HOW FOOD IS USED IN THE BODY.

EXPERIMENTS WITH MEN IN A RESPIRATION APPARATUS.

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HOW does the body make use of its food? What ingredients make muscle and fat and blood and bone and brain? Which yield heat and force? What proportions of different food-materials are needed by people of different classes for the building and repair of tissue, and for the yielding of energy for warmth and work? Such are some of the questions which modern science is asking, and for which physiological chemists are seeking answers by actual experiments with animals and with man. The larger part of the inquiry is carried on in Europe, but of late it has been undertaken actively in the United States. For some time past research has been going on in the chemical laboratory of Wesleyan University, in co-operation with the Storrs (Connecticut) Experiment Station, and under the auspices of the United States Department of Agriculture. A preliminary report of several experiments upon the transformation of material in the body has just been published. The purpose of the present article is to give a brief summary of the results. This I am very glad of the opportunity to do, the more so for the sake of correcting numerous unauthorized and incorrect statements which have appeared in public prints.

One fundamental question proposed in these experiments is this: How much of each of the different nutritive ingredients of food does a man actually consume in his body under different conditions of rest and work? Or, to put it in another way, Will a given diet, containing certain amounts of nutrients, supply more or less of each than he needs? This means that the experiments are intended to show just how much of each of the nutritive ingredients the body requires, and how much of its own substance it will gain or lose when supplied with a given diet.

At first thought it might seem very easy for a man to find whether he gains or loses body material on a given diet, and with any particular kind of work, by simply weighing himself on accurate scales. But the gain or loss of weight does not show what kinds of material the body has gained or lost. For instance, a man may grow heavy with a certain diet, but the scales do not show whether this increase in weight is muscle or fat or water. He may reduce his weight by reducing his food, or by increasing his muscular exercise, or by the use of drugs; but the scales do not show how much of this loss is fat, which perhaps he would be glad to be rid of, or how much is muscular or other tissue, which he cannot afford to lose. The only way to get at the facts is by accurate measurement of the income and outgo of the body.

When we speak of food and drink we think of such things as meat, bread, potatoes, milk, and the like. But for the present purpose we must consider the ingredients of the food. These are, first, the chemical elements, nitrogen, carbon, hydrogen, oxygen, sulphur, phosphorus, etc.; and, second, the compounds of these elements, such as water, protein, fats, carbohydrates, and mineral matters.[1]

[1] The principal classes of nutritive ingredients, or nutrients, of food are: (1) Protein compounds—*e. g.*, albumin, or white of egg; myosin, the principal ingredient of muscle and of lean meat; casein (curd) of milk; and gluten of wheat. These compounds are also called albuminoids, because they are all more or less similar to albumin. The collagen of tendon and the ossein of bone, which make gelatin, are also protein compounds. The term «proteids» is also applied to these protein compounds. (2) Fats—*e. g.*, the fat of meat, butter fat of milk, oil of olives and of wheat, etc. (3) Carbohydrates—*e. g.*, starches and sugars. The fats and carbohydrates consist of the chemical elements carbon, oxygen, and hydrogen. The protein compounds contain these and nitrogen also. The protein compounds of the food are the tissue-formers: they form muscle and blood and bone; they build up the bodily machine, and keep it in repair. The fats and carbohydrates serve as fuel. The protein compounds serve as fuel also, though to a limited degree.

The energy is measured by heat-units, or calories, one calory being the heat that would raise a kilogram of water one degree centigrade, or, what is the same thing, a pound of water four degrees Fahrenheit. This heat, transformed into mechanical power, would be equivalent to about $1\frac{1}{2}$ foot-tons—that is to say, it would suffice to raise a weight of $1\frac{1}{2}$ tons one foot. It is possible to measure energy, whether in the form of heat or mechan-

The income of the body consists of food, drink, and the oxygen of inhaled air. The outgo includes the carbonic acid and water given off by the lungs and skin, and the water and other ingredients of the products eliminated by the kidneys and intestine. In the experiments here described we find the weights of these substances and the proportions of their chemical compounds and elements; and from these we find the weights of elements and compounds of the income and of the outgo. Comparing one with the other, we have the figures for striking the balance of income and outgo of matter. In the experiments for this purpose, not only the food and the solid and liquid excreta, but also the inhaled and exhaled air, have to be measured, weighed, and analyzed. In other words, the products of respiration have to be taken into account. Accordingly, the apparatus for collecting and measuring the air is called a respiration apparatus, and the experiments are called respiration experiments. The respiration apparatus here described is the same in principle as that devised by the German experimenter Pettenkofer, and described in THE CENTURY MAGAZINE for June, 1887, though the details and the methods of experimenting are different.

But there is another balance to be considered—that of energy. In the food we receive potential energy, or, to use a more familiar expression, latent force. When the nutrients of the meat and the bread are transformed in the body, their potential energy is likewise transformed into the muscular energy which the body uses for its work, and into the heat that keeps it warm; and, according to the belief of many investigators, a considerable part is used for intellectual work, for the labor of the brain.

When the energy of the food is transformed in the body, part is given off in the form of heat, and part is used for the muscular work which the body performs. Attempts are being made by several European investigators to develop forms of apparatus for measuring the heat thus given off from the body of a man or an animal, and likewise for measuring the heat-equivalent of the muscular work performed. The term «calorimeter» is also applied to such an apparatus for heat measurement. These measurements are being attempted in connection with the experiments here described, and hence the name «respiration calorimeter» has been given to the apparatus.

HOW THE EXPERIMENTS ARE MADE—THE APPARATUS.

THE experiments are made with a man inside a cabinet, or a respiration chamber, as it is called. It is in fact a box of copper incased in walls of zinc and wood. In this chamber he lives—eats, drinks, works, rests, and sleeps. There is a constant supply of fresh air for ventilation. The temperature is kept at the point most agreeable to the occupant. Within the chamber are a small folding cot-bed, a chair, and a table. In the daytime the bed is folded and laid aside, so as to leave room for the man to sit at the table or to walk to and fro. His promenade, however, is limited, the chamber being 7 feet long, 4 feet wide, and 6⅓ feet high. Food and drink are passed into the chamber through an aperture which serves also for the removal of the solid and liquid excretory products, and the passing in and out of toilet materials, books, and other things required for comfort and convenience.

Outside are machinery for maintaining the current of air through the chamber, and apparatus for measuring and analyzing this air. There are also appliances for measuring

ical power or electrical energy. The potential energy of the food is measured in the chemical laboratory by burning it with oxygen in an apparatus called the calorimeter. A pound of protein, sugar, or starch would yield about 1860 calories, while a pound of fat, like the fat of meat, would yield 4220 calories.

In the explanations of the experiments, the terms «consumed» and «consumption» are applied to the materials, both of food and body tissue, which are either burned for fuel or are otherwise broken down and used to meet the demands of bodily and mental activity.

Of the more purely scientific aspects of such research this is hardly the place to speak. These experiments, in the main, confirm the results of previous inquiry in showing that muscular labor is performed at the expense of the fats, sugars, and starches. It is also clear that the body may draw upon protein for this purpose; but we have yet to learn just what are the conditions under which protein is used for muscular work. One of the most interesting questions for study is that of the sources of intellectual activity. Whether this will ever be solved no one can tell to-day; but apparently, if the solution is possible, the way to accomplish it is by accurate study of the income and outgo of the body.

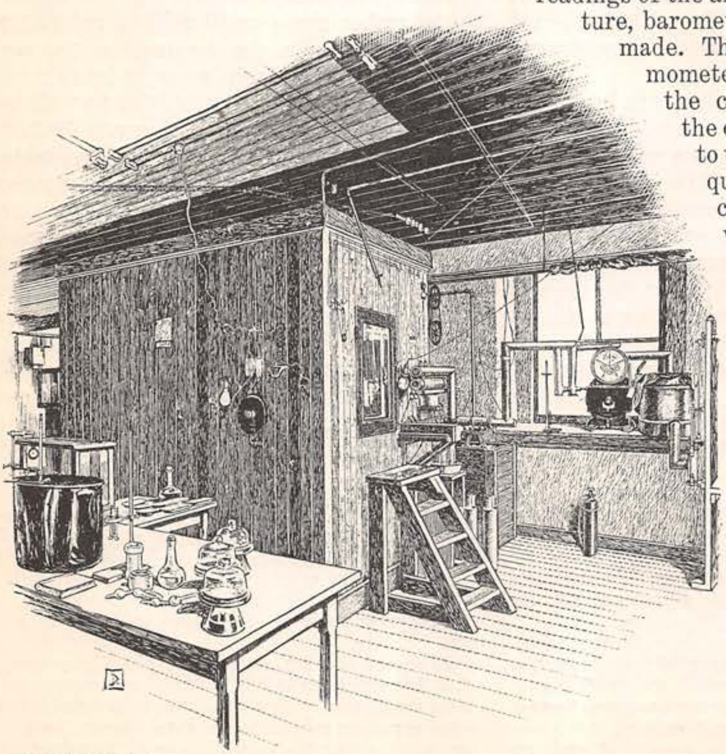
Still another problem, and one of no less intense interest, is that which has to do with the transformation and the conservation of energy in the living organisms. Is the animal organism subject to the same physical laws as those which govern the inorganic world? How does the body use the energy which is at its disposal? A number of investigators are addressing themselves most earnestly to these problems to-day. The results of our own experiments are not yet ready for publication, but I may say that they are such as to give good hope for ultimate success.

the heat given off from the body. These, however, are not described, as they are not used for the experiments here reported.

DAILY ROUTINE OF EXPERIMENTS.

THE actual carrying out of an experiment is a much more complex matter than the brief descriptions above would imply. The amount of labor involved is very considerable. During the day a force of five or six observers and assistants are employed. During the night, when the occupant is asleep, the force is reduced to three. In the experiments thus far reported the person remained inside the respiration chamber for 2¼ days, 5 days, and 12 days. It was necessary, however, as a part of these experiments, to learn just how much of the food eaten was actually digested. For this purpose a digestion experiment was made. This was begun in each case before the respiration experiment, and continued until the end of the latter. In the digestion experiment account was taken of the weights and composition of the food and the undigested residue, the difference between the two showing the amounts of the different ingredients actually digested from the food. On the second or third day of the digestion experiment the subject entered the respiration chamber. The occupants of the chamber passed the time in such ways as were most agreeable under the circumstances. They observed regular hours of eating and sleeping. They had almost no opportunity for exercise, though, of course, they could walk to and fro from one end of the chamber to the other. In one experiment, however, a special arrangement was made for vigorous muscular labor. The men had abundant opportunity for reading, they conversed with the experimenters outside as they chose, and the monotony was agreeably broken in upon from time to time by visitors.

The routine of each day was somewhat as follows: The night force of operators was relieved at 7 o'clock A. M. The chemist of the night force changed the absorption-tubes for the analysis of the air. The day chemist began his daily round of work. The readings of the air-meter, and of temperature, barometric pressure, etc., were made. The observations of thermometer and hygrometer inside the chamber were noted by the occupant, and telephoned to the observer outside. Inquiries were made as to the condition of the man within the chamber, and any things needed for his comfort received early attention in the morning. Breakfast was ordinarily served at about 7: 30 A. M., dinner at 12: 30, and supper at 6. The analyses were conducted, and the other details of the experiments, which were very numerous, were regularly attended to.

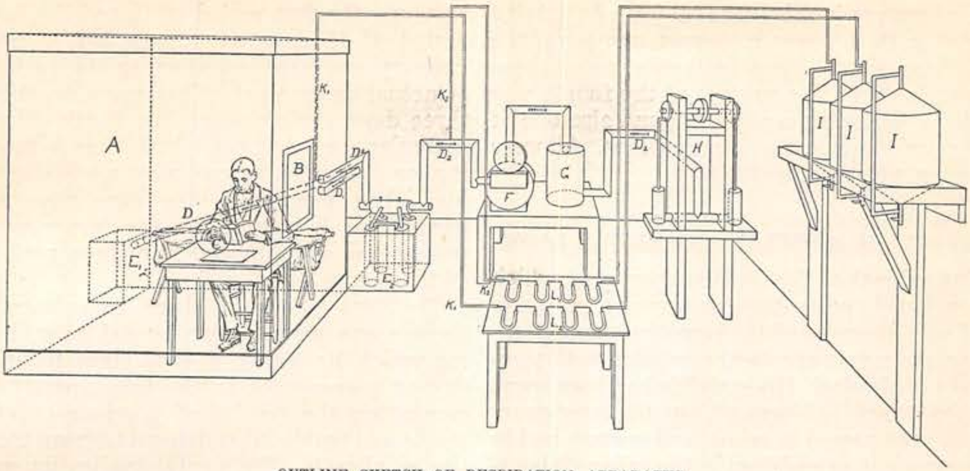


DRAWN BY W. H. DRAKE.

THE RESPIRATION CHAMBER.

This shows the chamber as it appeared when the experiments were made. The exterior is of wood; inside is a box of sheet copper in which the subject stays. The steps lead to the small glass door. At the right are the pipes for the ventilating current of air, and the meter by which the air is measured. Other apparatus not shown here stood still further to the right.

In former researches of this class, all of which have been made in Europe, the experimental periods have been much shorter, generally twenty-four hours or less. There has always been the feeling, however, that



OUTLINE SKETCH OF RESPIRATION APPARATUS.

A is the respiration chamber, which on the outside suggests a large refrigerator. The glass opening (B) in the front end consists of three doors corresponding to the metal and wooden walls of the chamber. These doors are about two feet square, to admit light and to allow the entrance of a man. The light within is sufficient for reading and working. The food aperture (D) is a brass tube, six inches in diameter, through which food, toilet articles, etc., are passed in and out; caps at the outer and inner ends being screwed on, removed, and replaced, so as to prevent entrance or escape of air. A telephone wire runs through the walls of the chamber. The current of air in these experiments is kept in motion by an air-pump (H). It enters by the pipes D_1, D_1 and passes out by D_2, D_2. Before the air enters the chamber it is cooled by the refrigerating apparatus E_1, in which nearly all of its moisture is collected. Coming out, it passes through another refrigerating apparatus (E_2), and thence through a meter (F), by which the volume is measured. As the air-current is irregular, owing to the motion of the pump, a tension-equalizer (G) is placed between the pump and the meter.

Samples of air for analysis are drawn by the aspirators (I, I, I). These samples pass through the tubes K_1 and K_2, and through the absorption-tubes (L_1 and L_2). These latter remove the water and carbonic acid from the air, and their increase in weight during a given period shows the amounts of the latter in the samples. For later experiments a special air-pump has been provided which both measures the total volume of air and delivers aliquot samples for analysis.

The food is prepared and cooked, and the analyses of samples of the food, drink, and excretory products are made, in adjoining rooms of the chemical laboratory.

such short experiments were less reliable than was to be desired. The details of these experiments show that this suspicion is well grounded, and that to get such results as are really needed, long experimental periods are necessary.

People often express surprise that any one can be found who is willing to stay in the chamber for so long a time. They say, «How can you persuade men to go in there? It must be extremely disagreeable.» But really it is not at all uncomfortable. Dr. Tower, who was the subject of an experiment of five days, insists that he rather enjoyed his stay in the chamber. He felt, when he entered, as if he were starting on a sea voyage. «It had this distinguishing feature, however, that the journey was to be made entirely alone. I was the only passenger, and I could talk with the crew only by telephone.» It was, of course, more or less monotonous; but between reading, writing, and looking out of the window, talking with the experimenters outside, and seeing occasional visitors, the time passed quite comfortably. The last entry in his journal is as follows: «As I watched them preparing to open the doors at the end of my five days' stay, I could hardly believe that I would soon be where I could take more than four steps without turning, and where I could see more of the world than the laboratory window disclosed. The confinement has not hurt me in the least, and I feel as well as ever.»

THE EXPERIMENTS THEMSELVES.

THE results of four experiments on the transformations of material in the body have been published.[1] The first two, of $2\frac{1}{4}$ days each, were made with Mr. E. Osterberg,

[1] See a bulletin entitled «Preliminary Report of Investigations on Metabolism by Man,» published by the Office of Experiment Stations of the United States Department of Agriculture. A less detailed report is published in the report of the Storrs Experiment Station for 1896, copies of which may be obtained from the Hon. T. S. Gold, Secretary of the Connecticut Board of Agriculture, West Cornwall, Conn.

It would be ungracious to omit mention of the share borne by my associates in the work here described. Professor E. B. Rosa has had the general charge of the physical side of the inquiry from the outset, and has been ably assisted by Mr. A. W. Smith and others. Professor C. D. Woods, and especially Dr. F. G. Benedict, have borne a large part of the burden of the chemical work, while Dr. O. F. Tower and Mr. A. P. Bryant have been efficient aids ; and Mr. H. M. Burr and others have also rendered valuable assistance.

a laboratory janitor. The subject of the third was Dr. O. F. Tower, a chemist, and one of the assistants in the investigations of which these form a part. The subject of the fourth was Mr. A. W. Smith, a physicist, and also one of the assistants in the investigations. All were young, vigorous, active men.

EFFECTS OF MUSCULAR AND MENTAL LABOR.

THE subject of the fourth experiment, which continued twelve days, was twenty-two years of age. He weighed 156 pounds without clothing, and was in excellent condition, both mental and physical. His early life had been spent upon a farm in Vermont, but the later years had been passed in school and college, and in the work of an assistant in the college laboratory. These occupations involved but little muscular activity. He was accustomed, however, to take a fair amount of exercise with his bicycle and otherwise. He was a small rather than a large eater. A study of the diet of his family, made by him on the occasions of visits at home in both summer and winter, showed that the food consumption to which he had been accustomed was rather small, especially in the amount of protein.

His diet was of his own selection, as in the other cases. He assumed that with the small amount of physical exercise which he would have during most of the time, somewhat less food would be needed than he was accustomed to consume. The results showed that in attempting to reduce the supply to what he presumed would be the need, he made the diet too small, so that it did not quite suffice to meet the needs of his body. The daily food and the amounts of nutrients were as follows:

Experiment No. 4. *A. W. S., Physicist.* 12 *days.*[1]

DAILY MENU.

Breakfast.	Grams.	Dinner.	Grams.	Supper.	Grams.
White bread	75	Beefsteak	96	Milk	500
Oatmeal	40	White bread	75	Brown bread	250
Beans, baked	120	Potatoes	100		
Milk	150	Butter	30		
Butter	15	Apples	125		
Sugar	20				

NUTRIENTS AND ENERGY IN DAILY FOOD.

	Protein.	Fat.	Carbohydrates.	Fuel value.
	Grams.	Grams.	Grams.	Calories.
In total food	101	65	329	2740
In food digested	93	62	321	2500

The whole twelve days of the experiment were divided into five periods. Of these, however, the first period of 1⅝ and the final period of 1⅜ days were regarded as preliminary and supplementary to the periods of actual experiment. They made together three days, during which Mr. Smith did no muscular work, but passed the time in reading, or otherwise, as was most agreeable to him. The remaining nine days were regarded as belonging to the experiment proper, and were divided into three periods of three days each.

The first of these three experimental periods was one of severe mental labor, during which Mr. Smith worked eight hours a day or thereabouts at the table, partly in computing the results of previous experiments and partly in studying a German treatise on physics. The mental application was as severe as he could well make it, or, as he expressed it in college parlance, «It was good, hard grinding.»

The second period was one of as nearly absolute rest as possible. He sat at the table or reclined upon the cot during the day, sleeping, of course, at night as usual. He says very aptly, «I tried to vegetate, and think I succeeded pretty well.»

During the third experimental period, likewise of three days, Mr. Smith engaged for eight hours a day in raising and lowering a heavy weight which was suspended by a cord passing over a pulley at the top of the chamber. The cord was grasped by a handle at one end, and the raising and lowering were done by movement, not of the arms only, but of the whole body. The exercise was decidedly severe, and the day's work exhausting.

The results summarized below are those of the three experimental periods proper. Those for the short preliminary and closing periods, in which no work was done, are very similar to those of the experimental period of absolute rest.

	Protein. Grams.	Energy. Calories.
In the daily income—*i.e.*, in the digested nutrients of the food in each period	93	2500
In the daily outgo—*i. e.*, material consumed:		
Period of severe mental work	79	2595
Period of rest	78	2715
Period of severe muscular work	98	4325

The daily gains and losses of the body were:

Period.	Protein. Grams.	Fat. Grams.	Energy. Calories.
Severe mental work	gain 14	loss 17	loss 95
Rest	gain 15	loss 41	loss 215
Severe muscular work	loss 5	loss 192	loss 1825

[1] It will be remembered that 28.4 grams = 1 ounce, and 453.6 grams = 1 pound, avoirdupois.

Two things are brought out very clearly by this experiment. One is the very large amount of material that is used with muscular work. During the periods of rest and of mental work, 78–79 grams, or $2\frac{3}{4}$ ounces, of protein sufficed to meet the daily needs of Mr. Smith's body; but with the severe muscular work the protein consumption rose to 98 grams. The fuel-value of the materials consumed during the days of rest and mental work ranged from 2600 to 2700 calories, but with the severe muscular work it was increased to 4325 calories. In this case the food did not supply enough, and the body drew upon its stock of reserve material. The draft was partly upon the protein, but mainly on the fat of the body. This is in accordance with very extensive European investigations upon the subject. The chief fuel ingredients are the carbohydrates and fats. When the food does not supply fuel enough the body draws upon its supply of these substances, especially its fat. In Mr. Smith's case, during the periods of rest and severe mental work the body stored about half an ounce of protein and lost about an ounce of fat daily; but with the hard muscular labor it was estimated to lose $\frac{1}{6}$ ounce of protein and $6\frac{3}{4}$ ounces of fat. If the daily food had been increased during the days of muscular work by doubling the amount of sugar and adding half a pound of bacon, the fuel would have about sufficed to meet the emergency. Whether it would have saved the protein from consumption, experiment alone can tell.

The other point of special interest is the consumption of material by the body during the period of severe mental work as compared with the period of rest. In this particular experiment the amounts actually used up were virtually the same in the two periods. In order to learn the effect of mental work upon the demands of the body, it will be necessary to make a large number of very accurate experiments, to extend them over considerable time, and to study very carefully the income and outgo of phosphorus, sulphur, and other elements, as well as of nitrogen and carbon. All this will doubtless come in good time.

PRACTICAL APPLICATIONS.

THE chief interest of experiments of this kind, from the purely practical standpoint, is in the light they throw upon the ways in which the food is used in the body, and the kinds and amounts which are appropriate for people of different classes and under different circumstances. Of course these few preliminary trials are by no means sufficient to warrant any broad conclusions. Their main value is in the promise they give of what may be done by patient, long-continued, careful experimenting. Much has already been done in this direction in Europe, and there is reason to believe that research will increase both there and in the United States.

One of the many lessons which such inquiry will teach is reasonably clear. Physicians tell us that a large amount of the disease with which they have to deal, especially among well-to-do people without much manual labor, comes from overeating. During the last few years a considerable number of studies have been made of the kinds and amounts of food bought and used by people of different classes and occupations in a number of places in the United States. These have included several groups of professional men and college students, whose eating-habits are doubtless fairly representative. The digestible protein of the daily food of the different groups is computed to range from 93 to 117, averaging 99 grams, and the energy from 2830 to 3965 calories, averaging 3390 calories. In the four experiments above referred to, the three young, vigorous men were actually found to use on the average 108 grams of digestible protein, with 2660 calories of energy when not engaged in manual labor. A series of respiration experiments, made a number of years ago in Munich, by Professor Voit, Dr. Ranke, and others, gave similar results. A little more food would doubtless be needed for ordinary indoor mental labor. A number of studies of dietaries of well-to-do and well-fed men in professional life—lawyers, physicians, and university professors—in Germany and Denmark have shown an average consumption of a very little more protein, and hardly any more energy, than were used by the men in the respiration apparatus.

The inference is that the people in professional and business life in the United States, whose labor is mostly mental and indoors, are inclined to eat more than they need, and that the special excess is in the fuel ingredients, that is to say, the fats and carbohydrates. Taking the results of these and various other experiments together, the details of which cannot be quoted here, we are, I think, justified in believing that the diet of a very large number of people is out of balance. It contains an excess of food-material, and this excess is largely due to the eating of fat meats, sugar, and the starchy foods. These results of accurate observation and experiment thus accord with and explain the current opinion of hygienists as to our ordinary habit of overeating.

THE SCIENTIFIC ASPECTS OF SUCH INQUIRY.

ONE favorable indication for the future is that these problems are being studied in Europe and, of late, in the United States. There is reason to hope that, with the rapid progress of science in other lines, it may advance in this direction likewise until the laws of the nutrition of man and of animals shall be far better understood. We may also hope that the knowledge will be disseminated and so applied in practical life that great good will come, not only to health and strength and purse, but to the higher intellectual and moral interests of mankind as well.

W. O. Atwater.

HOME LIFE AMONG THE INDIANS.

RECORDS OF PERSONAL EXPERIENCE.

THERE are no locks and keys in an Indian tribe. In the tent there is no closet; in the home there can be no secret, for the family skeleton, if there is one, is also public property. This lack of privacy in personal and social affairs becomes a definite factor in the education of the people; its exigencies are potent in the fixing of external habits and in the formation of personal character. The constant exposure to observation, the impossibility of wrestling alone with his petty faults during the formative period of life, develops in the Indian two extremes of feeling—obtuseness as to the interests of others, and over-sensitiveness to blame or approbation of himself. There is no covering up of the follies of youth; every lapse from the tribal standard of rectitude is known to all; and when once fixed in the indelible Indian memory, it is not easy to outgrow one's shortcomings. Reformation of a lost character becomes a discouraging task where there is no forgetting, and where criticism is a common privilege and ridicule a weapon. Reserve is the Indian's only defense, and self-restraint his only safeguard; and these virtues are the earliest lessons which the child receives. Indian reserve, often mistaken for sullenness, is susceptible of philosophical explanation.

Living among the people, I could not fail to be soon impressed by their peculiarities. Occasionally an Indian would unaccountably become silent, would refuse to answer when spoken to, and would turn away from the other inmates of the lodge. His conduct did not seem to surprise or disturb anybody; the voluntary exile to Coventry was allowed to take his own way unmolested, and to return to society when and how he chose. After I had been for several weeks living in the lodge, never away from the sight and sound of the people, one day I suddenly found myself with my back to all the world, not wishing to speak to, or even to look at, any one. This discovery of my own behavior set me to thinking why I had been guilty of precisely the same conduct which in the Indian I had attributed to savagery. I found that the constant enforced presence of others produced such mental fatigue that exhausted nature's demand for relief must be met in some way, and was met in the only way open to me. This expression of my own mood enlightened me as to many phases of Indian character, and helped me to appreciate all the more the many invariably sunny natures of my acquaintance, among men and women, whose charity raised them above their fellows; who were able to shut their eyes to that which could not be concealed in the lives of those less strong than themselves to resist temptation.

The necessity which we feel of individualizing our living-place, of having some one spot sacred from intrusion, has been partly recognized and provided for in the Indian dwelling. It is true that all live upon the ground, sitting, sleeping, eating there; yet the space within the lodge is divided—not by visible partitions, but by assigning certain places by long-established custom to the several members of the family.

Entering the lodge from the east, one finds the fire burning in the center. All tents, except in rare instances, are pitched facing friend begged him to shake it off. He quietly answered: «I will try.» Nights and days of marching and exposure followed. On the last day Shaw was deeply depressed, and talked despairingly. He asked to be left alone, so he could think of home. In an hour he had conquered; and his cheerful spirits returned. When his general asked him if he wished the privilege of leading the column of attack, his face brightened, and he answered, «Yes.» As the men, tired and hungry, lay flat on the ground before the assault, he was more familiar with them than he had ever been known to be before. He walked along the line, and encouraged them, saying: «Now, men, I want you to prove yourselves *men!*» «His lips were compressed, and now and then there was visible a slight twitching of the corners of the mouth, like one bent on accomplishing or dying.»

It is now nightfall, and at last all is ready. The regiment is formed in two lines, the colonel taking the right wing in front. Coming up to Lieutenant-Colonel Hallowell, he said: «Ned, I shall go in advance of the men with the National flag; you will keep the State flag with you. It will give the men something to rally round. We shall take the fort, or die there.» All his sadness had left him.

Then came the rush upon the fort. His friend saw him again «just for an instant, as he sprang into the ditch; his broken and shattered regiment were following him, eager to share with him the glory of his death.» When within one or two hundred yards of the fort a terrific fire of grape and musketry was poured upon them, tearing the ranks to pieces. They rallied again, went through the ditch, which held three feet of water, up the parapet with the flag, the colonel leading. He waved his sword, cried out, «Forward, Fifty-fourth!» and fell dead, with twenty or thirty of his officers and men killed close about him. The rest is well known. They «buried him with his niggers,» in one long trench, and his father refused to have that honorable grave disturbed.

But at last the trench itself has been washed away by the waves of the Atlantic, and in the South may now be found some of those who appreciate and cherish most tenderly the fame of Robert Shaw.

A letter to those who mourned, from one who had herself suffered in like measure, expressed the thought of multitudes when the news of this «costly sacrifice» was flashed through the North: «When the beautiful vision, which was beheld by so many thousands, of the inspired and brave young hero at the head of his dusky followers, is recalled, many who never had an earnest thought about it before will feel, ‹This must be a sacred cause for which such a youth has offered so willingly his life.› »

No death in the cause of liberty and union, save that of Lincoln himself, has been the occasion of such tributes as those which have been offered to the memory of Shaw. This was Lowell's hero when he wrote:

> Right in the van
> On the red rampart's slippery swell,
> With heart that beat a charge he fell
> Foeward, as fits a man;
> But the high soul burns on to light men's feet
> Where death for noble ends makes dying sweet.

And he was Emerson's youth who nobly answers to the voice of duty:

> So nigh is grandeur to our dust,
> So near is God to man,
> When Duty whispers low, *Thou must,*
> The youth replies, *I can.*

Already the prophecy of Motley is being fulfilled. «I have often thought,» he said, «how fondly his image will be retained in after-days as a type to inspire American genius. . . . Sculptors, painters, and poets will delight to reproduce that beautiful vision of undying and heroic *youth*, and eyes not yet created will dwell upon it with affection and pride. And when the history of these dark, tragic, but most honorable days comes to be written, there is nothing . . . that will fasten itself more closely on the popular memory than the storming of Fort Wagner by the Fifty-fourth, with their colonel falling on the rampart, sword in hand, cheering on those despised blacks to deeds of valor.»

The patriots of to-day are not now, and may not be, called upon to die «sword in hand»; but this country is in need of men who will bring into the fight against civic corruption as keen a sense of duty and as true a courage as that which inspired the young hero of Fort Wagner.

The Sculptor.

PERHAPS no living artist has so high a reputation as St. Gaudens, and so strong an artistic influence, with so little of his work familiar to the general public. His «Lincoln» in Chicago, and his «Farragut» in New York, are the statues most familiar to the people, and on these his just popular fame is mainly based. But in the art world St. Gaudens has long been known as the author of a series of medallions, of numerous portrait heads, memorial monuments, and pieces of decorative sculpture, all of which have the stamp of mastership. Before a great while his Shaw monument, his splendid and virile equestrian statue of Logan, his statue of Peter Cooper, his Sherman equestrian statue, and other works of a monumental character, will give still wider public proof of a genius the evidences of which have been fully known and appreciated by artists and critics for many years. THE CENTURY from time to time has given examples of his work, but in this number of the magazine a greater array of his sculpture is presented than on any other occasion. And although much is necessarily omitted, it is easy to see that the sculptor's fame already rests on foundations ample and absolutely secure. It is gratifying to know that he is in the fullness of his artistic strength, and that the future should hold for him as many triumphs as the past.

The Man in the Copper Box.

INASMUCH as the most serious daily inquiry of three fourths of the millions who struggle on the earth for a bare physical existence is, «How shall we be fed?» the paper beginning on page 246 of this number of THE CENTURY is of very wide significance. In it Professor Atwater offers the first popular explanation of a series of experiments which are conducted under the auspices of the government, and which promise, in their future development, to have an important bearing upon the problem of the economical and healthful feeding of humanity. Expressed in more scientific terms, the purpose of the investigation is to study the laws of nutrition: to find out more than is now known of the ways in which food builds up the different parts of the body, repairs its wastes, and supplies energy for work and thought. While, in one sense, these researches have a purely scientific object, which is the study of the application of the laws of the conservation of matter and the conservation of energy to the human organism, from another point of view they are intensely practical, as representing an effort to gain new knowledge regarding the food of man, and his needs for nourishment, the better to fit his diet to the demands of health, strength, and purse.

The researches Professor Atwater describes are the first of their especial kind on this side of the Atlantic, although experiments more or less similar have been conducted at several German universities for more than a quarter of a century, and of late have been carried on elsewhere in Europe. Most of those in Europe have been made with domestic animals. The number with men has been small, and in no case, it is believed, have they—for lack of material resources—been so painstaking and laborious as those here described.

Several years ago the first steps were taken at Wesleyan University, Middletown, Connecticut, toward the development of an apparatus for measuring the income and outgo of the animal body. The investigation was undertaken jointly by Professor Atwater and Professor E. B. Rosa. It was conducted under the patronage of the university, and in connection with the Storrs Experiment Station, of which Professor Atwater is director, and of which the more purely scientific researches are being prosecuted at the Wesleyan laboratories.

Fortunately for the enterprise, the resources, which were at first limited, were increased by appropriations from the public funds. In the year 1894 provision was made by an act of Congress for an inquiry into the food and nutrition of the people of the United States. The act places the investigation in the hands of the Secretary of Agriculture, and wisely allows him to distribute it among the experiment stations of the country, which are in close official relations with the Department of Agriculture. It is under the immediate charge of Professor Atwater as special agent of the department. While the larger part of the inquiry is given to the study of the kinds and nutritive values of foods and the economy of their purchase and use by people of different localities and classes, a portion is devoted to more abstract research, which would naturally include experiments of such fundamental importance as these.

In 1895 the legislature of Connecticut provided a special annual appropriation to be expended by the Storrs Experiment Station for food investigations. The resources of the station were thus increased, and with the supplement from the General Government, and the original private aid, it has been possible greatly to enlarge the scope of the inquiry. Indeed, this may be regarded as one of the class of cases in which the higher scientific research has been favored by a happy combination of public and private support in such way as not only to insure the greatest economy in the use of money and other resources, but also to promise a valuable outcome.

In order to control the conditions and measure the changes affecting the living organism under examination, the human subject is isolated in a copper box, a trifle higher and longer than the stature of an average man, and only twice the width of a broad pair of shoulders; and the process of «harmless vivisection,» as it might almost be called, is made tolerable by a glass window and a telephone, enabling the subject to see and converse with friends; by facilities for reading and writing; by provision for vigorous though rather cramped exercise; and by the maintenance of atmospheric conditions calculated to have a cheering effect on the spirits of a healthy man. That a person of active mind, though buoyed by scientific ardor, could lend himself for twelve days to the experimental mercies of the copper box, and emerge with grateful emotions, is a compliment to the foresight of the experimenters, and a promise of surprising results from this method of human analysis.

Ten years ago THE CENTURY began a series of seven papers by Professor Atwater, which in a way broke the ground for these experiments with the man in the copper box. The initial paper, entitled «The Composition of our Bodies and our Food,» in May, 1887, was followed by others on «How Food Nourishes the Body» (June, 1887), «The Potential Energy of Food» (July, 1887), «The Digestibility of Food» (September, 1887), «The Pecuniary Economy of Food» (January, 1888), «Food and Beverages» (May, 1888) and «What we Should Eat» (June, 1888). It stands to reason that a scientific diet, varied to repair wasted energy, mental or physical, with the smallest tax on the assimilative powers, would confer health and a better chance for wealth on the workers of the world. In time it might also reduce the ranks of the minority who «live to eat,» by rendering more certain of attainment the benefits of «eating to live.»

OPEN LETTERS

Portraits of Queen Victoria.

PRINCESS VICTORIA AT THE AGE OF FOUR.

THE portrait of «The Little Princess Victoria,» an engraving of which, by Peter Aitken, is the frontispiece of the present number of THE CENTURY, is a small oil-painting now in the Dulwich Gallery. It is a panel, eleven inches by eight and three quarters, acquired by the gallery in 1890. It is thus described in the catalogue:

(304) Her Majesty the Queen when Princess Victoria, aged 4 years. S. P. Denning. Full-length figure standing, large black hat with feathers, black velvet pelisse,