the extreme limits of a given variety are of diagnostic value. Although single starch grains are colorless and semitransparent, masses of them are pure white.

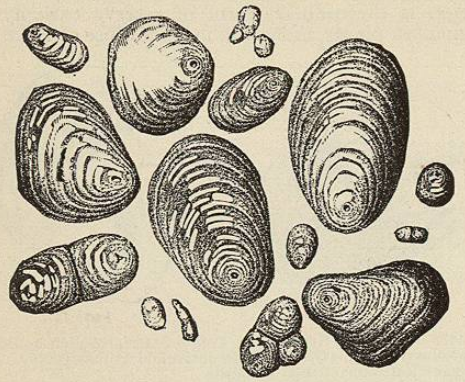

FIG. 4478.—Potato Starch.

Starch powder is very fine and smooth, but the ultimate grains are hard and gritty. They are very hygroscopic.

Starch has no odor, but a peculiar, though slight, farinaceous taste. The grain consists of two substances, *granulose*, which is colored blue by iodine, and another substance very similar to cellulose, colored pale yellow by iodine. Starch is insoluble in water and alcohol. Several substances are often spoken of as solvents of starch, but they all apparently change it into some other compound before the solution takes place. Water, under the influence of heat, converts it into hydrated starch, a transparent, jelly-like mass, which is then soluble in water. Alkali hydrates of a strength of more than five per cent. similarly dissolve it. Both these solutions are then precipitated by lime water, lead acetate, tannin, and some other reagents. Diastase, the principal enzyme which naturally exists with starch, is the agent which in the plant converts it into sugar, suitable for immediate use as food. The same agent can be made to perform this office artificially, as can dilute acids under the influence of heat, and as is done by the natural processes of digestion within the animal body. From the above-mentioned characters of starch, it is seen that it can readily be obtained by grinding finely any cellular structure which contains it, washing out with cold water and filtering or allowing to settle. It is also seen that, besides the interest which centres in starch for its own value, the characteristics of the starches contained in different plants, and more especially in drugs, may be utilized in the identification of the latter, in powdered form, as well as in the detection of adulterations.

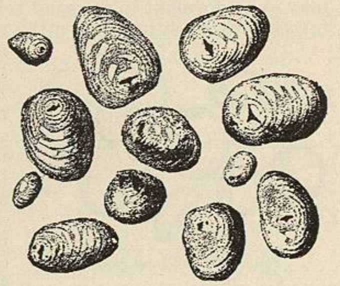

FIG. 4479.—Arrow-root Starch.

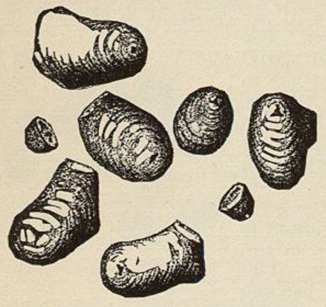

FIG. 4480.—Sago.

VARIETIES.—The only certain means of determining from what source a given specimen of starch has been derived is to examine it microscopically, when the size, shape, markings, and other visible peculiarities of the granules will generally suffice to make it certain. The accompanying illustrations of the commoner kinds are magnified uniformly three hundred and fifty diameters.

1. *Wheat Starch* (from various species and varieties of *Triticum* L. [fam. *Gramineæ*]) (Fig. 4476). In irregular, angular masses, which are easily reduced to powder; under the microscope appearing as granules, mostly very minute, *more or less lenticular in form, and indistinctly concentrically striated.* The granules average about 0.050 mm. in diameter.

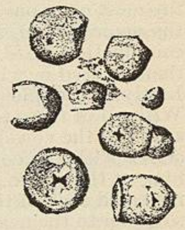

FIG. 4481.—Tapioca.

2. *Maize*, or *Corn Starch* (defined above, Fig. 4477), is smaller than the preceding, about 0.030 mm. in diameter, of polyhedral form, with central hilum.

3. *Rice Starch* (from *Oryza sativa* L. [fam. *Gramineæ*]) resembles maize starch, but is very much smaller.

4. *Potato Starch* (from *Solanum tuberosum* L. [Fam. *Solanaceæ*], Fig. 4478) consists of two classes of granules mingled together—fine spherical ones, from 0.01 to 0.03 mm. in diameter, and large ovoid ones with very eccentric hilums and very distinct *rugæ*, recalling oyster or clam shells, from 0.14 to 0.18 mm. long.

5. *Arrow-root* (from *Maranta arundinacea* L. [fam. *Marantaceæ*] Fig. 4479) is finer than potato starch, which it somewhat resembles; the granules are more spherical, with blunter, thicker ends, very distinct eccentric fissures, and less distinct *rugæ*. Canna starch, a variety of arrow-root, has enormous granules, nearly twice as large as those of potato. Neither of these varieties has the small forms of that from potato.

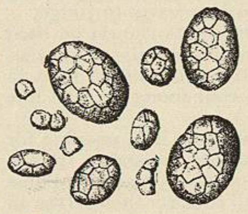

FIG. 4482.—Oat Starch.

6. *Sago* (chiefly from several species of *Metroxylon* Rottb. [fam. *Sabalaceæ*] Fig. 4480) has medium-sized (0.04–0.07 mm.), oblong, rather irregular, often faceted, sometimes shoe-shaped granules, with eccentric hilum and fairly distinct *rugæ*. The sago of commerce is often half-cooked, with many of the granules destroyed.

7. *Tapioca* (Fig. 4481) has spherical, medium-sized granules, with large facets; commercial tapioca is also partly cooked. (See also separate article on *Tapioca*).

Besides the above are the starches of numerous familiar grains and roots, which are not separated for sale or use, but which are of interest in detecting adulterations, mixtures, etc., or in identifying the powders of drugs. The accompanying cuts of oat and turmeric starches will serve as illustrations of this large class.

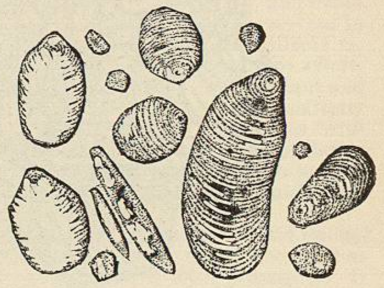

FIG. 4483.—Turmeric Starch.

Medical and Surgical Uses of Starch.—This substance can in no sense be called a medicine, as it is absolutely without physiological action. It is the type of crude carbonaceous or non-nitrogenous food, and its conversion into sugar in the mouth and intestine is one of the elementary facts of digestive physiology. As a toilet powder the finer varieties—rice and corn starches—are in universal use, and one or other of these is the foundation of most of the proprietary powders.

Boiled starch, and especially the flours of starchy substances, are frequently used as poultices, but they are not so convenient and suitable as the mucilaginous flours of linseed and slippery elm.

Starch mucilage is occasionally used for immovable bandages, but it is less adhesive and less suitable for this purpose than flour paste, glue, dextrin, silicate of potash, or plaster of Paris. One part dissolved glue, as prepared for cabinet-makers' use, and two or three of starch mucilage, a little thinner than the laundress uses it, mixed and applied hot, make a most excellent combination for such bandages—light, very stiff, and agreeable in color.

The only official preparation of starch is the Glycerite (*Glyceritum Amyli*, ten parts of starch dissolved in ninety of hot glycerin). This is a permanent translucent jelly, useful in moistening pill masses, for emulsions and similar purposes. Iodized Starch (*Amylum Iodatum*, formerly official) is rather a preparation of iodine. It is made by triturating five parts of iodine with ninety-five of starch, with the aid of a little water. It is a blue-black powder, and a suitable preparation to administer for free iodine if it is desired to give that drug internally.

W. P. Bolles.

Revised by *Henry H. Rusby.*

STARK MINERAL SPRING.—New London County, Connecticut.

POST-OFFICE.—Bozrah. Visitors accommodated in private families.

LOCATION.—Three miles from Yantic, on the Central Vermont Railroad.

The waters of this spring issue from a rocky hillside on the farm of Mr. Everett W. Stark, at an altitude of about 1,000 feet above the sea-level. Its history has been known to a few old families in the neighborhood since the first settlement of the country, and dates back to a time when all accurate record is lost in the obscurity of tradition. There seems to be no doubt, however, that its waters were used for medicinal purposes by the Indians long before the region was known to the European settlers. The surroundings of the spring are very charming during the summer months, and an increasing number of visitors are attracted to the spot every year. The flow of water is about three gallons per minute, and its temperature about 40° F. The following analysis was made by Prof. S. W. Johnson, of Yale University, in 1880:

One United States gallon contains (solids): Sodium chloride, gr. 0.33; sodium sulphate, gr. 0.18; sodium bicarbonate, gr. 0.30; potassium bicarbonate, gr. 0.10; calcium bicarbonate, gr. 1.23; magnesium bicarbonate, gr. 0.33; iron bicarbonate, gr. 0.06; silicic acid, gr. 0.85. Total, 3.38 grains.

The analysis shows the spring to be but feebly mineralized. The waters, however, have been considered useful in some of the functional disorders of the liver, kidneys, and bladder. It is a good table water.

James K. Crook.

STARVATION; FASTING.—The latter term signifies the partial or complete abstinence from the normal quantity of food. It may include the absence of both liquid and solid food, or of the latter while water only is ingested. This process, when carried out to a fatal result, constitutes starvation. The somewhat cumbersome word inanitiation has been used to refer to the condition of the animal which is progressing toward inanition.

The fasting animal carries on its vital functions, and whatever muscular action it may perform, not, as normally, by the conversion of food supplied by its ingesta, but at the expense of its own tissues. The physiology of fasting, which has not as yet been thoroughly elucidated, may be studied to best advantage by experiments upon the lower animals, for, in addition to the ability to control conditions, we thus eliminate psychical influences, and those other disorders which complicate the problem in those instances in which human beings undergo starvation while under the possibility of medical observation.

LOSS OF WEIGHT.—This is the earliest and most obvious symptom of the fasting animal. The daily loss is not, however, constant. It is greatest during the first day of the fast. Then it diminishes, and after a few days becomes a nearly constant quantity until the last days of life, when it again increases, but not usually to the amount of the first day. The proportional daily loss—that is, the loss in grams per kilogram of the animal's weight—is readily obtained from the absolute daily loss, the weight of the animal being known. But it must be remembered that the latter factor must be ascertained for each day in question, and must not be taken to be the original weight of the animal. Thus, for instance, a constant total daily loss of 200 gm. in an animal originally weighing 4 kgm. would at first mean a proportional daily loss of 50 gm. per kilogram, but would, with every successive day, represent a larger proportional loss. The mean daily loss may be obtained by dividing the total loss in a given number of days by that number; but of course it must be remembered, as said above, that the actual daily loss is not so constant. A mean daily proportional loss can, in the same way, be computed.

This figure varies with the different species of the animal kingdom. It is, as a rule, higher for the smaller animals. The horse loses less daily per kilogram than the dog, and the dog less than the cat. This fact is in accord with the greater nutritive activity of the small animals. That this greater activity is not due to increased heat production is shown by the fact that these small animals consume more oxygen per unit of time and weight, even when placed in a medium of the temperature of their bodies. An adult animal loses less daily per kilogram than a young animal of the same species. The daily mean proportional loss varies widely, being ten per cent. of the weight in the young turtle, and only 0.7 per cent. in the horse and dog.

What proportion of the body weight can an animal lose before succumbing to inanition? If we know this, and if the total weight loss during a period of starvation bore a constant ratio to the original body weight, we could easily compute, knowing the daily proportional loss, the length of time that life could last. It is, however, only true that the amount of the daily proportional loss, and the number of days that life can endure, are inversely proportional. Chossat stated that the total proportional weight-loss of an animal dying of inanition was forty per cent. of the initial weight. But further experiments have shown that a fat animal may lose fifty per cent. of its weight, while a lean one can lose only thirty-five per cent. Young animals in a growing stage have been observed to lose only thirty per cent. before they succumbed. Thus we have two reasons why young animals can endure fasting but a short time, namely, that their daily proportional loss is a maximum, and the total proportional loss of which they are capable a minimum. The reason of this last-mentioned fact seems to be that the demands of the growing organism have used up force which might otherwise be applied to the nutritive reserve of the body.

Organs and tissues.	Loss in Grams per 100 Gm. of Organ.		Loss in grams of each organ per 100 gm. of loss of whole animal.
	Fresh.	Dry.	
Osseous system	13.9	13.9	5.4
Muscular tissue	30.5	30.2	42.2
Liver	53.7	56.6	4.8
Kidneys	25.9	21.3	.6
Spleen	16.7	63.1	.6
Pancreas	17.0	17.0	.1
Lungs	17.7	18.0	.3
Heart	2.6	2.6	.02
Brain and cord	3.2	.0	.1
Fat	97.0	97.0	26.2
Blood	27.0	17.6	3.7

The proportion of the entire weight-loss which falls upon the different structures of the body varies somewhat with different experimenters. Voit found that a rather lean cat, which died on the thirteenth day of its fast, lost 734 gm. of solid material, of which 248.8 were fat and 118.2 muscle. The table on page 441 shows the most important facts of the loss of several of the organs' in proportion to their original weight, and in proportion to the entire weight-loss of the animal.

It should be said that Bidder and Schmidt, whose experiments were made upon a very fat cat, found that the muscular system lost sixty-seven per cent. of its original weight, the brain and cord 37.6 per cent., the blood ninety-four per cent., and the fat eighty per cent. Some of these discrepancies seem irreconcilable. Others, like the fat-loss, depend on different conditions in the respective animals. That of the latter observers had so much adipose tissue that, though he lived seventeen days, he had consumed only eighty per cent. of his fat, while the cat experimented on by Voit had used up ninety-seven per cent. of his in thirteen days.

What is substantially agreed is that the fatty tissue is the heaviest sufferer in the fasting animal; that certain glandular organs, principally those whose metabolic activity is greatest, come next, the average for all these being greater than for the body at large. The loss of the voluntary muscular system is about in the same proportion as that of the whole body, as is also that of the digestive tube (thirty per cent.—Voit). Those structures which are most essential to the life of the organism are spared longest. The heart muscle and the central nervous system lose practically nothing, and though their metabolic activity is high, they are sustained at the expense of less important tissues.

Temperature.—The experiments of Chossat, upon pigeons, show a remarkable and continuous effect upon temperature from the beginning to the end of a period of starvation. This shows itself at first in an increase of the diurnal range, owing to a lowering of the midnight temperature. Whereas, in the healthy pigeon, the daily oscillation is only 0.76° C. (from 42.22° at noon to 41.48° at midnight), in the fasting animal the mean noon temperature (prior to the last day) was 41.70°, and the mean midnight temperature 38.42°, giving an average diurnal range of 3.28° (four times as great as normal). The average loss of temperature at noon was only 0.52°, while that at midnight was 3.06°. That is to say, the loss of temperature at midnight was six times as great as at noon. Moreover, the diminution of temperature was progressive from the beginning to the end, as was also the amount of the daily oscillation. This latter was 1.9° the first day, and 4.3° the last day but one. The mean daily refrigeration during this period was 0.3°. As the animal grows weaker, the period of minimum (midnight) temperature begins earlier and lasts longer.

On the final day of starvation there is a great exaggeration in degree and in duration of this midnight refrigeration. Chossat gives it as a mean, in a number of pigeons, as 14°. In other words, the reduction of the animal heat is forty-seven times as great on the last day of life as on the average of the previous days.

This final plunge of the temperature is observed in all cases of starvation, and there seems little reason to doubt that it is the immediate cause of the fatal result. In the mammalia there was not that regular daily loss of heat that was observed in the pigeons. The temperature fell for the first day or two, but then nearly regained the normal, and so remained until the last day, when it rapidly sank. Chossat found that when this fall occurred, the resulting torpor, the precursor of death, could be dispelled by raising the temperature of the surrounding medium, and that sufficient vitality was thus imparted to allow of the taking of food and consequent perfect restoration of the animals. The nearly complete maintenance of temperature of warm-blooded animals for several successive days does not prove that the heat production was equal to the normal, for there is probably a lessening of the heat expenditure. Senator found that with dogs, on the second day of the fast, when the rectal temperature was not sensibly lowered, the heat production was nevertheless diminished about ten per cent.

Temperature studies in fasting men, of course, have been rare. Jürgensen found that in a healthy man, fasting for sixty-two hours, the rectal temperature, taken every ten minutes during the first thirty-eight hours, showed a slight prolongation of the period of diurnal minimum, with but very slight reduction (0.1°–0.2°) in the reading of the minimal temperature. But after that time there was a prolongation of the period of the maximal temperature, which Jürgensen accounted for by supposing that the substance of the consumed body set free more heat than the materials metabolized under ordinary circumstances.

Respiration.—The frequency of the respirations diminishes during fasting to four-fifths, or during the last day even to three-fifths, of the normal rate. Sometimes, however, just before death the breathing becomes hurried, shallow, and panting. The quantity of carbonic acid exhaled, which normally exceeds that of the oxygen taken in the proportion of about five pounds of carbonic oxide to four pounds of oxygen, becomes relatively smaller during fasting, and may even be absolutely less than the oxygen absorbed.

Circulation.—No very constant effects have been noted in this connection further than a general tendency to increase in the rate of the pulse accompanying exhaustion. One observer (Strelzoff) noted an increase in the blood pressure, which he ascribes to an atrophy and obliteration of a large number of the capillaries. Though this latter event occurs in the stomach and small intestine, and perhaps in other parts of the body, it probably is not sufficient to cause any general rise of blood pressure. The mass of the blood proportionally to the total weight, as above indicated, seems not to suffer very great reduction. Panum found no diminution in the number of blood corpuscles when the animal (a dog) was allowed all the water desired. On the other hand, Malassez found that in the guinea-pig the corpuscles were reduced on the fifth day from 4,156,000 per cubic millimetre to 3,444,000. In a chicken he observed a reduction, in an equal time, from 3,380,000 to 2,912,000. The diminution in both the last cases fell chiefly upon the latter days of the fast.

The density of the blood was found by Frerichs and others to diminish during a fast. In a dog, in which before the fast it was 1058.09, on the fourth day of the fast it was 1051.11, and on the twelfth 1037.69. On the other hand, in Voit's cat the density of the blood increased.

Urinary Secretion.—The amount of the urine during the first day of the fast is not usually affected. After that time, however, it gradually grows less and less. The specific gravity has been found during this period to range between 1.025 and 1.034.

The urea diminishes in the carnivora with every successive day of fasting, but never entirely ceases. The extent of the diminution depends upon the richness of the food in nitrogenous elements prior to the fast. The herbivora, on the other hand, which during a fast become carnivora, experience at that time a change in the character of the urine, which becomes denser, higher-colored, acid, and richer in urea. At the end of life the urea diminishes rapidly. In guinea-pigs it has been found that the urine taken from the bladder after death had only one-eighth as much urea as that passed on the preceding day.

The urea forming a measure of the decomposition of nitrogenous materials in the body, and nitrogenous ingesta (with all other) having been stopped in the fasting animal, the daily secretion of urea affords a means of estimating the amount of nitrogenous matter consumed each day of the fast. Physiologists have been divided over the question of a *luxus consumption*, a term applied by Bidder and Schmidt to the metabolism of certain surplus proteid material which, though inside the body, did not form a component part of any of its tissues, but constituted a kind of reservoir of force upon which the organism could draw. Not to enter upon this question, however, we will simply say that it is found that the

excretion of urea bears no fixed proportion, at any period of the fast, to the total weight of the animal, although after the first three or four days it tends to a uniformity for several days. If the animal possesses an abundance of fat there is a smaller consumption of proteids during fasting. This diminution of the urea is very noticeable in animals that have been freely fed, previously to beginning the fast, on fatty food. In the lean cat of Voit, already referred to, the urea was less for several days than in the animal of Bidder and Schmidt; but at the end of life (twelfth and thirteenth days) there was a rise of fifty per cent. in the urea excreted over that of the previous day, while the other animal showed no such increase even up to its death, on the seventeenth day. The former animal was found at the autopsy to have used up all his fat tissues, and the final rise in the urea was due to the metabolism falling entirely upon albuminoid material.

Of the other constituents of the urine the phosphates and sulphates undergo a diminution parallel to that of the urea. The chlorides also diminish, but more rapidly from the first. Albumin has been noted in some cases, but is not constant.

Fæces.—On the first day of the fasting there is usually an evacuation from the bowels, the fæcal matter containing the residue from the preceding alimentation. After this the fæces are scanty, often none being passed for many days. They consist, after the second day, almost entirely of bile. Scarcely any gastric or pancreatic juice is formed. Sometimes a colliquative diarrhœa sets in on the last day of life.

In the foregoing remarks we have had reference to a total deprivation, for a longer or shorter period of time, of food. It is now necessary to examine briefly the effects when, although a completely nutritious diet is wanting, certain partial nutriments are allowed. As is well known, the proteid foods, though uneconomical in the quantity required, and in the tax imposed on the digestive organs, are of themselves competent to support life. Not so, however, with the non-proteid albuminoids, gelatin and chondrin, or the non-nitrogenous fats and sugars. Yet all these classes of food will spare the destruction of a certain amount of the albuminoid matters of the body and thereby prolong life. Gelatin is the most effective of these palliatives of starvation. Voit estimates that 100 gm. of dry gelatin economize 50 gm. of dry albumin. If fat be given with plenty of water, not only some of the fat tissue of the animal is spared, but also some of the albuminoid, and there is a slight increase in the carbonic-acid elimination over that observed in an absolute fast. Sugar also (if water be allowed) prolongs life, and under its administration the carbonic-acid elimination is greater than when fat is allowed.

We come now to the influence exerted by the allowance or withholding of water upon starving animals.

Water Allowed and Solids Withheld.—The most important fact in this connection is that the administration of a moderate amount of water materially diminishes the loss of body weight and prolongs life to a corresponding degree. The elimination by the kidneys, and especially that by the lungs and skin, is increased by the drinking of water, but not to an extent equal to the water consumed. There is also less urea excreted when water is drunk.

Contrary, however, to what might perhaps be expected from what has just been said, the fasting animal requires a less quantity of water than the one which has plenty of food. The reason of this is that a considerable quantity of water is set free and put at the disposal of the organism by the destruction of tissue. Muscular substance contains 3.15 parts of water for each part of dry substance. In a dog experimented upon by Pettenkofer and Voit there was a loss of 175 gm. of albuminoid matter. This would set free 551.25 gm. of water. The water eliminated was found to be, as a matter of fact, less than this amount, being only about 506.1 gm., and in this case the animal, which was allowed to drink freely, took only 33 gm. The ingestion of water, then, while postponing the fatal result of a fast, produces no important change in the mode of death from that which occurs in simple inanition.

Solids Allowed and Water Withheld.—When an animal is deprived entirely of water and of foods containing any considerable amount of moisture, starvation takes place almost as it does when solids also are withheld, for the animal soon ceases to eat. Two pigeons on which this experiment was tried by C. Falck and Scheffer gave as a mean the following figures: At first, being given enough water and wheat to maintain a uniform weight, they took per 1,000 gm. of body weight, 103 gm. of water, and 85.5 gm. of wheat, a total of 188.5 gm., against which their total excreta were 187 gm. For the next four days water was withheld and wheat allowed *ad libitum*. Of the latter they took only 25.5 gm. per day, and their total daily excreta weighed 79.5 gm. Again, for eight days they received all the water and wheat they wished. This amounted in the first day to 442 gm. (342 of water and 80 of wheat). The excreta on this day were 180.5 gm. The average total ingestion for the first four days was 248.5 gm. (water 148.5 gm., wheat 100 gm.), the excreta 201 gm. On the next four days the ingesta were 176 gm. (water 91 gm., wheat 85 gm.); the excreta 176 gm. They had thus regained their former nutritional equilibrium. They were then again deprived of water until their death, which happened on the thirteenth day. The ingestion of wheat fell to 19 gm., and the excreta were 56 gm.

The mean daily loss of weight in pigeons so treated is from three and a half to five per cent. of their original weight, and the duration of life from nine to thirteen days. The total loss is from thirty-five to forty-nine per cent.—not materially different from what occurs where solids are withheld.

Duration of Life during Fast.—As has been seen above, this has wide variations, depending as it does upon many factors, as the temperature of the surrounding medium, the quantity of fat possessed by the animal, etc. Perhaps an average would be from eight to ten days, during which the animal loses say forty per cent. of his weight. But, as we shall see in speaking of fasting in the human subject, this length of time may be enormously exceeded, as indeed it frequently is, in animals. In the classical case of the fasting pig, the imprisoned animal, which was enormously fat, was released alive at the end of one hundred and sixty days, having fallen away in weight from one hundred and sixty pounds to forty pounds.

In Man.—Inanition in man is usually more or less incomplete, but in a partial form it is not very uncommon. The insane frequently refuse food, and inanition may become quite advanced before the patients are put into an asylum, where, of course, they are fed, if necessary, forcibly. One such case is reported where a young man took nothing but water flavored with orange juice for sixty-one days. At that time he was seen by a physician and induced to eat, but, perhaps through injudicious treatment, he died on the eleventh day afterward.

Hysterical patients are particularly given to fasting, and reports of such cases often get into the daily press. Critical investigation usually develops the fact that there has been a good deal of deception of the attendants; but it is undeniable that such patients do subsist for long periods on an incredibly small amount of nutriment. In one notable case investigated by Charcot, the urine and the vomitus showed, on a most careful analysis, that the daily excretion of urea was only 5 gm. In a man, during complete abstinence, it was found to be not less than 10 or 12 gm. Many instances are on record in which hysterical women have dropped off one article of food after another, and have finally reached a point when, under perhaps one-tenth the normal amount of food, they pass a merely vegetative existence, lying on the back, obstinately constipated, with dry, rough skin, saying nothing, and, perhaps, only by a turn of the eye after a moving attendant, showing any appreciation of their surround-