rimeters above described are cumbersome, many are suitable for experiments on small animals only, and none of them can be conveniently adapted to the clinical study of fever in the hospital. To obviate these disadvantages D'Arsonval attacked the problem of devising a calorimeter which should fulfil the following conditions:

"1. To be set up in any room in a hospital.

"2. To be light and easily portable.

"3. To allow the calorimetric observation to be made rapidly—say in five minutes.

"4. To be set up over the bed of a patient and give automatically continuous records in the form of a curve without requiring the presence of some one to watch the apparatus."

The calorimeter which, he claims, meets all these requirements is shown in Fig. 1076.

The principle of the calorimeter is very simple. The heat of the body causes the air to rise. This creates a current which passes through the chimney and sets the anemometer vane revolving. The more heat, the stronger the current and the more rapid the revolution of the vane. The heat given off was found to be directly proportional to the square of the number of revolutions of the vane in a unit of time.

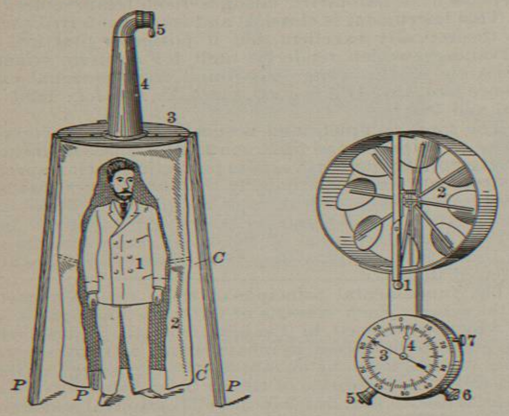

FIG. 1076. FIG. 1077.

FIGS. 1076 AND 1077.—D'Arsonval's Anemo-Calorimeter.

FIG. 1076.—Calorimeter. Description: 1, The subject of the experiment; 2, cylinder of woollen stuff fixed to a disc of wood, 3, and kept from collapsing by the hoops *C* and *C'*; part of the cylinder is cut away to show the subject; 4, conical chimney bent near its end; 5, opening of chimney with anemometer attached. The anemometer is shown. on a large scale, to the right (Fig. 1077).

FIG. 1077.—Anemometer. Description: 1, Lever for throwing the vane in connection with the recorder; 2, vane composed of eight aluminum fans; 3 and 4, hands of recorder; 5 and 6, binding posts for wires to odograph; 7, button for putting the hands back to 0.

Each instrument has to be graded separately by placing in it some source of heat which gives off a known quantity in a given time. It can then be calculated how many turns of the vane represent a given number of calories. The numbers are convenient for calculation; for example, in D'Arsonal's own instrument eighty revolutions per minute represent 21.6 great calories per hour.

One would hardly suppose, *a priori*, that such a crude arrangement would give accurate results, but the figures obtained by D'Arsonval while calibrating it would seem to leave no doubt as to its reliability. As a source of heat he employed a ferro-nickel spiral heated by an electric current. The error in the record of the anemometer was 2 revolutions in 2,400, and 5 in 3,600, so that it was practically exact.

The instrument has no time-loss in recording. Within one minute from the time a man enters the calorimeter the vane has attained its maximum velocity, and two minutes after this suffice for an observation, so that a whole experiment can be made in three minutes—a desideratum often important in clinical work.

The accuracy of the records of the anemo-calorimeter is independent of the room temperature. The vane revolves from a current of air which depends upon the difference in temperature between the air entering and the air leaving the calorimeter. This *difference* is constant for the same source of heat whatever may be the temperature of the air entering, *i.e.*, the temperature of the air of the room.

In his laboratory, D'Arsonval uses a wooden box with a glass door instead of the woollen curtain, of the portable form, shown in the figure.

Laulanie* used an anemo-calorimeter, and found that the heat produced runs closely parallel with the oxygen consumed.

When it is desired to make observations continuing for a considerable time, the apparatus is connected with a Marey odograph,† and the record is taken on a revolving cylinder. With the calorimeter thus arranged over his own bed, D'Arsonval made observations on himself during sleep.

Class E: Respiration Calorimeters.—A respiration calorimeter is one which is so arranged that the air taken in, and the air breathed out, by the animal can be analyzed; in other words, it is one which permits observations to be made by the method of indirect calorimetry and of direct calorimetry at the same time.

Nearly all the water calorimeters and air calorimeters have been arranged in this way. The most elaborate instrument of the kind is one recently perfected by Atwater and Rosa (see Water Calorimeters) with the assistance of funds supplied by the United States Department of Agriculture, and of the State of Connecticut. The description here given of this calorimeter is taken (condensed) directly from one of the papers by the original authors.‡

"*The Apparatus.*—The name here used for the apparatus, 'respiration calorimeter,' is suggested by the fact that it is essentially a respiration apparatus with appliances for calorimetric measurements. As a respiration apparatus it is similar in principle to that of Pettenkofer. The calorimeter is essentially a water calorimeter, that is to say, the heat evolved in the chamber is measured by a current of water. The appliances for measurement of both the respiratory products and the heat given off from the body differ in some important respects from those of any other apparatus with which we are familiar.

"The apparatus includes, first of all, a room or chamber in which the subject remains during the experiment. The chamber is furnished with a folding chair and table for the man's use during the day, and a folding bed on which he sleeps at night. When the experiments involve muscular work, a stationary bicycle, especially arranged for measuring the work done, is also introduced. Light enters through a window so that the occupant can see to read and write. Ventilation is provided by a current of fresh air, maintained by a pump specially devised for the purpose. This pump not only keeps up a constant current of air, but also measures its volume and withdraws samples regularly and accurately for analysis. The air is made to enter the chamber at the same temperature as when it goes out, so that the quantities of heat brought in and carried out by this ventilating current are the same. Arrangements are provided for passing food and drink into the chamber and for removing the solid and liquid excreta. Arrangements described beyond prevent the passage of heat through the walls of the apparatus.

"The heat given off from the body is carried away by a current of cold water which passes through a series of pipes inside the chamber. Houses are warmed in winter by a current of water which is heated in the basement of the house, and passes through pipes and radiators in the different rooms. The heat thus radiated from the water into the room keeps the air of the latter at the desired temperature. In like manner the house might be cooled in summer by a current of cold water. In this case the radiators would become absorbers. The heat would be taken up from the air of the room by the cold water and carried away. Exactly this is done by the absorbers inside the chamber of the respiration calorimeter. By regulating the temperature of this water current as it enters, and also its rate of flow, it is possible to carry away the heat just as fast as it is generated, and thus maintain a constant temperature inside the chamber.

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* Laulanie, Comptes rendus, Soc. de Biol., 1896, p. 5.

† Marey, "Methode graphique," Paris, 1878, p. 183.

‡ Atwater and Rosa, "Report of Storrs (Connecticut) Experiment Station," 1897.

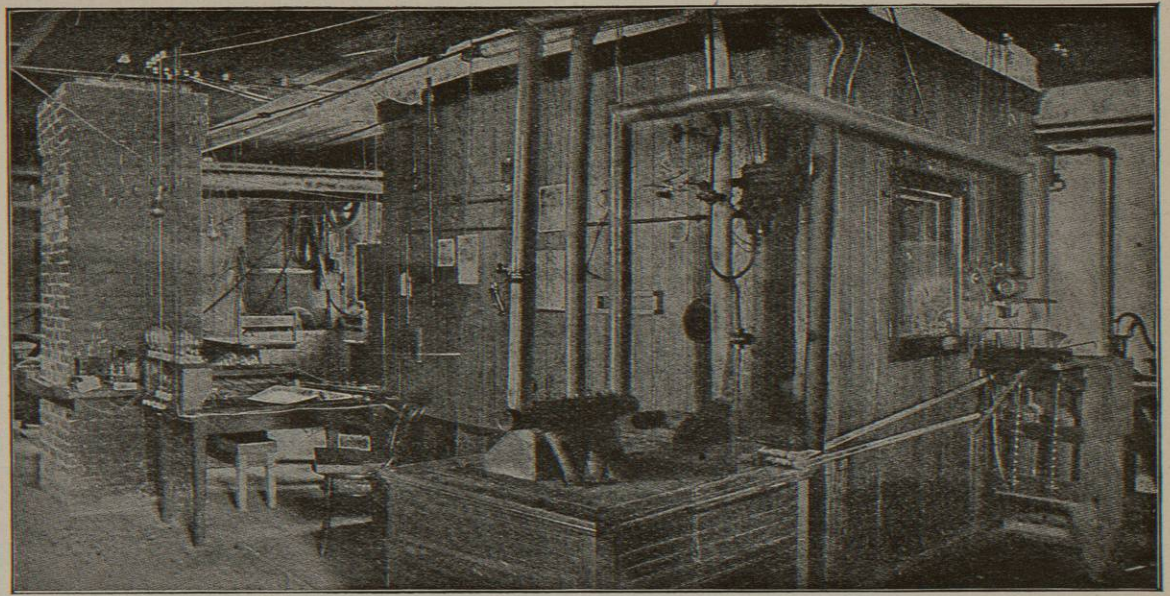

FIG. 1078.—Respiration Calorimeter. General view.

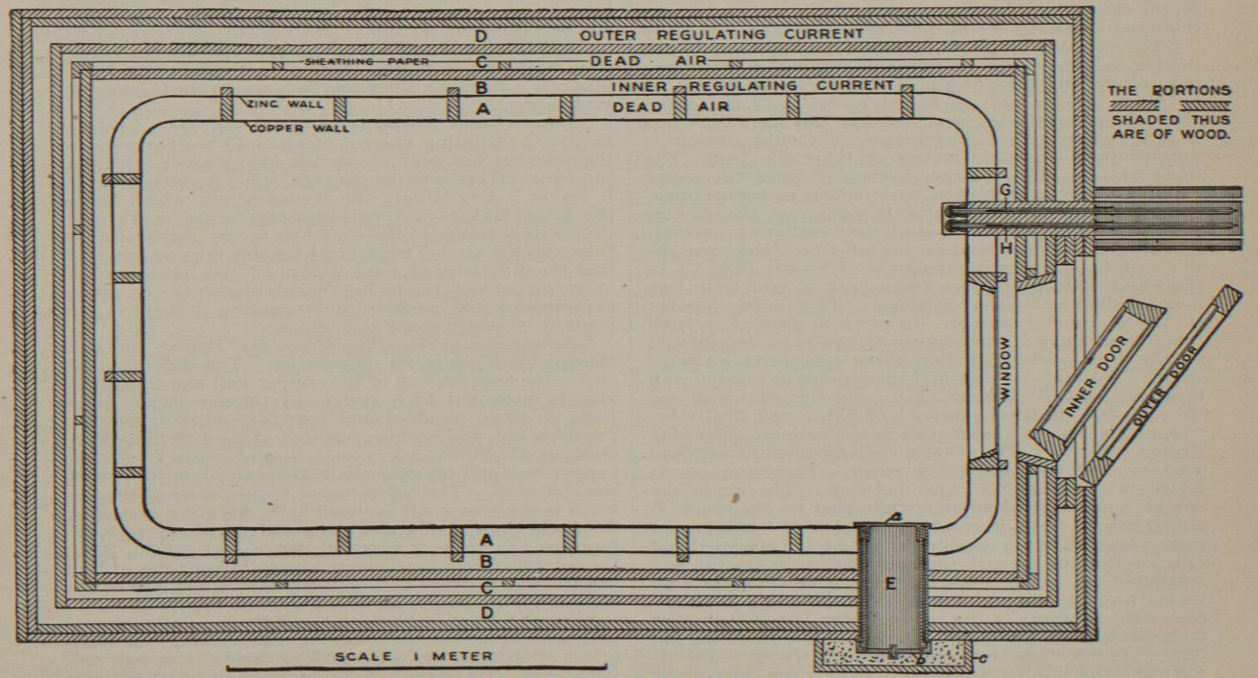

FIG. 1079.—Horizontal Cross-Section of Respiration Calorimeter.

The amount of the outgoing water and its temperature are measured, thus determining the heat carried away.

"A general idea of the apparatus can be had from Figs. 1078 and 1078. Fig. 1078, from a photograph, is a general view of the principal parts of the apparatus, though the pump and aspirators used for moving, measuring, and sampling the ventilating air current and the refrigerating machine are not shown. In the centre is the large chamber which is surrounded by sheathing of wood. At the end of the chamber, on the right, is shown a glass door which serves also as a window. In the foreground, near the centre and at the right, are the pipes through which the ventilating current of air passes. At the right of the window and just below it are the arrangements for cooling and for measuring the current of water which brings away the heat from the interior of the chamber. At the left, in front of the large brick pillar, is a table at which an observer sits to record the temperature of the interior of the apparatus and of the currents of air and water, these temperatures being measured by electrical thermometers. Behind the brick pillar is the refrigerating machine, not shown in the picture. The object of this is to cool the brine, *i.e.*, a solution of calcium chloride contained in a large tank in the centre foreground. The tank is surrounded by a wooden casing. The ventilating current of air, before it enters the chamber, is passed through copper cylinders which are immersed in brine in this tank, and thus cooled to a temperature of from −19° to −22° C., or from −2° to −8° F. At this very low temperature nearly all the water is removed from the air, so that it enters the chamber quite dry. Just before entering, at the right of the glass door, it is warmed to the temperature of the interior of the chamber. On coming out it passes once more through copper cylinders in the cold brine, and thus the larger part of the water which has been imparted to it by the respiration of the man inside the chamber is frozen and removed. The air pump is at the right and the aspirators are at the left of the position occupied by the camera in taking the photograph.

"*The Respiration Chamber.*—The internal construction of the chamber and the arrangements for regulating the temperature are shown in horizontal section in Fig. 1079.

"The chamber proper is practically an apartment with double walls of metal, the inner wall being of sheet copper and the outer one of zinc. The interior is 2.15 m. (7 ft.) long, 1.92 m. (6 ft. 4 in.) high, and 1.22 m. (4 ft.) wide, the corners being rounded. It thus has a little less than 28 square feet of floor space. The cubic content is not far from 4.8 cubic metres or 175 cubic feet. The inner wall is made of large sheets of copper, the seams being soldered so that when the windows and other openings are closed the chamber is air tight, and the only air which enters or leaves is that of the ventilating current. Outside this copper wall is one of zinc. Between the two metal walls is an air space (A) of 7.5 cm. (3 in.). In this space stands a wooden framework to which the two metal walls are securely attached. This metal chamber is the calorimeter proper. In order to protect it from the fluctuations of temperature of the room in which it stands, it is enclosed within three concentric walls of wood. Between the zinc and the innermost wooden wall is an air space (B) of 5 cm. (2 in.), between this wall and the next is a third air space (C) of 5 cm., and finally between this and the outer wall is a fourth air space (D), likewise of 5 cm. The wooden walls are made of matched pine covered with sheathing paper. The outer one is double with sheathing paper between. The air in the spaces A and C is 'dead air,' while that in the spaces B and D can be kept in constant circulation by means of rotary fans in boxes outside. Each of the spaces B and D is continuous around the sides and over the top and bottom of the calorimeter, and each communicates with its fan box by means of one passage extending from the top of the air space to the top of its fan box, and another from the bottom of the air space to the bottom of the fan box. We may thus look upon these air spaces as shields guarding the interior space occupied by the calorimeter from changes in temperature without. They thus render necessary aid in accomplishing a fundamental object, namely, the keeping of the temperature of the air in the space B the same as that of the interior of the chamber. When these temperatures are the same there will be no passage of heat through the walls, either into or out of the chamber.

"The outer air current (D) is used for the coarser regulations of temperature. In the middle of the dead air space (C) is a wall of sheathing paper intended to more effectually prevent the external temperature from affecting that of the calorimeter.

"The walls are provided at the right with glass doors or windows. At E in Fig. 1079 is a cylinder of copper which passes through the walls of the chamber and also through the encasing walls of wood. This cylinder, which is 15 cm. (6 in.) in diameter, serves for passing food and other materials into and out of the calorimeter chamber, and is here called the 'food aperture.' It is closed at the ends by caps *a* and *b*. The outer (*b*) is screwed tightly to the cylinder so as to make an air-tight closure. Outside of this is a box or cover (*c*), made of wood and filled with cotton or other non-conducting material, the purpose being to prevent the passage of heat through E.

"*Measurements of Temperature.* The measurements of temperature are made in part by mercury thermometers, but mainly by electrical methods. The electrical measurements of temperature are made by use of either the German silver-iron thermal junctions or by resistance coils of fine copper wire. Provision is made for connecting these with a D'Arsonval galvanometer especially constructed for the purpose by Mr. O. S. Blakeslee, mechanician of Wesleyan University. The electrical thermometers permit measurements of .01° C. or less.

"*Temperature of Air Inside the Chamber.* Inasmuch as the temperature of the air is not the same in different parts of the chamber, and it is desirable to know the average or resultant temperature of the whole, the attempt is made to learn the latter by the use of a series of five electrical thermometers at places near the sides, top, and bottom. These consist of resistance coils of copper wire connected with a slide wire Wheatstone bridge and the galvanometer outside. The measurements are so delicate that even slight movements of the person inside, such as rising from the chair, reveal themselves to the observer outside by the immediate rise in the thermometric reading.

"*Regulation of Temperature of Ingoing Air.* In order that the ventilating current of air shall not carry out of the chamber any more or any less heat than it brings in, the temperature must be the same when it enters as when it leaves. Accordingly the incoming air, which leaves the brine tank at a very low temperature, is warmed, before its entrance to the chamber, to the temperature of the outgoing air. The devices for this purpose are such that the difference of temperature of the incoming and outgoing currents can be kept inside of .01° C. In actual experiments the positive and negative differences are made to counterbalance each other.

"*Arrangements for Preventing the Passage of Heat through the Walls of the Calorimeter.* The difference between the temperature of the copper wall and that of the zinc is measured by a system of thermo-electric junctions, in three hundred and four pairs, distributed over the sides, top, and bottom, one-half of the junctions (iron-German silver) being in close thermal contact with the copper wall and the other half (German silver-iron), with the zinc wall. The difference of temperature of the two walls is made as small as possible by warming or cooling the air in the space B, and the positive and negative differences are made to counterbalance each other. Thus the corresponding movements of small quantities of heat inward and outward also counterbalance, and the chamber neither gains nor loses heat through the walls.

"For the measurement of the differences of temperature, as well as for the warming and cooling, the walls of the calorimeter are considered as divided into four sections, viz.: (1) the top; (2) the upper half of the sides or

'upper zone'; (3) the lower half of the sides or 'lower zone'; (4) the bottom. The systems of thermo-electric elements for heat measurements, wires for warming and of water pipes for cooling, are each divided into corresponding sections.

"*The Observer's Table.* This is shown in Fig. 1078 at the left, in front of the brick pier. A shelf fastened to the pier and shown on the right of the latter, behind the table in the picture, holds the galvanometer and scale. The scale is seen in the picture at the front end of the shelf over the table. The galvanometer is at the other end of the shelf, two metres from the scale and obscured by the pier. On the table are the switches to bring the various circuits into connection with the galvanometer, and with them the Wheatstone bridges, and the banks of electric lamps for varying the heating currents.

"With the aid of the devices thus briefly described an experienced operator at the observer's table can easily control the temperature of B and make it follow the variations of the interior of the chamber very closely. When the rate of generation of the heat in the chamber is reasonably uniform and the temperature is nearly constant, the deflection of the image on the scale at the observer's table can usually be kept within one division of the scale, which means an average difference of temperature between the copper and zinc walls of less than .01° C. In ordinary experiments the difference is generally kept within this limit and seldom reaches .05°. The differences are both positive and negative, and are easily made to counterbalance each other during shorter periods and during the whole experiment.

"*Measurement of the Heat Carried Out by the Water Current.* The principle here employed is simple. The chamber neither gains nor loses heat by the air current nor through the walls. The current of cold water which passes through the heat absorbers inside the chamber is caused to enter at a temperature generally but little above the freezing point, and to flow out at such a rate as to absorb and carry off the heat just as fast as it is generated inside the apparatus. The temperature of the water is measured as it enters and as it comes out. The mercury thermometers are shown at G and H in Fig. 1079. The electrical thermometer indicates the difference of temperature between the incoming and outgoing water currents by the difference of resistance of two coils of thin copper wire, of which one is in each pipe at the place of entrance or exit from the calorimeter. The difference is measured by a Wheatstone's bridge on the observer's table. The mass of water is measured automatically by the apparatus shown below and at the right of the window of the respiration chamber in Fig. 1078.

"From the mass of the water which has passed through the absorber in a given time, and the rise in temperature, the quantities of heat brought out are readily calculated. To this is to be added a certain amount of heat which is carried away with the water vapor produced in the apparatus. This is practically the difference between the water vapor in the incoming and outgoing air. From the amount of this vapor, and its latent heat at the temperature of exit, the amount of heat it carries out is easily computed.

"*Metre Pump for Regulating, Measuring, and Sampling the Ventilating Air Current.* For taking samples of air for analysis, aspirators of 150 litres capacity were employed at the outset and are still used. The measurements with these have been found quite accurate.* The most satisfactory arrangement we have found, and one which serves the threefold purpose of maintaining the air current, measuring its volume and delivering aliquot samples of convenient size for analyses, is an apparatus designed and made by Mr. O. S. Blakeslee, and appropriately designated by him as a 'metre-pump.' The air coming from the discharge pipe escapes into the room, but by a special device the air of each fiftieth stroke is diverted into a receptacle, from which it is being constantly drawn for analysis.

"*Cooling Apparatus.* It is desirable that the ventilating current of air shall enter the respiration chamber as dry as possible. To this end it is cooled to a temperature of −19° to −22° C. (−2° to −8° F.), by passing through copper cylinders which are immersed in brine in the tank shown in Fig. 1078. The brine is cooled by use of an ammonia refrigerating apparatus.* The air after passing out of the cylinder is warmed before entering the chamber in the way described. On coming out of the chamber the air current is again passed through copper cylinders immersed in the brine, and thus practically all of the water which has been imparted to it within the chamber is removed. The same brine is used for cooling the current of water which passes through the absorbers and conveys away the heat from the chamber.

"*Analyses of Air, Determinations of Carbon Dioxide and Water.* The methods used for these purposes are essentially the same as described in the 'Report of the Storrs Experiment Station,' and 'Bulletin 44 of the Office of Experiment Stations of the United States Department of Agriculture,' above referred to. It will therefore suffice to say here that the larger part of the water is caught in the copper cylinders, immersed in the cooling brine as above described, and its amount found by weighing. The residue of the water of both the incoming and outgoing air current is determined in samples by passing through U-tubes containing pumice stone and sulphuric acid. The carbonic acid is in like manner determined by passing through U-tubes containing soda lime.

"In the ordinary experiments the determinations of water, carbonic acid, and heat are made for periods of six hours."

§ 5. CALORIMETRY IN PHYSIOLOGY.—*Heat Centres.*—In § 3 it was pointed out that the temperature of the body depended upon the balance between two factors: heat production and heat dissipation. We know that heat dissipation is dependent chiefly upon three factors: the supply of blood to the skin, the sweat, and respiration. The more blood in the vessels of the skin the more heat will be radiated off; the more sweat formed the more heat will be lost by the temperature of the sweat and by evaporation; the more vigorous the respiration the more heat will be lost in the expired air and by evaporation in the air passages. Each of these functions is dominated by a special centre or set of centres, the vaso-motor, the sweat, and the respiratory centre, respectively. The question has naturally arisen, How is it with heat production? We know that the nervous system controls the chemical activities of the tissues—is there a centre which dominates this control? If so, how? Are there centres which cause an increased oxidation of food with increased production of heat? Are there centres which inhibit this oxidation and thus decrease heat production? Are there specific nerves through which such centres act on the tissues? It is in the experimental investigations relative to these questions that the calorimeter has been most employed in physiology.

The method of experiment has usually been to produce a lesion of the central nervous system, or to stimulate a definite area; and to note the effect on the animal's temperature, or to measure the effect on heat production and heat dissipation by direct or by indirect calorimetry.

It is obviously not within our province to undertake a critical review of all the work done on a specific subject, such as heat centres. Besides, our information is at present in a state more or less chaotic, as has always been the case with work of this kind on the central nervous system. We need only recall the confusion which existed fifteen or twenty years ago regarding experiments on "localization" in the cortex, of the centres of motion, and of the special senses, to get a fair idea of the present condition of our knowledge regarding heat

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* See "Report of the Storrs Station for 1896," p. 91, and "Bulletin 44 of the Office of Experiment Stations of the United States Department of Agriculture," p. 19.

* See description of the arrangements for cooling in "Report of the Storrs Experiment Station for 1896," p. 92, and "Bulletin 44 of the Office of Experiment Stations of the United States Department of Agriculture," p. 22.

centres. The outcome of it all has been that to-day practically no one denies the more or less definite localization in the motor area, but few would still adhere to the extreme views of invariable sharp localization of a given centre at a given spot, especially in the lower animals. So with the heat centres. The chief bone of contention has been to determine just what was injured in a given operation, rather than to doubt the accuracy of the calorimetric method, although this has not escaped criticism. Then, again, different animals were used in different experiments, and discrepant results were obtained in this way, just as in the case of motor localization. At present we have every gradation, from Ott,[*] who locates six cerebral heat centres, two in the cortex and four in the basal ganglia, to Mosso,[†] who, after a full review of all previous work, and numerous experiments of his own, is unable to admit "that there are, in the brain, centres which preside over animal heat."

The first observer to call attention to cerebral heat centres was Tscheschichin,[‡] who, working with Du Bois Reymond, found that lesions of the medulla in the neighborhood of the pons Varolii were followed by a decided rise in temperature. His work was on rabbits, and he did not use the calorimeter.

This was followed by Lewizky[§] in 1869, and by Bruck and Günter[‖] in 1870, disagreeing with Tscheschichin, and by Schreiber,[¶] in 1874, agreeing, for the most part, with Tscheschichin, and disagreeing with Lewizky and with Bruck and Günter.

This was the status of the question in 1880, when Wood[**] published his elaborate calorimetric researches on fever. Wood found that "section of the medulla at its junction with the pons is followed by increased heat dissipation and heat production, the increased heat dissipation usually keeping pace with the increased production, so that the bodily temperature rises." Wood also found (p. 143) that "destruction of the first cerebral convolution in the dog, posterior to, and in the vicinity of, the sulcus cruciatus is followed at once by a very decided increase of heat production, while after irritation of the same nervous tract there is a decided decrease of heat production." Mild irritation of this region has no influence on blood pressure—its destruction likewise is without vaso-motor effect (p. 153); therefore it is fair to presume that this centre influences body temperature through heat production—not heat dissipation. These earlier researches of Wood were confirmed later by a joint research of Wood, Reichert, and Hare,[††] and by others, who find that there are thermogenic centres which affect the production of heat independently of blood pressure.

Ott,[‡‡] Richet,[§§] and Aronsohn and Sachs,[‖‖] working simultaneously and independently, all claim to have demonstrated the presence, in the brain, of centres which cause a rise of temperature by heat production. Richet and Ott used a calorimeter, Aronsohn and Sachs used the indirect method, determining both O and CO_2.

This work has in the main been supported by the later calorimetric experiments of Ott[¶¶] and of Reichert,[***] and of a number of others who have not employed the calorimeter. These observers, while differing as to the exact location of centres and as to the mode of their action, do agree, for the most part, that such centres exist. Reichert, in the work just quoted, has made an important contribution to our knowledge of heat centres in the spinal cord. He ascribes more importance to them than to those located in the medulla, basal ganglia, or cortex.

The only later writer who takes an iconoclastic attitude with regard to cerebral heat centres, and bases this opposition on experimental data, is Mosso; and he[*] rather leans toward a position advocated by Girard,[†] who says that we cannot speak of a thermogenic centre, but of many such centres scattered in the brain and spinal cord and working together. It is quite probable that, when the confusion now existing is cleared up by later investigations, this view will be found very near to the truth.

Those who wish to study this question more closely are advised to consult the papers of Wood, Ott, Reichert, and Mosso, here quoted; also papers by Hale White[‡] and Riegel.[§] White's paper in Guy's Hospital Reports gives interesting clinical data, which he says support the calorimetrical findings of Wood. The only clinical evidence quoted against cerebral heat centres is a case, reported by Dana,[‖] of a monster in which there was no cerebrum, basal ganglia, or cerebellum, and only part of the pons—yet the temperature was normal. This would support Reichert's theory that the cord centres were the most important.

To sum up briefly our knowledge of heat regulation and body temperature, we may say that the body temperature depends upon the balance between heat production and heat dissipation, each of which is directly controlled by the nervous system. Either of these factors may vary independently of the other, in either direction, so that body temperature may vary, as in fever, as the result of a change in either factor separately or of both acting together. Centres which control heat production are located in the cortex, basal ganglia, medulla, and cord. Some of these produce an increase in metabolism with a consequent increase of heat production, while some appear to diminish metabolism. These are usually regarded as inhibitory to the centres which cause metabolic activity. The spinal cord contains centres which influence heat production, and these are still active after being cut off from the medulla.

There is a marked co-ordination, so to speak, between the centres which control heat production and those which control heat dissipation, the two striking a balance, in warm-blooded animals, which keeps the body temperature practically constant at a certain point. It will be shown, in the following section, that in fever neither of these sets of centres is completely paralyzed, but that the balance is established at a higher point.

The heat-regulating mechanism is more delicate in man than in apes, as shown by the experiments of Lefevre,[¶] which are also of great interest in showing the reaction of the heat regulators of patients in a cold bath.

The Separation of Motor and Trophic Nerves by Calorimetry.—Every muscular contraction is accompanied by the production of heat. It is well known that the muscles are the tissues in which is produced the greatest part of the heat which maintains the body temperature. That this heat may be produced independently of muscular contraction is proved by the fact that the body temperature remains practically constant even when the muscles are at rest, as during repose or sleep. The question arises, Does the same set of nerves control muscular contraction and heat production, or do we have one set (motor) controlling muscular motion and another set (trophic ?) controlling the chemical changes (metabolism) which give rise to heat? The first calorimetric experiments to solve this problem were undertaken by Kemp.[**] Making use of the fact that the drug curare paralyzes only the *endings* of the *motor* nerves, while leaving the nerve fibres and the muscle cells intact,

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[*] Ott, N. Y. Med. Journ., 1889, vol. xlix., p. 247.
[†] Mosso, Arch. Ital. de Biol., 1890, vol. xiii., p. 459.
[‡] Tscheschichin, Arch. f. Anat. u. Physiol., 1866, pp. 169–175.
[§] Lewizky, Arch. f. path. Anat., 1869, vol. xlvii., pp. 356–359.
[‖] Bruck and Günter, Arch. f. d. ges. Physiol., 1870, vol. iii., pp. 578–584.
[¶] Schreiber, Arch. f. d. ges. Physiol., 1874, vol. viii., pp. 576–596.
[**] Wood, "Smithsonian Contributions to Knowledge," No. 357, p. 74.
[††] Wood, Reichert, and Hare, Ther. Gaz., 1886, p. 678.
[‡‡] Journ. of Nerv. and Ment. Dis., 1884, vol. ix., p. 141.
[§§] Richet, Arch. de Physiol., 1885, vol. vi., p. 496.
[‖‖] Arch. f. d. ges. Physiol., 1885, vol. xxxvii., p. 232.
[¶¶] Ott, Journ. of Nerv. and Ment. Dis., 1887–88; Ther. Gaz., 1887, p. 399; N. Y. Med. Journ., 1889, vol. xlix., p. 247.
[***] Reichert, Univ. Med. Mag., 1893, vol. v., p. 406, and 1894, vol. vi., p. 303.

[*] Mosso, op. cit., p. 463.
[†] Girard, Arch. de Physiol., 1888, pp. 326–328.
[‡] Hale White, Journ. of Physiol., 1890–91; Guy's Hospital Reports, 1883–84, vol. xxvii., p. 48.
[§] Riegel, Arch. f. d. ges. Physiol., 1872, vol. v., p. 629.
[‖] N. Y. Med. Journ., 1889, vol. xlix., p. 248.
[¶] Lefevre, Compt. rend. Soc. de Biol., 1894–95.
[**] Kemp, Therap. Gaz., 1889, pp. 86 and 155.

Kemp studied the effect of different-sized doses of curare on dogs, and found that small doses, just sufficient to paralyze the motion of muscles, still allowed the heat-regulating mechanism to function, and the body temperature to be kept up to the normal or even to rise. Larger doses, he found, caused a fall of body temperature and a diminution of heat production as recorded by the calorimeter. His conclusion was that since the nervous system could still control heat production after paralysis of the motor nerve, either the motor-nerve endings paralyzed by curare retained their grip on metabolism after losing it on motion, or, what was more probable, there were two kinds of nerves, the motor and the trophic; the former being paralyzed by a small dose of curare, while the latter required a larger dose to throw them out of function. Two years later Reichert,[*] as part of an extended research on the rise of temperature produced by cocaine and caffeine, made a number of experiments covering the same ground as Kemp. The two sets of experiments were not under exactly the same conditions, and the results were not absolutely in harmony. The main point of difference lay in the effect of *large* doses of curare. Reichert found that these sometimes produced a fall in heat production, thus agreeing with Kemp; but in other instances he found the heat production could be kept up to the normal or even increased. The observations of both, however, are in thorough accord on the main point involved, viz.: that the heat-regulating mechanism can work through nerves which still function after the motor-nerve endings are completely paralyzed. Reichert also added the interesting observation that cocaine fails to produce its characteristic effects in animals even lightly curarized, while caffeine can still produce an increase in heat production and temperature, though its effects are somewhat modified (p. 250).

Mosso,[†] in working with curarized dogs, found that a dose of strychnine caused a rise of temperature. He did not use a calorimeter in these experiments. Reichert[‡] repeated these experiments and found that strychnine may produce an increase in heat production even when the animal is paralyzed by curare, which is an additional evidence for the theory that nerves, other than the motor, control metabolism in muscles. Reichert finds, however, that the rise of temperature is due more to lessened heat dissipation than to heat production.

Relation of Heat Production and Heat Dissipation to Daily Variations in Temperature.—Every clinician is familiar with the daily fluctuations in body temperature, both in health and in fever. A number of observations have been made on animals and on man to see whether there is a diurnal variation in heat production. Most of these have been by the method of indirect calorimetry, and all unite in showing the profound influence of *digestion* on the heat produced. Fredericq, for example, found the maximum absorption of oxygen to be at 10 A.M. and at 2 to 3 P.M. Vierordt, Langlois, and Ott all agree that the period of maximum heat production is about this time. Fredericq noticed that in a starving man these maxima did not occur, and Langlois found that heat production may rise thirty-five to forty per cent. after a meal. Though we may feel warmer after a meal, it is well known that there is no actual rise of temperature, as shown by the thermometer, whereas the evening rise and morning fall occur, in a well-fed man, whether a meal be missed or not.

Carter,[§] in Ott's laboratory, undertook an investigation of the relation of heat production and heat dissipation to this interesting phenomenon. His experiments were made on dogs, cats, and rabbits, both normal and with fever. He first established the fact that these animals have practically the same daily fluctuations of temperature as man, the maximum temperature occurring from 7 to 11 A.M., and the minimum from 7 to 11 P.M. As the result of his calorimetric observations, he found that "the maximum and minimum of heat production and heat dissipation do not occur synchronously with the maximum and minimum of animal temperature. The two are entirely independent of each other"; also, "the heat production and temperature are entirely independent of each other." This was true in fevered animals as well as in healthy ones. There is no paradox in these results, for we must recall, as shown in § 3, that the temperature depends upon two factors, heat production and heat dissipation, and that either or both of these may vary, at the same time, in either direction. What Carter's researches show is the interesting fact that there is something in the body of mammals which causes the balance between heat production and heat dissipation to be established on a different level at different times of the day, and that this something does not reside in the centres which control heat production, nor does it reside in those which control heat dissipation.

Lichatschew[*] found a closer relation between heat production and diurnal variations of temperature than was found by Carter.

Relation of the Size of an Animal to the Amount of Heat Produced.—As this is a subject of interest less from a medical than from a biological standpoint, and as its discussion would require considerable space, it will not be entered into here.

Most investigators give as a general law, that, *ceteris paribus*, the heat produced by an animal is directly proportional to the cube root of the square of the weight, while Reichert thinks that "if any distinct relation exists between body weight and the quantity of heat produced it is in direct proportion."

Those interested in studying this question more closely are referred to papers by Rosenthal,[†] Reichert,[‡] and Richet,[§] the latter of whom takes up a discussion of the effect of artificial conditions of the skin, such as shaving an animal, coating it with oil, clothing, etc.

§ 6. CALORIMETRY IN PATHOLOGY.—The chief use of calorimetry in pathology has been in connection with the study of fever. Some interesting results have also been obtained from investigating the effects on the system, of the products of the growth of specific micro-organisms; these latter will be taken up in § 7, on "calorimetry in experimental pharmacology," so that the present section will deal only with calorimetry in fever.

Lavoisier's theory, that animal heat resulted from combustions in the body, gained general acceptance about the beginning of the nineteenth century, and from that time until 1863 there was a strong feeling among pathologists that pyrexia was the direct result of abnormally great oxidation in the body. The conflicting theory put forward in 1863 was that of Traube,[‖] who attributed the pyrexia to *retention* of body heat, due to a constriction of blood-vessels in the skin, the result of which was to keep the heat of the blood from being lost by radiation at the surface. Traube's chief opponent at this time was Liebermeister, who attributed the rise in temperature to an increased heat production, denying that an increased heat retention ever took place.

Numerous experiments have been made by indirect calorimetry, to determine whether there was an increased oxidation of food or of the tissues in fever, and the oxygen used, the CO_2 given off, and the nitrogenous waste excreted have all been taken into account. The results of these researches have not been in harmony, but from some of the most trustworthy we would gather that while the fever is on the rise, there is an increase in the oxygen used and the CO_2 given off, while the opposite is true for the decline of pyrexia. While the fever remains constant more oxygen is used and more CO_2 is given off than in health (nutritive conditions being the same), but there is not as high a percentage increase as when

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[*] Reichert, Therap. Gaz., 1891, pp. 151, 242.
[†] Mosso, Virch. Arch., vol. cvi., p. 80.
[‡] Reichert, Therap. Gaz., 1892, p. 386.
[§] Carter, Journ. of Nerv. and Ment. Dis., 1890, vol. xvii., p. 785.

[*] See Richet's "Dictionnaire de Physiol.," vol. iii., p. 135.
[†] Rosenthal, Arch. f. Physiol., 1889, p. 31.
[‡] Reichert, Univ. Med. Mag., 1890, vol. ii., p. 225.
[§] Richet, article "Chaleur," in Richet's "Dictionnaire de Physiol.," Paris, 1898, vol. iii., pp. 127–138.
[‖] Traube, Allgem. med. Centralzeitung, 1863–64.

the temperature is rising. Most observers found that the respiratory quotient (vol. $CO_2 \div$ vol. O) is the same in fever as in health, but Regnard,[*] one of the most competent, says that it is diminished, which would mean that the character, as well as the amount, of metabolism was affected in fever.

Such experiments as these give valuable information about the chemical processes in the body during fever, and show that in fever there is increased oxidation, and hence increased heat production, as a rule; but they do not settle the question at issue between Liebermeister and Traube, viz.: "Does heat dissipation enter as an essential factor?" This can be answered only by direct calorimetry, as pointed out by Senator[†] when he undertook the first thorough series of investigations on the subject.

Leyden had already made this question the subject of calorimetric research, but his method was the unsatisfactory one of partial calorimetry by baths.[‡] His results, however, were in harmony with those of Senator and of Wood, in 1880, the latter's experiments being the most complete we have in calorimetry on fever. These observers all find that both heat production and heat dissipation play an important part in fever, thus showing that each of the older theories of Liebermeister and of Traube was partly right, but neither entirely so. This position has been substantiated by practically all later investigations. Our present views concerning the general pathology of fever cannot be better given than by the following quotations from some of the numerous generalizations of Wood:[§]

(*a*) "The rise of temperature in fever is not dependent altogether upon increased heat production, as in fever there certainly is sometimes less production of heat in the organism than there is at other times when the bodily temperature remains normal; also excessive heat production may occur even at the expense of the accumulated materials of the organism without elevation of the body temperature."

(*β*) "In fever a daily temperature variation occurs which is parallel to that seen in health, and differs from the normal variation only in having a higher mean."

(*γ*) "In fever vaso-motor paralysis, when produced, is followed by an immediate fall of temperature similar to, but greater than, that which is produced by a like disturbance in health."

(*δ*) "The decrease of heat production which follows section of the cord is much greater in the fevered than in the normal animal."

(*ε*) "The so-called inhibitory heat nervous system is not paralyzed in fever, but is less capable than in health of answering promptly and powerfully to suitable stimuli; in other words, it is in a condition of paresis or partial palsy."

(*ζ*) "The clinical succession and phenomena of a febrile paroxysm, such as that of an intermittent, seem plainly to depend upon the nervous system for their arrangement and relation."

(*η*) "Irritative fever, if it exists, is produced by an action of the nervous system."

(*θ*) "Fever occurring in cases of blood poisoning is often, and probably always, the result of a direct or indirect action of the poison upon the nervous system, and hence is a neurosis."

According to Mosso,[‖] there are two kinds of fevers: one produced by the nervous system, and one independent of the nervous system, which has its origin in the tissues themselves. He claims that cocaine produces fever through the nervous system; while cultures of staphylococcus pyogenes aureus, injected into the blood, produce fever by direct action on the tissues. He has found that chloral will prevent the rise of cocaine fever, but is without effect on the fever produced by the staphylococcus.

This question of the probable different origin of different fevers is an exceedingly interesting one, and would afford a fruitful field for further research. Certain drugs will influence one kind of fever but not another, and a careful study of this question would throw light not only on the action of drugs, but on the pathology of fever itself.

Before leaving the subject of calorimetry in fever, two clinical papers should be mentioned, since each was written with direct reference to previous calorimetric work, and deal with the relation of the nervous system to fever. After reading them, one can scarcely doubt that "fever of purely nervous origin" exists. The papers are those of Drs. Hale White and Mary Putnam-Jacobi.[*] White,[†] after a masterly review and synopsis of fourteen cases of lesions of the central nervous system, with clinical history and post-mortem findings, concludes that the results of Wood's experiments on dogs are corroborated by clinical and pathological observations on man.

§ 7. CALORIMETRY IN EXPERIMENTAL PHARMACOLOGY.—In this section it is not proposed to discuss the physiological action of the drugs and poisons considered, but simply to show which of these substances have been investigated by direct calorimetry, and what direct calorimetry has done for medicine along this line. Unfortunately, many of the findings which will be mentioned are based upon too few experiments, so that the value of this section will be to call attention to work thus far completed, and needing, for the most part, corroboration, rather than to show positively established facts in connection with the drugs or poisons. Only researches employing direct calorimetry are mentioned.

DRUGS.

Antifebrin.—Hare[1] finds that antifebrin reduces normal temperature, and in so doing affects both heat production and heat dissipation.

In fever it reduces pyrexia chiefly by decreasing heat production. It seems to have little effect on pepsin fever (see Pepsin, this section).

Antipyrin.—Wood, Reichert, and Hare[2] find that antipyrin lessens heat production independently of any action on the circulation. They think it influences the chemical changes in the body through the nervous system, especially the heat-inhibitory centre.

Girard[3] found that a lesion (*piqûre*) on the median side of one of the corpora striata produced less effect after giving antipyrin than before.

Martin[4] destroyed Ott's inhibitory heat centre, and found that antipyrin produced an increase of heat dissipation, the same dose not always giving the same quantitative results. Heat production was reduced in four out of six cases. He compared hydroquinone, antipyrin, thallin, and kairin, and all gave the above result. "As a rule, heat production followed heat dissipation, in its ups and downs, although the drugs sometimes reversed matters," especially antipyrin.

Gottlieb[5] attributes the fall of body temperature, after antipyrin, exclusively to increased heat dissipation. He says there is no concomitant diminution in heat production.

Atropine.—According to Ott,[6] atropine causes increased heat production and increased heat dissipation, the effect on heat production being the greater—consequently temperature rises.

Lewis[7] finds that small doses of atropine produced increased heat production and diminished heat dissipation, while with large doses the temperature fell with increased heat dissipation in spite of increased heat production.

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[*] Regnard, "Recherches expérimentales sur les variations pathologiques des combustions respiratoires," Paris, 1878.

[†] Senator, "Untersuchungen über den fieberhaften Process," etc., Berlin, 1873, p. 2.

[‡] See § 4, "Calorimetry by Baths."

[§] Wood, "Fever: A Study in Morbid and Normal Physiology," Philadelphia, 1880; also "Smithsonian Contributions to Knowledge," No. 357, pp. 254 et seq.

[‖] Mosso, Arch. Ital. de Biol., 1890, vol. xiii., p. 483.

[*] Jacobi, Journ. of Nerv. and Ment. Dis., 1890, vol. xvii., p. 373.

[†] White, Guy's Hospital Reports, 1883–84, vol. xxvii., p. 48.

Caffeine.—Reichert[8] finds that, under caffeine, heat production is always increased, while heat dissipation is not affected in any constant way. Curare modifies but does not check the action of caffeine.

Carbolic Acid.—Hare[1] (p. 525) gives a summary of his work with carbolic acid as follows: "Carbolic acid possesses considerable power in lowering normal bodily temperature. It possesses more influence over pyretic temperature than does salicylic acid, generally preventing a rise or causing a fall of temperature, but sometimes failing to do so. Its mode of decreasing normal bodily temperature is as yet not fully understood, although it would seem probable that it acts on both heat functions. When reducing bodily temperature in fever, it acts chiefly by decreasing heat production, although it affects both functions."

Chloral.—Bevan Lewis[7] says: "Hammarsten's statement that the rapid fall of temperature is dependent upon diminished heat production . . . is, I consider, fallacious; in fact, all my observations tend to confirm the statement previously made, viz., that the heat production is greatly increased, and that the fall of temperature is really dependent upon the increased dispersion of heat from the body, ensuing from exposure during very general vascular dilatation."

Cocaine.—As the result of a very complete research Reichert[9] finds that cocaine increases both heat production and heat dissipation. Its action on heat production is much the greater, so that temperature rises. Curare seriously interferes with the action of cocaine.

Curare.—See experiments of Kemp and of Reichert, § 5, Calorimetry in Physiology.

Ergotine.—Ergotine, according to Bevan Lewis,[7] produces a fall in heat production, with fall in temperature, followed by a rise in both.

Hydroquinone.—See Martin's[4] "Researches on Antipyrin," above.

Hyoscyamine.—Bevan Lewis[7] found that hyoscyamine always produced great commotion in heat production and heat dissipation, but no constant effect could be ascribed to it.

Kairin.—See Martin's "Researches on Antipyrin," above.

Neurin.—Ott[10] found that neurin produced fever by action on the nervous system independently of the circulation.

Pepsin.—Many forms of commercial pepsin, when rubbed up with water or salt solution, and injected into the blood, produce a decided fever apart from their action on the circulation. This fever is the result of an effect on both heat production and heat dissipation, the former being the more affected. The active substance in these cases is not pepsin, but proteoses and peptones, which are found along with the pepsin (see Ott,[10] and Wood, Reichert, and Hare[2]).

Peptone.—See Pepsin, above.

Proteoses.—See Pepsin, above.

Phenol.—See Carbolic Acid, above.

Picrotoxin was found by Bevan Lewis[7] to increase, enormously, heat production. The effect lasted longer than that of strychnine. Heat production then fell to a minimum just before convulsions set in.

Quinine.—Wood, Reichert, and Hare[2] investigated the action of quinine with the calorimeter, and found both heat production and heat dissipation to be affected. We quote them as follows: "We do not think that our results are sufficient to positively determine whether heat production or heat dissipation is the function which is primarily influenced." They think that quinine's chief value is due to its "stimulating or restoring the normal tone of the centres which are connected with thermogenesis, so as to enable them to resist the morbific fever-producing influences.

Another author[*] finds that doses of 0.1 to 0.2 of quinine lower the heat production in rabbits. In normal animals the diminution is from eight to eighteen per cent., in animals with fever from *piqûre* the diminution may be as high as forty per cent.

Salicylic Acid.—Hare[1] finds that salicylic acid can reduce normal temperature slightly; it has little power over the temperature in fever. In reducing normal temperature it probably acts on both heat production and heat dissipation; its action on fever is uncertain and irregular.

Solanine.—This alkaloid was studied by Bevan Lewis,[7] who found that its vaso-motor effect produced diminished heat, dissipation of heat, with consequent rise of temperature. This rise took place in the face of an enormously reduced heat production.

Strychnine.—Bevan Lewis[7] found that strychnine increased heat production—the best effects were from small doses. Chloral counteracts the effect of strychnine.

Thallin.—Martin[4] found that thallin regularly increased heat dissipation, but had no constant effect on heat production (see also Antipyrin, above).

BACTERIAL POISONS.

Tuberculin.—D'Arsonval and Charrin[*] found that tuberculin raised the rectal temperature and at the same time diminished heat production.

Pyocyaneus (bacillus).—Certain poisons produced by this bacillus had the same effect as tuberculin mentioned above.[*]

Pyogenes aureus (staphylococcus).—See account of Mosso's work in § 6, Calorimetry in Pathology.

George T. Kemp.

[1] Hare, Ther. Gaz., 1887, p. 389.
[2] Wood, Reichert, and Hare, Ther. Gaz., 1886, p. 811.
[3] Girard, Rev. méd. de la Suisse Romande, 1887.
[4] Martin, Ther. Gaz., 1887, p. 289.
[5] Gottlieb, Arch. f. exp. Path. u. Pharm., 1891, vol. xxviii., p. 184.
[6] Ott, Ther. Gaz., 1887, p. 514.
[7] Bevan Lewis, West Riding Asylum Reports, 1876, vol. vi., pp. 43–64.
[8] Reichert, Ther. Gaz., 1891, p. 249.
[9] Reichert, Univ. Med. Mag., 1889, vol. i., p. 448; and Ther. Gaz., 1891, p. 249.
[10] Ott, Journ. of Nerv. and Ment. Dis., 1884.

CALYCANTHUS.—(Properly *Butneria.*)—A genus of three species of shrubs in the family *Calycanthaceæ*, growing in the United States. The bark and leaves of *B. fertilis* (Walt.) Kearney, commonly known as the sweet-scented shrub or strawberry shrub, are used in domestic practice as an antiperiodic. The plant is chiefly of interest because of the poisonous nature of the seeds, sheep being killed by eating the fruit. An alkaloid, calycanthine, has been extracted by Dr. R. G. Eccles from these seeds.

H. H. Rusby.

CAMDEN, S. C.—Situated in the pinewood, sandhill region of the State, about 30 miles from Columbia and twenty hours from New York. It is a town of 3,500 inhabitants, between 150 and 200 feet above sea level, and is a winter health resort particularly suitable for cases of pulmonary tuberculosis. The soil is very dry and porous, so that after a heavy shower the roads are not wet, the water quickly soaking into the sandy soil. The water supply and drainage are said to be good and the accommodations excellent, there being two hotels and a number of boarding-houses. The climatic data are as follows:

Mean temperature (Fahrenheit): spring, 61.90°; summer, 79.32°; autumn, 62.26°; winter, 45.16°. Average annual rainfall for twenty years, 42.22 inches. The coldest noon temperature in February, 1890, was 50°; in March, 40°; in April, 50°. The warmest noon temperature was: in February, 83°; in March, 81°; in April, 86° (Solly). The prevailing winds are south and southwest. In February and March there are some high winds, but generally the air is remarkably soft, dry, and balmy.

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[*] These observations were found among the writer's notes without a reference to the original paper.

[*] D'Arsonval, Arch. de Physiol., 1894, p. 362.