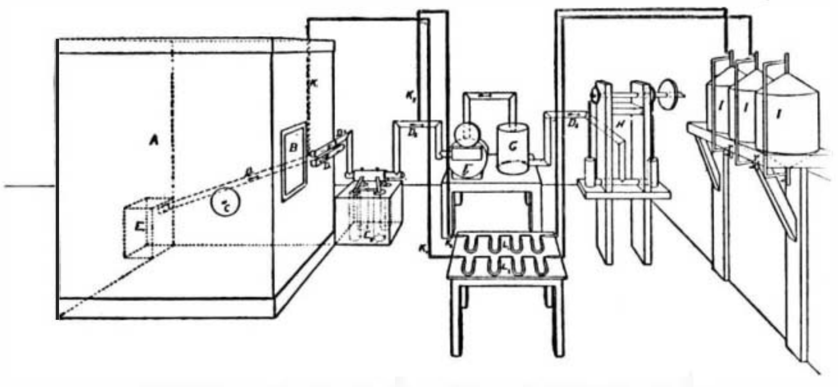
CONSERVATION OF ENERGY IN THE HUMAN BODY.

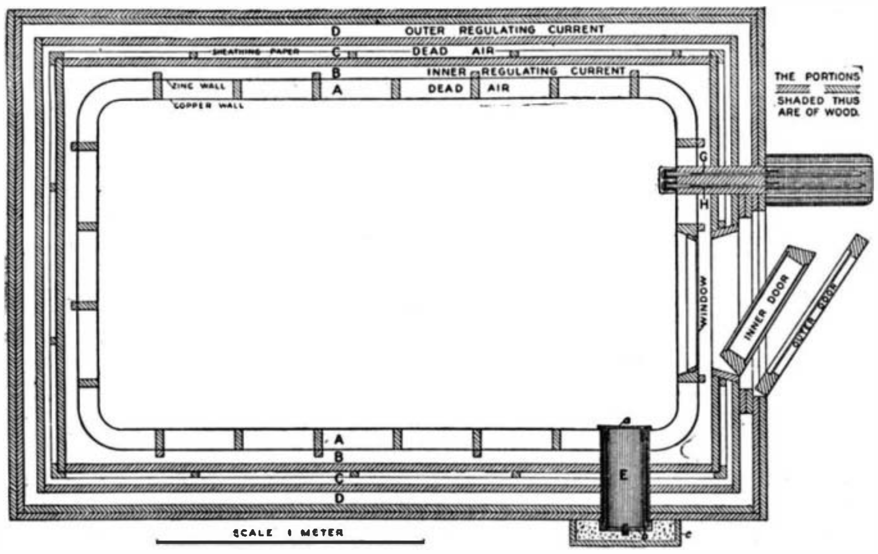
For several years Prof. W. O. Atwater, of Wesleyan University, and his assistants, have been carrying out some remarkable experiments relative to food and diet, viewed from a strictly scientific point of view. The results of their investigations have been published by the Department of Agriculture and by the Storrs Agricultural Experiment Station of Connecticut. Through the courtesy of Prof. Atwater and the office of the experiment stations of the United States Department of Agriculture, we are enabled to present an illustrated description of a respiration calorimeter which has been of the greatest assistance in making experiments on the conservation of energy in the human body. The purpose of the apparatus is to study, among other things, the conservation of matter and the conservation of energy in the animal organism. Viewed from the more practical standpoint, the object is to get more accurate information than we now have regarding the fundamental laws of animal nutrition, the uses of food in the body, the nutritive value of food materials, and the ways of fitting our food to the demands of health, work, and purse. The energy of the income is the potential energy of compounds of food and drink. The energy of the outgo is of two kinds, the potential energy of the incompletely oxidized materials excreted, especially by the intestines and kidneys, and the kinetic energy given off from the body in the forms of heat and external muscular work. This leaves out of account other forms of energy which may be given off from the body. The name by which the apparatus is called, "respiration calorimeter," is suggested by the fact that it is essentially a respiration apparatus with appliances for calorimetric measurements. 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 apparatus includes, first of all, a room or chamber in which the subject remains during the experiment. It is furnished with a folding chair and table for use during the day, and a folding bed for use at night. When the experiment involves muscular work, a stationary bicycle specially arranged for measuring the work 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 an 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 introducing food and drink into the chamber and for removing the excreta, and for preventing 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, being the reverse process by which houses are heated by hot water. In this case the radiators become absorbers. By regulating the temperature of 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. The amount of the outgoing water and its temperature are measured, thus determining the heat carried away. Our large engraving is made from a photograph of the apparatus and does not show the pump and the aspirators used for moving, measuring, and sampling the ventilating air current, and the refrigerating machine is also not shown.

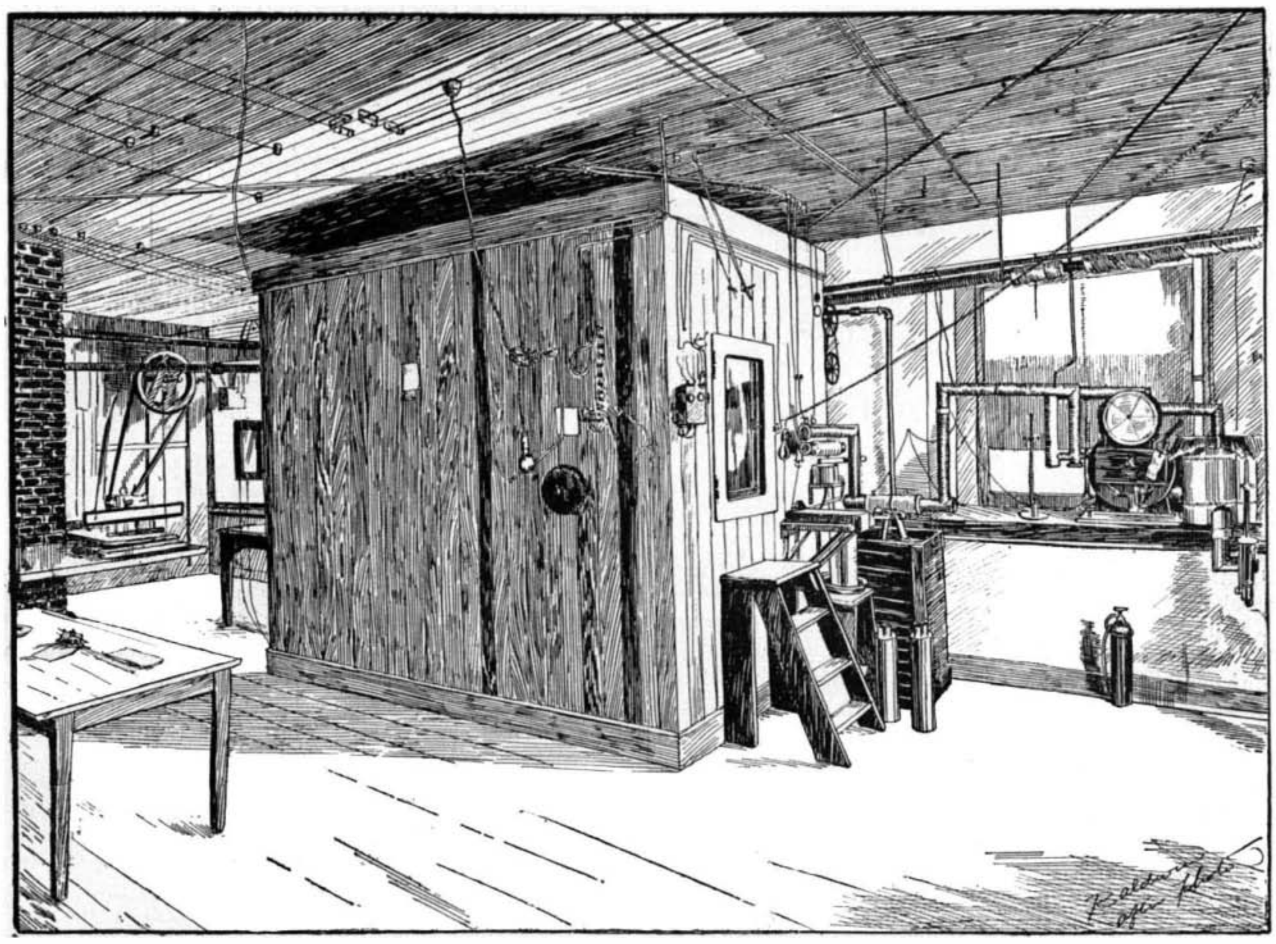
At the end of the chamber on the right is seen the glass door which serves as a window. To the right and just below it are the arrangements for cooling and for measuring the current of water which brings away the heat from the interior of the chamber. At the left in front of the brick pillar is a table at which the observer sits to record the temperature of the interior of the apparatus and of the currents of air and water. The refrigerating machine, which is behind the pillar, cools a solution of calcium chloride contained in a tank not shown in the engraving. The ventilating current of the air before it enters the chamber is passed through copper cylinders which are immersed in brine in this tank. The air is cooled to a temperature of from —2° to —8° F. At this low temperature nearly all of the water is removed from the air, so it enters the chamber quite dry. Just before entering the chamber at the right of the glass door it is warmed to the temperature of the interior of the chamber. The outgoing air is drawn from the upper left hand corner of the rear end of the chamber and then downward and out by the tube shown prominently in our diagram.



OUTLINE SKETCH OF RESPIRATION CALORIMETER.



HORIZONTAL CROSS SECTION OF RESPIRATION CALORIMETER.



ATWATER AND ROSA'S RESPIRATION CALORIMETER.

In coming out of the chamber, the air passes through another freezing apparatus shown as a square block in our outline sketch. Thus it passes through the meter, *F*, by which its volume is measured, and onward to the air pump, *H*. A tension equalizer, *G*, is placed between the pump and the meter. The respirators for sampling the air are shown at the extreme right.

The plan of the respiration chamber will be readily understood by reference to the cross section. The interior is 7 feet long, 6 feet 4 inches high and 4 feet wide, the corners being rounded. The cubic content is 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, so that all the air which comes in and goes out can be measured. There is a zinc wall 3 inches outside the copper wall. This metal chamber is the calorimeter proper and is supported by a wooden framework in the open space. In order to protect it from the fluctuations of the temperature of the room in which it stands, it is inclosed within three concentric walls of wood. Between the zinc and the innermost wooden wall is an air space of 2 inches wide. Between this wall and the next is a third air space of 2 inches, and finally a fourth air space of equal size. The wooden walls are made of matched pine covered with sheathing paper. The outer wall is double, with sheathing paper between. The air in the spaces, A and C, is dead air, while in the spaces, B and D, the air can be kept in constant circulation by means of rotary fans in boxes outside. It is thus possible to regulate the temperature with wonderful accuracy, the outer air current, D, being used for the coarser regulation of the temperature and the space, B, for finer regulations. The walls are provided at the right with a glass window and a door. At E is a copper cylinder which goes through all of the walls and the chambers. It is 6 inches in diameter, and serves for passing food and other materials in and out of the calorimeter chamber. Communication with the subject in the chamber is rendered easy by means of a telephone.

Measurements of the temperatures are made in part by mercury thermometers, but mainly by electrical methods. There are five electrical thermometers in different parts of the chambers, and the measurements are so delicate that even the 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. 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 and four pairs distributed over the sides, top and bottom. The difference of temperature of the two walls is made as small as possible by warming or cooling the air in the space, B. On the observer's table is a galvanometer and scale Wheatstone bridges, and banks of electric lamps, for varying the heating currents and switches to bring the various circuits into play. In front of the table is the record book for noting the observations, which are very numerous. With the aid of the devices which we have so briefly described, the experienced operator at the observer's table can easily control the temperature of the space, B, and make it follow the variations of the interior of the chamber very closely. The current of cold water which passes through the heat absorbers inside the chamber is but generally little above the freezing point, and it is arranged to flow at such a rate as to absorb and carry off the heat 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 volume of water is measured automatically by a proper apparatus. We have already referrd to the meter pump, which regulates. measures, and samples the ventilating air currents. We have also referred to the cooling apparatus.

For each experiment, which usually occupies several days, a diet is selected such as has been found by previous experiments to meet, as nearly as may be, the needs of the person under experiment. Most of the materials, and specially the meats, are prepared in advance, and are kept in cans after sterilizing, if necessary. In putting up bread for use, the crust is removed and the crumb is cut in small pieces and likewise canned. The butter is carefully weighed and put in small cups, and everything else is done in the same way. Samples of everything are taken for analysis. The determinations made are in general for water, carbon, hydrogen, nitrogen, ether extract, ash, and heat of combustion. A careful measurement and analysis is made of the excretory products. In the first or preliminary period of four days these analyses are made, the data sufficing for a digestion and nitrogen metabolism experiment, and on the evening of the fourth day the subject enters the respiration chamber, although the actual respiration calorimeter experiment does not begin until seven o'clock on the morning of the fifth day. A night's sojourn in the apparatus suffices to get the temperature of the air in the apparatus and its content of carbonic acid and water in equilibrium, so that accurate measurements may begin with the morning of the fifth day and continue until seven o'clock on the morning of the ninth day, thus making the duration of this experiment exactly four days. The man weighs himself on a small Fairbanks platform scale specially made for the purpose.

The report of the Storrs Agricultural Experiment Station, and also the reports of the Department of Agriculture, are filled with most interesting tables giving the results of the various experiments, which we cannot reproduce here. In our SCIENTIFIC AMERICAN SUPPLEMENT, Nos. 1210 and 1212, further information on food experiments will be found.

The following is a summary of the results of certain experiments. The purpose of the preliminary period of four days was to bring the body into at least approximate nitrogen and carbon equilibrium with the food and to make the determination of the amounts of nutrients absorbed as nearly accurate as practicable. The income and outgo of the nitrogen were determined during this period, which thus amounted to a digestion and metabolism experiment. The metabolism of nitrogen, carbon, hydrogen and energy was determined during the final period of four days. In one of the two experiments the man had as little muscular exercise as he could well have with comfort. In the other he was engaged in quite active muscular exercise. The external muscular work was expended in driving a dynamo which produced an electric current. The latter was passed through a resistance coil, and the energy was transformed into heat which was measured with that given off from the body. The difference between the income and outgo of energy as measured in these two cases was 3·2 and 1·1 per cent, and averaged 2·2 per cent. The amount of energy as measured was in each case less than the theoretical amount of potential energy in the material consumed. On the whole, the theoretical amounts of energy transformed and those found in the experiments is as close as could be expected under the circumstances. The experiments do not demonstrate completely the conservation of energy in the normal organism. They do, however, approach very closely to such demonstration.

The study of human nutrition is very important, and it is expected that in time, with the aid of the experience thus far gained, apparatus may be planned for experimenting with small animals, as sheep and dogs. If in turn this effort should prove successful, the next step will be to devise apparatus and methods for experiments with larger animals, such as horses, oxen, and cows. It may be asked what is the advantage of such minute and painstaking experiments, which are, necessarily, carried out at great expense. There are really few problems of more importance than that of nutrition, either as relating to man or animals. A better knowledge of these laws with reference to animals is needed as a foundation for proper understanding of practical problems which the farmer has to meet in the feeding of his stock.

The work of Prof. Atwater and his able assistants is being watched with interest by those who appreciate the serious and important nature of economic problems.

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ACCORDING to a recent Consular Report, there are eighteen locomotive factories in Germany ; fifteen of them build full-sized locomotives, and three build engines for light railways, steel works, etc. The total output of the factories is 1,400 per year. The combined working force is more than 15,000 men. German locomotives are exported to nearly every country in Europe, and also to some extent to Asia, Africa and South America. Up to the present time no locomotive **from the United States has entered Germany.**

Correspondence.

Use of Scientific Terms.

To the Editor of the SCIENTIFIC AMERICAN :

Is it not a matter of some surprise that modern scientific writers still cling to the use of obsolete names? Take for instance the term "Carbonic acid," or as it is sometimes written, "Carbonic acid gas," for the compound now more properly designated as carbon-dioxide, whose symbol is CO_2. Chemists have entirely discarded the use of the former names as being inaccurate, and now apply only the latter. There is, of course, another compound formed by the union of carbon-dioxide and water, which is the true carbonic acid. Its symbol is H_2CO_3. While difficult or perhaps impossible to isolate on account of its extreme instability, it is as positively known to be an acid as nitric acid or sulphuric acid, since from it are formed the primary and secondary carbonates of the metals represented by $MHCO_3$ and M_2CO_3.

Authors of late texts in chemistry all recognize this important distinction ; but such writers as Gage, Hopkins, Carhart, Chute and others, in their works on physics, and Tarr, in his otherwise admirable text on elementary geology, do not seem to have paid much attention to it. Some, or it may be all, of them recognize the modern name carbon-dioxide, but they still cling tenaciously to the use of the old.

Would it not be better for all scientific men "to mind the same thing" and be strictly accurate? Science is nothing if not truth. W. B. BONNELL.

Wesleyan College, Macon, Ga., July 11, 1899.

Protection Against Electric Storms.

To the Editor of the SCIENTIFIC AMERICAN :

At the present time there seems to be much said about tornadoes, or electrical storms, and their great destructiveness, and as I have given considerable thought to this subject for many years past, I believe that much can be done to lessen their disastrous effects.

As long ago as 1855 I began the study of atmospheric phenomena, and studied in various ways the atmospheric currents, electric and otherwise, for a number of years, with the view of establishing a weather bureau.

In the year above referred to, I was in Minnesota and observed one of these electrical storms in operation ; it was on the west of the Mississippi River, and had evidently come from a long distance. It passed through a primitive forest of immense growth just before reaching the river, and every tree, for nearly 1,000 feet wide and as far as I could see, was leveled to the ground as completely and evenly as though felled by the woodman's ax. I also noticed that this storm did not cross the Mississippi, but when it reached the stream it disappeared, the timber on the other side of the river not being disturbed at all.

In my studies since that time I have been more and more convinced that whenever these electrical storms reach large bodies of water they become dissipated—the electric current being taken up in the water. I have known small streams to be entirely dried up, and the water taken from them, when the water was not in sufficient amount to take up the current.

Observation from that day to this has led me to conclude that partial, if not full, protection to cities and towns can be obtained by the erection on the west and southwest of large copper or other metal conductors, strung upon steel or iron poles, and at intervals sunk deep into the earth—where water can be reached—these heavy electric conductors preferably of copper. When an electrical storm strikes these conductors, it will be taken up, as is often the case in telegraph lines, where I have known dozens of poles to be torn to pieces by one flash of lightning, while if made of steel and occasionally connected deep into the earth with water, the current would have been carried away and the damage averted.

Another and perhaps more effective method of carrying off these great bodies of electric currents contained in what is known as "whirlwinds," which form the worst kind of cyclones, would be to bond the rails of railways with copper—the same as electric railways for return currents—and occasionally sinking hundreds of feet into the earth (if need be to reach water) large copper or other metal conductors. This could easily be done without injury to a railway, perhaps at the expense of the county or State. The railways running in a line nearly north and south would be the most likely to absorb these currents, as nearly all tornadoes come from either the west or southwest, and where crossing these lines would be absorbed and conducted silently and harmlessly into the earth. Scarcely any railway extends very long distances without crossing either bodies of water or points where water can be reached ; and if the conductors from well-bonded rails reach water, even many miles from the point where an electric storm strikes, it would be absorbed and carried to that point ; but the more frequently water could be reached, the more effective would be this method of **carrying away surplus electricity causing these storms.**

It will be noted that this is only on the principle of the lightning rod—too many of which are defectively installed.

In this connection it will be understood that it is just as important to sink large conductors deep into the earth along the line of railways or other metal used as an electric conductor, in order to reach moisture, otherwise such bonding would not convert the railway into a safety guard any more than the ordinary electric road of to-day, which seldom has and does not so much need deep ground connections.

Pasadena, Cal., July 7, 1899. T. S. C. LOWE.

THE PEARL-BUTTON INDUSTRY OF THE MISSISSIPPI RIVER.

BY HUGH M. SMITH.

The business of making buttons from the shells of our native fresh water mussels is of quite recent origin, but has already reached comparatively large proportions and seems destined to have further growth. The fear is entertained, however, that, through indiscriminate fishing methods, the supply of mussels may be so seriously reduced that the continuance of the industry may be imperiled. The possibility of the early exhaustion of the mussel beds in that part of the Mississippi River which is in Iowa and Illinois led a number of interested persons to request the United States Fish Commission to make an investigation of the subject, as that is the section in which the business is more extensive and has been longest established. A comprehensive report[*] on the industry which has been prepared by the writer is about to be published by the Commission.

The manufacture of buttons from the shells of native fresh water mussels began in the United States in 1891, the inauguration of the business being made possible by the high duty on imported buttons imposed by the tariff bill of 1890. The first person to engage in this business was Mr. J. F. Boepple, who had for many years been similarly engaged in Hamburg, Germany. On account of an abundance of suitable mussels in its vicinity, Muscatine, Ia., was selected as the site of the first factory and has now become the leading center. Other towns on the Mississippi and its tributaries from time to time established works, until in 1898 there were twenty-one communities in Iowa and Illinois in which buttons were made. A remarkable development of the business occurred in 1898, no less than thirty-six factories being established during the first six months of that year. Button making has now become one of the principal businesses along a section of the Mississippi nearly 200 miles in length between Fort Madison, Ia., and Sabula, Ia. It gives employment to large numbers of people at what are considered good wages for such labor. It also supports a very important fishery, at which many hundred persons make a living. Another important feature of the Mississippi River button industry is the transformation of a hitherto useless product into a valuable commodity, which is placed on the markets at reasonable prices.

There are about 400 species of mussels found in the Mississippi River and its tributaries, but comparatively few are now utilized in or are adapted to button making. The requirements of a shell, from the button maker's standpoint, are sufficient thickness, a uniform color of the surface and various strata of the shell, and a degree of toughness that will withstand the necessary treatment without cracking or splitting. Thin-shelled mussels are absolutely useless for button making. Even if originally as thick as a button, the necessary grinding and polishing reduce them to mere wafers. The preferred color is white, but cream-colored shells are also employed. Shells with pink, purple, yellow, or salmon-colored nacre are not suitable, as the color fades with age and is apt to be not uniform. Certain shells that satisfactorily combine thickness and color are nevertheless useless, because they are soft or brittle and break easily during manufacture.

Coincident with the establishment of the button industry in Iowa and Illinois, there has arisen a new popular nomenclature for the mussels or "clams" utilized. The names applied by the fishermen and manufacturers have some reference to the color or shape of the shells. Originally quite local, they are now generally applied throughout the whole stretch of the river in which fishing is done.

By far the most important species of mussel used in button making is the "niggerhead." It has the general shape of the quahog or round clam, and is characterized by a very thick and heavy shell, with a black or dark brown outside skin and a glistening white interior, the latter color being uniform through the thickness of the shell. It is of relatively small size, the maximum being only 4½ or 5 inches for the greatest outside diameter, and the average about 3 inches. It is often found in immense beds, preferring muddy sand and muddy gravel bottom, but also frequenting sandy bottom. About a dozen other species are utilized. The principal, in the vernacular of the region, are the "sand shell," the "mucket," the "deerhorn," the "butterfly," the "bluepoint," and the "pocketbook."

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[*] The Mussel Fishery and Pearl-button Industry of the Mississippi River. Bulletin of the United States Fish Commission. 1898. 26 pages, 24 plates.