacillus	February 2,	2*, 4, 6, 8, 10, Cont. * A single colony.
Bacillus alvei	February 9,	2*, 4, 6, 8, 10, Cont. * A few colonies.
Bacillus butryeus	February 9,	2, 4, 6, 8, 10, Cont.
Wurtzel bacillus	March 4,	2*, 4, 6, 8, 10, Cont. * A single colony.

BACILLUS TUBERCULOSIS.—Schill and Fischer (1884), assuming that the tubercle bacillus forms spores, made quite a number of experiments to determine its thermal death-point. Using fresh sputum as the material, and testing the destruction of the vitality of the bacilli contained in this material by inoculations into guinea-pigs, they found that exposure to a temperature of 100° C., in steam, was efficient when the time of exposure was five minutes. When the time was reduced to two minutes a negative result was obtained in two out of three guinea-pigs inoculated, but in one death from tuberculosis occurred.

My experiments upon micrococci are recorded in the following table.

RECENT CULTURES OF MICROCOCCI IN FLESH-PEPTONE-GELATINE.

Organism.	Date.	Temperature to which exposed ten minutes.
Micrococcus of osteomyelitis	December 8, 1886.	50°, 52, 54, 56, 58, Cont.
	December 20,	52°, 54, 56*, Cont.
	February 8, 1887.	54°, 58*, 58, Cont.
Staphylococcus pyog. aureus	January 11, 1887.	54°, 58*, 58, 60, Cont.
Staphylococcus pyog. citreus	January 8, 1887.	58°, 60*, 62, 64, Cont.
	January 11,	54°, 58, 58*, 60*.
	January 20,	56°, 58*, 60, Cont.
Staphylococcus pyog. albus	December 26, 1886.	52°, 54, 58*, Cont.
	January 11, 1887.	54°, 56, 58*, 80*.
Streptococcus erysipelatus	December 28, 1886.	48°, 50, 52, Cont.
	January 20, 1887.	50°, 52, 58, Cont.
	January 25,	54°, 56, Cont.
Micrococcus tetragenus	January 25, 1887.	54°, 58*, 58, Cont.
Micrococcus Pasteuri	March 29, 1887.	60°, 52, 54, 56, 58, Cont.
	April 7,	48°, 48, 50*, 52, Cont.

FRESH CULTURES OF SARCINÆ IN FLESH-PEPTONE-GELATINE.

Organism.	Date.	Temperature to which exposed.
Sarcina aurantiaca	December 24, 1886.	56°, 58°, 60°, Cont.
	January 11, 1887.	54°, 56, 58°, 60.
	January 18,	56°, 60, Cont.
Sarcina lutea	December 29, 1886.	56°, 58°, 60°, Cont.
	January 7, 1887.	58°, 60°, 62°, 64, Cont.
	January 11,	56°, 58, 60°, Cont.
	January 18,	60°, 62, 64, Cont.

GONOCOCCUS OF NEISSER.—Believing, as I now do, that this organism is the cause of the infectious virulence of gonorrhœal secretions (see *The Medical News* of Feb. 26, 1887), I have made the following experiment with reference to its thermal death-point. Some gonorrhœal pus from a recent case which had not undergone treatment, was collected for me by my friend, Dr. George H. Rohé, in the capillary tubes heretofore described. A microscopical examination of stained cover-glass preparations showed that this pus contained numerous "gonococci" in the interior of the cells. Two of the capillary tubes were placed in a water bath maintained at 60° C. for ten minutes. The pus was then forced out upon two pledgets of sterilized cotton wet with distilled water. Two healthy men had consented to submit to the experiment, and one of these bits of cotton was introduced into the urethra of each and left *in situ* for half an hour. As anticipated, the result was entirely negative. For obvious reasons no control experiment was made, and no attempt was made to fix the thermal death-point within narrower limits.

In connection with these experiments upon the thermal death-point of known pathogenic organisms, it is of interest to inquire whether the virulence of infectious material in which it has not yet been demonstrated that this virulence is due to a microörganism, is destroyed by a correspondently low temperature. Evidently, if this proves to be the case, it will be a strong argument in favor of the view that we have to deal with a microörganism in these diseases also. We have experimental proof that a large number of pathogenic organisms are killed by exposure for ten minutes to a temperature of from 55° to 60° C. But, so far as I am aware, this low temperature would not be likely to destroy any of the poisonous chemical products which might be supposed to be the cause of infective virulence—leaving aside the fact that such chemical products have no power of self-multiplication, and, therefore, could not be the independent cause of an infectious disease.

VACCINE VIRUS.—Carstens and Coert have experimented upon the temperature required to destroy the potency of vaccine virus. In a paper read at the meeting of the International Medical Congress, in 1879, they report as the result of their experiments that the maximum

degree of heat to which fresh vaccine can be exposed without losing its virulence, probably varies between 52° and 54° C.

RINDERPEST.—According to Semmer and Raupach,[1] exposure for ten minutes to a temperature of 55° C. destroys the virulence of the infectious material in this disease.

SHEEP-POX.—The authors last mentioned[2] have also found that the same temperature—55° C. for ten minutes—destroys the virulence of the blood of an animal dead from sheep-pox.

HYDROPHOBIA.—Desiring to fix the thermal death-point of the virus of hydrophobia, I obtained through the kindness of Dr. H. C. Ernst, a rabbit which had been inoculated, by the method of trephining, with material which came originally from Pasteur's laboratory (see Dr. Ernst's paper in the April number of this journal). The rabbit sent me showed the first symptoms of paralytic rabies on the eighth day after inoculation. It died on the eleventh day (March 2, 1887), and I at once proceeded to make the following experiment:

A portion of the medulla was removed and thoroughly mixed with sterilized water, the milky emulsion was introduced into four capillary tubes, such as had been used in my experiments heretofore recorded. Two of these tubes were then placed for ten minutes in a water bath, the temperature of which was maintained at 60° C. Four rabbits were now inoculated by trephining, two with the material exposed to 60° C. for ten minutes, and two with the same material from the capillary tubes not so exposed. The result was as definite and satisfactory as possible. The two control rabbits were taken sick, one on March 10, and one on the 11th; both died with the characteristic symptoms of paralytic rabies on the third day. The two rabbits inoculated with material exposed to 60° C. remained in perfect health. On the 26th of March one of these rabbits was again inoculated by trephining with material from the medulla of a rabbit just dead from hydrophobia. This rabbit died from paralytic rabies on the 8th of April. Its companion remains in perfect health.

A second experiment was made in the same way on the 14th of March. Two rabbits were inoculated with material exposed for ten minutes to a temperature of 50° C.; two with material exposed for the same time to a temperature of 55° C.; and two control rabbits with material not so exposed. One of the rabbits inoculated with material exposed to 50° C. and one of the control rabbits died on the 25th, the other rabbit inoculated with the material exposed to 50°, the other control, and one inoculated with material exposed to 55°, on the 26th. The second rabbit inoculated with material exposed to 55° died five days later with the characteristic symptoms of the disease.

These experiments show then that the virus of hydrophobia is

[1] Deutsche Zeitschrift für Thier med., vii. p. 347. [2] Ibid.

destroyed by a temperature of 60° C., and that 55° C. fails to destroy it—the time of exposure being ten minutes.

For convenience of reference the results obtained in my own experimental studies, and those of others referred to, are brought together in a single table. Where the determination has not been made by myself the authority is given in parentheses after the name of the organism. The time of exposure is ten minutes, unless otherwise indicated by figures in parentheses following those representing the temperature. The table includes those non-pathogenic organisms which have been tested as well as those which are recognized as pathogenic. In this table I have adopted the nomenclature used by Dr. Flügge in his recent work *Die Mikroörganismen*.

THERMAL DEATH-POINT OF MICROÖRGANISMS.

NAME OF ORGANISM.	CENTIGRADE.	FAHRENHEIT.
Spirillum choleræ Asiaticæ	52°	125.6° (4 m.)
Spirillum tyrogenum[1]	52	125.6 (4 m.)
Spirillum Finkler-Prior	50	122
Bacillus anthracis (Chauveau)	54	129.2
Bacillus typhi abdominalis	56	132.8
Bacillus mallei[2] (Löffler)	55	131
Bacillus of schweine-rothlauf (Bouget of Pasteur)	58	136.4
Bacillus murisepticus	58	136.4
Bacillus Neapolitanus[3]	62	143.6
Bacillus cavicida[4]	62	143.6
Bacillus pneumoniæ[5]	56	132.8
Bacillus crassus sputigenus	54	129.2
Bacillus pyocyanus	56	132.8
Bacillus indicus	58	136.4
Bacillus prodigiosus	58	136.4
Bacillus cyanogenus	54	129.2
Bacillus fluorescens[6]	54	129.2
Bacillus gallinarum (Salmon)[7]	56	132.5
Bacillus acidi lactici[8]	56	132 8
Bacillus alvei; spores	100	212 (4 m.)
Bacillus anthracis; spores	100	212 (4 m.)
Bacillus butyricus; spores	100	212 (4 m.)
Bacillus mycoides; spores	100	212 (4 m.)
Bacillus tuberculosis (Schill and Fischer)	100	212 (4 m.)
Staphylococcus pyogenes aureus	58	136.4
Staphylococcus pyogenes citreus	62	143 6
Staphylococcus pyogenes albus	62	143.6
Streptococcus erysipelatus	54	129.2
Micrococcus tetragenus	58	136.4
Micrococcus Pasteuri	52	125.6
Micrococcus gonorrhœæ[9]	60	140
Sarcina lutea	64	147.2
Sarcina aurantiaca	62	143.6
Vaccine virus (Carstens and Coert)	54	129.2
Rinderpest virus (Semmer and Raupach)	55	131
Sheep pox virus (Semmer and Raupach)	55	131
Hydrophobia virus	60	140

[1] Cheese spirillum.
[2] Bacillus of glanders.
[3] Emmerich's bacillus.
[4] Brieger's bacillus.
[5] Friedländer's.
[6] From water.
[7] Pasteur's "microbe du choléra des poules."
[8] Old culture in flesh-peptone-gelatine not killed by 60°, probably owing to the presence of spores.
[9] A single experiment. A lower temperature would probably be effective.

By reference to the various tables giving the experimental data in detail, it will he seen that the results are not absolutely uniform for the same organism. Thus, in the experiments upon the typhoid hacillus no growth occurred after exposure to 55° in one experiment (January 15), while in another (November 30) colonies of the typhoid hacillus grew out after exposure to this temperature. In this case the thermal death-point is placed at 56°, no growth having occurred nfter exposure to this temperature. Similar differences, when the temperature approaches that which is uniformly successful in destroying vitality, may he observed with reference to several of the organisms tested. But these differences are within comparatively narrow limits. They are prohably due partly to a difference in resisting power depending upon the age of the culture, and partly to unavoidahle variations in the temperature during the experiments. By very careful supervision and frequent stirring of the water-bath, variations in temperature bave heen kept within narrow limits, hut it bas been impossible to avoid them entirely. The same thermometer has been used throughout (made hy Schlag and Berend, Berlin).

No attempt has been made to fix the thermal death-point within narrower limits than 2° C., and in the ahove tahle the lowest temperature is given which has been found, in the experiments made, to destroy all of the organisms in the material subjected to the test. No doubt more extended experimeats would result, in some instances, in a reduction of the temperature given as the thermal death-point for a degreo or more. But the results as stated are sufficiently accurate for all practical purposes, and permit us to draw some general conclusions:

(*a*) The temperature required to destroy the vitality of pathogenic organisms varies for different organisms.

(*b*) In the absence of spores, the limits of variation are about 10° Centigrade (18° F.).

(*c*) A temperature of 56° C. (132.8° F.) is fatal to the bacillus of anthrax, the bacillus of typhoid fever, the bacillus of glanders, the spirillum of Asiatic cholera, the erysipelas coccus, to the virus of vacciuia, of rinderpest, of sheep-pox, and probably of several other infectious diseases.

(*d*) A temperature of 62° C. (143.6° F.) is fatal to all of the pathogenic and non-pathogenic organisms tested, in the absenec of spores (witb the single exception of *sarcina lutea*, which, in one experiment, grew after exposure to this temperature).

(*e*) A temperature of 100° C. (212° F.) maintained for five minutes destroys the spores of all pathogenic organisms tested.

(*f*) It is probable tbat some of the bacilli which are destroyed hy a

temperature of 60° C. form endogenous spores which are also destroyed at this temperature.[1]

The experimental study, the results of which are recorded in the present paper, was made, through the courtesy of Prof. Wm. H. Welch, in the pathological laboratory of Johns Hopkins University.

A CONSIDERATION OF THE RESULTS IN 327 CASES OF TRACHEOTOMY,

PERFORMED AT THE BOSTON CITY HOSPITAL FROM 1864 TO 1887.

By Robert W. Lovett, M.D., and John C. Munro, M.D.,
FORMERLY HOUSE SURGEONS AT THE HOSPITAL.

The operation of tracheotomy was performed for croup 327 times at the Boston City Hospital from the time of its foundation in 1864 to January, 1887. Up to the year 1880, only 30 tracheotomies had been done, so that the greater part of the operations have been performed in the last six years. It should be noted, in passing, that a bad class of cases would naturally come to a city hospital for operation. In most instances being treated at home, medically, until an operation has become imperative and long after it has become advisable, they are brought hurriedly for operation often in a hopelessly bad condition. If the parents wish or if an operation seems likely to afford even temporary relief to the patient, tracheotomy is performed, and thus many hopeless cases are yearly operated upon; all of which are included in the analysis. We are indebted to the visiting surgeons of the hospital for permission to publish the following cases.

Of the 327 cases, 232 died and 95 (29.05 per cent.) recovered. The causes of death were, septicæmia in 62 cases, extension of the diphtheritic process to the trachea and bronchi (doubtless including many pneumonia cases) in 101 cases, exhaustion in 12 cases, death on the table in 10 cases, heart failure in 6 cases, various causes (pneumonia, peritonitis, scarlet fever, nephritis, embolism, marasmus) in 6 cases, undetermined in 35 cases.

Autopsies were so few that a clinical estimate of the cause of death had to serve in most cases; such a classification is approximate at best and the distinctions were by no means always clear. When death was preceded by gradually increasing dyspnœa it was considered that exten-

[1] This question demands further experimental investigation.